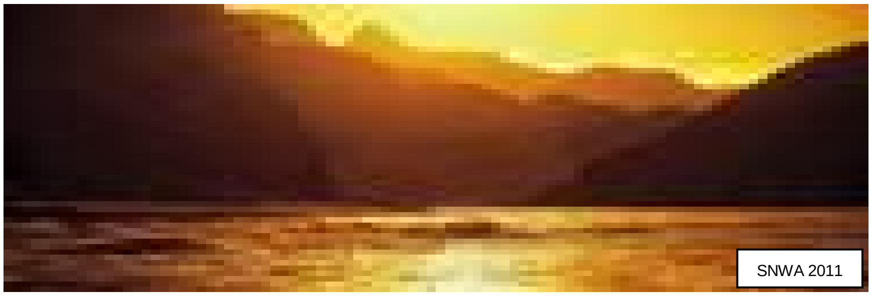


3.3 Water Resources

3.3.1 Affected Environment

Figure 3.3.1-1 shows the region of study for water resources. This study area (or hydrologic study area) includes the ROWs and groundwater development areas and encompasses 35 hydrographic basins, as defined by the NDWR (2009). Most (but not all) boundaries between the hydrographic basins correspond to topographic divides.

QUICK REFERENCE

BARCAS – Basin and Range Carbonate-Rock Aquifer System study

ET – Evapotranspiration

GPM – Gallons per minute

NDWR – Nevada Division of Water Resources

NRA – National Recreation Area

NRCS – Natural Resources Conservation Service

3.3.1.1 Overview

The general topographic and physiographic features of the region are discussed in Section 3.2, Geology. In summary, the region of study is situated within the Basin and Range physiographic region, characterized by a series of generally north- to northeast-trending mountain ranges separated by broad valleys. The mountain ranges typically are 40 to 80 miles long and are spaced approximately 5 to 15 miles apart. Within this hydrologic study area, the land-surface elevations range from 13,063 feet amsl (at Wheeler Peak in the Snake Range) to approximately 1,111 feet amsl at Lake Mead in November 2007.

The climatic conditions across the hydrologic study area are highly variable and reflect wide elevation changes, the presence of numerous mountain ranges, and a wide range in latitude. Precipitation generally increases with elevation (see Figure 20 in Welch et al. 2007). In the Great Basin, the mean annual precipitation ranges from less than 5 to 16 inches in the valleys and approximately 16 to 60 inches in the mountains (Harrill and Prudic 1998). Elevation and precipitation generally decrease from north to south across the region. Specific information about climate (including precipitation, temperature variations and trends, and discussions of climate change) are provided in Section 3.1, Air and Atmospheric Values.

Hydrographic basins are local drainage basins within large multi-basin flow systems. Hydrographic basins (or areas) are defined by the State Engineer's Office, Department of Conservation and Natural Resources (DCNR), Division of Water Resources. The terms *hydrographic areas, hydrographic basins,* and *groundwater basins* often are used interchangeably to describe the same area in published literature and reports.

This section describes water resources within the hydrologic study area. In addition, the section provides a summary of more-detailed, site-specific information for the five hydrographic basins (Spring, Snake, Delamar, Dry Lake, and Cave valleys) where pumping is proposed as part of future activities associated with the Proposed Action and alternatives. The initial Affected Environment subsections provide an overview of the regional flow systems within the region of study. The remaining sections provide a baseline summary of the surface water, groundwater, water quality, and water rights relevant to the project.

3.3.1.2 Regional Flow Systems

The 35 hydrographic basins within the hydrologic study area can be grouped into regional flow systems, and each can be defined as a set of hydraulically connected basins. As **Figure 3.3.1-1** shows, the hydrologic study area encompasses all or portions of five flow systems and includes, from north to south: 1) Goshute Valley flow system; 2) Great Salt Lake Desert flow system; 3) White River flow system; 4) Meadow Valley flow system; and 5) Las Vegas flow system.

Figure 3.3.1-1 Water Resources Region of Study and Groundwater Flow Systems

The northcentral section of the hydrologic study area includes a portion of the Goshute Valley flow system. The Goshute Valley flow system includes Steptoe and Southern Butte valleys (in the north-central portion of the study area), and Goshute Valley (immediately north of the hydrologic study area). Groundwater flow in this system generally is north, toward Goshute Valley.

The northeastern section of the hydrologic study area includes a portion of the Great Salt Lake Desert flow system. Hydrographic basins in the Great Salt Desert flow system in the study area include Tippet, Pleasant, Spring, Hamlin, Snake, and a small portion of Fish Springs Flat that encompasses Fish Springs. The overall direction of flow in this region is toward the northeast. This flow system terminates at the Great Salt Lake (northeast of the study area), with intermediate discharge at Fish Springs in Juab County, Utah.

The western and southern portions of the hydrologic study area encompass the White River and Meadow Valley Wash flow systems that are tributary to the Colorado River regional flow system. Both the entire White River and Meadow Valley flow systems are included within the hydrologic study area. The White River flow system consists of 19 hydraulically-interconnected basins, which flow from north to south over a distance of approximately 250 miles. The Meadow Valley flow system essentially is parallel to the White River flow system and includes nine basins. The flow direction in the Meadow Valley flow system also is north to south, and the system merges into the White River flow system in the southern portion of the hydrologic study area. Major surface discharge features in the lower end of the White River flow system include Muddy River Springs, which forms the headwaters of the Muddy River, and Rogers and Blue Point springs. The Muddy River is a tributary to the Colorado River and its current stream course terminates at Lake Mead. Rogers and Blue Point springs are located within the Lake Mead National Recreation Area. Subsurface outflow from the White River flow system is toward the south, into Lake Mead (SNWA 2009a).

The southwest corner of the study area includes a segment of the Las Vegas Valley hydrographic area (HA) that is part of the Las Vegas flow system.

3.3.1.3 Hydrologic Cycle and Conceptual Groundwater Flow

Surface water and groundwater discharged in the region originate from precipitation. Precipitation that falls to the land surface might infiltrate the soil or bedrock and recharge the groundwater system, evaporate, be transpired by plants, or flow as runoff through drainages. Surface water runoff that originates at higher mountain elevations generally flows in well-defined channels cut into bedrock in the mountain blocks; the runoff then discharges onto alluvial fans at the valley margin. Several potential outcomes exist for runoff that flows from the mountain blocks and into the valley bottom. As surface water moves from the mountains into the valley setting, it is continually removed from the surface-water system by a variety of processes including: 1) infiltration as recharge to groundwater (as seepage into fractures in bedrock or permeable sediments in the drainage channel, into alluvial fans at the margins of the mountain fronts, or into basin fill sediments in the central portions of the valley); 2) removed from the system by evaporation or transpired by plants (both in the channel, in ponds or lakes, and at playas in the valley bottom); and 3) diversion for irrigation or other beneficial uses.

Perennial surface water is supported by groundwater discharge in this region. Springs that discharge groundwater at the land surface can collect into channels to form perennial streams. Periodic rain storms and snow melt generate runoff that contributes to temporary stream-flow increases. However, a consistent base flow for streams and springs in the region observed even after prolonged dry periods is maintained by the discharge from the groundwater system.

The downward movement of water, through the soil to groundwater, is known as *infiltration*. Water infiltration that reaches a groundwater source is called *recharge*.

The movement of water from soil or groundwater into plants and then released into the atmosphere is known as *transpiration*.

An *alluvial fan* is a fan-shaped deposit of generally coarse material (sand, gravel, rocks) that is created where a stream flows out of the mountains and onto the valley floor.

A *perennial* stream (or stream reach) flows throughout the year.

A conceptual diagram of the groundwater flow system for the region is illustrated in **Figure 3.3.1-2**. This conceptual groundwater flow system is described in the BARCAS report (Welch et al. 2007), as follows:

> "Ground water in the study area is influenced by a combination of topography, climate, and geology. Ground water moves through permeable zones under the influence of hydraulic gradients from areas of recharge to areas of discharge, and this movement can be discussed in terms of local, intermediate, and regional flow systems.
>
> Local flow systems are characterized by relatively shallow and localized flow paths that terminate at upland springs. Local springs are low volume, tend to have temperatures similar to annual average ambient atmospheric conditions and have discharge that fluctuates according to the local precipitation. Intermediate flow systems include flow from upland recharge areas to discharge areas along the floor of the intermontane valley. Within intermediate flow systems, springs typically discharge near the intersection of the alluvial fan and the valley floor near the range front. Intermediate flow system springs often are of moderate volume and tend to have less variable flow relative to local springs.
>
> Regional ground-water flow follows large-scale (tens to hundreds of miles) topographic gradients as water moves toward low altitudes in the region. Discharge from these regional flow systems manifests as large springs and, in some areas, extensive wetlands."

Hydraulic gradient is the gradient or slope of a water table or potentiometric surface measured in the direction of the steepest change.

Intermontane refers to a feature that lies between mountains.

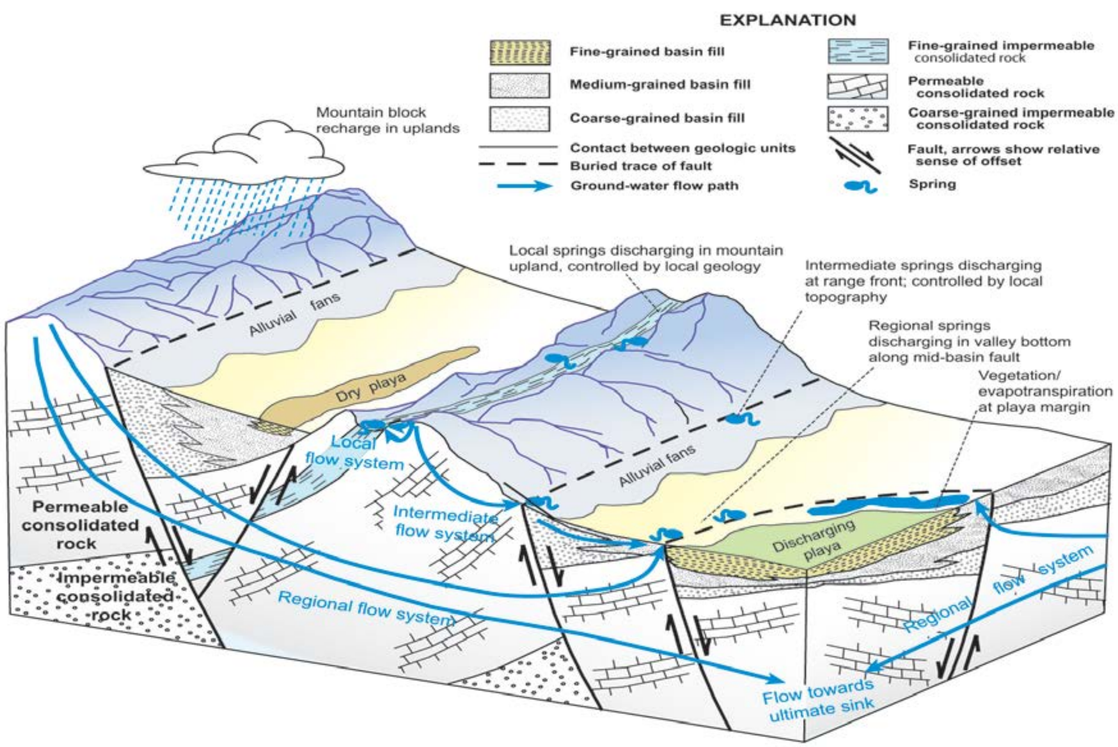


Figure 3.3.1-2 Conceptual Groundwater Flow System (From Welch et al. 2007)

Numerous springs occur in high-elevation areas in the mountains throughout much of the region. These springs generally are controlled by discharge from localized or perched groundwater systems that are not hydraulically connected to the regional groundwater system (Prudic et al. 1995). Many small springs also occur in the valleys or along the margins of the valleys. The occurrence and discharge of these springs generally is controlled by flow along intermediate flow paths (as described previously) that originate in the adjacent mountain ranges or alluvial fans.

Perched (localized) groundwater systems are not hydraulically connected to the regional groundwater system.

Large springs (>100 gpm) with relatively constant discharge rates are present in several valleys within the hydrologic study area. These springs typically discharge from carbonate rock or from basin fill that overlies or that is adjacent to carbonate rocks (Prudic et al. 1995). Discharge at these large springs is presumed to be controlled by groundwater that moves through a deep, regional groundwater flow system; this system is made up of interconnected basin-fill and carbonate-rock aquifers and is unconstrained by local topographic or drainage features (Plume 1996; Welch et al. 2007). As illustrated in the conceptual flow diagram (**Figure 3.3.1-2**), water enters the regional groundwater flow system primarily as recharge in the mountains and can flow through several basins and beneath mountain ranges before finally discharging at a regional spring.

Basin-fill and *carbonate-rock* aquifers are described in Section 3.3.3.1.

3.3.1.4 Surface Water Resources

Rights-of-way/Groundwater Exploratory Areas

Figure 3.3.1-3 shows perennial stream reaches and major regional springs that have been identified near the ROWs and groundwater development areas for the Proposed Action and alternatives.

The ROW for the Proposed Action (and Alternatives A through C) for the Snake Valley lateral would cross one perennial stream, Snake Creek, in the southern portion of the Snake Valley hydrographic basin. The ROWs for the main pipeline and laterals into Spring Valley and Cave Valley would not cross perennial streams. The ROW for the power line for the Proposed Action would cross Steptoe Creek (a perennial stream in Steptoe Valley).

The ROWs for the Proposed Action and alternatives would cross numerous ephemeral stream channels. Most of these channels are local drainage features on alluvial fans. Rainfall from severe storms poses a risk of flash flooding in these ephemeral channels. Two of the larger ephemeral or intermittent stream crossings include Lexington Creek in Snake Valley and Pahranagat Wash in Coyote Spring Valley. Lexington Creek is an incised, intermittent stream that is approximately 2 miles south of Big Wash in southern Snake Valley. Pahranagat Wash drains the northern half of Coyote Spring Valley. The wash is an ephemeral drainage up to approximately 0.5-mile-wide, where flash flooding is possible. The proposed ROWs would cross and parallel Pahranagat Wash for approximately 13 miles.

An *ephemeral* stream is a stream or portion of a stream that flows briefly in direct response to precipitation.

The proposed ROW would cross numerous small ephemeral washes through Las Vegas Valley. These washes typically drain runoff across alluvial fans that slope gently from the Las Vegas Range. Alluvial fan flooding is likely to occur in these areas.

Information that relates to perennial streams and springs within or near the groundwater exploratory is provided in subsequent sections that describe water resources within the region of study and in the proposed groundwater development basins.

Floodplains

Floodplains are areas where water overflows onto an area of typically dry land. Floodplains often occur adjacent to existing waterways and help to moderate flood flow, recharge groundwater, spread silt to replenish soils, and provide habitat for numerous plant and animal species. Executive Order (EO) 11988, Floodplain Management, requires federal

Figure 3.3.1-3 Perennial Streams and Springs

agencies to ensure that their actions minimize the impacts of floods on human health and safety and to restore the natural and beneficial values of floodplains. U.S. Department of Energy (USDOE) regulation 10 CFR Part 1022 requires public notification of floodplain involvement.

Federal Emergency Management Agency (FEMA) delineates 100-year floodplains. FEMA maps are available for Clark County; however, maps are only available for the local unincorporated areas of White Pine and Lincoln counties. In two areas within Clark County, the proposed pipeline and power lines cross FEMA-designated 100-year floodplain boundaries. A playa in Hidden Valley (within the Hidden Valley North hydrographic basin southwest of Moapa, Nevada) is designated as a 100-year floodplain. The pipeline and transmission lines parallel U.S. 93, which also crosses the Hidden Valley floodplain. The total pipeline and power line distance that crosses the floodplain is 4.6 miles. Immediately north of the Hidden Valley playa is an unnamed stream with a designated floodplain area. The span across this floodplain is approximately 0.2 miles.

Region of Study

Figure 3.3.1-1 shows the region of study for water resources. This section provides an overview of the perennial water sources (streams, springs, and seeps) within the region of study. Groundwater pumping under the Proposed Action and alternatives would occur in five hydrographic basins within the Great Salt Lake Desert flow system (Spring Valley and Snake Valley) and the White River flow system (Delamar, Dry Lake, and Cave valleys). Major surface-water discharge features within these two flow systems are described, followed by a description of surface-water resources in each of the five proposed groundwater pumping basins.

Surface-water resources within the region of study include intermittent washes, perennial streams, ponds or reservoirs, playas, and springs. In terms of streams, ephemeral drainages represent the predominant feature type. Perennial stream locations are shown in **Figure 3.3.1-3**; estimated miles of perennial stream, by basin, are provided in **Table 3.3.1-1**. Perennial stream reaches were defined by compiling available published and unpublished information that identified perennial streams (BLM 2007; NPS 2007; Elliott et al. 2006; SNWA 2006; Crookshanks 2011; USGS 2011; Eakin 1966, 1963). The length of the individual stream reaches were further evaluated using available aerial photo imagery.

Hydrographic basins with more than 100 miles of estimated perennial stream length include Steptoe Valley (162 miles), Spring Valley (207 miles), and Snake Valley (218 miles). All of the other basins have total estimated perennial stream lengths of less than 100 miles. Major perennial streams of interest controlled by discharge from the groundwater flow system include Big Spring Creek, in Snake Valley; White River, in White River Valley; Pahranagat Creek, in Pahranagat Valley; Meadow Valley Wash, in Lower Meadow Valley Wash; and Muddy River, which originates in the Muddy River Springs area.

Other perennial streams, ponds, and reservoirs are discussed in Section 3.7, Aquatic Biological Resources.

There are a total of 316 inventoried springs that have been identified in the region of study. For the purposes of this analysis, inventoried springs are springs that have been field-verified and typically include flow measurements. A list of the inventoried springs, including the spring names, location, average flow rate, and data source is provided in **Appendix F3.3.1**, **Table F3.3.1-1A**. Other data, such as temperature and water-quality, also are available for many of these springs. The inventoried springs compilation includes information from the following sources: 1) USGS spring data provided in the BARCAS study (Welsh et al. 2007), and National Water Information System (USGS 2009a); 2) SNWA's spring inventory for the project (SNWA 2007); 3) spring data collected by BIO-WEST (BIO-WEST 2008, 2007); and 4) spring data included in the Desert Research Institute (DRI) spring database.

The SNWA inventory documents baseline hydrologic conditions for selected springs in 13 hydrographic basins in the study area. The SNWA spring inventory includes existing data, photographic documentation, discharge measurements, water-chemistry sampling, and physical and geologic descriptions of the spring source area. BIO-WEST (2007) collected flow and temperature data of selected springs at 105 locations in 13 hydrographic basins (located inside and outside the study area boundary) as part of a baseline inventory of aquatic resources in the region.

Table 3.3.1-1 Perennial Stream Reaches Within the Region of Study

Groundwater Flow System	Basin Number (Upgradient to Downgradient)	Basin Name	Total Estimate Miles
White River	175	Long Valley	0.8
	174	Jakes Valley	21.8
	207	White River Valley	76.8
	180	Cave Valley	2.1
	172	Garden Valley	27.7
	171	Coal Valley	0.0
	208	Pahroc Valley	0.0
	181	Dry Lake Valley	0.9
	209	Pahranagat Valley	22.0
	182	Delamar Valley	0.0
	206	Kane Springs Valley	0.0
	210	Coyote Spring Valley	0.0
	219	Muddy River Springs Area	6.2
	218	California Wash	8.0
	220	Lower Moapa Valley	15.8
	217	Hidden Valley	0.0
	216	Garnet Valley	0.0
	215	Black Mountains Area	0.0
Goshute Valley	179	Steptoe Valley	161.8
	178B	Butte Valley (Southern Part)	19.1
Great Salt Lake Desert	196	Hamlin Valley	5.1
	185	Tippett Valley	2.2
	184	Spring Valley (184)	207.4
	194	Pleasant Valley	0.0
	195	Snake Valley	217.8
Meadow Valley	183	Lake Valley	8.3
	201	Spring Valley (201)	43.1
	202	Patterson Valley	1.6
	200	Eagle Valley	3.2
	199	Rose Valley	0.0
	198	Dry Valley	3.1
	203	Panaca Valley	7.4
	204	Clover Valley	17.9
	205	Lower Meadow Valley Wash	67.7
Las Vegas	212	Las Vegas Valley	0.0
Total			**947.8**

An additional 427 springs have been identified by the NPS in the GBNP (NPS 2007). Information on these springs includes location, an estimate of discharge (predominantly using a visual estimate rather than a measured value), and results for several field water quality parameters. Additional information on these springs is presented in the surface water discussions for Spring Valley and Snake Valley later in this section.

Numerous other spring locations have been mapped in the area but do not have documented flow, temperature, or water-quality data. These additional spring locations also are shown on **Figure 3.3.1-3**. These spring locations were compiled from the National Hydrography Dataset (USGS 2009b), digitized from 7.5 minute topographic maps for selected basins (i.e., Spring, Snake, Dry Lake, Delamar, and Coyote Spring valleys) (SNWA 2008), or identified from other sources. These springs have not been field-verified, so their actual existence and status as a perennial or ephemeral surface water feature has not been determined.

The locations of springs with flow data and their relative flow magnitudes are shown on **Figure 3.3.1-3**. Springs with reported average discharges of 200 gpm or greater are listed in **Table 3.3.1-2**. The largest spring discharge areas in the Great Salt Lake Desert and the White River regional flow systems area are briefly summarized in the following subsections.

Table 3.3.1-2 Springs with Average Discharges of 200 gpm or Greater in the Region of Study

Groundwater Flow System	Basin Number	Basin Name	Spring Name	Average Flow (gpm)
White River	174	Jakes Valley	Illipah Spring	900
	207	White River Valley	Hot Creek Spring	5,032
			Arnoldson Spring	1,608
			Cold Spring	582
			Preston Big Spring	3,572
			Lund Spring	3,594
			Moorman Spring	405
			Flag Springs 3	969
			Flag Springs 2	1,287
			Flag Springs 1	1,019
			Butterfield Spring	1,225
			Hardy Springs	200
			Nicholas Spring	1,185
			Moon River Spring	1,707
			Emigrant Springs	797
			Forest Home Spring	221
			Water Canyon Spring	320
			Indian Ranch Spring	236
			Sunnyside Creek Spring (Upper)	2,553
			Sunnyside Creek Spring (Lower)	5,284
	180	Cave Valley	Cave Spring	211
	209	Pahranagat Valley	Hiko Spring	2,735
			Crystal Springs	4,235
			Ash Springs	6,909
			Brownie Spring	224
			Cottonwood Spring	1,760

Table 3.3.1-2 Springs with Average Discharges of 200 gpm or Greater in the Region of Study (Continued)

Groundwater Flow System	Basin Number	Basin Name	Spring Name	Average Flow (gpm)
White River (Continued)	219	Muddy River Springs Area	Jones Spring	455
			Baldwin Spring	1,065
			Muddy Spring	3,148
			Iverson Flume	3,912
			M-11	515
			M-13	287
			M-15	702
			M-19	414
			M-20	363
			Warm Springs East	1,000
			Warm Springs West	2,431
			M-10	278
			Apcar Springs (Moapa)	264
	215	Black Mountains Area	Rogers Spring	771
			Blue Point Spring	223
Goshute Valley	179	Steptoe Valley	Murry Springs	3,179
			McGill Spring	4,782
			Monte Neva Hot Springs	649
			Indian Ranch Spring	215
			Big Spring	300
			Willow Creek Springs	624
			Big Indian Creek Spring	426
			Wilson Creek Springs	265
			Comins Lake Spring	334
			Nelson Spring	973
			Schoolhouse Spring	450
			Currie Springs	2,181
			Twin Springs	661
			Campbells Embayment Spring	2,746
			Egan Creek Springs	803
			Currie Gardens	225
			Borchert Spring	610
Goshute Valley (continued)			Cave Springs	300
			McGill Spring	450
			Lower Schellbourne Warm Spring	450
			Lower Schellbourne Pass Spring	314
			Willow Creek Springs	685
			Shallenberger Spring	450
			Bird Creek Spring	720
			McDermitt Ranch Springs	2,697
	178B	Butte Valley (Southern Part)	Stratton Springs	350

Table 3.3.1-2 Springs with Average Discharges of 200 gpm or Greater in the Region of Study (Continued)

Groundwater Flow System	Basin Number	Basin Name	Spring Name	Average Flow (gpm)
Great Salt Lake Desert	184	Spring Valley (184)	Kalamazoo Spring	869
			North Millick Spring	284
			South Millick Spring	506
			Swallow Springs	391
			Keegan Spring	234
			Minerva Spring	258
			Bastian Spring	1,150
			North Creek Spring	1,000
			Muncy Creek Spring	1,005
			West Spring Valley Complex # 1	438
			Keegan Spring Complex (North)	221
			West Spring Valley Complex # 5	756
			Swallow Spring	318
			Schellbourne Springs	242
			Kalamazoo Creek Spring	1,112
	195	Snake Valley	Rowland Spring	1,088
			Big Springs	4,289
			Gandy Warm Spring	7,426
			Foote Reservoir Spring	1,300
			Twin Springs	1,423
			Spring Creek Spring	1,205
			Miller Spring	206
			Outhouse Springs	500
			Stateline Spring/Lake Creek	3,663
	258	Fish Springs Flat	North Springs	3,140
Meadow Valley	183	Lake Valley	Geyser Springs	471
			North Creek Springs	397
			Unnamed spring flowing north	431
			Unnamed spring flowing south	974
			Dupont Spring	970
			Burnt Knoll Spring	972
			North Big Spring	1,400
	203	Panaca Valley	Panaca Spring	1,256

Great Salt Lake Desert Regional Flow System

The largest spring discharge area for the Great Salt Lake Desert flow system is at Fish Springs, along the extreme northeast edge of the region of study (**Figure 3.3.1-3**). The Fish Creek Range forms a surface-water divide between the Snake Valley and Fish Springs Flat hydrographic basins. Springs in the Fish Springs discharge area occur along a north-northwest trending zone that extends for approximately 10 miles and is coincident with the eastern margin of the Fish Springs Range in the Fish Springs Flat hydrographic basin. The discharge locations for most of these springs are assumed to be controlled by an inferred north-northwest trending fault (Bolke and Sumison 1978). Numerous springs discharge in the Fish Springs area. Specific springs that have been identified as the Fish Springs Group include North Spring, Deadman Spring, Walter Spring, and Fish Spring complex (including House, Mirror, Thomas, Middle, Lost, Crater, South, and Percy springs). The USFWS estimated that the total discharge at Fish Spring Group was approximately 21,000 afy, or 28.69 cubic feet per second (cfs) (USFWS 2004). An earlier water resources reconnaissance report for the Fish Flats hydrographic basin estimated that the Fish Springs had a combined discharge of approximately 24,000 afy, or 33.5 cfs (Bolke and Sumison 1978).

Several major springs are identified in Spring Valley and Snake Valley. The largest discharges occur at Gandy Warm Springs (approximately 15 cfs) and Big Springs (approximately 10 cfs) in Snake Valley. Discharge at Big Springs sustains perennial flows in Big Spring Creek. The springs in Spring Valley and Snake Valley are discussed in more detail under separate hydrographic basin headings.

White River Regional Flow System

Major perennial surface-water discharge occurs within the White River flow system in White River Valley, Pahranagat Valley, and the Muddy River Springs area. The White River Valley is located in the upper portion of the flow system and is characterized by numerous perennial surface-water features, which include approximately 13 major spring discharge areas. Major springs identified in White River Valley include (from north to south) Preston Big Springs, Moorman Spring, Hot Creek Spring, and Moon River Spring. The average annual discharge from these springs is approximately 17,000 afy (24 cfs). Lund Spring is another major spring that occurs in the northern portion of White River Valley and has an average discharge of approximately 5,700 afy (8 cfs). Other major springs in the valley include Cold Spring, Nicholas Spring, Arnoldson Spring, Hardy Springs, Emigrant Spring, Butterfield Spring, and Flag Springs. Spring discharge contributes flow to localized perennial reaches of the White River and to several surface-water features (e.g., ponds, reservoirs, marshes, wetlands) in the basin, including extensive surface-water features in the Kirch Wildlife Management area in the southern portion of the basin.

Pahranagat Valley is located near the middle of the White River flow system. Major surface-water resources in Pahranagat Valley include groundwater discharge at Hiko, Crystal, and Ash springs, along with Brownie Spring, and other smaller springs and seeps in the southern portion of the discharge area. Eakin (1963) indicated that Hiko, Crystal, and Ash springs have the largest discharge, with an estimated combined total discharge of approximately 25,000 afy (35 cfs). Discharge from the springs supports perennial flows and riparian vegetation along Pahranagat Wash in the Pahranagat hydrographic basin. Spring discharge likely also contributes to flow in lakes and wetlands, including flow to the Upper Lake, Middle Pond, and Lower Lake in the Pahranagat National Wildlife Refuge.

Muddy River Springs consists of numerous springs that discharge over approximate 3 square miles in the eastern portion of the Muddy River Springs hydrographic basin. These springs represent the largest groundwater discharge at the lower end of the White River flow system. Discharge from the springs forms the headwaters of the Muddy River and sustains perennial flow along portions of the Muddy River. The Moapa flow gauge on the Muddy River measures the total discharge from the Muddy River Springs area, minus diversions for municipal and industrial uses (SNWA 2009a). Eakin (1966) indicates that from 1914 to 1962, the average mean annual flow at the Moapa gauge was 33,700 afy (approximately 47 cfs). Between 1963 and 2004, the mean annual flow at the Moapa gauge exhibited a long term trend of reduced flows. From 2004 to 2010, flows at the gauge generally increased (ranging from approximately 24,000 to 25,900 afy) but were still reduced compared to the 1914 to 1962 conditions. As of 2010, the mean annual flow at the Moapa gauge was approximately 25,900 afy (approximately 36 cfs) or approximately 23 percent less than the average mean annual flow for the 1914 to 1962 period. Flow rates in the river are affected by diversions for agriculture and power generation. Spring discharge rates into Muddy River are controlled by water levels in the carbonate aquifer system that vary in response to climate conditions and groundwater pumping (Mayer and Congdon 2007). Rogers and Blue Point springs are located in the extreme southeastern margin of the study area, within the White River flow system. These springs occur in the Black Mountain Hydrographic Basin and are within the Lake Mead National Recreation Area. The spring discharge represents a mixture of local and regional water sources (Pohlmann et al. 1988). The combined discharge of these springs is approximately 1,600 afy (2.2 cfs).

Springs that support special status aquatic species are discussed in Section 3.7, Aquatic Biological Resources.

Surface Water Resources within the Proposed Pumping Basins

The following subsections provide an overview of the surface-water resources for the five basins proposed for groundwater development under the Proposed Action and alternatives.

Spring Valley

The Spring Valley hydrographic basin is a topographically closed basin that is bounded by the Schell Creek and Fortification Range on the west and the Snake Range on the east. Both Schell Creek and Snake Creek Ranges have extensive high-elevation areas (greater than 10,000 feet amsl). The lowest elevation of the valley floor is approximately 5,545 feet amsl and occurs in a playa area (Yelland Dry Lake) in the north-central segment of the valley north of

Highway 50. The elevation of the valley floor increases to approximately 6,500 feet amsl along both the north and south margins of the valley floor. A substantial band of irrigated fields, marshes, and open-water ponds occurs along the valley floor, south from Piermont Creek approximately 20 miles to Cleve Creek. In addition to stream flows, these features are maintained by irrigation ditches and numerous springs that discharge along the lower margin of the alluvial fans between elevations of approximately 5,570 to 5,600 feet, just above the valley floor.

Streams

Spring Valley Creek is an ephemeral stream with a north-to-south gradient and is the main channel along the valley axis. Spring Creek also is an ephemeral stream that occupies a similar position, with a south-to-north gradient from the southern end of the valley. Dry lakes and other smaller playa features occur in the valley bottom. Along the west side of the basin, stream flows originate in the Schell Creek Range. Runoff from the Fortification Range enters the basin from the southwest and flows originating in the Snake Range enter from the east.

Rush and Kazmi (1965) described the general-surface water resources in Spring Valley. In addition, SNWA identified 22 streams with perennial stream reaches (SNWA 2006, Table 4-1). **Figure 3.3.1-4** shows the locations of perennial stream reaches in the Spring Valley hydrographic basin. SNWA collected instantaneous discharge measurements between 1990 and 2006 at selected stream sites and compiled and evaluated miscellaneous discharge measurements from other sources for perennial streams in Spring Valley (SNWA 2006). Elliott et al. (2006) also conducted field investigations and flow monitoring to define surface water within and near the GBNP. The Elliott et al. (2006) study includes continuous stream-discharge data for Shingle Creek (also known as Willard Creek) and Williams Canyon, which drain the southern Snake Range.

Table 3.3.1-3 lists selected streams that drain from the Schell Creek and Snake ranges onto the alluvial fans of the basin. Perennial streams generally originate in channels in higher-elevation mountain settings and these flows tend to rapidly dissipate into the valley fill sediments after leaving the mountain front. A large number of other smaller canyons and channels also exit the surrounding ranges onto the valley floor. Physical descriptions of the streams in **Table 3.3.1-3** are provided in SNWA (2008) and Elliott et al. (2006).

Cleve Creek is a prominent surface-water feature and has the largest drainage area in Spring Valley. The USGS has intermittently operated several gauging stations on Cleve Creek since 1914. Cleve Creek has the longest period of record for streams in Spring Valley. The long-term mean annual discharge is 10.5 cfs, and the second highest mean annual discharge was reported as 21.6 cfs in 2005 (USGS 2007). Stream flow in this region fluctuates, depending on annual and seasonal precipitation variations.

Springs

Springs identified within the Spring Valley hydrographic basin are shown in **Figure 3.3.1-4**. This includes 52 inventoried springs (i.e., springs that have been field-verified and that have flow measurements) and 621 other springs (i.e., springs with map locations that have not been field verified) have been identified in the basin. The location, name, average flow, and data source for the inventoried springs are listed in **Table F3.3.1-1A** in **Appendix F3.3.1**.

A large number of springs occur in the Schell Creek, Snake, and Fortification ranges. Approximately 50 unnamed springs are shown on USGS maps for this area, paralleling the western margin of the valley at elevations of approximately 5,550 to 5,800 feet amsl. These lower-elevation springs contribute to surface-water uses and features on the valley floor.

Thirty-seven springs have been identified in GBNP within Spring Valley by the NPS (2007). These springs occur in the Lincoln Canyon (2 springs), Pine Creek and Ridge Creek (15 springs), Shingle Creek (9 springs) and Williams Canyon Creek (11 springs) watershed areas. Available field information for all the springs identified in GBNP is summarized under the Snake Valley subheading below

SNWA has conducted detailed field investigations at 10 representative springs in Spring Valley (SNWA 2008). SNWA selected these springs based on aerial distribution, discharge, and lithologic setting. The general characteristics of these springs are summarized in **Table 3.3.1-4** and discussed in the following paragraphs.

Figure 3.3.1-4 Spring Valley Perennial Streams and Springs

Table 3.3.1-3 General Characteristics of Perennial Streams In Spring Valley

Stream	Location	Estimated Mean Annual Stream Flow (gpm)[1]	Stream with Perennial Reaches
Muncy Creek	Schell Creek Range	853	Yes[3]
Kalamazoo Creek	Schell Creek Range	2,693	Yes[3]
Meadow Creek	Schell Creek Range	350	No
Siegel Creek	Schell Creek Range	462	Yes[3]
North Creek (station 1840401)	Schell Creek Range	557	Yes[6]
North Creek (station 1843401	Schell Creek Range	4	Yes[1,5]
Frenchman Creek	Schell Creek Range	242	Yes[3]
Piermont Creek	Schell Creek Range	754	Yes[3]
Garden Creek	Schell Creek Range	175	Yes[3]
Bassett Creek	Schell Creek Range	2,240	Yes[3]
Little Negro Creek	Schell Creek Range	386	Yes[3]
Negro Creek	Snake Range	1,176	Yes[3]
Odgers Creek	Schell Creek Range	1,064	Yes[3]
McCoy Creek	Schell Creek Range	3,025	Yes[3]
Taft Creek	Schell Creek Range	1,176	Yes[3]
Stephens Creek	Schell Creek Range	467	Yes[3]
Cleve Creek	Schell Creek Range	4,713 [2]	Yes[3]
Bastian Creek	Schell Creek Range	1,234	Yes[3]
Board Creek	Snake Range	13	Yes[1,5]
Eight Mile Creek	Snake Range	440	Yes[3]
Swallow Creek	Snake Range	3,434	Yes[3]
Dry Canyon and Williams Canyon	Snake Range	458	Yes[3,4]
Pine and Ridge Creeks	Snake Range	530	Yes[3,4]
Willard Creek	Snake Range	413	Yes[3]
Shingle Creek	Snake Range	431	Yes[4]
Ranger Creek	Schell Creek Range	27	Yes
South Taft Creek	Schell Creek Range	310	Yes[6]

[1]SNWA (2008), estimated mean annual stream flow for ungauged perennial streams and the gauge at Cleve Creek.
[2]USGS (2007).
[3]SNWA (2006).
[4]Elliott et al. (2006).
[5]Perennial stream reach not mapped.
[6]Crookshanks (2011).

Table 3.3.1-4 General Characteristics of Selected Springs in Spring Valley[1]

Spring Name	Location	Landscape Position	Elevation (feet)	Source Geology	Measured Discharge Range in gpm (Number of Measurements)	Water Temperature (Number of Measurements) °C[2]
Willow Spring	Schell Creek Range	Mountain upland	5,982	Carbonate bedrock	1.8–35.9 (5)	10.4–14.9 (3)
North Millick Spring	Snake Range	Valley margin	5,590	Unconsolidated sediment	196–328 (10)	10.9–15.5 (7)
South Millick Spring	Snake Range	Valley margin	5,592	Unconsolidated sediment	200–727 (13)	10.2–15.8.(10)
South Bastian Spring	Snake Range	Valley floor	5,660	Unconsolidated sediment	0.5–4.76 (3)	12–12.9 (2)
Willard Spring	Snake Range	Valley floor	5,755	Unconsolidated sediment	NMD–3 (2)	7.9 (1)
Layton Spring	Snake Range	Valley floor	5,698	Unconsolidated sediment	NMD–1.0 (7)	8.6–22 (5)
North Spring	Schell Creek Range	Valley floor	5,763	Unconsolidated sediment	10.0 (1)	22.7
The Cedars[3]	Snake Range	Valley floor	5,783	Alluvium	20.6–74.5 (6)	23.7–24.5 (6)
Swallow Springs	Snake Range	Valley floor	6,080	Alluvium	275–511 (13)	9.4–13.8 (10)
Blind Spring	Snake Range	Valley floor	5,773	Unconsolidated sediment	NMD (5)	2.2–25.3

NMD = No measurable discharge (dry or stagnant pond).
[1]Source: SNWA (2008) unless otherwise noted.
[2]Range of available temperature measurements; SNWA (2008), USGS (2007), BIO-WEST (2007).
[3] The area referred to as "The Cedars" contains surface discharges from two artesian wells that provide water to a wetland area (see text for additional description).

Willow Spring. Willow Spring is in northern Spring Valley. The spring has two distinct orifices that discharge into a small, man-made impoundment that forms a small pond used by livestock and wildlife.

The spring discharges from Quaternary alluvium and is one of several springs that surface along a northeast trending lineation, suggesting the presence of a concealed fault (SNWA 2008).

North and South Millick Springs. North and South Millick springs are approximately 3.5 miles southeast of the center of Yelland Dry Lake and approximately 6 miles east of the West Spring Valley Highway (State Route [SR] 893). They are in north-central Spring Valley on the west flank of the Snake Range, about 6 miles north of U.S. Highway 50. South Millick Spring is approximately 0.5 mile to the southwest of North Millick Spring. Several small orifices contribute flow to form large spring pools at each spring (SNWA 2008).

Both North and South Millick springs discharge from alluvium and are located on a northeast-southwest trending normal fault. Mean discharge was recorded at the South Millick Spring as approximately 506 gpm. The mean discharge of North Millick Spring was recorded as approximately 284 gpm. Water from the North and South Millick springs is used to water livestock (SNWA 2008).

Layton Spring. Layton Spring is approximately 2.5 miles north of U.S. Highway 50, along the eastern flank of Spring Valley. During a July 15, 2004 field visit, the spring was observed to be dry (SNWA 2008). When flowing, the spring discharges from a 2-inch diameter pipe into a watering trough and then overflows into a shallow reservoir (SNWA 2008).

South Bastian Spring. South Bastian Spring is located approximately 2.8 miles southeast of Bastian Creek Ranch and approximately 2.3 miles northwest of Layton Spring. The spring discharges along the western edge of an extensive marshy area with large cedar trees. Two other springs with similar conditions, including discharge from the Quaternary alluvium and diversion structures, also were observed in the area (SNWA 2008). Discharge at South Bastian Spring was measured at approximately 4 gpm during a July 15, 2004, field visit. Livestock and wildlife use the water (SNWA 2008).

North Spring. North Spring is 10 miles north of Lake Valley Summit and 2 miles east of U.S. Highway 93. North Spring discharges along a north-south-trending fault and is flanked on the east and west by additional north-south-trending faults. Another small spring approximately 900 to 1,200 feet north of North Spring appears to discharge from the same fault (SNWA 2008).

Discharge was estimated to be 10 gpm during a June 22, 2004, field visit (SNWA 2008). The spring flow travels only 150 yards before it is lost to infiltration and ET. The water is used for livestock watering and supports a small grassy area downstream of the spring (SNWA 2008).

Swallow Springs. Swallow Springs is in a grove of large cottonwood trees, 1.5 miles north of Shoshone, Nevada, and 1.5 miles east of SR 894. Swallow Springs is in the middle of a large alluvial fan, approximately 0.25 mile from an outcrop of middle Cambrian limestone (Hose et al. 1976). The combined discharge of the two orifices on November 29, 2007, was approximately 337 gpm. There are several historic water diversions in the area, and water currently discharges in the natural channel (SNWA 2008).

Blind Spring. Blind Spring is in southern Spring Valley, approximately 7 miles east of U.S. Highway 93 and 2 miles southwest of Minerva, Nevada. A raised rim surrounds Blind Spring and it appears to be manmade. The SNWA (2008) reports that the pool level might represent the potentiometric surface or groundwater table. At the time of the field visit, Blind Spring was discharging into a stagnant pool, so no discharge measurements were possible. Water from Blind Spring is used for wildlife and livestock (SNWA 2008).

A *potentiometric surface* is one that represents the static head of groundwater in tightly cased wells that tap a water-bearing unit (i.e., aquifer).

Other Major Ponds and Wetland Areas Fed by Groundwater Discharge

Shoshone Ponds Area. The Shoshone Ponds area is located in the southern portion of the Spring Valley approximately 10 miles south of U.S. Highway 6/50. The area consists of wet meadow/wetlands complex situated along the eastern margin of the valley floor that also is named “The Cedars” on topographic maps of the area. The source of water for the wet meadow/wetland complex is discharge from six artesian wells located along the eastern margin of the area. Five of the wells were constructed in the 1930s to supply water to a Civilian Conservation Corps Camp located in the area; the sixth well was constructed in the early 1970s for the NDOW to provide a water source for three ponds (known as the Shoshone Ponds) used as refugia for Nevada native fish (BLM 2010). (The management of the ponds as refugia for federally endangered fish is discussed in Section 3.7, Aquatic Biological Resources.) The SNWA conducted field investigations of the discharge characteristics at two of the artesian wells (SNWA 2008). The two wells are described as being situated at the toe of an alluvial fan that consists mainly of carbonate clasts. Discharge volume was measured for both wells on July 28, 2004. Total discharge from the two wells was estimated at 75 gpm.

Artesian well: A well in which the water pressure is so great that the water level in the well stands above the ground surface and may discharge at the surface without pumping (i.e., "flowing artesian well").

Snake Valley

Snake Valley is a western tributary to the Great Salt Lake drainage basin. The western margin of the valley is bounded by the Deep Creek and Snake ranges, which have extensive high-elevation areas (greater than 10,000 feet amsl). The eastern margin of the valley is bounded by the Fish Springs and Confusion ranges; neither exceeds 9,000 feet amsl. The elevation of the valley surface gently slopes toward the north, although it does not contain a well-defined continuous stream channel that extends the length of the valley (Hood and Rush 1965).

A gentle land surface separates the Snake Valley hydrographic basin from the Hamlin Valley hydrographic basin. Hamlin Valley Wash dissipates northward on the valley floor toward Snake Valley and Big Springs Creek and Lake Creek closely parallel the wash, also flowing north. Because of the subdued topography and surface drainage, some investigators include Hamlin Valley as the southernmost part of Snake Valley (Hood and Rush 1965; Welch et al. 2007).

Streams

Perennial stream reaches identified in the Snake Valley hydrographic basin are shown on **Figure 3.3.1-5**. These stream reaches were defined based on available information in the BLM Ely Proposed RMP/Final EIS (BLM 2007), in the GBNP Bio-Physical Report (NPS 2007), and in Elliott et al. (2006). From north to south, the perennial stream reaches include Trout Creek and several other perennial reaches that drain the Deep Creek Range; Deadman Creek, Deep Canyon Creek, Hampton Creek, Hendry's Creek, and Silver Creek in the Snake Range north of Highway 50; and Weaver Creek, Strawberry Creek, Mill Creek, Lehman Creek, Baker Creek, Snake Creek, Spring Creek, and Big Wash within or near the GBNP, as described by Elliott et al. (2006). Big Springs Creek/Lake Creek is a perennial stream in the southwest portion of Snake Valley that originates at Big Springs and terminates at Pruess Lake, with an estimated surface area of about 200 acres.

Hood and Rush (1965) identified 14 perennial streams in Snake Valley, including streams that discharge from Gandy Warm spring and Big Spring and 12 others that originate in the high mountains of the Deep Creek and Snake ranges. Discharge measurement and observations included in Hood and Rush (1965) are summarized in **Table 3.3.1-5**.

Mean annual discharge was estimated by the SNWA for 11 inventoried streams, and these results are presented in **Table 3.3.1-5** (SNWA 2008). Variation in mean annual discharge estimates on the same stream for different studies might be caused in part by differences in measurement location.

Great Basin National Park. Perennial streams identified within the GBNP are shown on **Figure 3.3.1-6**. The USGS and the NPS investigated streams originating in the GBNP and flowing into Snake Valley (Elliott et al. 2006; NPS 2007). The study characterized surface-water resources in the GBNP and included measuring the discharge of streams and springs and assessing the natural variability of their flow. Mean annual discharge was estimated for six stream gauges and Rowland Spring in Snake Valley. Snake Creek has four gauge sites and two of these sites had sufficient data to estimate a mean annual discharge.

Stream discharge characteristics reported in Elliott et al. (2006) are summarized in **Table 3.3.1-6**. This investigation included miscellaneous discharge measurements at different locations along the streams to further characterize variations and potential water sources along the channels. The results of the study indicated that substantial differences in discharge occur along the stream lengths and at different times of year. Multiple discharge measurements over short periods of time along Baker, Lehman, and Snake creeks indicate that these streams gain and lose water over relatively short stream reaches. These discharge fluctuations are attributed to the distribution of permeable and impermeable consolidated rocks that form the stream channels. Typically, higher values of discharge occur in the spring and summer months (June or July), and lower values occur in the fall (October). Lower flows in the fall typically are associated with higher specific conductance and lower temperatures (Elliott et al. 2006).

Cave Streams. Elliott et al. (2006) identified an area within the GBNP where surface water resources likely are susceptible to groundwater withdrawal. Baker (2009) has identified 6 caves in these susceptibility areas that are in direct contact with the water table or surface water. These include Model Cave, Ice Cave, Wheeler's Deep Cave, and Systems Key Cave in the Baker Creek watershed. There is limited information to define the hydrology of these caves or determine the source of water that occurs within these caves.

Trip reports from spelunkers published during the 1950s and 1960s reported explorations of the Baker Creek Cave System. Bridgemon (1967) describes the Baker Creek Cave System as 15 caves that occur within the Pole Creek Limestone. Wheeler's Deep Cave also is reported to have a perennial stream (Baker 2009). Model Cave is reported to be the most important cave within the Baker Creek Cave System and is reported to have one or more perennial streams (McLean 1965; Bridgemon 1967; Baker 2009). Lange (1954) describes slots in the floor of Model Cave that he believes were formed by upward (or artesian) flow. However, he does not provide data to determine if these features

Figure 3.3.1-5 Snake Valley Perennial Streams and Springs

Table 3.3.1-5 Mean Annual Stream Discharge Estimates for Selected Perennial Streams In Snake Valley

Stream	Location	Hood and Rush (1965)[1] cfs	Elliott et al. (2006) cfs	USGS (2007) cfs	SNWA (2008) cfs
Baker Creek	Southern Snake Range	8.53	9.08	NS	NS
Lehman Creek	Southern Snake Range	7.49	5.13	5.67	NS
Trout Creek	Deep Creek Range	4.34	NS	5.51	NS
Warm Creek	West Cental Snake Valley	Inventory	NS	NS	NS
Big Springs Creek	Southern Snake Range	Inventory	NS	NS	NS
Big Wash	Southern Snake Range	Inventory	NS	NS	1.44
Snake Creek	Southern Snake Range	Inventory	2.70	NS	9.50
Silver Creek	Northern Snake Range	Inventory	NS	NS	5.10
Hendry's Creek	Northern Snake Range	Inventory	NS	NS	2.62
Birch Creek	Deep Creek Range	Inventory	NS	NS	4.39
Granite Creek	Deep Creek Range	Inventory	NS	5.12	NS
Cedar Creek	Deep Creek Range	Inventory	NS	NS	NS
Thomas Creek	Deep Creek Range	Inventory	NS	NS	NS
Basin Creek	Deep Creek Range	Inventory	NS	NS	NS
Indian Farm Creek	Deep Creek Range	NS	NS	NS	4.24
Smith Creek	Northern Snake Range	NS	NS	NS	4.66
Hampton Creek	Northern Snake Range	NS	NS	NS	0.728
Weaver Creek	Southern Snake Range	NS	NS	NS	0.383
Strawberry Creek	Southern Snake Range	NS	0.58	NS	1.46
Lexington Creek	Southern Snake Range	NS	NS	NS	0.226

[1]Inventory = Discharge measurement used for basin estimate provided in Hood and Rush (1965), but no mean annual discharge estimate was reported.
NS = Mean annual stream discharge estimates not surveyed by this study.

likely were formed in the geologic past (i.e., under different hydrologic conditions) or were formed recently under present hydrologic conditions. If the latter were true, these features would suggest that artesian flow in the limestone is the source of water for the streams within in this cave. However, information is not available to evaluate the likely source (e.g., regional, intermediate, or localized flow system) that sustains the cave streams. Uncertainty exists regarding hydraulic interconnection between the Pole Creek limestone and the regional aquifer system that would be targeted for groundwater development in Snake Valley.

Ice Cave is reported to have a stream at times that is controlled by flow through a surface culvert directing water into the cave entrance (Baker 2009). Systems Key Cave is partially located beneath Baker Creek and has a small stream that originates in the ceiling, flows along the floor, and then disappears down a tight passage (Baker 2009). These descriptions suggest that stream flows within Ice Cave and Systems Key Cave likely are controlled by the infiltration of surface runoff and not by upward flow from the regional groundwater flow system.

Squirrel Springs Cave extends below the water table. The water table is reported to fluctuate and the cave experiences seasonal flooding (Baker 2009). These descriptions suggest that the water table observed in the cave is controlled at least in part by seasonal precipitation patterns. Water Trough Cave is described as containing ponded water. Information regarding the likely source of water in Water Trough Cave is not available.

Figure 3.3.1-6 Great Basin National Park Perennial Streams and Springs

Table 3.3.1-6 Summary of Stream Characteristics in and near GBNP

Basin	Stream Name	Discharge Range (cfs)	Water Temperature Range (°F)	Specific Conductance Range (µS/cm)
Snake Valley	Strawberry Creek	0.12 to 3.18	45 to 63	52 to 153
Spring Valley	Shingle Creek	0.59 to 2.02	45 to 55	60 to 80
Snake Valley	Lehman Creek	0.49 to 11.7	45 to 68	30 to 152
Snake Valley	Baker Creek	0 to 8.07	43 to 65	28 to 107
Snake Valley	Snake Creek	0 to 15.5	45 to 59	76 to 375
Snake Valley	Big Wash	0 to 5.05	45 to 57	341 to 475

µS/cm = microSiemens per centimeter.
Source: Elliott et al. 2006.

Springs

Springs that were identified in Snake Valley are shown on **Figure 3.3.1-5**.

Available spring data include: 1) inventoried springs with flow measurements; 2) additional springs identified in GBNP; and 3) other unverified spring locations identified on topographic maps or included in the National Hydrographic Dataset.

Thirty eight inventoried springs that have flow measurement data have been identified. The location, name, average flow, and data source for the inventoried springs are listed in **Table F3.3.1-1A** in **Appendix F3.3.1**.

GBNP Springs. The NPS has identified an additional 427 springs located in the GBNP (NPS 2007). Of these, 390 springs occur in Snake Valley in 13 watershed areas. The identified spring locations within the GBNP are shown in **Figure 3.3.1-6**. Information on these springs is summarized in **Table 3.3.1-7**, including the ranges of estimated discharge and the minimum and maximum reported field water quality results by watershed area. The location, watershed area, discharge method used, and estimated discharge range for the springs are listed in **Table F3.3.1-1B** in **Appendix F3.3.1**. The estimated spring discharge for springs is reported as a range in flow. The flow estimates were based on visual observations (305 springs), volumetric measurements (109 springs), and flow meter measurements (1 spring). No flow measurements were reported for 15 of these springs. The discharge and field water quality parameters were collected over a period from April through October 2003, April through October 2004, and July 2005.

Available information for Big Springs, Caine Springs, Gandy Warm Springs, Cave Springs, Rowland Springs, Spring Creek Spring and Needle Point Springs is presented in **Table 3.3.1-8** and summarized in the following paragraphs.

Big Springs. Big Springs provides water for irrigation at Big Springs Ranch and then flows northeast into Big Springs Creek, which becomes Lake Creek east of the Utah-Nevada border, and finally flows into Pruess Lake 3 miles southeast of Garrison, Utah (SNWA 2008).

There are several springs emanating from the alluvium in the area and Big Springs has the largest discharge. Two unnamed spring complexes are located northeast of Big Springs, possibly along the same north-northeast trending fault that controls Big Springs. North and South Little Springs complexes are to the southeast of Big Springs. These springs are located along separate, but sub-parallel, north-northeast trending faults with varying vertical and horizontal surface displacement.

Table 3.3.1-7 Summary of Springs Identified in GBNP

Hydrographic Basin	Watershed	Springs Inventoried	Number of Springs by Range of Estimated discharge (gpm)[1]			Water Temp °F		Specific Conductance (µS/cm)		pH (units)	
			0-10	10-100	100-1000	min	max	min	max	min	max
Snake Valley	Baker Creek	148	103	31	10	34	65	12.7	303	3	8.4
	Burnt Mill Creek	4	4			45	50	89.9	161.2	6.4	7.3
	Can Young Canyon	19	12	5		37	55	40.1	426.4	6.1	7.62
	Decathon Creek	1				63	63	399	399	7.1	7.1
	Lehman Creek	79	46	26	3	36	61	15.4	241.6	4.97	7.59
	Lexington Creek	1				56	56	630	630	7.67	7.67
	Mill Creek	13	9	3		40	52	19.1	290.8	6.2	7.5
	North Fork Big Wash	6	2	2	2	37	50	193	420.7	7.5	8
	Snake Creek	38	24	11	3	33	59	30.9	280.6	5.7	7.8
	South Fork Big Wash	12	6	3	3	43	47	169	414.4	7.47	8.5
	Strawberry Creek	59	39	11	9	39	54	38.4	324.5	6	7.8
	Weaver Creek	2	2			45	54	180	185.6	6.96	7.06
	Young Canyon	8	6	2		45	55	31.3	457.2	6.41	7.3
Spring Valley	Lincoln Canyon	2				37	37	281	362.5	7.7	8
	Pine Creek/Ridge Creek	15	13	2		39	52	25.7	101.5	6.4	10.2
	Shingle Creek	9	5	3	1	39	48	25.7	94.8	6.5	9.43
	Williams Canyon Creek	11	3	3	2	35	45	17	38.3	6.28	7.3
Total springs		427	274	102	33						

[1] Flow estimates based on visual observations (305 springs), volumetric measurements (109 springs), and flow meter measurements (1 spring).
[2] Temperature converted from °C and rounded to whole number.

Table 3.3.1-8 Selected Spring Discharge Measurements in Snake Valley

Spring Name	UTM[1] Easting (m)	UTM[1] Northing (m)	Elevation (feet amsl)	Mean Discharge (gpm) (Number of measurements)	Mean Discharge (cfs) (Number of measurements)	Temperature Range (°F) (Number of measurements)
Big Springs	749,476	4,287,141	5,572	4,267 (23)	9.5 (23)	61–64 (2)
Caine Spring	755,138	4,336,186	5,032	5.0 (1)	0.010 (1)	58 (1)
Gandy Warm Springs	756,007	4,371,984	5,156	7,252 (28)	16.2 (28)	76–82 (10)
Rowland Spring	741,778	4,321,448	6,580	1,032 (continuous)	2.2 (continuous)	48–50 (3)
Cave Springs	739,312	4,322,110	7,270	45 (daily 2004-2006)	0.1 (daily 2004-2006)	56 (356)
Spring Creek Spring	750,345	4,310,673	6,123	1,205 (2)	2.7 (2)	55 (1)
Needle Point Springs	758,117	4,293,839	5,460	see text	see text	Not available

[1]Coordinates are in UTM Zone 11 and North American Datum of 1983.
[2] Temperature converted from °C and rounded to whole number.
UTM = Universal Transverse Mercator.
m = meter.
Sources: SNWA 2008; Elliott et al. 2006; Summers 2008; NPS 2007

Discharge measurement location in the Big Springs area is important because of a number of diversions and because Big Spring Creek gains water before flowing into Lake Creek. The diversions at Big Springs include several portable pumps that divert water and a splitter box consisting of two weirs. The discharge for Big Springs (approximately 9 cfs [4,086 gpm]) is defined as the total measured below each of the two weirs (SNWA 2008). Additional springs that contribute flow downstream of the weirs increased the discharge to between 15 and 19 cfs (6,730 and 8,530 gpm) from June through November 1972 (Walker 1972).

Caine Spring. Caine Spring is approximately 10 miles north of Baker, Nevada. The spring discharges from two seeps. One of the seeps is enhanced by artesian flow from a 3-inch diameter well. The total discharge was estimated at 0.011 cfs, or 5 gpm (SNWA 2008).

Gandy Warm Springs. Gandy Warm Springs is a major surface-water feature and a popular recreation area with local Snake Valley residents. Swimmers are able to swim in the main discharge channel and into the large solution cavern where the spring discharges from Paleozoic carbonate rocks (SNWA 2008). The spring is located approximately 0.5 mile east of the Nevada state line and 3 miles west of Gandy, Utah. Spring flow is diverted to the south and the east towards Gandy, where it supports agriculture.

Water discharges from several orifices, which coincide with the intersection of fault and fracture zones perpendicular to a major northeast-southwest trending, normal fault. Discharge measurements of 8.0 cfs in November 1964 (Hood and Rush 1965) and 8.42 cfs (3,780 gpm) in June 2004 are anomalously low (SNWA 2008). These measurements appear to have missed a large volume of flow and are not included in the mean discharge estimates (16.8 cfs [7,562 gpm]) in **Table 3.3.1-8**.

Rowland Spring. Rowland Spring is located at the eastern boundary of the park. The spring discharges from alluvium and glacial sediments (Elliott et al. 2006). Discharge was monitored at Rowland Spring, a tributary to Lehman Creek, as part of the USGS study at GBNP. Rowland Spring is one of the major springs of the South Snake Range. Average annual discharge of Rowland Spring is 2.3 cfs based on 2 years of measurements (Elliott et al. 2006). The source of water for Rowland Springs is uncertain. Elliott et al. (2006) suggest that two possible sources for the discharge are eastward groundwater flow through the Pole Creek Limestone in the Lehman Creek Drainage or northeastward groundwater flow through carbonate rocks in the Baker Creek Drainage.

Cave Springs. Cave Springs is the water supply for the GBNP operational facilities. Mean annual discharge for 2004 through 2006 was 0.1 cfs (NPS 2007). Cave Springs consists of several small springs that discharge from alluvial and glacial deposits near the contact between quartzite and granite. A recent USGS investigation of Cave Springs (Prudic and Glancy 2009) investigated the source of water to the spring to evaluate the potential for depletion from groundwater development in Snake Valley. The results of the study indicate that the source of the water in the spring is primarily from winter precipitation that discharges from quartzite on the upstream contact between quartzite and granite. The study also indicated the potential for spring depletion from groundwater pumping in Snake Valley is less than if carbonate rocks were present beneath the springs as carbonate rocks would provide a better connection with alluvial aquifers in the valley.

Spring Creek Spring. Spring Creek Spring is located near the eastern boundary of the GBNP and is a tributary to Snake Creek. Spring Creek Spring discharges from the Fishtown and Lakehaven Dolomites at a fault contact with alluvial and glacial tertiary age sediments (Elliott et al. 2006). The spring discharge sustains perennial flows in Spring Creek; a tributary to Snake Creek. Most of the flow in Spring Creek is diverted into fish-rearing ponds with return flows entering Snake Creek downstream of the ponds. Discharge of Spring Creek just upstream of the fish-rearing ponds was 2.02 cfs (906.6 gpm) in June 2003 and 1.78 cfs (798.9 gpm) in October 2003 (Elliott et al. 2006), indicating a small (approximately 12 percent) reduction in flow between June and October.

Needle Point Springs. Needle Point Springs is located near the southeast margin of Snake Valley, approximately 5 miles northeast of Big Springs. The spring occurs in an area of basin alluvium, which is inferred to be underlain by fractured dolomite that is exposed at the surface in the Needle Point Mountain south of the spring (Summers 2008). The following summary is based on information compiled in an unpublished BLM report on Needle Point Springs, prepared by BLM Senior Hydrogeologist Paul Summers (Summers 2008).

Spring discharge has been documented as early as 1939 by the Civilian Conservation Corps work crew who performed improvements at the spring. The Civilian Conservation Corps camp engineers measured flow at 6 gpm on September 22, 1939. The spring was developed by digging approximately 10 feet into the alluvium and installing a 6-foot diameter circular steel tank, which was perforated to allow water to flow into the tank. An outlet pipe feeds water to a nearby trough and a surface pond, for easy access by stock and wild horses. Water at the spring has been used continuously for watering stock and wild horses. Prior to 1939, anecdotal reports of spring use suggest that water at this spring was used for several years by sheep and cattle operations in the area.

The following flow measurements were recorded by BLM staff between 1992 and 2001:

- Sept. 24, 1992, 6 gpm;
- Feb. 16, 1994, 7 gpm;
- July 11, 1997, 7 gpm;
- June 6, 2001, 2.4 gpm; and
- Late June, 2001: water level dropped below outlet pipe of the spring box and the flow to the watering trough and surface pond ceased.

After flow ceased in June 2001, the BLM installed a piezometer (i.e., a groundwater-elevation monitoring device) to measure the elevation of the water table next to the spring. The elevation of the water table in the spring-head box and in the piezometer have been monitored by the BLM staff on a regular basis since August 28, 2001. The results of the monitoring indicate that there has been no observable flow at the spring between the periods of record (available at the time of this evaluation) that extends from June 6, 2001 to December 1, 2010. Monitoring of the piezometer indicates that the water table has declined by as much as 6.05 feet, which occurred at the December 1, 2010, reading. The water table exhibits strong seasonal water level declines, corresponding to irrigation season cycles, with water levels declining for 5 to 6 months each year (typically starting in late March to early May and extending to late October), and partially recovering over the remainder of the annual cycle, when irrigation pumps are shut off. The water level recovery after each cycle of pumping does not return to the pre-pumping water level prior to the start of the previous year's pumping. Thus, the water levels at the end of each irrigation season have continuously trended downward, resulting in a continuously lowered water level year over year (Summers 2008).

Cave Valley

Figure 3.3.1-7 shows the perennial water resources in Cave Valley. This valley is a comparatively small basin, with a topographically closed, surface-drainage system. This system is defined by the southern Egan Range on the west and the southern Schell Creek Range on the east and is bounded in the south where these two ranges merge. The wash varies down-valley from ephemeral to intermittent, because of runoff from tributaries such as Haggerty Wash and Big Springs Wash. Ditches, small embankments, and several small stock ponds are located along Cave Valley Wash. Cave Valley Wash dissipates southward into the valley floor sediments. No discharge measurements are known to exist for these streams.

Springs

Springs that were identified within the Cave Valley hydrographic basin are shown in **Figure 3.3.1-7**. Four inventoried springs (**Table F3.3.1-1A** located in **Appendix F3.3.1**) and 44 other springs were identified in the basin.

The two inventoried springs (Cave and Sidehill springs) were investigated by SNWA personnel (SNWA 2008) are described below. Most of the other mapped springs occur in higher elevation areas in the northern part of the valley.

Discharge and temperature data for Cave and Sidehill springs are presented in **Table 3.3.1-9**. Cave Spring is located on the eastern side of the valley and discharges from Cambrian Pole Canyon limestone. The spring discharge flows into a small creek incised 3 to 4 feet into the alluvium. Discharge at Cave Spring was measured three times during separate field sessions in June, July, and September of 2004 (SNWA 2008). Spring discharge was observed to decrease during the summer months and the spring was observed to be dry in September. This variable discharge and the cold temperature of the water suggest that this spring is fed solely by local precipitation (SNWA 2008).

Figure 3.3.1-7 Cave Valley Perennial Streams and Springs

Table 3.3.1-9 Springs with Discharge Measurements in Cave Valley

Spring Name	UTM Easting[1] (m)	UTM Northing[1] (m)	Elevation[2] (feet amsl)	Mean Discharge, (gpm) (Number of Measurements)	Mean Discharge (cfs) (Number of Measurements)	Temperature Range (°C) (Number of Measurements)
Cave Spring	691,760	4,279,249	6,488	211 (11)	0.47 (11)	11.6 - 13 (5)
Sidehill Spring	692,407	4,254,280	6,527	1.84 (2)	0.003 (2)	15 - 17 (2)

[1]Coordinates are in UTM Zone 11 and North American Datum of 1983.
[2]Elevations are in North American Vertical Datum of 1988.
Source: SNWA 2008.

Sidehill Spring is located on the east side of Cave Valley and discharges from volcanic tuffs. Two reliable discharge measurements are available; they indicate an average flow of 0.006 cfs, or 1.8 gpm (SNWA 2008). The area around the spring has reportedly been disturbed by heavy equipment and other surface disturbances are present (SNWA 2008). The spring discharge is conveyed to a large livestock tank on the valley floor.

Dry Lake Valley

Figure 3.3.1-8 shows perennial water resources in Dry Lake Valley. Dry Lake Valley is bounded on the west by the North Pahroc Range and on the east by several smaller or more-localized low-elevation ranges, including the Fly Springs and Burnt Springs ranges. Dry Lake merges to the south with Delamar Valley and forms a single structural trough (Eakin 1963). Coyote Wash is the main south-trending channel in the basin. It is ephemeral and forms the axis of the valley floor. Coyote Wash has a large number of smaller, ephemeral tributaries that drain dissected fan piedmonts on either side of the valley. There are no perennial streams in Dry Lake Valley and no discharge measurements are known to exist.

<u>Springs</u>

Springs identified within the Dry Lake Valley hydrographic basin are shown in **Figure 3.3.1-8**. Seventeen inventoried springs and 95 other springs were identified in the basin. The location, name, average flow, and data source for the inventoried springs are listed in **Table F3.3.1-1A** in **Appendix F3.3.1**. A majority of these springs are at higher elevations.

Meloy, Bailey, Littlefield, and Coyote springs were investigated by the SNWA as summarized in **Table 3.3.1-10** and described in the following paragraphs.

Table 3.3.1-10 Springs with Discharge Measurements in Dry Lake Valley

Spring Name	UTM Easting[1] (m)	UTM Northing[1] (m)	Elevation[2] (feet amsl)	Mean Discharge (gpm) (Number of Measurements)	Mean Discharge (cfs) (Number of Measurements)	Temperature Range (°C) (Number of Measurements)
Meloy Spring	700,888	4,236,201	6,174	49.0 (3)	0.11 (3)	19.3 (1)
Bailey Spring	699,080	4,227,795	6,086	1.80 (3)	0.004 (3)	13.0 (1)
Littlefield Spring	701,112	4,233,949	6,146	27.1 (3)	0.06 (3)	15 - 17.9 (2)
Coyote Spring	687,693	4,211,513	5,220	1.32 (5)	0.003 (5)	18.0 (2)

[1]Coordinates are in UTM Zone 11 and North American Datum of 1983.
[2]Elevations are in North American Vertical Datum of 1988.
Source: SNWA 2008.

Figure 3.3.1-8 Dry Lake Valley Perennial Streams and Springs

Meloy Spring discharges from the base of small scarp in Tertiary volcanic rocks. During a 2004 field visit, the spring was inaccessible because of wild rose bushes, so no measurement was taken. In May 1980, the spring's discharge was measured at 82 gpm. In 1997, the discharge was estimated at 0.1 cfs (45 gpm) (SNWA 2008). Livestock and wildlife currently use the spring.

Bailey Spring is located near a small abandoned homestead and the spring area has been excavated. The spring discharges from Tertiary volcanic rocks along a small fault. At the time of a field visit in June 2004, wildlife was the only observable water user (SNWA 2008). The three available discharge measurements were obtained in 1912, 1980, and 2004.

Littlefield Spring discharges from the alluvium near an outcrop of volcanic rock. The mean of three discharge measurements is 27.1 gpm; this value is skewed by an anomalously high discharge of 59.7 gpm measured on July 25, 2005 (SNWA 2008).

Coyote Spring discharges from the base of a scarp in volcanic rocks. Discharge measurements date to 1912 and the average measured flow is 1.33 gpm. Modifications, including a large concrete livestock tank, have been made to the spring, but the spring currently is not in use (SNWA 2008).

Delamar Valley

Figure 3.3.1-9 presents perennial water resources in Delamar Valley. This valley is a topographically-closed basin, bounded in the east by the Delamar Mountains and on the west by the Pahroc Range. The unnamed ephemeral wash that forms the valley axis generally ranges in width from 600 to 1,200 feet. The wash might be inundated during and shortly after severe storms. Knoll Pond Reservoir is a small ephemeral water body within the northern part of the exploratory area in the center of the valley. At the southern end of the valley, Delamar Lake and the associated wash along the valley floor form a much-larger playa area subject to shallow flooding during and shortly after severe storms. The playa elevation is about 4,538 feet. Several ephemeral washes, including Cottonwood Wash, Monkey Wrench Wash, Delamar Wash, Jumbo Wash, and Big Lime Wash, drain westward from the mountains into the basin. All of these distribute runoff across alluvial fans. There are no perennial streams in Delamar Valley and no discharge measurements are known to exist.

Springs

Springs that were identified within the Delamar Valley hydrographic basin are shown in **Figure 3.3.1-9**. One spring (Grassy Spring) was investigated and documented by SNWA (**Table 3.3.1-11**); 2 springs were identified in the USGS National Water Information System and Desert Research Institute databases, and the remaining 28 springs were identified from additional location only datasets and topographic maps. The majority of the springs occur at higher elevations on the eastern side of the valley.

Table 3.3.1-11 Springs with Discharge Measurements in Delamar Valley

Spring Name	UTM Easting[1] (m)	UTM Northing[1] (m)	Elevation[2] (feet amsl)	Mean Discharge (gpm) (Number of Measurements)	Mean Discharge (cfs) (Number of Measurements)	Temperature Range (°C) (Number of Measurements)
Grassy Spring	695,124	4,157,193	5,786	4.62 (4)	0.26 (4)	11–21.2 (3)

[1]Coordinates are in UTM Zone 11 and North American Datum of 1983.

[2]Elevations are in North American Vertical Datum of 1988.

Source: SNWA 2008.

Information on Grassy Spring documented by the SNWA (2008) is summarized in **Table 3.3.1-11**. Grassy Spring is located along the western flank of the Delamar Mountains and supplies water to livestock. The spring discharges from alluvial sediments, near contact between the sediments and volcanic rocks (SNWA 2008). The mean discharge of four measurements is 4.62 gpm and the lowest flow recorded was 0.5 gpm on June 2, 2004.

Figure 3.3.1-9 Delamar Valley Perennial Streams and Springs

3.3.1.5 Groundwater Resources

This section includes a description of the hydrogeologic conditions, groundwater elevations, and water balance components for the region of study. Baseline information for the groundwater resources and hydrogeologic conditions in the region of study is derived in part from the project baseline characterization report (SNWA 2008). Other important information that was used to define these baseline conditions includes the recently completed the USGS BARCAS report (Welch et al. 2007) and various other USGS reports completed as part of the Regional Aquifer System Analysis Program for the Great Basin Region (including Harrill et al. 1988; Harril and Prudic 1998; Plume and Carlton 1988; Prudic et al. 1995; Thomas and Dettinger 1996; Plume 1996).

Hydrogeologic Conditions

Recharge, storage, movement, and discharge of groundwater are dependent in part on the regional geologic conditions and the topography. The general stratigraphic and structural framework of the region of study is described in Section 3.2, Geology. As described in that section, the geology across the region of study is both stratigraphically and structurally complex. To characterize the groundwater conditions in the area, the geologic formations are grouped into 12 HGUs (SNWA 2008). The HGUs were developed by grouping geologic map units with similar lithologic properties and inferred ability to transmit water. The HGUs range from Precambrian to Holocene in age. The general distribution of these units is presented in the generalized hydrogeologic map (**Figure 3.3.1-10**), and their physical characteristics are summarized in **Table 3.3.1-12**. Major structural features in the region are illustrated on **Figure 3.3.1-11**; generalized cross-sections at representative locations are presented in **Appendix F3.3.3**.

Lithologic refers to the composition of rock formations.

The 12 HGUs include two distinct types of materials: fractured rock (carbonate, siliceous, intrusive, volcanic, and metamorphic), and unconsolidated to poorly-consolidated sediments (alluvial and basin fill deposits). In the bedrock units, recharge, storage, flow, and discharge of groundwater primarily are controlled by the secondary features (fractures, faults, and solution cavities) that have enhanced the porosity and permeability of the rock. In the unconsolidated to poorly-consolidated sediments, the groundwater is stored and transmitted through interconnected pores within the sediments.

Regional Aquifer Systems

Two principal aquifer systems—the carbonate-rock aquifer system and basin-fill aquifer system—occur in the region of study. The volcanic rock unit might be an important aquifer in particular areas, depending on actual rock types and fracture characteristics. The volcanic rocks also might be regionally conduits for flow, where they have sufficient permeability and are in contact with the carbonate or basin-fill aquifer systems. The other rocks are believed to act as impediments (i.e., aquitards) to flow. These aquitards divide the carbonate rocks into an upper and lower flow system and serve as boundaries to flow.

Aquitards are geologic strata (i.e., beds) that act as impediments to flow between aquifers.

Carbonate-Rock Aquifer System

The carbonate-rock aquifer system is regionally extensive and underlies the eastern two-thirds of the Great Basin (Plume 1996). This system is an important conduit for recharge and interbasin groundwater flow (Welch et al. 2007). The carbonate-rock aquifer system consists of lower and upper carbonate-rock aquifers that are stratigraphically separated by low-permeability, fine-grained clastic rocks that restrict vertical flow between the two aquifers (Plume and Carlton 1988; Winograd and Thordarson 1975; Welch et al. 2007). The lower carbonate-rock aquifer consists of the Cambrian carbonate rocks and Mississippian to Ordovician carbonate rock HGUs (SNWA 2008). The lower carbonate-rock aquifer is generally present over most of the region of study, except within caldera complexes or areas underlain by igneous plutons. The Mississippian Siliciclastic Unit includes abundant, shaley, predominantly fine-grained rocks (including the Chainman Shale) with low permeability; these rocks act as a confining bed for vertical flow between the lower and upper carbonate-rock aquifer. The upper carbonate-rock aquifer is composed of a

Clastic pertains to rock or sediment that is composed primarily of broken fragments that have been transported some distance from their origin.

Figure 3.3.1-10 Hydrogeologic Formations

Table 3.3.1-12 HGUs in the Study Area

HGU	Map Symbol	Geologic Map Units[1] (Geologic Age)	Equivalent HGU in BARCAS (Welch et al. 2007)	General Occurrence and Range of Thickness	Major Lithologic Characteristics	Generalized Aquifer Characteristics
Quaternary and Tertiary Sediments	QTs	Ts2, Ts3, Ts4, QTa	Fine-grained Younger Sedimentary HGU; Coarse-grained Younger Sedimentary HGU; Older Sedimentary HGU	Occurs below the valley bottoms in the hydrographic basins Average thickness in basins ranges from 1,000 -13,000 feet	Predominantly basin-fill deposits (QTa) consisting gravel, sand, silt, and clay; unconsolidated near surface and becomes moderately consolidated at depth. Locally tuffaceous and contains minor limestone. Unit also includes Tertiary sedimentary rocks (Ts2, Ts3, and Ts4) that underlie basin fill sediments that consist of sandstone, conglomerate, and minor limestone and tuff beds.	Basin fill sediments are considered significant aquifers in hydrographic basins; unit includes beds of less permeable finer-grained sediment and volcanic ash that act as local confining beds within the sequence. Older consolidated rocks (Ts2, Ts3, and Ts4) have significantly lower permeabilities than the overlying basin fill sediments.
Quaternary and Tertiary Basalt	QTb	QTb	Volcanic Flow Unit	Localized, typically less than 200 feet thick	Basalt flows; generally thin and localized.	Basalt flows typically contain closely spaced joints and breccia zones that are highly permeable; however, because of limited thickness and distribution in the region of study, this unit is not a significant regional aquifer.
Tertiary Volcanic Rocks	Tv	Tmb, Ta1, Ta2, Ta3, Ta4, Tr1, Tr2, Tr3, Tr4, Tt1, Tt2, Tt3 and Tt4	Volcanic Flow Unit; Volcanic Tuff Unit	Outside caldera complexes the unit typically ranges from 1,000-4,000; within the calderas the unit generally is >10,000 thick	Volcanic rock units that include poorly to densely welded ash flow tuffs with interbedded air fall tuffs; rhyolite, andesite, and dacitic lava flows, with flow breccias and mudflow breccias, and megabreccia associated with caldera development.	Volcanic rocks generally are moderately permeable; depending upon jointing and fracture characteristics, the rocks may be significant aquifers.
Older Tertiary Sediments	Tos	Ts1	Older Sedimentary HGU	Localized occurrence; thickness ranges from 600 – 3,000 feet.	Mostly nonresistant sandstone, mudstone, conglomerate and minor lacustrine limestone that locally underlies Tv.	Overall permeability probably similar to the consolidated rocks included in the QTs unit. Not a significant regional aquifer due to limited lateral extent and porosity and permeability.

Table 3.3.1-12 HGUs in the Study Area

HGU	Map Symbol	Geologic Map Units[1] (Geologic Age)	Equivalent HGU in BARCAS (Welch et al. 2007)	General Occurrence and Range of Thickness	Major Lithologic Characteristics	Generalized Aquifer Characteristics
Tertiary to Jurassic Intrusive Rocks	TJi	Ji, Ki, TKi, Ti	Intrusive Unit	Occurs as large plutons that form a significant portion of the Snake, Schell Creek, Egan and Kern ranges, and beneath caldera complexes.	Predominantly quartz monzonite, granodiorite, and diabase composition.	Plutonic rocks typically act as impediments to groundwater flow. Relatively small quantities of water move through these rocks where sufficiently fractured or weathered.
Cretaceous to Triassic Siliciclastic Rocks	KTrs	Trs, Js, Ks	Mesozoic Sedimentary HGU	Occurs in the southeast portion of the region of study and in a few isolated areas in other portions of the region of study. Average thickness ranges from <1,000 - ~10,000 feet.	Includes a broad range of rock types from massive to soft variegated mudstones and siltstone and gypsiferous beds ("red beds"). Also includes siltstone, limestone, claystone, shale, and conglomerate.	The aquifer characteristics depend on the actual rock types present in specific areas. For example, thick sandstone beds likely have moderate permeability, particularly where fractured and are potential aquifers. Fine-grained rocks such as the shales, soft mudstones, and siltstones are potential aquitards. However, the unit has restricted occurrence and only locally affects groundwater flow patterns.
Permian and Pennsylvanian Carbonate Rocks	PPc	P, PP, Pr, Pa, Par, Pp, Pz	Upper Carbonate HGU	Occurs over broad regions in the central and northern portion of the region of study. Ranges from <1,000 – 9,000 feet thick	Mostly carbonate rocks with minor clastic rocks.	Major regional aquifer. Movement and storage of groundwater primarily controlled by networks of fractures or solution openings (or vuggy zones along fractures). Unit contains zones of high transmissivity that can be controlled by structural deformation, solution openings or karstic features. Unit potentially important as a conduit for interbasin groundwater flow.
Mississippian Siliciclastic Rocks	Ms	Mc, Md, MDd	Upper Siliciclastic HGU	Occurs over broad regions in the central and northern portion of the region of study. Ranges from 1,000 – 3,000 feet thick	Predominantly fine-grained clastic rocks (i.e., shale)	Regional aquitard that impedes flow between the lower and upper Paleozoic carbonate rock units.

Table 3.3.1-12 HGUs in the Study Area

HGU	Map Symbol	Geologic Map Units[1] (Geologic Age)	Equivalent HGU in BARCAS (Welch et al. 2007)	General Occurrence and Range of Thickness	Major Lithologic Characteristics	Generalized Aquifer Characteristics
Mississippian to Ordovician Carbonate Rocks	MOc	Ol, SOu, So, Ds, Dg, Dn, Dd, Du, DO, DS, MD	Lower Carbonate HGU	Occurs over broad regions throughout most of the region of study. Ranges from 1,000 – 12,000 feet thick	Predominantly carbonate rock with interbedded clastic rocks (i.e., shale, quartzite).	Major regional aquifer. Similar characteristics to PPc; movement and storage of groundwater primarily controlled by networks of fractures, solution openings (particularly vuggy zones or solution cavities formed along fracture zones). Unit contains zones of high transmissivity typically controlled by structural deformation, solution openings or karstic features. Unit potentially important as a conduit for interbasin groundwater flow.
Cambrian Carbonate Rocks	Cc	Cm, Cc	Lower Carbonate HGU	Occurs over broad regions throughout most of the region of study. Ranges from 2,000 – 6,000 feet thick	Predominently carbonate with limited clastic rocks	Major regional aquifer with similar properties to the MOc unit.
Cambrian to Precambrian Siliciclastic Rocks	CpCs	CpCs	Lower Siliciclastic HGU	Occurs over broad regions throughout most of the region of study. Ranges from 4,000 – 9,000 feet thick	Nonmetamorphosed to moderately metamorphosed siliciclastic rocks (predominantly shale and quartzite).	Regional aquitard with low permeability. Where it occurs at shallow depths, rocks are commonly highly fractured and can transmit relatively small flows.
Precambrian Metamorphic Rocks	PCm	PC	Lower Siliciclastic HGU	Basement rocks throughout region; exposed in the core of several mountain ranges	Crystalline metamorphic rocks including metamorphosed quartzite, slate and argillite.	Regional aquitard with very low permeability

[1]See Section 3.2, Geology, and SNWA (2008) for description of geologic map units.

Source: SNWA (2008); Welch et al. (2007); additional references for aquifer properties provided in text.

Figure 3.3.1-11 Structural Features

sequence of Pennsylvanian to Permian age carbonate rocks with minor clastic rocks. Both the Mississippian Siliciclastic Unit and upper carbonate-rock aquifer occur over broad areas in the northern and central regions of the region of study. However, these units have been removed by erosion and generally are not present in the southern portion of the region of study (i.e., south of Pahroc Valley).

Where both the upper and lower carbonate units are present, extensive normal faulting throughout the region has juxtaposed these units such that they are commonly in fault contact and probably are hydraulically connected in most areas (Plume and Carlton 1988). In addition, the carbonate-rock aquifer system is locally bounded by relatively impermeable, intrusive rocks, truncated by major faults zones that juxtapose the carbonate sequence against low-permeability rocks that potentially compartmentalize the aquifer into different flow systems (Winograd and Thordarson 1975).

Groundwater in the carbonate rocks primarily is stored and transmitted within a network of fractures that may have been solution-widened to varying degrees. Solution channels typically develop by the dissolution of carbonate minerals along secondary openings (such as fractures and faults) in the rock mass. As a result, solution channels are appreciably wider than the original secondary opening. Solution channel widths can range from inches to tens of feet (Plume 1996).

Analyses of 10 aquifer-pumping tests in the Cambrian to Devonian age carbonate sequence at the Nevada Test Site, northwest of Las Vegas and outside of the region of study, indicate a hydraulic conductivity that ranges from 0.7 to 700 feet per day (Winograd and Thordarson 1975), with a mean value of 80 feet per day and median values of 6 feet per day. Estimates from four wells in Pennsylvanian and Permian limestone, drilled and tested as part of the MX missile–siting program, indicate hydraulic conductivity ranging from 0.1 feet per day to 900 feet per day, with a mean of 200 feet per day and a median of 9 feet per day (Bunch and Harrill 1984). Higher values are assumed to reflect fault or fracture zones with solution widening; lower values are assumed to reflect relatively unfractured rock.

The combined thickness of the carbonate-rock aquifer system typically is greater than 20,000 feet. There is uncertainty regarding the depth of the groundwater flow within the carbonate-rock aquifer system. Significant secondary permeability does not extend over the entire stratigraphic thickness (Plume 1996). The base of the groundwater system is either the underlying siliclastic rocks or impermeable carbonate rocks presumed to occur at great depth (Plume 1996).

Basin-Fill Aquifer System

The basin-fill aquifer system is the most important and most developed aquifer in the region (Welch et al. 2007). Each HA within the region of study is characterized by a structural basin, filled by thousands of feet of clastic sediments eroded from adjacent mountain ranges. These clastic sediments include older and younger basin-fill deposits. The older deposits consist of Tertiary age, consolidated deposits of conglomerate, sandstone, siltstone, claystone, freshwater limestone, and evaporite, with local interbeds of volcaniclastic rocks. The older basin fill deposits are overlain by younger Pliocene to Holocene aged alluvium, colluvial, and lacustrine sediments that are predominantly uncemented and unconsolidated near the surface and are more-indurated with increasing depth. These deposits include coarser-grained material (predominantly sandy gravel with interbedded gravelly sand and sand) and fine grained playa and lake deposits (Welch et al. 2007). In general, the younger basin-fill deposits are coarser near the valley margins and become progressively finer towards the central axis of the valley. However, valleys drained by perennial streams typically have associated channel and flood-plain deposits that include coarse-grained materials. In summary, younger basin-fill deposits are inherently heterogeneous, characterized by complexly interfingered coarse- and fine-grained materials.

Lacustrine pertains to or is produced by a lake.

Colluvial material consists of alluvium and angular fragments of rocks that are typically found at the bottom or on lower slopes of hills.

The thickness of the basin-fill deposits ranges from zero at the valley margin to several thousands of feet along the axis of the valley. In some valleys in the region of study, the thickness of the basin fill locally exceeds 10,000 feet (SNWA 2008). In some valleys, the basin fill sediments are entirely enclosed by low-permeable bedrock. In other valleys, the basin fill extends laterally into one or more adjacent basins and is part of a multibasin flow system. Even where the basin-fill sediments are not laterally continuous between basins, they may be connected hydraulically by flow through permeable rocks.

Permeability is the ability of a material, such as rocks, to allow the passage of a liquid, such as water.

The permeability and hydraulic conductivities of the basin-fill deposits are highly variable and reflect the heterogeneous characteristics of the unit. The hydraulic properties of the material in a specific area depend on the lithology of the material, degree of sorting, and amount of interfingering and interbedding of coarse- and fine-grained sediments (Plume 1996). Aquifer tests in basin-fill sediments were conducted for the MX missile-siting investigation in valleys in central and eastern Nevada and western Utah. Those tests indicate that the hydraulic conductivity (for 18 tests) from 14 basins ranges from 0.02–140 feet per day and averaged 78 feet per day (Bunch and Harrill 1984).

Conductivity is the capacity of a rock or sedimentary deposit to transmit water (see the Glossary for additional description).

Volcanic Rock Aquifer

Volcanic rocks have a wide range of physical and hydraulic properties and can behave as either aquifers or flow barriers (Plume 1996). Despite the fact that volcanic rocks are widely distributed throughout the Great Basin, volcanic rocks have been identified as aquifers in relatively few areas (Plume 1996). Prudic et al. (1995) noted that fractured, basalt, and welded tuffs can yield significant quantities of water to wells, over large areas. At the Nevada Test Site, measured hydraulic-conductivity values for volcanic rocks (lava flows and ash flow tuffs) range from approximately 1.5 to 17 feet per day (Winograd and Thordarson 1975). Plume (1996) reported that 54 drill-stem tests in volcanic rocks in the Railroad and White River valleys in eastern Nevada produced hydraulic-conductivity values that range from less than 0.001 to 0.3 feet per day, with a mean value of 0.02 feet per day.

Potential Lithologic Barriers to Regional Groundwater Flow

Rocks with low permeability characteristics tend to confine, restrict, or impede groundwater flow in the regional aquifer systems. Although many of these rocks can yield or transmit small volumes of water if sufficiently fractured, in a regional framework, these rocks are not considered regional aquifers. Depending on their stratigraphic position and structural juxtaposition, these rocks have the potential to restrict both vertical and horizontal flow paths. Identifying the spatial distribution of these low-permeability rocks is important to understanding potential barriers to flow between basins, or boundaries that segregate flow systems within the carbonate-rock aquifer system (Prudic et al. 1995).

From oldest to youngest, the following HGUs are considered as potential barriers to regional flow: 1) Precambrian metamorphic rocks and Cambrian to Precambrian siliciclastic rocks (also collectively referred to as the Lower Siliciclastic Unit); 2) Mississippian siliciclastic rocks (also referred to as the Upper Siliciclastic Unit); 3) Cretaceous to Triassic siliciclastic rocks (also referred to as the Mesozoic Sedimentary Unit); 4) Tertiary to Jurassic intrusive rocks (also referred to as the Intrusive Unit) (Welch et al. 2007).

The two lowermost units—the Precambrian Metamorphic HGU and Cambrian to Precambrian Siliciclastic HGU—are believed to have very low permeability characteristics throughout the eastern Great Basin (Winograd and Thordarson 1975; Plume 1996). Regionally, the top of this unit represents the base of the groundwater flow system (Welch et al. 2007).

The Mississippian Siliciclastic HGU consists predominantly of shaley, fine-grained, low-permeability rocks. The water-bearing properties of this unit are not well known, but it is assumed to behave as a local barrier to flow between the upper and lower carbonate-rock aquifers.

The Cretaceous to Triassic Siliciclastic HGU occurs in local, isolated areas in the north and central portions of the region of study and along the margin of the Colorado Plateau in the southeastern portion of the region of study. This unit includes diverse lithologies, and its water-bearing properties are unknown (Plume and Carlton 1988). Because these rocks have only localized occurrences and are relatively thin, they are not considered to behave as important conduits for groundwater flow (Welch et al. 2007). However, in the southeastern portion of the region of study, these units are relatively thick and are likely to include lithologic zones with moderate permeability.

The Tertiary to Jurassic Intrusive HGU occurs as large plutons that form a large portion of the Snake, Schell Creek, Egan, and Kern ranges (SNWA 2008). Large intrusive bodies also are inferred to exist beneath ash flow tuff sequences within the White River, Indian Peaks, Central Nevada, and Caliente Caldera complexes. These intrusives primarily are composed of granodiorite and quartz monzonite. No aquifer tests have been performed on the intrusive rocks within the region of study. However, intrusive rocks generally have very low permeability and impede the movement of groundwater (Plume 1996). Belcher et al. (2001) report horizontal hydraulic conductivities from 0.002 feet per day to 3.3 feet per day for Jurassic- to Oligocene-age granodiorite, quartz monzonite, granite, and tonalite in Southern Nevada and parts of California. In some areas, plutons intrude the carbonate-rock aquifers and act as potential vertical barriers to groundwater flow.

Hydrostructural Conditions

In summary, the region of study is located within a region that has experienced various episodes of structural deformation, including compressional, extensional, and translational tectonics. As a result, the structural geology of the region of study is complex. Major fault or structural zones identified or mapped within the region of study include detachment faults, thrust faults, strike-slip faults, normal faults, and east-west lineaments (SNWA 2008). The structural geology and tectonic evolution of the region is discussed in Section 3.2, Geologic Resources.

Slip refers to a planar feature where movement along a fault has occurred and resulted in the displacement of formerly adjacent points on either side of the fault.

Groundwater flow pathways are influenced by major faults that offset and displace rock units and older alluvial deposits. The distribution of major fault zones and other structural discontinuities (i.e., lineaments) in the region of study are shown in **Figure 3.3.1-11**. Fault zones typically are lithologically heterogeneous (i.e., nonuniform) and structurally anisotropic (i.e., variable in different directions) (Caine et al. 1996). Depending on the physical properties of the rocks involved, the amount and type of structural deformation, and the alteration and mineralization history, fault zones may behave as barriers, conduits, or combined conduit/barrier systems that enhance or restrict groundwater flow (Caine et al. 1996). In addition, the hydraulic properties of the materials within individual fault zones can vary spatially along the fault zone.

Gouge is pulverized, clay-like material found along some faults; formed by the grinding of rock material during fault movement.

For the purposes of discussion, fault zones can be subdivided into two zones: the principal fault zone and the damaged zone. Both zones can have distinct physical properties that control the storage and movement of groundwater. The principal fault zone is defined as the zone in which most of the displacement has occurred and can consist of a wide range of materials, including a single slip or multiple slip surfaces, unconsolidated clay-rich gouge, breccia zones, chemically altered zones, or mylonite zones. The generation of fine-grained materials and alteration and mineral precipitation tends to reduce the porosity and permeability of the primary fault zone, compared to the adjacent unfaulted bedrock materials (Caine et al. 1996). The principal fault zone can be bounded on one or both sides by a damaged zone, defined as a zone of fractured or highly fractured rock that is associated with the fault zone and that has not experienced large displacement. By definition, rocks within the damaged zone are more highly fractured than the bedrock outside of the fault zone. The fracture network within the damaged zone tends to have a higher or enhanced permeability, compared to both the principal fault zone and the less-fractured regional bedrock material outside of the fault zone (Caine et al. 1996). In this way, major regional fault zones have the potential to behave as both conduits and barriers to groundwater flow.

Breccia is rock made up of angular fragments of other rocks, held together by mineral cement or a fine-grained matrix. Fault breccia is made by breaking and grinding rocks along a fault.

Mylonite is a brecciated, metamorphic rock frequently found in a fault zone; formed by the crushing actions of fault movement.

The major hydrostructural features that occur in the region, and their potential influence on groundwater flow patterns, are briefly summarized in the following paragraphs. In the region of study, the basin and range topography is defined by an extensive system of normal faults, which separate the basin and mountains ranges. The systems of north- to northwest-trending fault zones bound the mountain blocks and typically display vertical displacements of several thousand feet (or greater). These faults commonly juxtapose permeable basin-fill sediments against older consolidated rock as well as permeable rocks against low-permeability rocks. Fault displacement of aquifer units against materials with low permeabilities can result in fault compartmentalization of aquifers (Winograd and Thordarson 1975). Where they are not cemented, the highly fractured rocks (or damaged zone) associated with these faults can behave as conduits for groundwater flow (Prudic et al. 1995). Flow also can be restricted across these fault zones where they contain fault gouge or other fine-grained materials, alteration products, or mineral precipitation products.

Four east-west oriented transverse lineaments have been identified in the region of study (SNWA 2008). These lineaments generally are several tens of miles to hundreds of miles long and up to several miles wide and are oriented at nearly right angles to the basin and range normal faults. These lineaments are marked by alignment of such features as topographic breaks or terminations of mountain ranges, stratigraphic discontinuities, positioning of large volcanic fields and caldera boundaries, and in some instances, emplacement of large igneous intrusions. The influence of these large structural features on regional groundwater flow patterns is not well understood. Prudic et al. (1995) infer that these lineaments may behave as leaky barriers to groundwater flow or could act as barriers where they disrupt or truncate carbonate-rock aquifers.

Several shear zones, defined by either left-lateral or right-lateral movement, occur in the region of study (SNWA 2008). The identified shear zones primarily are restricted to the southern half of the region of study. The most notable shear zones are the Pahranagat shear zone and the Las Vegas shear zone. The Pahranagat shear zone consists of a series of roughly parallel left lateral faults that trend east-northeast in the southern portion of Pahranagat Valley, Delamar Valley, East Pahranagat Range, Hiko Range, and the southern Delamar Mountains and adjacent areas, as mapped by Ekren et al. (1976). Eakin et al. (1966) inferred that the relatively large hydraulic gradient between Pahranagat Valley and Coyote Valley was likely the result of the Pahranagat shear zone acting as an impediment to flow. The Las Vegas shear zone is a west-northwest trending right-lateral shear zone that defines the southern boundary of the region of study in the Las Vegas Valley. Winograd and Thordarson (1975) inferred that a steep gradient between adjacent wells in Las Vegas Valley is evidence that the shear zone is a barrier to groundwater flow.

Several major thrust faults have been mapped in the southern part of the region of study but occur in only few isolated areas in the northern and central parts of the region of study (SNWA 2008). The SNWA (2008) suggest that gouge and mylonite zones associated with these thrust faults act as impediments to flow, most notably in the Sheep and Pahranagat ranges, Delamar Mountains, and several other ranges in the southern portion of the region of study. Prudic et al. (1995) suggest that because they could not correlate the locations of major thrust faults with changes to simulated water levels and transmissivities during regional modeling, these structures may only minimally influence regional groundwater flow patterns.

Potential for Interbasin Groundwater Flow

Interbasin flow of groundwater depends both on the geologic conditions between basins and groundwater gradients. SNWA (2008) and Welch et al. (2007) identified locations in which the known or inferred geologic conditions between the hydrographic basins could allow for significant movement of groundwater, without respect to groundwater gradient. Groundwater flow could occur wherever the consolidated rocks under the valleys and in the mountains that separate the valleys are permeable and interconnected and wherever the basins are connected by unconsolidated sediments (basin fill). Groundwater flow between hydrographic basins is considered to be unlikely in areas where the hydrographic basins are separated by relatively impermeable bedrock. For additional information and discussion of potential locations for interbasin flow, see SNWA 2008 and Welch et al. 2007.

Groundwater Elevations, Gradients, and Potential Flow Directions

The following summary of groundwater elevations is based on the information in the report "Water Level Data Compilation and Evaluation for the Clark, Lincoln, and White Pine Counties Groundwater Development Project" (SNWA 2008). This report presents the results of a comprehensive compilation and evaluation of water-level data for the project basins and other hydrographic basins included within the region of study.

As described in this baseline report, water-level measurements were compiled from 1,976 wells and springs in the region of study, derived from published and unpublished reports and agency databases. The data evaluation included determining the effective open interval and the HGU for each well completion, calculating water-level elevations from depth-to-water data, and identifying outlier and non-steady state water-level measurements. The resulting data set was used to construct water-level contour maps for the basin-fill aquifer for each hydrographic basin. Additional maps that show areas of shallow groundwater also were developed for basins where there is significant groundwater discharge from ET. A water-level contour map also was constructed for the carbonate-rock aquifer system for the entire region of study (**Figure 3.3.1-12**).

Details regarding the data reduction and analysis methodologies and a complete set of water-level contour maps for all basins were provided in the report. The following section provides an overview of the water-level data for the five basins proposed for groundwater development under the Proposed Action and alternatives.

Spring Valley

Basin Fill Aquifer

A water-level elevation map for the basin-fill aquifer in Spring Valley is presented in **Figure 3.3.1-13**. Water-level elevations for wells completed in the basin-fill aquifer range from 6,862 feet amsl (in the northern portion of the valley) to 5,537 feet amsl (in the central portion of valley). The water levels are higher in the north and south ends of the valley and lower in the center of the valley, indicating that the general direction of groundwater flow within the basin-fill material is toward the central portion of the valley. The hydraulic gradient is approximately 25 to 30 feet per mile in the northern part of the valley and approximately 5 feet per mile in the southern part of the valley (SNWA 2008).

In addition, the water-level data suggest that a groundwater divide in southern Spring Valley separates groundwater that flows toward the central portion of Spring Valley from groundwater that flows towards Hamlin Valley.

As shown on the depth-to-water map (**Figure 3.3.1-14**), shallow groundwater conditions exist over large portions of the valley floor in Spring Valley. Depths to groundwater ranges from above ground surface (i.e., flowing wells and spring discharge areas) to greater than 400 feet below ground surface near the southern end of the valley. The central portion of the valley contains a number of springs, ponds, and small playa lakes; most of these features are presumably controlled by groundwater discharge.

Carbonate-Rock Aquifer

Water-level elevation data for the carbonate-rock aquifer system in Spring Valley are provided in the SNWA's baseline water resource report (SNWA 2008). The water level data were derived from water level measurements at six sites, which include three wells drilled prior to 2006 and three new locations drilled by SNWA in 2006 and 2007 (SNWA 2008). Each of the three SNWA locations includes a test well and a monitoring well.

The average water level elevations for the carbonate-rock wells range from a high of 6,645 feet amsl located along the east central edge of the valley near Sacramento Pass to 5,706 feet amsl for the southernmost SNWA test well situated at the Hamlin Valley hydrographic basin boundary. The SNWA (2008) noted that the high water elevations in the well near Sacramento Pass might be influenced by the presence of clastic rocks that confine the carbonate-rock aquifer in this area. The water-level data for the wells completed in the carbonate-rock aquifer system suggest there is a potential for groundwater to flow from north to south in the southern half of Spring Valley. The water-level data for the region suggest that there is a potential for groundwater in the carbonate-rock aquifer to flow from the southern half of Spring Valley into Hamlin Valley and then into Snake Valley.

A water-level elevation map of the carbonate-rock aquifer recently was completed as part of the BARCAS study (Wilson 2007). That study suggested that some of the groundwater in the carbonate-rock aquifer in the northern half of the Spring Valley HA flows northward into the Tippett Valley HA; and some water flows east into Snake Valley along the northeast boundary of the HA.

Trends

Hydrographs were constructed for wells that had 10 or more depth-to-water measurements (SNWA 2008). All of the wells that met the 10-or-more-measurement criterion are completed in the basin-fill aquifer. Review of the hydrographs indicates that most wells exhibit water-level variations of 1 to 10 feet in the basin-fill aquifer. Several wells display trends lasting several years of decreasing or increasing water levels. A USGS MX well near the center of the valley (N15 E67 26CA1) exhibits the maximum variation and indicates a long-term reduction of water levels of approximately 14.5 feet over the period of record (1981 and 2006). The SNWA (2008) suggests that some wells that show a reduction in water-level elevation occur in or near agricultural areas.

Figure 3.3.1-12 Carbonate-Rock Aquifer System Water-level Map

Figure 3.3.1-13 Spring Valley – Basin Fill Aquifer Water-level Elevation Map

Figure 3.3.1-14 Spring Valley – Basin Fill Aquifer Depth-to-Water Map

Snake Valley

Basin Fill Aquifer

Data has been compiled for more than 250 wells and springs in Snake Valley (SNWA 2008). **Figure 3.3.1-15** presents the average water levels for specific wells and springs and interpreted water-level elevation contours for the basin-fill aquifer system in Snake Valley. Water level elevations for wells on the valley floor range from approximately 5,522 feet amsl (along the southern margin of the valley) to 4,324 amsl (in the northernmost portion of the valley). The water-level contours indicate that groundwater in the basin fill sediments generally flows toward the north (towards the Great Salt Lake Desert HA) with a north-to-south hydraulic gradient of approximately 11 feet per mile (SNWA 2008).

The depth to groundwater in Snake Valley ranges from above ground surface to greater than 500 feet below ground surface. As shown in **Figure 3.3.1-16**, the depth to groundwater is less than 50 feet over large areas in the central portion of the valley. The depth to groundwater generally increases toward the margins of the valley and is greatest in the southeast and south margins of the valley.

Carbonate-Rock Aquifer

Water-level elevation data for the carbonate-rock aquifer system in Snake Valley is presented in the SNWA's baseline water resources report (SNWA 2008). This data set identified five wells completed in the carbonate-rock aquifer system; three of these are oil wells along the southern boundary of the HA. The water levels for these monitoring wells range from 6,194 feet amsl to approximately 4,988 feet amsl. The regional water-level data indicate that the gradient for groundwater flow in the carbonate rocks in Snake Valley is generally from southwest to northeast, across the basin.

Water-level elevation contour maps prepared as part of the USGS BARCAS study (Wilson 2007) indicate that in the central portion of the Snake Valley HA, groundwater in the carbonate-rock aquifer system flows from west to east, with a potential for flow beneath the Confusion Range and toward the Tule Valley HA. The USGS study also indicates that groundwater in the carbonate rock system in the northern portion of the Snake Valley HA flows toward the northeast (toward the Great Salt Lake Desert HA).

Trends

Hydrographs were constructed for wells with 10 or more depth-to-water measurements (SNWA 2008). All of the wells that met this criterion are completed in the basin-fill aquifer. Review of the hydrographs indicates that most wells exhibit variations of 10 feet or less; however, some wells show water-level fluctuations of as much as 50 feet. There is no consistent trend for water levels across the valley. Some wells exhibit relatively consistent water levels over their respective period of record, whereas many wells show increasing or decreasing water level trends that continue over several years or several decades. Additional description of water level trends and hydrographs for wells in Snake Valley are provided in the project baseline characterization report (SNWA 2008); and in the appendices to the transient groundwater model report (SNWA 2009b).

The USGS maintains a "groundwater watch" web site (USGS 2010) that provides up-to-date statistics on water level measurements and trends for active wells monitored in Snake Valley and throughout the nation. Review of the data sets for the central and southern portions of Snake Valley indicate that there is a cluster of wells located in the area around Eskdale, Utah (extending south to Highway 50/6 and west to Gandy Road), where most wells in the network within this area exhibit a trend of declining water levels starting in the late 1980s or early 1990s and continuing to the present (March 2011). The non-artesian wells located in this area have experienced a reduction of water levels over this period ranging from approximately 3 to 10 feet. Two other wells in this area, including the BLM's Shell-Baker Creek Well is located just south of Highway 50/6; and the USGS-MX (Snake Valley North) well located west of the Gandy Road in Nevada near the state line also show declining water level trends.

Two artesian wells in this area are included in the groundwater watch monitoring well network—the West Buckskin Well (USGS location number C-20-19 1bcc-1) located about 2 miles south of Eskdale; and Flowing Well #2 (USGS location number C-20-19 8bcb-1) located about 5 miles southwest of Eskdale. Both artesian wells are reported to be completed in the basin fill aquifer and have only limited head measurement data.

Figure 3.3.1-15 Snake Valley – Basin Fill and Volcanic Aquifers Water-level Elevation Map

Figure 3.3.1-16 Snake Valley – Basin Fill and Volcanic Aquifers Depth-to-Water Map

The head measured at the West Buckskin Well was reported as 12.2 feet above ground surface in 1951. Quarterly monitoring initiated in September 2009 indicated a head of 4.41 feet above ground surface that has continued to decline to 2.44 feet above ground surface as of March 2011. This limited dataset indicates that the head in the West Buckskin Well has declined a total of 9.13 feet since the 1951 measurement.

For Flowing Well #2, 4 measurements have been taken between 1936 and 1948 and 8 measurements taken quarterly between June 2009 and March 2011. The older water level data suggest that the head was relatively stable over the 1936 to 1948 period with measurements ranging from 7.4 to 8.6 feet above ground surface. All of the recent quarterly measurements indicate that the head in the well has dropped below surface with depth to water measurements fluctuating seasonally between 20.73 to 5.12 feet below ground surface. This limited dataset indicates that the head in Flowing Well #2 has declined a total of 13.12 to 28.73 feet depending on the season compared to the 1948 measurement. The limited water levels recorded during the recent quarterly monitoring are not sufficient to definitely identify any current trends in the well. The Utah Geological Survey (UGS) has recently established a groundwater monitoring network in Utah's west desert that includes a series of wells installed at 27 sites in Snake Valley HA. The wells were installed between 2007 and 2009 and include: 1) paired wells competed in the carbonate rock and basin fill aquifers; 2) wells located near agricultural areas; 3) water quality monitoring wells; 4) wells located near springs; and 5) shallow piezometers (less than 10 feet deep) in sensitive wetlands associated with spring discharge areas. Information on these monitoring locations, including water level hydrographs for the wells, is provided at the UGS web site (UGS 2010). Water levels have declined in the vicinity of Needle Point Springs as previously discussed in the surface water resources section for Snake Valley. UGS monitoring network includes continuous water level monitoring at Needle Point Springs and at a new well located approximately 1 mile south of Needlepoint Springs.

Cave Valley

Basin-Fill Aquifer

A water-level elevation map for the basin-fill aquifer in Cave Valley is presented on **Figure 3.3.1-17**. Water-level elevations that were completed in the basin-fill aquifer range from 6,896 feet amsl (near the north end of the valley) to 5,790 feet amsl (in the southern portion of Cave Valley). The water-level data indicate that the general direction of groundwater flow within the basin fill material is from north to south, with a gradient of approximately 48 feet per mile. The depth to groundwater ranges from near surface in the northern portion of the valley (**Figure 3.3.1-18**) to greater than 200 feet below ground surface in the southern portion of the valley.

Carbonate-Rock Aquifer

Water-level elevations for five wells completed in the carbonate-rock aquifer system in Cave Valley are presented in SNWA's water resource baseline report (SNWA 2008). These limited data suggest that in Cave Valley, a potential exists for groundwater flow from south to north within the carbonate-rock aquifer. However, Cave Valley can be subdivided into a north and south subbasin with distinct structural characteristics that are separated by an oblique-slip fault (SNWA 2008) or normal fault (Welch et al. 2007). This fault and structural discontinuity between the two subbasins could disrupt or partition the groundwater flow system in the carbonate-rock aquifer in Cave Valley (SNWA 2008).

On a regional scale, the water levels in the carbonate wells in the central and southern portion of Cave Valley typically are several hundred feet higher than those in carbonate wells in White River Valley. The difference in water-level elevations between these two adjacent basins suggests the potential for groundwater in the carbonate-rock aquifer system in Cave Valley to flow towards the west or southwest into White River Valley (Harrill et al. 1988; Wilson 2007).

Trends

A well drilled during the MX missile program and completed in the carbonate-rock aquifer system in the south central portion of the region of study has shown a gradual increase in water levels of approximately 10 feet since 1980. There are no other wells with long-term (greater than 10 years) water-level recordings in Cave Valley (SNWA 2008).

Figure 3.3.1-17 Cave Valley – Basin Fill and Volcanic Aquifers Water-level Elevation Map

Figure 3.3.1-18 Cave Valley – Basin Fill and Volcanic Aquifers Depth-to-Water Map

Dry Lake and Delamar Valleys

Basin-Fill Aquifer

Water level data for the basin-fill aquifer system in Dry Lake and Delamar valleys is presented on **Figures 3.3.1-19** and **3.3.1-20**, respectively. Water-level data for these two basins is limited. Water-level elevations for wells completed in the upper valley basin-fill sediments ranges from greater than 5,431 feet amsl (near the north end of Dry Lake Valley) to 3,845 feet amsl (near the center of Delamar Valley). The water-level data indicate that the general direction of groundwater flow within the basin-fill material is from north to south, with a gradient between the central portions of one valley to another of approximately 13 feet per mile. The depth to groundwater ranges from 200 to 500 feet below ground surface in Dry Lake Valley and exceeds 800 feet in Delamar Valley.

Carbonate-Rock Aquifer

Only two wells completed in the carbonate-rock aquifer have been identified in these hydrographic basins (SNWA 2008). Both wells are near the west margin of Dry Lake Valley. The average water levels for the two wells are 4,541 to 4,288 feet and suggest a general north-to-south flow direction in the carbonate-rock aquifer system in this region. These carbonate-rock water levels are more than 1,000 feet lower in elevation than water levels in Cave Valley that adjoin to the north and more than 2,000 feet higher than water levels in wells in Coyote Spring Valley that adjoin to the south. These numbers suggest a potential for groundwater in the carbonate-rock aquifer in southern Delamar Valley to flow toward the south into Coyote Spring Valley.

Trends

Only a few monitoring wells in these basins have been used for long-term water-level recordings. Five wells completed for the MX missile–siting program have reliable water-level data that extend back to the early 1980s. Water-level data for a well completed in the carbonate-rock aquifer system in Dry Lake Valley indicate that there has been a gradual increase in water levels of approximately 5 feet over the past 25 years. Hydrographs for wells completed in the basin-fill sediments also tend to show a gradual water-level increase of as much as several feet over the past 1 to 2 decades (SNWA 2008).

Groundwater Budget Estimates

A groundwater budget is a basic accounting of the inflows and outflows from an aquifer system in a specific area. Water budgets provide a means to quantitatively evaluate the availability and sustainability of a water resource (Healy et al. 2007). Under predevelopment conditions, the major components of inflow in a groundwater system include recharge from precipitation and groundwater inflow from adjacent basins. The principal groundwater outflow components include discharge of groundwater by ET and groundwater that leaves the area as subsurface flow in the aquifer system.

A *groundwater budget* is a basic accounting of the inflows and outflows from an aquifer system in a specific area.

This section provides an overview of past and relatively recent water-balance estimates developed for the five basins identified for the Proposed Action and alternatives. In the 1960s and 1970s, the USGS, in cooperation with the State of Nevada, conducted water-resource reconnaissance studies throughout Nevada. These studies were intended to evaluate the availability of groundwater resources within specific hydrographic basins. These reports typically provide an estimate of recharge and ET and discuss groundwater subsurface flow into or out of the hydrographic basins. Recharge to the groundwater system from direct precipitation was estimated using an empirically derived relationship between precipitation and recharge developed by Maxey and Eakin (1949). Water resource reconnaissance reports are available for all of the basins within the region of study. The recently completed USGS BARCAS study (Welch et al. 2007) provides a reevaluation of the recharge and groundwater discharge components for basins in the northern portion of the region of study, including three (i.e., Spring Valley, Snake Valley, and Cave Valley) of the five basins that would be developed under the Proposed Action. Precipitation recharge to groundwater was estimated using a mathematical model known as the Basin Characterization Model, which incorporates data sets for geology, soils,

The *Basin Characterization Model* (BCM) incorporates data sets for geology, soils, vegetation, air temperature, slope aspect, potential ET, and precipitation to create a mathematical estimate of the precipitation recharge to groundwater in a given basin.

Figure 3.3.1-19 Dry Lake Valley – Basin Fill and Volcanic Aquifers Water-level Elevation Map

Figure 3.3.1-20 Delamar Valley – Basin Fill and Volcanic Aquifers Water-level Elevation Map

vegetation, air temperature, slope, aspect, potential ET, and precipitation (Flint and Flint 2007). Groundwater ET discharge was reevaluated by using the Landsat Thematic Mapper (TM) to map ET units. The ET units were selected to correspond to different vegetation and soil conditions common to ET areas. The ET losses were estimated by determining the acreages of land cover types within each basin for each ET unit, multiplying the acreages by a coefficient to estimate ET losses, and summing the losses for each unit to estimate the total ET losses within each area.

The BARCAS study used a groundwater-accounting computer model to estimate groundwater flow between the hydrographic basins. The computer model is described as a simplified, mass-balance mixing model that uses deuterium as a trace. The model was based on deuterium concentrations from sites distributed throughout the BARCAS region of study (Welch et al. 2007).

The SNWA has completed several studies in the past several years; these studies were submitted as exhibits to provide estimates of water availability for water rights hearings for Coyote Spring Valley (LVVWD 2001), Spring Valley (SNWA 2006), and Cave, Delamar, and Dry Lake valleys (SNWA 2008). Recharge to the groundwater system from precipitation was estimated by using an empirically derived relationship between precipitation, recharge, and altitude, similar to that developed by Maxey and Eakin (1949). The revised Maxey-Eakin relationship is based on a distribution of average annual precipitation, derived from the PRISM (Parameter-elevation Regressions on Independent Slopes Model) into zones where each zone is related to groundwater recharge via empirically derived recharge coefficients. Recent studies by the SNWA (SNWA 2006 and 2008) also have used remote sensing imagery to map the ET units and have estimated ET by using methods similar to those used by the USGS for the BARCAS (Welch et al. 2007).

Recent compilations of published and unpublished water-balance estimates for the hydrographic basins within the region of study are discussed in the BARCAS study (Welch et al. 2007), SNWA documents (LVVWD 2001; SNWA 2009a, 2008, 2006), and Burbey (1997).

Spring Valley

Selected water-balance estimates for the Spring Valley HA are presented on **Table 3.3.1-13**. Rush and Kazmi (1965) conducted the first comprehensive evaluation of the water resources in Spring Valley. They estimated that the average annual groundwater recharge for the Spring Valley HA was 75,000 afy. Of this 75,000 afy of recharge, Rush and Kazmi (1965) estimated that an average of approximately 70,000 afy was consumed by ET on the valley floor; 4,000 afy was discharged from the southeastern boundary into Hamlin Valley; and (in 1964) less than 1,000 acre feet of groundwater was pumped for stock, domestic, and irrigation use.

Table 3.3.1-13 Estimated Groundwater Inflow and Outflow for the Spring Valley Hydrologic Area (afy)[1]

Water Balance Component	Rush and Kazmi (1965)	SNWA (2006)	Welch et al. (2007)	SNWA (2009a)[2]
Groundwater Inflow				
Precipitation Recharge (Direct and Mountain Front Recharge)	75,000	98,800	93,100	81,300
Groundwater Inflow from Tippet Valley HA		2,000	0	
Groundwater Inflow from Steptoe Valley HA			4,000	
Groundwater Inflow from Lake Valley HA			29,000	
Total Inflow	**75,000**	**100,800**	**126,100**	**81,300**
Groundwater Outflow				
ET	70,000			75,600
Natural Vegetation and Dry Playa		90,000	72,000	
Irrigated Crops		5,800	4,000	
Other Groundwater Uses (mining and milling, stock water, quasi-municipal, wildlife)	<1,000	300	100	
Groundwater Outflow to Tippets Valley HA			2,000	
Groundwater Outflow to Snake Valley HA			16,000	

Table 3.3.1-13 Estimated Groundwater Inflow and Outflow for the Spring Valley Hydrologic Area (afy) (Continued)

Water Balance Component	Rush and Kazmi (1965)	SNWA (2006)	Welch et al. (2007)	SNWA (2009a)[2]
Groundwater Outflow to Hamlin/Snake HA	4,000	4,000	33,000	5,700
Total Outflow	**75,000**	**100,100**	**127,100**	**81,300**
Yield and Storage Estimates				
Estimated Groundwater Storage (upper 100 feet saturated basin fill)	4,200,000		3,788,000	

[1] Estimates rounded to the nearest hundred afy.

[2] Estimated predevelopment steady-state groundwater budget.

The SNWA presented estimates of the water balance for Spring Valley at the hearings for their water rights applications in Spring Valley (SNWA 2006). At that time SNWA estimated that the average annual groundwater inflow to Spring Valley consisted of 98,800 afy of precipitation recharge and 2,000 afy of groundwater subflow from Tippets Valley HA (SNWA 2006). Groundwater outflow from Spring Valley included losses through ET from native vegetation and playas (90,000 afy), crop irrigation (5,800 afy), other uses (300 afy), and discharge to Hamlin Valley (4,000 afy).

The groundwater balance derived from estimates provided in the BARCAS study (Welch et al. 2007) suggests that there is substantially more groundwater moving through the Spring Valley HA than previously recognized. The BARCAS water budget estimates indicate that in addition to recharge (93,100 afy), groundwater flows from the west into the basin from Steptoe Valley (4,000 afy) and Lake Valley (29,000 afy). Although the ET estimates for natural vegetation and playa areas are similar to the estimates in the water resources reconnaissance report (Rush and Kazmi 1965), the BARCAS study indicates that a large percentage of the groundwater moving through the basin discharges as subsurface flow into the adjacent Snake and Hamlin valleys HAs (49,000 afy) to the west and the Tippet Valley HA (2,000 afy) to the north.

The SNWA provided new estimates of the steady-state predevelopment (i.e., prior to any groundwater development) groundwater budget for each basin within the hydrologic study area in the Conceptual Model Report (SNWA 2009a). These estimates indicate that groundwater inflow to the Spring Valley consists of 81,000 afy of precipitation recharge with no groundwater inflow from adjacent basins. Groundwater discharged from the basin was estimated at 76,000 afy to ET and 6,000 afy as groundwater outflow to the Hamlin Valley HA.

Snake Valley

Both the water resources reconnaissance report (Hood and Rush 1965) and the BARCAS study (Welch et al. 2007) define Snake Valley as the combination of the Snake Valley HA (Hydrographic Basin 195) and the Hamlin Valley HA (Hydrographic Basin 196), as designated by the NDWR (2009). Note that the NSE administers water rights individually for each of these basins. The baseline data reports for this project also address resources individually for each of these basins (SNWA 2008).

Selected water-balance estimates for groundwater inflow and outflow to the combined Snake Valley/Hamlin Valley HA are listed in **Table 3.3.1-14**. The water resources reconnaissance report estimates that the average groundwater inflow into this area (104,000 afy) is comprised of 100,000 afy of precipitation recharge and 4,000 afy of groundwater inflow from southern Spring Valley to Hamlin Valley (Hood and Rush 1965). The average annual groundwater outflow from this area is estimated to consist of 80,000 afy of ET from phreatophytes in the valley bottom; 7,000 afy pumped from wells used for irrigation and other uses; and 10,000 afy of groundwater that discharges through the alluvium across the north boundary of the Snake Valley HA into the Great Salt Lake Desert hydrographic basin (Hood and Rush 1965). Hood and Rush (1965) assumed that the difference between the estimated inflow and outflow components is groundwater that is discharged out of the area through the carbonate rock system. Using estimates provided in Hood and Rush (and accounting for losses from groundwater use for irrigation and other uses), the net difference is 7,000 afy.

Table 3.3.1-14 Estimated Groundwater Inflow and Outflow for the Combined Snake and Hamlin Valleys Hydrographic Basins (afy)[1]

Water Balance Component	Hood and Rush (1965)	Welch et al. (2007)	SNWA (2009a)[3]
Groundwater Inflow			
Precipitation Recharge (Direct and Mountain Front Recharge)	100,000	111,000	151,000
Groundwater Inflow from Spring Valley HA	4,000	49,000	5,700
Total Inflow	**104,000**	**160,000**	**156,700**
Groundwater Outflow			
ET (Natural Vegetation and Playa)	80,000	124,000	132,300
Irrigated Crops	7,000	8,000	
Other Groundwater Uses (mining and milling, stock water, quasi-municipal, wildlife)			
Groundwater Outflow to Great Salt Lake Desert HA to north	10,000	29,000	
Groundwater Outflow to Carbonate Rock System to east[2]	7,000	0	
Groundwater Outflow to Great Salt Lake Desert Flow System (to north and east)			24,400
Total Outflow	**104,000**	**161,000**	**156,700**
Yield and Storage Estimates			
Estimated Groundwater Storage (upper 100 feet saturated basin fill)	12,000,000	8,944,900	

[1]Estimates rounded to the nearest hundred afy.

[2]Estimated using the difference between inflow and outflow components provided in Hood and Rush (1965).

[3]Estimated predevelopment steady-state groundwater budget provided in Appendix I, SNWA 2009a.

The groundwater budget derived from recent estimates developed for the BARCAS study (Welch et al. 2007) is provided in **Table 3.3.1-14**. The results of the BARCAS study suggest that substantially more groundwater is moving through the Hamlin and Snake valleys hydrographic basins than was estimated in the water resources reconnaissance report (Hood and Rush 1965). The BARCAS water budget estimates that the total groundwater inflow to the area is 160,000 afy, comprising 111,100 afy of precipitation recharge and 49,000 afy of groundwater inflow from the Spring Valley HA. The BARCAS study results infer that groundwater inflow from the Spring Valley HA occurs in two general areas. The first area is between the Kern Mountains and Snake Range, along the northeast boundary of the Spring Valley HA, where estimated groundwater inflows of 16,000 afy flow into the northern portion of Snake Valley. The second area is along the southeast boundary of the Spring Valley HA, where an estimated 33,000 acre foot per year of water is inferred to flow into Hamlin Valley south of the Snake Range.

The BARCAS study estimates that groundwater outflow from the area occurs through ET (124,000 afy), pumping for crop irrigation (8,000 afy), and groundwater outflow (29,000 afy) (Welch et al. 2007). Most of the groundwater outflow is inferred to discharge across the northern boundary of Snake Valley into the Great Salt Lake Desert HA.

The SNWA estimates of the steady-state predevelopment quantities provided in the Conceptual Model Report (SNWA 2009a) indicates groundwater inflow to the combined Snake and Hamlin Valley HAs consists of 151,000 afy of precipitation recharge and 5,700 afy of groundwater inflow from the Spring Valley HA. Groundwater discharged from the basin was estimated at 132,300 afy to ET and 24,400 afy outflow to the Great Salt Lake Desert Flow System along the boundary of the study area. Compared to the BARCAS water balance estimates, the SNWA estimate assumes greater inflow from recharge, and substantially less groundwater inflow from Spring Valley. However, the total inflow estimates for the BARCAS study (160,000 afy) and SNWA conceptual model (156,700 afy) are similar.

Cave Valley

The water resource reconnaissance study (Eakin 1962) for the Cave Valley HA estimated the average annual recharge at 14,000 afy (**Table 3.3.1-15**). The reconnaissance study also indicates that ET is no more than a few hundred acre feet per year and estimates that most of the recharge leaves Cave Valley by subsurface flow toward the west and southwest. Harrill et al. (1988) interpret that the approximately 14,000 afy estimated by Eakin (1962) flows west into the White River HA.

Table 3.3.1-15 Estimates of Groundwater Inflow and Outflow for the Cave Valley Hydrologic Area (afy)[1]

Water Budget Component	Eakin (1962)	Welch et al. (2007)	SNWA (2007)	SNWA (2009a)
Groundwater Inflow				
Precipitation Recharge	14,000	11,000	14,700	15,000
Groundwater Inflow from adjacent basins	0	0	0	0
Total Inflow	**14,000**	**11,000**	**14,700**	**15,000**
Groundwater Outflow				
ET	few 100	1,600	1,300	1,500
Groundwater Outflow:	about 14,000			
Outflow to White River Valley HA		9,000	4,000	13,500
Outflow to Pahroc Valley HA			9,400	
Total Outflow	**about 14,000**	**10,600**	**14,700**	**15,000**
Yield and Storage Estimates				
Estimated Groundwater Storage (upper 100 feet saturated basin fill)	1,000,000		805,200	

[1]Estimation rounded to the nearest hundred afy.

The BARCAS study estimates the average groundwater recharge for the Cave Valley at 11,000 afy. Under predevelopment conditions, the BARCAS study estimates that of the 11,000 afy recharge, 1,600 afy is discharged by ET and that the remaining balance (9,000 afy) leaves the hydrographic basin by subsurface flow out to the White River Valley (Welch et al. 2007).

The SNWA's water budget prepared for the 2008 water rights hearings for the Cave, Delamar, and Dry Lake HAs estimate that approximately 14,700 afy of recharge in the Cave Valley HA (SNWA 2007). Groundwater outflow from the Cave Valley HA was estimated to consists of 1,300 afy from ET, and groundwater outflow to the White River Valley HA (4,000 afy) and Pahroc Valley HA (9,400 afy). The SNWA's revised estimates provided in the Conceptual Model Report (SNWA 2009a) are similar to the 2007 estimates. The SNWA estimate for total inflow and outflow (15,000 afy) are similar to Eakin's (Eakin 1962) estimate (14,000 afy) and approximately 33 percent greater than those estimated in the BARCAS study (Welch et at. 2007) (11,000 afy).

Dry Lake Valley

Selected estimates of groundwater inflow and outflow to the Dry Lake Valley HA are listed in **Table 3.3.1-16**. The water resources reconnaissance report for Dry Lake Valley (Eakin 1963) estimates that the average recharge for Dry Lake Valley is 5,000 afy and that all or nearly all of the recharge discharges by subsurface flow into Delamar Valley.

Table 3.3.1-16 Estimates of Groundwater Inflow and Outflow for the Dry Lake Valley Hydrographic Basin (afy)[1]

Water Budget Component	Eakin (1963)	SNWA (2007)	SNWA (2009a)
Groundwater Inflow			
Precipitation Recharge	5,000	15,700	16,200
Groundwater Inflow from Pahroc Valley HA		2,000	2,000
Total Inflow	**5,000**	**17,700**	**18,200**
Groundwater Outflow			
ET	Minor	0	0
Groundwater Outflow to Delamar Valley HA	5,000	17,700	18,200
Total Outflow	**5,000**	**17,700**	**18,200**
Yield and Storage Estimates			
Estimated Groundwater Storage (upper 100 feet saturated basin fill)			

[1]Estimation rounded to the nearest hundred afy.

The SNWA's (2007) estimates (prepared for the 2008 water rights hearings for the Cave, Delamar, and Dry Lake HAs) indicate that the Dry Lake Valley hydrographic basin receives approximately 15,700 afy of recharge and 2,000 afy of subflow from the Pahroc Valley hydrographic basin. The total inflow of 17,700 afy discharges as subflow into Delamar Valley. The SNWA's revised estimates provided in the Conceptual Model Report (SNWA 2009a) are similar to their 2007 estimates. These estimates suggest there is approximately 3 times more recharge in this HA than originally estimated by Eakin (Eakin 1963).

Delamar Valley

The water resources reconnaissance report (Eakin 1963) estimates that the average recharge for Delamar Valley HA is 1,000 afy, and subsurface flow from the Delamar Valley HA is approximately 5,000 afy (**Table 3.3.1-17**). There is essentially no ET in the valley, and all of the inflow discharges as groundwater outflow. SNWA (2007) estimates a much higher recharge and subsurface flow from Delamar Valley HA and assumes the entire inflow (24,100 afy) discharges into Coyote Spring Valley HA. The recently revised groundwater budget provided in the Conceptual Model Report (SNWA 2009a) is very similar to the earlier 2007 estimate.

Table 3.3.1-17 Estimates of Groundwater Inflow and Outflow for the Delamar Valley Hydrographic Basin (afy)[1]

Water Balance Component	Eakin (1963)	SNWA (2007)	SNWA (2009a)
Groundwater Inflow			
Precipitation Recharge	1,000	6,400	6,600
Groundwater Inflow from Dry Lake Valley HA	5,000	17,700	18,200
Total Inflow	**6,000**	**24,100**	**24,800**
Groundwater Outflow			
ET	0	0	0
Groundwater Outflow (Coyote Spring Valley HA)	6,000	24,100	**24,800**
Total Outflow	**6,000**	**24,100**	**24,800**
Yield and Storage Estimates			
Estimated Groundwater Storage (upper 100 feet saturated basin fill)			

[1]Estimation rounded to the nearest hundred afy.
[2]Assumed to be equal to recharge.

3.3.1.6 Water Quality

Groundwater quality generally is controlled by the composition of the water that reaches an aquifer and its subsequent interactions with aquifer materials. Groundwater quality also is affected by the length of time that the groundwater is in contact with aquifer materials and can change with distance along a flow path. Some of the processes that influence groundwater quality that have been identified in the regional aquifer systems of the Great Basin include dedolomitization (gypsum and dolomite dissolution and calcite precipitation, which releases sulfate and magnesium ions), exchange of calcium and magnesium in the groundwater for sodium in clays, and dissolution of volcanic rock (which releases sodium to the groundwater). In some localized areas, calcium, sodium, sulfate, and chloride are released to groundwater by gypsum and halite dissolution.

Three aquifer types have been identified in the region of study: carbonate, volcanic, and basin-fill. The general baseline characteristics of groundwater associated with these three aquifer types have been described by SNWA (2008). Groundwater from carbonate-rock aquifers tends to have a calcium-bicarbonate composition with varying amounts of magnesium and sulfate; this water corresponds to the calcium-magnesium-bicarbonate groundwater facies described by Winograd and Thordarson (1975). Groundwater associated with volcanic rocks in the Great Basin generally has a sodium-potassium-bicarbonate composition with a lower pH than groundwater associated with carbonates. The composition of groundwater associated with valley fill generally is a function of the source of the valley fill. Calcium-magnesium-bicarbonate water occurs in basin-fill aquifers composed chiefly of carbonate-rock material (Winograd and Thordarson 1975; SNWA 2008). The SNWA (2008) identified sodium, chloride, and sulfate as the dominant constituents in basin-fill aquifers composed mainly of volcanic rocks. Valley-fill aquifer materials composed of a mixture of volcanic and carbonate rocks produce mixed-cation groundwater compositions (Winograd and Thorgardson 1975; SNWA 2008).

The water quality in the region of study generally is good. The composition of the groundwater generally is controlled by its interaction with the deeper carbonate-rock aquifer material. Interaction between the groundwater and volcanic material and evaporites commonly results in increased sodium, sulfate, and chloride concentrations with groundwater transport distance in the White River Flow System. Concentrations of minor elements usually are low; all water samples from the Great Salt Lake Regional Flow System had minor element concentrations below the USEPA maximum contaminant levels (MCLs). However, the majority of the arsenic values from Coyote Spring Valley in the White River Flow System exceeded the USEPA MCL of 10 micrograms per liter. Some samples from both flow systems exceeded MCLs, including pH, chloride, and sulfate in the Great Salt Lake Desert Regional Flow System and aluminum, iron, manganese, and total dissolved solids in the White River Flow System.

Characterization of the water quality and stable isotope concentrations in the Great Salt Lake Desert, and White River Flow Regional Flow Systems, including water-quality summary tables for each flow system, is provided in **Appendix F3.3.4**.

3.3.1.7 Water Rights and Water Use

Water law in both Nevada and Utah are based on the doctrine of prior appropriation, or first in time – first in right, and is administered by the respective State Engineer. Nevada's water law is contained in Nevada Revised Statutes, Chapters 532 through 538; Utah's water law is contained in Utah Code, Title 73. Both states' laws provide that water is the property of the state's public, and a water right is the right to put that water to beneficial use. The basis of a water right is the beneficial use. The process of obtaining a water right in both states begins with applying for an appropriation and ends with the right being "perfected" through filing proof of beneficial use or through final adjudication.

Adjudication is a state initiated finalization process for beneficial uses that existed prior to the law establishing a permit system of the respective states, and uses established through federal reserved water rights (discussed later in this section). Adjudication may be requested by the entity that manages the lands containing the right (e.g., private landowner, Tribe, or federal agency), or initiated by the state.

Active water rights within the hydrologic study area were inventoried to identify the location and status of water rights. The inventory was based on water rights records on file with the NDWR. Water rights on file with the UDWRi also were inventoried for the Utah portion of the study area. The water rights are summarized in **Appendix F3.3.2**. The summary tables list the point of diversion, type of water rights permit, owner, water source (such as stream, spring, or underground), beneficial use, and annual duty (i.e., quantity of water use per year allocated by the water rights permit) for the each water right. The water source identified for water rights associated with water-well development in the water-rights databases for both states is referred to as "underground." For descriptive purposes in this draft EIS, water rights that are listed with an "underground" source designation are informally referred to as "groundwater rights."

The points of diversion for active surface water rights and groundwater rights within the region of study are shown on **Figures 3.3.1-21** and **3.3.1-22**, respectively. The surface water and groundwater rights for each of the basins within the study area are summarized in **Tables 3.3.1-18** and **3.3.1-19**, respectively.

State Water Rights held by Federal Bureaus.

Federal bureaus have established state water rights in both states through the processes administered by the respective State Engineer. **Figure 3.3.1-23** depicts those water rights held by federal bureaus as returned by searches of NDWR and UDWRi water rights databases.

Nevada records both state-perfected water rights and state-adjudicated federal reserved water rights for federal bureaus.

In Utah, "diligence claims" have been filed in the project area by the BLM for the establishment of multiple water rights. Diligence claims are Utah's vehicle for establishing and recording beneficial uses of surface water prior to 1903 or groundwater prior to 1935.

Figure 3.3.1-21 Surface Water Rights

Figure 3.3.1-22 Groundwater Rights

Table 3.3.1-18 Surface Water Rights Summary Table (Number of Surface Water Rights)

GW Flow System	Basin Number	Basin Name (Upgradient to Downgradient)	Commercial	Industrial	Mining and Milling	Municipal	Domestic	Irrigation	Stockwatering	Storage	Recreational	Wildlife	Other	Total
White River	175	Long Valley						2	20					22
	174	Jakes Valley				2	1	3	27	4				37
	207	White River Valley		7	1	3	2	74	59			4	2	152
	180	Cave Valley					1	11	47				2	61
	172	Garden Valley					1	16	14					31
	171	Coal Valley							13					13
	208	Pahroc Valley							10				1	11
	181	Dry Lake Valley						3	88				1	92
	209	Pahranagat Valley				1		11	20				3	35
	182	Delamar Valley			1	2		1	46				2	52
	206	Kane Springs Valley							18					18
	210	Coyote Spring Valley							8			3		11
	219	Muddy River Springs Area		4		2	1	8				1		16
	218	California Wash											1	1
	220	Lower Moapa Valley						11				2	2	15
	215	Black Mountains Area										1		1
Goshute Valley	179	Steptoe Valley		10	8	7	2	100	179	1	3	9	10	329
	178B	Butte Valley (Southern Part)						11	38					49
Salt Lake Desert	196	Hamlin Valley					2	20	57				20	99
	185	Tippett Valley						5	34					39
	184	Spring Valley (184)		1	16		1	115	90				30	253
	194	Pleasant Valley						7	19			1		27
	195	Snake Valley		2		1	1	58	61		1	2	24	150
	258	Fish Springs Flat											2	2
Meadow Valley	183	Lake Valley			1	3		22	49				1	76
	201	Spring Valley (201)						7	62			1	47	117
	202	Patterson Valley			1			5	37				2	45
	200	Eagle Valley						1	2				6	9
	198	Dry Valley						4	3		1		3	11
	203	Panaca Valley	1			3		8	8			1	17	38
	204	Clover Valley						2	20				29	51
	205	Lower Meadow Valley Wash	1		2	3		21	48	1	3	2	60	141
Las Vegas	212	Las Vegas Valley							7			13		20
Total			**2**	**24**	**30**	**27**	**12**	**526**	**1084**	**6**	**8**	**40**	**265**	**2024**

[1]The "other" category applies only to water rights in Utah where the use is not specified.
[2]Does not include water rights in the Fish Springs Flat HA since most of this HA is located outside of the study area boundary.

Table 3.3.1-19 Groundwater Rights Summary Table (Number of Groundwater Rights)

GW Flow System	Basin Number	Basin Name (Upgradient to Downgradient)	Commercial	Industrial	Mining and Milling	Municipal	Domestic	Irrigation	Stockwatering	Recreational	Wildlife	Other	Total
White River	175	Long Valley			5			1	15				21
	174	Jakes Valley							2				2
	207	White River Valley	2		6	8		83	44	1		1	145
	180	Cave Valley							8				8
	172	Garden Valley		1				3	6				10
	171	Coal Valley							3				3
	208	Pahroc Valley							4				4
	181	Dry Lake Valley			1				5				6
	209	Pahranagat Valley	4			7	1	34	8		2		56
	182	Delamar Valley							1				1
	206	Kane Springs Valley				4							4
	210	Coyote Spring Valley		16		4		1					21
	219	Muddy River Springs Area	3	30		5		17			1		56
	218	California Wash		2		4		5			3		14
	220	Lower Moapa Valley	2		2	2		17					23
	217	Hidden Valley (North)				1							1
	216	Garnet Valley	3	11	1	10	1						26
	215	Black Mountains Area		3	9	7					2		21
Goshute Valley	179	Steptoe Valley	3	31	35	54	2	148	23	3	4		303
	178B	Butte Valley (Southern Part)			1				10				11
Salt Lake Desert	196	Hamlin Valley					2	4	14			44	64
	185	Tippett Valley						1	1				2
	184	Spring Valley (184)			5	3		36	28		2		74
	194	Pleasant Valley						2					2
	195	Snake Valley	3			3	21	73	37			119	256
	258	Fish Springs Flat										1	1
Meadow Valley	183	Lake Valley			1	3		69	39				112
	201	Spring Valley (201)				3		3		1			7
	202	Patterson Valley			3	8		11	14		1		37
	200	Eagle Valley				2		3					5
	199	Rose Valley						4					4
	198	Dry Valley						21	3	2			26
	203	Panaca Valley	4			8	1	73	3			7	96
	204	Clover Valley		1		4		14	12			6	37
	205	Lower Meadow Valley Wash	8	8	1	7	1	56	2	2	1	5	91
Las Vegas	212	Las Vegas Valley	2			2							4
Total			**34**	**103**	**70**	**149**	**29**	**679**	**282**	**9**	**16**	**183**	**1554**

[1] The "other" category only applies to water rights in Utah where the use is not specified.
[2] Does not include water rights in the Fish Springs Flat HA since most of this HA is located outside of the study area boundary.

Figure 3.3.1-23 Federal Agency Water Rights within the Region of Study

Federally Reserved Water Rights

The federally reserved water rights doctrine was originally established in 1908 by the U.S. Supreme Court in *Winters v. United States*, and is commonly known as the "Winters Doctrine." In a conflict over competing use of surface water between non-Indian settlers and Indians on the Fort Belknap Reservation in Montana, the U.S. Supreme Court held that when the Reservation lands were reserved by a 1888 agreement, water rights for the Indians also were reserved by necessary implication for farming and pastoral purposes. The Winters Doctrine was upheld and further defined by the U.S. Supreme Court in *Arizona v. California* (1964). The U.S. Supreme Court held that the doctrine applied to the establishment of a Reservation by treaty, statute or EO; that the water rights are reserved as of the date of creation of the Reservation; that the quantity of water reserved for Indian use is that amount sufficient to irrigate all the practicably irrigable acreage of the Reservation; and that the rights are not lost by non-use. The doctrine has been defined further in the state general stream adjudication process authorized by the McCarren Amendment (43 U.S.C. 666). In: *In Re the General Adjudication of All Rights To Use Water In The Gila River System and Source, W-1 (Salt), W-2 (Verde), W-3 (Upper Gila), W-4 (San Pedro) (Consolidated)*, the Arizona Supreme Court ruled that the homeland purpose is a valid Reservation purpose and that there is a reserved right to groundwater. The Homeland purpose has been interpreted to include a variety of water uses, including recreation, agriculture, domestic use, stock watering, commercial, and industrial uses.

The federally reserved water rights doctrine also applies to Reservations for non-Indian purposes, such as for National Parks (NPs), wildlife refuges, certain BLM lands, and national forests, although the U.S. Supreme Court has interpreted the uses of reserved water rights for non-Indian purposes more narrowly than the Indian reserved water rights. See *United States v. New Mexico* (1978) and *Cappaert v. United States* (1976). These rights, similar to the Indian reserved rights discussed above, include the amount of water necessary to fulfill the primary purposes of the federal Reservation, with a priority date of the establishment of the Reservation. Water is taken from the unappropriated water at the time of creation of the Reservation. The right does not arise by use nor can it be lost by nonuse. Water is reserved for both present and future needs. The most common type of federal reserved water rights on BLM lands in the project area are Public Water Reserves (PWR), which set aside certain quantities of water from public water holes and springs for human and animal consumption. PWR were originally established on an individual basis; the earliest being PWR No. 1 established in 1912, which included wetland areas in Snake Valley. President Coolidge issued the Executive Order of April 17, 1926, that created PWR No. 107 that reserved water yields from springs and natural water holes for human and animal consumption over vast tracks of public lands. Because of this, the vast majority of state-recognized PWRs hold the priority date of the EO.

The locations of federal reserved water rights included in the Nevada DWR water rights database within the region of study, along with state-adjudicated water rights held by Federal Bureaus in both Nevada and Utah are shown on **Figure 3.3.1-23**. No federal reserved water rights were returned through searches of the UDWRi database, potentially because such rights in Utah have been established through "diligence claims" as discussed above. The federal reserved water rights returned by the NDWR water rights database include 161 water rights owned by the BLM and 9 water rights owned by the USFWS. All of these water rights are surface water rights at springs. The manner of use listed for the BLM's water rights includes "other" (143), stockwatering (15), wildlife (2), and irrigation (1). The BLM federal reserved water rights are distributed within 20 hydrographic basins; with the largest number occurring in Spring Valley (HA 184).

The USFWS federal reserved water rights returned though searches of the NDWR water rights database are all used for wildlife at locations within the Las Vegas Valley hydrographic basin. Unless the state has initiated a McCarran Amendment adjudication, federal reserved water rights would not necessarily be included in that state's data base.

The unknown nature of unadjudicated federal reserved water rights, regarding both locations and quantities of water, limit the ability to further describe water use of this type in the hydrologic study area. Although the rights exist, without further judicial action there have been no details provided beyond what has been recorded by the state water administrations and what has been generally described here.

Proposed Pumping Basins Water Rights

The groundwater rights for each of the proposed groundwater development basins are summarized in **Table 3.3.1-20**. For Nevada, this summary is based on the data in the NDWR "Hydrographic Basin Summary by Manner of Use," downloaded from the NDWR on April 21, 2011 (NDWR 2011), and data provided by UDWRi (as summarized in

SNWA 2008). **Table 3.3.1-20** includes the "perennial yield" estimates for each of the hydrographic basins listed by NDWR in its basin summaries. The perennial yield is the estimated amount of groundwater available for appropriation in each basin. NDWR defines perennial yield as follows:

> "The perennial yield of a ground-water reservoir may be defined as the maximum amount of ground water that can be salvaged each year over the long term without depleting the ground-water reservoir. Perennial yield is ultimately limited to the maximum amount of natural discharge that can be salvaged for beneficial use. The perennial yield cannot be more than the natural recharge to a ground-water basin and in some cases is less. If the perennial yield is exceeded, ground-water levels will decline and steady-state conditions will not be achieved, a situation commonly referred to as ground-water mining" (NDWR 2007).

Table 3.3.1-20 Summary of Active Groundwater Rights by Beneficial Use (afy) for the Proposed Pumping Basins

	Hydrographic Basin					
	Spring	Snake Valley		Cave	Dry Lake	Delamar
Manner of Use	**Valley**	**Nevada**	**Utah**	**Valley**	**Valley**	**Valley**
Commercial	35	12	0	0	0	0
Domestic	0	2	111	0	0	0
Industrial	0	0	0	0	0	0
Irrigation	19,805	10,611	37,942	0	1,009	0
Mining and Milling	1,356	0	0	0	18	0
Municipal	0	0	0	0	0	0
Quasi-municipal	79	56	0	0	0	0
Stockwatering	404	35	824	47	38	7
Wildlife	58	0	0	0	0	0
Other [1]	NA	NA	1,563	NA	NA	NA
Total[2]	**21,736**	**10,715**	**40,440**	**47**	**1,066**	**7**
Perennial Yield Estimate[3]	**80,000**	**25,000[4]**		**5,000**	**12,700**	**2,550**
		80,000[5]				
Perennial Yield Reference Source:	State Engineers Ruling 5726 (NDWR 2007)	USGS Open File Report 78-768 (Nolin 1986)	USGS Recon. 34 (Hood and Rush 1965)	State Engineer Ruling 5875	State Engineer Ruling 5875	State Engineer Ruling 5875

[1]The "other" category only applies to water rights in Utah where the use is not specified

[2] Totals may differ from the sum of the individual numbers due to rounding.

[3] Perennial yield estimates and data references for Nevada from the NDWR basin summary reports dated 4-21-11 (NDWR 2011). Although State Engineer Rulings 5726 and 5875 have been vacated by the Nevada Supreme Court, the perennial yield information contained in these Rulings is the most up to date analysis provided by the Nevada State Engineer. These estimates may change based on the outcome of future water right hearings.

[4,5] For Snake Valley, the 25,000 afy (Nolin 1986) represents the Nevada fraction of total basin yield of 80,000 AFY (Hood and Rush 1965) and is the estimate provided by the NDWR for Hydrographic Basin 195.

Sources: NDWR (2011) for Nevada; SNWA (2008) for Utah.

The sources of information used to estimate perennial yields referenced by NDWR are included in **Table 3.3.1-20**. Note that the State Engineer can modify estimates of perennial yield as new data and analyses becomes available or as necessary when considering all available hydrologic studies as part of a water rights hearings process.

The following subsection briefly summarizes the active water rights and their designated beneficial uses in Nevada and Utah within the five groundwater development basins included under the Proposed Action and alternatives. The locations of the points of diversion for active water rights in these basins are shown in **Figures 3.3.1-21** and **3.3.1-22**. Additional information on water rights in these basins and other basins in the region is available at the NDWR and UDWRi web sites and in the project baseline characterization report (SNWA 2008).

Spring Valley

Based on the NDWR database, there are a total of 334 active water rights in the inventoried area, which includes 253 surface water rights and 88 groundwater rights. The surface water rights include 24 reserved rights filed by the BLM and 16 claims of vested rights by the USFS (SNWA 2008). The primary uses for surface water are irrigation, stock watering, mining and milling, and domestic use.

The designated use for active groundwater rights is presented in **Table 3.3.1-20**. According to the NDWR records (2011), as of August 1, 2010, the authorized annual duty or withdrawal rates for the total groundwater rights in Spring Valley are 21,845 afy, and the estimated perennial yield for the basin is 80,000 afy.

Snake Valley

Snake Valley includes land in both Nevada and Utah. Water development in Snake Valley supports crop irrigation on the valley floor and the communities of Garrison, Callao, Eskdale, Gandy, and Trout Creek. Water rights are associated with most of the perennial streams and major springs in the basin. The majority of the perennial streams originate on the east slope of the Snake Range. The estimated total of 563 active water rights includes 136 surface water rights and 427 groundwater rights.

NDWR indicates that there are 10,720 afy of active underground (groundwater) rights in Snake Valley within Nevada (**Table 3.3.1-20**). Irrigation accounts for 99 percent of the total groundwater use; the remainder of the water is designated for quasi-municipal use and stock watering. In the Utah portion of Snake Valley, approximately 338 water rights permits have been issued by the UDWRi; 205 of these are for groundwater. The total groundwater use permitted on the Utah side of the basin is 40,440 afy with 98 percent of this water being used for irrigation (SNWA 2008). Other uses of groundwater include stock watering and domestic supply.

Cave Valley

Based on the NDWR database, there are a total of 79 active water rights in Cave Valley, which includes 71 surface water rights and 8 groundwater rights. Most of the water rights are associated with springs used for stock watering. As shown on **Table 3.3.1-20**, the total annual duty (or discharge rate) associated with the groundwater rights is 47 afy and all of this water is designated for stock watering. The estimated perennial yield for the basin is 5,000 afy (NDWR 2011).

Dry Lake Valley

The majority of the water rights in Dry Lake Valley are springs; although there are surface water rights on ephemeral drainages on the eastern side of the basin (SNWA 2008). According to the NDWR database, there are a total of 99 active water rights in the inventoried area, which includes 93 surface water rights and 6 groundwater rights. The groundwater rights total 1,066 afy and this water is designated for irrigation, stock watering, and mining and milling (**Table 3.3.1-20**). The estimated perennial yield for the basin is 12,700 afy (NDWR 2011).

Delamar Valley

Most of the active water rights in Delamar Valley are associated with springs used for stock watering in the mountains above the valley floor. According to the NDWR database, there are a total of 55 active water rights in the inventoried area, which includes 54 surface water rights and 1 groundwater right. The total annual duty (or discharge rate) associated with the groundwater rights as summarized in **Table 3.3.1-20** is 7 afy and all of this water is designated for stock watering. The estimated perennial yield for the basin is 2,550 afy (NDWR 2011).

Irrigated Acres

The USGS has recently completed studies as part of BARCAS; that included an estimate of irrigated acreages in Spring Valley, Snake Valley, and Cave Valley hydrographic basins (Welch et al. 2007). The USGS mapped irrigated acreages using imagery processed from the TM sensor onboard the Landsat 4 and 5 satellites. These satellites have acquired images of the Earth nearly continuously since 1982, with a 16-day repeat cycle. Irrigated fields were mapped for 2000, 2002, and 2005. The analysis indicates that the estimated irrigated acres increased in both Spring and Snake valleys over these time intervals; however, there was no active irrigation in Cave Valley during the period. In 2005, the USGS conducted field work during the growing season to evaluate the TM data for accuracy. The field verification studies indicated that less than 5 percent of the fields identified on the TM images as active were determined to be inactive, and the estimates for 2005 were adjusted accordingly. The USGS estimated irrigated acreages for Spring and Snake valleys for 2005 are listed in **Table 3.3.1-21**.

Table 3.3.1-21 Estimated Irrigated Acreages for the Proposed Groundwater Development Basins

Hydrographic Basin	Irrigated Acreage (acres)	
	BARCAS[1] (2005 Imagery)	**SNWA[2] (2002 Imagery)**
Spring Valley	4,888	4,101
Snake Valley	9,200	12,594
Cave Valley	0	0
Dry Lake Valley	NA	0
Delamar Valley	NA	0

[1]Welch et al. (2007).
[2]SNWA (2008).

The SNWA estimated irrigated acres by using satellite imagery from June 2002 for all of the basins within the region of study (SNWA 2008). The SNWA irrigated acreage estimates for the five proposed groundwater development basins is summarized in **Table 3.3.1-21**. The SNWA estimates indicate that at the time of the imagery, there was essentially no active irrigation occurring in Cave, Delamar, and Dry Lake valleys. Both the USGS and SNWA estimates indicate that the largest areas of irrigated land occur in Snake Valley, and considerably fewer acres occur in Spring Valley. As shown on **Table 3.3.1-21**, the SNWA estimate for irrigated acreages for Spring Valley and Snake Valley are approximately 16 percent less and 37 percent greater, respectively, than the USGS estimate.

3.3.2 Environmental Consequences

3.3.2.1 Rights-of-way

Issues

Project development would require surface disturbance for construction of the pipelines, power lines, and ancillary facilities. The following water resource issues were evaluated as part of the impact analysis for construction and operation of the groundwater development project within the primary pipeline and power line ROWs.

- Surface disturbance to springs, seeps, and streams.
- Erosion and release of sediment from disturbed areas.
- Impacts to surface water quality from project construction-related activities.
- Damage to pipeline and ancillary facilities from flooding or scour.

Other potential impacts to wetlands and riparian areas are discussed in the Section 3.5, Vegetation Resources; and Section 3.7, Aquatic Biological Resources. Potential impacts to water resources resulting from the transportation, storage, and use of hazardous substances are addressed in Section 3.19, Public Safety and Health.

Methodology

Surface disturbance-related impacts to water resources were evaluated according to the following steps:

- Identify water resources (springs and seeps) located within the construction ROWs;
- Identify perennial, intermittent, and ephemeral streams that would be crossed or disturbed by the proposed facilities;
- Evaluate erosion and sedimentation impacts associated with construction and operation-related activities;
- Identify known flood zones and flood hazards that would be crossed or disturbed by the proposed facilities;
- Evaluate the existing BLM RMP management actions and BMPs, and ACMs to limit the extent and duration of predicted impacts;
- Recommend additional mitigation measures if warranted, to avoid, reduce or offset impacts;
- Evaluate the effectiveness of the proposed mitigation measures; and
- Estimate residual impacts after the BLM management actions and BMPs, ACMs, and recommended mitigation measures are applied.

The applicant has committed to measures to minimize potential impacts. These ACMs are presented in **Appendix E**. The assessment of potential impacts to water resources assumes that these ACMs would be implemented as part of construction and operation of the project.

3.3.2.2 Proposed Action, Alternatives A through C

The development associated with the primary pipeline and power line ROWs would be the same for the Proposed Action and Alternatives A through C. The proposed development within the ROW areas is described in detail in Chapter 2. Chapter 2 also provides estimates of surface disturbance from construction-related activities. In summary, the development would include construction of 306 miles of pipeline, 323 miles of overhead power lines, and two primary and five secondary electrical substations. Ancillary facilities that would be developed include five pumping stations, six regulating tanks, three pressure reducing stations, a water treatment facility, buried storage reservoir, access roads, and communication facilities.

Surface Disturbance of Water Sources

No known springs are located within the boundaries of the disturbance area for the ROWs and ancillary facilities. There are 4 known or suspected springs located downgradient near (i.e., within 1,000 feet) the proposed ROW. These include one inventoried spring (Big Springs located in Snake Valley) and 3 other non-inventoried springs (located in Snake Valley and Dry Lake Valley) identified from the National Hydrography Database or topographic maps. The actual existence and flow characteristics of these non-inventoried springs have not been confirmed by field investigation. Springs located downgradient and in the near vicinity of the ROW could be impacted by erosion and sedimentation from construction disturbance. However, implementation of the Storm Water Pollution Prevention Plan (SWPP Plan) and erosion control ACMs discussed below should protect these resources from construction-related impacts.

The proposed pipeline ROW would cross one perennial stream reach (Snake Creek) and two intermittent stream reaches (Big Wash and Lexington Creek) all located in Snake Valley. The intermittent stream reaches may be flowing during the period when the pipeline is constructed across the creeks. Construction across live (flowing) stream crossings would be accomplished using one of two methods: an open cut method with temporary diversions of stream flow, or a jack and bore method to tunnel under the stream. All construction across live streams would be accomplished in accordance with USACE and State of Nevada permit requirements.

The open cut method for live streams would consists of constructing a temporary diversion to divert flows around the stream crossing, excavating a trench across the stream bed from one or both banks, installing the pipe and cover, reconstructing the stream channel, and finally, diverting flows back into the reclaimed stream channel. Applying open cut methods to construct the pipeline across live streams would result in short-term (up to 2 years) impacts to the stream reach; and depending on the stream bed and stream bank characteristics and site specific construction methods, could result in longer term (>2-year) impacts to the stream channel and downstream stream reach.

The jack and bore method requires the construction of a pit on either side of the stream. From these pits, the tunnel is created under the stream using a bore machine. The main advantage of the jack and bore method is that it generally does not result in alteration of the stream bed or flow conditions in the stream reach. Therefore, impacts to the stream channel using the jack and bore method should be minimal; however, there is a potential for erosion and sedimentation at the entrance and exit points for the bore.

Ground disturbance associated with the construction of the 306 miles of pipeline (including main and lateral pipelines) and ancillary facilities also would result in direct impacts to an estimated 720 ephemeral stream reaches intersected along the ROWs. These ephemeral stream reaches predominantly are dry washes that only flow for short periods in response to infrequent runoff events. Construction across dry washes would use standard cut and cover methods with implementation of erosion control measures in accordance with an approved SWPP Plan required by the NDEP as part of the General Permit for Stormwater Discharges that will be required prior to any surface disturbance.

ACM A.1.52 also requires that construction across perennial, intermittent, and ephemeral drainages follow industry standards, permit requirements, and the BLM's guidance practices (DOI 2007). The BLM RMP guidance recommends an analysis of channel degradation and scour be completed to determine the depth of burial at all stream crossings that would prevent exposure or damage of the pipeline during extreme runoff events. Therefore, with implementation of ACM A.1.52, impacts associated with channel degradation and scour are not anticipated.

Other ACMs (including A.1.53 through A.1.68) include measures to control stormwater and minimize erosion and channel degradation. ACM A.4.1 requires that BMPs be used for the pipeline crossing of Snake Creek and Big Wash (if flowing).

The proposed overhead power line would span two perennial stream reaches (Snake Creek in Snake Valley and Steptoe Creek in Steptoe Valley) and two intermittent streams (Big Wash and Lexington Creek in Snake Valley). The 323-mile length of proposed power line also would span an estimated 642 ephemeral drainages. Transmission towers would not be located within active channels of these streams. The location of roads required for access and maintenance of the power system and tower locations will be determined in the final POD. Depending on location, construction of access roads associated with the power line and transmission tower could result in localized disturbance of the identified perennial and intermittent streams located within the corridor.

Other ancillary facilities associated with construction of the pipeline are located to avoid perennial water sources, intermittent and ephemeral drainages, and springs and seeps. Therefore, impacts to water resources associated with construction of these facilities are not anticipated.

Pipeline construction dewatering trenches are not anticipated to be necessary. However, if detailed geotechnical investigations indicate that dewatering is needed, a dewatering plan would be developed. That plan would specify that discharge waters be directed to prevent flow from entering streams, wetlands, or sensitive environmental areas (ACM A.1.51).

Hazardous and toxic materials (e.g., fuels, solvents, lubricants, acids) used during construction would be controlled to prevent accidental spills. Refueling of vehicles or equipment would be prohibited within 100 feet of any wash or stream (ACM A.1.43). Spill cleanup kits would be available on equipment so that accidental spills can be cleaned up quickly (ACM A.1.44). Therefore, the risk of spills into live streams or springs would be low, and impacts are not anticipated.

Conclusions. There are no springs that would be crossed by the pipeline ROW; and impacts to springs located downgradient and in the near vicinity of the ROW are unlikely due to implementation of required stormwater and erosion controls and ACMs.

The proposed pipeline ROW would cross one perennial stream reach (Snake Creek) and two intermittent stream reaches (Big Wash and Lexington Creek) all located in Snake Valley. Construction across live (flowing) stream crossings would include either an open cut method or a jack or bore method. Typically, open cut methods would result in short-term (up to 2 years) impacts to the stream reach; however, longer-term (>2 year) impacts to these stream reaches could occur.

Ground disturbance associated with the pipeline ROW also would impact an estimated 720 ephemeral streams (i.e., dry washes). Implementation of required erosion control measures and ACMs are expected to generally limit these to short-term (up to 2 years) effects.

Overhead power lines would span two perennial streams, two intermittent streams, and 642 ephemeral drainages. Depending on location, construction of access roads associated with the power line and transmission tower could result in localized disturbance of the two perennial streams located within the corridor. Additional mitigation measures could be required in some situations, depending on the proximity of the streams and drainages and site-specific conditions at the time of construction.

Proposed mitigation measures:

ROW-WR-1: Stream Crossing Construction Plan. A site-specific plan would be developed to detail the construction procedures, erosion control measures, and reclamation that would occur for pipeline construction across live (flowing) stream reaches. The plan would include site-specific designs using either open cut or jack and bore techniques and site-specific measures to minimize disturbance of the stream bed, and release of sediment from the construction area into the downstream stream reach. The plan would be reviewed and approved by the BLM and NDOW prior to initiation of any construction activities within the stream corridor. Effectiveness: This mitigation measure would be moderately effective at reducing construction-related impacts to the streambed. Implementation of this additional mitigation measure, combined with other federal and state requirements, likely would result in a reduction of short-term impacts and minimize or eliminate long-term impacts at live stream crossings. Effects on other resources: This measure would not adversely affect other environmental resources.

ROW-WR-2: Avoid Power Line Structures in Streams. Power line structures would be designed to span all perennial streams and other ephemeral/intermittent streams or washes. No power line structures or ancillary facilities would be located within the active channels of these streams. Access roads constructed for the power line would be located to avoid or minimize disturbance to perennial and intermittent streams. Effectiveness: This measure would be highly effective in mitigating potential erosion and ground disturbance-related impacts to perennial streams associated with the power line construction. This avoidance measure is not currently included in the SNWA ACMs. Effects on other resources: This measure would not adversely affect other environmental resources.

Residual impacts include:

- Implementation of the federal and state requirements, ACMs, and additional mitigation measures should effectively mitigate construction-related impacts to water sources including perennial springs and streams and intermittent and ephemeral stream channels. Therefore, long-term adverse residual impacts to these water resources are not anticipated.

Erosion and Sedimentation

Erosion would occur in the disturbance areas for pipelines, power lines, and ancillary facility construction. Stormwater and erosion control measures include the preparation of site-specific SWPP Plans (ACM A.1.54) to identify and develop methods to control all potential sources of pollution affecting the quality of stormwater discharges from the construction site. Other ACMs to control erosion include developing construction plans to minimize the construction time frame, and implementing erosion and sediment control measures using both non-structural and structural construction BMPs (ACMs A.1.53-A.1.68). Examples of these measures include siltation or filter berms, filter or silt fencing, sediment barriers, rock or gravel mulches, and jute and synthetic netting. After construction, all temporary erosion and sediment controls not required for the protection of facilities would be removed and the drainages restored to their original form. Soils used for erosion control, and soils captured by sedimentation control structures during construction would either be used in the ROW for construction or disposed of in approved borrow pits (ACM A.1.66).

Ground surface would be graded to match the surrounding topography and slopes as closely as possible. Perennial streams, washes, or ephemeral/intermittent drainages would be restored to pre-existing conditions as closely as possible. Permanent erosion control measures would be installed where necessary and could include vegetation restoration, placing matting on steep slopes to maintain stability, berming, and placement of rip-rap (ACMS A.1.67 and A.1.68).

Construction of the pipeline would require permanent disposal of excess soil generated during pipeline excavation. This includes soil volume displaced by the volume of the pipe and bedding material not generated from the excavation; and anticipated expansion of the soil material after excavation. Excess soil material generated from the trench operation would be spread evenly over the ROW disturbance corridor. The estimated volume of excess soil to be disposed of during construction and potential erosion impacts are discussed in Section 3.4, Soils.

<u>Hydrostatic Testing</u>. Hydrostatic testing would be required during construction to test the integrity of the pipeline. Discharge of these waters would be subject to conditions defined in a Hydrostatic Discharge Plan submitted to the BLM for approval (ACM A.1.64). The discharge plan would include energy dissipaters to minimize impacts from sedimentation and erosion. It currently is anticipated that discharge flow rates and volumes would not be allowed to exceed the 2- to 5-year storm event for the individual drainages (ACM A.1.62). If flows exceed these rates, the potential for erosion and scour would increase, resulting in deposition of sediment downstream. Water used for hydrostatic testing and for other construction activities would be tested and treated if necessary prior to discharge or disposal in accordance with the National Pollutant Discharge Elimination System (NPDES) permit requirements. Water not discharged locally would be hauled offsite for disposal (ACM A.1.65).

<u>Emergency Drains</u>. Construction of the water pipeline system would include drain valves located at low points along the pipeline. The location of the drains and design of the discharge points and erosion control measures would be determined prior to final BLM approval. Conceptually, the drains would discharge through energy dissipating devices and then would flow to dry washes lined with rip rap to control erosion. A detailed hydrologic analysis would be conducted during facility design for each discharge point to provide sufficient erosion control and prevent scouring. It currently is anticipated that discharge flow rates and volumes would not be allowed to exceed the 2- to 5-year storm event for the individual drainages (ACM A.1.62).

<u>Conclusions</u>. Surface disturbance from construction activities could affect water quality from sediment input on a short- and long-term basis. The development of construction plans, implementation of ACMs referenced above, and development of SWPP Plan and a Hydrostatic Discharge Plan would define methods to control runoff from construction activities.

Application of the ACMs to control erosion and sedimentation outside of the disturbed areas should minimize the potential impacts to perennial water sources and ephemeral and intermittent drainages. Although the ACMs would minimize erosion and sedimentation from construction activities, there is potential for erosion and sedimentation to occur locally until reclamation is completed, particularly after large storm events. These storm events could release sediment into drainages downgradient of the disturbance area.

Proposed mitigation measures:

None.

Residual impacts include:

- Disturbance areas in the ROW, particularly soils disturbed for pipeline excavation, likely would experience localized erosion in both the short- and long-term periods. Erosion likely would increase sedimentation to some water resources located downgradient from the disturbance areas. Resulting sedimentation would predominantly affect ephemeral drainages that terminate on the valley floors within closed basins.
- The amount of long-term erosion and sedimentation would depend on reclamation success and would be expected to diminish over time.

Flooding

The ROW project components would be subject to periodic localized flooding during the life of the project. Flooding risks include areas where facilities are located in a designated floodplain. The water pipelines and associated power line transmission structures cross two FEMA-designated 100-year floodplain areas in Clark County, Nevada. For discussion purposes, the northernmost floodplain is referred to as the "Unnamed Stream Floodplain Crossing"; and the southernmost floodplain is referred to as the "Hidden Valley Floodplain."

The unnamed stream drainage floodplain crossing would require a span of approximately 894 feet. The proposed power line crossing the floodplain has above-ground structures with a maximum span between structures of approximately 800 feet. Therefore, at least one power line structure would need to be placed in that floodplain. The power line alignment also would cross approximately 4.6 miles of the Hidden Valley floodplain; requiring approximately 31 structures to be located within the floodplain. Long-term disturbance would be limited to the footprint of the structures and access roads for maintenance activities. The structures located within the floodplains would not impede the natural action or function of the floodplains. Considering the slope gradient within the floodplain areas, the potential for the structures to be damaged by flooding would be low.

The water pipeline located along the same alignment would be buried underground with a minimum of 6 feet of cover. Because the pipeline is underground, it would not impede the natural action or function of the floodplains. Both floodplains occur in areas with relatively gentle slopes (< 5 percent), and it is unlikely that flooding in these areas would result in erosion that could expose the pipeline. Therefore, potential damage to the buried pipeline from flooding in these areas is low.

The water treatment facility, buried storage reservoir, and a secondary electrical substation are located within the boundaries of FEMA mapping in Clark County (FEMA 2009); however, none of these facilities are located within the 100-year floodplain. Therefore, potential impacts associated with flooding are not anticipated for these facilities.

A substantial portion of the project area is not covered by the FEMA 100-year floodplain delineation. Without specific delineation, it is assumed that construction of the pipeline and power lines, as well as pumping stations, electrical substations, staging areas, and borrow pits and access roads located near stream and playa crossings could be subject to localized flooding.

The ROW construction also would cross drainages that are subject to flash flooding. As discussed above, perennial, intermittent, and ephemeral stream crossings by the pipelines would be constructed according to the BLM design guidelines incorporated into ACM A.1.52 such that the final pipeline is constructed at sufficient depth to minimize the risk associated with scour and channel degradation. Even with appropriate design and construction practices, there is a risk of impact to project facilities from localized flooding. These types of impacts likely would be short-term and would be addressed as part of maintenance of the project components.

Conclusions. Construction and maintenance of project components within the ROW areas would be subject to periodic localized flooding during the life of the project. Even with appropriate design and construction practices, there is a risk of impact to project facilities from localized flooding.

Proposed mitigation measures:

None.

Residual impacts include:

- Portions of the ROW would be subject to flooding and flash-flood risks. Any resulting impacts would be managed as part of ongoing maintenance activities.

Construction Water Supply

Construction of the pipeline and ancillary facilities would require a water supply for dust suppression, hydrostatic testing, pipe bedding, and trench backfill compaction. It is estimated that between 5.5 and 8.7 million gallons of construction water would be needed for every mile of pipeline, with less water needed for dust control in wet winter conditions. Approximately one water supply well would be needed every 10 miles along the pipeline alignment, and would need to be capable of delivering up to 800 gallons per minute. The construction water supply would be obtained from existing wells or constructing new wells at the time of construction. Additional temporary construction water wells would be drilled within the construction staging areas; therefore, no additional surface disturbance is anticipated for the construction water supply. Groundwater withdrawal for the construction water supply could result in localized drawdown effects.

Conclusions. Impacts associated with the construction of water supply wells could result in localized drawdown effects. Identification of volumes and source of water required during construction needs to be completed prior to construction for the ROW areas and additional mitigation may be needed on a case-by-case basis.

Proposed mitigation measures:

The following proposed mitigation measure is intended to minimize and control potential impacts associated with the development of water required during construction. A specific construction water supply plan and agency coordination to approve such a plan are not included in the SNWA ACMs.

ROW-WR-3: Construction Water Supply Plan. A Construction Water Supply Plan would be provided to the BLM for approval prior to construction. The plan would identify the specific locations of water supply wells that would be used to supply water for construction of the water pipeline and ancillary facilities; identify specific groundwater aquifers that will be used; estimate effects to surface water and groundwater resources resulting from the groundwater withdrawal; define the methods of transport and delivery of the water to the construction areas; and, identify reasonable measures to reuse or conserve water. The BLM would review and approve the plan and, if necessary, include any monitoring or mitigation requirements required to minimize impacts prior to construction approval. Effectiveness: This measure would be highly effective in identifying specific local impacts to water resources and provide for mitigation measures if necessary to avoid, reduce, or offset the identified localized effects. Effects on other resources: This measure is not anticipated to adversely affect other environmental resources.

Residual impacts include:

- Residual impacts from development of construction water supply could include localized drawdown related impacts associated with groundwater pumping. The residual impacts would be quantified during subsequent BLM review following plan submittal.

3.3.2.3 Alternative D

Development in Snake Valley and the White County portion of Spring Valley would be eliminated under Alternative D. The same ROW construction and operational maintenance issues discussed for the Proposed Action and Alternatives A through C would apply to Alternative D, which would require 225 miles of pipeline, and 208 miles of power lines in Clark and Lincoln counties, Nevada. In addition, the BMPs and ACMs described for the Proposed Action, and Alternatives A through C would be applied to construction and operation to minimize impacts to water resources.

Surface Disturbance of Water Sources

Conclusions. No known springs are located with the boundaries of the disturbance area for the ROWs and ancillary facilities. There is one spring located downgradient near (i.e., within 1,000 feet) the proposed ROW. This is an unnamed spring located in Dry Lake Valley that has not been field verified. There are no springs that are crossed by the pipeline ROW; and impacts to springs located downgradient and in the near vicinity of the ROW are unlikely due to required stormwater and erosion controls and ACMs.

The proposed pipeline and power line ROWs would not cross any perennial stream reach and or intermittent stream reaches. Ground disturbance associated with the pipeline ROW would impact an estimated 504 ephemeral streams (i.e., dry washes); overhead power lines also would span 380 ephemeral drainages. Implementation of required erosion control measures and ACMs are expected to generally limit these to short-term (up to 2 years) effects.

Proposed mitigation measures:

None.

Residual impacts include:

- Implementation of the federal and state requirements, and ACMs should effectively mitigate construction-related impacts to water sources. Therefore, long-term, adverse residual impacts to these water resources are not anticipated.

Erosion and Sedimentation

Conclusions. Surface disturbance from construction activities could affect water quality from sediment input on a short- and long-term basis. The development of construction plans, implantation of ACMs referenced above, and development of SWPP Plan and a Hydrostatic Discharge Plan would define methods to control runoff from construction activities.

Application of the ACMs to control erosion and sedimentation outside of the disturbed areas should minimize the potential impacts to water resources located downslope from the ROWs. Although the ACMs would minimize erosion and sedimentation from construction activities, there is potential for erosion and sedimentation to occur locally until reclamation is completed, particularly after large storm events. These storm events could release sediment into drainages downgradient of the disturbance area.

Proposed mitigation measures:

None.

Residual impacts include:

- Disturbance areas in the ROW, particularly soils disturbed for pipeline excavation, likely would experience localized erosion in both the short- and long-term periods. Erosion from disturbed areas would likely increase sedimentation to some water resources located downgradient from the disturbance areas. The resulting sedimentation would predominantly affect ephemeral drainages that terminate on the valley floors within closed basins. The amount of long-term erosion and sedimentation would depend on reclamation success and would be expected to diminish over time.

Flooding

Conclusions. Construction and maintenance of project components within the ROW areas would cross delineated flood zones as discussed previously for the Proposed Action, and Alternative A through C. The ROW construction also would cross drainages that are subject to flash flooding. As a result, project components within the ROW areas would be subject to periodic localized flooding during the life of the project. Even with appropriate design and construction practices, there is a risk of impact to project facilities from localized flooding.

Proposed mitigation measures:

Mitigation measure ROW-WR-2 described under the Proposed Action previously also would apply to Alternative D. This would avoid placement of power lines or ancillary facilities in active stream channels. This measure would be highly effective in mitigating potential erosion and ground disturbance-related impacts to streams associated with the power line construction.

Residual impacts include:

- Portions of the ROW would be subject to flooding and flash flood risks. Any resulting impacts would be managed as part of ongoing maintenance activities.

Construction Water Supply

Construction of the pipeline and ancillary facilities would require a water supply for dust suppression, hydrostatic testing, pipe bedding, and trench backfill compaction. The construction water supply would be obtained from existing wells or constructing new wells at the time of construction. Additional temporary construction water wells would be drilled within the construction staging areas; therefore, no additional surface disturbance is anticipated for the construction water supply. Groundwater withdrawal for the construction water supply could result in localized drawdown effects.

Conclusions. Impacts associated with the construction of water supply wells could result in localized drawdown effects.

Proposed mitigation measures:

Mitigation measure ROW-WR-3 described under the Proposed Action previously also would apply to Alternative D. This would require that a Construction Water Supply Plan be approved by the BLM prior to construction. This measure would be effective in identifying specific local impacts to water resources and provided for mitigation measures if necessary to avoid, reduce, or offset the identified effects.

Residual impacts include:

- Residual impacts from development of construction water supply could include localized drawdown related impacts associated with groundwater pumping. The residual impacts would be quantified during subsequent BLM review following plan submittal.

3.3.2.4 Alternative E

Development in Snake Valley would be eliminated under Alternative E. The same ROW construction and operational maintenance issues discussed for the Proposed Action, and Alternatives A through C would apply to Alternative E, which would require 263 miles of pipeline, and 280 miles of power lines in Clark and Lincoln counties, Nevada. In addition, the BMPs and ACMs described for the Proposed Action, and Alternatives A through C would be applied to construction and operation to minimize impacts to water resources.

Surface Disturbance of Water Sources

Conclusions. No known springs are located with the boundaries of the disturbance area for the ROWs and ancillary facilities. There is one spring located downgradient near (i.e., within 1,000 feet) the proposed ROW. This is an unnamed spring located in Dry Lake Valley that has not been field verified. There are no springs that are crossed by the pipeline ROW; and impacts to springs located downgradient and in the near vicinity of the ROW are unlikely due to required stormwater and erosion controls and ACMs.

The proposed pipeline and power line ROWs would not cross any perennial stream reach and or intermittent stream reaches. Ground disturbance associated with the pipeline ROW would impact an estimated 581 ephemeral streams (i.e., dry washes); overhead power lines also would span 514 ephemeral drainages. Implementation of required erosion control measures and ACMs are expected to generally limit these to short-term (up to 2 years) effects.

Proposed mitigation measures:

Mitigation measure ROW-WR-2 described under the Proposed Action previously also would apply to Alternative D. This would avoid placement of power lines or ancillary facilities in active stream channels This measure would be highly effective in mitigating potential erosion and ground disturbance-related impacts to streams associated with the power line construction.

Residual impacts include:

- Implementation of the federal and state requirements, and ACMs should effectively mitigate construction-related impacts to water sources. Therefore, residual impacts to these water resources are not anticipated.

Erosion and Sedimentation

Conclusions. Surface disturbance from construction activities could affect water quality from sediment input on a short- and long-term basis. The development of construction plans, implementation of the ACMs referenced above, and development of SWPP Plan and a Hydrostatic Discharge Plan would define methods to control runoff from construction activities.

Application of the ACMs to control erosion and sedimentation outside of the disturbed areas should minimize the potential impacts to water resources located downslope from the ROWs. Although the ACMs would minimize erosion and sedimentation from construction activities, there is potential for erosion and sedimentation to occur locally until reclamation is completed, particularly after large storm events. These storm events could release sediment into drainages downgradient of the disturbance area.

Proposed mitigation measures:

None.

Residual impacts include:

- Disturbance areas in the ROW, particularly soils disturbed for pipeline excavation, likely would experience localized erosion in both the short- and long-term periods. Erosion from disturbed areas would likely increase sedimentation to some water resources located downgradient from the disturbance areas. The resulting sedimentation would predominantly affect ephemeral drainages that terminate on the valley floors within closed basins. The amount of long-term erosion and sedimentation would depend on reclamation success and would be expected to diminish over time.

Flooding

Conclusions. Construction and maintenance of project components within the ROW areas would cross delineated flood zones as discussed previously for the Proposed Action, and Alternative A through C. The ROW construction also would cross drainages that are subject to flash flooding. As a result, project components within the ROW areas would be subject to periodic localized flooding during the life of the project. Even with appropriate design and construction practices, there is a risk of impact to project facilities from localized flooding.

Proposed mitigation measures:

None.

Residual impacts include:

- Portions of the ROW would be subject to flooding and flash flood risks. Any resulting impacts would be managed as part of ongoing maintenance activities.

Construction Water Supply

Construction of the pipeline and ancillary facilities would require a water supply for dust suppression, hydrostatic testing, pipe bedding, and trench backfill compaction. The construction water supply would be obtained from existing wells or constructing new wells at the time of construction. Additional temporary construction water wells would be drilled within the construction staging areas; therefore, no additional surface disturbance is anticipated for the construction water supply. Groundwater withdrawal for the construction water supply could result in localized drawdown effects.

<u>Conclusions</u>. Impacts associated with the construction of water supply wells could result in localized drawdown effects.

Proposed mitigation measures:

Mitigation measure ROW-WR-3 described under the Proposed Action previously also would apply to Alternative D. This would require that a Construction Water Supply Plan be approved by the BLM prior to construction. This measure would be effective in identifying specific local impacts to water resources and provided for mitigation measures if necessary to avoid, reduce, or offset the identified effects.

Residual impacts include:

- Residual impacts from development of construction water supply could include localized drawdown related impacts associated with groundwater pumping. The residual impacts would be quantified during subsequent BLM review following plan submittal.

3.3.2.5 Alignment Options 1 through 4

Alignment Options 1 through 4 would adjust the location of specific segments of the Proposed Action ROWs, as described in Chapter 2. Potential effects to water resources associated with these alignment modifications are summarized in **Table 3.3.2-1**.

Table 3.3.2-1 Water Resources Impact Summary for Alignment Options 1 through 4

Alignment Option	Analysis
Alignment Option 1 - Humboldt-Toiyabe Power Line Alignment (Modifies a portion of the 230-kV power line from the Gonder Substation near Ely to Spring Valley)	Impacts associated with the Humboldt-Toiyabe Power Line Alignment would be similar to the comparable section of the Proposed Action alignment (similar number of ephemeral stream crossings but no perennial stream or spring crossings).
Alignment Option 2 – North Lake Valley Pipeline Alignment (Modifies the location of the mainline pipeline and electrical transmission line in North Lake Valley)	Potential impacts associated with the North Lake Valley Pipeline Alignment would be similar to the Proposed Action and Alternatives A through C segment except for the following: 1) Three springs; North Big Spring, Wambolt Springs, and an un-named spring are located downslope and within 1,000 feet of the construction ROW. The reported flow at North Big Springs is 1,400 gpm. Flow rates have not been reported for Wambolt Springs; and the unnamed spring was located based on National Hydrography Database data and has not been field verified. In contrast, no springs are located downslope and within 1,000-feet of construction disturbance for the comparable section of the Proposed Action ROWs.

Table 3.3.2-1 Water Resources Impact Summary for Alignment Options 1 through 4 (Continued)

Alternative	Analysis
	2) Geyser Creek, a perennial stream located in Lake Valley, would be crossed by the pipeline and spanned by the power line but would not be crossed by the comparable sections of the Proposed Action ROWs. Potential surface disturbance related impacts would be essentially the same as discussed for the Snake Creek crossing in Snake Valley under the Proposed Action. Therefore, mitigation measure ROW-WR-1 described under the Proposed Action also would apply to the Geyser Creek crossing.
Alignment Option 3 – Muleshoe Substation and Power Line Alternative (Eliminates the Gonder to Spring Valley transmission line, and constructs the Muleshoe Substation that would interconnect with an interstate power line in Muleshoe Valley)	Potential impacts for this option would be less than the comparable Proposed Action and Alternatives A through C segment because of the elimination of the Steptoe Creek crossing associated with the Humboldt-Toiyabe Power Line ROW.
Alignment Option 4 - North Delamar Valley Pipeline and Power Line Alignment (Modifies the location of a short section of mainline pipeline in Delamar Valley to follow an existing transmission line.)	Impacts associated with the North Delamar Valley Pipeline and Power Line Alignment would be similar to the comparable section of the Proposed Action alignment (same number of ephemeral stream crossings but no perennial stream or spring crossings).

3.3.2.6 No Action Alternative

As described in Chapter 2, the No Action Alternative assumes that the BLM would not grant ROWs for the proposed project. Under this scenario, the proposed pipelines, power lines, ancillary facilities, and well fields would not be developed. Therefore, construction or operational impacts to water resources associated with the proposed GWD Project would not occur.

3.3.2.7 Comparison of Alternatives

Impacts resulting from construction and operation and maintenance activities on water resources from the Proposed Action and Alternative A through E are listed in **Table 3.3.2-2.**

Table 3.3.2-2 Comparison of Potential Effects to Water Resources Associated with Construction, Operation and Maintenance of the Primary Rights-of-way

Parameter	Proposed Action, Alternatives A through C	Alternative D	Alternative E
Springs (Number of Springs)			
Within ROW	0	0	0
Downslope[1] of ROW	4	1	1
Perennial Stream Crossings			
Pipelines			
-Snake Creek	Yes	No	No
Power Lines			
-Snake Creek	Yes	No	No
-Steptoe Creek	Yes	No	No
Intermittent Stream Crossings			
Pipeline			
-Big Wash	Yes	No	No
-Lexington Creek	Yes	No	No
Power Lines			
-Big Wash	Yes	No	No
-Lexington Creek	Yes	No	No
Ephemeral Stream Crossings (number of crossings)			
Pipelines	720	504	581
Power Lines	642	380	514
Ground Disturbance (Acres)	12,303	8,843	10,696

[1] Within 1,000 feet of ROW disturbance.

3.3.2.8 Groundwater Development and Groundwater Pumping

Issues

The following water resource issues were evaluated as part of the programmatic impact analysis for construction and operation of the well fields within the groundwater development areas.

Groundwater Well Field Construction and Facility Maintenance

- Surface disturbance to springs, seeps, and streams.
- Erosion and release of sediment from disturbed areas.
- Impacts to surface water quality from project construction-related activities.
- Damage to pipeline and ancillary facilities from flooding or scour.

Groundwater Pumping

- Reduction of groundwater levels from pumping activities resulting in adverse effects on water supply.
- Potential drawdown impacts to perennial springs, seeps, and streams.
- Potential drawdown impacts to surface and groundwater rights.
- Potential water balance changes (including reduction in ET discharge) from the pumping basins and regional flow system from groundwater withdrawal.
- Potential degradation of surface water or groundwater quality attributed to groundwater pumping.
- Potential effects to caves resulting from groundwater drawdown.

Potential impacts to wetlands and riparian areas are discussed in Section 3.5, Vegetation, and aquatic resources are discussed in Section 3.7, Aquatic Biological Resources. Potential effects to caves are discussed in Section 3.2, Geology, and Section 3.6, Terrestrial Wildlife. Potential impacts to water resources resulting from the transportation, storage, and use of hazardous substances are addressed in Section 3.19, Public Safety and Health.

Methodology, Assumptions, and Limitations

This section describes the general methodology, assumptions, and limitations used to quantify potential effects to perennial water sources associated with groundwater withdrawal, including:

- A summary of the numerical groundwater flow modeling used to predict changes in groundwater levels and flow rates;
- A definition of the drawdown area used in the analysis;
- A description of the method used to identify springs and streams that could be affected within the drawdown area;
- A description of the method used to evaluate potential changes in flow in selected springs and spring-fed streams; and
- Methods used to evaluate impacts to water rights.

Groundwater Flow Modeling

A numerical groundwater flow model was developed for this EIS to evaluate the probable long-term effects of groundwater withdrawal on a regional scale. The model, known as the Central Carbonate-Rock Province (CCRP) Model was developed specifically for this EIS by the SNWA under the BLM's guidance (SNWA 2009a,b; 2010a,b).

The model was constructed by: 1) developing a conceptual model of the groundwater flow system including the definition of major HGUs across the region, and estimating groundwater budget components (i.e., recharge, groundwater discharge by ET, and interbasin inflow and outflow); 2) constructing a numerical model to represent the conceptual model; and 3) calibrating the model to transient conditions.

The final calibrated model was used to simulate groundwater withdrawal under the seven different pumping scenarios (i.e., six project pumping alternatives and the No Action pumping scenario) for a period extending to full build out plus 200 years. The model also was used to evaluate the combined effects associated with continuation of existing and historic pumping, project pumping, and reasonably foreseeable future pumping in the region over the same time period.

The following section provides a brief description of other important groundwater flow models for the region and a description of the construction, calibration, and uncertainty and limitations associated with the CCRP model.

Other Important Groundwater Flow Models for the Region

There currently are three other regional groundwater flow models that encompass two or more of the proposed groundwater development basins:

1. Great Basin Regional Aquifer Systems Analysis (RASA) Model previously developed by the U.S. Geological Survey to evaluate the conceptual flow system in the carbonate-rock province (Prudic et al. 1995);

2. GBNP Model recently developed by the USGS for the NPS to evaluate the potential effects of pumping in Snake Valley on springs, streams and water levels in and adjacent to GBNP (Halford and Plume 2011);

3. Eastern Nevada-Western Utah (ENWU) Regional Model in development (Durbin and Loy 2010; Loy and Durbin 2010) for the BLM (Utah State Office), NPS, USFWS, and BIA to evaluate potential impacts of groundwater pumping resulting from several water rights applications filed in Iron and Beaver Counties, Utah. This model evaluated impacts to groundwater resources in White Pine and Lincoln Counties, Nevada, and Iron and Beaver Counties, Utah.

RASA Model. The RASA model was constructed as a steady-state, three-dimensional, finite-difference groundwater flow model using MODFLOW (McDonald and Harbaugh 1988). The model encompassed a very large region (approximately 92,000 square miles) with coarse discretization (individual cells of 5 miles by 7.5 miles in dimension). The model was constructed with two layers and was intended to be conceptual in nature for the purpose of evaluating the possible interconnection between the deep flow through the carbonate rocks and the shallow flow system (Prudic et. al 1995). The model was later modified to develop “first approximations” of the possible effects of groundwater withdrawal of 180,800 afy by the Las Vegas Valley Water District in 17 basins in Nevada (Schaefer and Harrill 1995). The RASA model was not used to predict effects associated with the proposed groundwater withdrawal for this EIS because of:

- The broad regional nature of the model and its coarse discretization;
- The highly generalized assumptions and simplifications used to construct the model;
- The fact that the model was not calibrated to transient conditions; and
- The lack of model set up to simulate the effects associated with existing pumping in the region.

In summary, the CCRP model used for this EIS was constructed to provide a more detailed representation of a portion of the regional carbonate-rock groundwater flow system that was conceptually evaluated by the earlier RASA model.

GBNP Model. The GBNP model was constructed by refinement of the RASA model in Spring and Snake valleys, which encompass the GBNP study area. Groundwater flow in the GBNP study area was simulated with a 4-layer, finite-difference MODFLOW model that extends from the water table to 2,000 feet below the water table. The model incorporates a refined grid cell network that encompasses the park with cells measuring 1,620 feet by 1,620 feet. The refined model-simulated local flow in mountain blocks that was not simulated in the original RASA model.

The model was calibrated to existing water level data, simulated water levels from the original RASA model, depth-to water beneath ET areas, spring discharges, and changes in discharge on selected stream reaches in the vicinity of GBNP. The final calibrated model was used to simulate the potential effects of groundwater withdrawals associated with pumping in Snake Valley at nine points of diversion identified on the SNWA’s water rights applications. Model simulations were conducted for groundwater withdrawal rates of 10,000 afy, 25,000 afy, and 50,000 afy over a

200-year period. Separate simulations were conducted with and without the addition of existing irrigation pumping. The irrigation pumping was based on the estimated distribution and rate of pumping that occurred in 2002, and assumed that this rate of pumping would continue in the future over the 200 year simulation period. Results from the GBNP model scenarios are presented as maps of groundwater capture and drawdown, time series of drawdowns and discharges from selected wells, and time series of discharge reductions from selected springs and streams.

Since the model design is currently focused on the Spring Valley and Snake Valley area, and pumping only in Snake Valley, the model results cannot be used to evaluate the potential effects to water resources associated with pumping in Spring, Cave, Dry Lake, or Delamar valleys. Additionally, the GBNP model results for Snake Valley assume pumping occurs at SNWA's original points of diversion and therefore, it cannot be used to evaluate potential effects associated with the distributed pumping in Snake Valley included in the Proposed Action and Alternatives A and C. However, given the points of diversion used in the GBNP model were the same ones used to simulate Alternative B, a preliminary comparison of simulated reductions of spring and stream flow results in Snake Valley will be discussed for the 50,000 afy GBNP model simulation and the CCRP model simulation for Alternative B (50,000 afy). While the amounts of water pumped at each point of diversion differ between the two model simulations, the comparison is still informative in bracketing the potential range of impacts.

ENWU Model. The ENWU model was developed using FEMFLOW3D version 3.01. This is a modified version of an earlier USGS code originally developed in 1998 that employs a different computational method than MODFLOW. The ENWU model domain extends further east into Utah, but not as far west and southwest in Nevada as the CCRP model used for this EIS; it only includes two of the five pumping basins included in the SNWA's proposed groundwater development project. Specifically, the ENWU model was not designed to evaluate the SNWA's proposed pumping in Cave, Dry Lake, and Delamar valleys. As a result, many of the areas where drawdown related impacts are indicated by the SNWA simulations are not included in the ENWU model.

A preliminary review of the documentation for the ENWU model indicated that the model has not been peer reviewed and the documentation does not currently provide sufficient information to make a rigorous evaluation (Poeter 2010; Halford 2010). Halford (2010) also raised concerns regarding the assumed hydraulic properties used to represent non-carbonate rocks within mountain blocks and the distribution of recharge.

The ENWU model assumes that the average annual rate of discharge from the combined Snake and Hamlin valleys is 78,000 afy instead of the 132,000 afy estimated from the recent BARCAS study (Welch et al. 2007) used in the CCRP model. Compared to the CCRP model, the pumping scenarios used for the ENWU model simulations included additional future pumping in Snake Valley and pumping in Pine and Wah Wah valleys by the Central Iron County Water District, but does not include the proposed pumping in Cave, Delamar, and Dry Lake valleys. Since the two models used different assumptions for ET discharge in Snake Valley and different pumping scenarios, it is not possible to make a direct comparison of their respective simulation results. In consideration of the preliminary review of the model and simulation results, the BLM has determined that the CCRP model designed and developed specifically for this EIS analysis currently is the best available tool for evaluating the probable long term effects of groundwater withdrawal from the project on a regional scale.

CCRP Model Construction, Calibration, Uncertainty, and Limitations

Technical Review Team

The BLM established a technical review team of hydrology specialists from the BLM Nevada and Utah State Offices and National Operations Center in Denver, the USGS; and AECOM (BLM EIS Contractor) to review the CCRP model. The review team included two groundwater flow modeling experts: Dr. Keith Halford (USGS); and Dr. Eileen Poeter (Poeter Engineering). A technical specialist from the Nevada State Engineer's Office observed the review process. The technical review team was formed to assist the BLM by reviewing the model documentation reports and providing recommendations to the BLM for improvements to the model. The review team held periodic conference calls and meetings with the SNWA modeling team and the BLM EIS project management team at various stages of the model development. The review team reviewed early work products, modeling files, data compilations and draft reports, and the most recent updated reports used for this impact analysis. The technical team requested specific improvements to the model. Key issues identified by the review team and their resolution, or improvements made to the model to address these issues, are discussed in Section 3.0 of SNWA (2009a), and in SNWA (2010a).

Model Development

The following discussion provides an overview of the CCRP model that was developed for use in the water resource impact analysis. Detailed documentation of the model is provided in the following technical documents:

1. Conceptual Model of Groundwater Flow for the Central Carbonate-Rock Province: Clark, Lincoln, and White Pine Counties GWD Project, SNWA, November 2009 (SNWA 2009a);

2. Transient Numerical Model of Groundwater Flow for the Central Carbonate-Rock Province: Clark, Lincoln, and White Pine Counties GWD Project, SNWA, November 2009 (SNWA 2009b);

3. Addendum to the Groundwater Flow Model for the Central Carbonate-Rock Province: Clark, Lincoln, and White Pine Counties Groundwater Development Project, Draft, August 2010 (SNWA 2010a);

4. Simulation of Groundwater Development Scenarios Using the Transient Numerical Model of Groundwater Flow for the Central Carbonate-Rock Province: Clark, Lincoln, and White Pine Counties GWD Project, SNWA, Draft September 2010 (SNWA 2010b).

Model Construction. The transient, three-dimensional, finite-difference numerical groundwater flow model was developed by the SNWA's modeling team using the USGS groundwater flow program, MODFLOW-2000 (Harbaugh et al. 2000). The parameter-estimation code UCODE_2005 (Poeter et al. 2006) was used to assist in the calibration process.

The model domain is the same area as the hydrologic study area depicted on **Figure 3.3.1-1**; encompassing approximately 35 hydrographic basins and 20,688 square miles. The model grid is oriented north and the cells are uniform in size with a side dimension of 3,281 feet (1 kilometer). The model includes 11 layers that vary in thickness from 328 to 6,252 feet. The model extends vertically from -10,000 feet amsl to the water table, which varies from about 1,148 feet to more than 9,022 feet amsl.

Hydrogeologic Framework. Available geologic information was compiled and simplified to develop a geologic map and representative cross-sections for the region. This geologic representation was further simplified by combining geologic units with similar hydraulic properties to delineate regional HGUs and major structural features that may control groundwater flow. Two of the regional HGUs are important regional aquifers: the basin fill aquifer and the carbonate rock aquifer. Other units include basement rock that comprises the base of the flow system, plutons, plateau sedimentary rocks, and an upper aquitard that separates the upper and lower carbonate aquifers throughout much of the northern study area. Available hydraulic parameter data was compiled and evaluated to establish a range of properties for each of the regional HGUs. The spatial distribution of the regional HGUs is represented in the numerical model as zones of variable hydraulic properties. A function was added to the model to account for the reduction of hydraulic conductivity with increasing depth resulting from increased compression under load.

Representation of Structural Features. Major structural features are believed to influence or control groundwater flow in the region (SNWA 2009a,b). Faults can behave as barriers or conduits to flow. Major structural features include: a) basin-bounding faults; b) faults that cause large juxtaposition of geologic units; c) faults that exhibit large disturbances to HGUs; and d) faults that are known to restrict or partition groundwater flow. Major structural features include normal basin and range faults, strike-slip (lateral) fault zones, caldera bounding structures, and regional thrust faults. Fifty faults (or fault zones) have been represented in the numerical model (Figure 4-11, p. 4-20, SNWA 2009b). The hydraulic conductivities for these faults were treated as parameters and were estimated during the model calibration process.

Recharge. Recharge refers to infiltration of precipitation or stream flow into the groundwater system. Recharge is the primary mechanism for replenishment of groundwater supplies within the region. Groundwater recharge cannot be measured directly in the field for areas as large as the model area. Groundwater recharge is spatially and temporally variable and its distribution is affected by many factors, including the amount and type of precipitation, topography and the hydrogeology of the unsaturated zone as well as the saturated zone.

The spatial distribution of precipitation across the region was estimated based on an averaged 30-year historical record (PRISM normal precipitation grid). This precipitation grid was used because it is recognized as the best available spatial climate data for the region. Recharge from precipitation was estimated using the groundwater balance method whereby recharge was calculated as the difference between total volume of groundwater discharge (i.e., groundwater ET plus subsurface outflow) and the volume of subsurface inflow as described in SNWA 2009a. This methodology was used to estimate an annual potential recharge by basin. The potential recharge from precipitation for a given area was then proportioned using hydrogeologic factors into in-place recharge and runoff recharge (i.e., infiltration down gradient and along streams).

Groundwater recharge is input into the numerical model as an average annual rate that is held constant during the entire modeling period. The model is not set up to simulate wet and dry cycles, or seasonal fluctuations. The actual rates, distribution, and timing of recharge remain very uncertain and therefore, the current model cannot provide a realistic simulation of wet and dry cycles over the region of study.

Evapotranspiration and Spring Flow. Groundwater discharges to the surface in ET areas or as spring or stream flow. Groundwater ET estimates were derived by delineating different types of ET areas and applying appropriate ET rates to estimate ET flow (SNWA 2009a). The groundwater discharge to ET areas and selected springs was simulated as drains in the numerical model. Large springs and streams controlled by groundwater discharge in Pahranagat Valley, Muddy River Springs Area, and Big Springs were simulated as streams in the model where the springs may flow upward through a number of layers, gaining or losing water along the route, and the spring discharge to streams at the surface can infiltrate into the flow system downstream from the spring orifice.

Boundary Conditions. Potential locations where flow could occur were initially identified based on the three-dimensional hydrogeologic framework (SNWA 2008). Boundary segments where the geologic conditions were favorable for flow were further evaluated using available water level data, interpretive hydrogeologic framework information, and estimates from previous studies. Estimates of flow across external model boundaries are presented in SNWA 2009a. These flow estimates were used as flow observation targets during steady-state calibration of the model. The length of the flow segments were modified in some locations based on testing during the model calibration process and additional evaluation of geologic data as described in the numerical modeling report (SNWA 2009b). Flow into and out of the perimeter of the model was simulated by constant head cells. The locations of the constant head boundaries used in the model are described by basin (SNWA 2009b). The initial constant-head values assigned in the model were derived from published information (SNWA 2009b). However, the constant-head values were treated as model parameters that were adjusted during the model calibration process.

Calibration Process. Calibration entails adjustment of input parameter values to identify a set of parameter values that agrees with field observations and causes hydraulic heads and flows calculated by the model to generally match hydraulic heads and flows measured in the field. Model calibration can provide estimates of parameters that cannot be measured directly.

The model was calibrated to both steady-state and transient stress periods. The initial steady-state period represents predevelopment conditions prior to 1945. The transient calibration period extends from 1945 to 2004.

During the model calibration, the conceptual model represented in the numerical model was modified (or refined) to yield a better fit to field observations. The calibration was accomplished primarily through a trial and error, iterative process. During the model calibration process, variations in the: 1) hydrogeologic framework, 2) external flow boundaries, 3) recharge processes, and 4) discharge areas were tested and major improvements in model fit were retained in the final calibrated model. Major model refinements that were developed during the calibration process are briefly described below and discussed in detail in SNWA 2009a and 2010a.

Two conceptual models were considered during early stages of model development. The first model consisted of assigning rocks in mountain blocks with very low hydraulic conductivities; the second model assigned rocks in mountain blocks with moderately low hydraulic conductivities, combined with faults with low cross-fault transmissivity (i.e., flow barriers). The second conceptual model was adopted for the final model because this model configuration generally improved the calibration by: 1) improving the simulation of hydraulic head elevations in the mountain blocks; 2) eliminating or substantially diminishing the overall size of areas where the earlier model-simulated water levels above the ground surface; and 3) allowing for the simulation of large spring discharges (that in many cases, could not be simulated without the fault barrier) (SNWA 2009b). Subsurface data, aquifer test data, and water level monitoring data are not available in most areas to evaluate if the major regional faults act as barriers to flow. One example of where there is water level data across a major normal fault zone is in Dry Lake Valley and Patterson Valley where substantial drops in groundwater elevations across two normal faults appear to be controlled by faulting rather than mountain block bedrock characteristics (SNWA 2009b). In addition, major fault zones typically consist of a wide range of characteristics, including a single slip or multiple slip surfaces, unconsolidated clay-rich gouge, breccia zones, chemically altered zones, or mylonite zones. The generation of fine-grained materials and alteration and mineral precipitation tends to reduce the porosity and permeability of the primary fault zone, compared to the adjacent unfaulted bedrock materials (Caine et al. 1996). Therefore, it is plausible that major regional fault structures could behave as impediments to groundwater flow. The hydraulic properties of the materials along the external flow boundaries are largely unknown. The external flow boundaries were adjusted during the model calibration process (SNWA 2009b) to improve the model representation of hydraulic heads (i.e., groundwater elevations) and ET and spring discharge to more closely match field observations. The modifications of the external flow boundaries were consistent with the current understanding of the hydrogeologic conditions in these areas (SNWA 2009b).

The amount of recharge was not modified during final calibration. However, the runoff distribution paths were adjusted manually to reduce unrealistic simulated mounds in the water table. Modifications during calibration typically consisted of extending the distribution path to resolve the mounding problem. Other refinements were made to better constrain the distribution of ET across valley bottom areas, and improve spring discharge rates (SNWA 2009a).

Detailed comparisons between measured or estimated values and model-simulated values are provided in the numerical model report (SNWA 2009b). Overall, the model results indicate that the calibrated model is a reasonable representation of the regional groundwater flow system. The aquifer parameters incorporated into the model generally lie within the range of estimated values for the HGUs. The distributions of hydraulic conductivity values generally are consistent with the conceptual model. Transmissivities, while high in some areas, are reasonable overall.

Model Uncertainty

Major sources of uncertainty inherent in the regional model results are associated with incomplete or limited information for the region, or generalizations required for model construction including:

- Limitations regarding the current understanding of the hydrogeologic framework that controls groundwater flow throughout the region;
- Limitations resulting from the gross simplification of hydrogeologic conditions required for construction of a regional scale model;
- Limitations and generalizations imposed by the use of a 1-kilometer (3,281 feet) grid cell width;
- Assumption of homogeneity within a given regional model unit or parameter zone as a result of data limitations and generalizations;
- Uncertainty regarding the mean recharge and spatial distribution of recharge across the region; and
- Uncertainties regarding the hydraulic interconnection between the groundwater flow system throughout the region.

There is uncertainty regarding the final set of aquifer parameters used to represent the HGUs across the region. A sensitivity analysis was performed by adjusting the hydraulic conductivity and storage properties simultaneously and within a reasonable and plausible range, to evaluate how this adjustment in parameters could change the drawdown results. The results of this sensitivity analysis (using the Alternative A pumping scenario) are provided in Figure 5-2 in SNWA 2010b. The results indicate that shifting these aquifer parameters within a plausible range would expand the areal extent of the area encompassed within the 10-foot drawdown contour. The changes in parameter values used in this sensitivity analysis, however, reduced the model fit compared with the calibrated model (SNWA 2010b).

Groundwater model solutions are not unique. In other words, the choice of parameter values and boundary conditions is not unique and other combinations of parameter values and boundary conditions may provide an equally justified calibrated model that also approximates the groundwater flow system. However, predictions from that model may differ from the current predictions. In addition, it is well established that groundwater models cannot be validated (Konikow and Bredehoeft 1992). Konikow and Bredehoeft explain that calibration is “only a limited demonstration of the reliability of the model." The term "validation" has been used to describe the successful simulation of a post-calibration stress to the groundwater system. However, one such success does not assure that the model will reliably predict a different future stress. Konikow and Bredehoeft note that realistic expectations of models "will help to shift emphasis towards understanding complex hydrogeological systems and away from building false confidence into model predictions." Although false confidence cannot be placed in numerical models, it is more realistic that hydrologists build a reasonable model that uses field information to estimate future conditions than to ignore such capability in lieu of less rigorous estimates. The goal is for the numerical model to reasonably represent the system.

Additional uncertainties are associated with the observation data sets (such as hydraulic head measurements, ET discharge estimates, and historic groundwater pumping estimates) used for calibration. These and other model uncertainties are discussed in detail in the transient model report and model simulation reports (SNWA 2009b,c; 2010a,b).

Climate Change. Section 3.1.3.2, Climate Change Effects to All Other Resources, discusses the current research into climate change and predicted future trends for the Great Basin and provides a discussion of the range of potential effects on water resources. Current climate change models suggest that within the study area, mean temperatures are expected to rise and annual precipitation is likely to remain similar to present conditions as the century progresses (Redmond 2009). However, there is insufficient information available to predict how changes in climate would affect the rate of groundwater recharge in the region. Because of the uncertainties regarding potential effects of climate change on the groundwater flow system, it was not possible to provide a reasonable or meaningful simulation of the combined effects of pumping and climate change on water resources.

Model Limitations

All models have limitations and the CCRP model is no exception. A detailed discussion of the model limitations and accuracy of the model to reproduce measured groundwater levels and estimated groundwater budget components is provided in the numerical model report (SNWA 2009b). Although the model results provide valuable insight as to the general, long-term drawdown patterns and relative trends likely to occur from the various pumping scenarios, the model does not have the level of accuracy required to predict absolute values at specific points in time (especially decades or centuries into the future). Two major limitations of the model for predictive studies include: 1) a lack of reliable information regarding the hydraulic properties of faults included in the model; and 2) representation of future climate as discussed below.

Regional information suggests that the presence of faults throughout the region strongly influences the movement of groundwater. However, reliable estimates of hydraulic properties of faults included in the model are not available. Considering the size of the study area, number of faults, and the fact that these properties would likely vary both horizontally and vertically along these structures, it is not practical (and likely would be impossible) to collect reliable estimates of hydraulic parameters for all of the major faults in the region of study. It also is probable that other faults exist in the model area that affect groundwater flow have not been identified or incorporated into the model. This pervasive lack of information regarding fault hydraulic parameters is considered a major limitation of the model. As described previously, 50 faults (or fault zones) have been represented in the numerical model (Figure 4-11, p. 4-20, SNWA 2009b). The hydraulic conductivities for these faults were treated as model parameters and were estimated during the model calibration process. Most of the major regional faults included in the calibrated model are represented as low permeability structures that inhibit flow across the fault zones. The presence of these structures in the model tends to influence the pattern and magnitude of drawdown simulated by the model.

Another limitation is that the recharge estimates used as model input assumes that the same average precipitation rate and pattern observed over approximately the past 30 year period is representative of the average conditions that will occur over the 245 year future simulation period (i.e., assumption that the annual recharge rates do not vary over the 245 year future simulation period [2005 – 2250]). For this reason, the calibrated model should not be considered an accurate or precise predictor of future conditions because it does not account for variations in future climate conditions that cannot be accurately forecasted at this time.

Conclusion. Although there are inherent uncertainties and limitations associated with results of a regional groundwater flow model over a broad region with complex hydrogeologic conditions, the calibrated CCRP model is a reasonable tool for estimating probable regional-scale drawdown patterns and trends over time, resulting from the various pumping alternatives that were evaluated. When combined with the baseline information on water resources in the study area, the simulated drawdowns, flow estimates, and water budget estimates provide reasonable and relevant results for analyzing the probable regional-scale effects and comparing alternatives for this programmatic level analysis.

Defining the Drawdown Area

For this impact analysis, the model-simulated area that would experience a change (decrease) in groundwater elevation of 10 feet or more is defined as the "drawdown area." The 10-foot drawdown contour is used as a frame of reference to identify water dependent water resources within the drawdown area that may be at risk of impact, and for comparison of the potential effects between the various pumping scenario alternatives. Drawdowns of less than 10 feet could reduce flows in perennial springs or streams that are controlled by discharge from the regional groundwater flow system, which in turn could potentially cause declines in the diversity and abundance of associated riparian flora and fauna that may only be able to tolerate water declines on the order of a few feet. However, considering the regional scale of the model and unavoidable uncertainty associated with the model predictions (summarized below), the BLM does not believe that it is reasonable or appropriate to use the regional model to quantify changes in groundwater elevation of less than 10 feet. In addition, in many areas within the study area, changes in groundwater levels of less than 10 feet can be difficult to distinguish from natural seasonal and annual fluctuations in groundwater levels. The BLM has used the 10-foot drawdown contour to define the drawdown area for quantification of impacts associated with groundwater pumping in many other EISs in Nevada over the past 10-15 years[1]. The BLM recognizes that refinements, such as the collection of additional site-specific hydrologic information and model refinement (such as the development of embedded models in specific areas of interest) would be necessary to improve the ability to predict drawdown impacts at a more localized scale.

The drawdowns used in the impact evaluation were calculated as follows:

- For the No Action pumping scenario the drawdowns results are calculated as the difference between the initial hydraulic heads (those simulated at the end of 2004 by the calibrated numerical model) and the simulated hydraulic head for the specific time frame.
- The drawdowns presented for the Proposed Action and Alternatives A through E pumping scenarios represent the estimated incremental drawdown attributable to each specific pumping scenario without the effects of the No Action pumping. These were calculated as the difference between the total drawdown simulated by the combined No Action pumping scenario plus the specific groundwater development pumping scenario (included in the Proposed Action or Alternatives A through E) subtracted from the No Action drawdown results for the specific time frame.
- The results for the cumulative pumping scenarios represent the combined effects of: 1) continuation of the No Action pumping scenario in the future; 2) addition of identified reasonably foreseeable future pumping actions; and 3) pumping associated with groundwater development project (Proposed Action or Alternatives A through E pumping scenarios). All of the drawdown results for the cumulative analysis were calculated as the difference between the initial hydraulic heads (those simulated at the end of 2004 by the calibrated numerical model) and the simulated hydraulic head for the specific time frame.

Spring and Stream Impacts Evaluation

Potential impacts to springs and streams were evaluated by identifying and evaluating the potential risk to all known or suspected perennial water sources in the defined drawdown area using the methodology described below. Because of the regional nature of the groundwater flow model and model limitations discussed previously, it is not possible to accurately predict site specific changes in flow for springs or streams. However, the model is viewed as a useful and relevant tool for predicting flow trends resulting from the various pumping scenarios at selected springs and streams, primarily those with large flows that likely represent discharge from the regional groundwater flow system. These flow

[1] A few Nevada BLM EIS examples include: Final EIS Cortez Hills Expansion Project, September 2008; Final EIS Phoenix Project, January 2002; Draft SEIS Barrick Goldstrike Mines Inc. Betze Project, September 2000; Draft EIS Leeville Project, March 2002; Final EIS Newmont Mining Corporation South Operation Area Project Amendment, April 2002.

predictions were used to evaluate: 1) if and when impacts to flow were likely to occur; and 2) the relative magnitude of change that could occur. The methodology used for each of these evaluations is summarized below.

Identification of Springs and Streams Susceptible to Drawdown Impacts

The springs and streams in the region can be characterized as either ephemeral, intermittent, or perennial. Ephemeral and intermittent springs and stream reaches flow only during or after wet periods in response to seasonal runoff. By definition, these surface waters are not controlled by discharge from the regional groundwater flow systems. During the low-flow period of the year, ephemeral and intermittent springs and stream reaches typically are dry. In contrast, perennial springs and stream reaches generally flow throughout the year. Flows observed during the high-flow periods in perennial springs and streams include a combination of surface runoff and groundwater baseflow discharge, whereas during the low-flow period, flows are sustained entirely by baseflow discharge from the groundwater system. If the flow from the perennial spring or stream is controlled by discharge from the aquifer used for the GWD Project, a reduction of groundwater levels from well field production could reduce the groundwater discharge to perennial springs or streams with a corresponding reduction in spring flows, lengths of perennial stream reaches, and their associated riparian/wetland areas.

The actual impacts to individual seeps, springs, or stream reaches are dependent on the source of groundwater that sustains the perennial flow (i.e., regional versus local or perched groundwater flow systems) and the actual extent of drawdown that occurs in the area. The interconnection (or lack of interconnection) between the perennial surface waters and deeper groundwater sources is controlled by the specific hydrogeologic conditions that occur at each site. Considering the complexity of the hydrogeologic conditions over this broad region, inherent uncertainty in numerical modeling predictions (discussed above) related to the exact areal extent and magnitude of drawdown, and uncertainty in the site-specific hydrogeologic conditions controlling flow at most of the springs within the model domain, it is not possible to conclusively identify specific springs and seeps that would show effects from future drawdown from the various pumping scenarios considered in this analysis. However, the regional model results, coupled with a generalized understanding of the groundwater flow system, provide the most reasonable means available at this time to identify areas where impacts associated with the proposed action (or alternative) pumping are likely to occur. This drawdown impact evaluation for springs and streams is limited to a prediction of areas of risk with the recognition that actual impacts to individual springs and streams distributed over this broad region cannot be determined precisely prior to pumping.

Potential impacts to all perennial streams and springs located within the defined drawdown area were evaluated by:

1. Identifying perennial streams and springs within the model-simulated drawdown area (defined by the 10-foot drawdown contour at various future points in time); and
2. Evaluating the likely source of the water to identify water resources that are potentially susceptible to groundwater development drawdown impacts.

Baseline information for perennial springs and streams in the study area is summarized in Section 3.3.2. The spring databases compiled for this project include two types of data: 1) inventoried springs, and 2) other springs. For the purposes of this study, "inventoried springs" are springs that have been field verified and include one or more flow measurements. "Other springs" are mapped spring locations that have not been field verified and therefore do not include flow measurements. The other springs were identified based on locations shown on topographic maps or included in the National Hydrography Database.

As described in Section 3.3.1.3, Hydrologic Cycle and Conceptual Groundwater Flow, the conceptual model indicates that springs are controlled by local, intermediate, or regional flow systems. For this impact analysis, it is assumed that the intermediate and regional groundwater flow systems are hydraulically connected within the drawdown areas. For the purposes of discussion, unless otherwise specified, the use of the term "regional groundwater flow system" in the remainder of this document refers to the combined intermediate and regional groundwater flow systems described in Section 3.3.1.3.

The water resource impact analysis uses the geomorphic setting (i.e., valley floor, valley margin, and upland areas) defined in **Table 3.3.2-3**, combined with water level data, to identify the general risk level for each perennial water source within the simulated drawdown areas. For this analysis, springs in upland areas (i.e., high elevation regions or mountain block settings) are assumed to be controlled by discharge from local or perched groundwater systems that are unlikely to be hydraulically connected to the regional groundwater flow system that would be affected by groundwater withdrawal. Therefore, the analysis assumes that the risk of impacts to springs and perennial stream reaches located in upland settings is considered low regardless of the drawdown in the regional groundwater flow system that may occur beneath these areas.

Table 3.3.2-3 Assumptions Used to Evaluate Potential Impacts to Perennial Water Resources Located Within the Drawdown Area

Generalized Geomorphic Setting	Predominant Groundwater Flow System Assumed to Control Discharge to Perennial Springs and Streams	Relative Risk of Impacts to Perennial Water Resources within the Drawdown Area	Explanation
Upland Areas	Local or Perched	Low	Impacts are unlikely to occur regardless of predicted model drawdown.
Valley Margin Areas	Local and Intermediate[1]	Moderate[2]	Impacts to some perennial waters may occur in springs discharging from aquifers hydraulically connected to the regional flow system. Impacts are unlikely to occur to perennial waters discharging from local or perched groundwater flow systems that are not hydraulically connected to the regional flow system.
Valley Floor Areas	Regional	High[2]	Impacts are likely to occur to perennial water resources that depend on discharge from the regional groundwater flow system. Impacts are unlikely to occur in localized perched aquifers that occur in some areas.

[1] Intermediate flow system is assumed to be interconnected with the regional flow system.
[2] Except where available water level data indicates that surface water resources are likely perched or hydraulically isolated from the regional groundwater flow system (see text for further explanation).

Springs located in valley floor settings are assumed to be controlled predominantly by discharge from the regional groundwater flow system. The impact analysis further assumes a high risk of impacts to most springs (and associated stream reaches fed by springs) that discharge on the valley floors within the drawdown area. It is important to recognize that perched aquifers may occur in localized valley floor settings; however, localized perched aquifers in valley floor settings are not identified or evaluated as part of this regional impact assessment.

Springs (and stream reaches fed by springs) located in valley margin settings may be controlled by discharge from local, intermediate, or in some instances, regional groundwater flow systems. The actual discharge source for each spring or stream reach in these areas is controlled by site-specific hydrogeologic conditions that typically are not well understood. Considering the uncertainty associated with the source of groundwater discharge for individual springs and hydraulic interconnection between the spring source and the aquifer systems that would be affected by groundwater pumping, the impact analysis assumes that there is a moderate risk of impacts to springs (and stream reaches fed by springs discharging in these areas) located within the valley margin setting in the drawdown area.

The geomorphic settings (i.e., valley floor, valley margin, and upland areas) were determined for each basin within the study area using slope, elevation, and geology (based on the simplified hydrogeologic framework used to construct the numerical flow model provided in SNWA 2009b). The valley floor area was defined as the flat valley bottoms with the lowest elevations within each basin. The valley floor areas are underlain by unconsolidated basin fill deposits. The valley margin areas are generally characterized by the intermediate slope and intermediate elevation zones between the flat valley floor and steeper bedrock areas in the mountain block. The valley margin areas generally are underlain by alluvial fans but may locally include bedrock, including carbonate bedrock units, which extend beneath the valley floor areas and their associated basin fill deposits. The upland areas are characterized as higher elevation areas with typically steeper terrain that is predominantly underlain by bedrock.

Site-specific water level data is not available in all locations to evaluate if perennial water resources are likely or unlikely to be connected to the regional groundwater system. Available depth-to-water data for the region is provided in the baseline characterization report (SNWA 2008 Volume 4), supplemented in Snake Valley with new information collected by UGS (2010). The data points (i.e., wells) with water level data are spatially variable between the different geomorphic settings. Depth to water information is scarce to nonexistent in most upland areas, available locally in some areas within the valley margin zone, and typically available in the valley floor areas in most basins. However, the number of data points within the valley floor areas varies greatly between basin and by area within each basin. In most areas, the depth-to water data correlates with the geomorphic setting in that shallow water levels (<100 feet) generally occur in valley floor settings, and deeper water levels (>100 feet) generally occur in the valley margin and upland areas. The areas of potential high risk initially identified using the geomorphic setting (summarized in **Table 3.3.2-3**) were adjusted in some areas if there was sufficient water level data to demonstrate that the depth to the regional water table was relatively deep for a particular region or hydrographic basin. Specifically, if there were sufficient data to demonstrate that the depth-to-water in the valley floor setting was >100 feet, the level of risk was adjusted to "moderate risk"; if the water level data indicated that the depth-to-water was >150 feet, the risk level for that area was adjusted to "low risk". For example, in Delamar Valley, the depth-to-water is greater than 800 feet below ground surface indicating that surface water resources in this basin are not controlled by discharge from (or are hydraulically connected to) the regional groundwater system in this basin that would be affected by the proposed groundwater withdrawal. *Therefore*, the potential risk to surface water resources in the Delamar Valley hydrographic basin are assumed to be low (i.e., impacts are unlikely to occur regardless of drawdown) even if these resources occur in a valley floor or valley margin setting.

Identification of Springs and Streams Susceptible to Drawdown Impacts within Great Basin National Park.

As described previously, this analysis uses the geomorphic setting (i.e., valley floor, valley margin, and upland areas) combined with site-specific water level data to identify the general risk level for each perennial water source within the predicted drawdown areas. This analysis has identified springs and perennial stream reaches located in lower elevation areas along the valley margin area of the park where surface waters could be impacted. The USGS has conducted a more detailed, site-specific study within GBNP and adjacent areas in Spring Valley and Snake Valley to evaluate the susceptibility of surface water resources to groundwater pumping. This study is described below.

The NPS requested a study by the USGS to identify areas within the GBNP where surface water resources are susceptible to groundwater pumping in the valleys adjacent to the park. The results of this study were published in the USGS report "Characterization of Surface-Water Resources in the GBNP Area and Their Susceptibility to Ground-Water Withdrawals in Adjacent Valleys, White Pine County, Nevada" (Elliott et al. 2006). The study assessed surface water resources to identify areas vulnerable to groundwater pumping effects. The results of the study delineated specific areas within and near the park; these areas were defined as follows:

(1) "Areas where surface-water resources likely are susceptible to ground-water withdrawals;" and

(2) "Areas where surface-water resources potentially are susceptible to ground-water withdrawal."

Prudic (2006), a coauthor of the susceptibility study, provided responses to comments on the susceptibility study that included an explanation of the difference between the two types of susceptibility areas identified on Plate 1. Prudic explained that the 'likely susceptible" areas are more vulnerable to groundwater pumping effects than the "potentially susceptible areas." He also states in the concluding summary of this document that "Results from the study indicate that surface-water resources in most of the Park are not susceptible to ground-water pumping in the adjacent valleys. However, we identify a few areas area within and near the Park's boundaries that are susceptible (potentially or likely); these warrant additional monitoring and study."

The areas identified in and adjacent to the park as "likely susceptible to groundwater withdrawal" (Elliott et al. 2006) are shown on **Figure 3.3.2-1** and include:

Spring Valley Hydrographic Basin:

- Shingle Creek (middle and lower reaches along the west boundary of the park)
- Pine and Ridge Creeks (middle and lower reaches along the west boundary of the park)
- Williams Canyon (middle and lower reaches along the west boundary of the park) and adjacent Shoshone Ponds and Minerva spring complexes

Figure 3.3.2-1 Surface Water Susceptibility Zones, Great Basin National Park

Snake Valley Hydrographic Basin:

- Weaver Creek (full reach along the north boundary of the park)
- Strawberry Creek (lower reaches) and adjacent springs (along the north boundary of the park)
- Lehman and Baker Creek (middle to lower reaches), and Rowland and Cave Springs (along the northeast boundary of the park)
- Snake Creek and its tributary Spring Creek Tributary (lower reach along the eastern boundary of the park)
- Big Wash (lower reach east of the park boundary)
- Big Springs Creek/Lake Creek and associated springs (full reach from Nevada into Utah, southeast of the park boundary)

The areas identified in and adjacent to the park as "potentially susceptible" to groundwater withdrawal (Elliott et al. 2006) also are shown on **Figure 3.3.2-1** and include:

- Snake Creek and its tributaries (middle reach located upgradient of the likely susceptible lower reach)
- Big Wash (middle reach below confluence of North and South Forks of Big Wash, east of the park boundary)

The risk analysis used for this regional water resource impact evaluation has incorporated the results of the Elliot et al. study by assuming that there is a moderate risk of impacts to perennial water resources located within the susceptibility zones as defined on **Figure 3.3.2-1** within the boundaries of GBNP. For this analysis, the susceptibility zones delineated in **Figure 3.3.2-1** that occur outside park boundaries are defined as moderate or high risk depending on whether the perennial resources in these areas occur in the valley margin or valley floor setting, respectively.

Evaluation of Model-simulated Stream Flow Results

The numerical groundwater flow model was used to simulate changes in baseflow in a few selected springs and streams resulting from the Proposed Action and alternatives. The specific methods used to simulate spring and stream flow in the numerical model is provided in the model documentation (SNWA 2009b). Baseflow is the groundwater component of surface water flow and is distinct from the contributions to streamflow associated with runoff from precipitation or snowmelt. There is a high level of uncertainty associated with long-term simulations of changes in baseflow (or groundwater discharge) in streams and springs distributed over large regions. The numerical model encompasses over 20,000 square miles. As discussed previously, the groundwater flow model is based on a conceptual model that represents a simplified and generalized understanding of the hydrogeologic and hydrologic conditions over a very large region. A major source of uncertainty is the hydraulic interconnection between the regional groundwater flow system and the springs and streams represented in the model. Due to the simplified assumptions in the model and unknown or poorly-understood conditions that control flow in most of the springs and streams, the baseflow may not change as predicted by the model.

Considering the limitations of the regional model and inherent uncertainty associated with the flow predictions, the model-simulated spring flows are used in this analysis to identify major spring discharge areas outside of the identified drawdown area (including White River Valley, Pahranagat Valley, Muddy River, Big Springs, and Gandy Warm Springs in Snake Valley) where potential flow reductions could occur; they also are used to provide an indication of potential trends in flow that are likely to occur to springs located both within and outside the defined drawdown area. However, as explained previously, considerable uncertainty exists regarding the accuracy of these predictions. Therefore, it is not reasonable to use the results to predict the absolute change in flow over the long-term simulation period.

For the springs or streams with flow predictions, a simulated incremental change in flow of less than 5 percent was inferred to indicate that measureable impacts were unlikely to occur. A less than 5 percent reduction of flow would be difficult to accurately measure or distinguish from natural fluctuations and is presumed to be within the model uncertainty. The impact analysis further assumes that springs with model-simulated flow reductions of 5 percent or greater could be affected.

Big Springs Flow Predictions. An earlier version of the numerical model was set up such that a low permeability hydraulic flow barrier (HFB) was used to control the discharge at Big Springs (SNWA 2009b). The HFB was situated immediately east of Big Springs at the location of a local Quaternary fault. This model construction was able to closely approximate the discharge at Big Springs. However, the placement of the north-south fault barrier immediately east of the spring, and the assumed distribution of pumping wells on the east side of the fault restrict the drawdown impacts to Big Springs. The geologic map and cross-section provided in the baseline report indicate that the simulated fault is subparallel to a major range-bounding fault located approximately 0.75 mile to the west of Big Springs (SNWA 2008) that was not simulated in this version of the model. After review of the model construction, the BLM technical review team requested that the model be modified in southern Snake Valley that consisted of shifting the position of the HFB to essentially match the major range-bounding fault. In the final calibrated model used for the EIS, the HFB in the area of Big Springs was moved to the west to closely match the location of the range-bounding fault, as requested by the BLM (SNWA 2010a). As a result of this move, the local fault situated east of Big Springs on the valley floor was no longer represented in the regional model.

With this revised configuration, the model was only able to simulate discharge of about one-half of the observed discharge at Big Springs. It was not possible to simulate a larger spring discharge without drastic changes to the numerical model (SNWA 2010a). However, this fit to the observed discharge is similar to the quality of fit at other locations in the model. Because of this different representation of the spring in the earlier and final version of the models, the decrease in springflow caused by pumping is different. The spring discharge simulated by the original model decreases following a gentle slope. By the end of the simulation period, spring discharge has been reduced by less than a third of the rate in 2005. The spring discharge simulated by the modified numerical model decreases following approximately the same rate of decrease as the one simulated by the original model until about the year 2050 (when pumping is initiated in Snake Valley). After that time, the rate of decrease increases drastically causing the discharge at the spring to cease (SNWA 2010b). These alternative model configurations illustrate that there is considerable uncertainty regarding the hydrogeologic conditions that control the groundwater discharge at Big Springs. Therefore, the simulated reduction in flows should not be viewed as reliable predictions of future flows at specific points in time in the future. Rather, these flow predictions from the regional model should be viewed as indicators of the potential risk to the spring associated with pumping in southern Snake Valley and Spring Valley.

Water Rights Impact Evaluation

This impact evaluation is not intended to determine reasonable (or unreasonable) effects to water rights allowable under state law such as the Nevada Statue (NRS 534.110{4}) that allows for a reasonable lowering of the static water level at the points of diversion for existing water rights provided that the existing water rights can be satisfied. The water rights impacts evaluation is intended to provide a disclosure of potential effects to existing surface and groundwater rights resulting from the various proposed pumping alternatives.

Active water rights including their points of diversion and manner of use were identified within the hydrologic study area as described in Section 3.3.1.5, Groundwater Resources. The impact assessment was conducted by overlaying the predicted drawdown on the water right points of diversions to identify water rights that may be affected. For surface water rights, it was assumed that water rights located within the model-simulated drawdown area (defined by the 10-foot drawdown contour) and located within the identified high and moderate risk areas previously described for perennial water could be affected. It also was assumed that groundwater rights located within the same defined drawdown area could be affected. Groundwater rights were further evaluated by determining the magnitude and timing of the drawdown at the points of diversions. Potential impacts to surface water rights and groundwater rights were summarized by determining the number of water rights potentially affected in each hydrographic basin for each alternative. Additional information regarding uncertainty associated with the water rights impact assessment is presented under the Proposed Action drawdown effects analysis.

Presentation of Results

The results of the groundwater pumping analysis are summarized by alternative in the following section. Additional details and the supporting information used to develop the summaries and quantification of potential impacts to water resources are provided in the substantial material in **Appendices F3.3.7** through **F3.3.16**. This includes the following information provided for each pumping scenario and comparison time frame (i.e., full build out, full build out plus 75 years, and full build out plus 200 years).

- Drawdown maps for each pumping scenario at each time frame (**Appendix F3.3.7**);
- Maps delineating the risk to perennial surface water resources within the predicted drawdown areas (**Appendix F3.3.8**);
- Tables listing the number of springs by basin that occur within the high, moderate, and low risk areas for each pumping scenario and time frame (**Appendix F3.3.9**);
- Tables identifying the inventoried springs that occur within the moderate and high risk areas for each pumping scenario and time frame (**Appendix F3.3.10**);
- Tables listing the miles of perennial stream within areas where effects to surface waters could occur for each pumping scenario and time frame (**Appendix F3.3.11**);
- Maps illustrating the risks to surface water rights by manner of use within the drawdown areas for each pumping scenario and time frame (**Appendix F3.3.12**);
- Tables defining the risk to surface water rights by basin within the drawdown areas for each pumping scenario and time frame (**Appendix F3.3.13**);
- Maps illustrating the drawdown effects to groundwater rights by manner of use for each pumping scenario and time frame (**Appendix F3.3.14**);
- Tables defining the risk to groundwater rights by basin within the drawdown areas for each pumping scenario and time frame (**Appendix F3.3.15**); and
- Tables presenting the simulated groundwater budgets by basin and flow system for each pumping scenario and time frame (**Appendix F3.3.16**).

3.3.2.9 Proposed Action

Groundwater Development Areas

Groundwater development areas have been identified in the five groundwater development basins (i.e., Spring, Snake, Cave, Delamar, and Dry Lake valleys). Groundwater development areas are located in portions of the valley floor and valley margins within each basin. Development within the groundwater development areas would include groundwater production wells, collector pipelines, staging areas, power facilities, pumping stations, and access roads. The actual location of specific facilities within the groundwater development areas has not been identified at this stage of the project and will be subject to future site-specific NEPA analysis.

Construction and Operation

Springs identified within the groundwater development areas are summarized in **Table 3.3.2-4**. Under the Proposed Action, there are 60 springs located within the boundaries of the development areas. Of these 60 springs, 13 have been verified in the field and include flow data. The remaining 47 springs were identified based on locations shown on topographic maps or included in the National Hydrography Database. These springs occur within the groundwater development areas within Spring Valley (37 springs), Snake Valley (11 springs), Cave Valley (1 spring), Dry Lake Valley (4 springs), and Delamar Valley (7 springs).

There also are 28 separate perennial stream reaches with a total length of 29 miles that occur within the groundwater development areas (**Table 3.3.2-5**). This includes 23 perennial stream reaches located in Spring Valley and 5 located in Snake Valley.

The potential for impacts to springs and streams located within these groundwater development areas would depend on the location of facilities. For this programmatic analysis, it is assumed that the ACMs discussed for construction of the primary ROWs that address surface water resources, stream crossings, and erosion control measures would apply to these future ROWs. In addition, SNWA Programmatic Measures indicate that: 1) well pads would avoid riparian and wetland areas (ACM B.1.1); and 2) as feasible, collector pipeline, electrical service lines, substations, would avoid wetlands and stream crossings (ACM B.1.3). Implementation of these combined measures would minimize impacts to perennial water sources associated with the well field development.

Table 3.3.2-4 Number of Springs Located within the Groundwater Development Areas

Alternative				Proposed Action, A and C		B		D		E	
GW Flow System	**Basin #**	**Basin Name**	**Name**	**Inv. Spg.[1]**	**Other Spgs.[2]**	**Inv. Spg.[1]**	**Other Spgs.[2]**	**Inv. Spg.[1]**	**Other Spgs.[2]**	**Inv. Spg.[1]**	**Other Spgs.[2]**
White River	180	Cave Valley	381658114523300	–	1	–	–	–	1	–	1
	181	Dry Lake Valley	181 S01 E64 06DB 1	–	1	–	–	–	1	–	1
			Unnamed Springs		3	–	–	–	3	–	3
	182	Delamar Valley	Grassy Spring	1	–	–	–	1	–	1	
			Unnamed Springs	–	6	–	–	–	6	–	6
Salt Lake Desert	184	Spring Valley (184)	Blind Spring	1	–	–	–	–	–	1	–
			Four Wheel Drive Spring	1	–	–	–	–	–	1	–
			Indian Springs	1	4	–	–	–	–	1	4
			Kalcheck Springs	–	1	–	–	–	–		1
			Layton Spring	2	–	–	–	–	–	2	–
			N. Millick Spring	1	–	–	–	–	–	1	–
			S. Bastian Spring	1	–	–	–	–	–	1	–
			S. Bastian Spring 2	1	–	–	–	–	–	1	–
			S. Millick Spring	1	–	–	–	–	–	1	–
			The Seep	1	–	–	–	–	–	1	–
			Unnamed Springs	–	21	–	–	–	1	–	21
			Unnamed Springs east of Cleve Creek	1	–	–	–	–	–	1	–
	195	Snake Valley	363854114072701	–	1	–	–	–	–	–	–
			Kious Spring	–	–	1	–	–	–	–	–
			Unnamed Caine Spring	–	1	–	–	–	–	–	–
			Unnamed Caine Spring - South	–	1	–	–	–	–	–	–
			Unnamed Spring SW of Caine Spring	–	1	–	–	–	–	–	–
			Unnamed Springs	1	6	–	5	–	–	–	–
			Youn-Aquainv-003	–	–	1	–	–	–	–	–
Total				**13**	**47**	**2**	**5**	**1**	**12**	**12**	**37**
Total All Springs				**60**		**7**		**13**		**49**	

[1]Inventoried spring (field verified).
[2]Other springs (not field verified).

Table 3.3.2-5 Perennial Streams within the Proposed Groundwater Development Areas

GW Flow System	Basin #	Basin Name	Stream Name	Proposed Action, and A and C	B	D	E
Salt Lake Desert	184	Spring Valley (184)	Bassett Creek	0.8			0.8
			Bastian Creek	2.0			2.0
			Big Negro Creek	2.7			2.7
			Cleve Creek	2.3			2.3
			Freehill Creek	0.4			0.4
			Garden Creek	1.1			1.1
			Gordon Creek	0.1			0.1
			Indian Creek	1.7			1.7
			Kalamazoo Creek	0.1			0.1
			McCoy Creek	2.4			2.4
			McCoy Creek (Unnamed Wash)	0.5			0.5
			Meadow Creek	1.3			1.3
			Muncy Creek	0.2			0.2
			North Millick Spring Creek	0.6			0.6
			Odgers Creek	0.7			0.7
			Piermont Creek	0.7			0.7
			Ranger Creek	0.4			0.4
			Shingle Creek	0.5			0.5
			South Millick Spring Creek	0.1			0.1
			Spring Creek (GBNP)	0.1			0.1
			Spring Valley (Unnamed Creek 1)	0.4			0.4
			Stephens Creek	0.8			0.8
			Vipont Creek	0.4			0.4
	195	Snake Valley	Big Springs Creek	5.3	2.7		
			Big Wash	2.0			
			Lake Creek	0.1			
			Lehman Creek	0.2	1.0		
			Lehman Creek Diversion	1.2	2.1		
Total Miles				**29.0**	**5.7**		**20.3**

Although the SNWA Programmatic Measures commit to avoiding wetlands and stream crossing where feasible, the final facility would likely include some (unavoidable) perennial stream crossings. Potential construction related impacts to perennial streams generally would be minimized by the implementation of the BLM's BMPs and ACMs discussed previously for the primary pipeline and power line ROWs. These measures would minimize erosion and potential channel degradation and scour impacts. However, construction across perennial streams likely would result in short-term (2-year) impacts; depending on site-specific conditions and construction methods, construction also could result in long-term (>2 year) impacts. Construction also would result in short-term disturbance of the stream beds in the other intermittent and ephemeral streams crossed by a pipeline or access road.

Construction of well pads, access roads, gathering pipelines, and electrical service lines would result in an estimated maximum surface disturbance of approximately 8,400 acres within 5 hydrographic basins. This surface disturbance would result in an increase in erosion and sedimentation from construction of facilities in the groundwater development areas. Stormwater and erosion control measures including the preparation of site-specific SWPP Plans, implementation of the BLM Management Decisions and BMPs, and temporary and permanent erosion control measures included in the ACMs (previously discussed for the Primary ROWs) should minimize potential impacts to perennial water sources and ephemeral and intermittent drainages.

The development areas are not located within any mapped or delineated flood zone. However, the development areas incorporate drainage areas that are subject to periodic flooding, flash flooding, and associated erosion and sedimentation during extreme or prolonged runoff events. Potential periodic impacts from flooding likely would be localized and short-term and would be addressed as part of ongoing maintenance activities.

Monitoring and Mitigation Recommendations

In addition to all mitigation measures identified for ROW activities the following monitoring and mitigation measures are recommended to supplement the ACMs and State and Federal regulations to protect or reduce potential impacts to perennial water sources within the groundwater development areas.

Monitoring

GW-WR-1: Spring Inventories. A spring inventory would be conducted in all groundwater development areas to verify and map the location of all springs prior to construction. Construction and development of the groundwater development areas would avoid ground disturbance in the vicinity (i.e., 0.5 mile) of all verified spring locations. Effectiveness: This measure should effectively mitigate impacts to springs from ground disturbance and construction related activities.

Mitigation

GW-WR-2: Stream Crossing Plans. A site specific plan would be developed to detail the construction procedures, erosion control measures, and reclamation that would occur for pipeline construction across live (flowing) stream reaches. The plan also would incorporate information from BLM Technical Reference 423, for hydraulic considerations in designing pipeline stream crossings (DOI 2007). The plan would include site-specific designs using either open cut or jack and bore techniques and site specific measures to minimize disturbance of the stream bed, and release of sediment from the construction area into the downstream stream reach. The plan would be reviewed and approved by the BLM and NDOW prior to initiation of any construction activities within the stream corridor. Effectiveness. This measure would be effective in ensuring the use of best construction methods at all stream crossings.

Conclusion. Construction of well pads, access roads, gathering pipelines, and electrical service lines would result in an estimated maximum surface disturbance of approximately 8,400 acres within five hydrographic basins. There are 60 known or suspected springs identified within the groundwater development areas. These springs occur within the groundwater development areas within Spring Valley (37 springs), Snake Valley (11 springs), Cave Valley (1 spring), Dry Lake Valley (4 springs) and Delamar Valley (7 springs). There also are 37 separate perennial stream reaches located in Spring Valley (32), Snake Valley (4), and Cave Valley (1) with a total length of 54.7 miles within the groundwater development areas. The potential for impacts to springs and streams located within these groundwater development areas would depend on the location of facilities. Implementation of the ACMs would minimize impacts to perennial water sources associated with the well field development. Additional mitigation recommendations include all previous, applicable ROW mitigation measures.

Groundwater Pumping

Groundwater Pumping Scenario

The groundwater pumping scenario for the Proposed Action assumes pumping at the full quantities (i.e., approximately 177,000 afy) listed on the pending water rights application for the 5 proposed project pumping basins (Spring, Snake, Cave, Delamar, and Dry Lake valleys). The well distribution developed by SNWA for this model scenario (**Figure 3.3.2-2)** distributes the simulated production wells spatially within the groundwater development areas in an effort to minimize pumping effects. For all pumping scenarios, pumping simulations were set up such that production wells associated with the SNWA groundwater development project were completed (depending on location) in either the Upper Valley Fill, Lower Valley Fill, or Lower Carbonate unit. Details regarding the assumed pumping schedule used for the model simulations are provided in the model simulation report (SNWA 2010a). The pumping schedule reflects the proposed staged general south-to-north sequence of basin development for the project.

Impacts to Water Levels

The predicted change in groundwater levels attributable to groundwater development under the Proposed Action at full build out, full build out plus 75 years, and full build out plus 200 years are provided in **Figures 3.3.2-3**, **3.3.2-4**, and **3.3.2-5** , respectively. These figures illustrate areas where the water levels are predicted to decrease in comparison to the simulated No Action water levels.

At full build out, the drawdown areas are localized in the vicinity of the pumping wells in Spring, Cave, Delamar, and Dry Lake valleys. Drawdown does not occur at this time period in Snake Valley because pumping is not projected to begin in Snake Valley until the final stage of the development. Comparison of the simulation results for the three representative points in time indicates that the drawdown area continues to progressively expand as pumping continues into the future.

At the full build out plus 75 years time frame, there are two distinct drawdown areas. The northern drawdown area encompasses most of valley floor in Spring Valley, southern Snake Valley, and northern Hamlin Valley. The southern drawdown area extends across the Cave, Delamar, and Dry Lake valleys in an elongate north-south direction and extends into the eastern margin of Pahranagat Valley and northwestern margin of Lower Meadow Valley Wash.

By the full build out plus 200 years time frame, the 2 drawdown areas merge into one that extends approximately 190 miles in a north-south direction and up to 55 miles in a east-west direction. At this time frame, the simulated drawdown area extends into Tippetts Valley, southeastern Steptoe Valley, the eastern margins of Pahroc and Pahranagat valleys, and the western margins of Panaca Valley and Lower Meadow Valley Wash.

The locations of six selected observation wells located within the proposed pumping basins are presented in **Figure 3.3.2-6**. Water level hydrographs for each of these observation wells within the pumping basins are provided in **Figures 3.3.2-7** and **3.3.2-8**. The hydrographs illustrate the predicted rate and magnitude of water level decline at these representative locations over the simulation period. The hydrographs for the observation wells indicate that water levels are predicted to continue to decrease over the model simulation and are not predicted to reach a renewed equilibrium (or steady state condition) before the end of the simulation period. These results further suggest that with continued pumping beyond 200 years, additional drawdown is likely to occur after the model simulation period (i.e., after the full build out plus 200 year period).

Impacts to Springs and Streams

The estimated potential risks to springs located within the projected drawdown area at full build out, and at full build out plus 75 years and full build out plus 200 years are presented in **Figures F3.3.8A-1**, **F3.3.8A-2**, and **F3.3.8A-3**, respectively, in **Appendix F3.3.8**. The number of springs within the drawdown area and relative risk of impacts by hydrographic basin are summarized in **Table F3.3.9-1A**. Specific inventoried springs located within the drawdown area at the representative points in time are listed in **Appendix F3.3.10**.

Potential effects to perennial springs and streams are summarized in **Table 3.3.2-6**. Comparison of the results of the model simulations and the resource impact evaluation for the three representative time periods indicated that the number of springs and miles of perennial streams that potentially could be affected increases at each successive time period.

Figure 3.3.2-2 Pumping Distribution, Proposed Action

Figure 3.3.2-3 Predicted Change in Groundwater Levels Proposed Action Full Build Out

Figure 3.3.2-4 Predicted Change in Groundwater Levels Proposed Action + 75 Years

Figure 3.3.2-5 Predicted Change in Groundwater Levels Proposed Action + 200 Years

Figure 3.3.2-6 Representative Water-level Hydrograph Locations

Figure 3.3.2-7 Representative Water-Level Hydrograph Locations for Spring and Snake Valleys

Figure 3.3.2-8 Representative Water-Level Hydrograph for Cave, Dry Lake, and Delamar Valleys

Table 3.3.2-6 Summary of Potential Effects to Water Resources Resulting from the Proposed Action Pumping Scenario[1,2]

Water Resource Issue / Time Frame	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Drawdown:			
• Number of hydrographic basins affected by drawdown	7	16	18
Drawdown effects on perennial springs:			
• Number of inventoried springs located in areas where impacts to flow could occur[3]	3	44	59
• Number of other springs located in areas where impacts to flow could occur[4]	5	168	248
• Model-simulated flow reduction at Big Springs (as percent flow reduction)	2%	100%	100%
Drawdown effects on perennial streams:			
• Number of basins with perennial stream reaches where impacts to flow could occur	1	2	6
• Miles of perennial stream located in areas where impacts to flow could occur	6	80	112
Drawdown effects on surface water rights:			
• Number of surface water rights located in areas where impacts to flow could occur	25	145	212
Drawdown effects on groundwater rights:			
• Number of groundwater rights located within the 10-50 foot drawdown area	28	129	96
• Number of groundwater rights located within the 50-100 foot drawdown area	0	68	134
• Number of groundwater rights located within the >100 foot drawdown area	0	2	34
• (Total groundwater rights in drawdown area)	(28)	(199)	(264)
Percent reduction in ET and spring discharge: [5]			
• Spring Valley	45%	77%	84%
• Snake Valley	0%	28%	33%
• Great Salt Lake Desert Flow System[1]	18%	48%	54%
• White River Flow System	0%	1%	3%
Reduction in flow from Snake Valley to Pine, Wah Wah, and Tule valleys Hydrographic Basins:[5]			
• AFY	0	660	1,800
• Percent Reduction	0%	4%	10%

[1]Located within the groundwater flow model domain.
[2]Unless otherwise noted, supporting information for these estimates are provided in **Appendices F3.3.5** through **F3.3.16**.
[3]Specific inventoried springs identified in moderate or high risk areas are identified in **Table F3.3.10A** in **Appendix F3.3.10**.
[4]Other Springs" are springs identified in the National Hydrography Database or topographic maps that have not been field verified.
[5] Estimate derived from the model-simulated values provided in SNWA 2010b with comparison to No Action pumping results.

For the predicted drawdown area at full build out plus 75 years, there are 44 inventoried springs and 168 "other" springs located within the high and moderate risk areas. At full build out plus 200 years, there are 57 inventoried springs and 248 "other" springs located within the high and moderate risk areas. These springs occur in Cave, Hamlin, Spring (HA 184), Snake, and Lake valleys.

The estimated total number of miles of perennial streams located in drawdown areas where surface waters could be affected is summarized in **Table 3.3.2-6**. The results indicate that the total estimated length of perennial streams located in areas where there is a high to moderate risk of impacts increases from approximately 80 miles at 75 years to 112 miles at full build out plus 200 years. This includes stream reaches located in Pahranagat, Steptoe, Spring (HA 184), Snake, and Lake valleys, and Lower Meadow Valley Wash.

Impacts to individual springs and streams would depend on the actual drawdown that occurs in these areas and the site specific hydraulic connection between the groundwater systems impacted by pumping and the perennial water source. Perennial water sources that are hydraulically connected to the groundwater system impacted by pumping and within the drawdown area would likely experience a reduction in baseflow. Depending on the severity these reductions in flow, this could result in drying up of springs or reducing the length of the perennial stream reaches and their associated riparian areas. Potential impacts to vegetation, wildlife and aquatic resources resulting from these potential drawdown effects are addressed in Sections 3.5, Vegetation, 3.6, Terrestrial Wildlife, and 3.7, Aquatic Biological Resources.

Model-simulated Spring and Stream Discharge Estimates. Model-simulated changes in spring flow for selected springs are presented in **Table 3.3.2-7**. Spring discharge was simulated at 11 springs within White River Valley. The model results indicate that two of these springs, Butterfield Spring and Flag Springs 3, are predicted to experience 7 percent flow reduction at the full build out plus 75 years time frame, and 18 percent and 17 percent flow reductions, respectively, at the full build out plus 200 years time frame. These results suggest that the groundwater development eventually could affect flows in springs located along the southeastern margin of the valley floor in White River Valley. This area is located near the drawdown boundary for these two time frames (see **Figures 3.3.2-4** and **3.3.2-5**). The model results indicate that other springs located in the northern portion of the valley floor in White River Valley are unlikely to experience impacts (>5 percent reductions) attributable to the Proposed Action pumping.

The model results also indicate that the groundwater development is not predicted to reduce flows in the other major regional spring discharge areas within the White River Flow System, including Pahranagat Valley and the Muddy River Springs Area near Moapa. Impacts to flows in the major regional springs discharging in Steptoe Valley in the Goshute Valley Flow System and at Panaca Spring in Panaca Valley in the Meadow Valley Flow System are not anticipated.

In the Great Salt Lake Desert Flow System, spring discharge was simulated at 3 springs in Spring Valley and 4 springs in Snake Valley. In Spring Valley, the model simulations indicate that by full build out plus 75 years, Keegan, North Millick, and South Millick springs all show reductions of flow. At full build out plus 200 years, these springs are predicted to experience flow reductions ranging from 75 to 100 percent. These three springs are all located near the margin of the valley floor in the north central portion of the valley. These results suggest that springs located in the southern portion of the valley that are hydraulically connected to the regional flow system are likely to experience some reduction in flow over the long term.

In Snake Valley, the model simulation results were used to evaluate potential changes in flow at Big Springs, Foote Reservoir Springs, Kell Spring, and Gandy Warm Springs. The model indicated that measurable flow reductions (>5 percent) are not anticipated at Foote Reservoir Springs, Kell Springs, and Gandy Warm Springs located in the central portion of the basin. The results suggest that the springs located on the valley floor in the central and northern portion of the basin are unlikely to experience impacts (>5 percent flow reduction). Big Springs located in the southern portion of the basin is predicted to experience a substantial reduction in flow by the full build out plus 75 years time frame. Reductions of flow at Big Springs would reduce flows in Big Springs Creek and reduce flows to Lake Creek and into Pruess Lake. The results suggest that the springs located on the valley floor in the southern portion of the valley likely would experience reductions in flow.

Table 3.3.2-7 Model-simulated Flow Changes (Proposed Action)

(Project Specific)					Proposed Action		
					Incremental Change in Flow % (from No-Action)		
Flow System	**Hydrographic Basin**	**Spring**	**Average Flow (Actual) in gpm**	**Model-simulated Average Flow (2005) in gpm**	**Full Build Out**	**75 years after Full Build Out**	**200 years after Full Build Out**
White River	White River Valley (207)	Arnoldson Spring	1,608	946	0	0	-1
		Butterfield Spring	1,225	471	-1	-7	-18
		Cold Spring	582	503	0	0	-1
		Flag Springs 3	969	560	-1	-7	-17
		Hardy Springs	200	73	0	0	-1
		Hot Creek Spring	5,032	6,899	0	-1	-3
		Lund Spring	3,594	3,314	0	0	-1
		Moon River Spring	1,707	1,457	0	0	-1
		Moorman Spring	405	353	0	-1	-3
		Nicolas Spring	1,185	872	0	0	-1
		Preston Big Spring	3,572	3,794	0	0	-1
	Pahranagat Valley (209)	Ash Springs	6,909	7,453	0	-1	-2
		Brownie Spring	224	277	0	0	0
		Crystal Springs	4,235	4,647	0	0	-1
		Hiko Spring	2,735	1,985	0	0	-2
	Muddy River Springs Area (219)	Muddy River near Moapa[1]	20,931	15,383	0	0	-1
	Lower Moapa Valley (220)	Muddy River near Glendale[1]	19,565	14,895	0	0	-1
	Black Mountains Area (215)	Blue Point Spring	223	393	0	0	0
		Rogers Spring	771	515	0	0	0
Goshute Valley	Steptoe Valley (179)	Campbel Ranch Springs	2,746	2,088	0	0	0
		Currie Spring	2,181	1,419	0	0	0
		McGill Spring	4,783	2,074	0	0	0
		Monte Neva Hot Springs	649	280	0	0	-1
Great Salt Lake Desert	Spring Valley (184)	Keegan Spring	234	63	-58	-100	-100
		North Millick Spring	284	98	-31	-62	-75
		South Millick Spring	506	278	-55	-94	-99
	Snake Valley (195)	Big Springs	4,289	1,977	-2	-100	-100
		Foote Res. Spring	1,300	211	0	-1	-2
		Kell Spring	120	59	0	-1	-2
		Warm Creek near Gandy, UT	7,426	2,697	0	0	-1
Meadow Valley	Panaca Valley (203)	Panaca Spring	1,455	1,208	0	0	0

[1] Simulated using Stream Flow Routing 2 package for MODFLOW.

Source: SNWA 2010.

Water Resources Within or Adjacent to the GBNP. Surface water resources located within or adjacent to the GBNP that occur within both the model-simulated drawdown area and within the susceptibility zones identified by Elliot et al. (2006) are listed in **Table 3.3.2-8**. For the purpose of the draft EIS analysis, these areas are considered zones of moderate risk as defined in **Table 3.3.2-3** (i.e., impacts may occur to some perennial waters that are hydraulically connected to the regional flow system). At full build out plus 75 years, Outhouse Springs and Spring Creek Spring, both located outside the GBNP boundary, and 6.4 miles of Snake Creek are within the area of moderate risk. By full build out plus 200 years, three springs, Outhouse, Rowland (located along the park boundary), and Spring Creek Springs, along with 9 miles of Snake Creek and its tributaries, are within the area of moderate risk.

Table 3.3.2-8 GBNP Water Resources Risk Evaluation Summary by Alternative

	Proposed Action		Alt. A		Alt. B		Alt. C		Alt. D		Alt. E		No Action	
Years	**75**	**200**	**75**	**200**	**75**	**200**	**75**	**200**	**75**	**200**	**75**	**200**	**75**	**200**
Springs[1]														
Cave Spring					X	X								
Outhouse Springs	X	X	X	X	X	X		X		X				
Rowland Springs		X		X	X	X								
Spring Creek Spring	X	X	X	X	X	X								
Other springs[2]	1	1	1	1	17	27	0	1	0	1	0	0	0	0
Streams (Miles[3]**)**														
Baker Creek and tributaries	0.0	0.0	0.0	0.0	1.7	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lehman Creek and tributaries	0.0	0.5	0.0	0.5	2.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Snake Creek and tributaries	6.4	9.0	5.6	8.8	12.9	15.1	0.0	8.0	0.0	8.0	0.0	2.1	0.0	0.0

[1] "X" indicates spring is located both within the simulated drawdown area and susceptibility zones as defined by Elliot et al. (2006).

[2] Other springs identified in GBNP are listed in **Appendix F3.3.1**, **Table F3.3.1-1B**.

[3] Miles of perennial stream identified in the GBNP located both within the simulated drawdown area and susceptibility zones as defined by Elliot et al. (2006).

Available information on water resources identified in caves within the GBNP is summarized in Section 3.3.1.4, Surface Water Resources. Baker (2009) has identified 6 caves in the susceptibility areas defined by Elliott et al. (2006) that are in direct contact with the water table or surface water. (Note that details regarding the locations and known subsurface extent of these cave systems was not available for BLM review at the time the draft EIS was written.) These include Model Cave, Ice Cave, Wheeler's Deep Cave, and Systems Key Cave in the Baker Creek watershed. Available information (summarized in Section 3.3.1.4) suggests that stream flow within Ice Cave and Systems Key Cave are likely controlled by the infiltration of surface runoff and not by upward flow from the regional groundwater flow system. Wheeler's Deep Cave also is reported to have a perennial stream (Baker 2009). Model Cave is reported to be the most important cave within the Baker Creek Cave System and is reported to have one or more perennial streams (McLean 1965; Bridgemon 1967; Baker 2009). Lange (1954) describes slots in the floor of Model Cave that he believes were formed by upward (or artesian) flow. However, he does not provide data to evaluate if these features were likely formed in the geologic past (i.e., under different hydrologic conditions) or were formed recently under present hydrologic conditions. If the latter were true, these features would suggest that artesian flow in the limestone is the source of water for the streams within in this cave. In summary, there is insufficient information to define the likely water source (i.e., local flow system or artesian flow through the carbonate aquifer system) that sustains the cave streams and these uncertainty regarding hydraulic interconnection between the limestone and the regional aquifer system that would be the targeted for groundwater development in Snake Valley. Therefore, potential impacts to perennial streams reported within the Wheeler's Deep Cave and Baker Creek Cave System are uncertain.

Utah Surface Water Resources

For the predicted drawdown area, there are three inventoried springs (Stateline, Caine, and Needle Point springs) and three perennial reaches (Big Wash, Lake Creek and Snake Creek) in Snake Valley located within the high risk areas at the full build out plus 75 years and full build out plus 200 years time frames.

The Pine Valley hydrographic basin is located east of Snake Valley and east of the water resource region of study defined by the numerical groundwater flow model domain boundaries used in the EIS analysis. The model simulations indicate that drawdown could propagate into Pine Valley. At the full build out plus 75 years and full build out plus 200 years time frames, the maximum drawdown simulated at the boundary of the model between Snake and Pine valleys is approximately 17 feet and 51 feet, respectively. Therefore, the model simulations suggest that drawdown could eventually propagate into the Pine Valley hydrographic basin.

The potential for drawdown originating in Snake Valley to affect surface water resources in Pine Valley was evaluated by compiling available information to characterize the surface water and groundwater conditions in the basin to identify the likely source of water that controls perennial water sources and discharges in ET areas (see **Appendix F3.3.17** for baseline data) and potential interconnection to the regional groundwater system that would be affected by the groundwater development.

Stephens (1976) investigated the water resources in Pine Valley as part of a series of USGS investigations of water resources within western Utah. With respect to spring occurrence, Stephens reported that: 1) approximately 80 springs were identified from topographic maps; 2) that all springs in the basin discharge at elevations of 6,200 feet (amsl) along the base of the Needle Range and southern part of the Wah Wah Range; 3) many appear to only flow in response to runoff and are dry part of the year; 4) many of the springs that discharge from the volcanic rocks on the eastern flank of the Needle Range probably are perched; and 5) shallow water table conditions occur locally along Pine Grove Creek upstream of Pine Grove Spring.

Groundwater elevation data for eight wells located in the south, central, and northern portion of the valley can be found in **Appendix F3.3.17**. Seven of the 8 wells are generally located in the valley floor or near the toe of the alluvial fans in lower elevation areas within the basin; the eighth well appears to be situated in an alluvial fan. The average depth to water for the eight wells ranges from a low of 302 feet in the northern portion of the basin to 717 feet for a well located near the southern margin of the basin. These deep depths to groundwater suggest that the springs and other surface water features that occur in Pine Valley are likely controlled by local groundwater occurrences that are perched above the regional groundwater flow system. This depth-to-water data also suggest that drawdown of the regional aquifer system resulting from pumping in Snake Valley is unlikely to impact surface water resources in Pine Valley.

Drawdown could, however, eventually result in a reduction in water levels in water supply wells that exist now or may exist in the future. It also is important to note that the drawdown at the boundary is larger than it would be if the model was extended further east because the model boundary is set up as a no-flow boundary. In other words, if the model were extended to encompass Pine Valley, the drawdown at full build out plus 75 years would be less than the 17 feet currently simulated by the model. The actual maximum drawdown at the individual well locations would depend in part on the distance between the well and the northwest boundary between Pine and Snake valleys where the model simulates drawdown could occur. With these considerations, it seems reasonable to assume that the magnitude of the drawdowns at individual wells located in the Pine Valley would be less than the drawdowns simulated by the current model at the boundary between the Snake Valley and Pine Valley hydrographic basins. Therefore, potential reduction in water levels at production wells located within Pine Valley would be less than 17 feet at full build out plus 75 years and less than 51 feet at full build out plus 200 years.

Impacts to Surface Water Rights

For surface water rights, the actual impacts to individual water rights would depend on the site-specific hydrologic conditions that control surface water discharge. Only those waters sustained by discharge from the regional groundwater system targeted or intercepted by the groundwater pumping would be susceptible to impacts.

The locations and manner of use of the active surface water rights within the drawdown area at full build out, full build out plus 75 years, and full build out plus 200 years are presented in **Figures F3.3.12A-1**, **F3.3.12A-2**, and **F3.3.12A-3**, respectively, in **Appendix F3.3.12**. These maps also illustrate the relative risk to perennial surface water resources within the projected drawdown area. **Table F3.3.13-1A** lists the number of active surface water rights within the drawdown area that occur within the high-, moderate-, and low-risk areas at the three representative time frames.

These results indicate that the number of surface water rights that potentially could be affected increases over the model simulation period.

At full build out plus 75 years, there are a total of 145 surface water rights located in areas where there is a moderate to high risk of impacts to surface flows. By the full build out plus 200 years time frame, there are 212 surface water rights located in areas where there is a moderate to high risk of impacts to surface flows.

The predominant beneficial use for the surface-water rights within the high- and moderate-risk areas are irrigation, stockwatering, and municipal uses. Other beneficial uses associated with the water rights identified in these risk areas include commercial, industrial, mining and milling, domestic, recreational, wildlife, and other (not specified). It is important to note that some surface water rights only divert surface water runoff or groundwater discharge from local or perched groundwater systems that are not dependent on discharge from the regional or intermediate groundwater flow system. In these cases, impacts to surface water flows are not anticipated regardless of the predicted drawdown. For surface water rights that are dependent on groundwater discharge, a potential reduction in the water table at the point of diversion could reduce or eliminate the flow available at the point of diversion for the surface water right.

Impacts to Groundwater Rights

For the purposes of this evaluation, it is assumed that wells located within the areas affected by drawdown of 10 feet or greater could experience impacts. Specific impacts to individual wells would depend on the: 1) well completion, including pump setting, depth, yield, predevelopment static and pumping groundwater levels; 2) interconnection between the aquifer in which the well is completed in and the aquifer targeted by the GWD Project; and 3) the magnitude and timing of the drawdown that occurs at the specific location.

Figures F3.3.14A-1, **F3.3.14A-2**, and **F3.3.14A-3** in **Appendix F3.3.14** illustrate the location and manner of use of existing groundwater rights in relation to the magnitude of the model-simulated drawdown at full build out, full build out plus 75 years, and full build out plus 200 years; **Table F3.3.15-1A** lists the groundwater rights by hydrographic basin within the drawdown areas that are predicted to occur.

As summarized in the **Table 3.3.2-6**, the number of groundwater rights potentially impacted from drawdown is projected to increase over the model simulation period. At full build out plus 75 years, there are 199 groundwater rights located within areas that are predicted to experience a reduction in groundwater levels of at least 10 feet. One hundred and twenty nine of these occur in areas with predicted drawdowns of 10 to 50 feet, 68 occur in areas with predicted drawdowns of 51 to 100 feet, and 2 occur in areas with predicted drawdowns of greater than 100 feet.

At full build out plus 200 years, there are 264 groundwater rights located within areas that are predicted to experience a reduction in groundwater levels of at least 10 feet. Ninety six of these occur in areas with predicted drawdowns of 10 to 50 feet, 134 occur in areas with predicted drawdowns of 51 to 100 feet, and 34 occur in areas with predicted drawdowns of greater than 100 feet. However, considering the model uncertainty, the actual drawdown could be larger or smaller than predicted.

The predominant beneficial uses for the active groundwater rights within the drawdown area at full build out plus 200 years are irrigation and stockwatering. Additional beneficial uses associated with water rights that could be affected include commercial, mining and milling, municipal, domestic, and wildlife. Impacts to wells could include a reduction in yield, increased pumping cost, or if the water level were lowered below the pump setting or the bottom of the well, the well could be rendered unusable.

The Shoshone Ponds area is located in the drawdown area in the southern portion of the Spring Valley (described in Section 3.3.1.4). The source of water for three ponds (known as the Shoshone Ponds) used as refugia for Nevada native fish (BLM 2010) is artesian flow from a well. Actual impacts to the artesian flow would depend on the interconnection between the aquifer that sustains flow in the artesian well and the aquifers developed for production from proposed well field development. Considering the simulated drawdown and the hydrogeologic setting, there is a high risk that well field pumping could eventually result in reducing or drying up flows that sustain Shoshone Ponds. Potential impacts aquatic resources in Shoshone Ponds are discussed in Section 3.7, Aquatic Biological Resources.

Impacts to Water Balance

The model-simulated groundwater budget for current conditions is presented in **Appendix F3.3.16**, **Table F3.3.16-1A**. Under the current conditions, the principal groundwater outflow component for the groundwater flow systems is discharge of groundwater by ET. The ET estimate accounts for spring discharge that supports riparian and phreatophyte vegetation within delineated ET areas. Basins with large ET discharge rates (i.e., greater than 20,000 afy) that occur in the Great Salt Lake Desert and White River Groundwater Flow Systems include: Spring Valley (73,700 afy) and Snake Valley (105,800 afy) (the Great Salt Lake Desert Groundwater Flow System); and White River (65,600 afy), Pahranagat Valleys (21,800 afy), and Lower Moapa Valley (20,900 afy) (the White River Groundwater Flow System).

Potential changes in the water balance for the groundwater system within the region of study were estimated using the groundwater flow model (SNWA 2009c) results provided in **Appendix F3.3.16**, **Table F3.3.16-1B** with comparison to the simulated water balance under No Action. The estimated reductions in ET and spring discharge for selected basins and flow systems are summarized in **Table 3.3.2-6**.

For Spring Valley, the pumping is estimated to result in reductions of groundwater discharge for ET that increase from 77 percent at full build out plus 75 years to 84 percent at full build out plus 200 years. In Snake Valley, the pumping is estimated to result in reductions of groundwater discharge for ET of 28 percent at full build out plus 75 years and 33 percent at full build out plus 200 years, with most of this reduction occurring in the southern portion of the valley.

The proposed pumping is estimated to result in a total reduction of ET discharge from the portion of the Great Salt Lake Desert Flow System included within the study area of 48 percent at full build out plus 75 years and 54 percent at full build out plus 200 years. These predicted reductions in ET discharge rates indicate that spring discharge within and associated with these ET areas would be reduced. Estimates of the potential impacts to vegetation within ET areas are evaluated in Section 3.5, Vegetation.

The pumping is estimated to have minimal impact on ET discharge within the other pumping basins and the White River Flow System.

Pine Valley, Wah Wah Valley, Tule Valley, and Fish Springs Flat hydrographic basins (identified in **Figure 3.0-2**) are located to the east of the northeast boundary of the region of study for the groundwater flow model. The model simulation results indicate that the drawdown area is projected to eventually intercept the model boundary that extends along the southeast margin of Snake Valley and eastern margin of Hamlin Valley. These model boundary areas are adjacent to the Pine Valley hydrographic basin located immediately east of the model domain. The results suggest that drawdown attributable to the Proposed Action pumping scenario could eventually extend into Pine Valley. The potential impacts to surface water resources in Pine Valley resulting from drawdown attributable to the proposed pumping in Snake Valley was discussed previously under the heading "*Utah Surface Water Resources.*"

The total predicted reduction of flow to Pine, Wah Wah, and Tule valleys is summarized in **Table 3.3.2-6**. This reduction corresponds to an approximate 4 percent and 10 percent reduction in flow to these basins at the full build out plus 75 years and full build out plus 200 years time frames. Pine, Wah Wah, and Tule valleys are part of the Great Salt Lake Desert groundwater flow system. A major discharge area located downgradient from Pine Valley is Fish Springs. As discussed in Section 3.3.1.4, estimates for the total discharge at Fish Springs range from 21,000 afy to 24,000 afy (USFWS 2004; Bolke and Sumison 1978; respectively). The actual groundwater flow paths and interconnection between Snake and Hamlin valleys and the valleys east of the model boundary (Pine Valley, Tule Valley, Fish Springs Flat, and Fish Springs) are not well understood. If the groundwater flow system is interconnected and regional flow from Snake Valley contributes to flow at Fish Springs, then a reduction of flow from Snake Valley to Pine, Wah Wah, and Tule valleys could eventually result in a reduction of discharge at Fish Springs. The model-estimated reduction of groundwater outflow from Snake Valley to these basins along the eastern boundary of Snake Valley is 1,800 afy at full build out plus 200 years, which represents approximately 7 to 9 percent of the surface discharge at Fish Springs. It important to understand that there is considerable uncertainty regarding the amount of subsurface flow that occurs between Hamlin and Snake valleys (within the model area) and Pine, Wah Wah, Tule Valley, and Fish Springs Flat (located east of the model boundary). For example, the estimates of interbasin flow from Snake Valley to Tule Valley range from 15,000 to 42,000 afy; for Snake Valley to Pine Valley, estimates range from -5,500 to 16,500 afy (SNWA 2009a). There also is uncertainty regarding the interconnection between underflow leaving from Snake Valley and the flow at Fish Springs. For these reasons, it is not possible to determine (using available data and the results from the CCRP) if the groundwater development is likely to produce a measurable reduction in discharge at Fish Springs.

The GBNP Model (Halford and Plume 2011) was set up to simulate flows at Fish Springs. The simulation results from the GBNP Model indicate that pumping in Snake Valley (at the points of diversion listed in the SNWA water rights applications), at the full application rate (50,000 afy) combined with continuation of existing agricultural pumping would not reduce flows in Fish Springs over the 200 year simulation period. These model results suggest that pumping associated with the groundwater development in Snake Valley is unlikely to result in a measureable reduction in flows at Fish Springs.

Impacts to Water Quality

As described above, the results of the numerical modeling and water resource impact assessment indicate that the GWD Project likely would result in flow reductions and drying up of some perennial water sources. Flow changes could potentially be accompanied by changes in water quality. Considering the complex hydrogeologic conditions over the hydrologic study area, it is not possible to predict the actual change in water quality that would occur from flow reductions at specific springs or streams. The actual changes in water quality would depend on the magnitude of the flow change and the source of the surface discharge. Depending on the origin of the groundwater that discharges at the surface as a seep, spring, or stream, a reduction of flow could potentially be accompanied by a change in water quality. For example, where the source of the surface discharge is a single hydrostratigraphic unit (or aquifer) with relatively constant water quality, lowering the water level within the unit, and thereby reducing the surface discharge rate, should not result in a substantial change in water quality. However, reductions in flow could affect temperatures and temperature-dependent water quality constituents. Conversely, where the source of surface groundwater discharge is a mixture of waters from two different sources, such as a deeper, older regional groundwater flow and a younger intermediate flow, a reduction in discharge from one of the sources could potentially skew the discharge water quality toward the less affected source.

Stipulated Agreements, Applicant-committed Measures and Monitoring and Mitigation Measures

Stipulated Agreements

Stipulation agreements between the DOI and SNWA exist for groundwater development in four (Spring, Cave, Delamar, and Dry Lake valleys) of the five proposed pumping basins. No stipulation agreement between the Department of the Interior and SNWA regarding SNWA's groundwater withdrawal permit applications currently exists for Snake Valley; however, approved monitoring plans (hydrologic and biologic) that are part of the Spring Valley stipulation agreement include certain portions of Snake Valley. The agreements are provided in **Appendix C**. The stipulations require that SNWA implement hydrologic monitoring, management, and mitigation plans. The current monitoring and mitigation plans for groundwater development in these four basins are as follows:

1. Spring Valley Hydrologic Monitoring and Mitigation Plan (Hydrographic Area 184) (SNWA 2009c)
2. Hydrologic Monitoring and Mitigation Plan for Delamar, Dry Lake, and Cave Valleys (SNWA 2009d)

The current plans for locations of spring, stream and groundwater monitoring sites included under these agreements in relation to the model-simulated drawdown areas are presented in **Figures 3.3.2-9** and **3.3.2-10**. Details regarding monitoring well completion, monitoring well data collection, baseline data collection, and modeling and reporting requirements are defined in the above reference documents. A few of the key surface water and groundwater monitoring components included in the monitoring plans are the following:

- Monitoring groundwater levels in a network of monitoring wells distributed over the region. Individual wells will be monitored on either a quarterly, semiannual, or continuous basis;
- Monitoring groundwater levels in two new monitoring wells located in the vicinity of Shoshone Ponds in Spring Valley on a continuous basis;

Figure 3.3.2-9 Spring and Well Monitoring Sites, Spring Valley Stipulated Agreement

Figure 3.3.2-10 Spring and Well Monitoring Sites, Delamar, Dry Lake and Cave Valley Stipulated Agreement

- Monitoring groundwater levels in six new monitoring wells (i.e., four in the carbonate-rock aquifer and two in the basin-fill aquifer) in the "Interbasin Groundwater Monitoring Zone" in Spring and Hamlin valleys on a continuous basis.
- Monitoring wells in White River Valley and Pahranagat Valley;
- Monitoring groundwater levels continuously in shallow piezometers located adjacent to selected springs;
- Monitoring flow at Cleve Creek (Spring Valley) and Big Springs Creek (Snake Valley) using surface water gauges;
- Monitoring spring flow at other selected springs on a biannual basis; and
- Monitoring flow at Hot Creek Spring, Ash Springs, and Crystal Spring on a continuous basis.

The monitoring plans also include monitoring precipitation at various stations distributed across the area, water quality sampling, and baseline monitoring requirements.

Reporting and analysis requirements of the stipulated agreements would include the following:

- Annual reporting to the NSE presenting the results of the required monitoring and sampling and updated water level drawdown maps for both the basin fill and carbonate aquifer; and
- Updating an NSE approved groundwater flow model every 5 years after pumping begins and providing predictive results at 10-, 25-, and 100-year periods.

These stipulated agreements also would require the SNWA to modify or curtail pumping to mitigate impacts if required by the NSE.

Applicant Committed Adaptive Management Plan and Measures

In addition to the stipulated agreements, the SNWA has developed an adaptive management plan that was submitted as part of the Plan of Operations for the proposed project to address uncertainties in predicting potential effects of SNWA's groundwater production on water dependent resources and water rights holders. The adaptive management plan is intended to allow for the SNWA and the BLM to identify, avoid, minimize, and mitigate adverse effects associated with the proposed pumping in all five hydrographic basins and includes a framework for:

1. Monitoring baseline conditions;
2. Monitoring groundwater pumping effects;
3. Establishing groundwater-dependent, early warning thresholds to comply with the stipulated agreements, Nevada State Engineer Rulings, and the draft Snake Valley Agreement;
4. Implementation of adaptive mitigation measures designed to minimize or mitigate impacts to water dependent resources;
5. Monitoring the effects of implementation of adaptive management measures to meet environmental goals;
6. Implementing alternative adaptive mitigation measures if environmental goals are not met; and
7. Annual reporting requirements.

If the BLM determines those early warning thresholds have been reached as a result of the SNWA's groundwater withdrawal; one or more adaptive management measures may be implemented. These measures could include the following actions:

- Geographic redistribution of groundwater withdrawals (ACM C.2.1);
- Reduction or cessation in groundwater withdrawals (ACM C.2.1);

- Augmentation of water supply for Federal and existing water rights and Federal resources using surface and groundwater sources (ACM C.2.1);
- Conduct recharge projects to offset local groundwater drawdown (ACM C.2.21); and
- Implementation of cloud seeding programs to enhance groundwater recharge (ACM C.2.22).

Utah Geological Survey Monitoring

In addition to monitoring included in the stipulated agreements, the UGS recently established a groundwater monitoring network in Utah's west desert. The UGS groundwater monitoring network includes a series of wells installed in the Snake Valley HA and additional wells in adjacent basins in Utah to monitor: 1) groundwater elevations and water quality, and 2) shallow water levels at wetlands near selected springs. The Utah Geological Survey also established surface- and spring-flow gauges at selected springs. The Utah Geological Survey intends to use the monitoring network to establish baseline groundwater elevations, surface flow, and geochemical conditions, and to monitor for changes in these conditions after pumping begins. The UGS also intends to maintain and operate this monitoring network for at least the next 50 years (UGS 2010).

Monitoring and Mitigation Recommendations

The following proposed monitoring and mitigation measures are intended to supplement the existing monitoring and mitigation commitments included in the stipulation agreements and the ACMs described in **Appendix E**.

GW-WR-3: Monitoring and Modeling. The existing Stipulated Agreements between the DOI and SNWA for Spring, Cave, Delamar, and Dry Lake valleys require the SNWA to submit annual reports to the NSE to provide the results of the monitoring programs and updated water level drawdown maps. The stipulated agreements also require that the NSE approved groundwater flow model be updated every 5 years after pumping begins. This mitigation measure would require that SNWA provide the BLM with the following information on an annual basis after pumping is initiated:

1. Results of any surface water, groundwater, or meteorological monitoring required for the project;
2. Drawdown maps indicating the change in groundwater levels from the previous year, and total drawdown since groundwater pumping was initiated;
3. Description of any deviation of the monitoring results from the current groundwater flow model predictions;
4. Proposed modifications to the monitoring plans based on the results of the monitoring (i.e., changes to the monitoring well network, or network of springs, seeps, streams).

The regional model would be updated and recalibrated at least every 5 years (after pumping is initiated) or sooner if BLM identifies major differences between the model simulations and monitoring results and determines that model recalibration is necessary.

In addition to the regional groundwater flow model, the SNWA would develop more detailed (local scale) groundwater flow models designed to simulate the effects of pumping within each specific basin. These basin specific models would be developed and approved by the BLM prior to the BLM's NEPA review of specific groundwater development activities proposed by the SNWA. The basin specific models would be linked to the regional model. This can be accomplished by constructing a separate model whose boundary conditions are linked to the regional model, or constructing an "embedded" model where the local model is coupled to the regional model, or using another method approved by the BLM. The basin specific models also will be recalibrated at least every 5 years (after pumping is initiated) or sooner if the BLM identifies major differences between the model simulations and monitoring results and determines that model recalibration is necessary.

The regional groundwater flow model and basin specific models would be maintained through the life of the project unless the Technical Review Teams established under the DOI Stipulated Agreements determine groundwater flow modeling is no longer necessary or other groundwater flow models should be used.

<u>Effectiveness</u>: It is anticipated that BLM's annual review of monitoring results combined with the updated groundwater modeling predictions would provide early warning of potentially undesirable impacts to water-dependent

resources to allow for possible implementation of appropriate management measures to mitigate their effects. Implementation of these measures likely would reduce potential impacts to critical areas but would not entirely eliminate impacts to water dependant resources.

GW-WR-4: Monitoring, Mitigation and Management Plan for Snake Valley. Mitigation measure GW-WR-4 described below includes the water resource components of the draft documents prepared by BLM during preparation of the DEIS:

1) Monitoring, Mitigation and Management Plan for Snake Valley, Utah-Nevada; and
2) Guidance to Technical Working Group for Development of Snake Valley Monitoring, Mitigation and Management Plan.

The complete Monitoring, Mitigation, and Management (3M Plan) documents are provided in **Appendix B**.

The SNWA, working in conjunction with the BLM and other DOI agencies, and with input from the States of Nevada and Utah, will develop and implement a long-term monitoring, management, and mitigation plan for Snake Valley (3M Plan) as outlined below. When the 3M Plan is fully developed, it will be comparable to the monitoring plans developed (or to be developed) under the existing stipulation agreements for other basins addressed in this EIS. The 3M Plan will reflect a staged approach to implementing monitoring, management, and mitigation activities because of the time period that may elapse between this EIS and construction and operation of groundwater infrastructure in Snake Valley. Building and implementing the various stages of the 3M Plan will be dependent upon triggers as the SNWA moves closer to implementing groundwater development in Snake Valley.

The purpose of the 3M Plan is to insure that: 1) implementation of the ROD protects water dependent resources and water-related resources on public lands, 2) protects federal water rights managed by federal agencies, and 3) provides a process for mitigating impacts. To accomplish this purpose, the 3M Plan will establish a network of groundwater and surface water monitoring sites to collect baseline data and monitor the effects of groundwater development on water resources. The intent of the 3M Plan is to provide early warning of potential adverse impacts to water rights and water-dependent sensitive resources, and provide time and flexibility to implement management measures and gauge their effectiveness. Following this intent, the highest priority actions in the Snake Valley 3M Plan will be tied to predicted impacts from groundwater development, as identified in this EIS.

The 3M Plan would be required to be implemented and updated as long as the SNWA maintains long-term plans to develop groundwater and remove it from Snake Valley. If the SNWA terminates plans to develop groundwater from Snake Valley and the 3M Plan adopted for Spring Valley shows no interbasin effects from pumping in Spring Valley, then BLM may terminate the requirement for a Snake Valley 3M Plan.

<u>Key Concepts of Proposed Snake Valley 3M Plan</u>

Hydrologic Provisions – The Snake Valley 3M Plan will include sections to address hydrologic issues and would be similar to the plans developed with the BLM and other DOI agencies for the other groundwater development basins analyzed in this draft EIS. The 3M Plan will include:

- Development and implementation of baseline monitoring plans;
- Establishment of new monitoring sites and use of existing monitoring sites, including monitoring wells, piezometers, stream flow gages, and precipitation or meteorological stations;
- Collection of data on groundwater elevations, spring and stream flow rates, water quality, aquifer testing, vegetation communities, special status and water-dependent species and their habitats; and
- Updates or revisions to groundwater flow numerical modeling.

Management and Mitigation Actions – The initial 3M Plan generally will identify available management options and mitigation actions to address any adverse effects of SNWA pumping. These actions may include:

- Geographic redistribution of groundwater withdrawals;
- Reduction or cessation of groundwater withdrawals;
- If water supplies used for consumptive purposes, such as irrigation, domestic and livestock watering use were limited by the project, then the SNWA will provide alternate supplies of water;
- Acquisition of real property and/or water rights dedicated to management of special status species; and
- Augmentation of water supply and/or acquisition of existing water rights.

The initial 3M Plan will include triggers that will prompt the SNWA and the Technical Working Group (described below) to develop more detailed management response actions and specify conditions when those management actions will be implemented.

Staged Approach with Triggers for 3M Plan Activities – The SNWA and the Technical Working Group will develop an initial 3M Plan within 1 year of the ROD for this EIS. The initial 3M Plan will focus on:

- Identification of existing monitoring sites that would be useful in establishing baseline conditions;
- Identification of additional monitoring sites that will be needed to build full sets of baseline data;
- Processes for sharing monitoring data with interested parties;
- Description of other monitoring, management, and mitigation activities that will begin at later stages of project development; and
- Triggers, such as decisions by the NSE regarding water rights for Snake Valley or completion of the interstate agreement between Nevada and Utah regarding Snake Valley, which will initiate additional activities under the 3M Plan.

When these triggers occur, sections of the initial 3M Plan that were only generally described will be more fully developed to meet the objective of early detection of potential project impacts. Resources that must be committed by SNWA to build and implement the 3M Plan are expected to gradually increase over time, commensurate with SNWA implementation of groundwater development in Snake Valley.

Management Committee and Technical Working Group – As part of the 3M Plan, a management committee and a Technical Working Group will be formed to implement the various aspects of the 3M Plan to achieve its purpose. SNWA, in conjunction with BLM, will develop appropriate guidelines for the management committee and Technical Working Group. The BLM Nevada State Director, or his designee, will chair the management committee. Members of the management committee and Technical Working Group may include representatives from the SNWA, federal agencies, and the States of Nevada and Utah. Final approval of the Snake Valley 3M Plan (or any interim plans) rests with the BLM.

SNWA Management and Reporting Responsibilities – The SNWA would be responsible for the development and implementation of management actions associated with the 3M Plan including all monitoring activities during the life of the project. In the initial phase of the 3M Plan, the SNWA will provide results of monitoring on a quarterly basis and provide a detailed analysis of monitoring in an annual report provided to the BLM. The report would include maps indicating drawdown extent and magnitude and hydrographs indicating water levels and spring discharge measurements over time. When subsequent phases of the 3M Plan implement additional activities, such as research, groundwater modeling, and groundwater testing, reporting requirements would be similar as specified in the Spring Valley Monitoring and Mitigation Plan (SNWA 2009c). These reports would be made available to the public on BLM's website.

Monitoring Area – The monitoring areas associated with the 3M Plan are to be located within the Great Salt Lake Desert Flow System. Subject to input from the management committee and the Technical Working Group, it is anticipated that the highest intensity area for monitoring efforts will occur between Miller Springs at the northern end of Snake Valley and the southern boundary of the Snake Valley hydrographic area. Lower intensity monitoring efforts will occur in adjacent hydrographic basins, including Fish Springs Flat, Tule Valley, Pine Valley, and Wah Wah Valley. The Technical Working Group will be tasked with coordinating operation of the Snake Valley and Spring Valley Plans.

Management of Monitoring Data – The Technical Working Group will be responsible for establishing data collection methodology and quality control procedures. The Technical Working Group also will be responsible for integrating and interpreting monitoring results from a variety of sources, including the USGS, UGS, and SNWA-operated monitoring well locations. SNWA will be responsible for constructing and maintaining a database to house the collected data and make it publicly available.

Hydrologic Monitoring Provisions – The 3M Plan will include the following provisions for hydrologic monitoring**.** The technical working group will be tasked with prioritization and sequencing of monitoring tasks, so that increased monitoring obligations will be linked to accomplishment of significant milestones toward groundwater development. Accordingly, all of the monitoring tasks listed below may not be implemented immediately, and the recommended timing of each task below will be addressed in the initial 3M Plan.

- **Monitoring Wells** – The 3M Plan will rely upon existing groundwater monitoring networks established by the United States Geological Survey and by the UGS. The SNWA will construct and operate additional monitoring well sites at locations where the greatest impacts of groundwater diversions are expected to occur and in sites where geologic and aquifer properties are not well known. The monitoring plan and operation will be approved by the management committee and the Technical Working Group. The well monitoring network will collect both groundwater level data and water quality data, with the objective of establishing baseline conditions.
- **Spring Monitoring** –The 3M Plan also will include a program for monitoring spring discharge and groundwater levels associated with springs. Monitoring efforts will be focused on identification of early warning of groundwater declines that could impact springs. The SNWA, working with the technical working group, will initially identify the springs to be monitored and this will be updated as the information indicates needs for additional or changed monitoring locations. The initial list of springs to be considered for monitored will be derived from springs that may experience flow rate reductions, according to the groundwater modeling analysis for this draft EIS. Initially, the spring monitoring would be accomplished using continuous water level monitoring in piezometers located near each spring and biannual monitoring of flow at the spring.
- **Stream Monitoring** – The SNWA may be required to construct and operate stream gauges on creeks within Snake Valley or adjacent valleys that are not currently monitored by the USGS gauges or by the State of Utah or State of Nevada. Emphasis will be placed on monitoring stream reaches that could be directly affected by the SNWA groundwater diversions and streams that make significant contributions to the Snake Valley groundwater budget.
- **Meteorological (Climate) Stations** – The SNWA will be required to construct and operate meteorological monitoring stations to provide information for geographic areas not covered by current stations operated by USGS, BLM, NOAA, State of Utah, or State of Nevada. Emphasis will be placed on locations that require better groundwater recharge estimates for use in groundwater modeling procedures. Data collected would include, at a minimum, precipitation, temperature, wind, soil moisture and temperature, and relative humidity (although not all stations may require all parameters).

Hydrologic Analysis Provisions – Hydrologic analysis activities that will be included in the 3M Plan are set forth below. These activities are not expected to be fully implemented until later stages of the 3M Plan, with timing based upon triggers established by the Technical Working Group.

- **Aquifer Characterization** – The regional groundwater model used to support the NEPA process identified areas of uncertainty with regard to geologic and hydraulic characteristics of Snake Valley and adjacent valleys. The Technical Working Group will determine whether the SNWA should conduct additional studies to determine lithology and structure (such as faulting) of geologic units and aquifers in Snake Valley. One area of research focus will be to better characterize inter-basin flow zones in valleys adjacent to Snake Valley. Results from these additional studies will be used to enhance groundwater modeling efforts.

- **Numerical Modeling of Snake Valley Groundwater Flow** – The SNWA will develop a groundwater flow system numerical model that is specific to Snake Valley, in cooperation with the Technical Working Group. The Technical Working Group will determine the characteristics of the Snake Valley flow model, such as grid size and representation of existing groundwater depletions. The SNWA will develop the flow model well in advance of any proposals from SNWA for specific production well locations, so that model results can be used to identify areas of uncertainty that could be reduced by investigations that could be implemented by the technical working group.

Effectiveness. It is anticipated that the 3M Plan would provide early warning of potentially undesirable impacts to water-dependent resources and provide time and flexibility to implement management measures to mitigate their effects. However, since groundwater development presumes some level of vegetation change and significant reduction in groundwater levels in some parts of Snake Valley, not all impacts would be avoided by this mitigation measure. The Snake Valley 3M Plan may include mitigation measures offered by the SNWA, in coordination with the State of Utah, to mitigate impacts that occur to lands, water rights, and water-dependent resources owned by private parties, local governments, and state governments. However, the BLM cannot enforce mitigation measures on lands owned by other parties and cannot insure that the funding and land access necessary to implement these measures will be made available.

GW-WR-5: Shoshone Ponds. Drawdown is likely to impact the source of water that supports important aquatic resources for Shoshone Ponds (as discussed in Section 3.7, Aquatic Biological Resources). Impacts to Shoshone Ponds that are attributable to the SNWA's groundwater pumping would be mitigated by improving the existing well or drilling a new well, and installing a pump such that the well, pump, and water conveyance system are designed to maintain the flow to the ponds for the foreseeable future regardless of the groundwater drawdown. Any new well should be designed to pump groundwater from the same aquifer currently used as the source of water for the ponds. Effectiveness: Pumping groundwater water from the existing well or new well located within the same aquifer is a feasible mitigation measure that is expected to effectively mitigate the anticipated reductions of flow resulting from the groundwater development project. Pumping water to replace the existing water supply would result in an incremental increase in drawdown. Impacts to water quality are unlikely to occur if the water supply used for mitigation pumps water from the same aquifer that is currently used to supply water to the ponds.

GW-WR-6: Well and Water Rights. Impacts to water wells and water rights would be mitigated, as required by the State of Nevada or Utah (most likely acting under authority of an interstate agreement between Utah and Nevada that would be developed in the future prior to development). Mitigation for impacts to water rights would depend on the site-specific conditions and impacts and could include a variety of measures. Methods for addressing impacts to water rights may include but would not be limited to the following:

- For wells, mitigation could include lowering the pump, deepening an existing well, drilling a new well, or providing a replacement water supply of equivalent yield and general water quality.
- For surface water rights, mitigation could require providing a replacement water supply of equivalent yield and general water quality.

Effectiveness: Mitigation for impacts to water rights would be mitigated on a case-by-case basis as determined by the NDWR or UDWRi. Implementation of appropriate mitigation measures is likely to effectively mitigate impacts to water rights in accordance with applicable state laws addressing protection of existing water rights.

Potential Residual Impacts

Potential residual impacts resulting from groundwater pumping for the Proposed Acton are discussed below.

Groundwater drawdown associated with groundwater development is predicted to expand for at least full build out plus 200 years and persist for the foreseeable future. Successful implementation of the stipulations and adaptive management plan would likely minimize residual adverse effects to water resources at selected locations. The feasibility and success of the mitigation would depend on the site-specific conditions and details of the mitigation plan. However, considering the regional scale of the predicted drawdown and number of perennial water sources identified that could be affected, it may not be feasible to effectively mitigate impacts to all of the potentially affected water sources. In addition, adequate mitigation measures for long-term reductions of groundwater discharge, or baseflow, may not be available for all locations.

The SNWA has identified several adaptive management measures that could be implemented to address adverse impacts. Two of these adaptive management measures would adjust groundwater withdrawal to minimize impacts, specifically: 1) geographic redistribution of groundwater withdrawal; or 2) reduction or cessation in groundwater withdrawal. Implementation of these adaptive management measures would reduce the magnitude of drawdown in specific areas. However, as described in **Appendix F3.3.5** (Pumping Cessation – Recovery Analysis), recovery of water levels in specific areas of interest to pre-project conditions could take several years or decades depending on location and implementation of these specific adaptive management measures that may not successfully mitigate long-term impacts to surface water resources in some areas. Therefore, a long-term reduction in surface discharge at perennial surface water source areas is likely to occur in some areas even after implementation of the SNWA proposed adaptive management measures and proposed mitigation measures. This potential reduction in surface discharge at perennial surface water source areas is considered an unavoidable adverse impact associated with the proposed groundwater development.

The groundwater development is predicted to result in a long-term reduction in groundwater discharge to ET areas in Spring and Snake valleys. Some of these ET areas are sustained by spring discharge. It is not feasible to mitigate all impacts to ET areas resulting from the reduction in groundwater discharge. Long-term reductions in groundwater discharge to ET are considered unavoidable residual impacts associated with the proposed groundwater development.

3.3.2.10 Alternative A

Groundwater Development Areas

Groundwater development associated with the well fields would occur within the general areas identified within the five groundwater development basins (i.e., Spring, Snake, Cave, Delamar, and Dry Lake valleys). The groundwater development areas defined for Alternative A are the same as previously described for the Proposed Action. As with the Proposed Action, development within the groundwater development areas would include groundwater production wells, collector pipelines, staging areas, power facilities, pumping stations, and access roads. The actual location of specific facilities within the groundwater development areas has not been at this stage of the project and will be subject to future site specific NEPA analysis.

Conclusion. Construction of well pads, access roads, gathering pipelines, and electrical service lines would result in an estimated maximum surface disturbance of approximately 4,800 acres within 5 hydrographic basins. As described under the Proposed Action, there are 60 known or suspected springs identified within the groundwater development areas (**Table 3.3.2-4**). These springs occur within the groundwater development areas within Spring Valley (37 springs), Snake Valley (11 springs), Cave Valley (1 spring), Dry Lake Valley (4 springs) and Delamar Valley (7 springs). There also are 37 separate perennial stream reaches located in Spring Valley (32 streams), Snake Valley (4 streams), and Cave Valley (1 stream) with a total length of 54.7 miles within the groundwater development areas (**Table 3.3.2-5**). The potential for impacts to springs and streams located within these groundwater development areas would depend on the final locations of facilities. Implementation of the ACMs would minimize impacts to perennial water sources associated with the well field development. Additional monitoring and mitigation recommendations (GW-WR-1; GW-WR-2) described under the Proposed Action would apply to Alternative A and include identifying and establishing an avoidance buffer around all springs; and developing site specific plans for minimize impacts at perennial stream crossings within the groundwater development areas.

Groundwater Pumping

Groundwater Pumping Scenario

The groundwater pumping scenario for Alternative A assumes pumping at reduced quantities (approximately 115,000 afy) from those listed on the pending water rights application for the 5 proposed project pumping basins (Spring, Snake, Cave, Delamar, and Dry Lake valleys). The well distribution developed by SNWA for this model scenario (**Figure 3.3.2-11)** distributes the simulated production wells spatially within the groundwater development areas in an effort to minimize pumping effects. Details regarding the assumed pumping schedule used for the model simulations are provided in the model simulation report (SNWA 2010a). The pumping schedule reflects the proposed south to north sequence of basin development for the project.

Figure 3.3.2-11 Pumping Distribution Alt. A – (Distributed Pumping/Reduced Quantities) and Alt. C – (Intermittent Pumping)

<u>Impacts to Water Levels</u>

The predicted change in groundwater levels attributable to groundwater development under the Alternative A at full build out, full build out plus 75 years, and full build out plus 200 years are provided in **Figures 3.3.2-12**, **3.3.2-13**, and **3.3.2-14**, respectively. These figures illustrate areas where the water levels are predicted to decrease in comparison to the simulated No Action water levels.

At full build out, the drawdown areas are localized in the vicinity of the pumping wells in Spring, Cave, Delamar, and Dry Lake valleys. Drawdown does not occur at this time period in Snake Valley because pumping is not projected to begin in Snake Valley until the final stage of the development. Comparison of the simulation results for the three representative points in time indicates that the drawdown area continues to progressively expand as pumping continues into the future.

At full build out plus 75 years time frame, there are three distinct drawdown areas. The northernmost drawdown area is a relatively small localized drawdown area located in the northern portion of Spring Valley. The second drawdown area encompasses the southern Spring Valley, southern Snake Valley, and northern Hamlin Valley. The third drawdown area extends across Cave, Delamar, and Dry Lake valleys in an elongate north-south direction that is primarily confined to the pumping these three pumping basins.

By the full build out plus 200 years time frame, the two main drawdown areas are beginning to merge into one that extends approximately 170 miles in a north-south direction and up to 50 miles in a east-west direction. At this time frame, the simulated drawdown area extends into southeastern Steptoe Valley, and into eastern margins of Pahroc and Pahranagat Valleys, and extreme western margins of Panaca Valley and northwest margin of Lower Meadow Valley Wash.

The locations of six selected observation wells located within the proposed pumping basins are presented in **Figure 3.3.2-6**. Water level hydrographs for each of these observation wells within the pumping basins are provided in **Figures 3.3.2-7** and **3.3.2-8**. The hydrographs illustrate the predicted rate and magnitude of water level decline at these representative locations over the simulation period. As with the Proposed Action, the hydrographs indicate that water levels are predicted to continue to decrease over the model simulation period; and not reach a renewed equilibrium (or steady state condition) before the end of the simulation period. The representative hydrographs illustrate that the reduced groundwater withdrawal under the Alternative A pumping scenario is predicted to result in a reduction in the amount of drawdown within the pumping basins as compared to the Proposed Action.

Potential effects to water resources resulting from the Alternative A pumping scenario are summarized in **Table 3.3.2-9**.

Impacts to Springs and Streams

The estimated potential risks to springs located within the projected drawdown area at full build out, and at full build out plus 75 years and full build out plus 200 years are presented in **Figures F3.3.8A-4**, **F3.3.8A-5**, and **F3.3.8A-6**, respectively, in **Appendix F3.3.8**. The number of springs within the drawdown area and relative risk of impacts by hydrographic basin are summarized in **Table F3.3.9-2A** in **Appendix F3.3.9**. Specific inventoried springs located within the drawdown area at the representative points in time are listed in **Table F3.3.10-1A** in **Appendix F3.3.10**. The estimated miles of perennial streams (by hydrographic basin) located in the predicted drawdown areas where surface waters could be impacted are listed in **Table F3.3.11-2A** in **Appendix F3.3.11**.

Potential total effects to perennial springs and streams are summarized in **Table 3.3.2-9**. For the predicted drawdown area at full build out plus 75 years, there are 29 inventoried springs and 86 “other” springs located within the high and moderate risk areas. By full build out plus 200 years, this increased to 46 inventoried springs and 136 “other” springs located within the high and moderate risk areas. These springs occur in Cave, Steptoe, Hamlin, Spring (HA 184), Snake, and Lake valleys.

The total estimated length of perennial stream located in areas where there is a high to moderate risk of impacts resulting from the predicted drawdown increases from approximately 58 miles at 75 years to 81 miles at full build out plus 200 years. This includes stream reaches located in Steptoe, Spring (HA 184), Snake and Lake valleys.

Figure 3.3.2-12 Predicted Change in Groundwater Levels Alt. A – (Distributed Pumping/Reduced Quantities) Full Build Out

Figure 3.3.2-13 Predicted Change in Groundwater Levels Alt. A – (Distributed Pumping/Reduced Quantities) + 75 Years

Figure 3.3.2-14 Predicted Change in Groundwater Levels Alt. A – (Distributed Pumping/Reduced Quantities) + 200 Years

Table 3.3.2-9 Summary of Potential Effects to Water Resources Resulting from the Alternative A Pumping Scenario[1,2]

Water Resource Issue / Time Frame	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Drawdown:			
• Number of hydrographic basins affected by drawdown	5	10	16
Drawdown effects on perennial springs:			
• Number of inventoried springs located in areas where impacts to flow could occur[3]	1	29	46
• Number of other springs located in areas where impacts to flow could occur[4]	2	86	136
• Model-simulated flow reduction at Big Spring (as percent flow reduction)	2%	100%	100%
Drawdown effects on perennial streams:			
• Number of basins with perennial stream reaches where impacts to flow could occur	1	2	4
• Miles of perennial stream located in areas where impacts to flow could occur	1	58	81
Drawdown effects on surface water rights:			
• Number of surface water rights located in areas where impacts to flow could occur	14	109	151
Drawdown effects on groundwater rights:			
• Number of groundwater rights located within the 10-50 foot drawdown area	15	171	93
• Number of groundwater rights located within the 50-100 foot drawdown area	0	3	128
• Number of groundwater rights located within the >100 foot drawdown area	0	0	2
• (Total groundwater rights in drawdown area)	(15)	(174)	(223)
Percent reduction in ET and spring discharge[5]:			
• Spring Valley	30%	51%	57%
• Snake Valley	0%	23%	27%
• Great Salt Lake Desert Flow System[1]	12%	34%	39%
• White River Flow System	0%	0%	1%
Reduction in flow from Snake Valley to Pine, Wah Wah, and Tule Valleys Hydrographic Basins[5]:			
• AFY	0	440	1,100
• Percent Reduction	0%	2%	6%

[1]Located within the groundwater flow model domain.

[2]Unless otherwise noted, supporting information used to developed these estimated effects are provided in **Appendices F3.3.5** through **F3.3.16**.

[3]Specific inventoried springs identified in moderate or high risk areas are identified in **Table F3.3.10-1A** in **Appendix F3.3.10**.

[4]"Other Springs" are springs identified in the National Hydrography Database or topographic maps that have not been field verified.

[5] Estimate derived from the model-simulated values provided in SNWA 2010A with comparison to No Action pumping results.

Potential site specific impacts to individual springs and streams affected by drawdown would be the same as discussed for the Proposed Action.

Model-simulated Spring and Stream Discharge Estimates. Model-simulated changes in spring flow for selected springs are presented in **Table 3.3.2-10**. The model results indicate that two of the modeled springs in White River Valley, Butterfield Spring and Flag Springs 3, are predicted to experience 8 percent flow reduction at the full build out plus 200 years time frame. These results suggest that the groundwater development eventually could affect flows in springs located along the south eastern margin of the valley floor in White River Valley. The model results also indicate that other springs located in the northern portion of the valley floor in White River Valley, are unlikely to experience flow reductions (>5 percent) attributable to the Alternative A pumping. The model results indicate that measurable flow reductions attributable to this alternative are not anticipated in major regional spring discharge areas within the White River Flow System including Pahranagat Valley, Muddy River Springs Area near Moapa.

In the Great Salt Lake Desert Flow System, spring discharge was simulated at 3 springs in Spring Valley, and 4 springs in Snake Valley. In Spring Valley, the model simulations indicate that by full build out plus 75 years, the flow at Keegan, North Millick, and South Millick Springs all show reductions of flow. At full build out plus 200 years these springs are predicted to experience flow reductions ranging from 11 to 36 percent. In Snake Valley, the model simulation results are essentially the same as those described for the Proposed Action.

Water Resources Within or Adjacent to GBNP. Surface water resources located within or adjacent to the GBNP that occur within both the model-simulated drawdown area and within the susceptibility zones identified by Elliot et al. are listed in **Table 3.3.2-8**. For the purpose of the EIS analysis, these areas are considered zones of moderate risk as defined in **Table 3.3.2-3** (i.e., impacts may occur to some perennial waters that are hydraulically connected to the regional flow system). At the full build out plus 75 years time frame, Outhouse Springs and Spring Creek Spring both located outside the GBNP boundary; and 5.6 miles of Snake Creek (located inside the GBNP boundary) are within the area of moderate risk. By the full build out plus 200 years time frame, three springs, Outhouse, Rowland (located along the park boundary), and Spring Creek Springs along with 8.8 miles of Snake Creek and its tributaries are within the area of moderate risk. Potential risk to streams in caves systems are uncertain as discussed under the Proposed Action. However, it important to note that the magnitude of drawdown simulated by the numerical model beneath the GBNP is generally less under Alternative A compared to the Proposed Action. Therefore, if any perennial waters or waters in cave systems are hydraulically connected to the regional aquifer system affected by groundwater withdrawal, potential impacts to these water sources would be anticipated to be less than those occurring under the Proposed Action.

Utah Surface Water Resources. There are three inventoried springs (Caine Spring, Stateline Springs, and Needle Point Springs in Snake Valley) and three perennial stream reaches (Big Wash, Lake Creek, and Snake Creek) in Snake Valley located area that could be impacted at either the full build out plus 75 years or full build out plus 200 years time frames. Flow reductions in Lake Creek would result in reduced flow to Pruess Lake.

The model simulations indicate that drawdown could propagate into Pine Valley. At the full build out plus 75 years and full build out plus 200 years time frames, the maximum drawdown simulated at the boundary of the model between Snake and Pine Valley is approximately 0 feet and 31 feet, respectively. Therefore, the model simulations suggest that drawdown could eventually propagate into the Pine Valley hydrographic basin. As described under the Proposed Action, available information suggest that drawdown from pumping in Snake Valley is unlikely to impact surface water resources in Pine Valley (see Proposed Action for further discussion).

Impacts to Surface Water Rights

The locations and manner of use of the active surface water rights within the drawdown area at full build out and full build out plus 75 years and full build out plus 200 years are presented in **Figures F3.3.12A-4**, **F3.3.12A-5**, and **F3.3.12A-6**, respectively in **Appendix F3.3.12**. **Table F3.3.13-2A** lists the number of active surface water rights within the drawdown area that occur within the high-, moderated-, and low-risk areas at the three representative time frames. At full build out plus 75 years there are a total of 109 surface water rights located in areas where there is a moderate to high risk of impacts to surface flows. By the full build out plus 200 years time frame, there are 151 surface water right located in areas where there is a moderate to high risk of impacts to surface flows. For surface water rights that are dependent on groundwater discharge, a potential reduction in the water table at the point of diversion, could reduce or eliminate the flow available at the point of diversion for the surface water right.

Table 3.3.2-10 Model-simulated Flow Changes (Alternative A Pumping)

(Project Specific)					Alternative A (Reduced Pumping)		
					Incremental Change in Flow % (from No-Action)		
Flow System	Hydrographic Basin	Spring	Average Flow (Actual) in gpm	Model-simulated Average Flow (2005) in gpm	Full Build Out	75 years after Full Build Out	200 years after Full Build Out
White River	White River Valley (207)	Arnoldson Spring	1,608	946	0	0	0
		Butterfield Spring	1,225	471	0	-3	-8
		Cold Spring	582	503	0	0	-1
		Flag Springs 3	969	560	-1	-3	-8
		Hardy Springs	200	73	0	0	-1
		Hot Creek Spring	5,032	6,899	0	-1	-2
		Lund Spring	3,594	3,314	0	0	-1
		Moon River Spring	1,707	1,457	0	0	-1
		Moorman Spring	405	353	0	0	-1
		Nicolas Spring	1,185	872	0	0	0
		Preston Big Spring	3,572	3,794	0	0	-1
	Pahranagat Valley (209)	Ash Springs	6,909	7,453	0	0	-1
		Brownie Spring	224	277	0	0	0
		Crystal Springs	4,235	4,647	0	0	-1
		Hiko Spring	2,735	1,985	0	0	-1
	Muddy River Springs Area (219)	Muddy River near Moapa[1]	20,931	15,383	0	0	0
	Lower Moapa Valley (220)	Muddy River near Glendale[1]	19,565	14,895	0	0	0
	Black Mountains Area (215)	Blue Point Spring	223	393	0	0	0
		Rogers Spring	771	515	0	0	0
Goshute Valley	Steptoe Valley (179)	Campbel Ranch Springs	2,746	2,088	0	0	0
		Currie Spring	2,181	1,419	0	0	0
		McGill Spring	4,783	2,074	0	0	0
		Monte Neva Hot Springs	649	280	0	0	0
Great Salt Lake Desert	Spring Valley (184)	Keegan Spring	234	63	-12	-28	-36
		North Millick Spring	284	98	-4	-9	-11
		South Millick Spring	506	278	-10	-21	-24
	Snake Valley (195)	Big Springs	4,289	1,977	-2	-100	-100
		Foote Res. Spring	1,300	211	0	-1	-1
		Kell Spring	120	59	0	-1	-1
		Warm Creek near Gandy, UT	7,426	2,697	0	0	0
Meadow Valley	Panaca Valley (203)	Panaca Spring	1,455	1,208	0	0	0

[1] Simulated using Stream Flow Routing 2 package for MODFLOW.

Source: SNWA 2010b.

Impacts to Groundwater Rights

Figures F3.3.14A-4, **F3.3.14A-5**, and **F3.3.14A-6** in **Appendix F3.3.14** illustrate the location and manner of use of existing groundwater rights in relation to the magnitude of the model-simulated drawdown at full build out and at full build out plus 75 years and full build out plus 200 years. **Table F3.3.15-2A** (**Appendix F3.3.15**) lists the groundwater rights by hydrographic basin within the drawdown area. At full build out plus 75 years, there are 174 groundwater rights located within areas that are predicted to experience a reduction in groundwater levels of at least 10 feet. At full build out plus 200 years, the number increases to 223 groundwater rights located within areas that are predicted to experience a reduction in groundwater levels of at least 10 feet. The potential impacts to individual wells are the same as discussed under the Proposed Action.

Impacts to Water Balance

The model-simulated groundwater budget for the Alternative A pumping scenario is presented in **Appendix F3.3.16**, **Table F3.3.16-2B**. Compared to the simulated conditions under No Action, for Spring Valley, the Alternative A pumping is estimated to result in reductions of groundwater discharge for ET of 51 percent at full build out plus 75 years and 57 percent at full build out plus 200 years time frame. In Snake Valley, the pumping is estimated to result in reductions of groundwater discharge to support ET and spring discharge of 23 percent at full build out plus 75 years, and 27 percent at full build out plus 200 years with most of this reduction occurring in the southern portion of the valley. As with the Proposed Action, the Alternative A pumping is estimated to have minimal impact on ET discharge within the other pumping basins and the White River Flow System.

The total predicted reduction of flow to Pine, Wah Wah, and Tule Valleys is summarized in **Table 3.3.2-9**. This reduction corresponds to an approximate 2 percent and 6 percent reduction in flow to these basins at the full build out plus 75 years and full build out plus 200 years time frame. If the groundwater flow system is interconnected and regional flow from Snake Valley contributes to flow at Fish Springs, then a reduction of flow from Snake Valley to Pine, Wah Wah, and Tule Valleys could eventually result in a reduction of discharge at Fish Springs. The model estimated reduction of groundwater outflow from Snake Valley to downgradient basins in the Great Salt Lake Desert Flow System along the eastern boundary of Snake Valley is 1,100 afy at the full build out plus 200 years. This flow reduction represents approximately 5 percent of the surface discharge at Fish Springs. Flow reduction of this magnitude at Fish Springs would likely be difficult to measure and distinguish from natural flow variations.

The GBNP Model (Halford and Plume 2011) was set up to simulate flows at Fish Springs. The simulation results from the GBNP Model indicate that pumping in Snake Valley (at the points of diversion listed in the SNWA water rights applications), at the full application rate (50,000 afy) combined with continuation of existing agricultural pumping would not reduce flows in Fish Springs over the 200 year simulation period. These model results suggest that pumping associated with the groundwater development in Snake Valley is unlikely to result in a measureable reduction in flows at Fish Springs.

Water Quality

Potential impacts to water quality would be the same as described under the Proposed Action.

Monitoring and Mitigation Recommendations

Additional mitigation recommendations GW-WR-3 (Monitoring and Modeling); GW-WR-4 (Monitoring, Mitigation and Management Plan for Snake Valley); GW-WR-5 (Shoshone Ponds Mitigation); and, GW-WR-6 (Water Rights Mitigation) described under the Proposed Action would apply to Alternative A.

Potential Residual Impacts

Potential unavoidable residual impacts associated with the groundwater development are described under the Proposed Action. Because of the reduced maximum groundwater withdrawal rate (as compared to the Proposed Action), the magnitude of the potential unavoidable residual impacts to water resources associated with the Alternative A pumping scenario would be substantially less than the Proposed Action and Alternative B.

3.3.2.11 Alternative B

Groundwater Development Areas

For the purpose of analysis of surface disturbance related impacts, Alternative B (Points of Diversion) assumes that surface disturbance would be focused primarily near (i.e., within 1 mile radial distance) the points of diversion identified in the water rights applications in five basins (i.e., Spring, Snake, Cave, Delamar, and Dry Lake valleys). The development would include groundwater production wells, collector pipelines, staging areas, power facilities, pumping stations, and access roads. The actual location of specific facilities within the groundwater development areas has not been determined at this stage of the project and will be subject to future site specific NEPA analysis.

Conclusion. Construction of well pads, access roads, gathering pipelines, and electrical service lines would result in an estimated maximum surface disturbance of approximately 4,660 acres within 5 hydrographic basins. As summarized in **Table 3.3.2-4**, there are 7 known or suspected springs identified within the potential disturbance areas, all located in Snake Valley. This includes two inventoried springs (Kious Spring and Youn-Aquainv-003) and five springs identified based on National Hydrography Database or topographic mapping data that have not been field verified. There are three perennial stream reaches in Snake Valley within the potential disturbance area (**Table 3.3.2-5**). The potential for impacts to springs and streams located within these groundwater development areas would depend on the actual location of facilities. Implementation of the ACMs would minimize impacts to perennial water sources associated with the well field development. Additional monitoring and mitigation recommendations (GW-WR-1; GW-WR-2) described under the Proposed Action also would apply to Alternative B and includes measures to identifying and establishing an avoidance buffer around all springs, and developing site specific plans for minimize impacts at perennial stream crossings within the groundwater development areas.

Groundwater Pumping

Groundwater Pumping Scenario

The groundwater pumping scenario for Alternative B assumes pumping at the full diversion rates (i.e., approximately 177,000 afy) listed on the pending water rights application for the five proposed project pumping basins (Spring, Snake, Cave, Delamar, and Dry Lake valleys). The well distribution for this model scenario (**Figure 3.3.2-15**) assumes that wells would be developed at the actual points of diversion listed on the water rights applications. The pumping in each valley was distributed equally among the points of diversion based on the demand schedule up to the maximum diversion rate associated with each application. Details regarding the assumed pumping schedule used for the model simulations are provided in the model simulation report (SNWA 2010a). The pumping schedule reflects the proposed south to north sequence of basin development for the project.

Impacts to Water Levels

The predicted change in groundwater levels attributable to groundwater development under the Alternative B at full build out, full build out plus 75 years, and full build out plus 200 years are provided in **Figures 3.3.2-16**, **3.3.2-17**, and **3.3.2-18**, respectively. These figures illustrate areas where the water levels are predicted to decrease in comparison to the simulated No Action water levels.

At full build out, the drawdown areas are localized in the vicinity of the pumping wells in Spring, Cave, Delamar, and Dry Lake valleys. Drawdown does not occur at this time period in Snake Valley because pumping is not projected to begin in Snake Valley until the final stage of the development. Comparison of the simulation results for the three representative points in time indicates that the drawdown area continues to progressively expand as pumping continues into the future.

At full build out plus 75 years time frame, there are three drawdown areas: 1) northernmost drawdown area encompasses the southern Spring Valley, southern Snake Valley, and northern Hamlin Valley; 2) a smaller drawdown area extends across Cave Valley; and 3) southernmost drawdown area that extends across Dry Lake and Delamar valleys.

By the full build out plus 200 years time frame, the drawdown areas merge into one large drawdown area that extends approximately 150 miles in a north-south direction and up to 57 miles in a east-west direction. At this time frame, the simulated drawdown area extends into southeastern Steptoe Valley, the eastern margin of White River Valley, Pahroc

Figure 3.3.2-15 Pumping Distribution Alternative B – (Points of Diversion)

Figure 3.3.2-16 Predicted Change in Groundwater Levels Alternative B – (Points of Diversion) Full Build Out

Figure 3.3.2-17 Predicted Change in Groundwater Levels Alternative B – (Points of Diversion) + 75 Years

Figure 3.3.2-18 Predicted Change in Groundwater Levels Alternative B – (Points of Diversion) + 200 Years

and Pahranagat Valleys, Lake Valley, and western margins of Panaca Valley, northwest margin of Lower Meadow Valley Wash, and northeast portion of Kane Springs Valley. Compared to the Proposed Action, the drawdown area for Alternative B does not extend into northern Spring Valley (HA 184) or Tippett Valley.

The locations of six selected observation wells located within the proposed pumping basins are presented in **Figure 3.3.2-6**. Water level hydrographs for each of these observation wells within the pumping basins are provided in **Figures 3.3.2-7** and **3.3.2-8**. The hydrographs illustrate the predicted rate and magnitude of water level decline at these representative locations over the simulation period. As with the Proposed Action, the hydrographs illustrate that the water levels are predicted to continue to decrease over the model simulation period; and not reach a renewed equilibrium (or steady state condition) before the end of the simulation period. With the exception of Snake Valley where the drawdown at the observation wells is predicted to be essentially the same as the Proposed Action, the representative hydrographs illustrate that the groundwater withdrawal under the Alternative B pumping scenario is predicted to result in a reduction in the amount of drawdown within the pumping basins as compared to the Proposed Action at the selected observation wells for Spring, Cave, Delamar, and Dry Lake valleys.

In Snake Valley, the model simulation results indicate that under the Alternative B pumping scenario, the magnitude of drawdown would increase (compared to all other alternatives) along the eastern margin of the southern Snake Range. At the full build out plus 200 year time frame, the simulation results indicate that drawdown of >200 feet would encroach along the eastern margin of GBNP.

Potential effects to water resources resulting from the Alternative B pumping scenario are summarized in **Table 3.3.2-11**.

Impacts to Springs and Streams

The estimated potential risks to springs located within the projected drawdown area at full build out, and at full build out plus 75 years and full build out plus 200 years are presented in **Figures F3.3.8A-7**, **F3.3.8A-8**, and **F3.3.8A-9**, respectively in **Appendix F3.3.8**. The number of springs within the drawdown area and relative risk of impacts by hydrographic basin are summarized in **Table F3.3.9-3A** in **Appendix F3.3.9**. Specific inventoried springs located within the drawdown area at the representative points in time are listed in **Table F3.3.10-1A** in **Appendix F3.3.10**. The estimated miles of perennial streams (by hydrographic basin) located in the predicted drawdown areas where surface waters could be impacted are listed in **Table F3.3.11-3A** in **Appendix F3.3.11**.

Potential total effects to perennial springs and streams are summarized in **Table 3.3.2-11**. For the predicted drawdown area at full build out plus 75 years, there are 54 inventoried springs and 121 “other” springs located within the high and moderate risk areas. By full build out plus 200 years this increased to 78 inventoried springs and 210 “other” springs located within the high and moderate risk areas. These springs occur in Cave, Steptoe, Hamlin, Spring (HA 184), Snake, and Lake Valleys.

The total estimated length of perennial streams located in areas where there is a high to moderate risk of impacts resulting from the predicted drawdown increases from approximately 91 miles at full build out plus 75 years to 120 miles at full build out plus 200 years. This includes stream reaches located in Pahranagat, Steptoe, Spring (HA 184), Snake, Lake Valleys and Lower Meadow Valley Wash.

Potential site specific impacts to individual springs and streams affected by drawdown would be the same as discussed for the Proposed Action.

<u>Model-simulated Spring and Stream Discharge Estimates</u>. Model-simulated changes in spring flow for selected springs are presented in **Table 3.3.2-12**. The model results indicate that two of the modeled springs in White River Valley, Butterfield Spring and Flag Springs 3, are predicted to experience flow reductions of 20 and 19 percent respectively by the full build out time frame. Hot Creek Spring and Moorman Spring also are predicted to experience flow reductions of 7 and 6 percent, respectively at the full build out plus 200 years time frame. These results suggest that the groundwater development eventually could affect flows in springs located along the south eastern margin of the valley floor in White River Valley. The model results also indicate that other springs located in the northern portion of the valley floor in White River Valley, are unlikely to experience measurable reductions (>5 percent) attributable to the

Table 3.3.2-11 Summary of Potential Effects to Water Resources Resulting from the Alternative B Pumping Scenario[1,2]

Water Resource Issue / Time Frame	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Drawdown:			
• Number of hydrographic basins affected by drawdown	10	15	17
Drawdown effects on perennial springs:			
• Number of inventoried springs located in areas where impacts to flow could occur[3]	13	54	78
• Number of other springs located in areas where impacts to flow could occur[4]	28	121	210
• Model-simulated flow reduction at Big Spring (as percent flow reduction)	7%	100%	100%
Drawdown effects on perennial streams:			
• Number of basins with perennial stream reaches where impacts to flow could occur	1	4	5
• Miles of perennial stream located in areas where impacts to flow could occur	3	91	120
Drawdown effects on surface water rights:			
• Number of surface water rights located in areas where impacts to flow could occur	34	141	186
Drawdown effects on groundwater rights:			
• Number of groundwater rights located within the 10-50 foot drawdown area	26	143	148
• Number of groundwater rights located within the 50-100 foot drawdown area	0	33	108
• Number of groundwater rights located within the >100 foot drawdown area	0	8	45
• (Total groundwater rights in drawdown area)	(26)	(184)	(301)
Percent reduction in ET and spring discharge[5]:			
• Spring Valley	36%	66%	73%
• Snake Valley	0%	18%	24%
• Great Salt Lake Desert Flow System[1]	15%	37%	44%
• White River Flow System	0%	3%	5%
Reduction in flow from Snake Valley to Pine, Wah Wah, and Tule Valleys Hydrographic Basins[5]:			
• AFY	0	450	1,400
• Percent Reduction	0%	2%	7%

[1]Located within the groundwater flow model domain.

[2]Unless otherwise noted, supporting information used to developed these estimated effects are provided in **Appendices F3.3.5** through **F3.3.16**.

[3]Specific inventoried springs identified in moderate or high risk areas are identified in **Table F3.3.10-1A** in **Appendix F3.3.10**.

[4]"Other Springs" are springs identified in the National Hydrography Database or topographic maps that have not been field verified.

[5] Estimate derived from the model-simulated values provided in SNWA 2010A with comparison to No Action pumping results.

Table 3.3.2-12 Model-simulated Flow Changes (Alternative B Pumping)

(Project Specific)					Alternative B (Points of Diversion)		
					Incremental Change in Flow % (from No-Action)		
Flow System	Hydrographic Basin	Spring	Average Flow (Actual) in gpm	Model-simulated Average Flow (2005) in gpm	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
White River	White River Valley (207)	Arnoldson Spring	1,608	946	0	-1	-2
		Butterfield Spring	1,225	471	-20	-34	-45
		Cold Spring	582	503	0	-1	-2
		Flag Springs 3	969	560	-19	-29	-37
		Hardy Springs	200	73	-1	-2	-4
		Hot Creek Spring	5,032	6,899	-3	-5	-7
		Lund Spring	3,594	3,314	0	-1	-2
		Moon River Spring	1,707	1,457	-1	-2	-2
		Moorman Spring	405	353	-2	-4	-6
		Nicolas Spring	1,185	872	0	-1	-1
		Preston Big Spring	3,572	3,794	0	-1	-2
	Pahranagat Valley (209)	Ash Springs	6,909	7,453	0	-1	-2
		Brownie Spring	224	277	0	0	0
		Crystal Springs	4,235	4,647	0	0	-1
		Hiko Spring	2,735	1,985	0	-1	-2
	Muddy River Springs Area (219)	Muddy River near Moapa[1]	20,931	15,383	0	0	-1
	Lower Moapa Valley (220)	Muddy River near Glendale[1]	19,565	14,895	0	0	-1
	Black Mountains Area (215)	Blue Point Spring	223	393	0	0	0
		Rogers Spring	771	515	0	0	0
Goshute Valley	Steptoe Valley (179)	Campbel Ranch Springs	2,746	2,088	0	0	0
		Currie Spring	2,181	1,419	0	0	0
		McGill Spring	4,783	2,074	0	0	0
		Monte Neva Hot Springs	649	280	0	0	0
Great Salt Lake Desert	Spring Valley (184)	Keegan Spring	234	63	0	-3	-5
		North Millick Spring	284	98	-2	-18	-42
		South Millick Spring	506	278	-8	-47	-99
	Snake Valley (195)	Big Springs	4,289	1,977	-7	-100	-100
		Foote Res. Spring	1,300	211	0	0	-1
		Kell Spring	120	59	0	0	-1
		Warm Creek near Gandy, UT	7,426	2,697	0	0	0
Meadow Valley	Panaca Valley (203)	Panaca Spring	1,455	1,208	0	0	0

[1] Simulated using Stream Flow Routing 2 package for MODFLOW.

Source: SNWA 2010b.

Alternative B pumping. Measurable flow reductions attributable to this alternative are not anticipated in major regional spring discharge areas within the White River Flow System including Pahranagat Valley, Muddy River Springs Area near Moapa.

In the Great Salt Lake Desert Flow System, spring discharge was simulated at 3 springs in Spring Valley, and 4 springs in Snake Valley. In Spring Valley, the model simulations indicate that by full build out plus 75 years, the flow at Keegan, North Millick, and South Millick Springs all show reductions of flow. At full build out plus 200 years these springs are predicted to experience flow reductions ranging from 5 to 99 percent.

In Snake Valley, the model simulation results are essentially the same as those described for the Proposed Action.

Water Resources Within or Adjacent to the GBNP. Surface water resources located within or adjacent to the GBNP that occur within both the model-simulated drawdown area and within the susceptibility zones identified by Elliot et al. (2006) are listed in **Table 3.3.2-8**. For the purpose of the EIS analysis, these areas are considered zones of moderate risk as defined in **Table 3.3.2-3** (i.e., impacts may occur to some perennial waters that are hydraulically connected to the regional flow system). At the full build out plus 75 years and full build out plus 200 years timeframe, Cave, Outhouse, Rowland, and Spring Creek Spring are within the area of moderate risk. There also are 17 other springs (identified in NPS 2007) at the full build out plus 75 years timeframe that increases to 27 springs at the full build out plus 200 years timeframe located in moderate risk areas. Perennial segments on Baker, Lehman and Snake Creek and their tributaries occur within the area of moderate risk at both the full build out plus 75 years and full build out plus 200 years timeframe. Potential risk to streams in caves systems are uncertain as discussed under the Proposed Action. However, it important to note that the magnitude of drawdown simulated by the numerical model beneath GBNP is generally greater under Alternative B compared to the Proposed Action and other alternatives. Therefore, if any perennial waters or waters in cave systems are hydraulically connected to the regional aquifer system affected by groundwater withdrawal, potential impacts to these water sources would be anticipated to be greater than those occurring under the Proposed Action.

Model simulations have been performed using the Snake Valley RASA model developed by Halford and Plume (2011) to evaluate the potential effects of groundwater pumping in Snake Valley. These models simulate groundwater pumping in Snake Valley and only consider pumping at the points of diversions specified in the water right applications. The model-simulated flow reductions from pumping at the points of diversions are summarized in **Table 3.3.2-13**. These results indicate that pumping in Snake Valley at the points of diversions would impact flows in Big Springs, Home Farm Springs, Kious Spring, Rowland Spring, Spring Creek Spring, and would not affect flows in Twin Spring located north of the proposed groundwater development area; and not affect flows in Fish Springs located in the Fish Springs Flat hydrographic basin.

Cave Springs are used as the water supply for the Lehman Caves Visitor Center at the GBNP. Cave Springs was identified as “likely susceptible” in the Elliott et al 2006 report. The model simulations summarized in **Table 3.3.2-13** indicate flow reductions of 5 percent or less. Prudic and Glancy (2009) conducted geochemical investigations of the Cave Springs to evaluate the potential for depletion resulting from groundwater pumping in Snake Valley. The results of their study conclude that the source of water to these springs is primarily from winter precipitation and the source area for the springs is the steep east slope of Jeff Davis Peak and not from alluvial and glacial deposits west of the springs. They also indicated that it is unlikely that the Pole Creek Limestone occurs near the stream. The results of this study suggest that the source of flow to Cave Springs is derived from local precipitation; and limestone that could provide a potential hydraulic connection between the spring and the regional groundwater system is unlikely to occur at the stream. Therefore, the risk of impacts to flow is inferred to be low (i.e., unlikely to occur).

Utah Surface Water Resources. There are three inventoried springs (Caine, Stateline Springs, and Needle Point Springs in Snake Valley) and three perennial stream reaches (Big Wash, Lake Creek, and Snake Creek) in Snake Valley located area that could be impacted at either the full build out plus 75 years or full build out plus 200 years time frames. Flow reductions in Lake Creek would result in reduced flow to Pruess Lake.

The model simulations indicate that drawdown could propagate into Pine Valley. At the full build out plus 75 years and full build out plus 200 years time frames, the maximum drawdown simulated at the boundary of the model between

Table 3.3.2-13 Model-simulated Flow Reduction from Pumping at Points of Diversion in Snake Valley Only (Snake Valley RASA Model)

I. SNWA Pumping (No Irrigation Pumping)											
		25,000 afy Pumping Scenario					50,000 afy Pumping Scenario[1]				
	Model-simulated Pre-development Flow (gpm)	Years (After Pumping Initiated) (Percent)					Years (After Pumping Initiated) (Percent)				
Spring or Stream		10	25	50	100	200	10	25	50	100	200
Big Springs	4,340	25	35	35	48	53	28	40	50	60	69
Cave Spring	62	0	0	0	0	0	0	0	1	3	5
Home Farm Spring 6	90	0	0	0	0	0	22	60	100	100	100
Kious Spring	224	0	0	1	2	3	2	13	27	39	48
Lehman Creek	1,364	0	0	0	0	0	0	1	3	6	8
Rowland Spring	434	0	0	0	0	0	0	1	4	10	16
Spring Creek Spring	898	48	87	100	100	100	53	100	100	100	100
Strawberry Creek	124	0	0	0	0	0	0	0	1	3	7
Twin Spring	2,480	0	0	0	0	0	0	0	0	0	0
Warm Spring	2,046	0	0	0	0	0	0	0	0	0	0
Fish Springs (3-8)	15,934	0	0	0	0	0	0	0	0	0	0
II. SNWA Pumping + Irrigation Pumping											
		25,000 afy Pumping Scenario					50,000 afy Pumping Scenario[1]				
	Model-simulated Pre-development Flow (gpm)	Years (After Pumping Initiated) (Percent)					Years (After Pumping Initiated) (Percent)				
Spring or Stream		10	25	50	100	200	10	25	50	100	200
Big Springs	4,340	31	42	51	59	67	34	47	59	72	84
Cave Spring	62	0	0	0	0	0	0	0	1	3	5
Home Farm Spring (6)	90	4	4	5	6	6	62	100	100	100	100
Kious Spring	224	1	1	2	4	6	4	15	30	44	55
Lehman Creek	1,364	0	0	0	0	0	0	1	3	5	7
Rowland Spring	434	0	0	0	0	0	0	1	4	10	17
Spring Creek Spring	898	50	90	100	100	100	55	100	100	100	100
Strawberry Creek	124	0	0	0	0	0	0	0	1	3	7
Twin Spring	2,480	0	0	0	0	1	0	0	0	0	1
Fish Springs (3-8)	15,934	0	0	0	0	0	0	0	0	0	0

[1] Actual pumping was restricted to approx. 40,000 - 43,000 afy because drawdown was not allowed to exceed 1,000 at point of diversion.

Source: Derived from model results provided in Halford and Plume 2011.

Snake and Pine Valley is approximately 12 feet and 46 feet, respectively. As described under the Proposed Action, available information suggest that drawdown from pumping in Snake Valley is unlikely to impact surface water resources in Pine Valley (see Proposed Action for further discussion)

Impacts to Surface Water Rights

The locations and manner of use of the active surface water rights within the drawdown area at full build out and full build out plus 75 years and full build out plus 200 years are presented in **Figures F3.3.12A-7**, **F3.3.12A-8**, and **F3.3.12A-9**, respectively in **Appendix F3.3.12**. **Table F3.3.13-3A** lists the number of active surface water rights within the drawdown area that occur within the high-, moderated-, and low-risk areas at the three representative time frames. At full build out plus 75 years there are a total of 141 surface water rights located in areas where there is a moderate to high risk of impacts to surface flows. By the full build out plus 200 years time frame, there are 186 surface water right located in areas where there is a moderate to high risk of impacts to surface flows. For surface water rights that are dependent on groundwater discharge, a potential reduction in the water table at the point of diversion, could reduce or eliminate the flow available at the point of diversion for the surface water right.

Impacts to Groundwater Rights

Figures F3.3.14A-7, **F3.3.14A-8**, and **F3.3.14A-9** in **Appendix F3.3.14** illustrate the location and manner of use of existing groundwater rights in relation to the magnitude of the model-simulated drawdown at full build out and at full build out plus 75 years and full build out plus 200 years. **Table F3.3.15-3A** (**Appendix F3.3.15**) lists the groundwater rights by hydrographic basin within the drawdown area. At full build out plus 75 years, there are 184 groundwater rights located within areas that are predicted to experience a reduction in groundwater levels of at least 10 feet. At full build out plus 200 years, the number increases to 301 groundwater rights located within areas that are predicted to experience a reduction in groundwater levels of at least 10 feet. The potential impacts to individual wells are the same as discussed under the Proposed Action.

Impacts to Water Balance

The model-simulated groundwater budget for the Alternative B pumping scenario is presented in **Appendix F3.3.16**, **Table F3.3.16-3B**. Compared to the simulated conditions under No Action, for Spring Valley, the pumping is estimated to result in reductions of groundwater discharge for ET of 66 percent at full build out plus 75 years and 73 percent at full build out plus 200 years. In Snake Valley, the pumping is estimated to result in reductions of groundwater discharge to support ET and spring discharge of 18 percent at full build out plus 75 years, and 24 percent at full build out plus 200 years with most of this reduction occurring in the southern portion of the valley. Alternative B pumping is estimated to have minimal impact (5 percent or less) on ET discharge within the White River Flow System.

The total predicted reduction of flow to Pine, Wah Wah, and Tule Valleys is summarized in **Table 3.3.2-11**. This reduction corresponds to an approximate 2 percent and 7 percent reduction in flow to these basins at the full build out plus 75 years and full build out plus 200 years time frame. If the groundwater flow system is interconnected and regional flow from Snake Valley contributes to flow at Fish Springs, then a reduction of flow from Snake Valley to Pine, Wah Wah, and Tule Valleys could eventually result in a reduction of discharge at Fish Springs. The model estimated reduction of groundwater outflow from Snake Valley to downgradient basins in the Great Salt Lake Desert Flow System along the eastern boundary of Snake Valley is 1,100 afy at the full build out plus 200 years. This flow reduction represents approximately 6 percent of the surface discharge at Fish Springs. Flow reduction of this magnitude at Fish Springs likely would be difficult to measure and distinguish from natural flow variations. (See Proposed Action for discussion of uncertainty regarding these flow reduction estimates using the results of the CCRP Model.)

The GBNP Model (Halford and Plume 2011) was set up to simulate flows at Fish Springs. The simulation results from the GBNP Model indicate that pumping in Snake Valley (at the points of diversion listed in the SNWA water rights applications), at the full application rate (50,000 afy) combined with continuation of existing agricultural pumping would not reduce flows in Fish Springs over the 200 year simulation period. These model results suggest that pumping associated with the groundwater development in Snake Valley is unlikely to result in a measureable reduction in flows at Fish Springs.

Water Quality

Potential impacts to water quality would be the same as described under the Proposed Action.

Monitoring and Mitigation Recommendations

Additional mitigation recommendations GW-WR-3 (Monitoring and Modeling); GW-WR-4 (Monitoring, Mitigation and Management Plan for Snake Valley); GW-WR-5 (Shoshone Ponds Mitigation); and, GW-WR-6 (Water Rights Mitigation) described under the Proposed Action would apply to Alternative B.

Potential Residual Impacts

Potential unavoidable residual impacts associated with the groundwater development are described under the Proposed Action. The potential magnitude of residual adverse impacts to water resources associated with the Alternative B pumping scenario would be similar to those described under the Proposed Action. However, the distributed pumping included in the Proposed Action would likely reduce impacts to springs and perennial streams with sensitive resources.

3.3.2.12 Alternative C

Groundwater Development Areas

For Alternative C (Intermittent Pumping), the infrastructure and therefore, ground disturbance effects would be identical to Alternative A. Groundwater development would occur within the areas identified in the five groundwater development basins (i.e., Spring, Snake, Cave, Delamar, and Dry Lake valleys). As with the Alternative A, development within the groundwater development areas would include groundwater production wells, collector pipelines, staging areas, power facilities, pumping stations, and access roads. The actual location of specific facilities within the groundwater development areas has not been determined at this stage of the project and will be subject to future site specific NEPA analysis.

Conclusion. Construction of well pads, access roads, gathering pipelines, and electrical service lines would result in an estimated maximum surface disturbance of approximately 4,800 acres within five hydrographic basins. There are 60 known or suspected springs identified within the groundwater development areas (**Table 3.3.2-4**). These springs occur within the groundwater development areas within Spring Valley (37 springs), Snake Valley (11 springs), Cave Valley (1 spring), Dry Lake Valley (4 springs) and Delamar Valley (7 springs). There also are 28 separate perennial stream reaches with a total length of 29 miles that occur within the groundwater development areas (**Table 3.3.2-5**). This includes 23 perennial stream reaches located in Spring Valley, and 5 located in Snake Valley. The potential for impacts to springs and streams located within these groundwater development areas would depend on the location of facilities. Implementation of the ACMs would minimize impacts to perennial water sources associated with the well field development. Additional monitoring and mitigation recommendations (GW-WR-1; GW-WR-2) described under the Proposed Action would apply to Alternative C and include identifying and establishing an avoidance buffer around all springs, and developing site specific plans for minimize impacts at perennial stream crossings within the groundwater development areas.

Groundwater Pumping

Groundwater Pumping Scenario

The groundwater pumping scenario for Alternative C assumed that the groundwater production wells would be developed and pumped using the distributed well locations shown in **Figure 3.3.2-11** and pumping schedule defined for Alternative A until the project reaches full build out in 2050. The pumping schedule reflects the same south to north sequence of basin development for the project included in the Alternative A pumping scenario. After full development, the pumping rates are assumed to cycle from minimum to maximum pumping rates every 5 years for the remainder of the simulation period. The minimum pumping rate is 9,000 afy and with minimal pumping in all five pumping basins. The maximum pumping rate under this scenario is the same as for Alternative A (approximately 115,000 afy). Details regarding the assumed pumping schedule used for the model simulations are provided in the model simulation report (SNWA 2010a).

Impacts to Water Levels

The predicted change in groundwater levels attributable to groundwater development under the Alternative C at full build out, full build out plus 75 years, and full build out plus 200 years are provided in **Figures 3.3.2-19**, **3.3.2-20**, and **3.3.2-21**, respectively. These figures illustrate areas where the water levels are predicted to decrease in comparison to the simulated No Action water levels.

Figure 3.3.2-19 Predicted Change in Groundwater Levels Alternative C – (Intermittent Pumping) Full Build Out

Figure 3.3.2-20 Predicted Change in Groundwater Levels Alternative C – (Intermittent Pumping) + 75 Years

Figure 3.3.2-21 Predicted Change in Groundwater Levels Alternative C – (Intermittent Pumping) + 200 Years

At full build out, the drawdown areas are localized in the vicinity of the pumping wells in Spring, Cave, Delamar, and Dry Lake valleys. As with the Proposed Action, drawdown does not occur at this time period in Snake Valley because pumping is not projected to begin in Snake Valley until the final stage of the development. Comparison of the simulation results for the three representative points in time indicates that the drawdown area continues to progressively expand as pumping continues into the future.

At full build out plus 75 years and full build out plus 200 years time frame, there are two distinct drawdown areas. The northern drawdown area encompasses the southern Spring Valley, southern Snake Valley, and northern Hamlin Valley. The southern drawdown area extends across Cave, Delamar, and Dry Lake valleys in an elongate north-south direction

Water level hydrographs for observation wells located within the pumping basins are provided in **Figures 3.3.2-7** and **3.3.2-8**. As with the Proposed Action, the hydrographs indicate that water levels are predicted to continue to decrease over the model simulation period; and not reach a renewed equilibrium (or steady state condition) before the end of the simulation period. The representative hydrographs illustrate that the reduced groundwater withdrawal under the Alternative C pumping scenario is predicted to result in a substantial reduction in the amount of drawdown within the pumping basins as compared to the Proposed Action.

Potential effects to water resources resulting from the Alternative C pumping scenario are summarized in **Table 3.3.2-14**.

Impacts to Springs and Streams

The estimated potential risks to springs located within the projected drawdown area at full build out, and at full build out plus 75 years and full build out plus 200 years are presented in **Figures F3.3.8A-10**, **F3.3.8A-11**, and **F3.3.8A-12**, respectively in **Appendix F3.3.8**. The number of springs within the drawdown area and relative risk of impacts by hydrographic basin are summarized in **Table F3.3.9-4A** in **Appendix F3.3.9**. Specific inventoried springs located within the cumulative drawdown area at the representative points in time are listed in **Table F3.3.10-1A** in **Appendix F3.3.10**. The estimated miles of perennial streams (by hydrographic basin) located in the predicted drawdown areas where surface waters could be impacted are listed in **Table F3.3.11-4A** in **Appendix F3.3.11**.

Potential total effects to perennial springs and streams are summarized in **Table 3.3.2-14**. For the predicted drawdown area at full build out plus 75 years, there are 19 inventoried springs and 44 “other” springs located within the high and moderate risk areas. By full build out plus 200 years this increased to 26 inventoried springs and 70 “other” springs located within the high and moderate risk areas. These springs occur in Hamlin, Spring (HA 184) and Snake valleys.

The total estimated length of perennial stream located in areas where there is a high to moderate risk of impacts resulting from the predicted drawdown increases from approximately 37 miles at full build out plus 75 years to 59 miles at full build out plus 200 years. This includes stream reaches located in Spring (HA 184), Snake and Lake valleys.

Potential site specific impacts to individual springs and streams affected by drawdown would be the same as discussed for the Proposed Action.

Model-simulated Spring and Stream Discharge Estimates. Model-simulated changes in spring flow for selected springs are presented in **Table 3.3.2-15**. The model results indicated that two of the modeled springs in White River Valley, Butterfield Spring and Flag Springs 3, are predicted to experience flow reductions of 5 percent respectively by the full build out plus 200 years time frame. These results suggest that the groundwater development eventually could affect flows in springs located along the south eastern margin of the valley floor in White River Valley. The model results also indicate that other springs located in the northern portion of the valley floor in White River Valley, are unlikely to experience measurable reductions (>5 percent) attributable to the Alternative C pumping. Measurable flow reductions attributable to this alternative are not anticipated in major regional spring discharge areas within the White River Flow System including Pahranagat Valley, Muddy River Springs Area near Moapa.

Table 3.3.2-14 Summary of Potential Effects to Water Resources Resulting from the Alternative C Pumping Scenario[1,2]

Water Resource Issue / Time Frame	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Drawdown:			
• Number of hydrographic basins affected by drawdown	5	10	14
Drawdown effects on perennial springs:			
• Number of inventoried springs located in areas where impacts to flow could occur[3]	1	19	26
• Number of other springs located in areas where impacts to flow could occur[4]	2	44	70
• Model-simulated flow reduction at Big Spring (as percent flow reduction)	2%	87%	100%
Drawdown effects on perennial streams:			
• Number of basins with perennial stream reaches where impacts to flow could occur	1	2	2
• Miles of perennial stream located in areas where impacts to flow could occur	1	37	59
Drawdown effects on surface water rights:			
• Number of surface water rights located in areas where impacts to flow could occur	14	78	98
Drawdown effects on groundwater rights:			
• Number of groundwater rights located within the 10-50 foot drawdown area	15	132	169
• Number of groundwater rights located within the 50-100 foot drawdown area	0	1	2
• Number of groundwater rights located within the >100 foot drawdown area	0	0	0
• (Total groundwater rights in drawdown area)	(15)	(133)	(171)
Percent reduction in ET and spring discharge[5]:			
• Spring Valley	30%	37%	37%
• Snake Valley	0%	15%	17%
• Great Salt Lake Desert Flow System[1]	12%	24%	25%
• White River Flow System	0%	0%	1%
Reduction in flow from Snake Valley to Pine, Wah Wah, and Tule Valleys Hydrographic Basins[5]:			
• AFY	0	200	400
• Percent Reduction	0%	1%	2%

[1]Located within the groundwater flow model domain.

[2]Unless otherwise noted, supporting information used to developed these estimated effects are provided in **Appendices F3.3.5** through **F3.3.16**.

[3]Specific inventoried springs identified in moderate or high risk areas are identified in **Table F3.3.10-1A** in **Appendix F3.3.10**.

[4]"Other Springs" are springs identified in the National Hydrography Database or topographic maps that have not been field verified.

[5] Estimate derived from the model-simulated values provided in SNWA 2010A with comparison to No Action pumping results.

Table 3.3.2-15 Model-simulated Flow Changes (Alternative C Pumping)

(Project Specific)					Alternative C (Intermittent Pumping)		
					Incremental Change in Flow % (from No-Action)		
Flow System	Hydrographic Basin	Spring	Average Flow (Actual) in gpm	Model-simulated Average Flow (2005) in gpm	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
White River	White River Valley (207)	Arnoldson Spring	1,608	946	0	0	0
		Butterfield Spring	1,225	471	0	-2	-5
		Cold Spring	582	503	0	0	0
		Flag Springs 3	969	560	-1	-2	-5
		Hardy Springs	200	73	0	0	0
		Hot Creek Spring	5,032	6,899	0	0	-1
		Lund Spring	3,594	3,314	0	0	0
		Moon River Spring	1,707	1,457	0	0	0
		Moorman Spring	405	353	0	0	-1
		Nicolas Spring	1,185	872	0	0	0
		Preston Big Spring	3,572	3,794	0	0	0
	Pahranagat Valley (209)	Ash Springs	6,909	7,453	0	0	-1
		Brownie Spring	224	277	0	0	0
		Crystal Springs	4,235	4,647	0	0	0
		Hiko Spring	2,735	1,985	0	0	-1
	Muddy River Springs Area (219)	Muddy River near Moapa[1]	20,931	15,383	0	0	0
	Lower Moapa Valley (220)	Muddy River near Glendale[1]	19,565	14,895	0	0	0
	Black Mountains Area (215)	Blue Point Spring	223	393	0	0	0
		Rogers Spring	771	515	0	0	0
Goshute Valley	Steptoe Valley (179)	Campbel Ranch Springs	2,746	2,088	0	0	0
		Currie Spring	2,181	1,419	0	0	0
		McGill Spring	4,783	2,074	0	0	0
		Monte Neva Hot Springs	649	280	0	0	0
Great Salt Lake Desert	Spring Valley (184)	Keegan Spring	234	63	-12	-14	-15
		North Millick Spring	284	98	-4	-5	-5
		South Millick Spring	506	278	-10	-12	-11
	Snake Valley (195)	Big Springs	4,289	1,977	-2	-87	-100
		Foote Res. Spring	1,300	211	0	0	-1
		Kell Spring	120	59	0	-1	-1
		Warm Creek near Gandy, UT	7,426	2,697	0	0	0
Meadow Valley	Panaca Valley (203)	Panaca Spring	1,455	1,208	0	0	0

[1] Simulated using Stream Flow Routing 2 package for MODFLOW.

Source: SNWA 2010b.

In the Great Salt Lake Desert Flow System, spring discharge was simulated at 3 springs in Spring Valley, and 4 springs in Snake Valley. In Spring Valley, the model simulations indicate that by full build out plus 75 years, the flow at Keegan, North Millick, and South Millick springs all show reductions of flow. At full build out plus 200 years these springs are predicted to experience flow reductions ranging from 5 to 15 percent. In Snake Valley, the model simulation results are very similar to those described for the Proposed Action.

Water Resources Within or Adjacent to the GBNP. Surface water resources located within or adjacent to the GBNP that occur within both the model-simulated drawdown area and within the susceptibility zones identified by Elliot et al. are listed in **Table 3.3.2-8**. For the purpose of the EIS analysis, these areas are considered zones of moderate risk as defined in **Table 3.3.2-3** (i.e., impacts may occur to some perennial waters that are hydraulically connected to the regional flow system). At the full build out plus 75 years time frame there are no inventoried springs or perennial streams within the moderate risk zone. By the full build out plus 200 years time frame, Outhouse Spring (located approximately 2 miles outside the park boundary and 8 miles of Snake Creek and its tributaries are within the area of moderate risk. Potential risk to streams in caves systems are uncertain as discussed under the Proposed Action. However, it important to note that the magnitude of drawdown simulated by the numerical model beneath GBNP is less under Alternative C compared to the Proposed Action and Alternatives A and B. Therefore, if any perennial waters or waters in cave systems are hydraulically connected to the regional aquifer system affected by groundwater withdrawal, potential impacts to these water sources would be anticipated to be less than those occurring under these alternatives.

Utah Surface Water Resources. There are two inventoried springs (Caine and Stateline Springs in Snake Valley) and three perennial stream reaches (Big Wash, Lake Creek, and Snake Creek) in Snake Valley located in an area that could be impacted at the full build out plus 75 years and full build out plus 200 years time frames. Flow reductions in Lake Creek would result in reduced flow to Pruess Lake.

The model simulations indicate that drawdown could propagate into Pine Valley. At the full build out plus 75 years, and full build out plus 200 years time frames, the maximum drawdown simulated at the boundary of the model between Snake and Pine Valley is approximately 0 feet and 10 feet, respectively. As described under the Proposed Action, available information suggest that drawdown from pumping in Snake Valley is unlikely to impact surface water resources in Pine Valley (see Proposed Action for further discussion).

Impacts to Surface Water Rights

The locations and manner of use of the active surface water rights within the drawdown area at full build out and full build out plus 75 years and full build out plus 200 years are presented in **Figures F3.3.12A-10**, **F3.3.12A-11**, and **F3.3.12A-12**, respectively in **Appendix F3.3.12**. **Table F3.3.13-4A** lists the number of active surface water rights within the drawdown area that occur within the high-, moderated-, and low-risk areas at the three representative time frames. At full build out plus 75 years there are a total of 78 surface water rights located in areas where there is a moderate to high risk of impacts to surface flows. By the full build out plus 200 years time frame, there are 98 surface water right located in areas where there is a moderate to high risk of impacts to surface flows. For surface water rights that are dependent on groundwater discharge, a potential reduction in the water table at the point of diversion, could reduce or eliminate the flow available at the point of diversion for the surface water right.

Impacts to Groundwater Rights

Figures F3.3.14A-10, **F3.3.14A-11**, and **F3.3.14A-12** in **Appendix F3.3.14** illustrate the location and manner of use of existing groundwater rights in relation to the magnitude of the model-simulated drawdown at full build out and at full build out plus 75 years and full build out plus 200 years. **Table F3.3.15-4A** (**Appendix F3.3.15**) lists the groundwater rights by hydrographic basin within the drawdown area. At full build out plus 75 years, there are 133 groundwater rights located within areas that are predicted to experience a reduction in groundwater levels of at least 10 feet. At full build out plus 200 years, the number increases to 171 groundwater rights located within areas that are predicted to experience a reduction in groundwater levels of at least 10 feet. The potential impacts to individual wells are the same as discussed under the Proposed Action.

Impacts to Water Balance

The model-simulated groundwater budget for the Alternative C pumping scenario is presented in **Appendix F3.3.16**, **Table F3.3.16-4B**. Compared to the simulated conditions under No Action, for Spring Valley, the pumping is estimated to result in a 37 percent reduction of groundwater discharge for ET at the full build out plus 75 years and full build out plus 200 years time frame. In Snake Valley, the pumping is estimated to result in reductions of groundwater discharge to support ET and spring discharge of 15 percent at full build out plus 75 years, and 17 percent at full build out plus 200 years with most of this reduction occurring in the southern portion of the valley. Alternative B pumping is estimated to have minimal impact (1 percent or less) on ET discharge within the White River Flow System.

The total predicted reduction of flow to Pine, Wah Wah, and Tule Valleys is summarized in **Table 3.3.2-14**. This reduction corresponds to an approximate 1 percent and 2 percent reduction in flow to these basins at the 75- and 200-year time frame. If the groundwater flow system is interconnected and regional flow from Snake Valley contributes to flow at Fish Springs, then a reduction of flow from Snake Valley to Pine, Wah Wah, and Tule Valleys could eventually result in a reduction of discharge at Fish Springs. The model estimated reduction of groundwater outflow from Snake Valley to downgradient basins in the Great Salt Lake Desert Flow System along the eastern boundary of Snake Valley is 400 afy at the 200 years after full build. This flow reduction represents approximately 2 percent of the surface discharge at Fish Springs. Flow reduction of this magnitude at Fish Springs would likely be difficult to measure and distinguish from natural flow variations.

The GBNP Model (Halford and Plume 2011) was set up to simulate flows at Fish Springs. The simulation results from the GBNP Model indicate that pumping in Snake Valley (at the points of diversion listed in the SNWA water rights applications), at the full application rate (50,000 afy) combined with continuation of existing agricultural pumping would not reduce flows in Fish Springs over the 200 year simulation period. These model results suggest that pumping associated with the groundwater development in Snake Valley is unlikely to result in a measureable reduction in flows at Fish Springs.

Water Quality

Potential impacts to water quality would be the same as described under the Proposed Action.

Monitoring and Mitigation Recommendations

Additional mitigation recommendations GW-WR-3 (Monitoring and Modeling); GW-WR-4 (Monitoring, Mitigation and Management Plan for Snake Valley); GW-WR-5 (Shoshone Ponds Mitigation); and, GW-WR-6 (Water Rights Mitigation) described under the Proposed Action would apply to Alternative C.

Potential Residual Impacts

Potential unavoidable residual impacts associated with the groundwater development are described under the Proposed Action. Because of the reduced maximum groundwater withdrawal rate (as compared to the Proposed Action), and intermittent pumping schedule, the magnitude of the potential unavoidable residual impacts to water resources associated with the Alternative C pumping scenario would be substantially less than the Proposed Action and Alternatives A and B.

3.3.2.13 Alternative D

Groundwater Development Areas

Development in Snake Valley and the White Pine County portion of Spring Valley would be eliminated under Alternative D (LCCRDA). As a result, groundwater development for Alternative D would be restricted to the southernmost portion of Spring, Cave, Delamar, and Dry Lake valleys. Development within the groundwater development areas would include groundwater production wells, collector pipelines, staging areas, power facilities, pumping stations, and access roads. The actual location of specific facilities within the groundwater development areas has not been determined at this stage of the project and will be subject to future site specific NEPA analysis.

<u>Conclusion</u>. Construction of well pads, access roads, gathering pipelines, and electrical service lines would result in an estimated maximum surface disturbance of approximately 4,000 acres within four hydrographic basins. There are 13 known or suspected springs identified within the groundwater development areas (**Table 3.3.2-4**). These springs occur within the groundwater development areas within Spring Valley (1 spring), Cave Valley (1 spring), Dry Lake Valley (4 springs), and Delamar Valley (7 springs). There are no perennial stream reaches located miles within the assumed groundwater development areas (**Table 3.3.2-5**). The potential for impacts to springs located within these groundwater development areas would depend on the location of facilities. Implementation of the ACMs would minimize impacts to perennial water sources associated with the well field development. Additional monitoring and

mitigation recommendations (GW-WR-1) described under the Proposed Action would apply to Alternative D and include identifying and establishing an avoidance buffer around all springs, and developing site specific plans for minimize impacts at perennial stream crossings within the groundwater development areas.

Groundwater Pumping

Groundwater Pumping Scenario

The groundwater pumping scenario for Alternative D assumes that no pumping will occur in Snake Valley, and pumping in Spring Valley would be restricted to the southern portion of the valley within Lincoln County as shown in **Figure 3.3.2-22**. The maximum groundwater production rate under this scenario is approximately 79,000 afy for the four pumping basins (Spring, Cave, Delamar, and Dry Lake valleys) is the same as the maximum pumping rate assumed for these basins under Alternative A, C, and E. The well distribution developed by SNWA for this model scenario includes the same spatial distribution of wells included in Alternative A for Cave, Delamar, and Dry Lake valleys. Details regarding the assumed pumping schedule used for the model simulations are provided in the model simulation report (SNWA 2010a). The pumping schedule reflects the proposed south to north sequence of basin development for the project.

Impacts to Water Levels

The predicted change in groundwater levels attributable to groundwater development under the Alternative D at full build out, full build out plus 75 years, and full build out plus 200 years are provided in **Figures 3.3.2-23**, **3.3.2-24**, and **3.3.2-25**, respectively. These figures illustrate areas where the water levels are predicted to decrease in comparison to the simulated No Action water levels.

At full build out, the drawdown areas are localized in the vicinity of the pumping wells in Spring, Cave, Delamar, and Dry Lake valleys. At this time frame a drawdown cone is predicted to develop in southern Spring Valley in response to the focused groundwater withdrawal in this area. As with all other pumping alternatives, the simulation results for the three representative points in time indicates that the drawdown area continues to progressively expand over the model simulation period.

At full build out plus 75 years time frame, there are two distinct drawdown areas. The northern drawdown area encompasses the approximate southern Spring Valley, northern Hamlin Valley and overlaps along the south west margin of Snake Valley and north margin of Lake Valley. The central portion of this drawdown cone is predicted to result in drawdowns greater than 200 feet. The southern drawdown area extends across Cave, Delamar, and Dry Lake valleys in an elongate north-south direction that is generally restricted to these pumping basins.

By the full build out plus 200 years time frame, the two main drawdown areas have merge into one that extends approximately 120 miles in a north-south direction and up to 55 miles in a east-west direction. Compared to the Proposed Action, Alternative D limits drawdown in the central and northern portion of Spring Valley and southern portion of Snake Valley. At the full build out plus 200 years time frame, in addition to the pumping basins, the simulated drawdown area extends across Lake Valley, and into the southeastern Steptoe Valley, eastern margins of Pahroc and Pahranagat Valleys, and extreme western margins of Panaca Valley and northwest margin of Lower Meadow Valley Wash. The central portion of this drawdown cone predicted drawdowns greater than 200 feet extends across the entire southern portion of Spring Valley.

Water level hydrographs for each of these observation wells within the pumping basins provided in **Figures 3.3.2-7** and **3.3.2-8** show the predicted rate and magnitude of water level decline at these representative locations over the simulation period. As with the Proposed Action, the hydrographs indicate that water levels are predicted to continue to decrease over the model simulation period; and not reach a renewed equilibrium (or steady state condition) before the end of the simulation period. The hydrographs illustrate that because the same pumping schedule is the same for Alternative A and Alternative D for Cave, Delamar, and Dry Lake valleys, the rate and magnitude of drawdown are the same in those valleys. As shown on **Figure 3.3.2-7**, this alternative would reduce the drawdown area in Snake Valley in the vicinity of Baker.

Figure 3.3.2-22 Pumping Distribution Alternative D – (LCCRDA Distributed Pumping)

Figure 3.3.2-23 Predicted Change in Groundwater Levels Alternative D – (LCCRDA Distributed Pumping) Full Build Out

Figure 3.3.2-24 Predicted Change in Groundwater Levels Alternative D – (LCCRDA Distributed Pumping) + 75 Years

Figure 3.3.2-25 Predicted Change in Groundwater Levels Alternative D – (LCCRDA Distributed Pumping) + 200 Years

Potential effects to water resources resulting from the Alternative D pumping scenario are summarized in **Table 3.3.2-16**.

Impacts to Springs and Streams

The estimated potential risks to springs located within the projected drawdown area at full build out, and at full build out plus 75 years and full build out plus 200 years are presented in **Figures F3.3.8A-13**, **F3.3.8A-14**, and **F3.3.8A-15**, respectively in **Appendix F3.3.8**. The number of springs within the drawdown area and relative risk of impacts by hydrographic basin are summarized in **Table F3.3.9-5A** in **Appendix F3.3.9**. Specific inventoried springs located within the drawdown area at the representative points in time are listed in **Table F3.3.10-1A** in **Appendix F3.3-10**. The estimated miles of perennial streams (by hydrographic basin) located in the predicted drawdown areas where surface waters could be impacted are listed in **Table F3.3.11-5A** in **Appendix F3.3.11**.

Potential total effects to perennial springs and streams are summarized in **Table 3.3.2-16**. For the predicted drawdown area at full build out plus 75 years, there are 13 inventoried springs and 28 “other” springs located within the high and moderate risk areas. By full build out plus 200 years this increased to 31 inventoried springs and 92 “other” springs located within the high and moderate risk areas. These springs occur in Cave Steptoe, Hamlin, Spring (HA 184), Snake, Lake, Spring (HA 201), and Patterson Valleys.

The total estimated length of perennial stream located in areas where there is a high to moderate risk of impacts resulting from the predicted drawdown increases from approximately 4 miles at full build out plus 75 years to 48 miles at full build out plus 200 years. This includes stream reaches located in Steptoe, Spring (HA 184), Snake, Lake and Spring (HA 201) Valleys.

Potential site specific impacts to individual springs and streams affected by drawdown would be the same as discussed for the Proposed Action.

<u>Model-simulated Spring and Stream Discharge Estimates</u>. Model-simulated changes in spring flow for selected springs are presented in **Table 3.3.2-17**. The model-simulated results for springs in White River Valley and other within the White River flow system are essentially the same as previously described for Alternative A.

In the Great Salt Lake Desert Flow System, the model simulations results indicate that Alternative D would not impact flows at Keegan, North Millick, and South Millick springs. In Snake Valley, the model simulation results are very similar to those described for the Proposed Action.

<u>Water Resources Within or Adjacent to GBNP</u>. Surface water resources located within or adjacent to the GBNP that occur within both the model-simulated drawdown area and within the susceptibility zones identified by Elliot et al. are listed in **Table 3.3.2-8**. For the purpose of the EIS analysis, these areas are considered zones of moderate risk as defined in **Table 3.3.2-3** (i.e., impacts may occur to some perennial waters that are hydraulically connected to the regional flow system). Potential effects to water resources within or adjacent to GBNP are essentially the same as described under Alternative C.

<u>Utah Surface Water Resources</u>. Reduced flows at Big Springs would reduce flows in Big Springs Creek, and likely reduce flows to Lake Creek and into Pruess Lake. The model simulations indicate potential flow reductions at Big Springs (and downstream in Lake Creek).

The model simulations indicate that drawdown could propagate into Pine Valley. At the full build out plus 75 years, and full build out plus 200 years time frames, the maximum drawdown simulated at the boundary of the model between Snake and Pine Valley is approximately 18 feet and 53 feet, respectively. As described under the Proposed Action, available information suggest that drawdown from pumping in Snake Valley is unlikely to impact surface water resources in Pine Valley (see Proposed Action for further discussion).

Table 3.3.2-16 Summary of Potential Effects to Water Resources Resulting from the Alternative D Pumping Scenario[1,2]

Water Resource Issue / Time Frame	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Drawdown:			
• Number of hydrographic basins affected by drawdown	6	11	16
Drawdown effects on perennial springs:			
• Number of inventoried springs located in areas where impacts to flow could occur[3]	1	13	31
• Number of other springs located in areas where impacts to flow could occur[4]	0	28	92
• Model-simulated flow reduction at Big Spring (as percent flow reduction)	19%	100%	100%
Drawdown effects on perennial streams:			
• Number of basins with perennial stream reaches where impacts to flow could occur	0	3	5
• Miles of perennial stream located in areas where impacts to flow could occur	0	4	48
Drawdown effects on surface water rights:			
• Number of surface water rights located in areas where impacts to flow could occur	1	23	56
Drawdown effects on groundwater rights:			
• Number of groundwater rights located within the 10-50 foot drawdown area	2	21	196
• Number of groundwater rights located within the 50-100 foot drawdown area	0	4	11
• Number of groundwater rights located within the >100 foot drawdown area	0	2	6
• (Total groundwater rights in drawdown area)	(2)	(27)	(213)
Percent reduction in ET and spring discharge[5]:			
• Spring Valley	0%	18%	28%
• Snake Valley	0%	4%	8%
• Great Salt Lake Desert Flow System[1]	0%	10%	16%
• White River Flow System	0%	0%	0%
Reduction in flow from Snake Valley to Pine, Wah Wah, and Tule Valleys Hydrographic Basins[5]:			
• AFY	0	0	200
• Percent Reduction	0%	0%	1%

[1]Located within the groundwater flow model domain.

[2]Unless otherwise noted, supporting information used to developed these estimated effects are provided in **Appendices F3.3.5** through **F3.3.16**.

[3]Specific inventoried springs identified in moderate or high risk areas are identified in **Table F3.3.10-1A** in **Appendix F3.3.10**.

[4]"Other Springs" are springs identified in the National Hydrography Database or topographic maps that have not been field verified.

[5] Estimate derived from the model-simulated values provided in SNWA 2010A with comparison to No Action pumping results.

Table 3.3.2-17 Model-simulated Flow Changes (Alternative D Pumping)

(Project Specific)					Alternative D (LCCRDA)		
					Incremental Change in Flow % (from No-Action)		
Flow System	Hydrographic Basin	Spring	Average Flow (Actual) in gpm	Model-simulated Average Flow (2005) in gpm	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
White River	White River Valley (207)	Arnoldson Spring	1,608	946	0	0	0
		Butterfield Spring	1,225	471	0	-3	-9
		Cold Spring	582	503	0	0	0
		Flag Springs 3	969	560	0	-3	-9
		Hardy Springs	200	73	0	0	-1
		Hot Creek Spring	5,032	6,899	0	0	-2
		Lund Spring	3,594	3,314	0	0	-1
		Moon River Spring	1,707	1,457	0	0	-1
		Moorman Spring	405	353	0	0	-1
		Nicolas Spring	1,185	872	0	0	0
		Preston Big Spring	3,572	3,794	0	0	0
	Pahranagat Valley (209)	Ash Springs	6,909	7,453	0	0	-1
		Brownie Spring	224	277	0	0	0
		Crystal Springs	4,235	4,647	0	0	0
		Hiko Spring	2,735	1,985	0	0	-1
	Muddy River Springs Area (219)	Muddy River near Moapa[1]	20,931	15,383	0	0	0
	Lower Moapa Valley (220)	Muddy River near Glendale[1]	19,565	14,895	0	0	0
	Black Mountains Area (215)	Blue Point Spring	223	393	0	0	0
		Rogers Spring	771	515	0	0	0
Goshute Valley	Steptoe Valley (179)	Campbel Ranch Springs	2,746	2,088	0	0	0
		Currie Spring	2,181	1,419	0	0	0
		McGill Spring	4,783	2,074	0	0	0
		Monte Neva Hot Springs	649	280	0	0	0
Great Salt Lake Desert	Spring Valley (184)	Keegan Spring	234	63	0	0	0
		North Millick Spring	284	98	0	0	0
		South Millick Spring	506	278	0	0	0
	Snake Valley (195)	Big Springs	4,289	1,977	-19	-100	-100
		Foote Res. Spring	1,300	211	0	0	0
		Kell Spring	120	59	0	0	0
		Warm Creek near Gandy, UT	7,426	2,697	0	0	0
Meadow Valley	Panaca Valley (203)	Panaca Spring	1,455	1,208	0	0	0

[1] Simulated using Stream Flow Routing 2 package for MODFLOW.

Source: SNWA 2010b.

Impacts to Surface Water Rights

The locations and manner of use of the active surface water rights within the drawdown area at full build out plus 75 years and full build out plus 200 years are presented in **Figures F3.3.12A-13**, **F3.3.12A-14**, and **F3.3.12A-15**, respectively in **Appendix F3.3.12**. **Table F3.3.13-5A** lists the number of active surface water rights within the drawdown area that occur within the high-, moderated-, and low-risk areas at the three representative time frames. At full build out plus 75 years there are a total of 23 surface water rights located in areas where there is a moderate to high risk of impacts to surface flows. By the full build out plus 200 years time frame, there are 56 surface water right located in areas where there is a moderate to high risk of impacts to surface flows. For surface water rights that are dependent on groundwater discharge, a potential reduction in the water table at the point of diversion, could reduce or eliminate the flow available at the point of diversion for the surface water right.

Impacts to Groundwater Rights

Figures F3.3.14A-13, **F3.3.14A-14**, and **F3.3.14A-15** in **Appendix F3.3.14** illustrate the location and manner of use of existing groundwater rights in relation to the magnitude of the model-simulated drawdown at full build out and at full build out plus 75 years and full build out plus 200 years. **Table F3.3.15-5A** (**Appendix F3.3.15**) lists the groundwater rights by hydrographic basin within the drawdown area. At full build out plus 75 years, there are 27 groundwater rights located within areas that are predicted to experience a reduction in groundwater levels of at least 10 feet. At full build out plus 200 years, the number increases to 213 groundwater rights located within areas that are predicted to experience a reduction in groundwater levels of at least 10 feet. The potential impacts to individual wells are the same as discussed under the Proposed Action.

Impacts to Water Balance

The model-simulated groundwater budget for the Alternative D pumping scenario is presented in **Appendix F3.3.16**, **Table F3.3.16-5B**. Compared to the simulated conditions under No Action, for Spring Valley, the pumping is estimated to result in an18 percent reduction of groundwater discharge for ET at the 75 and 28 percent reduction at full build out plus 200 years time frame. In Snake Valley, the pumping is estimated to result in reductions of groundwater discharge to support ET and spring discharge of 4 percent at full build out plus 75 years, and 8 percent at full build out plus 200 years in the southern portion of the valley. Alternative D pumping is estimated to have minimal impact (1 percent or less) on ET discharge within the White River Flow System; and reductions of flow to Pine, Wah Wah, and Tule Valleys and Fish Springs.

The GBNP Model (Halford and Plume 2011) was set up to simulate flows at Fish Springs. The simulation results from the GBNP Model indicate that pumping in Snake Valley (at the points of diversion listed in the SNWA water rights applications), at the full application rate (50,000 afy) combined with continuation of existing agricultural pumping would not reduce flows in Fish Springs over the 200 year simulation period. These model results suggest that pumping associated with the groundwater development in Snake Valley is unlikely to result in a measureable reduction in flows at Fish Springs.

Water Quality

Potential impacts to water quality would be the same as described under the Proposed Action.

Monitoring and Mitigation Recommendations

Additional mitigation recommendations GW-WR-3 (Monitoring and Modeling); GW-WR-4 (Monitoring, Mitigation and Management Plan for Snake Valley); GW-WR-5 (Shoshone Ponds Mitigation); and, GW-WR-6 (Water Rights Mitigation) described under the Proposed Action would apply to Alternative D.

Potential Residual Impacts

Potential unavoidable residual impacts associated with the groundwater development are described under the Proposed Action. The magnitude of potential unavoidable adverse impacts to water resources resulting from reduced pumping in Cave, Delamar, and Dry Lake valleys would be less than the Proposed Action. The magnitude of potential unavoidable adverse impacts to Snake Valley also would be considerably less than the Proposed Action, since there would be no pumping in Snake Valley. The intensive groundwater withdrawal focused in southern Spring Valley would result in substantially higher magnitude of drawdown in the south Spring Valley and adjacent areas compared to the Proposed Action and all other pumping alternatives. Implementation of adaptive mitigation measures proposed by the applicant and included in the stipulated agreements would be difficult to implement to control the magnitude and aerial extent of drawdown resulting from the pumping in southern Spring Valley. Therefore, the potential for residual adverse impacts in southern Spring Valley and adjacent areas affected by pumping in southern Spring Valley would likely be greater than under the Proposed Action and all other alternatives.

3.3.2.14 Alternative E

Groundwater Development Areas

Development in Snake Valley would be eliminated under Alternative E (Spring, Cave, Delamar, and Dry Lake valleys Alternative). The delineated groundwater development areas for Spring, Cave, Delamar, and Dry Lake valleys are assumed to be the same as those defined for the Proposed Action. Development within the groundwater development areas would include groundwater production wells, collector pipelines, staging areas, power facilities, pumping stations, and access roads. The actual location of specific facilities within the groundwater development areas has not been determined at this stage of the project and will be subject to future site-specific NEPA analysis.

Conclusion. Construction of well pads, access roads, gathering pipelines, and electrical service lines would result in an estimated maximum surface disturbance of approximately 4,080 acres within 4 hydrographic basins. There are 49 known or suspected springs identified within the groundwater development areas (**Table 3.3.2-4**). These springs occur within the groundwater development areas within Spring Valley (37 springs), Cave Valley (1 spring), Dry Lake Valley (4 springs), and Delamar Valley (7 springs). There also are 23 separate perennial stream reaches with a total length of 20.3 miles that occur within the groundwater development areas (**Table 3.3.2-5**). All of these perennial stream reaches are located in Spring Valley. The potential for impacts to springs and streams located within these groundwater development areas would depend on the location of facilities. Implementation of the ACMs would minimize impacts to perennial water sources associated with the well field development. Additional monitoring and mitigation recommendations (GW-WR-1; GW-WR-2) described under the Proposed Action would apply to Alternative E and include identifying and establishing an avoidance buffer around all springs, and developing site specific plans for minimize impacts at perennial stream crossings within the groundwater development areas.

Groundwater Pumping

Groundwater Pumping Scenario

The groundwater pumping scenario for Alternative E assumes that no pumping will occur in Snake Valley as shown in **Figure 3.3.2-26**. The maximum groundwater production rate under this scenario is approximately 79,000 afy for the four pumping basins (Spring, Snake, Cave, Delamar, and Dry Lake valleys) is the same as the maximum pumping rate assumed for these same basins under Alternative A, C, and D. The well distribution developed by SNWA for this model scenario includes the same spatial distribution of wells included in Alternative A for Spring, Cave, Delamar, and Dry Lake valleys. Details regarding the assumed pumping schedule used for the model simulations are provided in the model simulation report (SNWA 2010a). The pumping schedule reflects the proposed staged general south to north sequence of basin development for the project.

Impacts to Water Levels

The predicted change in groundwater levels attributable to groundwater development under the Alternative E at full build out, full build out plus 75 years, and full build out plus 200 years are provided in **Figures 3.3.2-27**, **3.3.2-28**, and **3.3.2-29**, respectively. These figures illustrate areas where the water levels are predicted to decrease in comparison to the simulated No Action water levels.

Because the pumping schedule for Alternative E is identical to Alternative A for Spring, Cave, Delamar, and Dry Lake valleys, the predicted drawdown for Spring, Cave, Delamar, and Dry Lake valleys (and adjacent areas) are essentially the same as previously described for Alternative A. Pumping in Spring Valley is predicted to eventually result in drawdown along the southwest margin of Snake Valley and northern portion of Hamlin Valley. As shown on **Figure 3.3.2-7**, this alternative would substantially reduce the drawdown area in Snake Valley in the vicinity of Baker compared with the Proposed Action.

Potential effects to water resources resulting from the Alternative E pumping scenario are summarized in **Table 3.3.2-18**.

Figure 3.3.2-26 Pumping Distribution Alt. E – (Spring, Delamar, Dry Lake and Cave Valleys)

Figure 3.3.2-27 Predicted Change in Groundwater Levels Alt. E – (Spring, Delamar, Dry Lake and Cave Valleys) Full Build Out

Figure 3.3.2-28 Predicted Change in Groundwater Levels Alt. E – (Spring, Delamar, Dry Lake and Cave Valleys) + 75 Years

Figure 3.3.2-29 Predicted Change in Groundwater Levels Alt. E – (Spring, Delamar, Dry Lake and Cave Valleys) + 200 Years

Table 3.3.2-18 Summary of Potential Effects to Water Resources Resulting from the Alternative E Pumping Scenario[1,2]

Water Resource Issue / Time Frame	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Drawdown:			
• Number of hydrographic basins affected by drawdown	5	10	16
Drawdown effects on perennial springs:			
• Number of inventoried springs located in areas where impacts to flow could occur[3]	1	19	30
• Number of other springs located in areas where impacts to flow could occur[4]	2	36	74
• Model-simulated flow reduction at Big Spring (as percent flow reduction)	2%	26%	78%
Drawdown effects on perennial streams:			
• Number of basins with perennial stream reaches where impacts to flow could occur	1	1	4
• Miles of perennial stream located in areas where impacts to flow could occur	1	7	23
Drawdown effects on surface water rights:			
• Number of surface water rights located in areas where impacts to flow could occur	14	60	94
Drawdown effects on groundwater rights:			
• Number of groundwater rights located within the 10-50 foot drawdown area	15	68	58
• Number of groundwater rights located within the 50-100 foot drawdown area	0	2	50
• Number of groundwater rights located within the >100 foot drawdown area	0	0	2
• (Total groundwater rights in drawdown area)	(15)	(70)	(110)
Percent reduction in ET and spring discharge:[5]			
• Spring Valley	30%	52%	56%
• Snake Valley	0%	0%	3%
• Great Salt Lake Desert Flow System[1]	12%	21%	24%
• White River Flow System	0%	0%	1%
Reduction in flow from Snake Valley to Pine, Wah Wah, and Tule Valleys Hydrographic Basins[5]			
• AFY	0	0	0
• Percent Reduction	0%	0%	0%

[1]Located within the groundwater flow model domain.

[2]Unless otherwise noted, supporting information used to developed these estimated effects are provided in **Appendices F3.3.5** through **F3.3.16**.

[3]Specific inventoried springs identified in moderate or high risk areas are identified in **Table F3.3.10-1A** in **Appendix F3.3.10**.

[4]"Other Springs" are springs identified in the National Hydrography Database or topographic maps that have not been field verified.

[5] Estimate derived from the model-simulated values provided in SNWA 2010A with comparison to No Action pumping results.

Impacts to Springs and Streams

The estimated potential risks to springs located within the projected drawdown area at full build out, and at full build out plus 75 years and full build out plus 200 years are presented in **Figures F3.3.8A-16**, **F3.3.8A-17**, and **F3.3.8A-18**, respectively in **Appendix F3.3.8**. The number of springs within the drawdown area and relative risk of impacts by hydrographic basin are summarized in **Table F3.3.9-6A** in **Appendix F3.3.9**. Specific inventoried springs located within the drawdown area at the representative points in time are listed in **Table F3.3.10-1A** in **Appendix F3.3.10**. The estimated miles of perennial streams (by hydrographic basin) located in the predicted drawdown areas where surface waters could be impacted are listed in **Table F3.3.11-6A** in **Appendix F3.3.11**.

Potential total effects to perennial springs and streams are summarized in **Table 3.3.2-18**. For the predicted drawdown area at full build out plus 75 years, there are 19 inventoried springs and 36 “other” springs located within the high and moderate risk areas. By full build out plus 200 years this increased to 30 inventoried springs and 174 “other” springs located within the high and moderate risk areas. These springs occur in Cave, Steptoe, Hamlin, Spring (HA 184), Snake, and Lake Valleys.

The total estimated length of perennial stream located in areas where there is a high to moderate risk of impacts resulting from the predicted drawdown increases from approximately 7 miles at full build out plus 75 years to 23 miles at full build out plus 200 years. This includes stream reaches located in Steptoe, Spring (HA 184), Snake, and Lake Valleys.

Potential site specific impacts to individual springs and streams affected by drawdown would be the same as discussed for the Proposed Action.

<u>Model-simulated Spring and Stream Discharge Estimates</u>. Model-simulated changes in spring flow for selected springs are presented in **Table 3.3.2-19**. The model-simulated flows and predicted changes in flows for springs in White River Valley and other springs within the White River flow system, and Spring Valley are the same as previously described for Alternative A. The model-simulated flows for springs in Snake Valley are the same as the Proposed Action and Alternative A except that Big Springs is predicted to experience a 26 percent reduction in flow by the full build out plus 75 years time frame, and 78 percent reduction in the full build out plus 200 year time frame. Reductions of flow at Big Springs would reduce flows in Big Springs Creek, and likely reduce flows to Lake Creek and into Pruess Lake. The results suggest that the springs located on the valley floor in the in the southern portion of the valley could potentially experience a reduction in flow from pumping in Spring Valley.

<u>Water Resources Within or Adjacent to the GBNP</u>. Surface water resources located within or adjacent to the GBNP that occur within both the model-simulated drawdown area and within the susceptibility zones identified by Elliot et al. are listed in **Table 3.3.2-8**. For the purpose of the EIS analysis, these areas are considered zones of moderate risk as defined in **Table 3.3.2-3** (i.e., impacts may occur to some perennial waters that are hydraulically connected to the regional flow system). There are no resources identified in the moderate risk zone at the full build out plus 75 years time frame; and 2.1 miles of Snake Creek at the full build out plus 200 years time frame. Potential risk to water resources (associated with the simulated drawdown) within or adjacent to the GBNP would be less under Alternative E than the Proposed Action and all other pumping alternatives.

<u>Utah Surface Water Resources</u>. Reduced flows at Big Springs would reduce flows in Big Springs Creek, and likely reduce flows to Lake Creek and into Pruess Lake. However, the model simulations suggest that potential flow reductions at Big Springs (and downstream in Lake Creek) would likely be less than under the other pumping alternatives. Also, model simulations indicate that drawdown is not expected to extend to the boundary of Snake and Pine Valleys.

Impacts to Surface Water Rights

The locations and manner of use of the active surface water rights within the drawdown area at full build out and full build out plus 75years and full build out plus 200 years are presented in **Figures F3.3.12A-16**, **F3.3.12A-17**, and **F3.3.12A-18**, respectively in **Appendix F3.3.12**. **Table F3.3.13-6A** lists the number of active surface water rights within the drawdown area that occur within the high-, moderated-, and low-risk areas at the three representative time frames. At full build out plus 75 years there are a total of 60 surface water rights located in areas where there is a

Table 3.3.2-19 Model-simulated Flow Changes (Alternative E Pumping)

(Project Specific)					Alternative E (Spring, Cave, Dry Lake, Delamar Only)		
					Incremental Change in Flow % (from No-Action)		
Flow System	Hydrographic Basin	Spring	Average Flow (Actual) in gpm	Model-simulated Average Flow (2005) in gpm	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
White River	White River Valley (207)	Arnoldson Spring	1,608	946	0	0	0
		Butterfield Spring	1,225	471	0	-3	-8
		Cold Spring	582	503	0	0	-1
		Flag Springs 3	969	560	-1	-3	-8
		Hardy Springs	200	73	0	0	-1
		Hot Creek Spring	5,032	6,899	0	-1	-2
		Lund Spring	3,594	3,314	0	0	-1
		Moon River Spring	1,707	1,457	0	0	-1
		Moorman Spring	405	353	0	0	-1
		Nicolas Spring	1,185	872	0	0	0
		Preston Big Spring	3,572	3,794	0	0	-1
	Pahranagat Valley (209)	Ash Springs	6,909	7,453	0	0	-1
		Brownie Spring	224	277	0	0	0
		Crystal Springs	4,235	4,647	0	0	-1
		Hiko Spring	2,735	1,985	0	0	-1
	Muddy River Springs Area (219)	Muddy River near Moapa[1]	20,931	15,383	0	0	0
	Lower Moapa Valley (220)	Muddy River near Glendale[1]	19,565	14,895	0	0	0
	Black Mountains Area (215)	Blue Point Spring	223	393	0	0	0
		Rogers Spring	771	515	0	0	0
Goshute Valley	Steptoe Valley (179)	Campbel Ranch Springs	2,746	2,088	0	0	0
		Currie Spring	2,181	1,419	0	0	0
		McGill Spring	4,783	2,074	0	0	0
		Monte Neva Hot Springs	649	280	0	0	0
Great Salt Lake Desert	Spring Valley (184)	Keegan Spring	234	63	-12	-28	-36
		North Millick Spring	284	98	-4	-9	-11
		South Millick Spring	506	278	-10	-21	-24
	Snake Valley (195)	Big Springs	4,289	1,977	-2	-26	-78
		Foote Res. Spring	1,300	211	0	0	0
		Kell Spring	120	59	0	0	0
		Warm Creek near Gandy, UT	7,426	2,697	0	0	0
Meadow Valley	Panaca Valley (203)	Panaca Spring	1,455	1,208	0	0	0

[1] Simulated using Stream Flow Routing 2 package for MODFLOW.

Source: SNWA 2010b.

moderate to high risk of impacts to surface flows. By the full build out plus 200 years time frame, there are 94 surface water right located in areas where there is a moderate to high risk of impacts to surface flows. For surface water rights that are dependent on groundwater discharge, a potential reduction in the water table at the point of diversion, could reduce or eliminate the flow available at the point of diversion for the surface water right.

Impacts to Groundwater Rights

Figures F3.3.14A-16, **F3.3.14A-17**, and **F3.3.14A-18** in **Appendix F3.3.14** illustrate the location and manner of use of existing groundwater rights in relation to the magnitude of the model-simulated drawdown at full build out and at full build out plus 75 years and full build out plus 200 years. **Table F3.3.15-6A** (**Appendix F3.3.15**) lists the groundwater rights by hydrographic basin within the drawdown area. At full build out plus 75 years, there are 70 groundwater rights located within areas that are predicted to experience a reduction in groundwater levels of at least 10 feet. At full build out plus 200 years, the number increases to 110 groundwater rights located within areas that are predicted to experience a reduction in groundwater levels of at least 10 feet. The potential impacts to individual wells are the same as discussed under the Proposed Action.

Impacts to Water Balance

The model-simulated groundwater budget for the Alternative E pumping scenario is presented in **Appendix F3.3.16**, **Table F3.3.16-6B**. Compared to the simulated conditions under No Action, for Spring Valley, the pumping is estimated to result in a 52 percent reduction of groundwater discharge for ET at the full build out plus 75 years time frame and 56 percent reduction at full build out plus 200 years time frame. In Snake Valley, the pumping is estimated to result in minimal reductions (<4 percent) of groundwater discharge to support ET. Alternative E pumping is estimated to have minimal impact (1 percent or less) on ET discharge within the White River Flow System; and reductions of flow to Pine, Wah Wah, and Tule Valleys and Fish Springs.

Water Quality

Potential impacts to water quality would be the same as described under the Proposed Action.

Monitoring and Mitigation Recommendations

Additional mitigation recommendations GW-WR-3 (Monitoring and Modeling); GW-WR-4 (Monitoring, Mitigation and Management Plan for Snake Valley); GW-WR-5 (Shoshone Ponds Mitigation); and, GW-WR-6 (Water Rights Mitigation) described under the Proposed Action would apply to Alternative E.

Potential Residual Impacts

Potential unavoidable residual impacts associated with the groundwater development are described under the Proposed Action. The magnitude of potential unavoidable adverse impacts would be less than the Proposed Action in Spring, Cave, Delamar, and Dry Lake valleys (because of reduced pumping). The magnitude of potential unavoidable adverse impacts to Snake Valley also would be considerably less than the Proposed Action and Alternatives A, B, and C since there would be no pumping in Snake Valley. The potential residual impacts to Snake Valley also likely would be less under Alternative E and Alternative D because of the reduction in the magnitude of drawdown that likely would propagate into this basin.

3.3.2.15 No Action

As described in Chapter 2, the No Action assumes that the BLM would not grant ROWs for the proposed project. Under this scenario, the proposed pipelines, power lines, ancillary facilities, and well fields would not be developed. Therefore, no construction or operational impacts to water resources would be associated with the proposed GWD Project.

Groundwater Pumping

Groundwater Pumping Scenario

The locations of the groundwater development wells assumed for modeling of the No Action pumping scenario are shown in **Figure 3.3.2-30**. The pumping scenario used for the No Action represents a continuation of currently existing water uses over the duration of the future model simulation period. The No Action also includes pumping SNWA's

Figure 3.3.2-30 Pumping Distribution No Action

existing water rights associated with their ranch properties in Spring Valley (SNWA 2010b). The No Action groundwater pumping scenario is based on the estimates of existing consumptive water use for the model area for agricultural, municipal, mining and milling, industrial, and power plant uses as described in the transient numerical model report (SNWA 2009b). Other uses associated with domestic wells and stock watering wells are not included; however these are assumed to represent a relatively small percentage of the estimated consumptive uses in the model area (SNWA 2009b). Additional information on the methodology used to derive the consumptive water-use estimates and identified points of diversion are provided in **Appendix C** of the transient numerical model report (SNWA 2009b).

Impacts to Water Levels

The predicted changes in groundwater levels attributable to the No Action pumping scenario at the full build out time frame[2], and full build out plus 75 years and full build out plus 200 years time frame are provided in **Figures 3.3.2-31**, **3.3.2-32**, and **3.3.2-33**, respectively. These figures illustrate areas where the water levels are predicted to decrease in comparison to the baseline groundwater elevations at the end of 2004. It is important to understand that these drawdowns are predicted to occur without any groundwater development associated with the proposed project.

Comparison of the simulation results indicate that the drawdown effects under No Action continue to expand as pumping continues into the future. At the full build out time frame, the largest drawdown area encompasses the southern portion of Lake Valley and northern Patterson Valley. Other smaller drawdown cones are localized in the near vicinity of pumping centers.

At the full build out plus 75 years time frame, there are 3 major drawdown areas. The largest drawdown area extends in a north-south direction from Lake Valley south to the northern margin of Meadow Valley Wash, a distance of approximately 70 miles. The two other major drawdown areas occur in the northern portion of White River Valley, and along the southern margin of the model area in the Black Mountain Area and Las Vegas Valley hydrographic basins.

At the full build out plus 200 years time frame, the drawdown area that extends from the Lake Valley to Lower Meadow Valley Wash hydrographic basins is up to 85 miles long (north-south). The drawdown areas in White River Valley and along the southern margin of the model area also are predicted to continue to expand between the time frames associated with full build out plus 75 years and full build out plus 200 years.

Potential effects to water resources resulting from the No Action pumping scenario are summarized in **Table 3.3.2-20**.

Impacts to Springs and Streams

The estimated potential risks to springs located within the projected drawdown area at the full build out, full build out plus 75 years, and full build out plus 200 years time frames are presented in **Figures F3.3.8A-19**, **F3.3.8A-20**, and **F3.3.8A-21** (**Appendix F3.3.8**), respectively. The springs within the drawdown area and relative risk of impacts by hydrographic basin is summarized in **Table F3.3.9-7A** (**Appendix F3.3.9**). The estimated miles of perennial streams (by hydrographic basin) located in the predicted drawdown areas where surface waters could be impacted are listed in **Table F3.3.11-7A** in **Appendix F3.3.11**.

For the predicted drawdown area at full build out plus 75 years, there are 12 inventoried springs and 34 “other” springs located within the high and moderate risk areas. By full build out plus 200 years this increased to 20 inventoried springs and 66 “other” springs located within the high and moderate risk areas. These springs occur in White River, Spring (HA 184), Lake, Spring (HA 201), Panaca, Clover Valleys, Lower Meadow Valley Wash, and Las Vegas Valley.

The total estimated length of perennial stream located in areas where there is a high to moderate risk of impacts resulting from the predicted drawdown increases from approximately 19 miles at full build out plus 75 years to 52 miles at full build out plus 200 years time frame. This includes stream reaches located in White River, Spring (HA 184), Lake, Spring (HA 201), Patterson, Eagle, Dry, Panaca, Clover Valleys, and Lower Meadow Valley Wash.

[2] The term “full build out time frame” refers to representative points in time in the future that were selected for comparison of potential effects associated with each of the alternatives. The full build out time frame corresponds to full build out of the groundwater development project as defined for Proposed Action.

Figure 3.3.2-31 Predicted Change in Groundwater Levels No Action Full Build Out

Figure 3.3.2-32 Predicted Change in Groundwater Levels No Action + 75 Years

Figure 3.3.2-33 Predicted Change in Groundwater Levels No Action + 200 Years

Table 3.3.2-20 Summary of Potential Effects to Water Resources Resulting from the No Action Pumping Scenario[1,2]

Water Resource Issue / Time Frame	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Drawdown:			
• Number of hydrographic basins affected by drawdown	10	18	20
Drawdown effects on perennial springs:			
• Number of inventoried springs located in areas where impacts to flow could occur[3]	6	12	20
• Number of other springs located in areas where impacts to flow could occur[4]	22	34	66
• Model-simulated flow reduction at Big Spring (as percent flow reduction)	9%	13%	16%
Drawdown effects on perennial streams:			
• Number of basins with perennial stream reaches where impacts to flow could occur	3	6	7
• Miles of perennial stream located in areas where impacts to flow could occur	7	19	52
Drawdown effects on surface water rights:			
• Number of surface water rights located in areas where impacts to flow could occur	58	105	164
Drawdown effects on groundwater rights:			
• Number of groundwater rights located within the 10-50 foot drawdown area	174	281	293
• Number of groundwater rights located within the 50-100 foot drawdown area	1	91	116
• Number of groundwater rights located within the >100 foot drawdown area	0	0	0
• (Total groundwater rights in drawdown area)	(175)	(372)	(409)
Percent reduction in ET and spring discharge[5]:			
• Spring Valley	5%	7%	7%
• Snake Valley	2%	3%	3%
• Great Salt Lake Desert Flow System[1]	3%	5%	5%
• White River Flow System	2%	3%	4%
Reduction in flow from Snake Valley to Pine, Wah Wah, and Tule Valleys Hydrographic Basins[5]:			
• AFY	0	0	0
• Percent Reduction	0%	0%	0%

[1]Located within the groundwater flow model domain.

[2]Unless otherwise noted, supporting information used to developed these estimated effects are provided in **Appendices F3.3.5** through **F3.3.16**.

[3]Specific inventoried springs identified in moderate or high risk areas are identified in **Table F3.3.10-1A** in **Appendix F3.3.10**.

[4]"Other Springs" are springs identified in the National Hydrography Database or topographic maps that have not been field verified.

[5] Estimate derived from the model-simulated values provided in SNWA 2010A with comparison to simulated 2004 conditions.

Potential site specific impacts to individual springs and streams affected by drawdown would be the same as discussed for the Proposed Action.

Model-simulated Spring and Stream Discharge Estimates. Model-simulated changes in spring flow for selected springs are presented in **Table 3.3.2-21**. Spring discharges simulated at 11 springs within White River Valley were used for this evaluation. At the full build out plus 75 years and full build out plus 200 year time frame, there are 4 springs (Arnoldson Spring, Cold Spring, Nicholas Spring, and Preston Big Spring in White River Valley), with a predicted reduction of 5 percent or greater. For these springs, the model simulations indicate flow reductions of less than 10 percent for all three time periods.

The model results also indicate that the continuation of existing pumping simulated under No Action is not predicted to result in a measurable flow reduction (i.e., >5 percent) in discharge at regional springs in Pahranagat Valley within the White River Flow System. However, the existing pumping in the Muddy River Springs Area, Lower Meadow Valley Wash, and Lower Moapa Valley hydrographic basins is predicted to result in a progressive reduction of flow over time in the Muddy River. At the full build out plus 200 years time frame, the flows in the Muddy River are predicted to be reduced by 9 percent at Moapa, 10 percent near Glendale, and 60 percent at Overton. (Note that the numerical model simulations do not account for the existing Muddy River Memorandum of Agreement regarding groundwater withdrawal in Coyote Spring Valley and California Wash basins, among the SNWA, Moapa Valley Water District, Coyote Spring Investment, Moapa Band of Paiutes, and USFWS, which includes minimum in-stream flow levels. The groundwater model could not address these minimum in-stream flow requirements, thus they are not reflected in the simulation results. Based on the agreement, potential flow reductions under the No Action pumping scenario are anticipated to be less than those simulated by the model.)

In the Great Salt Lake Desert Flow System, the model simulations results indicate that No Action pumping would not impact flows at Keegan, North Millick, and South Millick springs in Spring Valley. In Snake Valley, Big Springs is predicted to experience flow reductions of 13- and 16-percent at the full build out plus 75 years and full build out plus 200 years time frame, respectively. As with the Proposed Action, the No Action is not predicted to reduce flows in the 4 other simulated springs located in the central portion of Snake Valley (Foote Reservoir Spring, Kell Spring, and Warm Creek near Gandy).

Impacts to Surface Water Rights

The locations and manner of use of the active surface water rights within the simulated drawdown area for No Action at the full build out and full build out plus 75 years and full build out plus 200 years time frames are presented in **Figures F3.3.12A-19**, **F3.3.12A-20**, and **F3.3.12A-21**, respectively in **Appendix F3.3.12**. **Table F3.3.13-7A** lists the number of active surface water rights within the drawdown area that occur within the high-, moderated-, and low-risk areas at the three representative time frames. At full build out plus 75 years there are a total of 105 surface water rights located in areas where there is a moderate to high risk of impacts to surface flows. By the full build out plus 200 years time frame, there are 164 surface water right located in areas where there is a moderate to high risk of impacts to surface flows. For surface water rights that are dependent on groundwater discharge, a potential reduction in the water table at the point of diversion, could reduce or eliminate the flow available at the point of diversion for the surface water right.

Impacts to Groundwater Rights

Figures F3.3.14A-19, **F3.3.14A-20**, and **F3.3.14A-21** in **Appendix F3.3.14** illustrate the location and manner of use of existing groundwater rights in relation to the magnitude of the model-simulated drawdown at full build out and at full build out plus 75 years and full build out plus 200 years. **Table F3.3.15-7A** (**Appendix F3.3.15**) lists the groundwater rights by hydrographic basin within the drawdown area. At full build out plus 75 years, there are 372 groundwater rights located within areas that are predicted to experience a reduction in groundwater levels of at least 10 feet. At full build out plus 200 years, the number increases to 409 groundwater rights located within areas that are predicted to experience a reduction in groundwater levels of at least 10 feet. The potential impacts to individual wells are the same as discussed under the Proposed Action.

Table 3.3.2-21 Model-simulated Flow Changes (No Action Pumping)

(Project Specific)					No Action		
					Incremental Change in Flow % (from Current Conditions)		
Flow System	Hydrographic Basin	Spring	Average Flow (Actual) in gpm	Model-simulated Average Flow (2005) in gpm	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
White River	White River Valley (207)	Arnoldson Spring	1,608	946	-4	-6	-8
		Butterfield Spring	1,225	471	0	-1	-3
		Cold Spring	582	503	-3	-6	-8
		Flag Springs 3	969	560	0	-1	-3
		Hardy Springs	200	73	-1	-2	-2
		Hot Creek Spring	5,032	6,899	0	-1	-1
		Lund Spring	3,594	3,314	0	0	-1
		Moon River Spring	1,707	1,457	0	0	0
		Moorman Spring	405	353	0	-1	-1
		Nicolas Spring	1,185	872	-5	-7	-9
		Preston Big Spring	3,572	3,794	-2	-5	-7
	Pahranagat Valley (209)	Ash Springs	6,909	7,453	0	-1	-1
		Brownie Spring	224	277	0	0	0
		Crystal Springs	4,235	4,647	-1	-1	-2
		Hiko Spring	2,735	1,985	-1	-2	-3
	Muddy River Springs Area (219)	Muddy River near Moapa[1]	20,931	15,383	-4	-6	-9
	Lower Moapa Valley (220)	Muddy River near Glendale[1]	19,565	14,895	-5	-7	-10
	Black Mountains Area (215)	Blue Point Spring	223	393	0	-1	-2
		Rogers Spring	771	515	0	-1	-2
Goshute Valley	Steptoe Valley (179)	Campbel Ranch Springs	2,746	2,088	0	0	-1
		Currie Spring	2,181	1,419	0	-1	-1
		McGill Spring	4,783	2,074	0	0	0
		Monte Neva Hot Springs	649	280	0	-1	-1
Great Salt Lake Desert	Spring Valley (184)	Keegan Spring	234	63	-2	-2	-2
		North Millick Spring	284	98	0	0	0
		South Millick Spring	506	278	-1	-1	-1
	Snake Valley (195)	Big Springs	4,289	1,977	-9	-13	-16
		Foote Res. Spring	1,300	211	0	0	0
		Kell Spring	120	59	0	0	0
		Warm Creek near Gandy, UT	7,426	2,697	0	0	0
Meadow Valley	Panaca Valley (203)	Panaca Spring	1,455	1,208	-2	-5	-7

[1] Simulated using Stream Flow Routing 2 package for MODFLOW.

Source: SNWA 2010b.

Impacts to Water Balance

The model-simulated groundwater budget for the No Action pumping scenario is presented in **Appendix F3.3.16**, **Table F3.3.16-7B**. Compared to the simulated conditions in 2005, for Spring Valley, For Spring Valley, the No Action pumping is estimated to result in a 7 percent reduction of groundwater discharge for ET at the full build out plus 75 years and full build out plus 200 years time frames. In Snake Valley, the pumping is estimated to result in minimal reductions (<4 percent) of groundwater discharge to support ET. The pumping is estimated to result in a 3 to 4 percent reduction in groundwater discharge ET and springs within the White River Flow System. Reductions of flow to Pine, Wah Wah, and Tule Valleys and Fish Springs are not predicted.

3.3.2.16 Summary and Comparison of Alternative Pumping Scenarios

The drawdown areas predicted for the Proposed Action at the full build out plus 75 years and full build out plus 200 years time frame are compared to the drawdown areas for the various alternative pumping scenarios in **Figures 3.3.2-34** to **3.3.2-39**. All of the project pumping scenarios (Proposed Action and Alternatives A through E) simulation results indicates that the drawdown area continues to progressively expand as pumping continues into the future. The alternatives with the highest groundwater withdrawal volumes (Proposed Action and Alternative B) show the largest drawdown effects; and the alternatives with the lower groundwater withdrawal volume (Alternatives C, D, and E) show the smallest drawdown effects.

The groundwater pumping scenario for the Proposed Action assumes pumping at the full quantities (i.e., approximately 177,000 afy) listed on the pending water rights application for the five proposed project pumping basins (Spring, Snake, Cave, Delamar, and Dry Lake valleys). The well distribution developed by the SNWA for this model scenario distributes the simulated production wells spatially within the groundwater development areas in an effort to minimize pumping effects to surface water resources. For the Proposed Action pumping scenario, at full build out plus 75 years time frame, there are two distinct drawdown areas (**Figure 3.3.2-34**). The northern drawdown area encompasses most of valley floor in Spring Valley, southern Snake Valley, and northern Hamlin Valley. The southern drawdown area extends across the Cave, Delamar, and Dry Lake valleys in an elongate north-south direction and extends into the eastern margin of Pahranagat Valley and northwestern margin of Lower Meadow Valley Wash. By the full build out plus 200 years time frame, the two drawdown areas merge. At this time frame, the simulated drawdown area extends into Tippetts Valley, southeastern Steptoe Valley, and the eastern margins of Pahroc and Pahranagat valleys, and the western margins of Panaca Valley and Lower Meadow Valley Wash.

The groundwater pumping scenario for Alternative A assumes pumping at reduced quantities (approximately 115,000 afy) from those listed on the pending water rights application for the five proposed project pumping basins (Spring, Snake, Cave, Delamar, and Dry Lake valleys). The well distribution developed by the SNWA for this model scenario distributes the simulated production wells spatially within the groundwater development areas in an effort to minimize pumping effects. Compared to the Proposed Action, the reduced pumping under Alternative A would reduce the drawdown area (**Figure 3.3.2-34**) particularly in northern Spring Valley, northern Lake Valley and along the southern margin of the drawdown area.

The Alternative B pumping scenario assumes pumping at the full diversion rates (i.e., approximately 177,000 afy) listed on the pending water rights application for the five proposed project pumping basins (Spring, Snake, Cave, Delamar, and Dry Lake valleys) and that wells would be developed at the actual points of diversion listed on the water rights applications. Compared to the Proposed Action, the Alternative B pumping scenario would expand the area of drawdown along the southeast margin of Steptoe Valley, and in the Southern Snake Range between Spring and Snake Valley, and in southern Lake Valley (**Figure 3.3.2-35**). The drawdown area for Alternative B also does not extend into northern Spring Valley (HA 184) or Tippett Valley.

The Alternative C pumping scenario assumes the same groundwater production wells defined for Alternative A and that instead of pumping at a sustained rate (as in Alternative A) after full build out the pumping rates would cycle from minimum (9,000 afy) to maximum (115,000 afy) pumping rates every 5 years after full build out. The maximum pumping rate under this scenario is the same as for Alternative A (approximately 115,000 afy). The model simulations indicate that the reduction in groundwater withdrawal under Alternative C would further reduce the drawdown area as shown on **Figure 3.3.2-36**.

Figure 3.3.2-34 Drawdown Area Comparison Alternative A vs. Proposed Action

Figure 3.3.2-35 Drawdown Area Comparison Alternative B vs. Proposed Action

Figure 3.3.2-36 Drawdown Area Comparison Alternative C vs. Proposed Action

Figure 3.3.2-37 Drawdown Area Comparison Alternative D vs. Proposed Action

Figure 3.3.2-38 Drawdown Area Comparison Alternative E vs. Proposed Action

Figure 3.3.2-39 Drawdown Area Comparison No Action vs. Proposed Action

The groundwater pumping scenario for Alternative D assumes that no pumping will occur in Snake Valley, and pumping in Spring Valley would be restricted to the southern portion of the valley within Lincoln County**.** The maximum groundwater production rate under this scenario is approximately 79,000 afy for the four pumping basins (Spring, Cave, Delamar, and Dry Lake valleys) is the same as the maximum pumping rate assumed for these basins under Alternative A, C, and E. The well distribution developed by the SNWA for this model scenario includes the same spatial distribution of wells included in Alternative A for Cave, Delamar, and Dry Lake valleys. Compared to the Proposed Action, Alternative D limits drawdown in the central and northern portion of Spring Valley and southern portion of Snake Valley; and expands drawdown in Lake Valley, Hamlin Valley and into northern Spring Valley (HA 201) (**Figure 3.3.2-37**).

The Alternative E pumping scenario includes the same spatial distribution of wells included in Alternative A for Spring, Cave, Delamar, and Dry Lake valleys but assumes no pumping in Snake Valley. The maximum groundwater production rate under this scenario is approximately 79,000 afy for the four pumping basins (Spring, Cave, Delamar, and Dry Lake valleys) is the same as the maximum pumping rate assumed for these same basins under Alternative A, C, and D. Because the pumping schedule for Alternative E is identical to Alternative A for Spring, Cave, Delamar, and Dry Lake valleys, the predicted drawdown for Spring, Cave, Delamar, and Dry Lake valleys (and adjacent areas) are essentially the same as for Alternative A (**Figure 3.3.2-38**). This alternative would substantially reduce the drawdown area in Snake Valley compared with the Proposed Action and Alternative A.

For the No Action, the groundwater pumping scenario represents an estimate of the potential effects that would occur in the future resulting from a continuation of currently existing water uses. The No Action pumping scenario is based on the estimates of existing and consumptive water use for the model area for agricultural, municipal, mining and milling, industrial, and power plant uses. This includes pumping the SNWA's existing water rights associated with their ranch properties in Spring Valley. However, the No Action pumping scenario does not included any groundwater development associated with the water rights applications in Spring, Snake, Cave, Delamar, or Dry Lake valleys that are included in the proposed project (i.e., Proposed Action pumping scenario). The estimated drawdown attributable to the No Action pumping scenario was estimated by comparison to the baseline groundwater elevations at the end of 2004.

Comparison of the simulation results indicate that the drawdown effects under No Action continue to expand as pumping continues into the future. At the full build out plus 75 years time frame, there are 3 major drawdown areas. The largest drawdown area extends in a north-south direction from Lake Valley south to the northern margin of Meadow Valley Wash, a distance of approximately 70 miles. The two other major drawdown areas occur in the northern portion of White River Valley, and along the southern margin of the model area in the Black Mountain Area and Las Vegas Valley hydrographic basins. At the full build out plus 200 years time frame, the drawdown area that extends from the Lake Valley to Lower Meadow Valley Wash hydrographic basins is up to 85 miles long (north-south). The drawdown areas in White River Valley and along the southern margin of the model area also are predicted to continue to expand in the future over the model simulation period.

Table 3.3.2-22 provides a comparison of the potential impacts to water resources in the region of study associated with the various alternative pumping scenarios.

Impacts to Springs and Streams

As described previously, springs that are controlled by discharge from (or hydraulically interconnected with) the regional groundwater flow system and located within areas that experience a reduction in groundwater levels would likely experience a reduction in flow. The number of inventoried springs and miles of perennial stream located within the model-simulated drawdown area and located within areas determined to have a high or moderate risk of impacts are graphically illustrated in **Figures 3.3.3-40** and **3.3.3-41**. These charts indicate that the number of springs and miles of stream at risk of impacts increases over time for all of the alternative pumping scenarios. The model-simulated drawdown for the two alternatives with the largest groundwater withdrawal rate (Proposed Action and Alternative B) potentially could impact flows in the largest number of springs and miles of perennial stream reach. However, the distributed pumping assumed for Alternative A would reduce the number of springs and miles of perennial stream potentially at risk from drawdown effects. Compared to the Proposed Action, the reduced drawdown areas resulting

Table 3.3.2-22 Comparison of Potential Incremental Effects to Water Resources at the Full Build Out Plus 75 Years and Full Build Out Plus 200 Years Time Frame Resulting from the Alternative Pumping Scenarios[1]

Water Resource Issue	Proposed Action	Alt. A	Alt. B	Alt. C	Alt. D	Alt. E	No Action
Full Build Out Plus 75 Years							
Drawdown effects on perennial springs:							
• Number of inventoried springs located in areas where impacts to flow could occur[2]	44	29	54	19	13	19	12
Drawdown effects on perennial streams:							
• Miles of perennial stream located in areas where impacts to flow could occur[2]	80	58	91	37	4	7	19
Drawdown effects on surface water rights:							
• Number of surface water rights located in areas where impacts to flow could occur[2]	145	109	141	78	23	60	105
Drawdown effects on groundwater rights:							
• Total groundwater rights in areas with >10 feet of drawdown	199	174	184	133	27	70	372
• Number of groundwater rights in areas with >100 feet of drawdown	2	0	8	0	2	0	0
Percent reduction in groundwater discharge to ET:							
• Spring Valley	77%	51%	66%	37%	18%	52%	7%
• Snake Valley	28%	23%	18%	15%	4%	0%	3%
• Great Salt Lake Desert Flow System	48%	34%	37%	24%	10%	21%	5%
Full Build Out Plus 200 Years							
Drawdown effects on perennial springs:							
• Number of inventoried springs located in areas where impacts to flow could occur[2]	57	46	78	26	31	30	20
Drawdown effects on perennial streams:							
• Miles of perennial stream located in areas where impacts to flow could occur[2]	112	81	120	59	48	23	52
Drawdown effects on surface water rights:							
• Number of surface water rights located in areas where impacts to flow could occur[2]	212	151	186	98	56	94	164
Drawdown effects on groundwater rights:							
• Total groundwater rights in areas with >10 feet of drawdown	264	223	301	171	213	110	409
• Number of groundwater rights in areas with >100 feet of drawdown	34	2	45	0	6	2	0
Percent reduction in groundwater discharge to ET:							
• Spring Valley	84%	57%	73%	37%	28%	56%	7%
• Snake Valley	33%	27%	24%	17%	8%	3%	3%
• Great Salt Lake Desert Flow System[1]	54%	39%	44%	25%	16%	24%	5%

[1]Supporting information used to develop these estimated effects are provided in **Appendices F3.3.6** through **F3.3.16**.
[2]Total located in high or moderate risk areas.

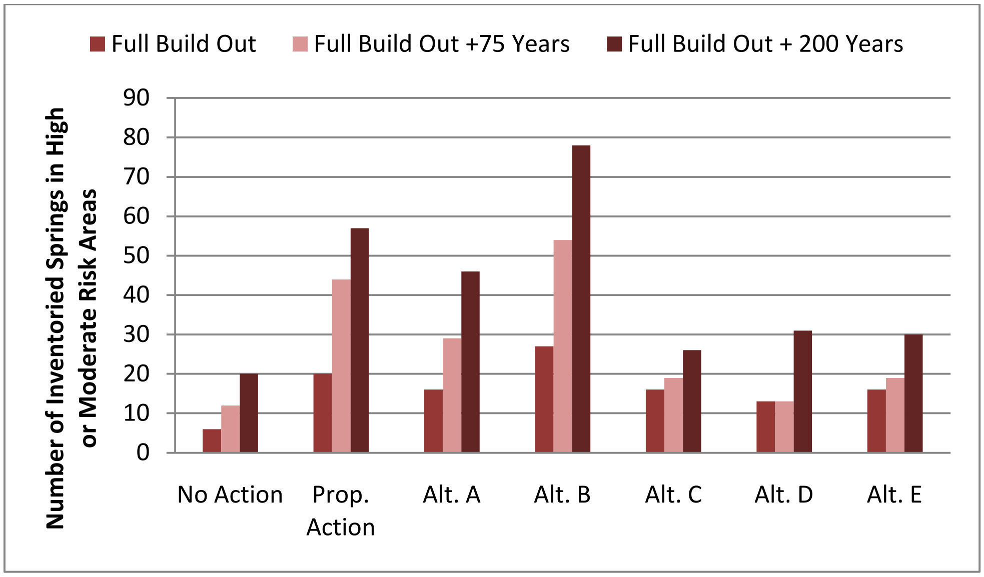


Figure 3.3.2-40 Number of Inventoried Springs Located within the Drawdown Area and Areas Where Impacts to Flow Could Occur (High or Moderate Risk Areas)

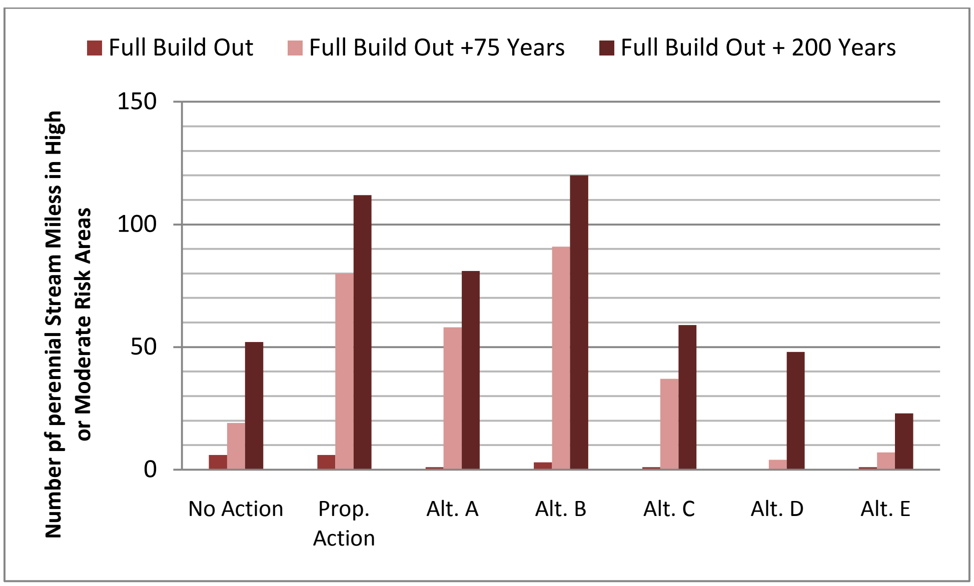


Figure 3.3.2-41 Miles of Perennial Streams Located within the Drawdown Area and Areas Where Impacts to Flow Could Occur (High or Moderate Risk Areas)

from the Alternative A pumping scenario would reduce the number of springs and miles of streams potentially impacted. The Alternative C, D, and E pumping scenarios would further reduce the drawdown area compared to Alternative A, and would potentially impact the smallest number of inventoried springs and miles of perennial stream reach in the region.

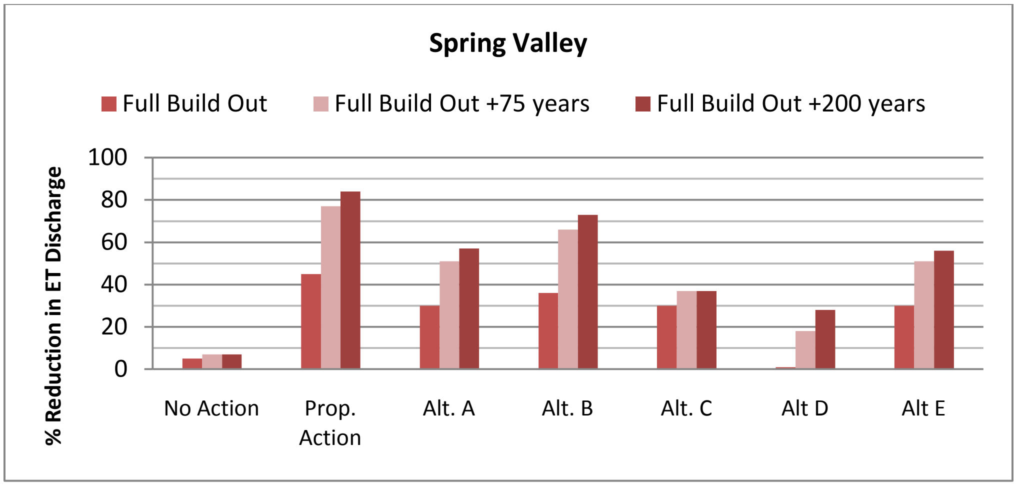
Impacts to Water Rights

The number of surface water rights located in areas where impacts to surface water resources could occur and number of groundwater rights located within the areas where the model simulations indicate drawdown of 10 feet or more are listed in **Table 3.3.2-22**. There are a large number of existing surface water rights located in areas where impacts from drawdown could occur under both the No Action and groundwater development pumping scenarios. The model results indicate that drawdown for the two alternatives with the largest groundwater withdrawal rate (Proposed Action and Alternative B) could potentially impact the largest number of water rights. The reduced drawdown areas resulting from the other alternatives (Alternatives A through E) would decrease the number of water rights impacted.

Impacts to Water Balance

Potential changes in the water balance for the groundwater system within the region of study were estimated using the groundwater flow model (SNWA 2010b). The estimated reductions in groundwater discharge to the ET areas for selected basins and flow systems are summarized in **Table 3.3.2-22** and illustrated in **Figure 3.3.3-42**.

The Proposed Action would result in the largest reductions in groundwater discharge to the ET areas within Spring and Snake valleys; with estimated reductions of up to 84 percent in Spring Valley, and up to 34 percent in Snake Valley. For Snake valley, most of the reductions of discharge to areas would occur in the south portion of the valley. The model results indicate that Alternative D would have the least impact to the ET areas in Spring Valley because the pumping is concentrated in the south end of the valley away from much of the ET areas. The concentrated pumping under Alternative D results in the deepest drawdown cone indicating that a higher percentage of the groundwater withdrawn under this scenario is from groundwater storage compared to the other groundwater development alternatives. Alternative E would result in the smallest impacts to the ET area in Snake Valley.



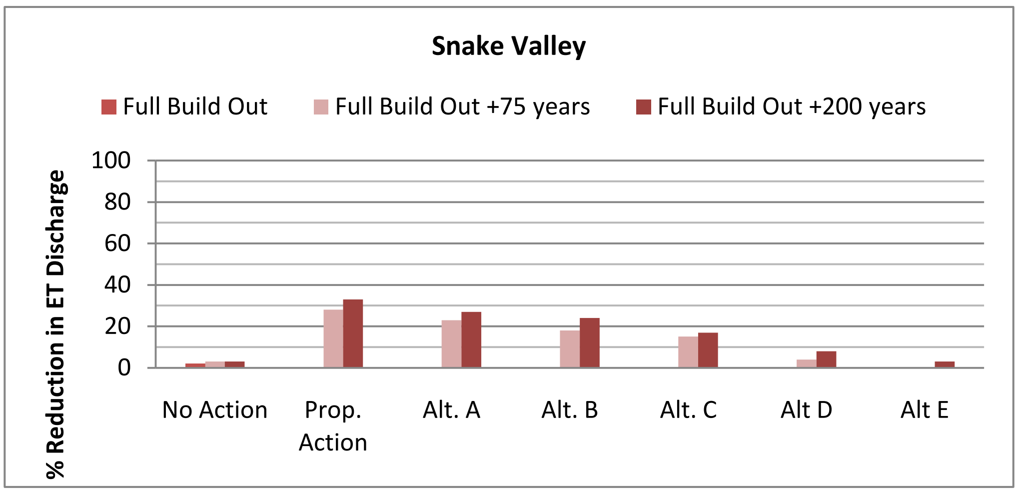


Figure 3.3.2-42 Model-simulated Reductions in Groundwater Discharge to Evapotranspiration Areas in Spring and Snake Valleys

3.3.3 Cumulative Impacts

3.3.3.1 Rights-of-way and Groundwater Development Area Construction and Operation

The water resources cumulative effects study area for evaluating impacts associated with surface-disturbance related effects includes all hydrographic basins experiencing surface disturbance associated with construction of the GWD Project. This includes all hydrographic basins crossed by the primary pipelines, power line ROWs and ancillary facilities; and groundwater production wells, collector pipelines, access roads, and other ancillary facilities constructed within the groundwater development areas identified in Spring, Cave, Delamar, and Dry Lake valleys.

The issues, methodologies, and assumptions used for the evaluation of cumulative effects are the same as previously described for the project specific impacts in Section 3.3.2.

3.3.3.2 No Action

Groundwater Development

As described in Chapter 2, the No Action Alternative assumes that the BLM would not grant ROWs for the proposed project. Under this scenario, the proposed pipelines, power lines, ancillary facilities, and well fields would not be developed. Therefore, construction or operational impacts (or cumulative impacts) to water resources associated with the proposed GWD Project would not occur.

3.3.3.3 Proposed Action and Alternatives A through E

Groundwater Development

The potential impacts to surface water resources associated with construction and operation of the Proposed Action and Alternatives A through E are described in Section 3.3.2. The potential construction- and operation-related impacts are similar for all of these alternatives. With respect to water resources, the main difference between these alternatives is that the Proposed Action and Alternatives A through C would construct a pipeline and well field(s) in Snake Valley; whereas, Alternatives D and E would not include surface disturbance in Snake Valley. The Proposed Action and Alternatives A through C would include pipeline construction across one perennial stream (Snake Creek), and two intermittent streams (Big Wash and Lexington Creek) in Snake Valley. Implementation of the BMPs, ACMs, and mitigation recommendations would mitigate long-term residual impacts to perennial stream and springs.

Depending on the alternative, the primary pipeline also would cross 504 to 720 ephemeral streams; typically consisting of dry washes. Implementation of required erosion control measures and ACMs are expected to generally limit these to short-term (up to 2 years) effects.

The cumulative impacts to water resources within the areas to be disturbed for the GWD Project take into account other actions that also could affect water resources. Past and present actions involving grazing, road construction, mining and recent wildfires have affected perennial water sources and contributed to localized erosion and sedimentation to drainages. The primary future actions consist of construction of new utilities (e.g., pipelines, electrical distribution lines), roads and turbine pads for wind energy projects, and collector fields for solar energy projects) in Spring, Dry Lake, Muleshoe, Delamar, and Coyote Spring valleys. These future actions would result in surface disturbance that could (depending the facility locations and access roads) directly disturb or contribute sediment to perennial streams and springs located within the cumulative effects study area.

Surface disturbance would overlap with past and present actions, and potentially would overlap or intersect with RFFAs in the areas shown on **Figures 2.9-1** and **2.9-2**. Overlapping or intersecting areas of ground disturbance would include existing road and highway crossings; utility corridor crossings; and service roads for future wind energy projects in Spring and Dry Lake valleys. The major additive cumulative effects would be the expansion in the width of adjacent utility ROWs, which could cross streams or be located adjacent to streams and springs in Spring Valley. New roads associated with these RFFAs potentially could cross live streams in Spring and Snake Valley. Overall, the ground disturbance associated with the Proposed Action and Alternatives A through E are not anticipated to result in a substantial increase in cumulative impacts to surface water resources in the study area.

3.3.3.4 Groundwater Pumping

The hydrologic study area for cumulative impacts from groundwater withdrawal encompasses the 35 hydrographic basin region defined in **Figure 3.3.1-1**. The boundaries of the hydrologic study area for cumulative effects are the same as those used for the regional numerical groundwater flow model developed to evaluate potential effects of the proposed groundwater development project. The study area for cumulative effects was selected to include the 5 hydrographic basins where the proposed pumping would occur and all or portions of the potentially affected regional groundwater flow systems. Unless otherwise noted in the impact discussion, the issues, methodology, assumptions, and limitations used to quantify potential effects to water resources are the same as those previously described in Section 3.3.2.8. The baseline conditions in this regional study area are described in Section 3.3.1. For the purposes of the analysis, the proposed groundwater pumping is assumed to continue in perpetuity. As described in Section 3.3.2, drawdown-related impacts to water resources are predicted to progressively increase over time for the foreseeable future. To evaluate these increasing effects over time, the cumulative impact analysis estimated potential impacts to water resources at three representative time frames (full build out, full build out plus 75 years, and full build out plus 200 years) as discussed previously in Section 3.0. Detailed results of the cumulative effects at these three representative time frames are provided in tables and figures in **Appendix F3.3**. The summary of potential cumulative impacts provided in the following paragraphs is restricted to a description of the impacts at the later two time frames (i.e., full build out plus 75 years and full build out plus 200 years).

The estimated historical groundwater consumptive uses for the study area are described in **Appendix C** of the Transient Numerical Model Report (SNWA 2009b). The baseline conditions are described in Section 3.3.1and reflect the aggregate effects of past groundwater withdrawals that have historically occurred across the region. The cumulative effects to water resources described in this analysis estimate the total effects that could potentially occur relative to conditions at the end of 2004. The end of 2004 corresponds to end date final calibration period for the transient numerical flow model (SNWA 2009b).

Groundwater Pumping Scenarios

The cumulative effects to water resources were evaluated using the regional groundwater flow model developed for the GWD Project. The pumping scenarios for the cumulative effects analysis were developed to simulated the combined effects associated with: 1) the continuation of existing pumping in the region included under the No Action pumping scenario described in Section 3.3.2.15; 2) additional pumping associated with the proposed groundwater development project, or alternative groundwater development scenarios (i.e., Alternatives A through E); and 3) additional reasonably foreseeable groundwater developments that have been identified within the cumulative study area.

The reasonably foreseeable future groundwater developments included in this cumulative impact evaluation are listed in **Table 2.9-3**. These include future development of existing permitted groundwater rights associated with private lands and previously authorized projects and potential future projects with a groundwater-demand component that have submitted formal development plans to regulatory agencies for permitting purposes.

No Action Cumulative Pumping Scenario. The cumulative pumping scenario for No Action includes the No Action pumping described in Section 3.3.2.15 and reasonable foreseeable future groundwater developments. The location of the existing pumping wells and reasonable foreseeable future groundwater development assumed for the No Action cumulative pumping scenario are shown in **Figure 3.3.3-1**.

Groundwater Development Project Pumping Scenarios (Proposed Action and Alternatives A through E). The cumulative pumping scenarios for each of the groundwater development alternatives provide an estimate of the effects associated with the combined pumping included in: 1) the No Action cumulative pumping scenario (i.e., existing pumping and reasonably foreseeable future pumping); and 2) the well distributions and pumping schedules used for the simulations of the productions wells previously described for the incremental effects analysis (Sections 3.3.2-9 to Section 3.3.2-14).

Impacts to Water Levels

No Action Cumulative Pumping Scenario. The predicted changes in groundwater levels attributable to the No Action cumulative pumping scenario at the full build out plus 75 years and full build out plus 200 years time frames are provided in **Figures 3.3.3-2** and **3.3.3-3**, respectively. Comparisons between these figures with the drawdown at the

Figure 3.3.3-1 Pumping Distribution No Action Cumulative Scenario

Figure 3.3.3-2 Predicted Change in Groundwater Levels No Action Cumulative Effects + 75 Years

Figure 3.3.3-3 Predicted Change in Groundwater Levels No Action Cumulative Effects + 200 Years

same time frame for the No Action pumping scenario (**Figures 3.3.2-32** and **3.3.2-33**) illustrate areas where the additional pumping included under reasonably foreseeable future actions would result in additional drawdown. The major differences attributable to the assumed reasonably foreseeable future pumping included in the No Action cumulative scenario results in the development of new or expanded drawdowns in the following areas:

Steptoe Valley: Development of a new drawdown area along the northern margin of Steptoe Valley associated with existing permitted water rights for a proposed power plant.

Clover Valley: Substantial expansion of the areal extent and magnitude of drawdown in Clover Valley and adjacent areas resulting from the assumed pumping from the proposed Lincoln County/Vidler groundwater development project.

Kane Springs: Development of a new drawdown area in Kane Springs Valley and adjacent areas resulting from pumping of existing permitted water rights for Lincoln County/Vidler.

Coyote Spring Valley: Development of a new drawdown area in Coyote Spring Valley and adjacent areas resulting from pumping of existing permitted water rights for the SNWA Coyote Spring Pipeline and Coyote Springs Investment.

The model simulations indicate that pumping included in the No Action cumulative scenario does not substantially contribute to drawdowns in Spring and Snake valleys.

Groundwater Development Pumping Scenarios (Proposed Action and Alternatives A through E). The cumulative drawdown predicted for each of the six groundwater development pumping scenarios (Proposed Action and Alternatives A through E) at the representative time frames are provided in **Appendix F3.3.7**. These drawdown maps reflect the combined effects associated with the No Action cumulative drawdown scenario described above, and the incremental effects attributable to the groundwater pumping under the specific alternate described in Sections 3.3.2-9 to 3.3.2-14.

Figures 3.3.3-4 to **3.3.3-5** illustrates the predicted drawdown associated with the Proposed Action cumulative pumping scenario at the full build out plus 75 years and full build out plus 200 years time frame. The Proposed Action provides an example of the maximum extent of the cumulative drawdown predicted to occur for the six groundwater development cumulative pumping scenarios. Comparison of the results for the No Action cumulative pumping scenario with the six project alternative pumping cumulative scenarios results in the following major observations.

(1) Spring and Snake Valleys: The predicted cumulative drawdown is essentially the same as the project only drawdowns described previously. In other words, the continuation of existing pumping and reasonably foreseeable pumping (included in the No Action cumulative pumping scenario) is not expected to substantially increase drawdown effects over those predicted in Section 3.3.2 for the project specific effects.

(2) White River, Cave, Dry Lake, and Lake Valleys: Drawdown associated with the project pumping scenarios is predicted to overlap with the drawdowns predicted for the No Action cumulative scenario in Lake Valley and adjacent areas. The overlap of the drawdown effects associated with the project pumping and existing pumping in Lake Valley is predicted to result in increased drawdown in Lake Valley and in Cave and Dry Lake valleys. (Drawdown impacts to springs in White River Valley associated with pumping in Cave Valley are discussed below under model-simulated spring and stream discharge estimates.)

(3) Delamar Valley, Lower Meadow Valley Wash, and Clover Valley: Substantial drawdown is predicted to occur in Clover Valley under the No Action cumulative pumping scenario. The proposed groundwater development is not anticipated to contribute to drawdown in Clover Valley. However, the overlapping drawdown from pumping in Clover Valley and Delamar Valley is predicted to increase drawdown in the northern portion of the Lower Meadow Valley Wash, which is situated between these two pumping centers.

Figure 3.3.3-4 Predicted Change in Groundwater Levels Proposed Action Cumulative Effects + 75 Years

Figure 3.3.3-5 Predicted Change in Groundwater Levels Proposed Action Cumulative Effects + 200 Years

(4) Coyote Spring, Muddy River Springs, Hidden Valley North, Garnet Valley, Black Mountain Area, and Las Vegas Valley: The drawdown effects in these basins is essentially the same under both the No Action cumulative scenarios, and project pumping cumulative scenarios. These results indicate that the incremental drawdown attributable to project pumping is not anticipated to substantially contribute to drawdown effects beyond those simulated for the No Action cumulative scenario in Coyote Spring, Muddy River Springs, Hidden Valley North, Garnet Valley, Black Mountain Area, and Las Vegas Valley.

These observations generally apply to all six alternative cumulative pumping scenarios unless otherwise noted. However, the alternatives with the highest groundwater withdrawal volume (Proposed Action and Alternative B) show the largest overlapping drawdown effects; and the alternative with the lowest groundwater withdrawal volume (Alternative C) show the smallest amount of overlapping drawdown effects.

Impacts to Water Resources

The estimated potential risks to perennial springs and streams, water rights, and simulated water balance resulting from the cumulative groundwater pumping projected at full build out, and at full build out plus 75 years and full build out plus 200 years for each of the cumulative pumping scenarios are provided in the following locations:

- Tables presenting the model-simulated flow changes for selected springs (**Appendix F3.3.6**);
- Drawdown maps for each pumping scenario at each time frame (**Appendix F3.3.7**);
- Maps delineating the risk to perennial surface water resources within the model-simulated drawdown areas (**Appendix F3.3.8**);
- Tables listing the number of springs by basin that occur within the high, moderate, and low risk areas for each pumping scenario and time frame (**Appendix F3.3.9**);
- Tables identifying the inventoried springs that occur within the moderate and high risk areas for each pumping scenario and time frame (**Appendix F3.3.10**);
- Tables listing the miles of perennial stream present within areas where effects to surface waters could occur for each pumping scenario and time frame (**Appendix F3.3.11**);
- Maps illustrating the risks to surface water rights by manner of use within the drawdown areas for each pumping scenario and timeframe (**Appendix F3.3.12**);
- Tables defining the risk to surface water rights by basin within the drawdown areas for each pumping scenario and time frame (**Appendix F3.3.13**);
- Maps illustrating the drawdown effects to groundwater rights by manner of use for each pumping scenario and time frame (**Appendix F3.3.14**);
- Tables defining the risk to groundwater rights by basin within the drawdown areas for each pumping scenario and time frame (**Appendix F3.3.15**);
- Tables presenting the simulated groundwater budgets by basin and flow system for each pumping scenario and time frame (**Appendix F3.3.16**).

Potential effects to water resources resulting from the cumulative pumping scenario at the full build out plus 75 years and full build out plus 200 years time frames are summarized in **Table 3.3.3-1**. The following discussion provides a summary of potential major effects and compares the results for the alternative pumping scenarios.

Impacts to Springs and Streams

As described previously, springs that are controlled by discharge from (or hydraulically interconnected with) the regional groundwater flow system and located within areas that experience a reduction in groundwater levels would likely experience a reduction in flow. The number of inventoried springs and miles of perennial stream located within the model-simulated cumulative drawdown area and located within areas determined to have a high or moderate risk of

Table 3.3.3-1 Comparison of Potential Cumulative Effects to Water Resources at the Time Periods Associated with Full Build Out Plus 75 and Full Build Out Plus 200 Years[1]

Water Resource Issue	Proposed Action	Alt. A	Alt. B	Alt. C	Alt. D	Alt. E	No Action
Full Build Out Plus 75 Years							
Drawdown effects on perennial springs:							
• Number of inventoried springs located in areas where impacts to flow could occur[2]	65	53	77	42	34	42	19
Drawdown effects on perennial streams:							
• Miles of perennial stream located in areas where impacts to flow could occur[2]	131	110	137	98	53	56	42
Drawdown effects on surface water rights:							
• Number of surface water rights located in areas where impacts to flow could occur[2]	305	274	299	257	198	224	159
Drawdown effects on groundwater rights:							
• Total groundwater rights in areas with >10 feet of drawdown	683	667	679	635	541	558	500
• Number of groundwater rights in areas with >100 feet of drawdown	21	19	27	19	21	19	19
Percent reduction in ET and spring discharge:							
• Spring Valley	78%	55%	69%	43%	24%	55%	6%
• Snake Valley	30%	25%	21%	17%	7%	4%	2%
• Great Salt Lake Desert Flow System[1]	50%	38%	41%	28%	14%	25%	4%
Full Build Out Plus 200 Years							
Drawdown effects on perennial springs:							
• Number of inventoried springs located in areas where impacts to flow could occur[2]	82	74	102	63	53	62	28
Drawdown effects on perennial streams:							
• Miles of perennial stream located in areas where impacts to flow could occur[2]	193	166	201	151	119	120	79
Drawdown effects on surface water rights:							
• Number of surface water rights located in areas where impacts to flow could occur[2]	422	372	393	341	302	315	228
Drawdown effects on groundwater rights:							
• Total groundwater rights in areas with >10 feet of drawdown	783	752	754	730	672	642	555
• Number of groundwater rights in areas with >100 feet of drawdown	181	76	171	66	139	76	66
Percent reduction in groundwater discharge to ET:							
• Spring Valley	86%	61%	76%	42%	35%	60%	9%
• Snake Valley	35%	29%	27%	20%	11%	6%	3%
• Great Salt Lake Desert Flow System[1]	56%	42%	47%	29%	21%	28%	5%

[1]Supporting information used to develop these estimated effects are provided in **Appendices F3.3.6** through **F3.3.16**.

[2]Total located in high or moderate risk areas.

impacts are presented in **Figure 3.3.3-6** and **Figure 3.3.3-7**. These charts illustrates that the number of springs and miles of stream at risk of impacts increases over time for all of the cumulative pumping scenarios. For the No Action cumulative pumping scenario, there are 19 and 28 inventoried springs at the full build out plus 75 years and full build out plus 200 years time frame, respectively, located in areas where impacts to perennial water could occur. Because the No Action cumulative pumping scenario is a component of the other alternative pumping scenarios, the total number of springs and miles of perennial stream identified for the No Action cumulative scenario is included in the other 6 groundwater development pumping alternatives (i.e., Proposed Action and Alternatives A through E).

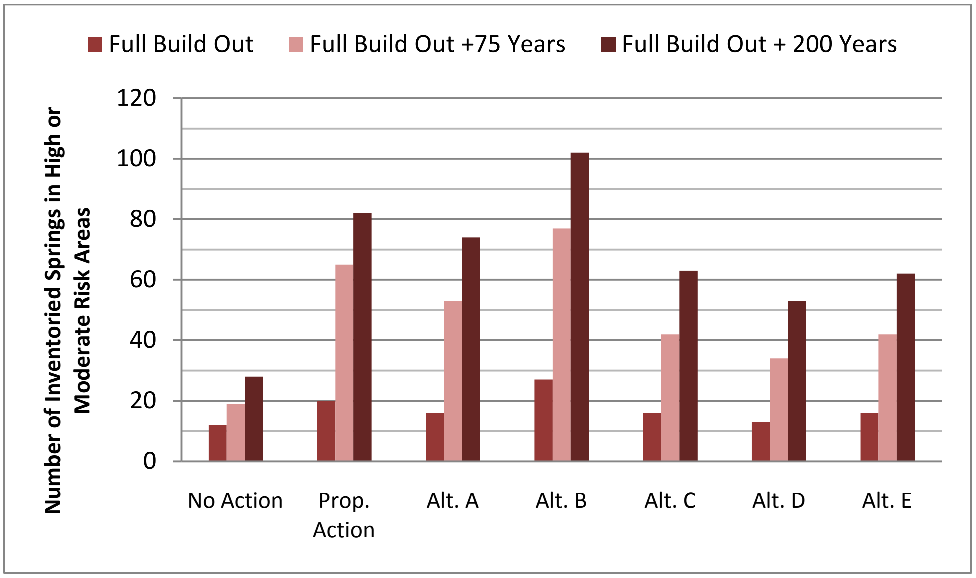


Figure 3.3.3-6 Number of Inventoried Springs Located within the Cumulative Drawdown Area and Areas Where Impacts to Flow Could Occur

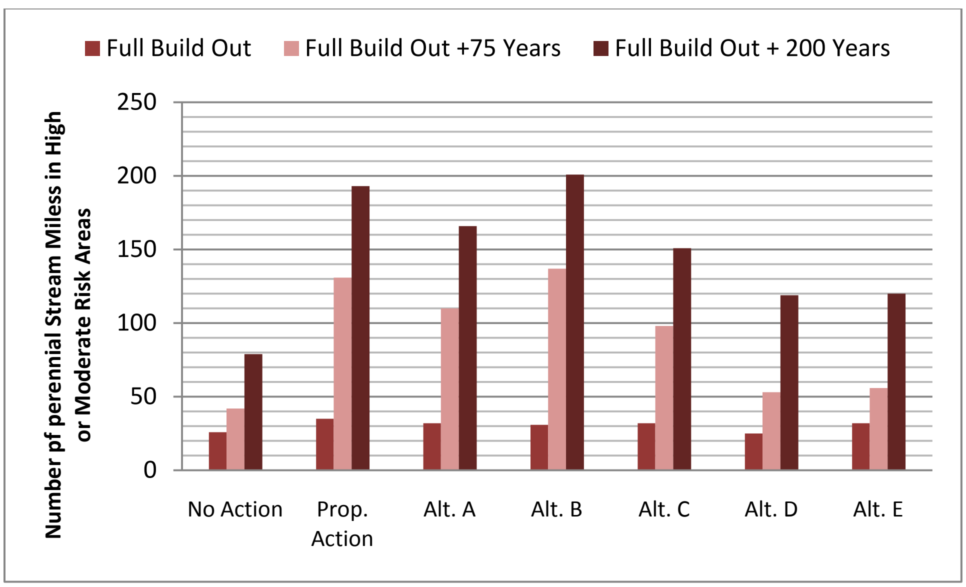


Figure 3.3.3-7 Miles of Perennial Stream Located within the Cumulative Drawdown Area and Areas Where Impacts to Flow Could Occur

The model-simulated drawdown for the two alternatives with the largest groundwater withdrawal rate (Proposed Action and Alternative B) potentially could impact flows in the largest number of springs and miles of perennial stream reach. The reduced drawdown areas resulting from the Alternative A cumulative pumping scenario potentially would reduce the number of springs and miles of streams impacted. The Alternative C, D, and E cumulative alternatives would further reduce the drawdown area compared to Alternative A, and potentially would impact the smallest number of inventoried springs and miles of perennial stream reach.

Model-simulated Spring and Stream Discharge Estimates

Model-simulated changes in spring flow for selected springs for each of the cumulative pumping scenarios are provided in **Appendix F3.3.6**. The model results for Preston Big Spring, Butterfield Spring, and Flag Springs 3 in White River Valley are presented in **Figure 3.3.3-8**. Preston Big Spring is located in the valley floor in the northern portion of White River Valley. The model results indicate that the flow at Preston Big Springs would be reduced by up to 7 percent from groundwater withdrawals included in the No Action cumulative pumping scenario. Additional reductions in flow resulting from the pumping included in the groundwater development alternatives (i.e., Proposed Action and Alternatives A through E) would be negligible. The model-simulated flow changes at Cold Spring and Nicolas Spring, located in the same general area within White River Valley, show essentially the same results.

Butterfield Springs and Flag Spring are located near the eastern margin of the valley floor in the southern portion of White River Valley. The model results indicate that the No Action cumulative pumping scenario would result in a small reduction in flow (up to 3 percent) over the model-simulation period. The model simulations indicate that all of the groundwater development alternatives would result in reduced flow at these springs. These potential flow reductions result from pumping in Cave Valley. The maximum pumping rate in Cave Valley would occur under the Proposed Action and Alternative B and the greatest flow reduction at these springs would occur under Alternative B. The model results indicate that distributed pumping used in Proposed Action would substantially reduce the potential flow reduction in these springs compared to Alternative B. The reduced pumping in Cave Valley in Alternatives A, C, D and E pumping scenarios is anticipated to reduce effects to flows at these springs.

The regional springs that discharge in Pahranagat Valley (i.e., Hiko, Crystal, and Ash Springs) are predicted to experience small flow reductions (up to 4 percent) under the No Action cumulative pumping scenario. These model-simulated flow changes are essentially the same for all of the groundwater development cumulative pumping scenarios indicating that additional reductions in flow resulting from the GWD Project would be negligible for all alternatives.

Muddy River Springs near Moapa is the headwaters for Muddy River and represents the largest groundwater discharge at the lower end of the White River flow system. The predicted reductions in flow at Muddy River Springs are presented in **Figure 3.3.3-9**. The model results predict that groundwater withdrawal included in the No Action cumulative pumping scenario would eventually result in up to 61 percent reduction in flow at the Muddy River Springs.

(Note that the numerical model simulations do not account for the existing Muddy River Memorandum of Agreement regarding groundwater withdrawal in Coyote Spring Valley and California Wash basins, among the SNWA, Moapa Valley Water District, Coyote Spring Investment, Moapa Band of Paiutes, and USFWS, which includes minimum in-stream flow levels. The groundwater model could not address these minimum in-stream flow requirements, thus they are not reflected in the simulation results. Based on the agreement, potential flow reductions under the No Action cumulative pumping scenario are anticipated to be less than those simulated by the model.) Most of the reduction in flow can be attributed to the pumping included under reasonably foreseeable future actions in the region. These model-simulated flow changes are essentially the same for all of the groundwater development cumulative pumping scenarios, indicating negligible additional reductions in flow from the GWD Project for all alternatives.

The flow at Panaca Spring located in Panaca Valley also is expected to experience flow reductions from pumping included in the No Action cumulative pumping scenario; however, the groundwater development pumping would not likely contribute to these flow reductions.

The magnitude of flow changes predicted at Keegan, North Millick, and South Millick Springs in Spring Valley predicted under the cumulative pumping scenarios are similar to those simulated for the project specific effects summarized in Section 3.3.2.

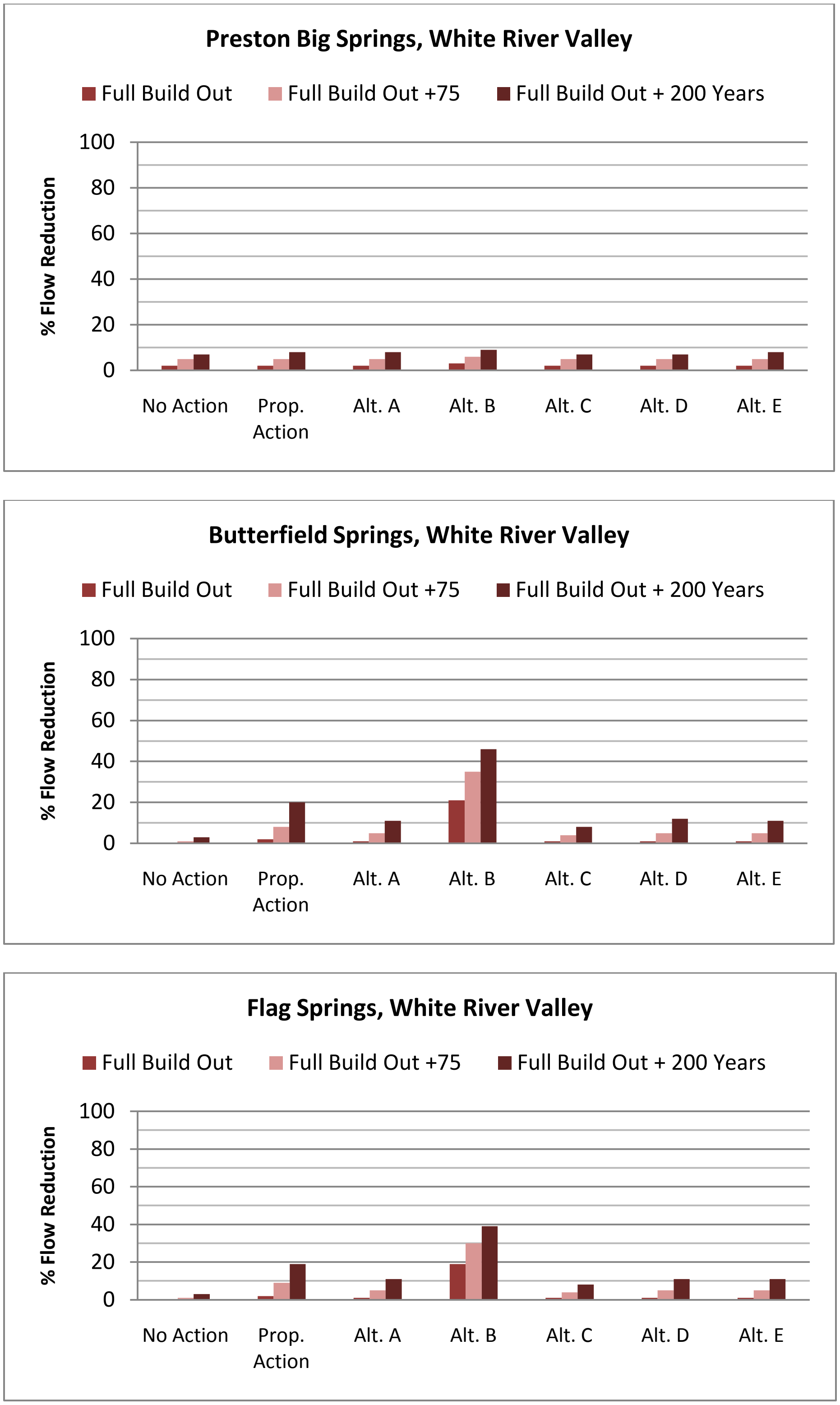


Figure 3.3.3-8 Model-simulated Cumulative Reduction in Flows at Preston Big Springs, Butterfield Springs, and Flag Springs 3, White River Valley

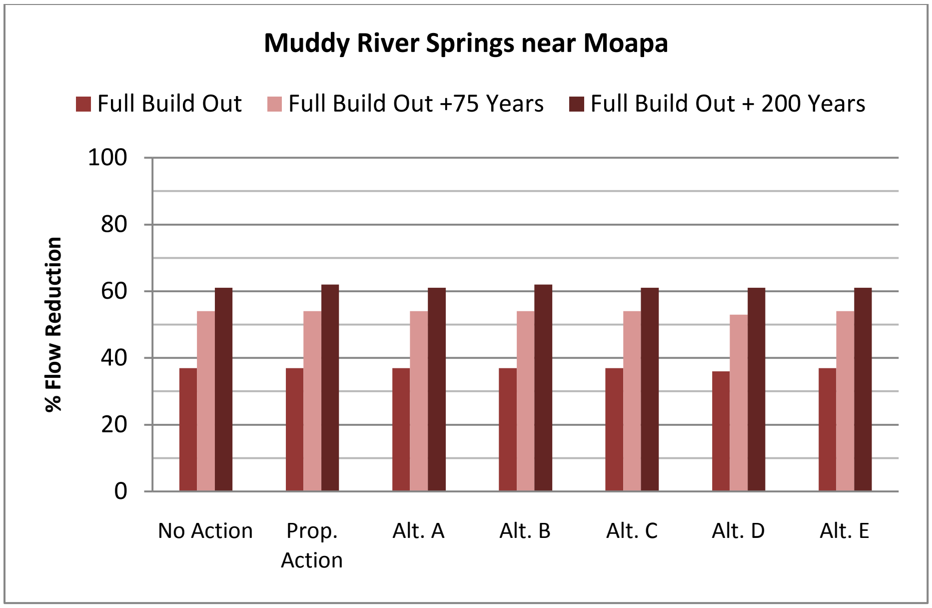


Figure 3.3.3-9 Model-simulated Cumulative Reduction in Flows at Muddy River Springs near Moapa

For Big Springs in Snake Valley, the model simulations results indicate that flow reductions for the No Action cumulative scenario are the same as previously described under the No Action pumping scenario (Section 3.3.2-16). All of the groundwater development alternatives are expected to result in substantial reduction in flow at Big Springs (**Figure 3.3.3-10**). The model simulations indicate that none of the cumulative pumping scenarios would reduce flows in the three other springs simulated in the groundwater model. These springs are located in the central portion of Snake Valley (Foote Reservoir Spring, Kell Spring, and Warm Creek near Gandy).

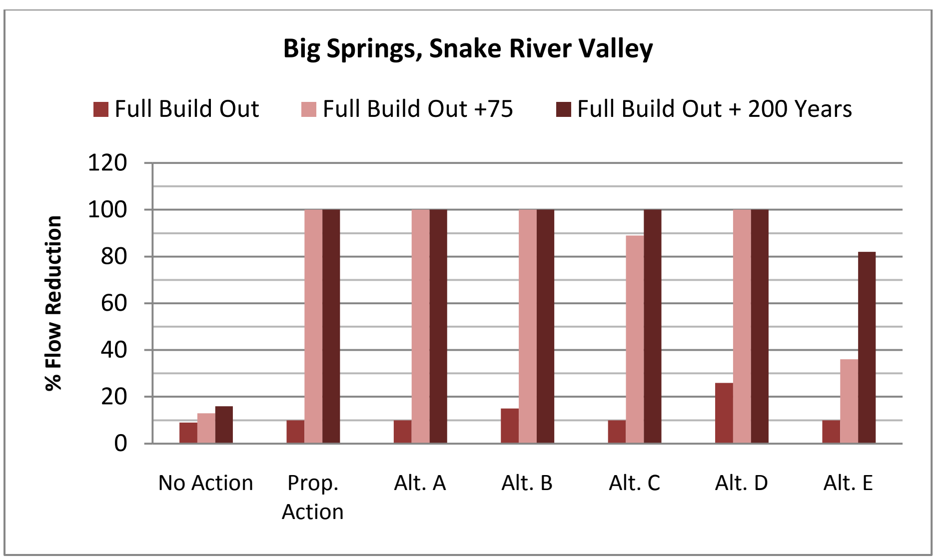


Figure 3.3.3-10 Model-simulated Cumulative Reduction in Flows at Big Springs, Snake Valley

Impacts to Water Rights

The number of surface water rights located in areas where impacts to surface water resources could occur and number of groundwater rights located within the areas where the model simulations indicate drawdown of 10 feet or more are listed in **Table 3.3.3-1**. There are a large number of existing surface water rights located in areas where impacts from drawdown could occur under both the No Action and groundwater development cumulative pumping scenarios. The model results indicate that drawdown for the two alternatives with the largest groundwater withdrawal rate (Proposed Action and Alternative B) could potentially impact the largest number of water rights. The reduced drawdown areas resulting from the other alternatives (Alternatives A through E) would decrease the number of water rights impacted. Potential impacts to individual water rights are the same as discussed under the Proposed Action (Section 3.3.2.9).

Impacts to Water Balance

Potential changes in the water balance for the groundwater system within the region of study were estimated using the groundwater flow model (SNWA 2010b). The estimated reductions in groundwater discharge to the ET areas for selected basins and flow systems are summarized in **Table 3.3.3-1** and illustrated in **Figure 3.3.3-11**. The model simulations indicate that groundwater withdrawal included in the No Action cumulative pumping scenario would have a relatively small effect on the groundwater discharge to ET areas in the Great Salt Lake Desert Flow System. For Spring Valley, the No Action pumping is estimated to result in a 6 and 9 percent reduction of groundwater discharge for ET at the full build out plus 75 years and full build out plus 200 years time frames, respectively. In Snake Valley, the pumping is estimated to result in minimal reductions (<4 percent) of groundwater discharge to support ET.

The Proposed Action would result in the largest reductions in groundwater discharge to the ET areas within Spring and Snake Valleys; with estimated reductions of up to 86 percent in Spring Valley, and up to 35 percent in Snake Valley. For Snake valley, most of the reductions of discharge to areas would occur in the south portion of the valley. The model results indicate that Alternative D would have the least impact to the ET areas in Spring Valley because the pumping is concentrated in the south end of the valley away from much of the ET areas. The concentrated pumping under Alternative D results in the deepest drawdown cone indicating that a higher percentage of the groundwater withdrawn under this scenario is from storage compared to the other groundwater development alternatives. Alternative E would result in the smallest impacts to the ET area in Snake Valley.

As described in Section 3.3.2, the model simulations indicate that the groundwater withdrawal associated with the groundwater pumping alternatives would have a have a minimal effect on amount of groundwater discharged to the ET areas within the White River Flow System. Pumping under the No Action cumulative scenario would not increase the potential reduction of flow to Pine, Wah Wah, and Tule valleys; and Fish Springs previously described for the specific groundwater pumping alternatives.

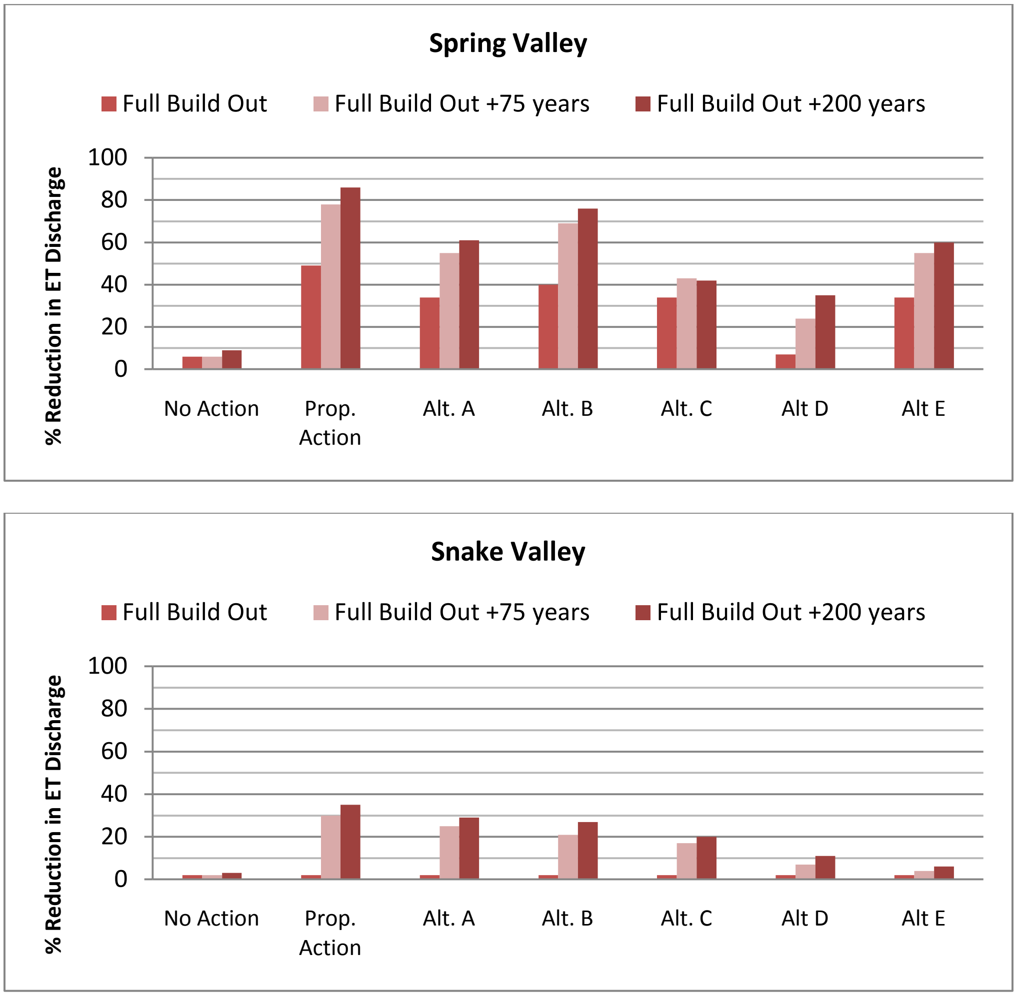


Figure 3.3.3-11 Model-simulated Cumulative Reductions in Groundwater Discharge to Evapotranspiration Areas in Spring and Snake Valleys