percentage of runoff in the GSLDFS. This is consistent with the less permeable rock types (PLUT and BASE) associated with the Snake and Deep Creek ranges.

6.4 Evaluation of Simulated Flow Systems

The flow systems simulated in the numerical model, including interbasin flow, flow regions, and groundwater budget, are discussed in this subsection. The discussion contains many details that are solely based on model interpretation. Modeling results are not unique and may not be representative of reality in many portions of the model domain because of sparse or nonexistent data.

6.4.1 Simulated Interbasin Flow

Simulated interbasin flow between basins (hydrographic areas) for predevelopment and 2004 conditions are presented in Tables 6-12 and 6-13, respectively. The net groundwater flows between flow-system boundaries for predevelopment and 2004 conditions are presented in Table 6-14. Interbasin flow between two given basins represents the net groundwater flow between the two basins. Totals of interbasin flows simply demonstrate the balance of the inflow and outflow components into a given flow system.

The interbasin flow rates simulated by the numerical model (Table 6-14) are shown on Plates 2 and 3. These two plates also illustrate simulated potentiometric surfaces and simulated groundwater flow regions for the shallow (water table) (Plate 2) and regional (carbonate) (Plate 3) portions of the flow system. The shallow portion of the flow system represents the water table, and the deep portion represents the potentiometric surface of the LC3 RMU. The hydraulic heads simulated in the LC3 RMU were selected to represent the regional carbonate aquifer because the LC3 RMU is the most areally-extensive carbonate unit.

As shown on Plates 2 and 3, simulated flow regions differ slightly from the flow-system boundaries adopted in the simplified conceptual model but are within the uncertainty envelope of the conceptual model (SNWA, 2009a). Plates 2 and 3 show that the simulated flow regions differ between the shallow and deep (regional) portions of the flow system. For example, the southeast boundary of Steptoe Valley and southern end of South Goshute Valley show shallow flow regions generally coincident with hydrographic-area boundaries, while the deep flow region extends toward central Steptoe and central South Butte valleys.

Interbasin flows, illustrated on Plates 2 and 3, are calculated for the entire saturated thickness of the numerical model. Therefore, interpretation of the interbasin flows should consider shallow and deep flow-region information and shallow and deep potentiometric surfaces to understand where flows occur across boundaries (i.e., vertically and laterally). Section 6.4.2 provides additional discussion of regional flows simulated by the numerical model.

6.4.2 Simulated Flow Regions

This section describes the characteristics of the flow systems as simulated by the numerical model (see Plates 2 and 3) and compares them to flow systems defined by previous studies. As similarly

Table 6-12
Net Groundwater Flow Between Hydrographic Areas (Steady-State)
(Page 1 of 2)

From Hydrographic Area	Interbasin Flow afy (m^3/d)	To Hydrographic Area
Butte Valley (South)	3,300 (11,300)	Jakes Valley
	5,600 (18,900)	Long Valley
	12,800 (43,200)	Steptoe Valley
Steptoe Valley	500 (1,800)	Tippett Valley
	2,600 (8,800)	Cave Valley
	3,600 (12,200)	Jakes Valley
	4,400 (14,900)	Lake Valley
	8,800 (29,900)	Spring Valley
	15,500 (52,500)	White River Valley
Las Vegas Valley	700 (2,300)	Coyote Spring Valley
	1,000 (3,200)	Garnet Valley
Clover Valley	2,000 (6,900)	Panaca Valley
	5,400 (18,200)	Lower Meadow Valley Wash
Dry Valley	1,900 (6,500)	Panaca Valley
Eagle Valley	0 (100)	Dry Valley
	4,600 (15,400)	Rose Valley
Lake Valley	1,900 (6,400)	Cave Valley
	3,000 (10,000)	Dry Lake Valley
	3,700 (12,500)	Spring Valley
	4,500 (15,100)	Patterson Valley
Lower Meadow Valley Wash	13,600 (45,800)	Lower Moapa Valley
Panaca Valley	800 (2,700)	Lower Meadow Valley Wash
Patterson Valley	200 (500)	Eagle Valley
	800 (2,700)	Dry Valley
	1,600 (5,400)	Dry Lake Valley
	9,500 (32,000)	Panaca Valley
Rose Valley	4,300 (14,500)	Dry Valley
Spring Valley	700 (2,300)	Patterson Valley
	800 (2,700)	Lake Valley
	1,500 (5,000)	Hamlin Valley
	3,700 (12,500)	Eagle Valley
Fish Springs Flat	2,300 (7,600)	Snake Valley
Hamlin Valley	0 (0)	Dry Valley
	100 (200)	Eagle Valley
	29,400 (99,300)	Snake Valley
Pleasant Valley	0 (0)	Spring Valley
	4,400 (14,800)	Snake Valley

Table 6-12
Net Groundwater Flow Between Hydrographic Areas (Steady-State)
(Page 2 of 2)

From Hydrographic Area	Interbasin Flow afy (m^3/d)	To Hydrographic Area
Spring Valley	7,600 (25,700)	Hamlin Valley
	11,800 (40,000)	Snake Valley
Tippett Valley	0 (0)	Pleasant Valley
	2,000 (6,900)	Spring Valley
California Wash	700 (2,300)	Black Mountains Area
	1,600 (5,500)	Lower Meadow Valley Wash
	4,100 (13,900)	Lower Moapa Valley
Cave Valley	1,300 (4,300)	Dry Lake Valley
	1,600 (5,300)	Pahroc Valley
	17,100 (57,700)	White River Valley
Coal Valley	10,800 (36,400)	Pahroc Valley
	29,200 (98,600)	Pahranagat Valley
Coyote Spring Valley	2,400 (8,000)	Hidden Valley (North)
	49,200 (166,200)	Muddy River Springs Area
Delamar Valley	0 (100)	Lower Meadow Valley Wash
	27,300 (92,300)	Pahranagat Valley
	2,400 (8,114)	Coyote Spring Valley
Dry Lake Valley	100 (400)	Panaca Valley
	300 (1,200)	Lower Meadow Valley Wash
	900 (3,000)	Pahroc Valley
	21,800 (73,500)	Delamar Valley
Garden Valley	25,300 (85,300)	Coal Valley
Garnet Valley	3,400 (11,300)	California Wash
Hidden Valley (North)	3,000 (10,000)	Garnet Valley
Jakes Valley	19,600 (66,200)	White River Valley
Kane Springs Valley	200 (800)	Delamar Valley
	1,800 (6,000)	Coyote Spring Valley
	2,000 (6,800)	Lower Meadow Valley Wash
Long Valley	2,000 (6,700)	Jakes Valley
Lower Moapa Valley	9,300 (31,400)	Black Mountains Area
Muddy River Springs Area	2,500 (8,600)	Lower Meadow Valley Wash
	8,600 (29,200)	California Wash
Pahranagat Valley	41,700 (140,700)	Coyote Spring Valley
Pahroc Valley	25,700 (86,900)	Pahranagat Valley
White River Valley	3,200 (10,700)	Garden Valley
	7,300 (24,500)	Pahroc Valley
	9,800 (33,200)	Coal Valley

Table 6-13
Net Groundwater Flow Between Hydrographic Areas (2004)
(Page 1 of 2)

From Hydrographic Area	Interbasin Flow afy (m^3/d)	To Hydrographic Area
Butte Valley (South)	3,300 (11,300)	Jakes Valley
	5,600 (18,900)	Long Valley
	12,800 (43,400)	Steptoe Valley
Steptoe Valley	500 (1,700)	Tippett Valley
	2,600 (8,800)	Cave Valley
	3,600 (12,200)	Jakes Valley
	4,400 (14,900)	Lake Valley
	8,800 (29,600)	Spring Valley
	15,500 (52,300)	White River Valley
Las Vegas	700 (2,300)	Coyote Spring Valley
	1,100 (3,600)	Garnet Valley
	1,100 (3,700)	Black Mountains Area
Clover Valley	2,100 (7,100)	Panaca Valley
	5,500 (18,700)	Lower Meadow Valley Wash
Dry Valley	1,900 (6,400)	Panaca Valley
Eagle Valley	0 (100)	Dry Valley
	4,800 (16,200)	Rose Valley
Lake Valley	1,700 (5,900)	Patterson Valley
	1,900 (6,300)	Cave Valley
	2,900 (9,700)	Dry Lake Valley
	3,700 (12,300)	Spring Valley
Lower Meadow Valley Wash	13,100 (44,100)	Lower Moapa Valley
Panaca Valley	900 (3,100)	Lower Meadow Valley Wash
Patterson Valley	200 (500)	Eagle Valley
	800 (2,900)	Dry Valley
	1,600 (5,300)	Dry Lake Valley
	9,400 (31,900)	Panaca Valley
Rose Valley	4,500 (15,200)	Dry Valley
Spring Valley	700 (2,300)	Patterson Valley
	800 (2,700)	Lake Valley
	1,500 (5,000)	Hamlin Valley
	3,800 (12,800)	Eagle Valley
Fish Springs Flat	2,300 (7,600)	Snake Valley
Hamlin Valley	0 (0)	Dry Valley
	100 (300)	Eagle Valley
	30,100 (101,600)	Snake Valley
Pleasant Valley	0 (0)	Spring Valley
	4,400 (14,800)	Snake Valley

Table 6-13
Net Groundwater Flow Between Hydrographic Areas (2004)
(Page 2 of 2)

From Hydrographic Area	Interbasin Flow afy (m^3/d)	To Hydrographic Area
Spring Valley	7,600 (25,600)	Hamlin Valley
	11,800 (40,000)	Snake Valley
Tippett Valley	0 (0)	Pleasant Valley
	2,100 (6,900)	Spring Valley
California Wash	800 (2,600)	Black Mountains Area
	1,900 (6,300)	Lower Meadow Valley Wash
	4,100 (13,800)	Lower Moapa Valley
Cave Valley	1,300 (4,400)	Dry Lake Valley
	1,600 (5,300)	Pahroc Valley
	17,100 (57,700)	White River Valley
Coal Valley	10,900 (36,800)	Pahroc Valley
	29,400 (99,300)	Pahranagat Valley
Coyote Spring Valley	2,400 (8,000)	Hidden Valley (North)
	50,000 (168,900)	Muddy River Springs Area
Delamar Valley	0 (100)	Lower Meadow Valley Wash
	27,300 (92,400)	Pahranagat Valley
	2,400 (8,114)	Coyote Spring Valley
Dry Lake Valley	200 (600)	Panaca Valley
	300 (1,200)	Lower Meadow Valley Wash
	900 (3,100)	Pahroc Valley
	21,800 (73,500)	Delamar Valley
Garden Valley	25,300 (85,400)	Coal Valley
Garnet Valley	3,300 (11,300)	California Wash
Hidden Valley (North)	3,100 (10,500)	Garnet Valley
Jakes Valley	19,700 (66,400)	White River Valley
Kane Springs Valley	200 (800)	Delamar Valley
	1,800 (6,100)	Coyote Spring Valley
	2,000 (6,800)	Lower Meadow Valley Wash
Long Valley	2,000 (6,700)	Jakes Valley
Lower Moapa Valley	9,300 (31,400)	Black Mountains Area
Muddy River Springs Area	2,100 (7,200)	Lower Meadow Valley Wash
	8,300 (27,900)	California Wash
Pahranagat Valley	41,700 (140,700)	Coyote Spring Valley
Pahroc Valley	26,000 (87,700)	Pahranagat Valley
White River Valley	3,200 (10,700)	Garden Valley
	7,300 (24,500)	Pahroc Valley
	9,800 (33,200)	Coal Valley

Table 6-14
Net Groundwater Flow Between Flow Systems

From Flow System	Net Groundwater Flow (Predevelopment) afy (m^3/d)	Net Groundwater Flow (2004) afy (m^3/d)	To Flow System	Comment
Goshute Valley	4,400 (14,900)	4,400 (14,900)	Meadow Valley	Steptoe Valley to Lake Valley
	9,400 (31,600)	9,300 (31,300)	Great Salt Lake Desert	Steptoe Valley to Spring Valley (HA 184); Steptoe Valley to Tippet Valley
	30,700 (103,700)	30,600 (103,500)	White River	Butte Valley to Jakes Valley; Steptoe Valley to Jakes Valley; Steptoe Valley to White River Valley; Steptoe Valley to Cave Valley
Las Vegas Valley	2,800 (9,300)	3,300 (11,100)	White River	Las Vegas Valley to Coyote Springs Valley, Hidden Valley (North), Garnet Valley, and Black Mountains Area
Meadow Valley Wash	5,200 (17,600)	5,200 (17,400)	Great Salt Lake Desert	Lake Valley to Spring Valley (HA 184); Spring Valley (HA 201) to Hamlin Valley
	13,700 (46,100)	13,100 (44,200)	White River	Meadow Valley Wash to Lower Moapa Valley, and Muddy River Springs Area; Patterson Valley to Dry Lake Valley; Lake Valley to Dry Lake Valley; Lake Valley to Cave Valley

stated by Prudic et al. (1995), it is important to recognize that even though the simulated directions and amounts of groundwater flow are provided in detail in Plates 2 and 3, they constitute but one solution to groundwater flow within the model domain. Because data are scarce in the model area, groundwater flow patterns and, therefore, flow-system boundaries, are uncertain. In fact, several interpretations exist as described by SNWA (2009a). The conceptualization resulting from the CCRP model is discussed for the following flow systems: Great Salt Lake Desert, Goshute Valley and Newark Valley, Meadow Valley, White River, and Las Vegas.

6.4.2.1 Great Salt Lake Desert Flow System

The GSLDFS is simulated to predominantly include Tippett, Pleasant, Spring, Snake, a portion of Lake, and Hamlin valleys hydrographic areas. The characteristics of the simulated GSLDFS shown in Plates 2 and 3 are as follows:

- Simulated groundwater recharge is derived from precipitation dominantly on the Schell Creek, Snake, and Deep Creek ranges with lesser amounts derived on the White Rock Mountains and Indian Peak Range above Hamlin Valley.

- Simulated groundwater discharge to the surface occurs both in the form of ET and spring flow throughout the flow system. Simulated groundwater ET occurs in Spring and Snake valleys and to a lesser degree in Tippett and Hamlin valleys.

- Simulated outflow occurs at northern Tippett Valley, at northern Snake Valley, out of Snake Valley at the southern Confusion Range, out of Snake Valley to Wah Wah Valley, and out of Snake Valley to Pine Valley.

The simulated flow patterns and flow-system boundaries are very similar to those described in BARCASS (Welch et al., 2008) and in the RASA model (Prudic et al., 1995) but are somewhat different from the interpretations of Harrill et al. (1988) and Eakin (1966).

6.4.2.2 Goshute Valley and Newark Valley Flow Systems

The GVFS is simulated to predominantly include the northern part of South Butte Valley and most of Steptoe Valley. The Newark Valley Flow System is simulated to predominantly include the southern part of South Butte Valley, Long Valley, and northern Jakes Valley. The characteristics of the simulated GVFS and Newark Valley Flow System shown in Plates 2 and 3 are as follows:

- Much of the groundwater recharge in these flow systems is derived from precipitation predominantly on the Cherry Creek, northern Egan, and White Pine ranges and the Butte Mountains.

- Simulated groundwater discharge in the GVFS occurs both in the form of ET and spring flow. Simulated ET occurs along the valley bottom throughout Steptoe Valley and northern Butte Valley South. Simulated groundwater discharge in the Newark Valley Flow System occurs predominantly in the form of ET in southern Butte Valley South and Long Valley.

- Simulated outflow from the GVFS occurs at northern South Butte Valley and at northern Steptoe Valley. Simulated outflow from the Newark Valley Flow System occurs at northern Long Valley and at southwestern Long Valley.

- The simulated flow patterns and flow-system boundaries are somewhat different from those described by Harrill and Prudic (1998). They are, however, similar to those described by Bedinger and Harrill (2004) and Welch et al. (2008). Similarities also exist with the CRP model (Prudic et al., 1995) in the northwestern part of the CCRP model domain.

6.4.2.3 Meadow Valley Flow System

The MVFS is located in the southeastern part of the CCRP model domain. The simulated MVFS includes a small part of southern Lake Valley and all or most of Dry, Rose, Eagle, Spring (HA 201), Patterson, Panaca, Clover, and Lower Moapa valleys, and Lower Meadow Valley Wash. Only the southernmost portion of Lake Valley is simulated as part of the MVFS. The general characteristics of the simulated MVFS shown in Plates 2 and 3 are as follows:

- Much of the groundwater recharge is derived from precipitation on the White Rock Mountains, the Wilson Creek Range, and the Clover Mountains.

- Simulated groundwater discharge occurs both as ET and spring flow along Meadow Valley Wash.
- Groundwater flowpaths are predominantly toward and along Meadow Valley Wash. Groundwater outflow is to Lower Moapa Valley and the Muddy River Springs Area.
- Simulated groundwater flow patterns are very similar to those described by Bedinger and Harrill (2004) and those simulated by Prudic et al. (1995) in the CRP model.

6.4.2.4 White River Flow System

The WRFS is located in the western part of the CCRP model domain. The simulated WRFS predominantly includes Jakes, White River, Cave, Garden, Coal, Pahroc, Dry Lake, Pahranagat, Delamar, Kane Springs, Coyote Spring, Hidden (North), and Garnet valleys and Muddy River Springs Area, California Wash, parts of South Butte Valley, Steptoe Valley, Lower Moapa Valley, and the Black Mountains Area. The general characteristics of the simulated WRFS shown in Plates 2 and 3 are as follows:

- Groundwater recharge is derived from precipitation predominantly on the White Pine, Egan, Schell Creek, Quinn Canyon, Seaman, Bristol and Sheep ranges with lesser amounts derived from the Delamar Mountains and Hiko, Pahranagat, and Pahroc ranges.
- Simulated groundwater discharge to the surface occurs both by ET and spring flow throughout the flow system. The largest areas of simulated ET occur along the valley bottom in White River Valley and along Pahranagat Wash in Pahranagat Valley.
- Flowpaths from the WRFS ultimately converge with groundwater flow from the MVFS at Muddy River that is either discharged to the river or evapotranspired into Lower Moapa Valley. Outflow is from the Muddy River Springs Area to Lower Moapa, the Black Mountains Area to Lake Mead, from Garden Valley to Penoyer Valley, and from Pahranagat Valley to Tikaboo Valley South.
- Flow patterns in the northern part of the WRFS are comparable to interpretations in BARCASS (Welch et al., 2008). As simulated, shallow flowpaths in Lake Valley contribute flow to the WRFS, and deep flowpaths in Lake Valley contribute flow to the GSLDFS.

6.4.2.5 Las Vegas Groundwater Basin

The extreme southern end of the CCRP model domain contains an area of simulated flow that originates predominantly as recharge on the Sheep Range. This groundwater flows east to southeast along the model boundary at the Las Vegas Valley Shear Zone and ultimately discharges to Las Vegas Valley or as spring flow at Rogers and Blue Point springs or as outflow to Lake Mead through the Black Mountains Area.

6.4.3 Simulated Groundwater-Budget Components

The large areal extent of the numerical model and the large uncertainties associated with external boundary conditions preclude a comprehensive and accurate assessment of all groundwater inflows and outflows. As a result, comparing the simulated volumetric budget to conceptual groundwater-budget estimates is difficult. Thus, when evaluating the groundwater budget, it is important to note that significant uncertainties still exist with regard to the groundwater-budget components of the flow system, including external boundary flows, groundwater discharge, and indirectly, groundwater recharge. A discussion of the simulated groundwater budget, however, is warranted.

Tables 6-15 and 6-16 list the simulated groundwater budget for the model area for the steady-state and 2004 stress periods. The budgets are organized by hydrographic area and flow system. A grand total for the model domain is also provided. Groundwater-inflow components are positive values; groundwater-outflow components are negative values.

As shown in Table 6-15, totals of interbasin-flow components are provided only to demonstrate the balance of in and out components.

As shown in Table 6-15, Constant Head is the net groundwater flow through external boundaries in each hydrographic area and flow system. ET and Springs is the discharge from ET zones and springs in each hydrographic area and flow system. Recharge is the total recharge (sum of in-place and runoff recharge components) in each hydrographic area and flow system. Stream Flow is the net groundwater flow from stream flow routing cells in each hydrographic area and flow system.

6.5 Summary of Model Calibration Evaluation

The results presented in this section suggest that the numerical model reproduces the measured hydraulic heads and estimated groundwater-budget components reasonably accurately but with noted levels of uncertainty. In addition, the estimated parameter values are reasonable. The *K* distribution patterns are generally consistent with the conceptual model. The transmissivities across the model area, while high in some locations, are reasonable.

Because the weighted residuals are not entirely random, some model error is indicated. This is mostly related to the occurrence of large positive-weighted residuals for some hydraulic-head observations located predominantly in large hydraulic-gradient areas and large weighted residuals for intermediate spring discharge and groundwater discharges in areas such as Pahranagat Valley. These errors are largely the result of sparse data and the way in which these areas relate to the regional flow system.

In addition, weighted residuals are not normally distributed. Previous groundwater modeling exercises in other parts of the southern Great Basin (D'Agnese et al., 1997, 2002; Faunt et al., 2004) suggest that additional calibration and reduction in conceptual model uncertainty may significantly improve model accuracy. This analysis suggests that the numerical model is a reasonable representation of the physical system, but evidence of model error exists.

Table 6-15
Simulated Groundwater-Budget Components Organized by Hydrographic Area

HA Number and Name	Net Interbasin Flow	Change in Storage	Groundwater Withdrawals	Constant Head	ET and Springs	Recharge	Stream Flow
	afy						
178B Butte Valley (South)	-21,700	0	0	-500	-8,900	31,100	0
179 Steptoe Valley	-22,800	0	0	-2,100	-88,700	113,600	0
Goshute Valley Total	**-44,500**	**0**	**0**	**-2,600**	**-97,600**	**144,700**	**0**
212 Las Vegas Valley	-2,800	0	0	0	0	2,800	0
Las Vegas Valley Total	**-2,800**	**0**	**0**	**0**	**0**	**2,800**	**0**
183 Lake Valley	-7,900	0	---	0	-2,400	10,400	0
198 Dry Valley	3,200	0	---	0	-4,800	1,600	0
199 Rose Valley	300	0	---	0	-400	100	0
200 Eagle Valley	-700	0	---	0	-400	1,100	0
201 Spring Valley	-6,700	0	---	0	-700	7,400	0
202 Patterson Valley	-6,900	0	---	0	0	6,900	0
203 Panaca Valley	12,800	0	---	0	-20,800	8,000	0
204 Clover Valley	-7,400	0	---	0	-1,900	9,400	0
205 Lower Meadow Valley Wash	-1,100	0	---	0	-14,600	15,700	0
Meadow Valley Total	**-14,400**	**0**	**0**	**0**	**-46,000**	**60,600**	**0**
184 Spring Valley	-4,900	0	0	0	-77,700	82,600	0
185 Tippett Valley	-1,500	0	0	-4,200	0	5,700	0
194 Pleasant Valley	-4,400	0	0	0	0	4,400	0
195 Snake Valley	47,900	0	0	-31,900	-122,600	106,900	-200
196 Hamlin Valley	-20,300	0	0	0	-800	21,100	0
258 Fish Springs Flat	-2,300	0	0	2,200	0	100	0
Great Salt Lake Desert Total	**14,500**	**0**	**0**	**-33,900**	**-201,100**	**220,800**	**-200**
171 Coal Valley	-4,900	0	0	0	0	4,900	0
172 Garden Valley	-22,100	0	0	-2,300	0	24,300	0
174 Jakes Valley	-10,700	0	0	0	0	10,700	0
175 Long Valley	3,600	0	0	-13,500	-800	10,700	0
180 Cave Valley	-15,400	0	0	0	0	15,400	0
181 Dry Lake Valley	-17,300	0	0	0	0	17,300	0
182 Delamar Valley	-7,500	0	0	0	0	7,500	0
206 Kane Springs Valley	-4,000	0	0	0	0	4,000	0
207 White River Valley	32,000	0	0	0	-73,100	41,100	0
208 Pahroc Valley	-5,500	0	0	0	0	5,500	0
209 Pahranagat Valley	40,600	0	0	-9,500	-23,000	6,100	-14,200
210 Coyote Spring Valley	-5,700	0	0	2,000	0	3,700	0
215 Black Mountains Area	11,600	0	0	-7,500	-2,100	0	-2,000
216 Garnet Valley	-200	0	0	0	0	200	0
217 Hidden Valley (North)	-200	0	0	0	0	200	0
218 California Wash	6,400	0	0	0	-7,500	0	1,200
219 Muddy River Springs Area	38,000	0	0	0	-4,200	100	-33,900
220 Lower Moapa Valley	8,400	0	0	-6,700	-21,300	100	19,500
White River Total	**47,100**	**0**	**0**	**-37,500**	**-132,000**	**151,800**	**-29,400**
Grand Total	**-100**	**0**	**0**	**-74,000**	**-476,700**	**580,700**	**-29,600**

Table 6-16
Simulated Groundwater-Budget Components Organized by Hydrographic Area (2004)

HA Number and Name	Net Interbasin Flow	Change in Storage	Groundwater Withdrawals	Constant Head	ET and Springs	Recharge	Stream Flow
	afy						
178B Butte Valley (South)	-21,800	0	-200	-500	-8,800	31,100	0
179 Steptoe Valley	-22,600	2,500	-11,900	-2,100	-79,600	113,600	0
Goshute Valley Total	**-44,400**	**2,500**	**-12,100**	**-2,600**	**-88,400**	**144,700**	**0**
212 Las Vegas Valley	-3,300	500	0	0	0	2,800	0
Las Vegas Valley Total	**-3,300**	**500**	**0**	**0**	**0**	**2,800**	**0**
183 Lake Valley	-5,000	10,600	-13,600	0	-2,400	10,400	0
198 Dry Valley	3,500	300	-3,500	0	-1,900	1,600	0
199 Rose Valley	300	100	-400	0	-100	100	0
200 Eagle Valley	-800	100	-100	0	-200	1,100	0
201 Spring Valley	-6,800	100	0	0	-700	7,400	0
202 Patterson Valley	-9,700	6,000	-3,300	0	0	6,900	0
203 Panaca Valley	12,700	4,900	-9,300	0	-16,400	8,000	0
204 Clover Valley	-7,600	300	-200	0	-1,800	9,400	0
205 Lower Meadow Valley Wash	-500	800	-3,100	0	-13,000	15,700	0
Meadow Valley Total	**-13,900**	**23,200**	**-33,500**	**0**	**-36,500**	**60,600**	**0**
184 Spring Valley	-4,900	2,000	-5,600	0	-74,100	82,600	0
185 Tippett Valley	-1,600	0	0	-4,200	0	5,700	0
194 Pleasant Valley	-4,400	0	0	0	0	4,400	0
195 Snake Valley	48,600	2,800	-21,600	-31,800	-104,700	106,900	-200
196 Hamlin Valley	-21,000	600	0	0	-700	21,100	0
258 Fish Springs Flat	-2,300	0	0	2,200	0	100	0
Great Salt Lake Desert Total	**14,400**	**5,400**	**-27,200**	**-33,800**	**-179,500**	**220,800**	**-200**
171 Coal Valley	-5,200	300	0	0	0	4,900	0
172 Garden Valley	-22,100	0	0	-2,200	0	24,300	0
174 Jakes Valley	-10,700	0	0	0	0	10,700	0
175 Long Valley	3,600	0	0	-13,500	-800	10,700	0
180 Cave Valley	-15,500	0	0	0	0	15,400	0
181 Dry Lake Valley	-17,500	100	0	0	0	17,300	0
182 Delamar Valley	-7,500	0	0	0	0	7,500	0
206 Kane Springs Valley	-4,000	0	0	0	0	4,000	0
207 White River Valley	32,000	3,400	-10,900	0	-65,600	41,100	0
208 Pahroc Valley	-5,700	100	0	0	0	5,500	0
209 Pahranagat Valley	41,100	400	-2,800	-9,500	-21,800	6,100	-13,500
210 Coyote Spring Valley	-6,500	800	0	2,000	0	3,700	0
215 Black Mountains Area	12,100	1,200	-1,700	-7,400	-2,100	0	-2,000
216 Garnet Valley	100	700	-1,000	0	0	200	0
217 Hidden Valley (North)	-300	200	0	0	0	200	0
218 California Wash	5,700	400	0	0	-7,500	0	1,400
219 Muddy River Springs Area	39,600	700	-8,100	0	-2,100	100	-30,200
220 Lower Moapa Valley	7,800	100	-2,700	-6,700	-20,900	100	22,200
White River Total	**47,000**	**8,400**	**-27,200**	**-37,300**	**-120,800**	**151,800**	**-22,100**
Grand Total	**-200**	**40,000**	**-100,000**	**-73,700**	**-425,200**	**580,700**	**-22,300**

Some of the simulated flow-system boundaries in the calibrated transient numerical model are similar to those described in BARCASS (Welch et al., 2008) and in the RASA model (Prudic et al., 1995). They do differ, however, from the interpretations of Harrill et al. (1988) and Eakin (1966) adopted in the simplified conceptual model as described in Sections 3.0 and 5.0. Because of the lack of regional data in the northwestern region of the model area, particularly in Jakes Valley, and the uncertainty associated with the recharge estimate, different interpretations of flow patterns and, therefore, flow-system boundaries are possible. This area of the model is located a significant distance away from the Project basins, and the locations of these flow-system boundaries should not affect the EIS analysis for which the numerical model is intended. Previous studies like Belcher (2004), for example, have shown that drawdowns are mostly sensitive to the hydraulic properties of the aquifers. The distribution of hydraulic conductivities derived from this model appears to be reasonable.

7.0 MODEL LIMITATIONS AND UNCERTAINTIES

The numerical model contains the most up-to-date representation of hydrogeologic data for the Central Carbonate-Rock Province of the Great Basin region. However, it is still a model covering a vast portion of remote Nevada where data are limited. This lack of data causes limitations and uncertainties in values simulated by the numerical model. These limitations and uncertainties are common for models developed in this region, as the DVRFS model describes many of the same (Belcher, 2004). Uncertainties are unavoidable but can be reduced with additional data collected in the future. Inherent model limitations result from uncertainty in five basic aspects of the model, including inadequacies in (1) the hydrogeologic framework, (2) the precipitation recharge, (3) the historical anthropogenic data, (4) the observations, and (5) the representation of hydrologic conditions. These limitations are disclosed below.

7.1 Hydrogeologic Framework

Accurate simulation of many of the important flow-system characteristics depends on an accurate understanding and representation of the hydrogeologic framework. Limitations exist in the numerical model because of the difficulties inherent in the interpretation and representation of the complex geometry and spatial variability of hydrogeologic materials and structures in a hydrogeologic framework and numerical model. The hydrogeologic framework is further complicated by the lack of data within the model area.

7.1.1 Complex Geometry

Geometric complexity of hydrogeologic materials and structures is apparent throughout the model domain. Notable large-scale examples that have a significant effect on regional groundwater flow are (1) the fault system at the Muddy River Springs Area, (2) the lateral faults of the Pahranagat Shear Zone, and (3) the calderas of the Caliente Caldera complex.

A system of apparent regional-scale normal and lateral faults likely provides the mechanisms for groundwater discharge at the Muddy River Springs Area. The complexity of this system is not fully known; however, the current understanding suggests that the hydrogeologic framework represented in the model is grossly simplified because of the coarse numerical model resolution.

Regional-scale lateral faults associated with the Pahranagat shear zone give rise to hydrogeologic features that contribute to a generally southward stair-stepping of the regional water table. The lack of available knowledge on this fault system adds uncertainty to the simulation of directions and quantities of groundwater flow out of Pahranagat Valley.

East and northeast of the Pahranagat shear zone, a series of calderas and intracaldera intrusions cause regional discontinuities in the flow system. The complex geometries associated with these calderas are not fully known and cause uncertainties in simulating the regional, large-hydraulic gradient coincident with these volcanic features.

7.1.2 Complex Spatial Variability

As with complex hydrogeologic geometries, spatial variability of material properties of the hydrogeologic units and structures is also a limitation in the CCRP model. The assumption of homogeneity within a given RMU in the hydrogeologic framework model, or hydraulic-conductivity parameter zone in the numerical model, limits the simulation by removing the potential effects of variability in grain-size distribution, degree of welding, and fracture density and orientation. This limitation is the direct result of data limitations and simplifications due to hydrogeologic framework and flow model construction and discretization.

The LVF RMU is a good example of a hydrogeologic unit that has significant spatial variability. This highly heterogeneous unit consists of (1) older Tertiary sediments, which possess varying grain-size distributions and degrees of lithification and (2) Tertiary volcanic rocks, which possess units of varying composition, degrees of welding, and hydrothermal alterations. These heterogeneities, which can affect hydraulic properties and consequently groundwater flow, cannot be represented in the hydrogeologic framework and numerical models. In fact, many of the limitations of the simulation within the Caliente Caldera complex and related calderas are in part due to the underrepresentation of local-scale hydrogeologic complexities in the regional-scale hydrogeologic framework and numerical models.

7.1.3 Hydrogeologic Model Representation

Discretization and abstraction of the physical hydrogeologic framework impose limitations on all components of the hydrogeologic framework and numerical models. While the 3,281 ft (1,000 m) resolution is appropriate to represent regional-scale conditions, it presents difficulty in accurately simulating areas of geologic complexity. The grid cells tend to generalize important local-scale complexities that have an impact on regional hydrologic conditions. This situation is particularly prevalent in large-hydraulic-gradient areas where sharp geologic contacts or local-scale fault characteristics can influence regional hydraulic heads and groundwater discharges. The current level of understanding of the geology throughout the model area does not warrant a higher-resolution regional flow model at this time.

7.2 Precipitation Recharge

Limitations in precipitation recharge stem from the approximate methods used to estimate recharge and the assumption that the effects of climate variability on recharge are negligible.

Groundwater recharge cannot be measured directly in the field for areas as large as the model area. Furthermore, groundwater recharge is spatially and temporally variable. The yearly rates and spatial distribution of the mean recharge were estimated through model calibration. Although a solution was obtained in this manner, the actual annual rates and particularly the spatial distribution of recharge remain very uncertain. Another source of uncertainty is the assumption that recharge does not vary with time. This assumption constitutes an important limitation, particularly in the simulations of the groundwater development scenarios. Under this assumption, potential variations in recharge due to climate change or the lowering of the water table by pumping, for example, cannot be simulated.

Climate variability over the course of the simulation affects precipitation and therefore groundwater recharge. The numerical model simulates a constant average recharge from precipitation rates averaged over 30 years (PRISM normal precipitation grid) and does not consequently account for climate variability over the simulation period.

7.3 Historical Anthropogenic Data

No historical groundwater-pumping or surface-water diversion records from which historical stress data sets can be derived exist for most of the hydrographic areas in the model area. Therefore, the historical anthropogenic data sets were estimated from the available information. The estimation process has important limitations leading to uncertainties in the data set.

As historical records of actual groundwater use are sparse, the consumptive water-use estimates were derived using estimates of consumptive water use based on water-rights information obtained from NDWR and the Utah Division of Water Rights (UDWR). Reported groundwater-production or surface-water diversion data were used where available to support the estimation process.

In many of the croplands, irrigation with groundwater could not be clearly identified because irrigation water is supplied by both surface water and groundwater. In these areas, groundwater is commonly pumped to supplement surface-water sources used to irrigate crops. This adds another layer of complexity to estimating groundwater use in that supplemental groundwater pumping generally only occurs when conditions warrant it, such as in low runoff years.

7.4 Observations

Hydraulic-head and groundwater-discharge observations constrain model calibration through the parameter-estimation process; therefore, uncertainty in these observations results in uncertainty in the numerical model. All available hydraulic-head-observation data were thoroughly analyzed prior to and throughout the calibration process. However, uncertainty still exists in (1) the quality of the observation data, (2) the appropriateness of the hydrogeologic interpretations, and (3) the way in which the observation was represented in the numerical model.

7.4.1 Quality of Observations

The sparse distribution and high concentration, or clustering, of hydraulic- head observations are numerical model limitations. Because available data in the overall region are scarce and available multiple observations in isolated areas are overemphasized, biasing occurs in those parts of the model. Water-level-data scarcity is particularly noticeable in Long, Jakes, Coal, Garden, Dry Lake, and Delamar valleys and Lower Meadow Valley Wash because of the lack of wells in those valleys.

High clustering of observations occurs along riparian areas of Pahranagat Wash, Meadow Valley Wash, and the Muddy River. A declustering method was used to address this situation; however, this declustering only applies to situations where multiple water levels occur in a given model cell.

7.4.2 Interpretation of Observations

It is difficult to determine whether hydraulic-head observations represent regional versus perched or localized conditions. Field testing is often not sufficient to distinguish conclusively between regional or localized conditions. The data necessary to determine unequivocally the presence of perched or local groundwater are rarely, if ever, available. Because large simulated hydraulic-head residuals in recharge areas often suggest the possibility of perched water, either the hydraulic-head observations in this category were removed or the observation weight was decreased. Fewer observations, or observations with lower weights, result in higher uncertainty in the numerical model.

Large-hydraulic-gradient areas also are difficult to interpret. Limited water-level data in these areas exacerbate the situation. Hydraulic-head observations defining large hydraulic gradients are also typically associated with perched or localized water.

The model also does not account for climate variability over the course of the simulation. Approximately 6 percent of the water-level hydrographs and 16 percent of the hydraulic-head or drawdown observations in the model are clearly influenced by climate variability. The majority of these (85 out of 112 climate-affected wells and 919 out of 1,225 observations) occur in Steptoe Valley. These wells and their associated observations however, only occur in isolated geographic locations within Steptoe Valley and occur within the time period of an extremely wet cycle in the region. The value of, or the ability to, extrapolate this climate variability information to the remainder of the 1,751 wells and 6,322 hydraulic-head and drawdown observations was not practical or considered valuable.

Accurate groundwater-discharge estimates for many of the springs and ET areas are not available and are thus numerical model limitations. Higher quality, spatially distributed, groundwater-discharge observations for the region only began to be collected in 2002 (SNWA, 2008; SNWA 2009a; Welch et al., 2008). The lack of estimates as well as the variability in the estimates, based on long-term data, limits how well these groundwater-discharge areas and related areas can be simulated. In addition, the assumptions necessary to use present-day groundwater discharge to approximate predevelopment groundwater-discharge conditions may introduce error. Reliable historical groundwater-discharge estimates are an unrecoverable data gap in the model that will add uncertainty to any groundwater flow simulation of this region.

7.4.3 Representation of Observations

Although the volumetric discharge from ET is reasonably matched, the model does not accurately simulate the areas where ET occurs. This is due to the limitations associated with the representation of groundwater ET areas in the model, including the course resolution and the setup of the drains.

Simulating small discharge volumes less than 296 afy (less than 1,000 m^3/d) was difficult in the CCRP numerical model. For instance, incised drainages and other focused discharge areas are difficult to simulate accurately. This difficulty is particularly noticeable along Meadow Valley Wash and Pahranagat Wash. In many cases, the hydraulic conductivity of the hydrogeologic units present at the land surface and the geometry of these topographic features control the simulated discharge.

The elevations assigned to define drains in the numerical model also affects the ability to simulate groundwater conditions more accurately. The elevations of drains in ET areas were set to values of land-surface elevation reduced by one of two values of extinction depth depending on location. The values of land-surface elevation were based on a 1:24,000-scale digital elevation model, and the extinction depth values were set to either 16.4 ft (5 m bgs) or 32.8 ft bgs (10 m bgs). This simplified method of representing drain elevations in the numerical model may not accurately approximate the extinction depth for all discharge areas, particularly in areas with highly variable rooting depths and discontinuous areas of capillary fringe. Snake Valley is an example of a discharge area that may have a zone of extensive capillary fringe. In areas of the model where these conditions exist, observed hydraulic heads may be lower than the drain elevations. The consequence of this limitation is that the numerical model has difficulty simulating groundwater discharge within the delineated ET areas.

In summary, in several cases, the distribution of ET is not simulated accurately; however, the total ET from a given ET area matches well. This limitation will cause drawdowns to propagate faster between the basin edge and simulated ET areas until ET is captured. Errors in ET simulation minimally affect drawdown propagation after capture starts because simulated discharge volumes are approximately correct.

7.5 Hydrologic Conditions Representation

The hydrologic conditions that, perhaps, most influence the CCRP numerical model are the representation of external and internal boundary conditions. Limitations in external-boundary-condition definition are the result of both incomplete understanding of natural conditions and associated poor representation of the natural conditions in the numerical model. Because very little data exist in the areas defined as lateral flow-system boundaries, the boundaries are highly uncertain. Also, defining these boundaries in the numerical model is effectively limited to either a no-flow or a constant-head boundary. Both types of boundary definitions impose significant constraints on model results.