Case No. 84739

IN THE SUPREME COURT OF THE STATE OF NEVADA

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Elizabeth A. Brown
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ADAM SULLIVAN, P.E., NEVADA STATE ENGINEER, et al.

Appellants,

vs.

LINCOLN COUNTY WATER DISTRICT, et al.

JOINT APPENDIX

VOLUME 40 OF 49

Table B-2
Continuously Monitored Stream Gage Locations and Calendar Year Periods of Record

HA Number	USGS Site Number	USGS Site Name	Period of Record
219	09416000	MUDDY RV NR MOAPA, NV	1914, 1917, 1945–2007
220	09419000	MUDDY RV NR GLENDALE, NV	1951–1982, 1985–2008

water-level measurements and well locations were obtained from two main sources, which are described in the following sections.

B.2.3.1 NDWR Well Net Data

The water-level data reported in the Baseline Report (SNWA, 2008) were compiled prior to the availability of the online NDWR water-level database (a.k.a. Well Net). Because of the current availability of this data, a comparison of the existing water-level data from the Baseline Report to that from the Well Net database was performed. As a result of the comparison, 79 new well locations were added to the existing data set. These 79 locations corresponded to 4,051 new water-level measurements. In addition, 4,413 new water-level measurements were added to existing sites in the study area. Water-level data for the new locations were added for the following hydrographic areas:

1. Steptoe Valley (HA 179) - 15 new locations
2. Lake Valley (HA 183) - 9 new locations
3. Snake Valley (HA 195) - 3 new locations
4. Dry Valley (HA 198) - 7 new locations
5. Rose Valley (HA 199) - 3 new locations
6. Eagle Valley (HA 200) - 2 new locations
7. Panaca Valley (HA 203) - 9 new locations
8. Lower Meadow Valley Wash (HA 205) - 6 new locations
9. Pahranagat Valley (HA 209) - 4 new locations
10. Coyote Spring Valley (HA 210) - 2 new locations
11. Muddy River Springs Area (HA 219) - 18 new locations
12. Lower Moapa Valley (HA 220) - 1 new location

The new well locations are listed in Table B-3. The table contains general information about each new site including the coordinates, land-surface elevations, and errors associated with both the coordinates and reference-point elevations. The spatial locations of the added wells are shown in Figure B-1.

B.2.3.2 Magma Nevada Mining Company/Robinson Mine Area

In addition to the NDWR Well Net data, monitoring plan compliance reports from Magma Nevada Mining Company were also obtained from NDWR for the Robinson Mine area in Steptoe and White River valleys. The reports document quarterly water-level and well discharge measurements for 1992

Table B-3
New Well Locations
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HA Number	Site No.	Station Name	UTM-N[a] (m)	UTM-E[a] (m)	Reference Point Elevation (ft amsl)	Var Z Error (ft^2)[b]	VAR LSE (ft^2)[b]	Data Source
179	179 N16 E63 01BBD 1	179 N16 E63 01BBD 1	4,350,586	686,265	6,271	0.005412284	625	NDWR Well Net
179	179 N16 E63 14AB 1	179 N16 E63 14AB 1	4,347,704	685,358	6,358	0.284789354	625	NDWR Well Net
179	179 N17 E63 01AC 1	179 N17 E63 01AC 1	4,359,986	684,877	6,149	0.074879935	625	NDWR Well Net
179	179 N17 E64 19BA 1	179 N17 E64 19BA 1	4,355,120	688,020	6,185	0.006268994	625	NDWR Well Net
179	179 N19 E63 26CC 2	179 N19 E63 26CC 2	4,372,332	684,247	6,067	0.091575280	625	NDWR Well Net
179	179 N20 E63 01DA 1	179 N20 E63 01DA 1	4,388,921	686,371	6,024	0.114960118	625	NDWR Well Net
179	179 N20 E64 17DD 1	179 N20 E64 17DD 1	4,385,172	689,972	6,031	0.036228899	625	NDWR Well Net
179	179 N20 E64 21BB 1	179 N20 E64 21BB 1	4,384,526	690,490	6,051	0.055288885	625	NDWR Well Net
179	179 N21 E63 35AD 1	179 N21 E63 35AD 1	4,390,891	687,032	6,032	0.090443072	625	NDWR Well Net
179	179 N21 E64 30DC 2	179 N21 E64 30DC 2	4,392,626	690,186	5,976	0.049746987	625	NDWR Well Net
179	179 N25 E65 04CA 2	179 N25 E65 04CA 2	4,438,176	701,853	5,907	0.011544952	625	NDWR Well Net
179	179 N25 E65 05DA 2	179 N25 E65 05DA 2	4,438,031	700,914	5,889	0.025470366	625	NDWR Well Net
179	179 N25 E65 08AA 1	179 N25 E65 08AA 1	4,437,316	699,401	7,456	86.828668096	625	NDWR Well Net
179	179 N26 E65 27CA 2	179 N26 E65 27CA 2	4,440,925	702,179	5,896	0.010192182	625	NDWR Well Net
179	179 N26 E65 34DA 1	179 N26 E65 34DA 1	4,439,672	702,801	5,913	0.054384693	625	NDWR Well Net
183	183 N05 E66 03DD	183 N05 E66 03DD	4,243,702	713,892	5,970	0.001031484	625	NDWR Well Net
183	183 N06 E66 22DC 1	183 N06 E66 22DC 1	4,248,718	713,739	5,964	0.000137065	625	NDWR Well Net
183	183 N06 E66 27AC 1	183 N06 E66 27AC 1	4,247,928	713,748	5,961	0.002243660	625	NDWR Well Net
183	183 N06 E66 27CAA 1	183 N06 E66 27CAA 1	4,247,532	713,714	5,960	0.004909051	625	NDWR Well Net
183	183 N06 E66 34CD 1	183 N06 E66 34CD 1	4,245,318	713,768	5,963	0.000290348	625	NDWR Well Net
183	183 N09 E65 13CC 1	183 N09 E65 13CC 1	4,279,127	705,707	5,953	0.064842026	625	NDWR Well Net
183	183 N09 E65 26AA 1	183 N09 E65 26AA 1	4,276,703	705,256	5,934	0.107702673	625	NDWR Well Net
183	183 N10 E65 36AC 1	183 N10 E65 36AC 1	4,284,733	706,329	5,993	15.460115840	625	NDWR Well Net
183	183 N10 E66 31BA 1	183 N10 E66 31BA 1	4,285,135	706,343	6,015	15.840237847	625	NDWR Well Net
195	195 N10 E70 24BDDB1	195 N10 E70 24BDDB1	4,290,407	753,898	5,508	0.059577473	625	NDWR Well Net
195	195 N10 E70 25CB 1	195 N10 E70 25CB 1	4,288,321	753,394	5,510	0.187533056	625	NDWR Well Net
195	195 N14 E70 28ABBC1	195 N14 E70 28ABBC1	4,327,586	748,942	5,334	0.162634029	625	NDWR Well Net
198	198 N01 E69 31CA 1	198 N01 E69 31CA 1	4,198,171	738,008	5,188	6.594736621	625	NDWR Well Net

Table B-3
New Well Locations
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HA Number	Site No.	Station Name	UTM-N[a] (m)	UTM-E[a] (m)	Reference Point Elevation (ft amsl)	Var Z Error (ft^2)[b]	VAR LSE (ft^2)[b]	Data Source
198	198 N01 E69 31DD 1	198 N01 E69 31DD 1	4,197,794	738,826	5,327	670.452220000	625	NDWR Well Net
198	198 N01 E69 32BB 1	198 N01 E69 32BB 1	4,199,008	739,206	5,221	5.603920796	625	NDWR Well Net
198	198 N01 E69 32CA 1	198 N01 E69 32CA 1	4,198,218	739,621	5,272	32.244404746	625	NDWR Well Net
198	198 S01 E69 06AC 1	198 S01 E69 06AC 1	4,196,940	737,041	5,172	11.678357431	625	NDWR Well Net
198	198 S01 E69 06AC 2	198 S01 E69 06AC 2	4,197,146	737,101	5,174	0.015433806	625	NDWR Well Net
198	198 S01 E69 07AC 1	198 S01 E69 07AC 1	4,195,633	736,695	5,142	0.049338793	625	NDWR Well Net
199	199 N01 E69 21AA 1	199 N01 E69 21AA 1	4,202,481	741,864	5,403	0.557542387	625	NDWR Well Net
199	199 N01 E69 21AB 1	199 N01 E69 21AB 1	4,202,403	741,495	5,384	0.324415070	625	NDWR Well Net
199	199 N01 E69 21AC 1	199 N01 E69 21AC 1	4,201,931	741,522	5,371	0.028155778	625	NDWR Well Net
200	200 N01 E69 10AD 1	200 N01 E69 10AD 1	4,204,923	743,542	5,486	0.196315632	625	NDWR Well Net
200	200 N01 E69 10DD 1	200 N01 E69 10DD 1	4,204,325	743,233	5,471	0.073606731	625	NDWR Well Net
203	203 S01 E68 33BB 1	203 S01 E68 33BB 1	4,189,304	729,993	4,787	4.266487975	625	NDWR Well Net
203	203 S02 E67 24BB 1	203 S02 E67 24BB 1	4,182,969	725,562	4,711	0.017313195	625	NDWR Well Net
203	203 S02 E67 25AC 1	203 S02 E67 25AC 1	4,181,285	726,204	4,668	0.030867354	625	NDWR Well Net
203	203 S02 E68 05CB 1	203 S02 E68 05CB 1	4,186,917	728,469	4,749	13.036499732	625	NDWR Well Net
203	203 S02 E68 05CC 1	203 S02 E68 05CC 1	4,186,516	728,480	4,744	0.062956026	625	NDWR Well Net
203	203 S02 E68 07AD 1	203 S02 E68 07AD 1	4,185,610	728,241	4,734	0.013572913	625	NDWR Well Net
203	203 S02 E68 08BB 1	203 S02 E68 08BB 1	4,186,115	728,491	4,739	4.617912404	625	NDWR Well Net
203	203 S02 E68 19AA 1	203 S02 E68 19AA 1	4,182,898	728,188	4,700	4.128819508	625	NDWR Well Net
203	203 S03 E67 22AB 2	203 S03 E67 22AB 2	4,173,229	723,184	4,531	0.000000233	625	NDWR Well Net
205	205 S14 E66 04DB 1	205 S14 E66 04DB 1	4,069,216	713,430	1,631	14.203069592	625	NDWR Well Net
205	205 S14 E66 15CA 1	205 S14 E66 15CA 1	4,066,009	714,677	1,577	0.025168284	625	NDWR Well Net
205	205 S14 E66 22DC 1	205 S14 E66 22DC 1	4,064,015	715,100	1,565	8.817230757	625	NDWR Well Net
205	205 S14 E66 26CD 1	205 S14 E66 26CD 1	4,062,443	716,381	1,544	5.257635924	625	NDWR Well Net
205	205 S14 E66 35CA 1	205 S14 E66 35CA 1	4,061,241	716,387	1,534	2.874385203	625	NDWR Well Net
205	205 S14 E66 35CACC1	205 S14 E66 35CACC1	4,061,107	716,323	1,531	0.033761658	625	NDWR Well Net
209	209 S04 E60 11CCCA1	209 S04 E60 11CCCA1 (NDWR)	4,163,529	656,539	3,912	0.171325388	625	NDWR Well Net

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HA Number	Site No.	Station Name	UTM-N[a] (m)	UTM-E[a] (m)	Reference Point Elevation (ft amsl)	Var Z Error (ft^2)[b]	VAR LSE (ft^2)[b]	Data Source
209	209 S05 E60 11DB 1	209 S05 E60 11DB 1	4,154,759	657,603	3,853	97.918324797	625	NDWR Well Net
209	209 S07 E61 09 1	209 S07 E61 09 1	4,135,923	664,138	3,612	0.791650546	625	NDWR Well Net
209	209 S07 E61 21AB 1	209 S07 E61 21AB 1	4,133,258	664,500	3,422	0.197873014	625	NDWR Well Net
210	210 S11 E62 24BD 1	210 S11 E62 24BD 1	4,094,391	678,990	2,536	0.537040456	625	NDWR Well Net
210	210 S11 E62 24DB 1	210 S11 E62 24DB 1	4,094,153	679,413	2,495	0.032465201	625	NDWR Well Net
219	219 S14 E65 08AB 1	219 S14 E65 08AB 1	4,068,141	702,237	1,828	0.127751829	625	NDWR Well Net
219	219 S14 E65 08AB 2	219 S14 E65 08AB 2	4,068,141	702,237	1,828	15.278992507	625	NDWR Well Net
219	219 S14 E65 08AC 1	219 S14 E65 08AC 1	4,067,740	702,222	1,829	3.237614303	625	NDWR Well Net
219	219 S14 E65 08AC 2	219 S14 E65 08AC 2	4,067,740	702,222	1,829	3.237614303	625	NDWR Well Net
219	219 S14 E65 08BD 1	219 S14 E65 08BD 1	4,067,731	701,850	1,839	2.308600849	625	NDWR Well Net
219	219 S14 E65 08DB 1	219 S14 E65 08DB 1	4,067,339	702,231	1,823	0.577945926	625	NDWR Well Net
219	219 S14 E65 08DB 2	219 S14 E65 08DB 2	4,067,339	702,231	1,823	0.004832364	625	NDWR Well Net
219	219 S14 E65 09CA 1	219 S14 E65 09CA 1	4,067,730	703,007	1,827	0.254086050	625	NDWR Well Net
219	219 S14 E65 09CC 1	219 S14 E65 09CC 1	4,066,958	703,035	1,801	20.027516919	625	NDWR Well Net
219	219 S14 E65 09DC 1	219 S14 E65 09DC 1	4,066,976	703,804	1,787	27.353193213	625	NDWR Well Net
219	219 S14 E65 14CD 1	219 S14 E65 14CD 1	4,065,438	706,547	1,725	0.000075838	625	NDWR Well Net
219	219 S14 E65 15AC 1	219 S14 E65 15AC 1	4,066,212	705,386	1,740	4.578752667	625	NDWR Well Net
219	219 S14 E65 21AB 1	219 S14 E65 21AB 1	4,064,941	703,827	1,920	9.869166603	625	NDWR Well Net
219	219 S14 E65 22AA 1	219 S14 E65 22AA 1	4,064,988	705,763	1,798	487.772668322	625	NDWR Well Net
219	219 S14 E65 23BB 1	219 S14 E65 23BB 1	4,064,997	706,160	1,713	0.807063339	625	NDWR Well Net
219	219 S14 E65 23BB 2	219 S14 E65 23BB 2	4,064,997	706,160	1,713	0.807063339	625	NDWR Well Net
219	219 S14 E65 23BC 1	219 S14 E65 23BC 1	4,064,596	706,145	1,783	44.102430928	625	NDWR Well Net
219	219 S14 E66 35DD 1	219 S14 E66 35DD 1	4,060,861	717,241	1,531	0.000000578	625	NDWR Well Net
220	220 S14 E67 29BCAD1	220 S14 E67 29BCAD1	4,063,501	721,009	1,754	0.477561122	625	NDWR Well Net
179	179 N16 E61 1AA 1 R-12	179 N16 E61 1AA 1 R-12	4,350,441	668,350	7,297	153,810.9845	625	Robinson Mine Data
179	179 N16 E62 10DB 1 DEEP RUTH SHAFT	179 N16 E62 10DB 1 DEEP RUTH SHAFT	4,348,053	674,434	6,946	51,627.29448	625	Robinson Mine Data
179	179 N16 E62 12CB 1 R-H	179 N16 E62 12CB 1 R-H	4,348,122	676,953	6,614	9,110.843423	625	Robinson Mine Data
179	179 N16 E62 13BB 1 R-C	179 N16 E62 13BB 1 R-C	4,347,192	676,607	7,018	449,117.2147	625	Robinson Mine Data

Table B-3
New Well Locations
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HA Number	Site No.	Station Name	UTM-N[a] (m)	UTM-E[a] (m)	Reference Point Elevation (ft amsl)	Var Z Error (ft^2)[b]	VAR LSE (ft^2)[b]	Data Source
179	179 N16 E62 13BD 1 SKKR13M	179 N16 E62 13BD 1 SKKR13M	4,346,650	677,200	7,003	810,783.8883	625	Robinson Mine Data
179	179 N16 E62 13CA 1 WCC6M	179 N16 E62 13CA 1 WCC6M	4,346,379	677,355	7,241	389,940.337	625	Robinson Mine Data
179	179 N16 E62 13DD 1 WCC1M	179 N16 E62 13DD 1 WCC1M	4,345,927	677,936	7,603	716,454.166	625	Robinson Mine Data
179	179 N16 E62 15CA 1 R-E	179 N16 E62 15CA 1 R-E	4,346,340	673,870	7,257	245,579.9514	625	Robinson Mine Data
179	179 N16 E62 16AD 1 SL-1M	179 N16 E62 16AD 1 SL-1M	4,346,779	673,406	7,301	554,774.1501	625	Robinson Mine Data
179	179 N16 E62 16BA 1 WCC5M	179 N16 E62 16BA 1 WCC5M	4,347,050	672,605	6,792	6,951,005.87	625	Robinson Mine Data
179	179 N16 E62 22AB 1 WCC2M	179 N16 E62 22AB 1 WCC2M	4,345,553	674,503	7,451	362.7461589	625	Robinson Mine Data
179	179 N16 E62 23DC 1 WCC4M	179 N16 E62 23DC 1 WCC4M	4,344,559	675,897	7,546	76,125.34	625	Robinson Mine Data
179	179 N16 E62 2CB 1 AB-3	179 N16 E62 2CB 1 AB-3	4,349,847	675,218	6,753	11,557.2194	625	Robinson Mine Data
179	179 N16 E62 2CC 1 K-2P	179 N16 E62 2CC 1 K-2P	4,349,372	675,300	6,810	104,808.4181	625	Robinson Mine Data
179	179 N16 E62 2CD 1 K-2M	179 N16 E62 2CD 1 K-2M	4,349,444	675,600	6,769	1,632,835.716	625	Robinson Mine Data
179	179 N16 E62 2CD 2 K-3M	179 N16 E62 2CD 2 K-3M	4,349,072	675,703	6,804	160,218.9475	625	Robinson Mine Data
179	179 N16 E62 3DA 1 AB-4	179 N16 E62 3DA 1 AB-4	4,349,857	674,815	6,763	3,849.965646	625	Robinson Mine Data
179	179 N16 E62 8DA 1 R-F	179 N16 E62 8DA 1 R-F	4,348,005	671,766	7,109	373,321.1523	625	Robinson Mine Data
179	179 N16 E63 18BA 1 R-B	179 N16 E63 18BA 1 R-B	4,347,373	678,801	6,557	2,071.315926	625	Robinson Mine Data
179	179 N16 E63 18DC 1 WCC3M	179 N16 E63 18DC 1 WCC3M	4,346,108	679,227	7,516	1,286,078.515	625	Robinson Mine Data
179	179 N16 E63 7CC 1 R-A	179 N16 E63 7CC 1 R-A	4,347,730	678,419	6,592	102,843.2134	625	Robinson Mine Data
179	179 N17 E62 33BB 1 NRC-2P	179 N17 E62 33BB 1 NRC-2P	4,352,071	671,944	6,912	3,197.239916	625	Robinson Mine Data
179	179 N17 E62 33CA 1 NRC-2M	179 N17 E62 33CA 1 NRC-2M	4,351,117	672,543	6,943	10,195.44048	625	Robinson Mine Data
179	179 N17 E62 33CA 2 NRC-3M	179 N17 E62 33CA 2 NRC-3M	4,351,086	672,296	7,015	637,526.9519	625	Robinson Mine Data
179	179 N17 E62 33DB 1 NRC-1P	179 N17 E62 33DB 1 NRC-1P	4,351,076	672,791	6,905	30,076.01055	625	Robinson Mine Data
179	179 N17 E62 35CC 1 R-1	179 N17 E62 35CC 1 R-1	4,350,890	675,311	6,726	30,111.43673	625	Robinson Mine Data
207	207 N16 E61 13AB 1 WCCG2	207 N16 E61 13AB 1 WCCG2	4,347,089	667,817	6,920	34,250.3139	625	Robinson Mine Data
207	207 N16 E61 25DB 1 WCCG1	207 N16 E61 25DB 1 WCCG1	4,343,332	667,894	6,677	15,630.01337	625	Robinson Mine Data
207	207 N16 E62 30CA 1 WCCG3	207 N16 E62 30CA 1 WCCG3	4,343,126	669,327	6,707	403,963.8922	625	Robinson Mine Data

[a]Universal Transverse Mercator projection, North American Datum 1983, Zone 11N
[b]For a discussion on the calculation of the error terms, Var Z Error and Var LSE, see SNWA (2008)

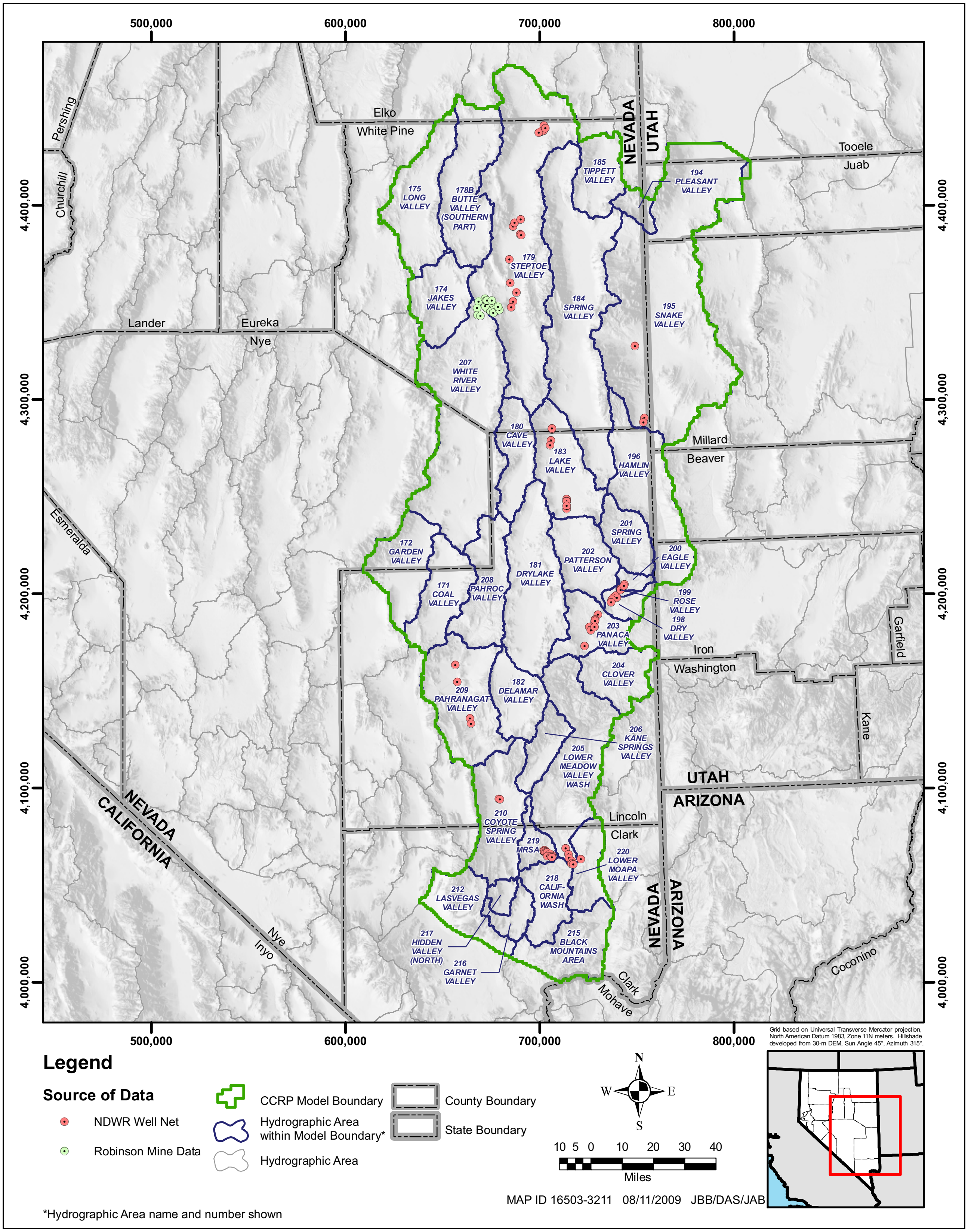

Figure B-1
Location of Wells Added to the Existing Water-Level Data Set

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through 1996. Based on these quarterly reports, 29 new well locations were added to the existing Baseline Report data set. These 29 locations have 461 corresponding new water-level measurements. The added wells are listed in Table B-3, and the spatial locations of the added wells are shown in Figure B-1.

B.3.0 DATA ANALYSIS

Analysis of the hydrologic data included reducing the daily mean discharge and water-level measurements into calendar year average measurements. In addition, statistics for the reduction of multiple measurements into one yearly average measurement were also calculated. Analysis of the data also included assigning "well-qualifier" and "use-code" flags to the wells in the study area. The following sections discuss the analysis of the updated hydrologic data sets in greater detail.

B.3.1 Spring Discharge Data

Analysis of the spring discharge data set consisted of (1) deriving calendar year average spring discharge measurements and statistics for each of the springs from the updated daily mean discharge data and (2) combining the yearly average discharge measurements for springs where multiple gages were necessary to capture the entire discharge from the spring (e.g., Big Springs in Snake Valley).

These steps are discussed in greater detail in the following sections:

B.3.1.1 Data Reduction and Statistics

The daily mean discharge measurements were reduced to calendar year discharge measurements for the period of record for a given spring. This was done to reduce the data set so that the spring discharge values could be used as observations in the model. The data reduction was performed in Microsoft Access.

In addition to the determination of the calendar year average discharge measurement, summary statistics were also calculated, including the standard deviation and variance. The resulting transient spring discharge data set can be found on the DVD included with this report.

B.3.1.2 Combination of Gages

A complicating factor in the estimation of yearly spring discharges for several of the spring locations in Table B-1 is that the total discharge is not always accounted for by one gage. For example, the total discharge for both Crystal and Ash springs is accounted for by gaging stations on both the main and irrigation diversion channels. Spring discharge for Big Springs in Snake Valley is accounted for by gages on both the north and south channels of Big Springs Creek. As a result, the reported discharges for those gages had to be combined to adequately account for the total discharge for the spring complexes.

For Crystal and Ash springs, the total spring discharge for the springs was derived by combining the calendar year average discharge measurements for years in which data were available for both gages. The calendar year averages and variances in flow from the daily mean data for Crystal and Ash springs can be seen in Table B-4.

For Big Springs, however, there was never a calendar year in which spring discharges were available for both of the gage locations in the same year. As a result, the total discharge for Big Springs was calculated in a slightly different manner. Specifically, the total discharge for Big Springs was estimated by averaging the two calendar years of record for the north channel (i.e., 2006 and 2007) and adding the one calendar year of discharge for the south channel (i.e., 2008). The estimated total spring discharge for Big Springs was 10.26 cfs with a variance of 0.32 cfs^2.

The combination of the gage data for Crystal, Ash, and Big springs can also be found on the DVD included with this report.

Table B-4
Calendar Year Average Discharges for Crystal and Ash Springs

USGS Site Name	Calendar Year Average Discharges/Variances (cfs)/(cfs^2)			
	2004	**2005**	**2006**	**2007**
209 S05 E60 10 1 CRYSTAL SPGS NR HIKO, NV	---	11.13/13.10	10.89/11.99	11.76/7.34
CRYSTAL SPGS DIV NR HIKO, NV	---	1.63/12.12	1.51/10.13	1.19/7.51
Total Discharge for Crystal Springs	**---**	**12.76/25.21**	**12.40/22.12**	**12.96/14.85**
ASH SPGS CK BLW HWY 93 AT ASH SPGS, NV	15.83/2.88	13.13/1.53	12.69/3.42	16.43/4.33
ASH SPGS DIV AT ASH SPGS, NV	2.15/0.95	3.33/0.96	3.84/3.08	3.46/1.43
Total Discharge for Ash Springs	**17.98/3.83**	**16.45/2.50**	**16.53/6.50**	**19.89/5.76**

B.3.2 Muddy River Stream Flow Data

Analysis of the stream flow data for the Moapa and Glendale gages consisted of (1) removing flood flows from the daily mean stream flow measurements, (2) deriving monthly discharge volumes from the daily mean stream flow measurements, and (3) calculating calendar year stream flow measurements. These steps are discussed in greater detail in the following sections.

B.3.2.1 Removal of Flood Flows

Local precipitation events contribute to the stream flow measured at the Moapa and Glendale gages. These additional flows are referred to as flood flows. These flood flows were removed from the daily mean flows to determine the actual baseflow at the gages. The methodology for the removal of flood flows is described in Johnson (1999), and the adjusted record is reported in LVVWD (2001). The method of removing the flood flows from the daily mean flows consisted of identifying the flood flows and then using a calculated median flow in place of the flood-flow volumes.

B.3.2.2 Derivation of Monthly Stream Flows

After the removal of the flood flows, the monthly flows for each gage were derived by summing the daily mean flows for each month for the period of record of both of the gages. The resulting adjusted data set allowed for a determination of the calendar year stream flows for both gages.

B.3.2.3 Derivation of Calendar Year Stream Flows

The adjusted calendar year stream flows were derived from the monthly stream flow data for each gage. The adjusted calendar year stream flows were derived by summing the monthly stream flow values (i.e., January to December) in a given year for the period of record of the gage. The adjusted calendar year stream flows for both gages are listed in Table B-5. This table also contains the unadjusted calendar year discharges from the NWIS website. The adjusted discharges represent the calendar year discharge measurements at the gages with the flood flows removed, while the unadjusted discharges represent the stream flows that would have passed by the gages including flood flows. Hydrographs of the calendar year flows for each of the gages can be seen in Figure B-2 and Figure B-3.

B.3.3 Water-Level-Elevation Data

Analysis of the updated water-level data set consisted of several steps. These steps were as follows:

1. Generated a transient water-level data set from the updated water-level data set.

2. Generated hydrographs for each well that show the original water-level-elevation data and the yearly averaged water-level elevations.

3. Assigned a well-qualifier flag to each well in the transient water-level data set.

4. Assigned a use-code flag to each well in the transient water-level data set.

The analysis of the transient water-level data set is discussed in greater detail in the following sections.

B.3.3.1 Transient Model Water-Level Data Set

The steps necessary to generate the water-level-elevation data set for the transient model were as follows:

1. Excluded specific water-level measurements from the water-level data set that are either considered to be outliers with respect to the rest of the water-level measurements or are flagged in such a way that indicates a specific measurement is affected by some type of external factor (e.g., pumping, a nearby site is pumping, or the site was recently pumping).

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Table B-5
Stream Flow Measurements for the Moapa and Glendale Gages
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Calendar Year	MUDDY RV NR MOAPA, NV Gage		MUDDY RV NR GLENDALE, NV Gage	
	NWIS Calendar Year Discharge (cfs)[a]	Adjusted Calendar Year Discharge (cfs)[a]	NWIS Calendar Year Discharge (cfs)[a]	Adjusted Calendar Year Discharge (cfs)[a]
1914	46.7	46.1	NA	NA
1917	46.6	46.6	NA	NA
1945	46.3	46.1	NA	NA
1946	47.1	46.8	NA	NA
1947	47.2	47.2	NA	NA
1948	46.1	46.3	NA	NA
1949	47.1	47.1	NA	NA
1950	46.0	46.0	NA	NA
1951	47.1	47.1	44.8	44.3
1952	46.9	46.9	54.5	47.7
1953	45.9	45.8	44.8	44.7
1954	45.9	45.8	44.4	43.8
1955	46.9	46.6	54.1	47.5
1956	45.7	45.8	43.4	43.1
1957	49.4	48.5	51.0	48.1
1958	48.3	48.0	46.2	44.8
1959	49.8	49.2	45.3	44.8
1960	48.0	47.3	57.9	45.9
1961	44.5	44.2	47.4	45.3
1962	44.2	44.1	43.0	41.9
1963	45.3	45.3	39.9	39.3
1964	43.6	43.7	40.3	40.4
1965	43.3	43.1	44.2	43.2
1966	42.3	41.7	42.3	38.1
1967	45.8	41.7	44.6	41.2
1968	40.9	40.9	43.7	42.5
1969	42.5	42.0	54.4	42.7
1970	39.8	39.8	45.7	43.1
1971	39.3	39.1	42.2	40.9
1972	45.7	42.2	44.1	39.9
1973	43.4	43.4	41.9	40.3
1974	40.1	40.1	39.3	39.1

Table B-5
Stream Flow Measurements for the Moapa and Glendale Gages
(Page 2 of 2)

Calendar Year	MUDDY RV NR MOAPA, NV Gage		MUDDY RV NR GLENDALE, NV Gage	
	NWIS Calendar Year Discharge (cfs)[a]	Adjusted Calendar Year Discharge (cfs)[a]	NWIS Calendar Year Discharge (cfs)[a]	Adjusted Calendar Year Discharge (cfs)[a]
1975	39.1	39.0	39.6	38.5
1976	41.9	39.1	42.9	39.8
1977	35.6	35.5	35.6	34.3
1978	36.9	36.2	55.7	39.7
1979	39.8	37.8	43.2	37.2
1980	39.5	39.1	45.0	37.8
1981	38.0	37.6	46.0	35.4
1982	37.6	37.3	37.2	36.8
1983	39.8	39.2	NA	NA
1984	39.2	36.1	NA	NA
1985	37.8	37.7	36.2	35.9
1986	36.6	36.5	37.1	37.2
1987	39.2	38.5	38.8	37.4
1988	37.4	37.5	35.6	35.7
1989	33.1	33.1	30.2	30.2
1990	36.7	34.3	41.0	32.3
1991	36.0	35.6	36.5	34.3
1992	37.1	37.0	38.1	36.4
1993	40.5	39.0	53.7	39.7
1994	39.4	39.2	33.6	33.6
1995	33.3	33.3	32.0	32.0
1996	32.9	33.0	30.7	30.5
1997	34.6	34.6	32.1	31.9
1998	34.6	34.0	56.4	38.2
1999	34.2	33.9	36.0	36.0
2000	34.2	33.8	38.4	33.4
2001	31.4	31.4	32.0	32.0
2002	32.5	32.5	31.9	31.9
2003	30.3	30.4	31.4	31.4
2004	31.5	31.4	40.3	32.4

NA = Not available
[a] Discharge rounded to the nearest tenth

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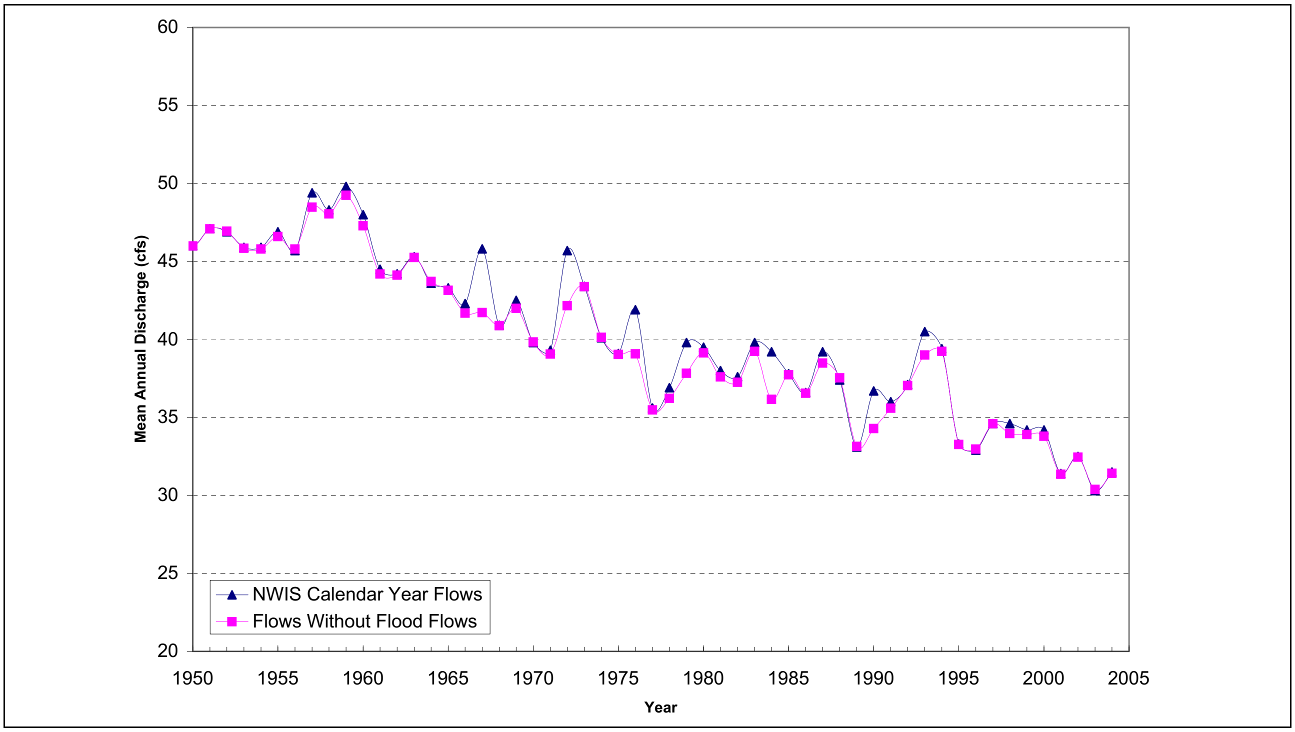

Figure B-2
Annual Flow with and without Flood Flows at USGS Gaging Station 0941600-MUDDY RV NR MOAPA, NV

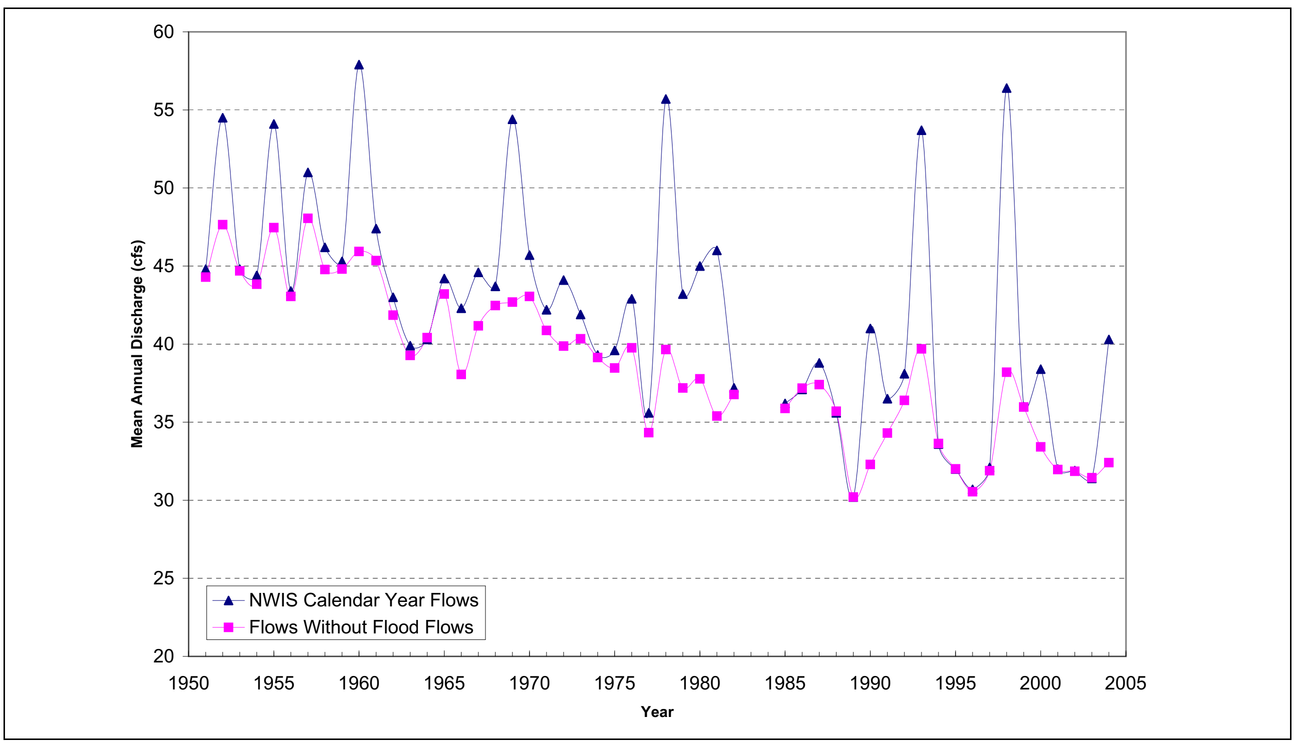

Figure B-3
Annual Flow with and without Flood Flows at USGS Gaging Station 09419000-MUDDY RV NR GLENDALE, NV

2. From the resulting data set in Step 1, calculated yearly average water-level elevations and statistics for each well in the data set.

3. Using the yearly average water-level elevations and statistics, calculated an acceptable range to select water-level elevations for each well for use as observations in the transient model calibration. The acceptable range is defined as the average yearly elevation ± 2 standard deviations.

4. Using the range from Step 3, flagged water-level measurements outside the acceptable range for the well.

5. Excluded the specific water-level measurements from the data set in Step 4 that were flagged as exceeding or being less than the acceptable range.

6. Using the data set from Step 5, recalculated yearly average water-level elevations and statistics for each well in the data set. The resulting data set represents the transient model water-level-elevation data set.

B.3.3.2 Hydrograph Construction

Hydrographs were constructed for each well in the water-level data set. These hydrographs display both the original water-level elevations (i.e., Step 1 results) and the yearly averaged water-level elevations that correspond to the transient model water-level-elevation data set (i.e., Step 6 results). The hydrographs are organized by hydrographic area and station name. For plotting purposes, the yearly averaged water-level elevations were assigned a date of June 15 for every year in the period of record. As a result, for wells with only one water-level elevation, there might be a shift between the two data points. In addition, some hydrographs may appear to be blank; however, the data for the well were likely prior to 1945, and the x-axis was set to encompass the historical development period of the study area. The constructed hydrographs can be found on the DVD included with this report.

The hydrographs were constructed in such a way as to allow for a set elevation to be applied to the maximum and minimum water-level elevations on the hydrograph. This allows for the hydrographs to have more consistent scales in an effort to standardize the overall trends displayed by the hydrographs. This buffer was set to 75 ft.

B.3.3.3 Well Qualification and Data Filtering

Well-qualifier flags were assigned to each well in the transient water-level database so that hydraulic-head and drawdown observations could be derived for the wells. The list of qualifying flags are listed in Table B-6. The flags were assigned to the wells included in the data set by inspection of the data in a Microsoft Access database, spatial querying of the well locations in ArcMap 9.3, and comparison of the well hydrographs in conjunction with a National Climatic Data Center (NCDC) climate index. The assignment of these flags is discussed in greater detail in the following sections. Figure B-4 shows the spatial distribution of the wells and their assigned flags.

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Table B-6
Well-Qualifier Flags

Flag	Definition
1	Preliminary flag that is no longer used.
2	Wells with only one yearly averaged water-level-elevation measurement.
3	Wells located in hydrographic areas where no groundwater pumping has occurred during the historical record (e.g., Garden and Coal valleys).
4	Wells located in hydrographic areas where groundwater pumping has occurred during the historical record. Wells are located near a groundwater pumping center.
5	Wells located in hydrographic areas where groundwater pumping has occurred during the historical record. Wells are not located near a groundwater pumping center.
6	Wells located in hydrographic areas where groundwater pumping has occurred during the historical record. Wells appear to be exhibiting fluctuations that can be attributed to climatic factors.

B.3.3.3.1 Inspection of Data in Access

The first step in the assignment of the flags was to perform a query in Microsoft Access that identified wells in the study area that had only one yearly averaged water-level measurement. These wells were assigned a Flag 2.

B.3.3.3.2 Spatial Querying of Transient Water-Level Data Set

The well locations in the updated transient water-level data set were also plotted in ArcMap 9.3. This was done so that spatial queries of the well locations could be made. For example, well locations that fall in hydrographic areas where little to groundwater use occurs (see Appendix C) were assigned a Flag 3 qualifier (e.g., Garden, Coal, Long, Butte, and Hamlin valleys). The spatial querying was also used to identify well locations that fall in hydrographic areas where a significant amount of groundwater pumping occurs. These wells were assigned Flag 4 or 5 qualifiers. Flag 4 was assigned to well locations that are located in close proximity to groundwater pumping centers. Flag 5 was assigned to well locations that are located in hydrographic areas that have significant pumping but are not located in close proximity to groundwater pumping centers.

B.3.3.3.3 Comparison of Water-Level-Elevation Hydrographs and Climate-Index Data

The last step in assigning the flags was to visually inspect the hydrographs for all well locations that fall in hydrographic areas with groundwater pumping centers. The hydrographs were constructed in conjunction with the creation of a drought index chart for the same time scales as the water-level elevations. Specifically, Palmer Drought Severity Index (PDSI) data were downloaded from the NCDC Climate Monitoring website (http://lwf.ncdc.noaa.gov/climate-monitoring/). According to the NCDC website, the PDSI attempts to measure the duration and intensity of the long-term drought-inducing circulation patterns (NCDC, 2009). The PDSI is a monthly value that indicates the severity of a wet or dry spell.

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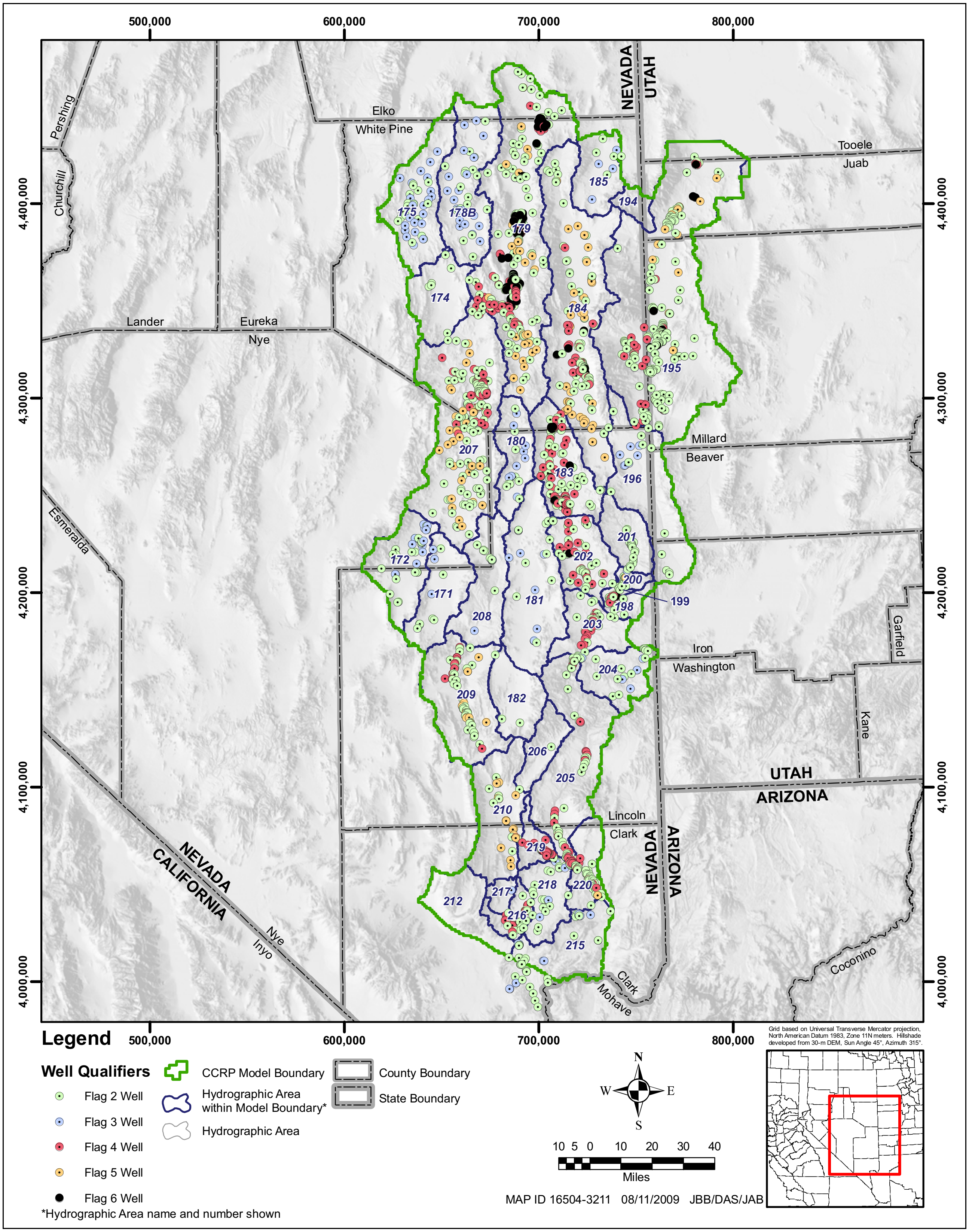

Figure B-4
Well Qualifiers

The downloaded PDSI data are applicable to specific climatological divisions. For the study area, PDSI data were downloaded for Nevada climatological divisions 2, 3, and 4. In addition, PDSI data were downloaded for Utah climatological division 1.

Inspection of the water-level-elevation hydrographs and the PDSI plots allowed for the determination of which wells in the study area might be exhibiting water-level-elevation fluctuations related to climate variability. These wells were assigned a Flag 6. Figure B-4 reflects that most of the wells assigned a Flag 6 were located in Steptoe, Spring, Lake, and Snake valleys.

B.3.3.4 Use-Code Flags

In addition to the assignment of the flags, each well in the transient water-level data set was also assigned a use-code flag. This flag was either a "Y" or an "N." The wells flagged with an N were ignored (i.e., removed from consideration) in the calibration of the transient model. The wells from the transient water-level data set flagged with an N are listed in Table B-7. This table is organized by hydrographic area and then by station name. The table also explains why a particular well was flagged with an N use code. Some of the reasons for flagging a well with an N included the following:

- Well was incorrectly located.
- Well had no date of measurement associated with the yearly averaged water-level-elevation measurement.
- Well was located in an area that is likely perched or in an area where issues with the framework of the model would prevent the accurate modeling of that particular location.

B.4.0 Transient Model Observation Data Sets

Transient model observation data sets were required for calibration of the numerical model. The transient model observation data sets were divided into two main types of observations. The two types of observations include observations prior to 1945 that correspond to the predevelopment period, and observations after 1945 that correspond to the historical period of development in the study area. The observations prior to 1945 were used for the first stress period of the transient calibration. The first stress period corresponds to the steady-state calibration of the numerical model. The observations post 1945 were used as transient observations for the historical development period. The transient model observations are discussed in greater detail in the following sections.

B.4.1 Pre-1945 Transient Model Observations

Hydrologic measurements made prior to 1945 were considered to be part of the predevelopment period in the study area. These measurements were used as steady-state (i.e., stress period 1) observations for the study area. These observations are discussed in greater detail in the following sections.

Table B-7
Wells Flagged as "N" and Not Used in Transient Calibration
(Page 1 of 5)

HA Number	Site No	Station Name	Reason
171	171 N02 E60 19CA 1	171 N02 E60 19CA 1	DTW measurement has no date associated with it
171	374716115253801	171 S02 E58 11A 2 USBLM	Perched or incorrectly located
171	171 S02 E58 14CB 1	171 S02 E58 14CB 1	Perched or incorrectly located
172	172 N01 E57 20 1	172 N01 E57 20 1	Located on mountain ridge
172	172 N02 E58 14C 1	172 N02 E58 14C 1	Inside perched ET zone
172	172 N02 E58 14CB 1	172 N02 E58 14CB 1	Inside perched ET zone
172	172 N03 E57 10BA 1	172 N03 E57 10BA 1	Perched or incorrectly located
172	172 N03 E57 15CC 1	172 N03 E57 15CC 1	Perched or incorrectly located
172	172 N03 E57 15DC 1	172 N03 E57 15DC 1	Perched or incorrectly located
172	380643115344201	172 N03 E57 16C 1	Perched or incorrectly located
172	381107115251901	172 N04 E58 23D 1 Well (Report R18)	Perched, Garden Valley
172	381123115252001	172 N04 E58 26ABA 1 USBLM	Perched, Garden Valley
172	381339115225501	172 N04 E59 06D 1	Perched, Garden Valley
172	172 N04 E59 08B 1	172 N04 E59 08B 1	Perched, Garden Valley
172	172 N04 E59 08B 2	172 N04 E59 08B 2	Perched, Garden Valley
172	375742115223001	172 N05 E59 32C 1	Perched, Garden Valley
172	381437115214901	172 N05 E59 32D 1	Perched, Garden Valley
172	381829115221601	207 N04 E59 08BCC 1	Perched, Garden Valley
174	390809115134801	174 N14 E60 04DBD 1 USBLM	Well is likely perched
174	174 N17 E59 09 1	174 N17 E59 09 1	Inside perched ET zone
174	174 N17 E59 10BA 1	174 N17 E59 10BA 1	Inside perched ET zone
174	392617115115801	174 N18 E60 10DAA 1 USBLM	Well located in incorrect section
174	174 N19 E60 21CB 1	174 N19 E60 21CB 1	Well is likely perched
175	175 N22 E58 34AD 1	175 N22 E58 34AD 1	DTW measurement has no date associated with it
178B	178B N19 E61 26DAD 1	178B N19 E61 26DAD 1	Well located in incorrect section
178B	178B N20 E61 23AC1	178B N20 E61 23AC1	DTW measurement has no date associated with it
178B	178B N22 E61 21BC 1	178B N22 E61 21BC 1	Perched or incorrectly located
178B	394355115053301	178B N22 E61 33 1	Perched or incorrectly located
178B	395146115014201	178B N23 E61 13 1	Perched or incorrectly located; DTW measurement has no date associated with it
178B	178B N24 E60 33BC 1	178B N24 E60 33BC 1	Perched or incorrectly located
179	179 N14 E63 14BB 1	179 N14 E63 14BB 1	Well located in incorrect section
179	390220114510401	179 N14 E63 36B 1	Perched or incorrectly located
179	179 N15 E63 15DC 1	179 N15 E63 15DC 1	Perched or incorrectly located
179	179 N15 E65 05DB 1	179 N15 E65 05DB 1	Perched or incorrectly located
179	179 N15 E65 07BC 1	179 N15 E65 07BC 1	Perched or incorrectly located
179	391715114574701	179 N16 E62 02A 1	Perched or incorrectly located
179	391546114535501	179 N16 E63 09CC 1	Perched or incorrectly located
179	391548114524301	179 N16 E63 15B 1	Perched or incorrectly located
179	391529114543601	179 N16 E63 17A 1 White Pine County School	Perched or incorrectly located
179	179 N16 E63 28BA 1	179 N16 E63 28BA 1	Perched or incorrectly located
179	391634114484901	179 N16 E64 06CBDC1 USBLM	Inconsistent elevations
179	392055115021501	179 N17 E62 07CDBD1 USBLM	Not likely part of the regional or intermediate flow systems

Table B-7
Wells Flagged as “N” and Not Used in Transient Calibration
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HA Number	Site No	Station Name	Reason
179	391903115021701	179 N17 E62 30A 1	Perched or incorrectly located
179	391749114584601	179 N17 E62 34BDDA1	Inside perched ET zone
179	392131114551401	179 N17 E63 07ABAD1	Inside perched ET zone
179	392112114550501	179 N17 E63 07ADCD1	Inside perched ET zone
179	179 N18 E61 34 1	179 N18 E61 34 1	Not likely part of the regional or intermediate flow systems
179	392343114570601	179 N18 E62 25CCA 1 USBLM	Inside perched ET zone
179	179 N18 E65 10B 1	179 N18 E65 10B 1	Perched or incorrectly located
179	392517114420901	179 N18 E65 18DCDC1	Inside perched ET zone
179	179 N18 E65 19CC 1	179 N18 E65 19CC 1	Inside perched ET zone
179	179 N19 E64 17DDB 1	179 N19 E64 17DDB 1	DTW measurement has no date associated with it
179	179 N19 E64 24DA 1	179 N19 E64 24DA 1	DTW measurement has no date associated with it
179	392952114433401	179 N19 E64 25A 1	Inside perched ET zone
179	392911114425301	179 N19 E64 25ADAD1	Inside perched ET zone
179	179 N19 E65 34CD 1	179 N19 E65 34CD 1	Perched or incorrectly located
179	179 N21 E64 14AC 1	179 N21 E64 14AC 1	Inside perched ET zone
179	179 N22 E64 22CD 1	179 N22 E64 22CD 1	Inside perched ET zone
179	179 N23 E63 06AA 1	179 N23 E63 06AA 1	Inside perched ET zone
179	395117114442601	179 N23 E64 21B 1	Perched or incorrectly located
179	395740114383601	179 N24 E65 17AADC1 USBLM	Well located in incorrect section
179	179 N24 E65 30DC 1	179 N24 E65 30DC 1	Well located in incorrect section
179	400043114481501	179 N25 E63 26A 1	Perched or incorrectly located
179	400504114373101	179 N26 E65 34DABA1	Inconsistent water-level trends in area
179	179 N26 E66 03 1	179 N26 E66 03 1	Perched or incorrectly located
181	181 N04 E65 26DC 1	181 N04 E65 26DC 1	Perched or incorrectly located
181	181 N05 E65 34DC 1	181 N05 E65 34DC 1	Perched or incorrectly located
181	181 N05 E65 35BA 1	181 N05 E65 35BA 1	Perched or incorrectly located
183	381911114235101	183 N05 E68 06C 1	Perched or incorrectly located
183	382336114210301	183 N06 E68 09CAC 1	Well is likely perched
183	382757114414301	183 N07 E65 17DAA 1 USBLM	Framework issues prevent the accurate modeling of this location
184	184 N10 E68 36DA 1	184 N10 E68 36DA 1	Well located in incorrect section
184	390448114274401	184 N14 E67 15C 1	Perched or incorrectly located
184	390952114214401	184 N15 E66 14DBBD1	Well appears to be incorrectly located
184	184 N15 E68 17DD 1	184 N15 E68 17DD 1	Well located in incorrect section
184	395314114373101	184 N23 E65 10D 1	Perched or incorrectly located
184	395234114363601	184 N23 E65 14C 1	Not likely part of the regional or intermediate flow systems
184	394949114331801	184 N23 E66 31AB 1	Not likely part of the regional or intermediate flow systems
184	394942114342001	184 N23 E66 31C 1	Perched or incorrectly located
184	184 N24 E66 31CB 1	184 N24 E66 31CB 1	Not likely part of the regional or intermediate flow systems
185	395606114094401	253 N24 E69 27BAAB1 Goshute Reservation	Well located outside of study area
195	393900113530001	(C-13-18)28ccc- 1	DTW measurement has no date associated with it
195	(C-14-18) 5C	(C-14-18) 5C	DTW measurement has no date associated with it

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Table B-7
Wells Flagged as "N" and Not Used in Transient Calibration
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HA Number	Site No	Station Name	Reason
195	(C-20-19)21B	(C-20-19)21B	DTW measurement has no date associated with it
195	(C-21-18)10CDD 1	(C-21-18)10CDD 1	DTW measurement has no date associated with it
195	(C-21-18)32ABD 1	(C-21-18)32ABD 1	Perched or incorrectly located
195	(C-21-19)31D	(C-21-19)31D	DTW measurement has no date associated with it
195	(C-22-19)6aad	(C-22-19)6aad	DTW measurement has no date associated with it
195	(C-22-19)6bbb	(C-22-19)6bbb	DTW measurement has no date associated with it
195	(C-22-19)6bbd 1	(C-22-19)6bbd1	DTW measurement has no date associated with it
195	(C-22-19)6bca2	(C-22-19)6bca2	DTW measurement has no date associated with it
195	(C-22-19)6bca3	(C-22-19)6bca3	DTW measurement has no date associated with it
195	(C-22-19)6bca4	(C-22-19)6bca4	DTW measurement has no date associated with it
195	(C-22-19)6ccb	(C-22-19)6ccb	DTW measurement has no date associated with it
195	(C-22-19)6ccd	(C-22-19)6ccd	DTW measurement has no date associated with it
195	(C-22-19)6dab1	(C-22-19)6dab1	DTW measurement has no date associated with it
195	(C-22-19)6dab2	(C-22-19)6dab2	DTW measurement has no date associated with it
195	(C-23-19)13AAB 1	(C-23-19)13AAB 1	DTW measurement has no date associated with it
195	(C-24-19)32ad	(C-24-19)32ad	DTW measurement has no date associated with it
195	(C-24-19)32dd	(C-24-19)32dd	DTW measurement has no date associated with it
195	390126114115701	195 N13 E69 11A 1	Perched or incorrectly located
195	195 N13 E69 11ABC 1	195 N13 E69 11ABC 1	Perched or incorrectly located
195	390028114110401	195 N13 E69 12CCDB1	Well assumed to be perched or the area has framework issues that prevent the modeling of this area correctly
195	390126114075901	195 N13 E70 09B 1 Ranger Station	Perched or incorrectly located
195	195 N13 E70 09BDD 1	195 N13 E70 09BDD 1	Perched or incorrectly located
195	195 N13 E70 09CA 1	195 N13 E70 09CA 1	DTW measurement has no date associated with it
195	390005114080601	195 N13 E70 16C 1	Perched or incorrectly located
195	195 N14 E69 13CD 1	195 N14 E69 13CD 1	Inside perched ET zone
195	390454114111101	195 N14 E69 24A 1	Inside perched ET zone
195	195 N14 E69 24BDD 1	195 N14 E69 24BDD 1	Inside perched ET zone
195	195 N14 E69 24DAB 1	195 N14 E69 24DAB 1	Inside perched ET zone
195	393047114124001	195 N19 E69 15C 1	Perched or incorrectly located
196	(C-30-19)21CAB	(C-30-19)21CAB	DTW measurement has no date associated with it
196	195 N10 E69 08BB 1	195 N10 E69 08BB 1	Perched or incorrectly located
198	375406114171901	198 N01 E69 32CAA 1	Perched or incorrectly located
198	198 S01 E69 02 1	198 S01 E69 02 1	Perched or incorrectly located
198	198 S01 E69 02 2	198 S01 E69 02 2	Perched or incorrectly located
198	198 S01 E69 35DB 1	198 S01 E69 35DB 1	Well located in incorrect section
199	199 N01 E69 16CB 1	199 N01 E69 16CB 1	Perched or incorrectly located
199	199 N01 E69 21AA 1	199 N01 E69 21AA 1	Perched or incorrectly located
201	201 N02 E70 18BB 1	201 N02 E70 18BB 1	Perched or incorrectly located
201	380750114102501	201 N03 E70 07A 1	Perched or incorrectly located
201	381221114121601	201 N04 E69 13CBA 1	Not likely part of the regional or intermediate flow systems
202	202 N01 E67 22AB1	202 N01 E67 22AB1	DTW measurement has no date associated with it
202	202 N01 E69 07CA 1	202 N01 E69 07CA 1	Perched or incorrectly located

Table B-7
Wells Flagged as "N" and Not Used in Transient Calibration
(Page 4 of 5)

HA Number	Site No	Station Name	Reason
202	202 N03 E66 20 1	202 N03 E66 20 1	DTW measurement has no date associated with it
202	202 N03 E66 28 1	202 N03 E66 28 1	DTW measurement has no date associated with it
202	202 N04 E67 02 1	202 N04 E67 02 1	Well located in incorrect section
202	202 N04 E67 02 2	202 N04 E67 02 2	Well located in incorrect section
202	202 N04 E67 02 3	202 N04 E67 02 3	Well located in incorrect section
202	202 N04 E67 02BB 1	202 N04 E67 02BB 1	Well located in incorrect section
202	202 N04 E67 02D 1	202 N04 E67 02D 1	Well located in incorrect section
202	202 N05 E65 25DD 1	202 N05 E65 25DD 1	Well located in incorrect section
202	381520114262901	202 N05 E67 35BCB 1	Well located in incorrect section
203	203 N01 E67 32AA1	203 N01 E67 32AA1	Well located in incorrect section; DTW measurement has no date associated with it
203	203 S01 E68 05CC 1	203 S01 E68 05CC 1	Perched or incorrectly located
203	374827114221901	203 S01 E68 33C 1	Perched or incorrectly located
203	374737114240501	203 S02 E68 06D 1	Perched or incorrectly located
203	203 S02 E69 05DB 1	203 S02 E69 05DB 1	Well located in incorrect section
204	204 S03 E70 36BC 1	204 S03 E70 36BC 1	Inside perched ET zone
204	373834114054801	204 S03 E71 31CBBA1 USBLM	Well located in mountain block / caldera
204	373704114285601	204 S04 E67 09AD 1	Perched or incorrectly located
204	373626114075001	204 S04 E70 11CCDD1 USBLM	Inside perched ET zone
204	373637114071101	204 S04 E70 11D 1	Inside perched ET zone
204	373324114095301	204 S04 E70 33BD 1 LA & Salt Lake Railroad	Inside perched ET zone
204	373324114095601	204 S04 E70 33CAB 1 LA & Salt Lake Railroad	Inside perched ET zone
204	373154114230301	204 S05 E68 09B 1 USBLM	Perched or incorrectly located
204	373135114140301	204 S05 E69 11D 1	Inside perched ET zone
204	373049114150701	204 S05 E69 15ADDD1	Inside perched ET zone
204	204 S05 E69 16BD 1	204 S05 E69 16BD 1	Inside perched ET zone
204	204 S05 E70 06DD 1	204 S05 E70 06DD 1	Inside perched ET zone
205	205 S12 E66 04BD 1	205 S12 E66 04BD 1	Perched
206	206 S08 E65 35AD 1	206 S08 E65 35AD 1	Perched
207	207 N06 E61 28DA1	207 N06 E61 28DA1	DTW measurement has no date associated with it
207	207 N06 E62 07AB1	207 N06 E62 07AB1	DTW measurement has no date associated with it
207	207 N07 E61 11AC1	207 N07 E61 11AC1	DTW measurement has no date associated with it
207	207 N08 E61 21AC1	207 N08 E61 21AC1	DTW measurement has no date associated with it
207	383544115173401	207 N09 E59 36 1	Well is volcanic, shallow, and likely perched
207	207 N10 E62 31CB1	207 N10 E62 31CB1	DTW measurement has no date associated with it
207	385400115024001	207 N12 E62 18DDAA1 USGS Well 24	Water levels affected by surface-water irrigation
207	207 N14 E60 01CD1	207 N14 E60 01CD1	DTW measurement has no date associated with it
207	207 N14 E60 04AB 1	207 N14 E60 04AB 1	Well is likely perched
208	380450114594201	208 N03 E62 35B 1 USBLM	Flagged for removal based on hydrograph analysis
208	374525115061801	208 S02 E61 23D 2	Flagged for removal based on hydrograph analysis
209	373808115124301	209 S03 E60 35DABD1	Water levels affected by local structural features
209	209 S04 E61 20DA1	209 S04 E61 20DA1	DTW measurement has no date associated with it
210	210 S11 E62 04AB 1	210 S11 E62 04AB 1	Well has too few measurements

Table B-7
Wells Flagged as "N" and Not Used in Transient Calibration
(Page 5 of 5)

HA Number	Site No	Station Name	Reason
210	210 S11 E62 13DB 1	210 S11 E62 13DB 1	Perched; DTW measurement has no date associated with it
210	365926114591301	210 S11 E62 13DBCB1	Perched
210	210 S11 E62 24BD 1	210 S11 E62 24BD 1	Elevations are extremely inconsistent with surrounding wells
210	210 S11 E62 24DB 1	210 S11 E62 24DB 1	Elevations are extremely inconsistent with surrounding wells
210	365834114590001	210 S11 E62 24DBAD1	Perched
210	210 S11 E62 27DD 1	210 S11 E62 27DD 1	Well located in incorrect section
210	365008114541101	210 S13 E63 11BACD1 USBLM (Dutch Flat)	Elevations are extremely inconsistent with surrounding wells
210	364352114544701	210 S14 E63 10 1	Elevations are extremely inconsistent with surrounding wells
215	360545114563401	212 S21 E63 28ACA 1 USBR LG006	Well located outside of study area
215	360644114563801	212 S21 E63 28ACA 2 USBR LG007	Well located outside of study area
215	362553114322701	215 S17 E67 30ABB 1 NV Division of State Parks	Flagged for removal based on hydrograph analysis
215	362003114341101	215 S19 E66 01ABBB1	Well located in incorrect section
215	215 S20 E63 04 1	215 S20 E63 04 1	Well located outside of study area
215	361349114524401	215 S20 E64 18CB 1	Well located outside of study area
215	BM-LIGHTFOOT-2	215 S20 E64 18CB 1 BM-LIGHTFOOT-2	Well located outside of study area
215	BM-LIGHTFOOT-3	215 S20 E64 18DB 1 BM-LIGHTFOOT-3	Well located outside of study area
215	361044114505601	215 S20 E64 29DADB1	Well located outside of study area
215	BM-HEISEN-2	215 S20 E64 29DD 1 BM-HEISEN-2	Well located outside of study area
215	BM-HEISEN-1	215 S20 E64 32AA 1 BM-HEISEN-1	Well located outside of study area
215	BM-MARTIN	215 S20 E64 32AA 2 BM-MARTIN	Well located outside of study area
215	215 S21 E63 02 1	215 S21 E63 02 1	Well located outside of study area
215	360714114542501	215 S21 E63 14DBD 1 USBR LG004	Well located outside of study area
215	360713114542501	215 S21 E63 14DBD 2 USBR LG005	Well located outside of study area
215	215 S21 E64 07D 1	215 S21 E64 07D 1	Well located outside of study area
215	360725114494301	215 S21 E64 21CC 1	Well located outside of study area
215	360938114434101	215 S21 E65 09DB 1 USNPS	Well located outside of study area
215	215 S21 E65 16CD 1	215 S21 E65 16CD 1	Well located outside of study area
215	215 S22 E64 03DB 1	215 S22 E64 03DB 1	Well located outside of study area
215	360345114482001	215 S22 E64 14CC 1 USNPS	Well located outside of study area
215	215 S22 E64 25CC 1	215 S22 E64 25CC 1	Well located outside of study area
216	CW-Pehlen	216 S17 E64 35BA 1 CW-Pehlen	Well has too few measurements
218	362732114435301	218 S11 E65 21BDAD1 Valley of Fire State Park	Well appears to be incorrectly located
218	MV-4	218 S15 E66 02CA 1 MV-4	DTW measurement has no date associated with it
218	CW-HALL	218 S17 E65 17DD 1 CW-HALL	Well has too few measurements
218	CW-JONES	218 S17 E65 21DC 1 CW-JONES	Well has too few measurements
218	362529114455101	218 S17 E65 31DBCD1	Well has too few measurements
220	MV-10	220 S15 E67 07CD 1 MV-10	Perched or incorrectly located
220	MV-1	220 S16 E66 22CC 1 MV-1	Well has too few measurements

DTW = Depth to Water

B.4.1.1 Spring Discharge Observations

For continuously monitored spring locations in this period in the study area (see Table B-1), no calendar year average discharge measurements existed prior to 1945. As a result, no continuously monitored spring discharge model observations are available. The spring discharge volumes and variances documented in the Conceptual Model Report (SWNA, 2009, Table G-1), however, were used as observation targets for the steady-state stress period of the transient model. The target flows were assigned a date of December 31, 1944, for identification and plotting purposes, and to indicate the predevelopment nature of the average discharges.

B.4.1.2 Stream Discharge Observations

For continuously monitored stream discharge locations in the study area, only one of the stream gage locations in Table B-2 had calendar year average discharge measurements prior to 1945. Specifically, the USGS MUDDY RV NR MOAPA, NV gage had calendar year average discharge measurements available for 1914 and 1917. Because these measurements preceded the predevelopment period by almost 30 years, no steady-state observation target (stress period 1) was defined or used.

B.4.1.3 Hydraulic-Head and Drawdown Observations

By definition of the development period, water-level-elevation data measured prior to 1945 were considered to be predevelopment observation data. Fifty-seven wells in the transient water-level data set discussed in Section B.3.3.1 had yearly averaged water-level-elevation measurements prior to 1945. Most of these wells had only one yearly averaged measurement prior to 1945, but five of the wells had more than one. For these wells, a mean water-level elevation was calculated using all of the pre-1945 data available for the well. These mean water-level-elevation measurements were then assigned a date of December 31, 1944, for identification and plotting purposes.

The variance associated with the mean water-level elevations was calculated as the sum of the location, land surface, and observation errors. For Flag 2 wells, the observation error was set at zero. For wells assigned Flags 3 and 5, the observation error was defined as the variance of all of the yearly averaged water-level elevations for a given well. For wells assigned Flags 4 and 6, the observation error was defined as the variance of reducing the measurements prior to 1945 to one average value for the predevelopment period. If there was only one measurement prior to 1945, the observation error was set as zero. The predevelopment hydraulic-head-observation data were combined with the post-1945 transient hydraulic-head and drawdown observation data. The combined transient observation data are provided on the DVD included with the report.

B.4.2 Post-1945 Model Observations

Hydrologic measurements made after 1945 were considered to be part of the historical development period for the study area. The hydrologic measurements were used to derive transient discharge, flow, and hydraulic-head observations for the study area. These observations are discussed in greater detail in the following sections.

B.4.2.1 Spring Discharge Observations

Spring discharge observations for the transient stress periods were derived from the spring discharge data set discussed in Section B.3.1. Because of the relatively limited periods of record for the continuously monitored springs (see Table B-1), there were no obvious declines in spring flows. As a result, it was assumed that the flows were approximately steady for all the springs and that there should be zero change in flow through time. The first yearly averaged spring discharge was treated as the transient flow observation target for a given spring, while the rest of the yearly averaged spring discharges were treated as change in flow observations. The variance associated with the first yearly averaged spring discharge was calculated as the variance associated with the reduction of the multiple yearly measurements to one yearly averaged discharge measurement. The variance associated with the changes in flow for the springs was calculated as the variance of all flows.

Table B-1 shows that for several of the continuously monitored spring locations transient data were available only after 2004. For these spring locations, an average of the spring discharge data after 2004 was applied as a transient spring discharge target for the year 2004. This was done so that the transient model calibration would match the spring flows at the end of the model, close to when measurements were taken, rather than to treat them as predevelopment steady-state targets. The spring discharge observation targets and the changes in flow by spring are provided on the DVD included with this report.

B.4.2.2 Muddy River Observations

Muddy River stream discharge observations were derived from the stream discharge data set discussed in Section B.3.2. Each calendar year average stream discharge measurement was treated as a flow observation for each of the gage locations. As a result, there was no calculation of a reduction in stream flow similar to what was done for the spring discharge measurements. The standard deviation in stream flow for the stream gage locations was defined as 15 percent which means that 95 percent of the daily discharges are within 15 percent of their true values. This was based on the USGS “fair” accuracy rating assumed for the gages. The flow observation data for the transient flow model are provided on the DVD included with this report.

B.4.2.3 Hydraulic-Head and Drawdown Observations

Based on the well qualifiers (flags), hydraulic-head and drawdown observations were derived from the transient water-level data set. Table B-8 provides a summary of the methodologies used to derive the hydraulic-head and drawdown observations for the transient model.

As described in Table B-8, for each flag type, a different methodology to derive the hydraulic-head and drawdown observations was used. For a given well, every yearly averaged water-level elevation represented either a hydraulic-head or drawdown observation. Specifically, the first yearly averaged water-level elevation was considered to be the hydraulic-head observation for a well. The subsequent yearly averaged water-level elevations were considered to be the drawdown observations.

Table B-8
Hydraulic-Head and Drawdown Observation Calculations for the Transient Stress Periods

Flag Type	Hydraulic Heads			Drawdowns		
	Description	Observation Calculation (ft amsl)	Variance Calculation[a, b, c] (ft^2)	Description	Observation Calculation (ft)	Variance Calculation[c] (ft^2)
1	Preliminary flag that is no longer used.					
2	Only one head observation	Yearly averaged head elevation	VAR = LOC + GS + OBS (OBS = 0)	No drawdown observations	NA	NA
3	One head observation for first yearly averaged time[d]	Mean elevation of all of the yearly averaged elevations	VAR = LOC + GS + OBS (OBS = variance of all the yearly averaged elevations for the well)	Observations at yearly averaged times[d] following the first yearly average	0	Variance = OBS (OBS = Variance of all the yearly averaged elevations for the well)
4	One head observation for first yearly averaged time[d]	First yearly averaged elevation for a given well	VAR = LOC + GS + OBS (OBS = variance of observations in first yearly averaged calculation; '0' if only 1 observation)	Observations at yearly averaged times[d] following the first yearly average	First yearly average value minus each subsequent yearly average value	Variance = OBS (OBS = Variance of all the yearly averaged elevations for the well)
5	One head observation for first yearly averaged time[d]	Mean elevation of all of the yearly averaged elevations	VAR = LOC + GS + OBS (OBS = variance of all the yearly averaged elevations for the well)	Observations at yearly averaged times[d] following the first yearly average	0	Variance = OBS (OBS = Variance of all the yearly averaged elevations for the well)
6	Head observation for each yearly averaged time	Yearly averaged head elevation for each year	VAR = LOC + GS + OBS (OBS = variance of observations for yearly averaged elevation; '0' if only 1 observation)	No drawdown observations	NA	NA

NA = Not applicable
[a]LOC - Location error for the well
[b]GS - Land-surface elevation error for the well
[c]OBS - Observation error for the well
[d]Yearly hydraulic-head averages are computed using head value observations falling within a given calendar year (i.e., Jan. 1 through Dec. 31). For plotting purposes, it was assumed that the yearly averaged value fell on June 15 of that year.

The exceptions to this were wells that were assigned Flags 2 or 6. For Flag 2 wells, there was only one yearly averaged water-level elevation. As a result, the water-level measurements for these wells were always hydraulic-head observations. For Flag 6 wells, each yearly averaged water-level-elevation measurement was treated as a hydraulic-head observation, and no drawdown observations were derived. The following sections discuss the calculation of the hydraulic-head and drawdown observations shown on Table B-8 for the transient well type flags in greater detail.

B.4.2.3.1 Flag 2 Hydraulic-Head and Drawdown Observations

Flag 2 wells had only one yearly averaged water-level-elevation measurement. As a result, Flag 2 wells have only a hydraulic-head-observation measurement and no drawdown observation. The hydraulic-head observation for Flag 2 wells was the yearly averaged water-level-elevation measurement. The variance calculated for the hydraulic-head observation was the sum of the location and land-surface-elevation errors for the well.

B.4.2.3.2 Flag 3 Hydraulic-Head and Drawdown Observations

Flag 3 wells were located in hydrographic areas with little to no groundwater pumping during the historical development period. It was assumed that any fluctuations in the water-level elevations for these wells were due to natural factors. As a result, the hydraulic-head observations for these wells were defined as the overall mean elevation of all the yearly averaged water-level elevations. The variance for the hydraulic-head observation was defined as the sum of the location, land surface, and observation errors. For Flag 3 wells, the hydraulic-head-observation error was defined as the variance associated with the reduction of the multiple yearly averaged water-level elevations into the one mean value.

Flag 3 wells have drawdown observations for each yearly averaged water-level elevation after the first one. The drawdown observations for Flag 3 wells were defined as zero. The variance for the drawdown observations for Flag 3 wells was defined as the variance associated with the reduction of the multiple yearly averaged water-level elevations into the one mean value.

B.4.2.3.3 Flag 4 Hydraulic-Head and Drawdown Observations

Flag 4 wells are located in hydrographic areas that have had groundwater pumping during the historical development period and, specifically, are near groundwater pumping centers. As a result, water-level-elevation fluctuations for these wells could be the result of groundwater pumping. These wells have both hydraulic-head and drawdown observations. The first yearly averaged water-level elevation was defined as the hydraulic-head observation, while the subsequent yearly averaged water-level elevations were defined as the drawdown observations. The hydraulic-head observation for Flag 4 wells was defined as the yearly averaged water-level elevation for the first measurement of record. The variance for the hydraulic-head observation was defined as the sum of the location, land surface, and hydraulic-head observation errors. For Flag 4 wells, the hydraulic-head-observation error was defined as the variance associated with the reduction of multiple measurements in a given year into the yearly averaged water-level elevation. If there was only one water-level-elevation measurement in a given year, the hydraulic-head-observation error was defined as zero.

The drawdown observations for Flag 4 wells were defined as the difference between the first yearly averaged water-level-elevation measurement and each subsequent yearly averaged water-level-elevation measurement. The draw down observations were negative for drawups and positive for drawdowns. The variance for the drawdown observations was defined as the variance associated with the reduction of the multiple yearly averaged water-level elevations into one mean value for a given well.

B.4.2.3.4 Flag 5 Hydraulic-Head and Drawdown Observations

Flag 5 wells are located in hydrographic areas that have had groundwater pumping during the historical development period. The wells, however, are not located near groundwater pumping centers. As a result, the hydraulic-head and drawdown observations for these wells are calculated the same as for the Flag 3 wells.

Hydraulic-head observations for Flag 5 wells were defined as the overall mean elevation of all the yearly averaged water-level elevations. The variance for hydraulic-head observation was defined as the sum of the location, land surface, and observation errors. For Flag 5 wells, the hydraulic-head-observation error was defined as the variance associated with the reduction of the multiple yearly averaged water-level elevations into the one mean value.

Flag 5 wells have drawdown observations for each yearly averaged water-level elevation after the first one. The drawdown observations for Flag 5 wells were defined as zero. The variance for the drawdown observations for Flag 5 wells was defined as the variance associated with the reduction of the multiple yearly averaged water-level elevations into the one mean value.

B.4.2.3.5 Flag 6 Hydraulic-Head and Drawdown Observations

Flag 6 wells are located in hydrographic areas where groundwater pumping has occurred during the historical record, but these wells have been identified as exhibiting water-level-elevation fluctuations that can be attributed to climatic factors. As a result, each yearly averaged water-level elevation for Flag 6 wells is treated as a hydraulic-head observation. Flag 6 wells have no drawdown observations.

Hydraulic-head observations for Flag 6 wells were defined as the yearly averaged water-level elevation for each of the years in the period of record for the well. The variance for the hydraulic-head observation was defined as the sum of the location, land surface, and observation errors. For Flag 6 wells, the hydraulic-head-observation error was defined as the variance associated with the reduction of multiple measurements in a given year into the yearly averaged water-level elevation. If there was only one water-level-elevation measurement in a given year, the hydraulic-head-observation error was defined as zero.

B.5.0 SUMMARY

Hydrologic data sets of spring flow, stream flow, and water-level elevations were compiled and analyzed for the purpose of developing observation data sets for inclusion into the transient numerical model that might potentially show a response to groundwater pumping in the study area. This process included updating the data sets documented in the Baseline Report (SNWA, 2008) by adding new well locations and new water-level measurements to existing sites. It also included obtaining daily mean discharge data for both springs and streams in the study area that have continuous measurements.

The hydrologic data sets were processed and analyzed by reducing multiple yearly measurements to one average yearly measurement, deriving calendar year discharges for spring and stream locations, deriving a transient water-level-elevation data set, and assigning well-qualifier and use-code flags to the well locations in the transient water-level data set to guide their use in the model calibration.

Based on the hydrologic data sets and data analysis, observation data sets were constructed for use in calibration of the transient flow model. Model observation data sets were derived for both the pre-1945 and post-1945 time periods.

B.6.0 REFERENCES

Johnson, J., 1999, Estimation of stormwater flows in Las Vegas Wash, Nevada and potential stormwater capture: In Las Vegas Wash Coordination Committee, (2000), Las Vegas Wash Comprehensive Adaptive Management Plan, Appendix 2.1, p. 1-31.

Las Vegas Valley Water District, 2001, Water resources and ground-water modeling in the White River and Meadow Valley flow systems, Clark, Lincoln, Nye, and White Pine counties, Nevada: Las Vegas Valley Water District, Las Vegas, Nevada, 297 p.

LVVWD, see Las Vegas Valley Water District.

National Climatic Data Center, 2009, U.S. Palmer drought indices [Internet], [accessed August 11, 2009], available from http://www.ncdc.noaa.gov/oa/climate/research/prelim/drought/palmer.html.

NCDC, see National Climatic Data Center.

SNWA, see Southern Nevada Water Authority.

Southern Nevada Water Authority, 2008, Baseline characterization report for Clark, Lincoln, and White Pine Counties Groundwater Development Project: Southern Nevada Water Authority, Las Vegas, Nevada, 1146 p.

Southern Nevada Water Authority, 2009, Conceptual model of groundwater flow for the Central Carbonate-Rock Province—Clark, Lincoln, and White Pine Counties Groundwater Development Project: Southern Nevada Water Authority, Las Vegas, Nevada, 416 p.

Appendix C

Water-Use Data Analysis

C.1.0 INTRODUCTION

This appendix describes the estimates of historical groundwater use for the study area. Historical records of anthropogenic stresses are very few within the study area. Such information is required, however, to characterize the regional flow system under transient conditions and must be reconstructed using the best estimation methods possible, when actual records do not exist. The most significant anthropogenic activities that generally affect the flow systems of the study area are groundwater withdrawals (i.e., pumping). In addition, stream diversions from the Muddy River may also have a significant impact on the flow system because this river is not only fed by large regional springs, but is also hydraulically connected to the flow system along its stream bed. Muddy River water is, in essence, groundwater. Based on the available potentiometric data provided in SNWA (2008) and Appendix B of this document, the regional flow system, except for a few localized areas, has essentially remained unaffected by human activities. Nonetheless, estimates of the historical groundwater use in the study area were needed to calibrate the numerical model to transient conditions. The transient model was then used to simulate how the historical groundwater use and the proposed Project pumping might affect groundwater conditions within the study area. A summary of background information is provided, followed by the purpose and scope of the work described in this appendix.

C.1.1 Background

Although groundwater and surface-water uses affect the hydrologic system in different ways, the net effect on the regional flow system is due to the consumptive portion of the total water use. According to NDWR (2008), consumptive water use can be defined as "the portion of water withdrawn from a surface water or groundwater source that is consumed for a particular use, and does not return to its original source or another body of water."

With respect to groundwater use, after water is pumped from the flow system, some of the pumped water is consumed and some is lost, while the remainder is returned to the flow system. If losses are assumed to be negligible, the net effect on the hydrologic system is caused by the consumptive use. This principle applies to irrigation, domestic, and industry uses. For agricultural water use, the consumptive use is the ET of the irrigated crop. For community water use, the consumptive use is the ET of landscape vegetation and the evaporation loss associated with wastewater disposal.

Regarding surface-water use, only the consumptive portion of water use impacts the hydrologic system. For example, after surface water is diverted from a stream or spring, some of the diverted water is consumed by plant life or lost to infiltration, while the remainder returns to the hydrologic system. Thus, the net water draft from the hydrologic system is the consumptive use. In the absence of a surface-water diversion, a stream flow or spring flow spreads out on the valley floor, where it naturally irrigates phreatophytes, evaporates, or infiltrates into the subsurface. With a diversion, the ultimate effect is to reduce the consumptive use of the phreatophytes by an amount equal to the consumptive-use part of the diversion. Except for stream diversions from the Muddy River in the southern portion of the study area, the effect of irrigation with surface water is assumed to have equilibrated within the flow system and is, therefore, implicitly accounted for by the groundwater ET estimates. Thus, except for major municipal and industrial and power plant diversions from the Muddy River, stream diversions will not be accounted for explicitly in the consumptive water-use estimates.

C.1.2 Purpose and Scope

Consumptive water-use estimates for the hydrographic areas composing the model domain were needed as input to the numerical model to calibrate the transient numerical model and to simulate the cumulative effects of groundwater pumping and Muddy River diversions.

The consumptive water-use estimates reflect groundwater and surface-water development related to municipal, agricultural, industrial and power plant, and mining and milling uses. The development of water resources from the natural condition represents an increase in the overall consumptive use of the regional flow system from the steady-state condition, in which the only consumptive uses were the transpiration of natural vegetation and evaporation.

The resultant work products are (1) a series of maps that depict the extent of groundwater-irrigated cropland in the study area for nine different time periods, (2) estimated historical consumptive water use for each of the identified time periods, and (3) a series of maps that depict the locations of the groundwater points of diversion or surface-water diversions for each of the time periods.

The remaining sections of this appendix discuss the water-use information available for the study area, the methodology used to estimate historical consumptive water use for the hydrographic areas in the study area, and the distribution of the consumptive water-use estimates to appropriate points of diversion. The consumptive water-use estimates were derived by hydrographic area and manner of use for the period 1945 to 2004.

C.2.0 AVAILABLE INFORMATION

Several agencies, including the USGS, NDWR, Nevada Division of Water Planning, and UDWR, have attempted to quantify water use for select portions of the study area. This section provides a brief summary of the pertinent sources.

The USGS reports data on water withdrawals by state, source of water, and category of use at 5-year intervals for the United States (e.g., Solley et al., 1993, 1998; Hutson et al., 2004). Data files associated with these reports estimate water use by county. In addition to the 5-year water-use estimates, the USGS estimated groundwater pumping and artificial recharge for the year 2000 in SIR 2004-5239 (Lopes and Evetts, 2004). That report provided estimates of groundwater pumping by hydrographic area for the entire state of Nevada for several categories of use, including irrigation, mining, water systems, geothermal, domestic, and miscellaneous. A subset of the data for the model area is provided in Table C-1. More recently, the USGS estimated water use in 2005 for 12 hydrographic areas in White Pine County as part of BARCASS (Welch et al., 2008). Welch et al. (2008) estimated water use for several types of use, including stock watering, mining, public supply, and domestic.

The State of Nevada has also estimated groundwater pumping and water use in Nevada in several reports published by the Department of Conservation and Natural Resources, including those by Smales and Harrill (1971) and the Nevada Division of Water Planning (1992). Groundwater-pumping inventories are also accessible on the NDWR website for some hydrographic areas. Typically, groundwater-pumping inventories are available from 1989 to the present. Available data for select hydrographic areas in the model area are listed in Table C-2. These estimates can be compared to the year 2000 estimates from the USGS. The table reflects that, for most of the hydrographic areas, the total estimated groundwater pumpage has varied very little between 2000 and 2004. Notable increases in groundwater pumpage between 2000 and 2004, however, can be seen in Panaca and Pahranagat valleys.

The UDWR prepares yearly reports on the groundwater conditions in Utah. These "Cooperative Investigations" reports are available from 1964 to 2007, include estimates of groundwater-use volumes by type of use, and cover the portion of Snake Valley located in Utah. These reports, however, do not include quantified estimates of the extent of the irrigated cropland.

Table C-1
Groundwater-Pumpage Estimates (in af) for Hydrographic Areas in the Model Area in 2000

HA Number	HA Name	Irrigation and Stock Watering	Mining	Water Systems	Geothermal Productions	Self-Supplied Domestic	Misc.	Total Pumpage
171	Coal Valley	0	0	0	0	30	0	30
172	Garden Valley	0	0	0	0	30	0	30
174	Jakes Valley	0	0	0	0	30	0	30
175	Long Valley	0	0	0	0	40	0	40
178	Butte Valley	3,560	0	0	0	80	0	3,640
179	Steptoe Valley	3,560	0	2,800	0	0	0	6,360
180	Cave Valley	0	0	0	0	40	0	40
181	Dry Lake Valley	0	0	0	0	60	0	60
182	Delamar Valley	0	0	0	0	30	0	30
183	Lake Valley	12,990	0	0	0	30	0	13,020
184	Spring Valley	4,170	0	20	0	90	0	4,280
185	Tippett Valley	0	0	0	0	20	0	20
194	Pleasant Valley	0	0	0	0	0	0	0
195	Snake Valley	470	0	30	0	30	0	530
196	Hamlin Valley	0	0	0	0	20	0	20
198	Dry Valley	5,170	0	0	0	10	0	5,180
199	Rose Valley	1,370	0	0	0	0	0	1,370
200	Eagle Valley	0	0	0	0	0	0	0
201	Spring Valley	0	0	0	0	20	0	20
202	Patterson Valley	2,170	0	40	0	0	0	2,210
203	Panaca Valley	9,250	0	470	0	70	0	9,790
204	Clover Valley	0	0	120	0	0	0	120
205	Lower Meadow Valley Wash	330	0	0	0	120	0	450
206	Kane Springs Valley	0	0	0	0	30	0	30
207	White River Valley	3,340	0	50	0	140	0	3,530
208	Pahroc Valley	0	0	0	0	30	0	30
209	Pahranagat Valley	2,320	0	390	0	80	0	2,790
210	Coyote Spring Valley	0	50	150	0	0	0	200
215	Black Mountains Area	0	0	1,700	0	1,090	0	2,790
216	Garnet Valley	0	0	0	0	40	0	40
217	Hidden Valley	0	0	0	0	10	0	10
218	California Wash	0	0	0	0	160	0	160
219	Muddy River Springs Area	0	0	130	0	0	0	130
220	Lower Moapa Valley	0	0	0	0	960	0	960

Source: Lopes and Evetts (2004)

Table C-2
NDWR Groundwater-Pumpage Inventories (in af) for Select Basins in the Model Area
(Page 1 of 2)

HA Number	HA Name	Year[a]	Irrigation	Recreation	Other[b]	Domestic	Stock Water	Total
198	Dry Valley	1989	5,354	---	---	---	---	5,354
		1990	5,354	---	---	---	---	5,354
		1991	5,230	---	---	---	---	5,230
		1992	4,959	---	---	---	---	4,959
		1993	4,959	---	---	---	---	4,959
		1994	4,959	---	---	---	---	4,959
		1995	4,959	---	---	---	---	4,959
		1996	4,959	---	---	---	---	4,959
		1997	4,959	---	---	---	---	4,959
		1998	4,908.4	1	---	11	---	4920.4
		1999	5,171.4	1	---	10	---	5,182.4
		2000	5,171.4	1	---	10	---	5,182.4
		2001	5,171.4	1	---	10	---	5182.4
		2002	5,171	1	---	14	---	5,186
		2003	5,171	10	---	19	5	5,205
		2004	5,171	10	---	21	5	5,207
199	Rose Valley	1989	590	---	---	---	---	590
		1990	NA	NA	NA	NA	NA	NA
		1991	661	---	---	---	---	661
		1992	1,063.5	---	---	---	---	1,063.5
		1993	1,058.8	---	---	---	---	1,058.8
		1994	1,083.8	---	---	---	---	1,083.8
		1995	1,083.8	---	---	---	---	1,083.8
		1996	1,083.8	---	---	---	---	1,083.8
		1997	1,083.8	---	---	---	---	1,083.8
		1998	1,367.5	---	---	3	---	1,370.5
		1999	1,367.5	---	---	3	---	1,370.5
		2000	1,367.5	---	---	3	---	1,370.5
		2001	1,367.5	---	---	3	---	1,370.5
		2002	1,368	---	---	6	---	1,374
		2003	1,388	---	---	6	---	1,394
		2004	1,388	---	---	6	---	1,394
203	Panaca Valley	1989	7,130	---	150	---	---	7,280
		1990	7,130	---	150	---	---	7,280
		1991	6,431.6	---	150	---	---	6,581.6
		1992	8,462	---	150	---	---	8,612
		1993	7,509	---	150	---	---	7,659

Table C-2
NDWR Groundwater-Pumpage Inventories (in af) for Select Basins in the Model Area
(Page 2 of 2)

HA Number	HA Name	Year[a]	Irrigation	Recreation	Other[b]	Domestic	Stock Water	Total
203 (Cont.)	Panaca Valley (Cont.)	1994	8,386	---	150	---	---	8,536
		1995	8,048	---	150	---	---	8,198
		1996	10,042	---	300	---	2	10,344
		1997	10,699	---	18	64	14	11,095
		1998	9,819	---	306	68	14	10,207
		1999	9,842	---	442	68	14	10,366
		2000	9,232	---	467	70	14	9,783
		2001	9,232	---	391	74	14	9,711
		2002	11,229	---	359	89	14	11,691
		2003	12,635	---	558	91	14	13,298
		2004	13,236	---	1,142	97	14	14,498
209	Pahranagat Valley	1989	4,210	---	---	200	---	4,410
		1990	4,197	---	---	200	---	4,397
		1991	4,901	---	---	200	---	5,101
		1992	4,396	---	---	200	---	4,596
		1993	4,198	---	---	200	---	4,398
		1994	4,103	---	---	200	---	4,303
		1995	3,707	---	---	200	---	3,907
		1996	2,151	---	332	73	37	2,593
		1997	2,586	---	331	73	37	3,027
		1998	2,827	---	214	78	35	3,154
		1999	2,310	---	401	80	37	2,828
		2000	2,279	---	390	84	37	2,790
		2001	1,566	---	339	85	38	2,028
		2002	3,334	---	337	89	45	3,805
		2003	3,758	---	327	91	45	4,221
		2004	3,732	---	293	92	47	4,164
215	Black Mountains Area	2001	---	0.12	1,602	---	---	1,602
		2002	---	---	1,915	1	---	1,916
		2003	---	---	1,976	2	---	1,978
		2004	---	---	1,938	---	---	1,938
216	Garnet Valley	2001	---	---	912	--	---	912
		2002	---	---	844	---	---	844
		2003	---	---	885	---	---	885
		2004	---	---	817	---	---	817

[a]Yearly data from the NDWR website accessed at http://water.nv.gov/
[b] "Other" includes quasi-municipal, industrial, mining, and commercial manners of use.
NA = Not available

C.3.0 HISTORICAL CONSUMPTIVE WATER-USE ESTIMATES

Based on the development history of the basins in the study area, as documented in the Nevada Ground-Water Resources-Reconnaissance Reports and the NDWR water-rights database, groundwater use by man did not become significant until the mid-1940s. However, prior to that time, Boulder Dam (now Hoover Dam) had been completed (i.e., 1937), and Lake Mead had been filled. Spring flow records at the Muddy, Roger, and Blue Point springs indicate that filling the lake has not significantly affected the majority of the flow system of the study area. Thus, predevelopment conditions are assumed to prevail up to 1945 with a historical mean lake level.

The historical development period is from 1945 to 2004. This period represents a time when significant development by man occurred. The end of this period is assumed to represent "current conditions" but is limited to 2004 because most data-compilation activities supporting the data analysis and model development were completed in 2005. In a report titled *Water-Use Trends in the Desert Southwest—1950–2000* (Konieczki and Heilman, 2004), the authors report that the total number of irrigated acreage in Nevada started to decrease in the mid-1970s and appeared to stabilize in the 1990s. The numbers are reported every 5 years. Considering the large scale of this regional study, both in space and time, year-to-year variations in groundwater-resource development are considered minor and beyond the scope of this study. It is, therefore, appropriate to assume that the conditions of the flow system have been approximately the same over the last few years.

For most of the hydrographic areas in the study area, no groundwater-pumping or surface-water diversion records exist from which historical consumptive water-use estimates can be derived. Derivation of a historical pumping schedule is further complicated by the fact that in many of these areas, water for irrigation is supplied by both surface water and groundwater. For example, 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. Nevertheless, estimates of the historical consumptive water use for the model area were made for four different categories of use for the period from 1945 to 2004. The four water-use categories included municipal, agricultural, mining and milling, and industrial and power plant water uses. Stock watering and self-supplied domestic uses were excluded because their consumptive water use is relatively small compared to the other manners of use in the study area.

The consumptive water-use estimates were derived using a combination of reported groundwater-pumping or surface-water diversion data and estimates of consumptive water use based on water-rights information obtained from NDWR and UDWR. The water-rights information was used as a surrogate to estimate consumptive groundwater use because, for the most part, quantifiable groundwater-use data are lacking for most of the study area, especially going back to 1945. Each type of water use will be discussed in greater detail in the following sections.

C.3.1 Municipal Water Use

Estimates of consumptive water use were made for the following municipalities in the study area: Ely, Lund, McGill, Caliente, Alamo, Panaca, Pioche, Moapa, and Moapa Valley. The water use attributed to a community was based on a combination of reported groundwater-pumping or surface-water diversion data and estimates of historical water use. In general, the overall approach consisted of the following steps:

1. Derived historical water-use estimates based on population estimates and per capita water-use rates.

2. Added reported (i.e., known) water-use data, when available, to the historical water-use estimates.

3. Used the reported data along with the population estimates to derive a scaling factor to adjust the population-based, historical water-use estimates. This step ensured that the estimates were consistent with the reported data.

4. Derived historical consumptive water-use estimates from the water-use estimates.

The following sections discuss the estimation of historical consumptive water use by municipalities in greater detail.

C.3.1.1 Water-Use Estimates Based on Population

Historical water-use estimates were derived from population estimates and per capita water-use rates according to the following equation:

$$WU = R \times P \times C \qquad \text{(Eq. C-1)}$$

where,

WU = Municipal water-use estimate, in afy
R = The per capita water-use rate, in gallons per capita per day
P = The population estimate, dimensionless
C = A conversion factor used to convert to afy

Equation C-1 was used to derive water-use estimates for each of the municipalities for each year between 1945 and 2004. Estimates of the independent variables in Equation C-1 are discussed in the following sections.

C.3.1.1.1 Per Capita Water-Use Rates

Per capita water-use rates were obtained from data files downloaded from http://water.usgs.gov/watuse/data/2000/nvco2000.xls. These data files provide water-use estimates by county for the

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United States, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands. These data files support the state-level water-use estimates published in USGS Circular 1268 (Hutson et al., 2004). From the data compiled by Hutson et al. (2004), a per capita water-use rate for municipal water was calculated for each county in Nevada. The per capita water-use rate in gallons per day was 344 for communities in Clark County, 401 for communities in Lincoln County, and 330 for communities in White Pine County.

C.3.1.1.2 Population Estimates

Population data for the communities in Clark, Lincoln, and White Pine counties were obtained from three main sources.

- The first source was a Nevada State Demographer report titled *Nevada County Population Estimates July 1, 1986 to July 1, 2004 Includes Cities and Towns* (Nevada State Demographer, 2004).

- The second source of population data was the Nevada State Library and Archives that can be accessed at http://nevadaculture.org/nsla/.

- The last source of population data was the Clark County Comprehensive Planning Group. They provided population data for the communities of Moapa and others in Lower Moapa Valley for the years 1990 to 1995 and 1990 to 2004, respectively.

Population data for cities, towns, or townships are available by decade. These population data go back to 1860 for certain cities. For the years in which actual population data were not available, estimates were made by linear interpolation between the known years. For example, most cities have population data for every ten years, but not for the individual years within a decade. In these instances, the missing records were derived by linear interpolation between the two known values. Population data from the Nevada State Library and Archives is reported sometimes in terms of a "township." For example, the 1940 U.S. census reports population data for the Alamo township, which includes the actual town of Alamo. The Alamo township included the entire western part of Lincoln County. When possible, these population estimates were scaled to a year in which both the township population and actual town population were both reported. Because each community had a slightly different method to estimate its population, each community is discussed in the following sections explicitly.

C.3.1.1.2.1 Ely

Population data for the city of Ely are available for the years 1940, 1950, 1960, 1970, and 1980 from the Nevada State Library and Archives. Population data for the years 1986 through 2004 are available from the Nevada State Demographer. Population data for the unknown years were estimated by linear interpolation between reported values.

C.3.1.1.2.2 Lund

Population data for "Lund township #4" are available for the years 1940, 1950, and 1960 from the Nevada State Library and Archives. Population data for "Lund township" are also available for the years 1970 and 1980 from the Nevada State Library and Archives. It was assumed that the population of the "Lund township" and "Lund township #4" were the population of the city of Lund for those years. Population data for the "Lund census county division" are available for the year 1990 from the Nevada State Library and Archives. The 1990 population of the "Lund township" was scaled to the year 2000 population of the city of Lund because both were reported for the year 2000. The scaling was not done for the earlier decades because the township boundaries were different prior to 1980. Population data for the city of Lund are available for 1996 to 2004 from the Nevada State Demographer. Population data for the missing years were estimated by linear interpolation between the two decades in which there were reported values.

C.3.1.1.2.3 McGill

Population data for "McGill unincorporated," "McGill census designated place," and "McGill precinct" are available for the years 1930, 1950, 1960, 1970, 1980, and 1990 from the Nevada State Library and Archives. It was assumed that these population values represented the population for the city of McGill. Population data for the city of McGill are available for the years 1996 to 2004 from the Nevada State Demographer. Population data for the missing years were estimated by linear interpolation between the two decades in which there were reported values.

C.3.1.1.2.4 Caliente

Population data for the city of Caliente are available for the years 1950, 1960, 1970, and 1980 from the Nevada State Library and Archives. Population data for "Caliente township" are available for the year 1940 from the Nevada State Library and Archives. The 1940 township population was scaled to the 1950 population that reported both the population of the city and the township. Population data for the city of Caliente are available for the years 1986 to 2004 from the Nevada State Demographer. Population data for the missing years were estimated by linear interpolation between the two decades in which there were reported values.

C.3.1.1.2.5 Alamo

Population data for the "Alamo township" are available for the years 1940, 1950, 1960, 1970, and 1980 from the Nevada State Library and Archives. Population data for the "Alamo census county division" are available for year 1990 from the Nevada State Library and Archives. Population data for the city of Alamo are available for the years 1996 to 2004 from the Nevada State Demographer. The "Alamo township" and "Alamo census county division" data were scaled to the population data for the city of Alamo in 2000 because both the census county division and city population data were available for that year. Population data for the missing years were estimated by linear interpolation between the two decades in which there were reported values.

C.3.1.1.2.6 Panaca

Population data for the "Panaca township" are available for the years 1940, 1950, 1960, 1970, and 1980 based on data from the Nevada State Library and Archives. It was assumed that the population of the "Panaca township" was equal to the population of the city of Panaca. Population data for the city of Panaca are available for 1996 to 2004 from the Nevada State Demographer. Population data for the missing years were estimated by linear interpolation between the two decades in which there were reported values.

C.3.1.1.2.7 Pioche

Population data for the "Pioche township" are available for the years 1940, 1950, 1960, 1970, and 1980 from the Nevada State Library and Archives. Population data for the "Pioche census county division" are available for the year 1990 from the Nevada State Library and Archives. Population data for the city of Pioche are available for 1996 to 2004 from the Nevada State Demographer. The "Pioche township" and "Pioche census county division" data were scaled to the population data for the city of Pioche for the year 2000 because both were reported for that year. Population data for the missing years were estimated by linear interpolation between the two decades in which there were reported values.

C.3.1.1.2.8 Moapa

Population data for "Moapa township #6" are available for the years 1940 and 1950 from the Nevada State Library and Archives. Population data for "Moapa township" are available for the years 1960, 1970, and 1980 from the Nevada State Library and Archives. It was assumed that the populations of the townships were equivalent to the population of the city for those decades. Population data for the city of Moapa are available for the years 1990 through 1995 from the Clark County Comprehensive Planning Group. Population data for the city of Moapa are available for the years 1996 to 2004 from the Nevada State Demographer. Population data for the missing years were estimated by linear interpolation between the two decades in which there were reported values.

C.3.1.1.2.9 Moapa Valley

Population data for Moapa Valley were estimated by summing the populations of the "Logan" (or "Logandale") and "Overton" townships for the years 1940, 1950, 1960, and 1970 from the Nevada State Library and Archives. The population of Moapa Valley was estimated in 1980 by adding the population of the "Logan township" and the "Overton census designated place" from the Nevada State Library and Archives. Population data for Moapa Valley are available for the years 1990 to 2004 from the Clark County Comprehensive Planning Group. Population data for the missing years were estimated by linear interpolation between the two decades in which there were reported values.

C.3.1.2 Groundwater-Pumping and Surface-Water Diversion Data

Municipal groundwater-pumping and surface-water diversion data were obtained from a number of sources including NDWR and the Moapa Valley Water District (MVWD). NDWR reported groundwater-pumping and surface-water diversion data for the communities of Alamo (1986-2004), Ely (2002-2004), and Panaca (1996-2004). These data were only available, however, for a select numbers of years. The MVWD provided groundwater-pumping and surface-water diversion data for the communities of Moapa, Glendale, Logandale, and Overton. Groundwater-pumping data were available for four wells operated by the MVWD. Surface-water diversion data were available for two spring diversion locations that, when not diverted, contribute water to the Muddy River. The surface-water diversion data are available for Jones Spring since 1959 and for Baldwin Spring since 1975. Groundwater-pumping data for Well MX-6 are available since 1986, while the remainder of the groundwater-pumping data from the MVWD (i.e., Arrow Canyon and Logandale wells) are available since 1992. The reported groundwater-pumping or surface-water diversion data from the MVWD are attributed to the actual well or spring diversion locations as opposed to the municipality locations.

C.3.1.3 Adjustment of Water-Use Estimates Based on Reported Data

The reported groundwater-pumping and surface-water diversion data also provided a means to derive historical water-use estimates based solely on the population. Adjustments were made for the communities of Alamo, Panaca, and Ely.

For those communities, scaling factors were derived from the population estimates and the reported water use in a given year. For example, population data and reported water-use data were available for the years 1996 through 2004 for the town of Panaca. An average scaling factor for those years was derived that relates the population to the reported water use. This average scaling factor was then applied to the population estimates for all of the other years to derive estimates of the municipal water use. These estimates were then used instead of the water-use estimates that were based solely on the population and the per capita water-use rate. These scaling factors produce historical water-use estimates that more closely match the reported data for a particular municipality.

The water-use estimate adjustment for the city of Ely was complicated by the fact that Ely obtains its municipal water from both groundwater and surface-water sources. As a result, an additional scaling factor was necessary to account for the source of the water. Based on three years of data (i.e., 2002, 2003, and 2004), the city of Ely obtains 95.8 percent of its municipal water from surface-water sources and 4.2 percent of its municipal water from groundwater sources. As a result, a combined scaling factor was derived to estimate the groundwater from the population estimate. The surface-water use by Ely was not accounted for as a net withdrawal from the regional flow system because the surface water originates from Murry Springs and creek, which are not considered to be part of the regional or intermediate groundwater flow system.

C.3.1.4 Derivation of Municipal Consumptive Water Use

For the sake of simplicity, this study assumed that municipal consumptive water use for all communities was equal to 50 percent of the municipal water use. This assumption is consistent with Harrill (1986) and Brothers et al. (1993) who also assumed that 50 percent of municipal water use was consumptively used. Municipal water use reported by MVWD for groundwater and surface-water diversions in the Muddy River Springs Area and Lower Moapa, however, was assumed to be 100 percent consumptively used because the water is removed from the system and typically transported large distances.

In summary, consumptive water-use estimates for communities in the study area were obtained from a combination of reported groundwater-pumping data, surface-water diversion data, and estimates of water use based on a community's population and a per capita water-use rate. Estimates of water use were obtained by multiplying the per capita water-use rate by the population of a given community or by using the derived scaling factor for a community multiplied by the population. Actual water-use data were used when available. For instance, population data were used to estimate the consumptive use of water for the communities of Alamo and Panaca prior to 1996. After 1996, reported groundwater-pumping data from NDWR were used.

C.3.2 Agricultural Water Use

Most of the consumptive water use in the study area occurs from irrigated croplands. The sources of water for irrigation include precipitation, surface water, and groundwater. Surface water is defined as water that originates as runoff from precipitation, while groundwater includes water that is pumped from underground or water that is discharged from regional springs. A sufficient amount of reported data is not available for the study area to accurately define the agricultural water use for each hydrographic area. As an example, NDWR conducts crop and groundwater-pumpage inventories for select hydrographic areas within the model area, but the data are only available for certain years and not for every hydrographic area. In addition, satellite imagery can be used to delineate agricultural land but is not available for every year back to 1945.

Because of the lack of historical water-use records, estimates of historical consumptive water use for irrigation were derived using a combination of data from the NDWR and UDWR databases, satellite imagery, and crop consumptive-use rates obtained for the study area. The general approach consisted of the following steps:

1. Obtained crop consumptive groundwater-use rates for those hydrographic areas that have agriculture.

2. Derived a series of place-of-use maps that represent the extent of cropland irrigated with groundwater for the years 1945 to 2004.

3. Estimated crop consumptive groundwater-use volumes based on the crop consumptive groundwater-use rates and area of cropland irrigated with groundwater.

The following sections discuss the estimation of crop consumptive groundwater-use volumes in greater detail.

C.3.2.1 Derivation of Crop Consumptive Groundwater-Use Rates

Crop consumptive groundwater-use rates vary based upon the crop type, local climate conditions, and geographic location. For basins in the study area, NDWR has recently updated crop ET and net irrigation water-requirement estimates for Nevada. Huntington and Allen (2009) stated that the updated estimates of ET and net irrigation water requirements will be used for updating basin water budgets and establishing the amount of irrigation water that is available for water transfers in the future in Nevada. According to Huntington and Allen (2009), the crop ET and net irrigation water-requirement estimates were made for major crops using more than 200 National Weather Service (NWS) stations located throughout the state. Specifically, Huntington and Allen (2009) stated that the net irrigation water requirements for crops were estimated using a dual-crop coefficient and daily soil-water-balance approach.

Huntington and Allen (2009) defined the net irrigation water requirement using the following equation:

$$ETc = (ETact) - (P) \qquad \text{(Eq. C-2)}$$

where,

ETc = The net irrigation water requirement (a.k.a, the net crop consumptive groundwater-use rate) (ft/yr)
ETact = The actual crop ET (ft/yr)
P = The precipitation residing in the root zone (ft/yr)

According to Huntington and Allen (2009), the mean annual net irrigation water requirement of alfalfa for all NWS stations analyzed was computed for the last 30 years of record available, and the results were then spatially distributed and averaged to hydrographic-area boundaries. The net irrigation water requirements of alfalfa for hydrographic areas in this study are provided in Table C-3.

C.3.2.2 Derivation of Groundwater-Irrigation Place-of-Use Maps

The place-of-use maps were derived to delineate the extent of the cropland areas irrigated with groundwater for the period between 1945 and 2004. Because of the lack of historical data, the extents of the croplands irrigated with groundwater were derived using a combination of information from water-right databases from NDWR and UDWR and the overall extent of the irrigated lands as interpreted from 2002 satellite imagery.

In general, the method consisted of the following steps:

1. Subdivided the historical period (1945 to 2004) into discrete time periods to reduce data processing and reporting requirements.

2. Created maps that represent the places of use associated with both surface-water and groundwater irrigation for each time period based on data obtained from NDWR and UDWR.

3. Identified the places of use irrigated exclusively with groundwater rights and the places of use associated with both groundwater and surface-water rights (i.e., commingled or supplemental water rights).

Table C-3
Irrigation Water Requirements for Alfalfa in Study Area

HA Number	HA Name	Alfalfa Net Consumptive Use[a] (ft/yr)
179	Steptoe Valley	2.8
183	Lake Valley	2.9
184	Spring Valley	3.1
194	Pleasant Valley	3.1[b]
195	Snake Valley	3.1[b]
198	Dry Valley	3[c]
199	Rose Valley	3[c]
200	Eagle Valley	3[c]
202	Patterson Valley	2.9[d]
203	Panaca Valley	4
204	Clover Valley	4
205	Lower Meadow Valley Wash	4.1
207	White River Valley	3.3
209	Pahranagat Valley	4.4
218	California Wash	4.6[e]
219	Muddy River Springs Area	4.6[e]
220	Lower Moapa Valley	4.6[e]

[a]Source: Felling (2009)
[b]The net consumptive use is assumed to be the same as for Spring Valley (HA 184)
[c]The net consumptive use is assumed to be the same as for Spring Valley (HA 201)
[d]The net consumptive use is assumed to be the same as for Lake Valley (HA 183)
[e]The net consumptive use is assumed to be the same as for Lower Moapa (HA 220)

4. Adjusted the place-of-use maps by limiting their aggregated extents to the agricultural extents identified on the 2002 satellite imagery (i.e., removed areas associated with the water rights that fall outside of the irrigated areas identified from 2002 satellite imagery).

The following sections discuss the derivation groundwater place-of-use maps in greater detail.

C.3.2.2.1 Subdivision of the Historical Period

The historical development period is from 1945 to 2004. This 60-year period represents a time when significant development by man occurred. Because of the lack of reported crop inventories or water use for the study area, it is difficult to derive groundwater-irrigation place-of-use maps for each year of the historical development period. As a result, the historical development period was subdivided into nine discrete time periods. These time periods include 1945 to 1955, 1956 to 1965, 1966 to 1975, 1976 to 1980, 1981 to 1985, 1986 to 1990, 1991 to 1995, 1996 to 2000, and 2001 to 2004. The periods at the beginning of the historical development period correspond to 10-year time intervals,

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while the periods at the end of the historical development period correspond to 5-year time intervals. The 5-year time intervals were used to obtain better resolution on the timing of irrigation development activities within the study area when more data to estimate water use are available. The subdivision of the historical development period into fewer discrete periods reduces data processing and reporting requirements from 60 yearly estimates of irrigated cropland to 9 estimates of irrigated cropland.

C.3.2.2.2 Surface-Water and Groundwater Places of Use

Maps that represent surface-water and groundwater places of use were derived from information obtained from NDWR and UDWR. NDWR provided a place-of-use database for the basins in the study area that contained irrigated land identified from the 2002 satellite imagery. The place-of-use database identified the number of acres being irrigated in a particular subdivision of the Public Land Survey System (PLSS). For example, a given water right might state that a farmer is allowed to irrigate 50 acres in Section 10 of Township 19N and Range 63E. These legal description locations were then converted to an x-y coordinate system for plotting purposes. In order to simplify this process, a given place-of-use location was plotted in the center of the smallest part of the legal description. For example, if a given place of use was in Township 19N and Range 63E, the place-of-use point was the center of that particular township. As a result, several degrees of accuracy were attributed to the place-of-use information (e.g., quarter-quarter section, quarter section, section, and Township and Range). A majority of the place-of-use information was located to the nearest quarter-quarter section; however, a number of places of use were only accurate to the nearest section or the nearest Township and Range.

Once each place of use was assigned x-y plotting coordinates, the data were further subdivided based on the status of the water right, the source of the water (i.e., groundwater versus surface water), and the time period (e.g., 1945 to 1955) to which each water right's filing date corresponded. The x-y data were then plotted in ArcGIS®. Only active water rights were used to create the maps representing the surface-water and groundwater places of use. For this study, active water rights included certificated, permitted, vested, reserved, and decreed water rights (along with the corresponding Utah equivalents). After the place-of-use information was subdivided into the appropriate aliquot parts, spatial queries were performed against PLSS shapefiles at the same accuracy as the place-of-use information to identify polygonal areas where irrigation was occurring. The polygonal areas for each accuracy were then combined into one map for each period and source of water. This methodology for identifying irrigation places of use overestimates the actual area of irrigation because, in almost all cases, a given water right is only irrigating a portion of the smallest part of the legal description. For example, a given water right might state that it is irrigating 15 acres of the NW1/4 of the NW1/4 of Section 10 Township 15N and Range 64E, but this methodology would have selected the entire 40 acres of the NW1/4 of the NW 1/4 of Section 10. Nevertheless, this methodology allows for a coarse determination of the locations of irrigation by surface water and groundwater during each of the historical periods. It should be pointed out that an active water right existing in a given time period does not necessarily mean that the water right was actually being used during that time period.

C.3.2.2.3 Identification of Sources of Water for Irrigation Places of Use

The groundwater and surface-water place-of-use maps that were created in the previous step were then used to identify areas where groundwater irrigation occurs. Essentially, the place-of-use maps were used to exclude areas being irrigated solely with surface water. This was done for each of the nine time periods. Surface-water irrigation areas were identified by combining the groundwater and surface-water place-of-use maps for each period. Spatial queries were then performed to identify those places of use that were irrigated solely with groundwater and areas that were irrigated with groundwater and surface water.

The identification of the sources of water for irrigation on the Utah side of Snake and Pleasant valleys was done in a slightly different manner than that used for the places of use in Nevada because a place-of-use database was not available for download. The UDWR website, however, has an online tool that allows for the querying of place-of-use information by section, township, and range. The query results indicate which water rights are being used in a particular aliquot of a section and the source of the water. This tool allowed for the determination of the source of water for the irrigated areas that were delineated from the 2002 satellite image for the Utah side of Snake and Pleasant valleys.

C.3.2.2.4 Adjustment of Place-of-Use Maps

The final step in the delineation of groundwater-irrigated croplands was to adjust the place-of-use maps by limiting their aggregated maximum extents to the actual cropland extents identified on the 2002 satellite imagery. This was done to reduce the irrigated cropland acreage that was obtained from the creation of the place-of-use maps, which overestimate the irrigation acreage. The study assumed that the irrigated areas interpreted from the 2002 satellite imagery represent the maximum extent of croplands irrigated in the study area.

This process consisted of using the place-of-use maps for each time period in conjunction with the delineated agricultural areas from the 2002 satellite imagery. When the places of use in a given time period corresponded to an agricultural area delineated from the 2002 satellite imagery, the delineated agricultural areas were then considered to have been present in that particular time period (see Figures C-1 through C-9 for the place-of-use maps). This build-out process allows for an estimation of the historical agricultural areas found in the study area. Several assumptions are implicit in this estimation methodology including:

- Once a groundwater right becomes active, it is assumed to stay active indefinitely.
- The extents of the irrigated areas interpreted from the 2002 satellite imagery represent the maximum extent.

The resulting estimates of the historical cropland acreages are listed in Table C-4 by basin and time period.

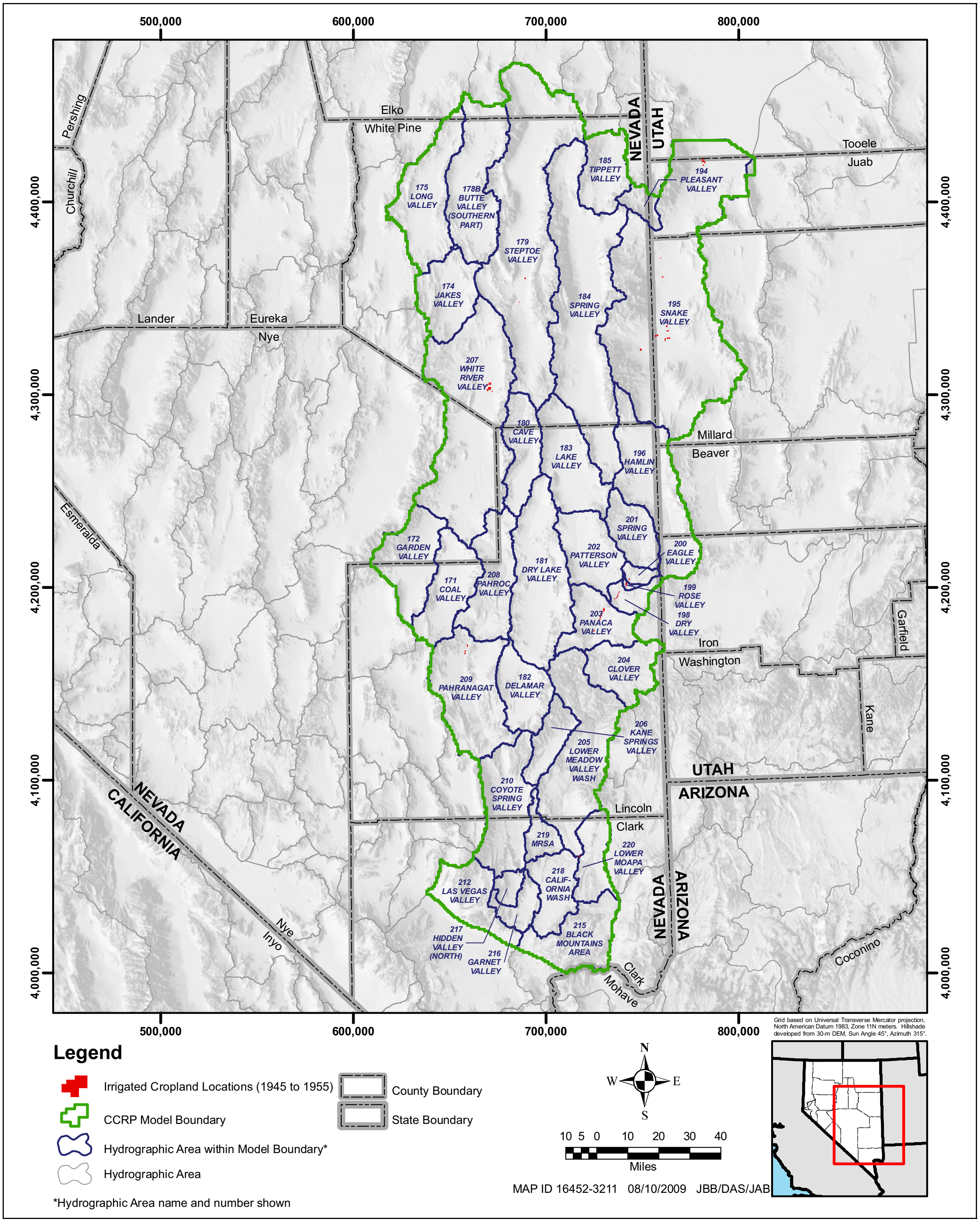

Figure C-1
Spatial Distribution of Groundwater-Irrigated Cropland for the 1945 to 1955 Time Period

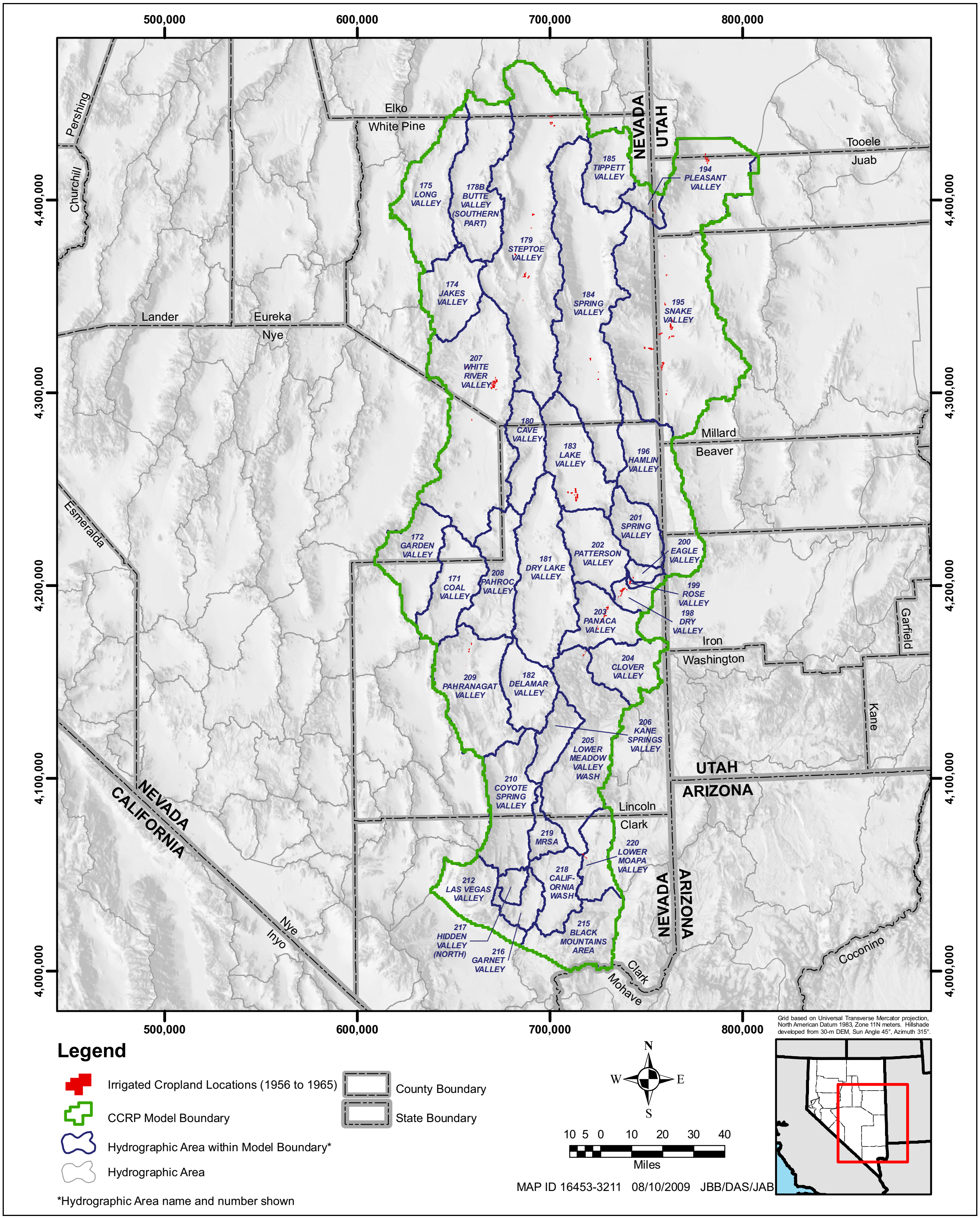

Figure C-2
Spatial Distribution of Groundwater-Irrigated Cropland for the 1956 to 1965 Time Period

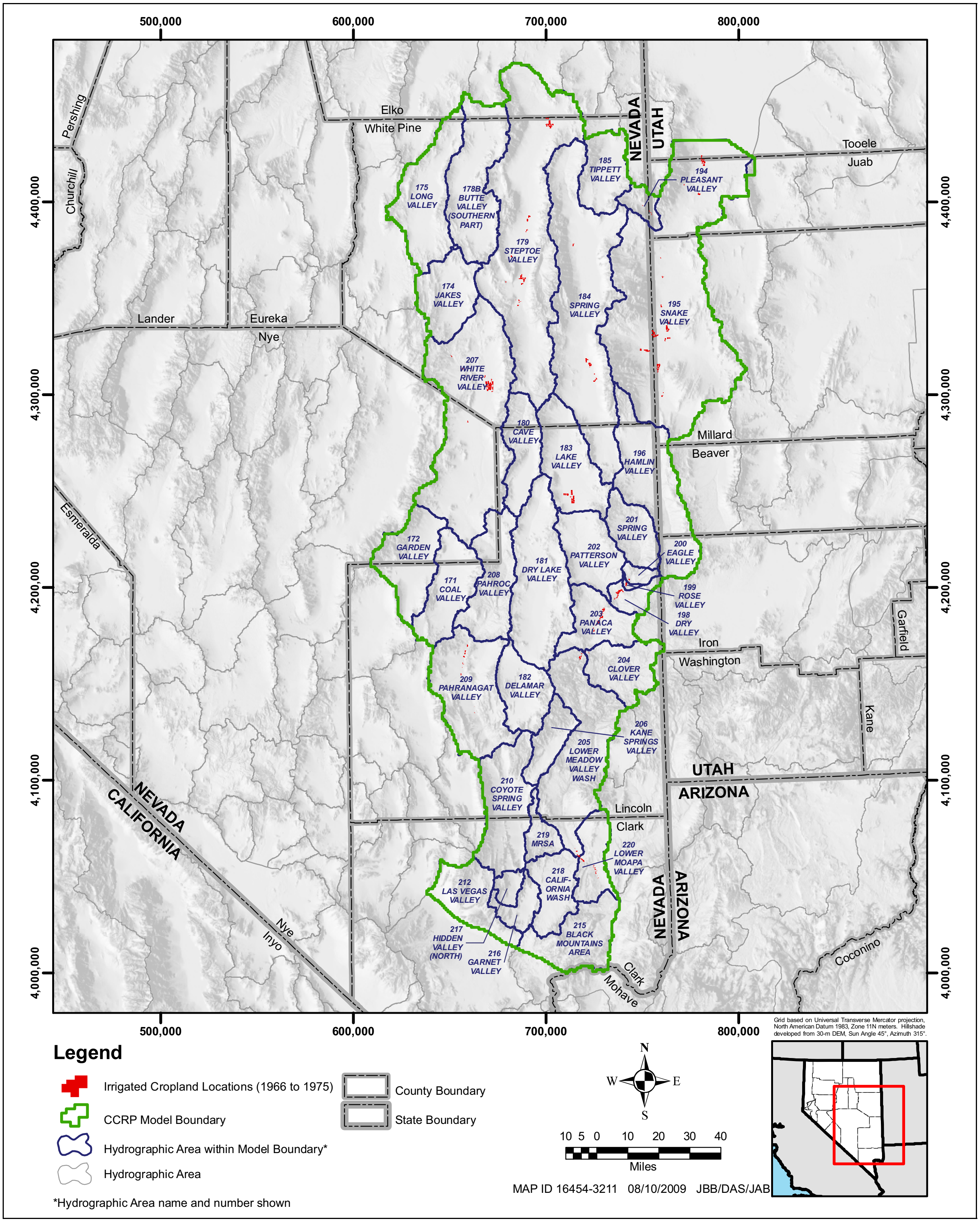

Figure C-3
Spatial Distribution of Groundwater-Irrigated Cropland for the 1966 to 1975 Time Period

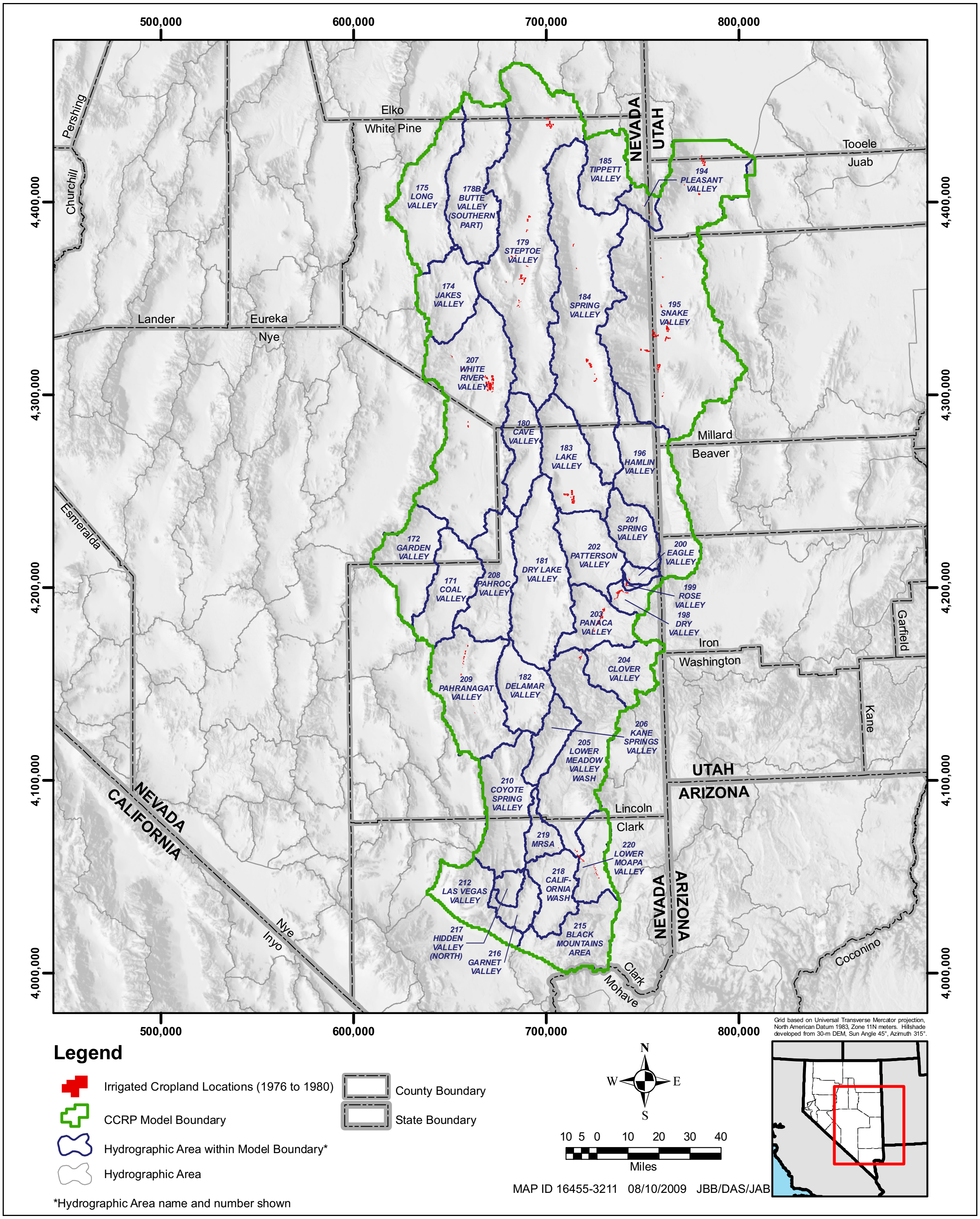

Figure C-4
Spatial Distribution of Groundwater-Irrigated Cropland for the 1976 to 1980 Time Period

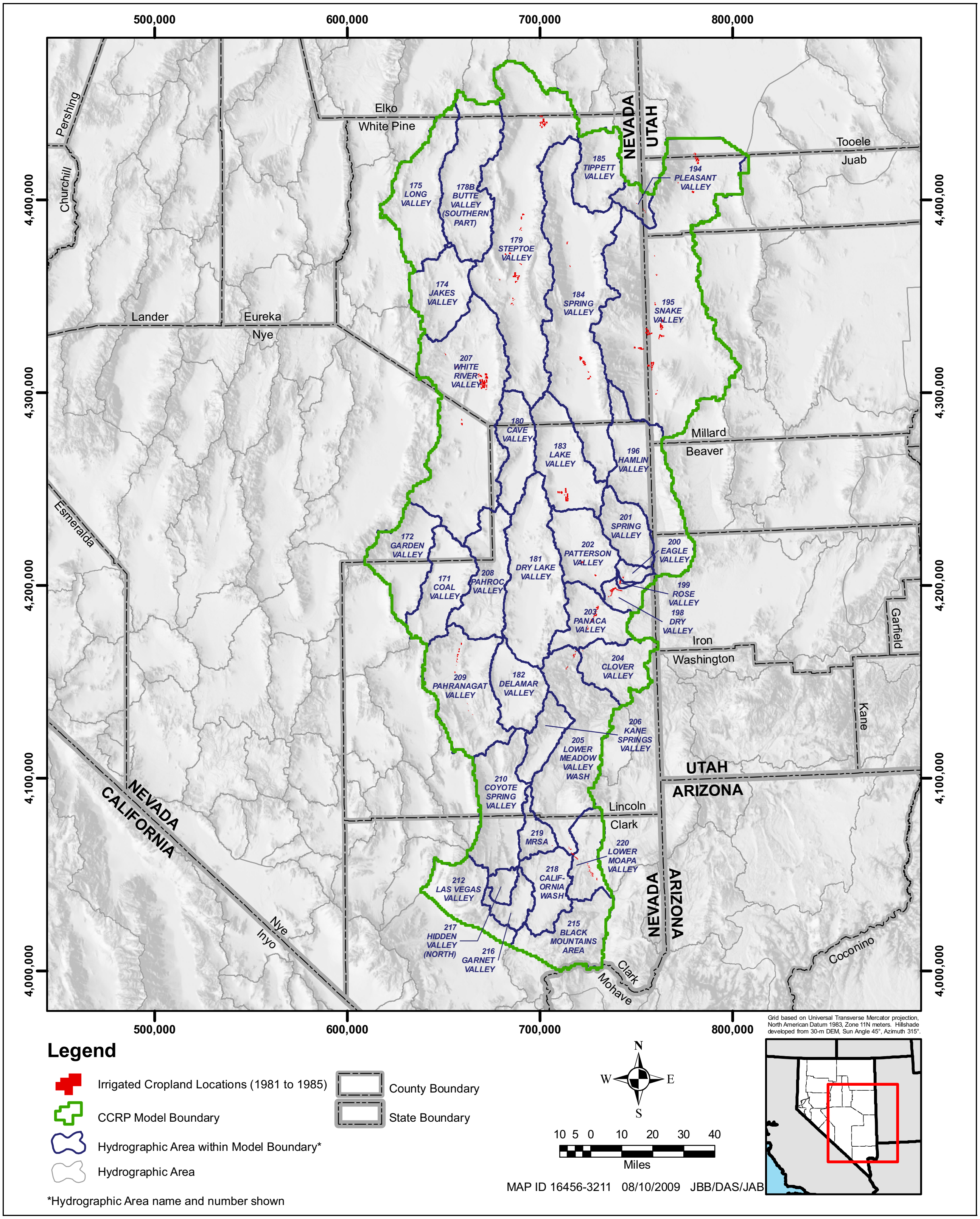

Figure C-5
Spatial Distribution of Groundwater-Irrigated Cropland for the 1981 to 1985 Time Period

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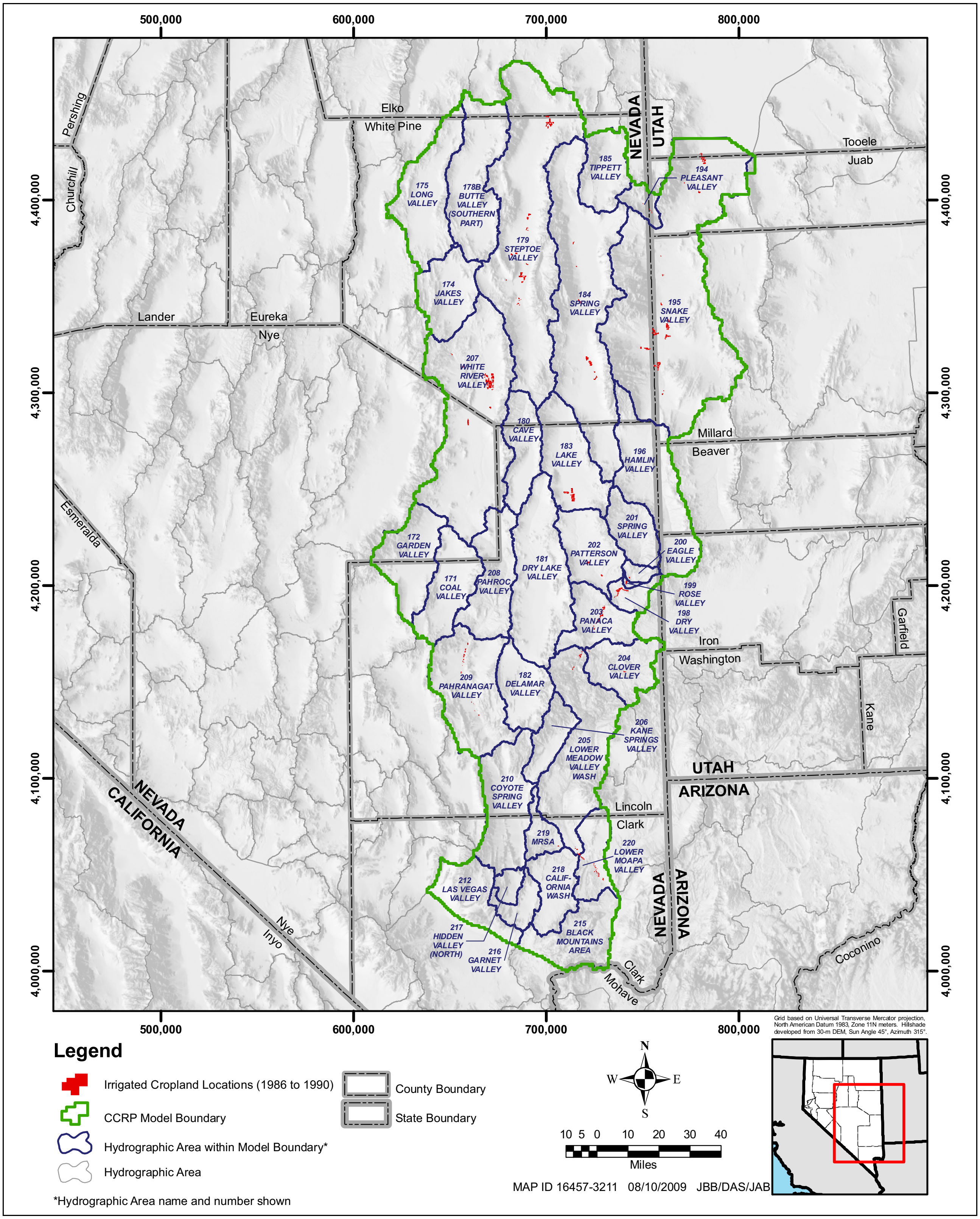

Figure C-6
Spatial Distribution of Groundwater-Irrigated Cropland for the 1986 to 1990 Time Period

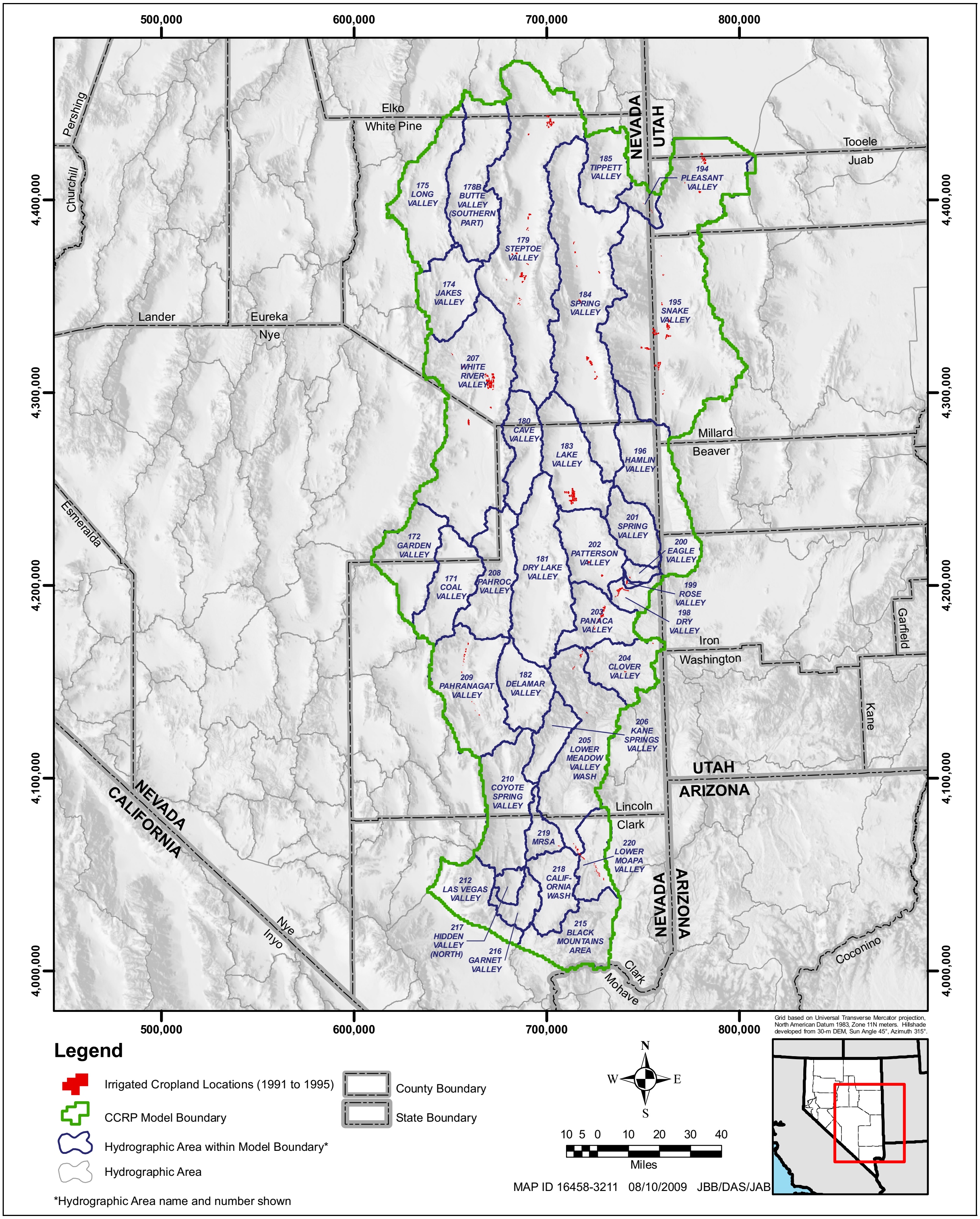

Figure C-7
Spatial Distribution of Groundwater-Irrigated Cropland for the 1991 to 1995 Time Period

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JA_16510

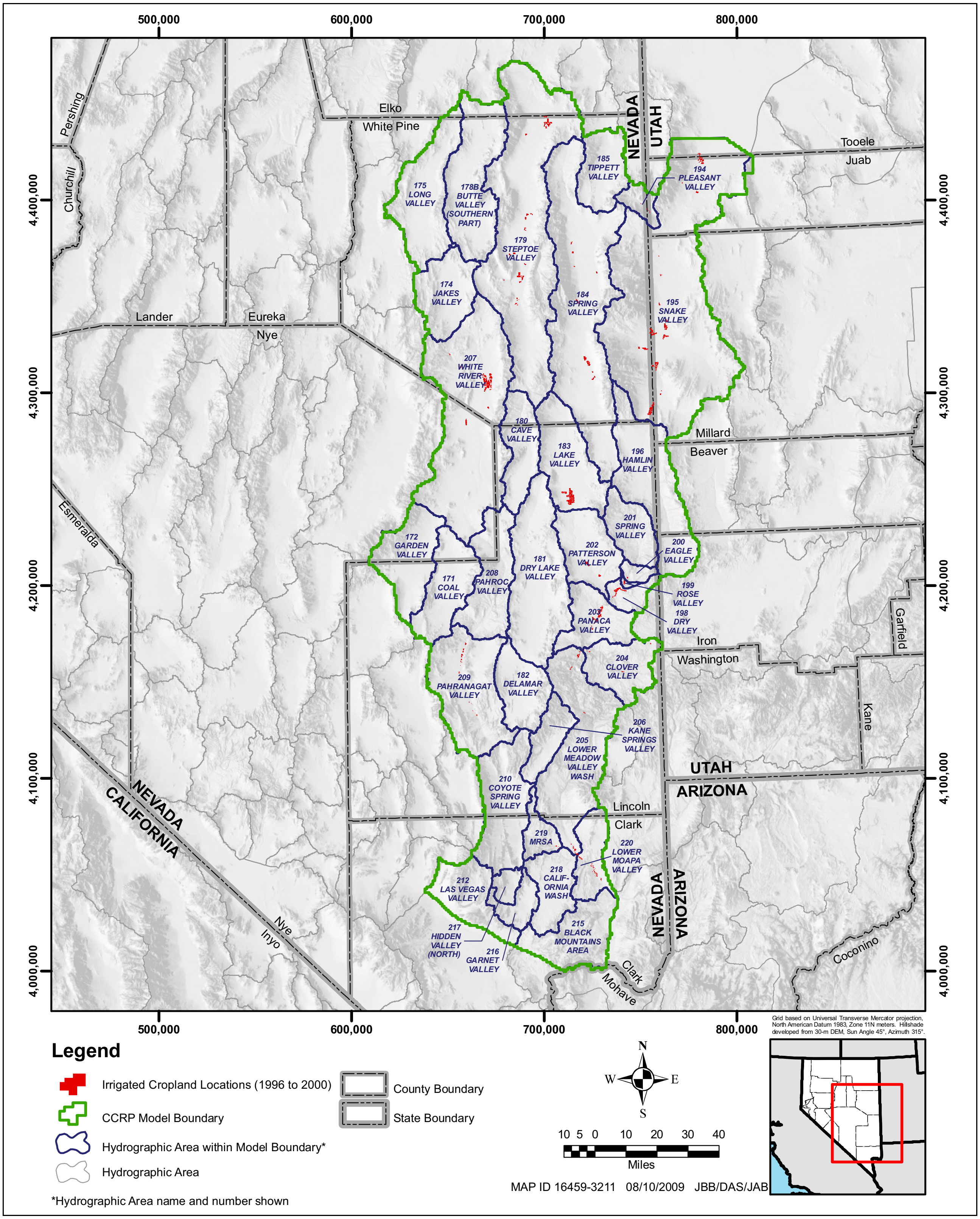

Figure C-8
Spatial Distribution of Groundwater-Irrigated Cropland for the 1996 to 2000 Time Period

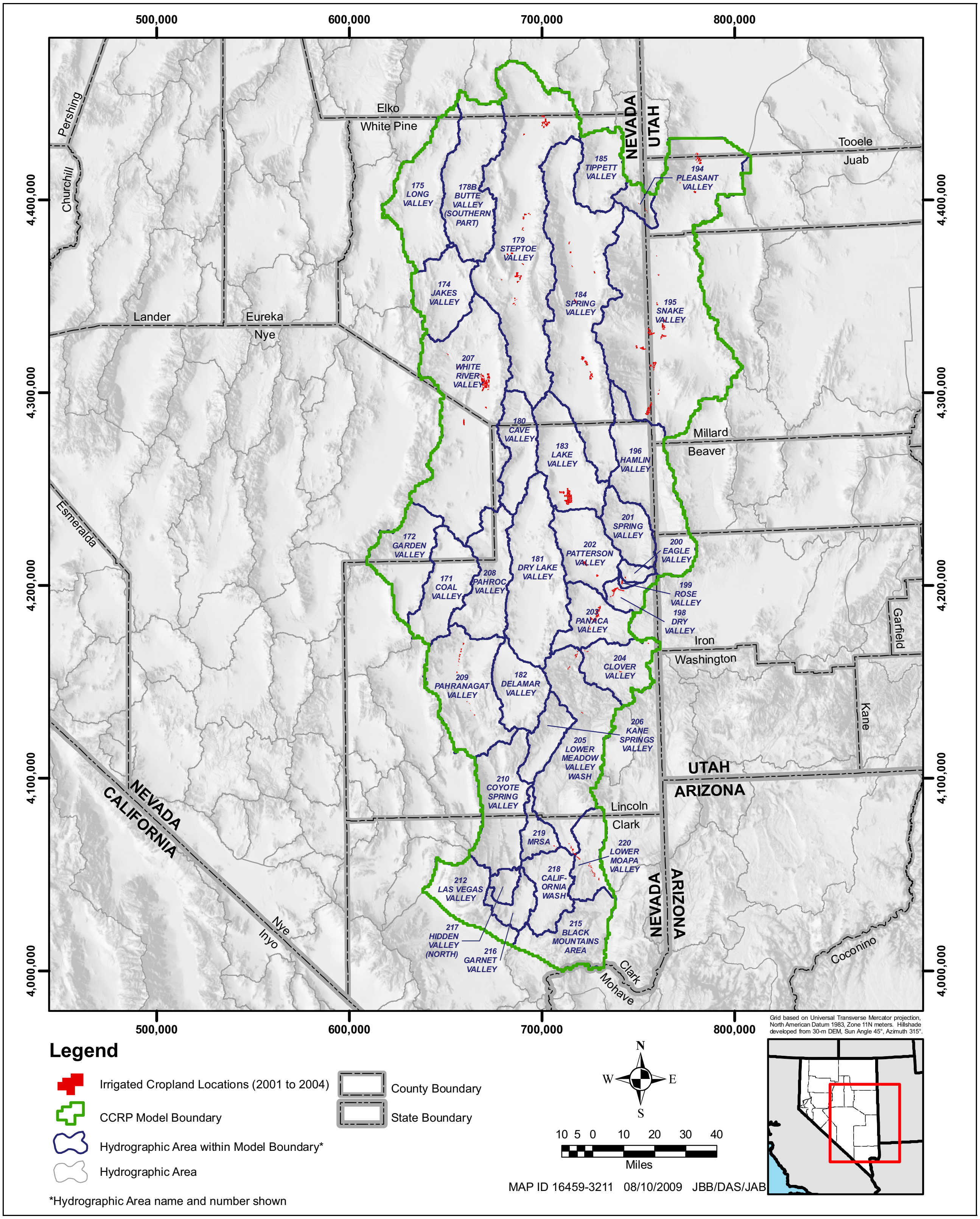

Figure C-9
Spatial Distribution of Groundwater-Irrigated Cropland for the 2001 to 2004 Time Period

Table C-4
Historical Cropland Acreages by Time Period

HA Number	HA Name	Area (acres)								
		1945-1955	1956-1965	1966-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2004
179	Steptoe Valley	138	1,714	3,336	3,630	4,023	4,023	4,118	4,249	4,249
183	Lake Valley	0	1,603	2,080	2,080	2,080	2,223	3,915	4,611	4,611
184	Spring Valley	0	251	1,100	1,500	1,527	1,780	2,014	2,014	2,568
194	Pleasant Valley	0	95	122	122	122	122	122	122	122
195	Snake Valley	1,890	4,408	5,684	5,928	6,089	6,229	6,251	8,052	8,222
198	Dry Valley	319	904	960	1,129	1,205	1,225	1,225	1,225	1,225
199	Rose Valley	223	231	231	231	231	231	231	231	231
200	Eagle Valley	25	43	43	43	43	43	43	43	43
202	Patterson Valley	0	0	0	71	496	496	569	921	921
203	Panaca Valley	811	1,187	1,495	1,495	1,495	1,495	1,872	2,213	2,393
204	Clover Valley	18	18	35	35	35	104	190	190	190
205	Lower Meadow Valley Wash	97	212	413	416	489	489	708	708	708
207	White River Valley	1,170	2,170	3,470	4,468	4,527	5,009	5,182	5,540	5,542
209	Pahranagat Valley	304	314	503	607	613	644	648	648	648
219	Muddy River Springs Area	0	34	34	58	58	81	87	91	91
220	Lower Moapa Valley	0	128	449	564	852	852	852	893	893
	Total Area	**4,995**	**13,311**	**19,954**	**22,376**	**23,886**	**25,047**	**28,027**	**31,750**	**32,657**

Note: The sum of the areas in a given time period may not match the “Total Area” value because of independent rounding.

C.3.2.3 Crop Consumptive Groundwater-Use Estimates

Crop consumptive groundwater-use estimates were derived for the hydrographic areas in the study area for each of the nine time periods using the crop consumptive groundwater-use rates and the estimated cropland acreages. In general, the crop consumptive groundwater-use volumes were derived in the following manner:

1. For places of use where only groundwater irrigation is assumed to occur, the area of the irrigated cropland (Table C-4) was multiplied by the NDWR crop consumptive groundwater-use rate for a particular hydrographic area and a factor of 1 to reflect the groundwater-only use of the water (Table C-3).

2. For places of use where both surface water and groundwater (i.e., supplemental or commingled) are used to irrigate the cropland, the area of irrigated cropland (Table C-4) was

multiplied by the NDWR crop consumptive groundwater-use rate (Table C-3) for a particular hydrographic area and a factor of 0.5 to reflect the intermittent use of supplemental water. This adjustment factor was chosen for several reasons including the Nevada State Engineer's Ruling #5726 (Spring Valley) that stated the maximum supplemental use in Spring Valley was 49.8 percent of the regular annual duty (Nevada State Engineer, 2007). In addition, groundwater-pumping inventories for Pahranagat Valley in the southern portion of the study area show that supplemental groundwater rights have duties assigned to them that are half the duty of nonsupplemental groundwater rights.

The crop consumptive groundwater-use volumes are presented in Table C-5. The table contains the groundwater consumptive use for the acreages and volumes of cropland irrigated solely with groundwater and the acreages and volumes of cropland irrigated by groundwater and surface water by hydrographic area for the selected 10- and 5-year periods. The total acreages and estimated consumptive groundwater-use volumes are plotted against time in Figure C-10.

C.3.3 Mining and Milling Water Use

Consumptive groundwater use in the study area as a result of mining and milling activities was estimated using a combination of groundwater-pumping data obtained from NDWR and estimates of consumptive groundwater use based on mining and milling water rights. Because of the lack of historical data, water-right abstracts were the main source of information for the estimation of mining and milling water use in the study area. In general, the procedure to estimate mining and milling consumptive groundwater use consisted of the following:

1. Derived historical mining and milling groundwater-use estimates for basins in the study area based on the duties associated with the water rights.

2. Added reported (i.e., known) groundwater-use data, when available, to the historical groundwater-use estimates.

3. Derived historical consumptive groundwater-use estimates from the historical groundwater-use estimates.

The following sections discuss the estimation of mining and milling historical water use in greater detail.

C.3.3.1 Derivation of Mining and Milling Groundwater-Use Estimates

Mining and milling groundwater-use estimates were derived by querying the water-right databases for certificated mining and milling water rights. The resulting data sets were then organized by hydrographic area and filtered for groundwater rights. The filtered data were then examined, and supplemental rights were excluded from the resulting data sets. Mining and milling groundwater-use estimates were based on the duty associated with the water right. It was assumed that water-right duties became active two years after the filing date of the water-right application. Presumably, this would allow a sufficient amount of time to begin proving beneficial use on a certificated water right.

Table C-5
Estimates of Groundwater-Irrigated Areas and Consumptive Groundwater-Use Volumes
(Page 1 of 4)

HA Number	Time Period	NDWR Rate	Groundwater Irrigation			Supplemental Groundwater Irrigation			Total Consumptive Groundwater-Use Volume[a]
			Area	Factor	Volume[a]	Area	Factor	Volume[a]	
		(ft/yr)	(acre)	(-)	(afy)	(acre)	(-)	(afy)	(afy)
179	1945 to 1955	2.8	107	1	301	31	0.5	43	344
	1956 to 1965	2.8	1,613	1	4,515	101	0.5	142	4,657
	1966 to 1975	2.8	3,227	1	9,035	110	0.5	154	9,188
	1976 to 1980	2.8	3,425	1	9,591	205	0.5	286	9,877
	1981 to 1985	2.8	3,813	1	10,675	210	0.5	294	10,970
	1986 to 1990	2.8	3,813	1	10,675	210	0.5	294	10,970
	1991 to 1995	2.8	3,817	1	10,688	301	0.5	421	11,109
	1996 to 2000	2.8	3,875	1	10,849	374	0.5	523	11,373
	2001 to 2004	2.8	3,875	1	10,849	374	0.5	523	11,373
183	1945 to 1955	2.9	0	1	0	0	0.5	0	0
	1956 to 1965	2.9	1,603	1	4,647	0	0.5	0	4,647
	1966 to 1975	2.9	2,080	1	6,033	0	0.5	0	6,033
	1976 to 1980	2.9	2,080	1	6,033	0	0.5	0	6,033
	1981 to 1985	2.9	2,080	1	6,033	0	0.5	0	6,033
	1986 to 1990	2.9	2,223	1	6,448	0	0.5	0	6,448
	1991 to 1995	2.9	3,915	1	11,353	0	0.5	0	11,353
	1996 to 2000	2.9	4,611	1	13,373	0	0.5	0	13,373
	2001 to 2004	2.9	4,611	1	13,373	0	0.5	0	13,373
184	1945 to 1955	3.1	0	1	0	0	0.5	0	0
	1956 to 1965	3.1	212	1	658	39	0.5	60	718
	1966 to 1975	3.1	705	1	2,186	394	0.5	611	2,798
	1976 to 1980	3.1	633	1	1,962	867	0.5	1,344	3,306
	1981 to 1985	3.1	633	1	1,962	895	0.5	1,387	3,348
	1986 to 1990	3.1	633	1	1,962	1,148	0.5	1,779	3,740
	1991 to 1995	3.1	779	1	2,413	1,235	0.5	1,914	4,328
	1996 to 2000	3.1	779	1	2,413	1,235	0.5	1,914	4,328
	2001 to 2004	3.1	910	1	2,820	1,658	0.5	2,570	5,390
194	1945 to 1955	3.1	0	1	0	0	0.5	0	0
	1956 to 1965	3.1	0	1	0	95	0.5	146	146
	1966 to 1975	3.1	27	1	85	95	0.5	146	232
	1976 to 1980	3.1	27	1	85	95	0.5	146	232
	1981 to 1985	3.1	27	1	85	95	0.5	146	232
	1986 to 1990	3.1	27	1	85	95	0.5	146	232
	1991 to 1995	3.1	27	1	85	95	0.5	146	232
	1996 to 2000	3.1	27	1	85	95	0.5	146	232
	2001 to 2004	3.1	27	1	85	95	0.5	146	232

Table C-5
Estimates of Groundwater-Irrigated Areas and Consumptive Groundwater-Use Volumes
(Page 2 of 4)

HA Number	Time Period	NDWR Rate	Groundwater Irrigation			Supplemental Groundwater Irrigation			Total Consumptive Groundwater-Use Volume[a]
			Area	Factor	Volume[a]	Area	Factor	Volume[a]	
		(ft/yr)	(acre)	(-)	(afy)	(acre)	(-)	(afy)	(afy)
195	1945 to 1955	3.1	1,639	1	5080	251	0.5	389	5,469
	1956 to 1965	3.1	2,354	1	7297	2,053	0.5	3,183	10,480
	1966 to 1975	3.1	3,246	1	10,063	2,438	0.5	3,778	13,841
	1976 to 1980	3.1	3,490	1	10,820	2,438	0.5	3,778	14,598
	1981 to 1985	3.1	3,652	1	11,320	2,438	0.5	3,778	15,099
	1986 to 1990	3.1	3,791	1	11,753	2,438	0.5	3,778	15,531
	1991 to 1995	3.1	3,814	1	11,823	2,438	0.5	3,778	15,601
	1996 to 2000	3.1	5,587	1	17,320	2,465	0.5	3,821	21,141
	2001 to 2004	3.1	5,745	1	17,809	2,478	0.5	3,840	21,649
198	1945 to 1955	3.0	267	1	800	52	0.5	79	879
	1956 to 1965	3.0	852	1	2,555	52	0.5	79	2,633
	1966 to 1975	3.0	908	1	2,724	52	0.5	79	2,803
	1976 to 1980	3.0	1,026	1	3,079	103	0.5	154	3,233
	1981 to 1985	3.0	1,102	1	3,307	103	0.5	154	3,461
	1986 to 1990	3.0	1,122	1	3,366	103	0.5	154	3,520
	1991 to 1995	3.0	1,122	1	3,366	103	0.5	154	3,520
	1996 to 2000	3.0	1,122	1	3,366	103	0.5	154	3,520
	2001 to 2004	3.0	1,122	1	3,366	103	0.5	154	3,520
199	1945 to 1955	3.0	10	1	31	212	0.5	319	350
	1956 to 1965	3.0	10	1	31	221	0.5	331	362
	1966 to 1975	3.0	10	1	31	221	0.5	331	362
	1976 to 1980	3.0	10	1	31	221	0.5	331	362
	1981 to 1985	3.0	10	1	31	221	0.5	331	362
	1986 to 1990	3.0	10	1	31	221	0.5	331	362
	1991 to 1995	3.0	10	1	31	221	0.5	331	362
	1996 to 2000	3.0	10	1	31	221	0.5	331	362
	2001 to 2004	3.0	10	1	31	221	0.5	331	362
200	1945 to 1955	3.0	25	1	76	0	0.5	0	76
	1956 to 1965	3.0	43	1	129	0	0.5	0	129
	1966 to 1975	3.0	43	1	129	0	0.5	0	129
	1976 to 1980	3.0	43	1	129	0	0.5	0	129
	1981 to 1985	3.0	43	1	129	0	0.5	0	129
	1986 to 1990	3.0	43	1	129	0	0.5	0	129
	1991 to 1995	3.0	43	1	129	0	0.5	0	129
	1996 to 2000	3.0	43	1	129	0	0.5	0	129
	2001 to 2004	3.0	43	1	129	0	0.5	0	129

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Table C-5
Estimates of Groundwater-Irrigated Areas and Consumptive Groundwater-Use Volumes
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HA Number	Time Period	NDWR Rate	Groundwater Irrigation			Supplemental Groundwater Irrigation			Total Consumptive Groundwater-Use Volume[a]
			Area	Factor	Volume[a]	Area	Factor	Volume[a]	
		(ft/yr)	(acre)	(-)	(afy)	(acre)	(-)	(afy)	(afy)
202	1945 to 1955	2.9	0	1	0	0	0.5	0	0
	1956 to 1965	2.9	0	1	0	0	0.5	0	0
	1966 to 1975	2.9	0	1	0	0	0.5	0	0
	1976 to 1980	2.9	71	1	206	0	0.5	0	206
	1981 to 1985	2.9	496	1	1,439	0	0.5	0	1,439
	1986 to 1990	2.9	496	1	1,439	0	0.5	0	1,439
	1991 to 1995	2.9	569	1	1,651	0	0.5	0	1,651
	1996 to 2000	2.9	921	1	2,671	0	0.5	0	2,671
	2001 to 2004	2.9	921	1	2,671	0	0.5	0	2,671
203	1945 to 1955	4.0	722	1	2,889	89	0.5	178	3,067
	1956 to 1965	4.0	1,021	1	4,086	166	0.5	331	4,417
	1966 to 1975	4.0	1,329	1	5,317	166	0.5	331	5,649
	1976 to 1980	4.0	1,329	1	5,317	166	0.5	331	5,649
	1981 to 1985	4.0	1,329	1	5,317	166	0.5	331	5,649
	1986 to 1990	4.0	1,329	1	5,317	166	0.5	331	5,649
	1991 to 1995	4.0	1,649	1	6,597	223	0.5	445	7,042
	1996 to 2000	4.0	1,990	1	7,961	223	0.5	445	8,406
	2001 to 2004	4.0	2,170	1	8,679	223	0.5	447	9,126
204	1945 to 1955	4.0	8	1	33	9	0.5	19	52
	1956 to 1965	4.0	8	1	33	9	0.5	19	52
	1966 to 1975	4.0	25	1	100	10	0.5	19	119
	1976 to 1980	4.0	25	1	100	10	0.5	19	119
	1981 to 1985	4.0	25	1	100	10	0.5	19	119
	1986 to 1990	4.0	95	1	380	10	0.5	19	399
	1991 to 1995	4.0	181	1	723	10	0.5	19	742
	1996 to 2000	4.0	181	1	723	10	0.5	19	742
	2001 to 2004	4.0	181	1	723	10	0.5	19	742
205	1945 to 1955	4.1	97	1	399	0	0.5	0	399
	1956 to 1965	4.1	187	1	768	25	0.5	51	819
	1966 to 1975	4.1	388	1	1,590	25	0.5	51	1,641
	1976 to 1980	4.1	391	1	1,602	25	0.5	51	1,653
	1981 to 1985	4.1	464	1	1,904	25	0.5	51	1,954
	1986 to 1990	4.1	464	1	1,904	25	0.5	51	1,955
	1991 to 1995	4.1	669	1	2,744	38	0.5	79	2,823
	1996 to 2000	4.1	669	1	2,744	38	0.5	79	2,823
	2001 to 2004	4.1	669	1	2,744	38	0.5	79	2,823

Table C-5
Estimates of Groundwater-Irrigated Areas and Consumptive Groundwater-Use Volumes
(Page 4 of 4)

HA Number	Time Period	NDWR Rate	Groundwater Irrigation			Supplemental Groundwater Irrigation			Total Consumptive Groundwater-Use Volume[a]
			Area	Factor	Volume[a]	Area	Factor	Volume[a]	
		(ft/yr)	(acre)	(-)	(afy)	(acre)	(-)	(afy)	(afy)
207	1945 to 1955	3.3	0	1	0	1,170	0.5	1,930	1,930
	1956 to 1965	3.3	262	1	864	1,908	0.5	3,148	4,012
	1966 to 1975	3.3	282	1	931	3,188	0.5	5,260	6,191
	1976 to 1980	3.3	1,011	1	3,337	3,457	0.5	5,704	9,041
	1981 to 1985	3.3	1,011	1	3,337	3,516	0.5	5,801	9,138
	1986 to 1990	3.3	1,391	1	4,590	3,618	0.5	5,969	10,559
	1991 to 1995	3.3	1,391	1	4,590	3,791	0.5	6,256	10,845
	1996 to 2000	3.3	1,515	1	4,999	4,025	0.5	6,642	11,641
	2001 to 2004	3.3	1,515	1	4,999	4,027	0.5	6,645	11,644
209	1945 to 1955	4.4	304	1	1,339	0	0.5	0	1,339
	1956 to 1965	4.4	304	1	1,339	10	0.5	22	1,361
	1966 to 1975	4.4	439	1	1,931	64	0.5	140	2,071
	1976 to 1980	4.4	496	1	2,184	111	0.5	244	2,427
	1981 to 1985	4.4	503	1	2,212	111	0.5	244	2,455
	1986 to 1990	4.4	534	1	2,348	111	0.5	244	2,592
	1991 to 1995	4.4	534	1	2,348	114	0.5	252	2,600
	1996 to 2000	4.4	534	1	2,348	114	0.5	252	2,600
	2001 to 2004	4.4	534	1	2,348	114	0.5	252	2,600
219	1945 to 1955	4.6	0	1	0	0	0.5	0	0
	1956 to 1965	4.6	34	1	157	0	0.5	0	157
	1966 to 1975	4.6	34	1	157	0	0.5	0	157
	1976 to 1980	4.6	34	1	157	24	0.5	54	211
	1981 to 1985	4.6	34	1	157	24	0.5	54	211
	1986 to 1990	4.6	49	1	225	32	0.5	74	299
	1991 to 1995	4.6	55	1	253	32	0.5	74	327
	1996 to 2000	4.6	59	1	271	32	0.5	74	344
	2001 to 2004	4.6	59	1	271	32	0.5	74	344
220	1945 to 1955	4.6	0	1	0	0	0.5	0	0
	1956 to 1965	4.6	128	1	588	0	0.5	0	588
	1966 to 1975	4.6	191	1	879	257	0.5	592	1,471
	1976 to 1980	4.6	191	1	879	373	0.5	857	1,736
	1981 to 1985	4.6	253	1	1164	599	0.5	1,378	2,541
	1986 to 1990	4.6	253	1	1164	599	0.5	1,378	2,541
	1991 to 1995	4.6	253	1	1164	599	0.5	1,378	2,541
	1996 to 2000	4.6	253	1	1164	640	0.5	1,472	2,636
	2001 to 2004	4.6	253	1	1164	640	0.5	1,472	2,636

[a]The sum of the groundwater and supplemental groundwater irrigation volumes may not match the “Total” volume because of independent rounding of the values. Also, the significant figures do not imply a specific degree of accuracy. They were included for tracking/accounting purposes.

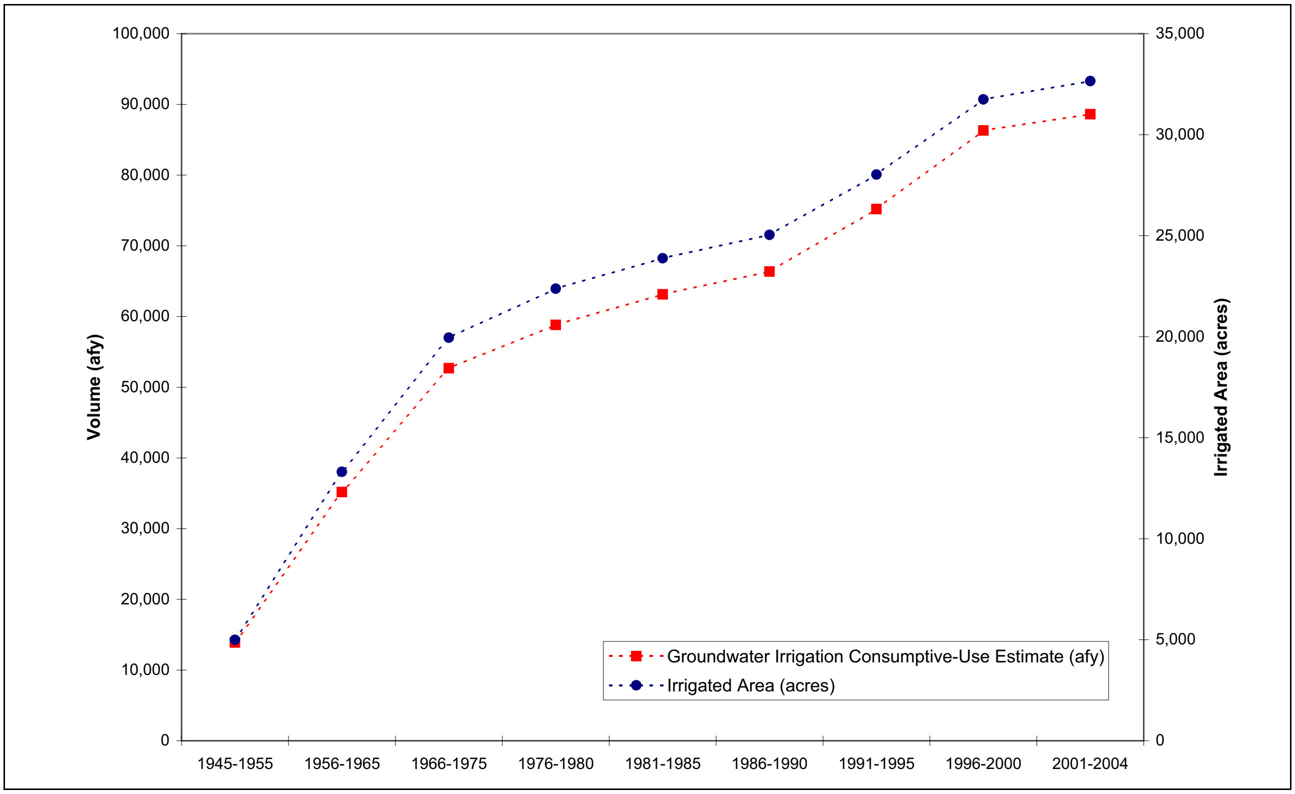

Figure C-10
Final Estimated Groundwater-Irrigated Acreages and Consumptive Groundwater-Use Volumes for the Study Area

Another assumption was that once a given water right became active, it was always active, unless shown to be otherwise. Using these assumptions as a guide, a yearly historical build-out was constructed for each basin in the study area that contained mining and milling water rights for the period 1945 to 2004.

C.3.3.2 Addition of Reported Mining and Milling Data

In addition to the water-right databases, NDWR provided groundwater-pumping reports for several active mines in Steptoe, Long, and White River valleys. Unfortunately, data were only available for years after 1992. The reported data for a particular water right replaced the estimated groundwater-use estimate that was derived in the previous section. In some instances, the groundwater-pumping data obtained from NDWR corresponded to certificated water rights listed as being “supplemental” or permitted rights. In those instances, the water rights that corresponded to the reported data were also added to the groundwater-use estimates from the previous section.

C.3.3.3 Derivation of Mining and Milling Consumptive Groundwater Use

Once the water-right estimates and reported groundwater-pumping data were assembled for the 1945 to 2004 time frame, the consumptive groundwater use for mining and milling was assumed to be 100 percent of the duty from the certificated water rights or from the known groundwater-pumping volumes. The 100 percent consumptive-use factor was based, in part, on Nevada Division of Water Planning (1992). This report stated that, in 1990, White Pine County withdrew 2,930 af of water for mining uses and consumptively used 2,828 af. This resulted in a 96 percent consumptive-use ratio for mining use. For Lincoln County, there was a 97 percent consumptive-use ratio, and for Clark County, there was a 74 percent consumptive-use factor. The 100 percent consumptive-use factor chosen for the model area represents a more conservative bound from the literature data. Mining and milling groundwater consumptive uses were deemed to be insignificant when they did not exceed 150 af in any year. In those cases, the historical groundwater-use estimates for those basins were removed from further consideration.

C.3.4 Industrial and Power Plant Water Use

Consumptive water use in the study area as a result of industrial and power plant use is limited to a relatively few hydrographic areas. The hydrographic areas in the study area with any significant industrial or power plant use are Lower Meadow Valley Wash, Muddy River Springs Area, Garnet Valley, and the Black Mountains Area. The consumptive water-use estimates for these hydrographic areas were based on groundwater and surface-water production data from Nevada Power Co., groundwater-pumping data from NDWR, groundwater-pumping estimates from LVVWD (2001), and groundwater-use estimates based on water-right abstracts. In general, the procedure to estimate industrial and power plant consumptive water use consisted of the following:

1. Derived historical industrial and power plant groundwater-use estimates for basins in the study area based on the duties associated with groundwater rights.

2. Added reported (i.e., known) water-use data, when available, to the historical water-use estimates.

3. Derived historical consumptive water-use estimates from the historical water-use estimates.

The following sections discuss the estimation of industrial and power plant historical water use in greater detail.

C.3.4.1 Derivation of Industrial and Power Plant Groundwater-Use Estimates

Industrial and power plant groundwater-use estimates were derived by querying the water-right databases for certificated industrial and power plant water rights. This was done because certificated rights have shown proof of beneficial use, and the water, at some point in the past, was actually used and theoretically is still in use for the stated volumes. The resulting data sets were then organized by hydrographic area and filtered for groundwater rights. The filtered data were then examined, and supplemental rights were excluded from the resulting data sets. Industrial and power plant groundwater-use estimates were based on the duty associated with a given water right. It was assumed that water-right duties became active two years after the filing date of the water-right application. Presumably, this would allow a sufficient amount of time to begin proving beneficial use on a certificated water right. Another assumption was that once a given water right became active, it was always active unless shown to be otherwise. Using these assumptions as a guide, a historical build-out was constructed for each basin in the study area that contained industrial and power plant water rights for the period 1945 to 2004.

C.3.4.2 Addition of Reported Industrial and Power Plant Data

In addition to the water-right databases, groundwater-pumping and surface-water diversion data were obtained from Nevada Power Co. and NDWR. Unfortunately, data were only available for a select number of years. The reported data for a particular water right replaced the estimated water use that was derived by the methods described in the previous section. It should be noted that in some instances the groundwater-pumping data obtained from NDWR or Nevada Power Co. corresponded to certificated water rights listed as being supplemental or permitted rights. In those instances, the water rights that corresponded to the reported data were also added to the groundwater-use estimates from the previous section. These data were included in the historical groundwater-use estimates because the information represented actual data. In addition, some of the reported data could not be correlated to a NDWR water-right number. These reported production data were attributed to the known well location instead. Surface-water diversions for two locations on the Muddy River were also reported by Nevada Power Co. These data were included in the historical water-use estimate because the information represents a withdrawal of water from the regional flow system. The surface-water diversion data were available after 1997. Using the reported data, groundwater-pumping and surface-water diversion data were added to the consumptive water-use estimates for the appropriate years. This combination of estimated water use and known groundwater and surface-water production data allows for a tabulation of water use for the period 1945 to 2005.

C.3.4.3 Derivation of Industrial and Power Plant Groundwater Consumptive Use

After the water-use estimates were tabulated for the time frame of interest, the consumptive use for industrial and power plant use was assumed to be 100 percent of the water-right duties or known groundwater-pumpinig data. The 100 percent consumption factor was appropriate because these types of water use tend to consume most of the available water and leave very little secondary recharge. Industrial and power plant groundwater consumptive uses were deemed to be insignificant when they did not exceed 150 af in any year. In those cases, the historical groundwater-use estimates for those basins were removed from further consideration.

C.3.5 Historical Consumptive Water-Use Data Set

All estimates of water uses identified in the model area were combined and distributed to points of diversion. These processes are described, followed by a description of the combined data set.

C.3.5.1 Combination of Historical Consumptive Water Uses

The municipal, mining and milling, and industrial and power plant consumptive water-use estimates were derived on a yearly basis from 1945 to 2004. The agricultural consumptive water-use estimates, however, were derived for the nine time periods identified in Section C.3.2.2.1. As a result, the municipal, mining and milling, and industrial and power plant consumptive water-use estimates were averaged for the same nine time periods used for the creation of the irrigation place-of-use maps.

This allowed for the combination of all the manners of use into one average consumptive water-use estimate for each time period.

The time-period-average annual consumptive water-use estimates for all the hydrographic areas basins in the study area can be seen in Figure C-11. This figure shows that irrigation accounts for the majority of the consumptive water use in each time period. The average consumptive water-use estimate for the period 1945 to 1955 was approximately 20,000 afy, while the average consumptive water-use estimate increased to slightly over 100,000 afy for the 2001 to 2004 time period. Figures C-12 through C-20 illustrate the average consumptive water-use estimates by hydrographic area and manner of use for each of the nine time periods. It can be seen from the figures that for almost every hydrographic area, irrigation water use accounts for the majority of the water use. The notable exceptions are in the far southern portion of the study area in the Muddy River Springs Area, Black Mountains Area, and Garnet Valley hydrographic areas.

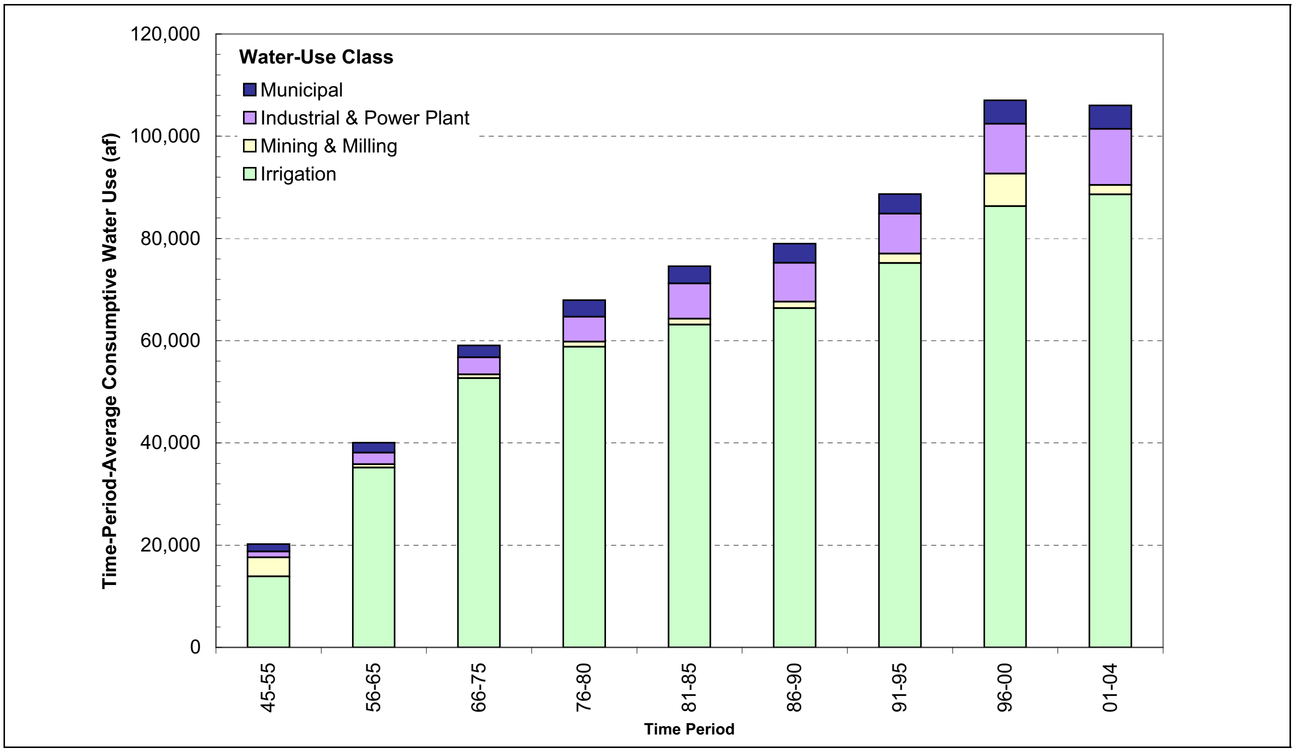

Figure C-11
Average Consumptive Water Use by Time Period for the Study Area

C.3.5.2 Distribution of Consumptive Water-Use Volumes to Points of Diversion

The average estimated consumptive water-use volumes were distributed by time period to various water-right points of diversion, wells, surface-water diversions, and town locations, depending on the type of water use. This section discusses the spatial distribution of the estimated consumptive water-use volumes in greater detail.

The municipal consumptive water-use volumes were spatially distributed to either the town locations responsible for the water use or to the known locations of water-supply wells or surface-water

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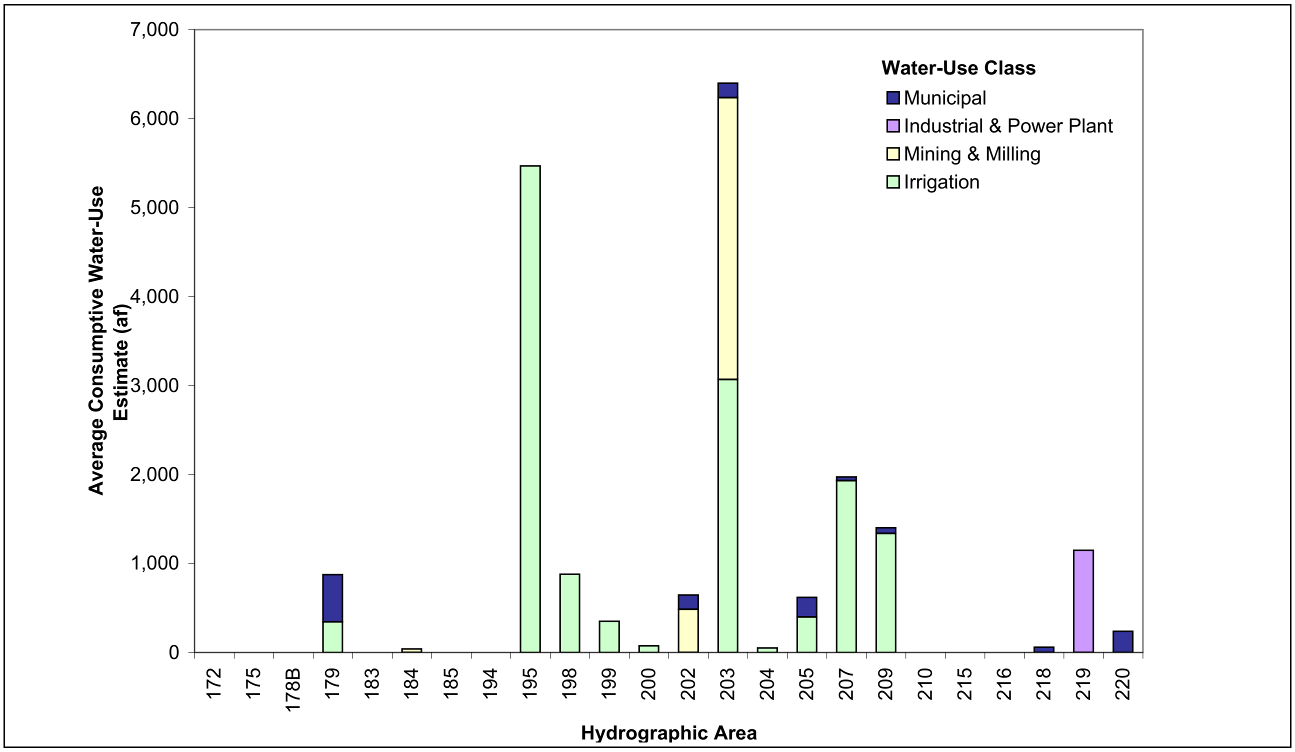

Figure C-12
Average Consumptive Water Use by HA for Time Period 1945-1955

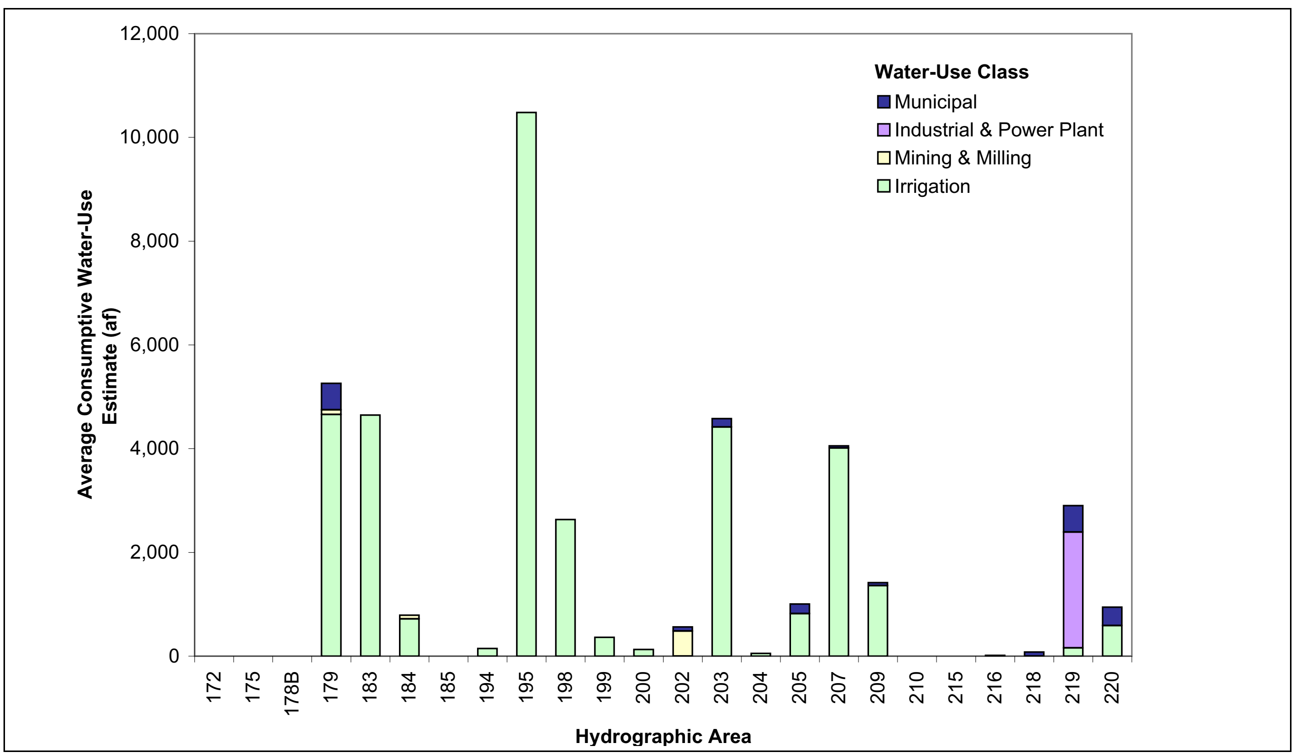

Figure C-13
Average Consumptive Water Use by HA for Time Period 1956-1965

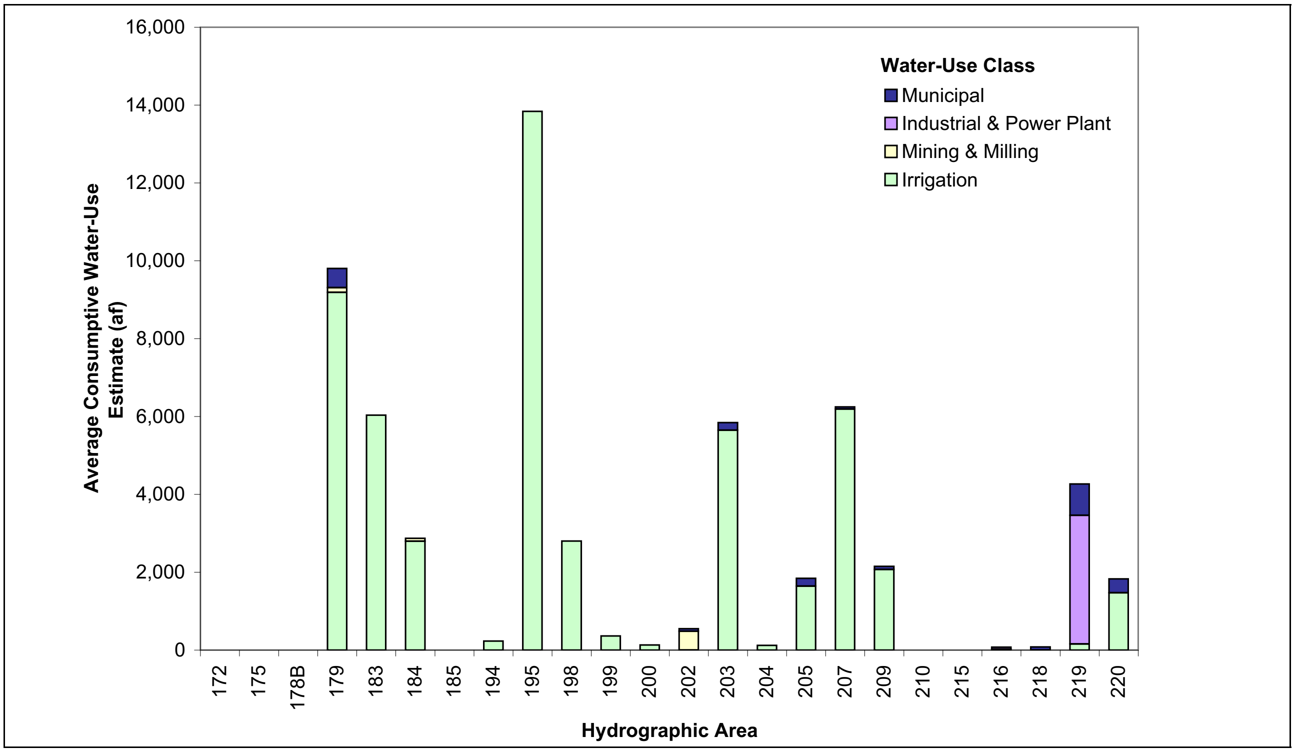

Figure C-14
Average Consumptive Water Use by HA for Time Period 1966-1975

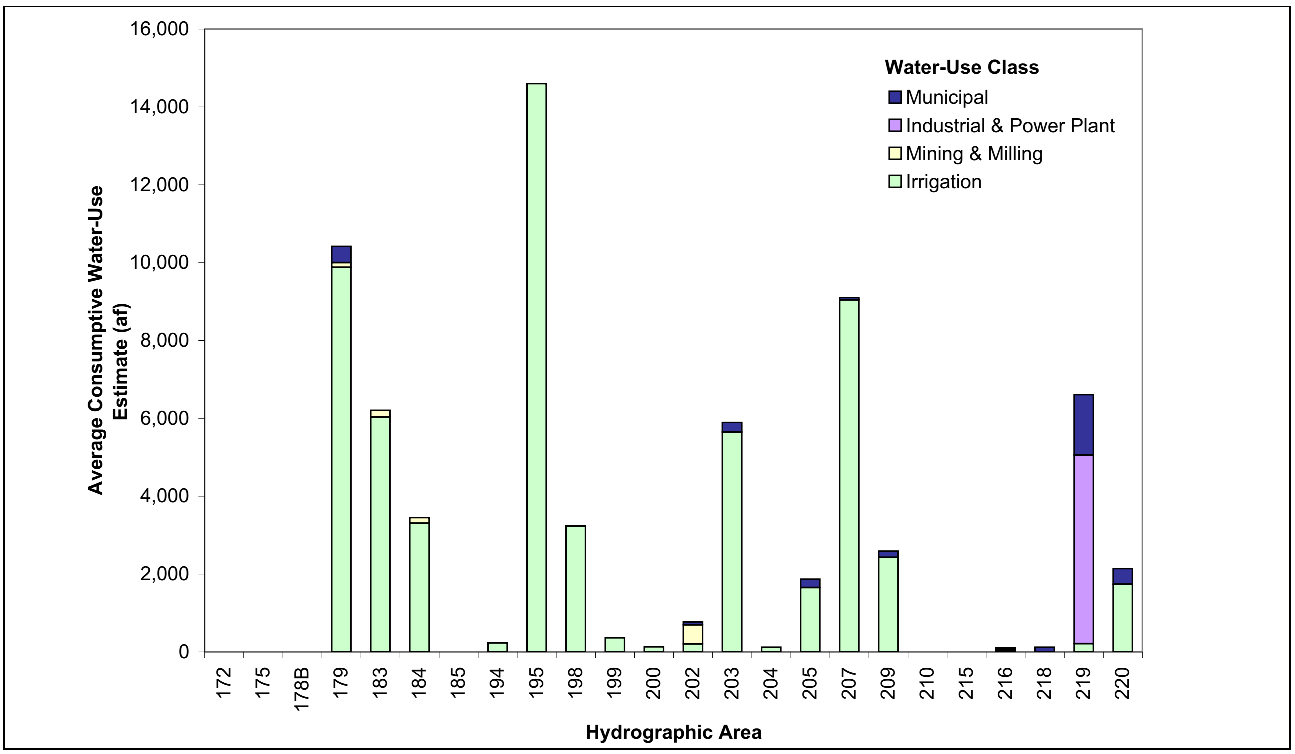

Figure C-15
Average Consumptive Water Use by HA for Time Period 1976-1980

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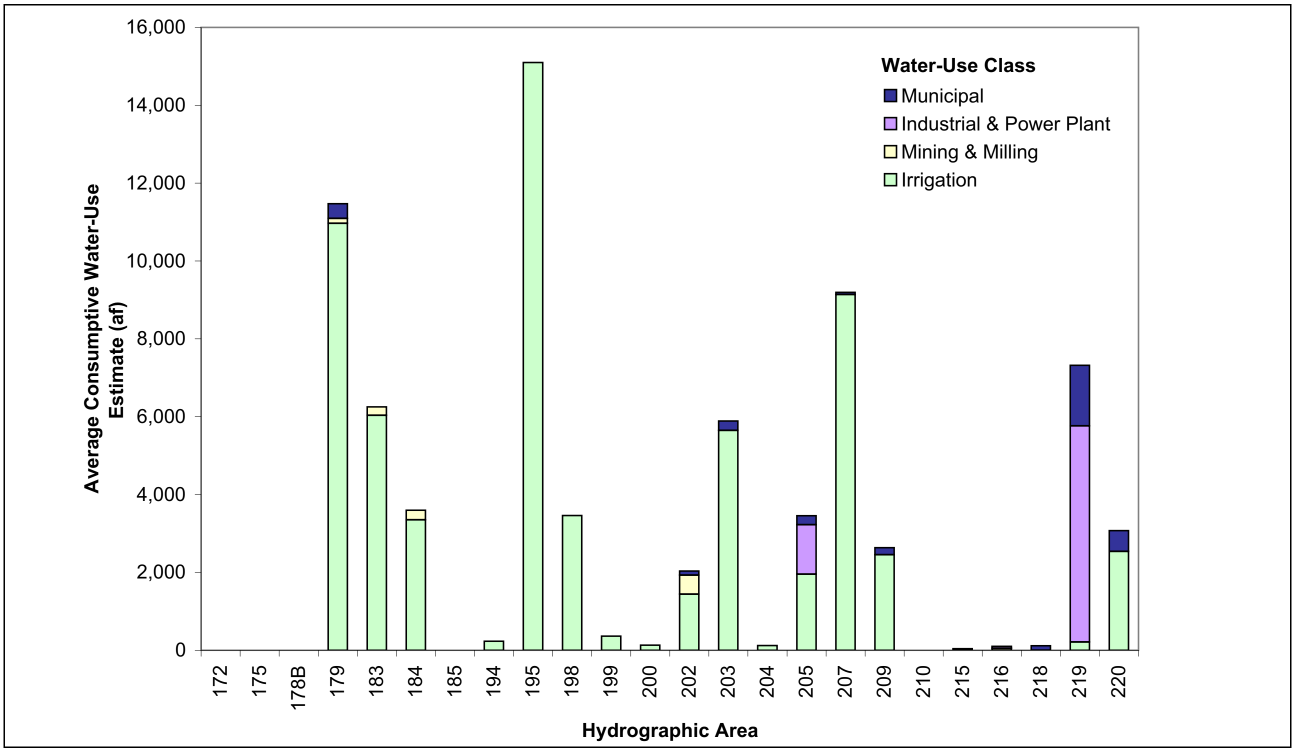

Figure C-16
Average Consumptive Water Use by HA for Time Period 1981-1985

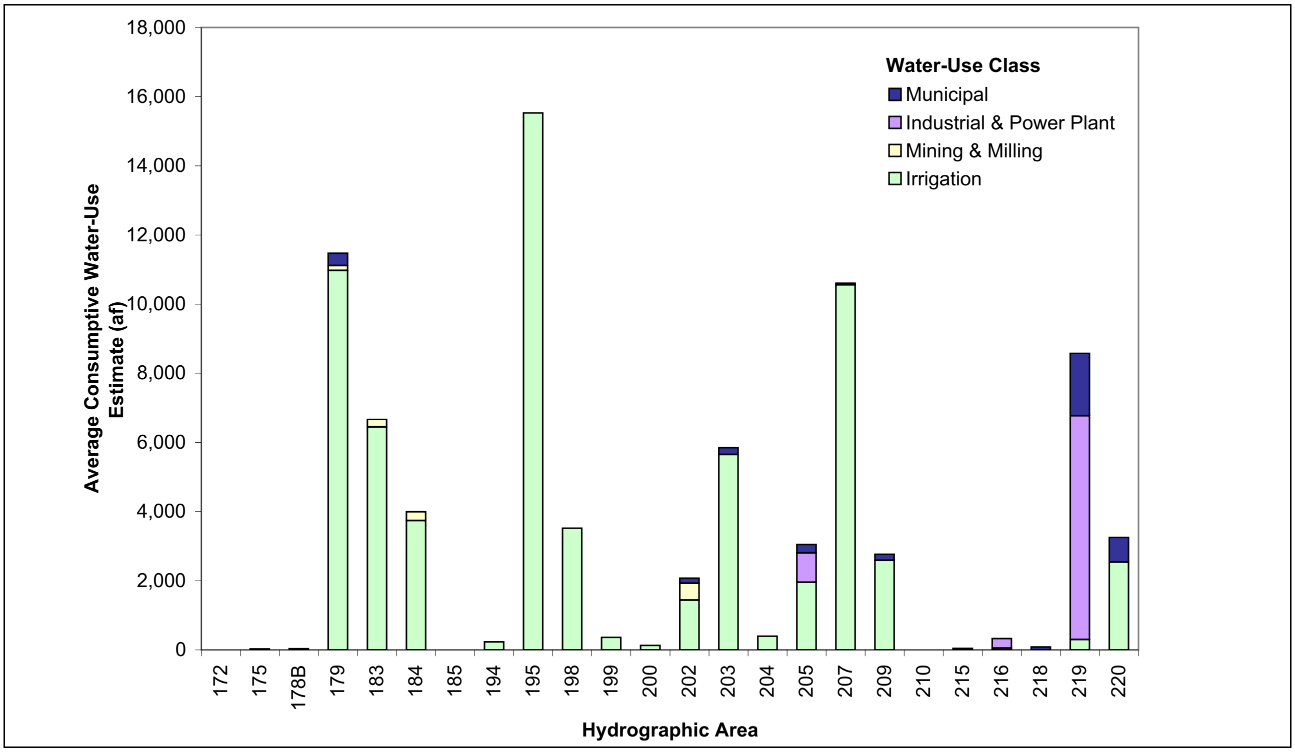

Figure C-17
Average Consumptive Water Use by HA for Time Period 1986-1990

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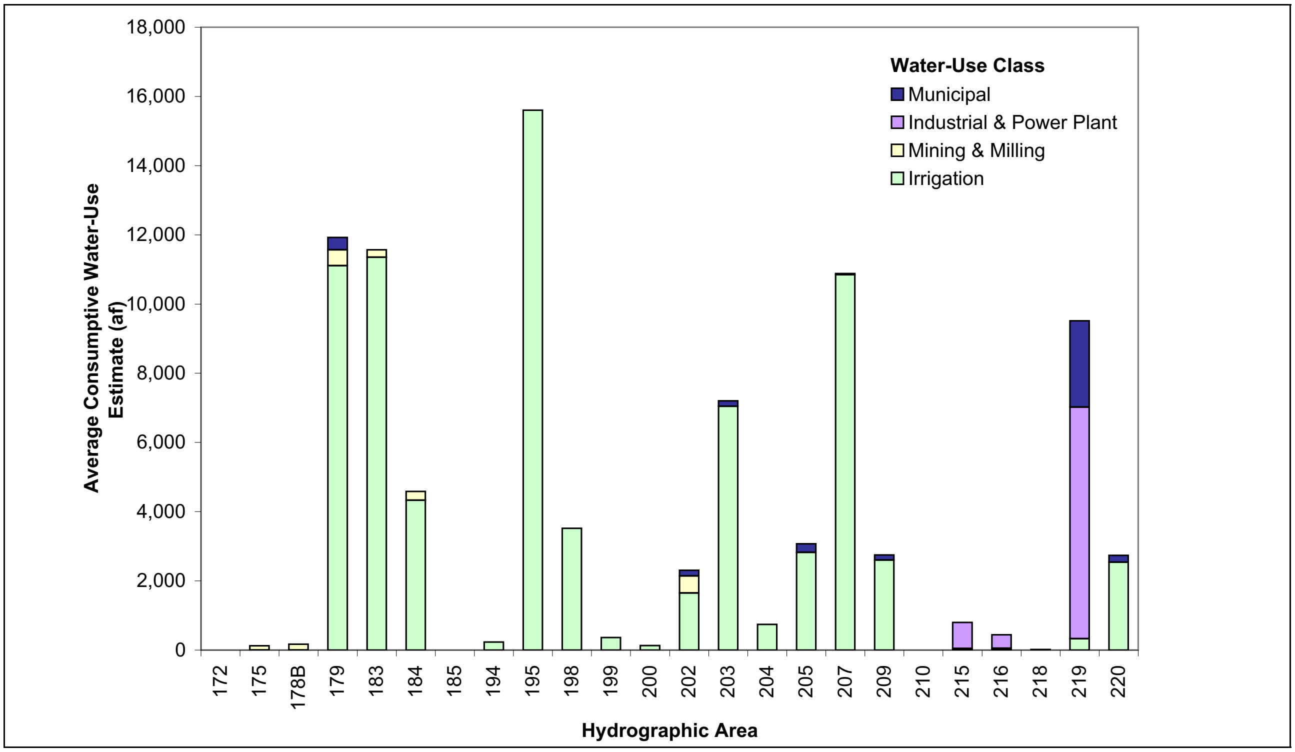

Figure C-18
Average Consumptive Water Use by HA for Time Period 1991-1995

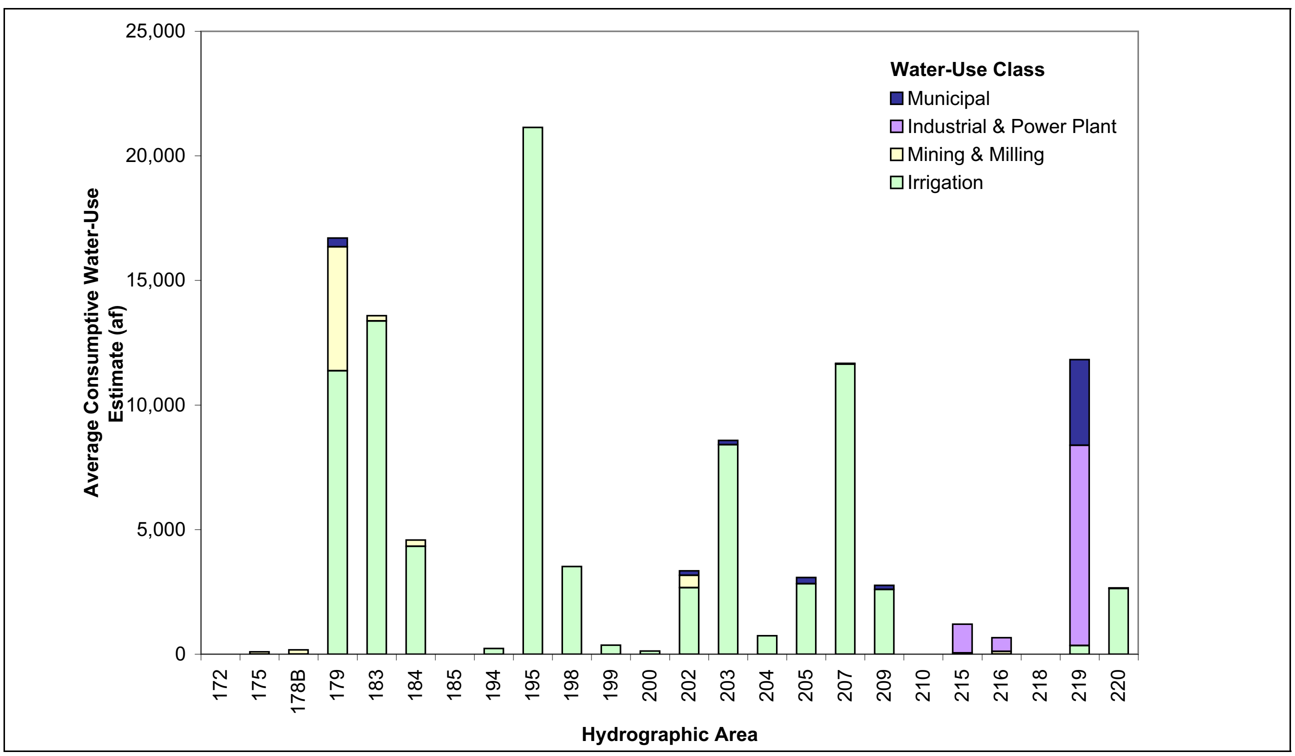

Figure C-19
Average Consumptive Water Use by HA for Time Period 1996-2000

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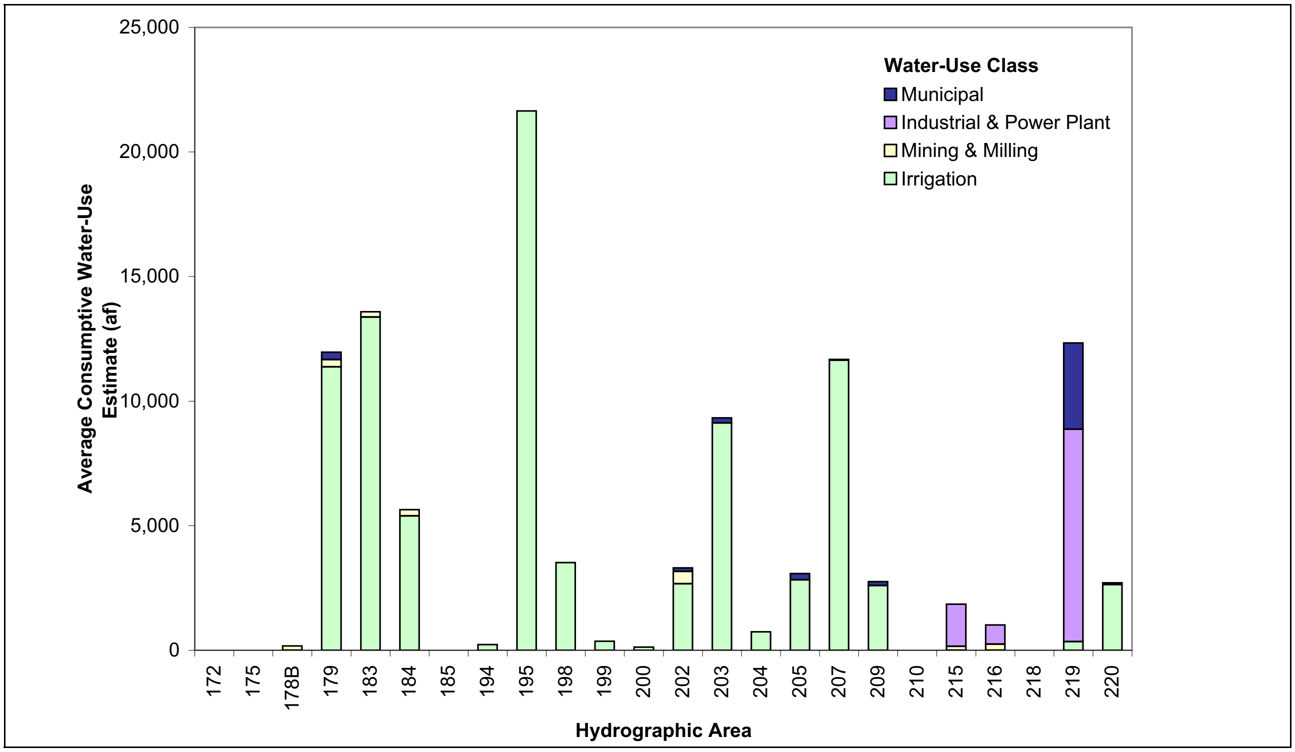

Figure C-20
Average Consumptive Water Use by HA for Time Period 2001-2004

diversions. For example, well locations are unknown for the consumptive water-use estimates based on population. As a result, the estimated consumptive water use was assumed to be withdrawn from a point that corresponds to the location of the town with the assumption that the water was supplied from an underground source. For the towns of Moapa, Logandale, Glendale, and Overton, municipal water is supplied by MVWD. As a result, the known locations of MVWD water-supply wells and surface-water diversions are used, instead of the town locations, to represent the withdrawal or diversion of water from the regional flow system.

The agricultural consumptive groundwater-use volumes were spatially distributed to the water-right points of diversion. The points of diversion were correlated with the groundwater-irrigation places of use used to create the irrigated cropland maps in Section C.3.2.2.4. Specifically, the consumptive groundwater-use volume for each delineated, irrigated cropland was equally distributed to the water-right points of diversion that were most likely used for the irrigation of the cropland. This is a simplification of what is actually occurring because it is unknown which wells, and which specific intervals, would be used for irrigation. In addition, for areas with numerous irrigated crops, it is difficult to resolve which point of diversion is actually responsible for a particular parcel of irrigation. For example, numerous points of diversion were used to equally distribute the crop consumptive water-use volumes for the irrigated croplands in northern White River Valley near Lund, Nevada, and in northern Snake Valley near Callao, Utah.

The mining and milling consumptive groundwater-use volumes were spatially distributed to either water-right points of diversion or known well locations, when available. Most of the mining and milling consumptive groundwater-use volumes were derived using the water-right duties. In those instances, the consumptive groundwater-use volumes were spatially distributed to the water-right points of diversion. For several of the hydrographic areas, however, it was possible to correlate known well locations with the mining and milling water rights. In those instances, the actual well locations were used to represent the withdrawal of groundwater.

The industrial and power plant consumptive groundwater-use volumes were spatially distributed to either water-right points of diversion or known well and surface-water diversion locations, when available. Most of the industrial and power plant consumptive groundwater-use volumes were derived using the water-right duties. In those instances, the consumptive groundwater-use volumes were spatially distributed to the water-right points of diversion. For several of the hydrographic areas, however, it was possible to correlate known well and surface-water diversion locations with the industrial and power plant water rights. In those instances, the actual well and surface-water diversion locations were used to represent the withdrawal of water.

The spatial distribution of the points of diversion, where groundwater and surface-water diversions are assumed to occur for the nine time periods, are depicted on Figure C-21 (1945 to 1955), Figure C-22 (1956 to 1965), Figure C-23 (1966 to 1975), Figure C-24 (1976 to 1980), Figure C-25 (1981 to 1985), Figure C-26 (1986 to 1990), Figure C-27 (1991 to 1995), Figure C-28 (1996 to 2000), and Figure C-29 (2001 to 2004).

C.3.5.3 Data Set Description

The combined consumptive water-use data set is provided in electronic form on the DVD included with this report. The data set contains the following fields along with their respective definitions:

- Timeperiod - Identifier to indicate the time period for the point of diversion.
- id - Unique identifier for the point of diversion used to link with the transient model input data sets.
- use - The manner of use for the point of diversion.
- site_name - The more common name for a particular well or diversion location.
- app - The NDWR water-right application number.
- cert - The NDWR water-right certificate number.
- app_status - The status of the water right.
- basin - The hydrographic area for the point of diversion.
- source - The NDWR source of water for the water right.
- src - A more simplistic flag to indicate the source of water (e.g., Groundwater or surface-water).

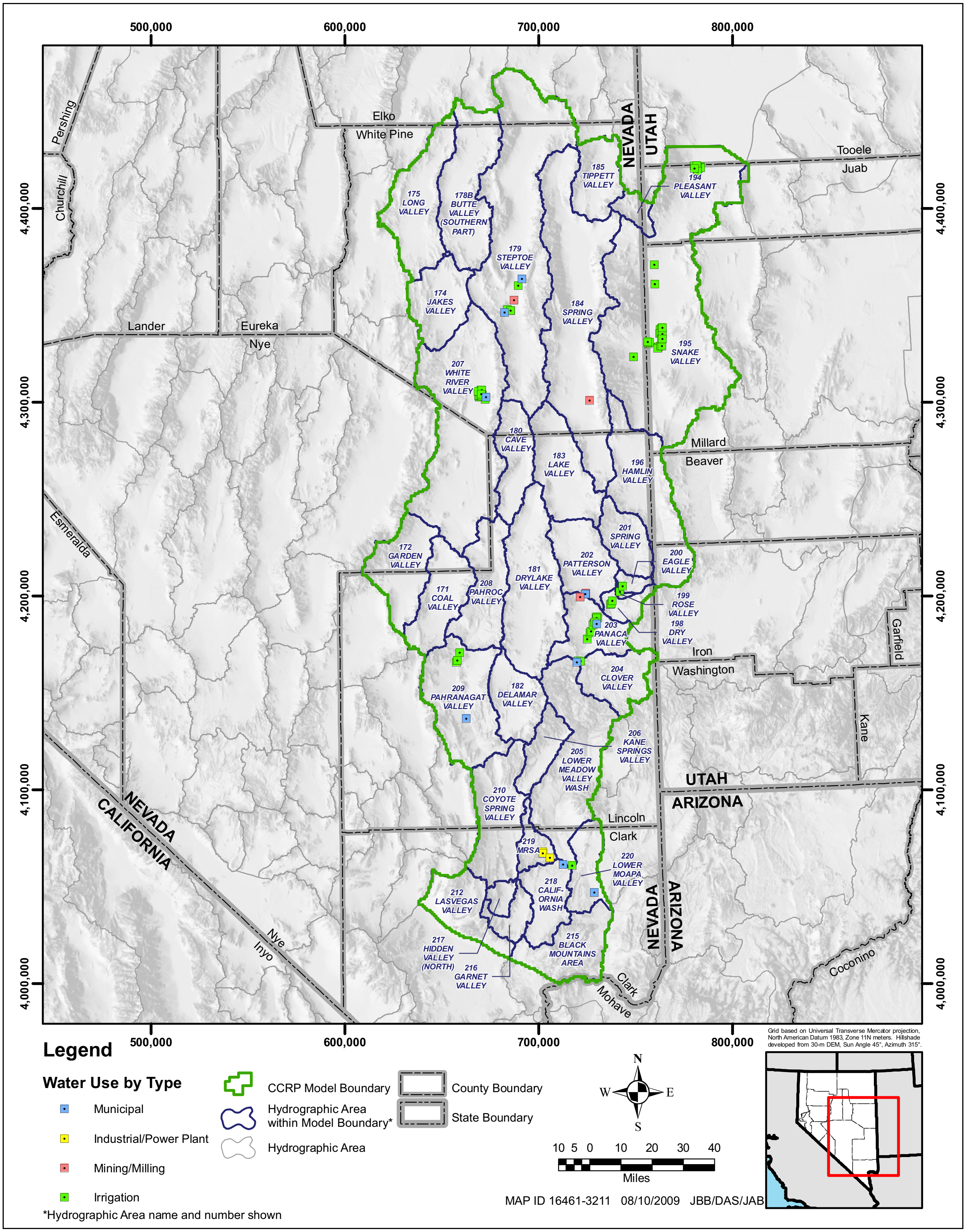

Figure C-21
Spatial Distribution of Diversion Locations for the 1945 to 1955 Time Period

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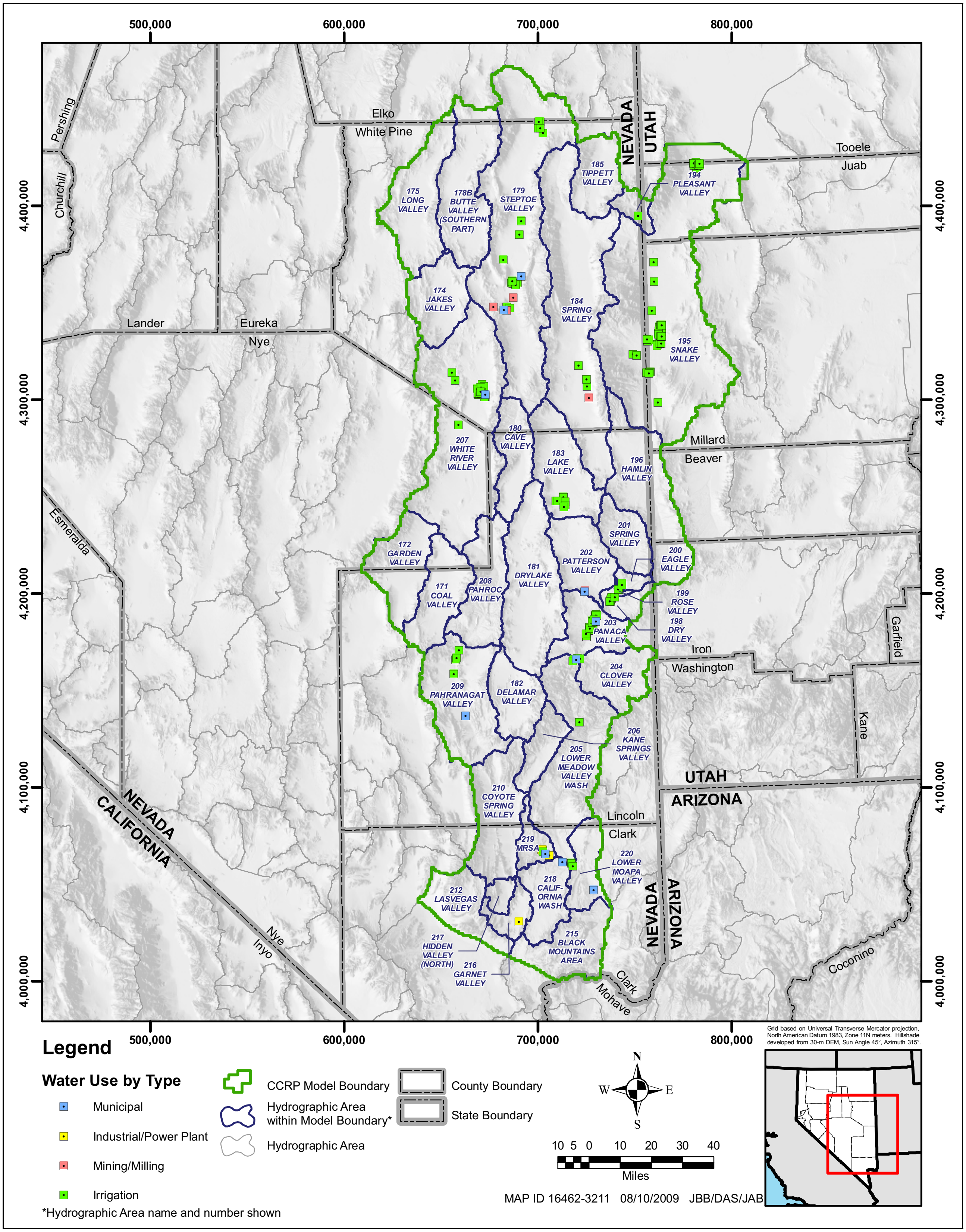

Figure C-22
Spatial Distribution of Diversion Locations for the 1956 to 1965 Time Period

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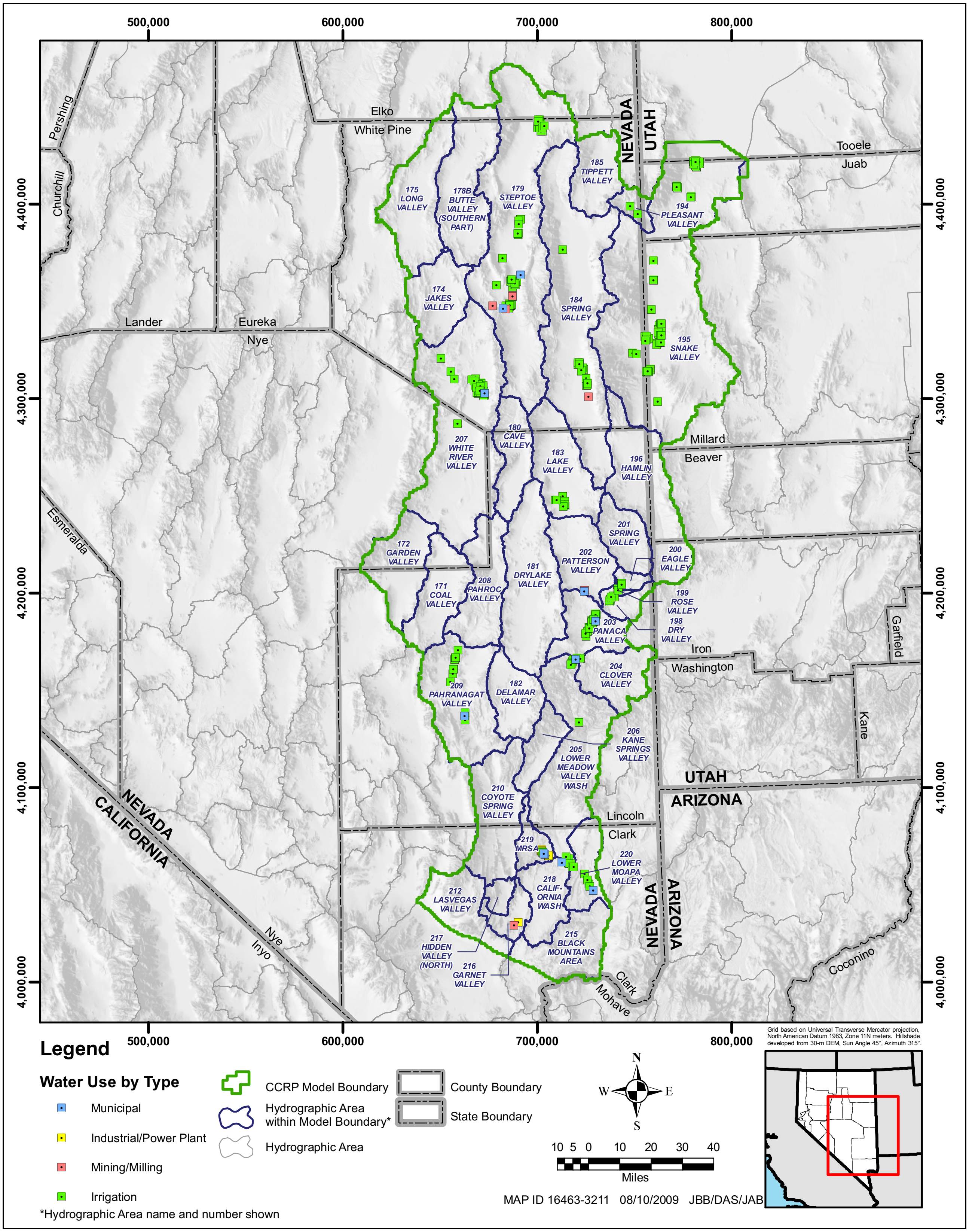

Figure C-23
Spatial Distribution of Diversion Locations for the 1966 to 1975 Time Period

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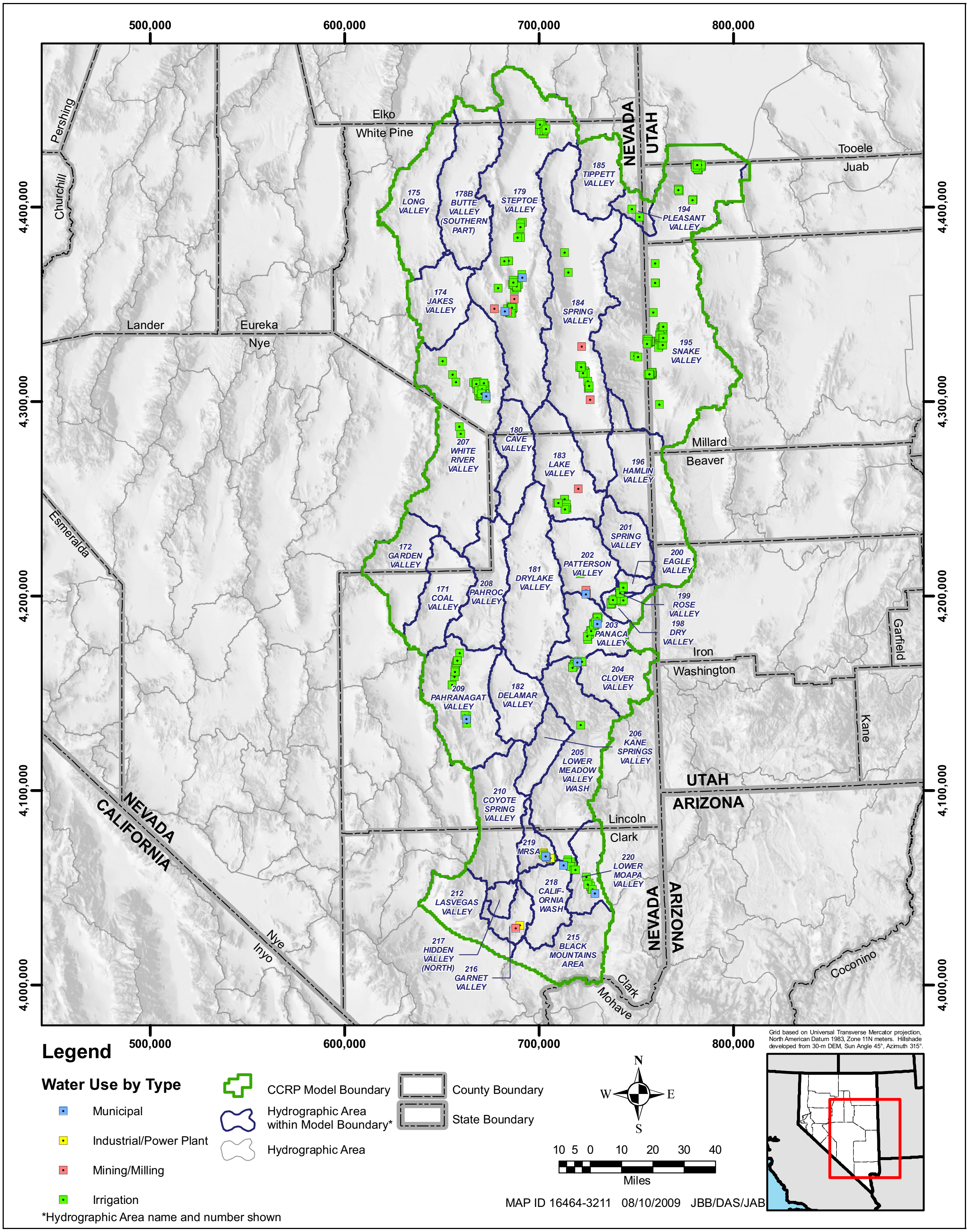

Figure C-24
Spatial Distribution of Diversion Locations for the 1976 to 1980 Time Period

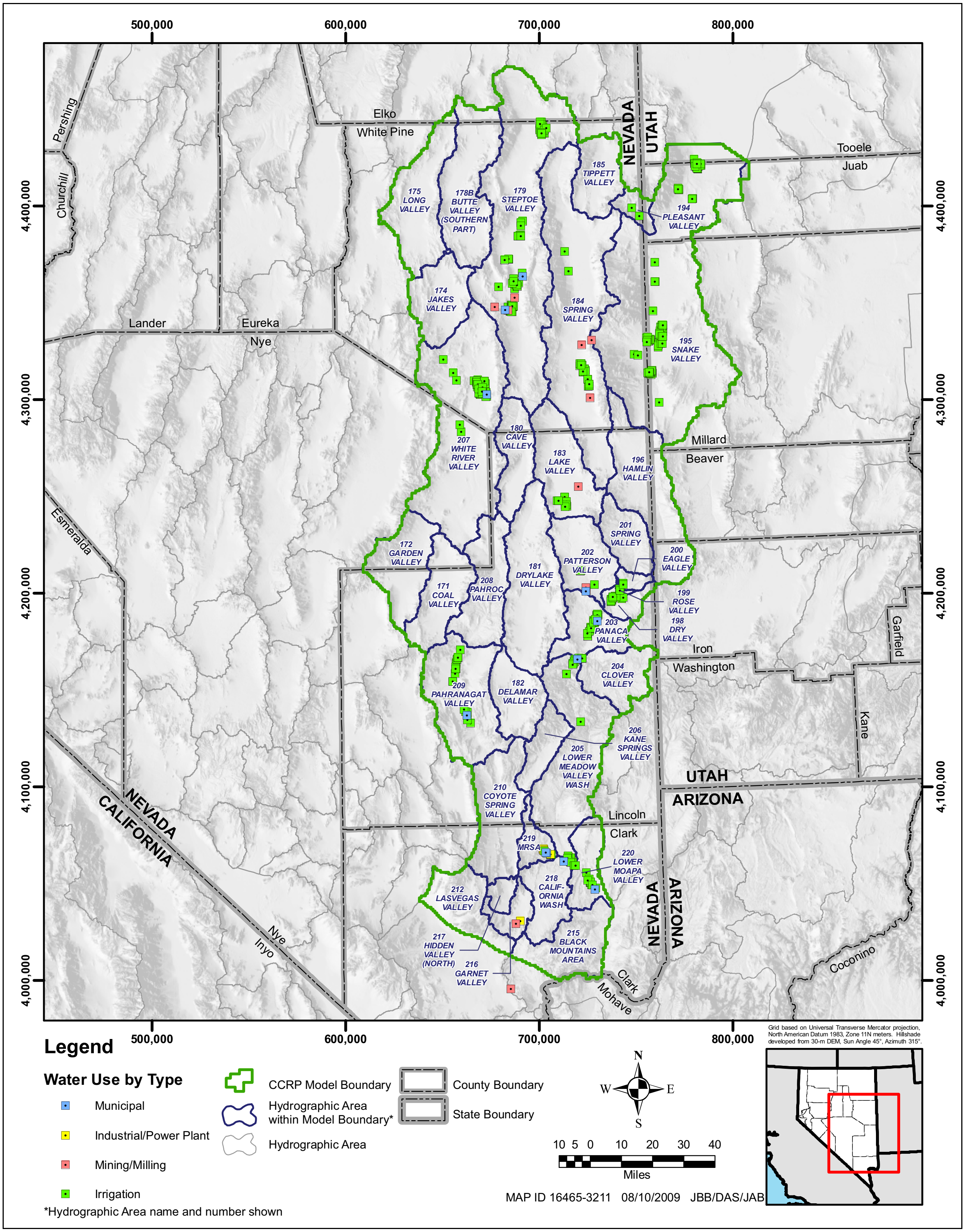

Figure C-25
Spatial Distribution of Diversion Locations for the 1981 to 1985 Time Period

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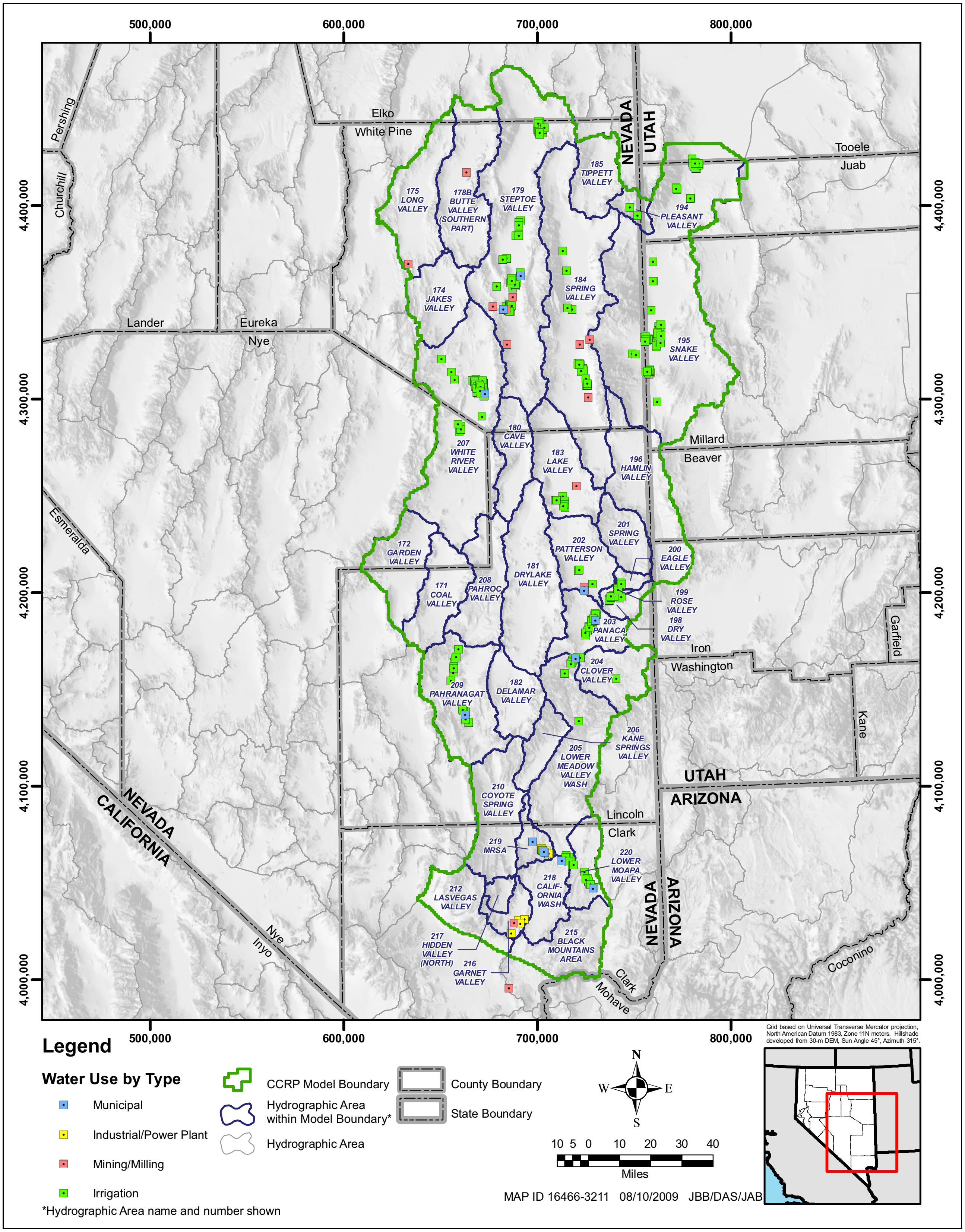

Figure C-26
Spatial Distribution of Diversion Locations for the 1986 to 1990 Time Period

SE ROA 51133

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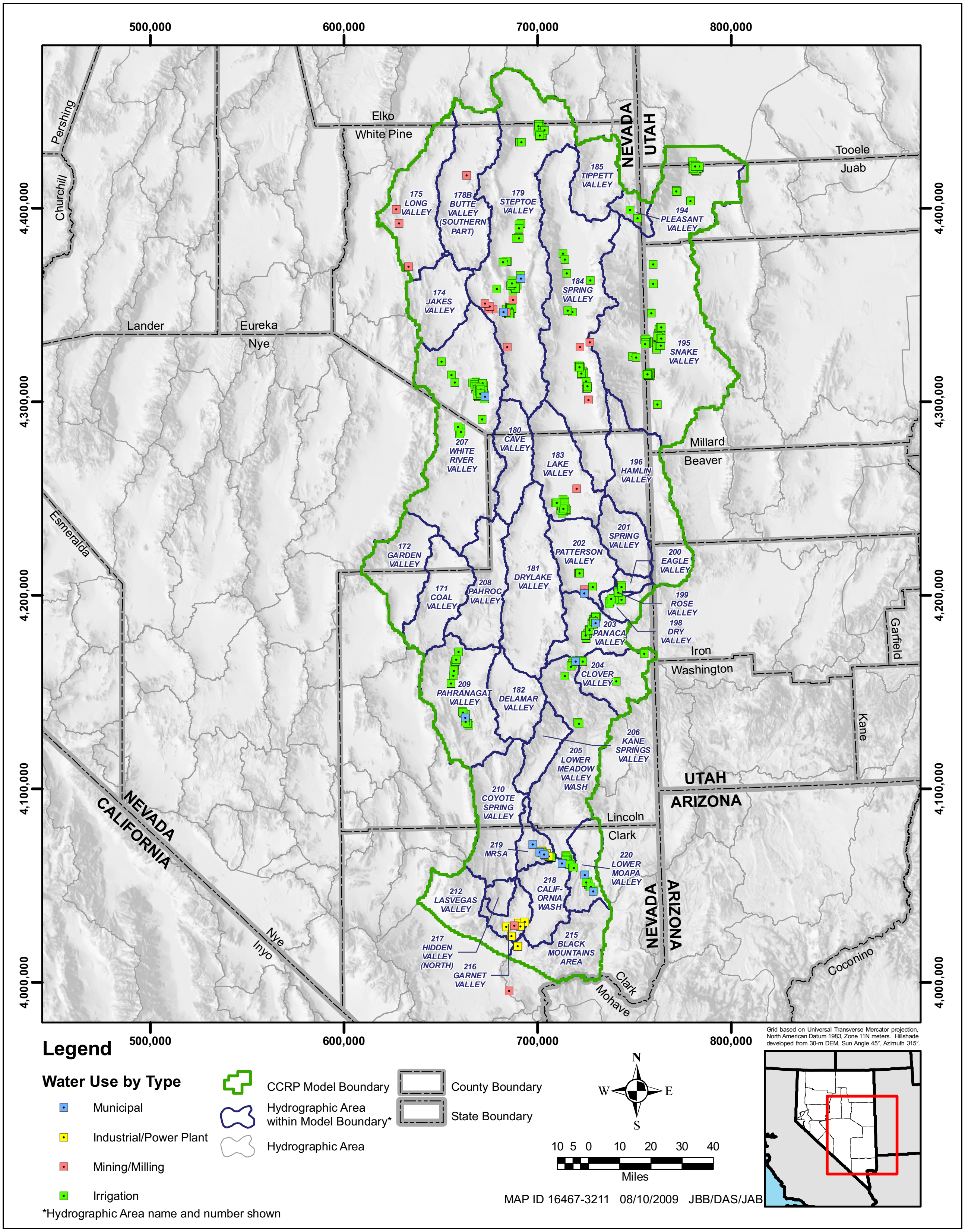

Figure C-27
Spatial Distribution of Diversion Locations for the 1991 to 1995 Time Period

SE ROA 51134

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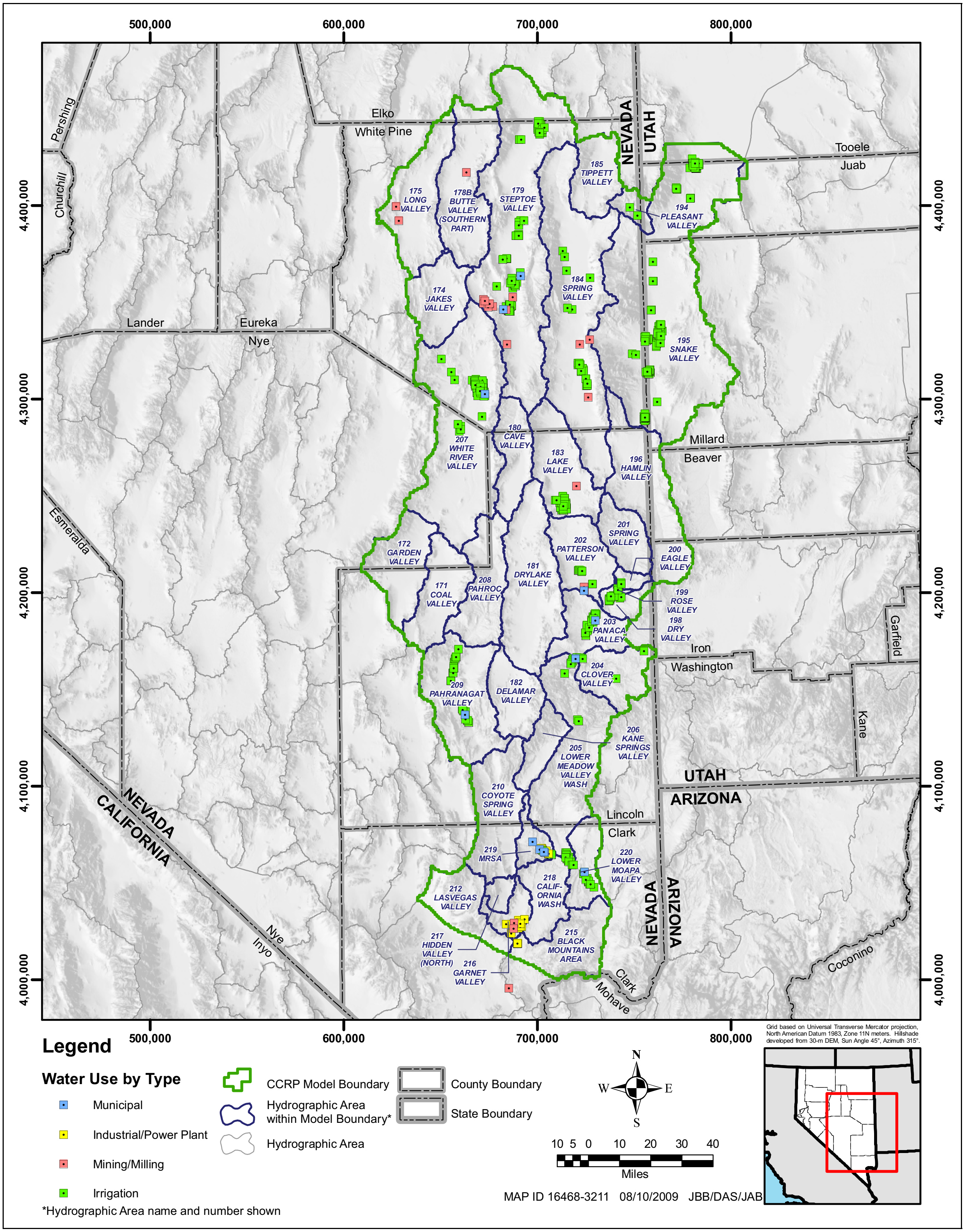

Figure C-28
Spatial Distribution of Diversion Locations for the 1996 to 2000 Time Period

SE ROA 51135

JA_16536

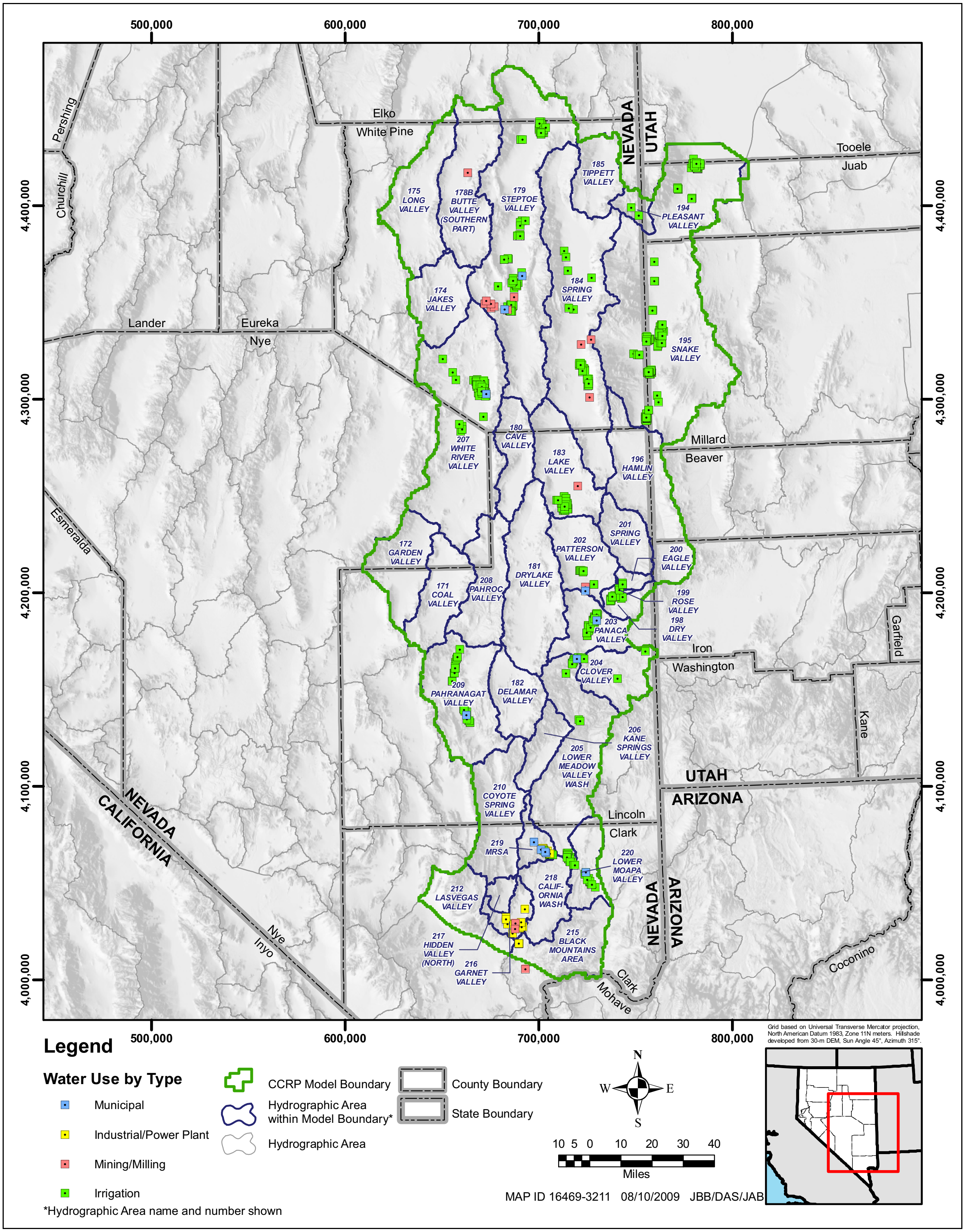

Figure C-29
Spatial Distribution of Diversion Locations for the 2001 to 2004 Time Period

- mou - The NDWR manner of use associated with the water right.
- well_log1 - The well log (NDWR) or well identification (Utah) number associated with the water right.
- file_dt - The filing date for the water-right application.
- prior_dt - The priority date for the water-right application.
- UTM_N_N83 - The UTM northing coordinates for the point of diversion.
- UTM_E_N83 - The UTM easting coordinates for the point of diversion.
- Open_Interval - The perforated or open interval for the well.
- Match_ID - Unique identification used to link the points of diversion to specific irrigated croplands.
- Final_Volume - The volume in afy associated with the point of diversion in a particular time period.

C.4.0 REFERENCES

Brothers, K., Buqo, T.S., and Tracy, J.V., 1993, Hydrology and steady state ground-water model of Snake Valley, east-central Nevada, and west-central Utah: Las Vegas Valley Water District, Cooperative Water Project, Report No. 9, 97 p.

Felling, R., 2009, Personal communication of May 5 to D. Sloop (Southern Nevada Water Authority) regarding crop evapotranspiration rates, Carson City, Nevada.

Harrill, J.R., 1986, Ground-water storage depletion in Pahrump Valley, Nevada-California, 1962-75: U.S. Geological Survey Water-Supply Paper 2279, 53 p.

Huntington, J.L., and Allen, R.G., 2009, Evapotranspiration and net irrigation water requirements for Nevada, *in* Starrett, S., editor, World environmental and water resources congress 2009—Great Rivers, Proceedings of World Environmental and Water Resources Congress 2009, Kansas City, Missouri: Reston, Virginia, Environmental and Water Resources Institute, p. 1-15.

Hutson, S.S., Barber, N.L., Kenny, J.F., Linsey, K.S., Lumia, D.S., and Maupin, M.A., 2004, Estimated use of water in the United States in 2000: Reston, Va., U.S. Geological Survey Circular 1268, 46 p.

Konieczki, A.D., and Heilman, J.A., 2004, Water-use trends in the desert Southwest-1950-2000: U.S. Geological Survey Scientific Investigations Report 2004-5148, 32 p.

Las Vegas Valley Water District, 2001, Water resources and ground-water modeling in the White River and Meadow Valley flow systems, Clark, Lincoln, Nye, and White Pine counties, Nevada: Las Vegas Valley Water District, Las Vegas, Nevada, 297 p.

Lopes, T.J., and Evetts, D.M., 2004, Ground-water pumpage and artificial recharge estimates for calendar year 2000 and average annual natural recharge and interbasin flow by hydrographic area, Nevada: U.S. Geological Survey Scientific Investigations Report 2004-5239, 82 p.

LVVWD, see Las Vegas Valley Water District.

NDWR, see Nevada Division of Water Resources.

Nevada Division of Water Planning, 1992, Nevada Water Facts: Nevada Department of Conservation and Natural Resources, Division of Water Planning, 79 p.

Nevada Division of Water Resources, 2008, Water words dictionary [Internet], [accessed July 2, 2008], available from http://water.nv.gov/WaterPlanning/dict-1/ww-index.cfm.

Nevada State Demographer, 2004, Nevada county population estimates July 1, 1986 to July 1, 2004, includes Cities and Towns, [Internet], [accessed May 05, 2005], available from http://www.nsbdc.org/what/data_statistics/demographer/.

Nevada State Engineer (The office of the State Engineer of The State of Nevada), 2007, Ruling (#5726) in the matter of applications 54003 through 54021, inclusive, filed to appropriate the underground waters of the Spring Valley hydrographic basin (184), White Pine County, Nevada.

Smales, T.J., and Harrill, J.R., 1971, Water for Nevada—Report 2—Estimated water use in Nevada: Nevada Department of Conservation and Natural Resources, Division of Water Resources, 32 p.

SNWA, see Southern Nevada Water Authority.

Solley, W.B., Pierce, R.R., and Perlman, H.A., 1993, Estimated use of water in the United States in 1990: U.S. Geological Survey Circular 1081, 85 p.

Solley, W.B., Pierce, R.R., and Perlman, H.A., 1998, Estimated use of water in the United States in 1995: U.S. Geological Survey Circular 1200, 79 p.

Southern Nevada Water Authority, 2008, Baseline characterization report for Clark, Lincoln, and White Pine Counties Groundwater Development Project: Southern Nevada Water Authority, Las Vegas, Nevada, 1146 p.

Southern Nevada Water Authority, 2009, Conceptual model of groundwater flow for the Central Carbonate-Rock Province—Clark, Lincoln, and White Pine Counties Groundwater Development Project: Southern Nevada Water Authority, Las Vegas, Nevada, 416 p.

Welch, A.H., Bright, D.J., and Knochenmus, L.A., eds., 2008, Water resources of the Basin and Range Carbonate-Rock Aquifer System, White Pine County, Nevada, and adjacent areas in Nevada and Utah: U.S. Geological Survey Scientific Investigations Report 2007–5261, 112 p.

Plates

PLATE 1: PARAMETER ZONES DEFINED FOR THE LC2 AND LC3 RMUS IN THE CCRP MODEL

SE ROA 51141

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PLATE 2 - GROUNDWATER FLOW REGIONS AND FLOWPATHS AT THE WATER TABLE SIMULATED FOR STEADY-STATE CONDITIONS BY THE CCRP TRANSIENT MODEL

PLATE 3 - GROUNDWATER FLOW REGIONS AND FLOWPATHS IN THE LC3 RMU SIMULATED FOR STEADY-STATE CONDITIONS BY THE CCRP TRANSIENT MODEL