Appendix 8: Development of Historical Well Withdrawal Estimates for the Great Basin Carbonate and Alluvial Aquifer System Study Area, 1940–2006

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Appendix 8 of

Conceptual Model of the Great Basin Carbonate and Alluvial Aquifer System

Edited by Victor M. Heilweil and Lynette E. Brooks

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
gallon (gal)	3.785	cubic decimeter (dm^3)
cubic foot (ft^3)	28.32	cubic decimeter (dm^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
	Flow rate	
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year (hm^3/yr)
foot per year (ft/yr)	0.3048	meter per year (m/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per day (ft^3/d)	0.02832	cubic meter per day (m^3/d)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
inch per day (in./d)	25.38	millimeter per day (mm/d)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

Note: The conversion factors given above are for the entire report. Not all listed conversion factors will be in any given chapter of this report.

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F=(1.8×°C)+32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
°C=(°F-32)/1.8

Temperature in kelvin (K) may be converted to degrees Fahrenheit (°F) as follows:
°F=1.8K-459.67

Temperature in kelvin (K) may be converted to degrees Celsius (°C) as follows:
°C=K-273.15

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Appendix 8: Development of Historical Well Withdrawal Estimates for the Great Basin Carbonate and Alluvial Aquifer System Study Area, 1940–2006

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To evaluate general groundwater development trends within the Great Basin carbonate and alluvial aquifer system (GBCAAS) study area, historical annual well withdrawals for the period of 1940–2006 were estimated based on the compilation and interpolation of existing well-withdrawal data. Very few of the hydrographic areas (HAs) within the GBCAAS had complete well-withdrawal records for the period 1940–2006. This appendix presents the methodologies used to estimate well withdrawals in areas and for time intervals in which historical withdrawal data do not exist.

Sources of Historical Well Withdrawal Estimates

The state of Utah began compiling well withdrawals on an annual basis in 1963 as part of their "Ground-water conditions in Utah" reports (Arnow and others, 1964). Additionally, in HAs 267, 280, 281, 282, 283, 284, 286 and 287, annual withdrawal estimates extend back to the 1930s, 1940s, and 1950s (fig. A8–1). For irrigation wells, pumping well discharge is generally measured once every 3 years, and power consumption records are used to estimate average annual discharge. Public supply well withdrawals are reported to the state of Utah by each municipality.

For HAs in Nevada and California within the Death Valley groundwater flow system (fig. A8–1), estimates of annual well withdrawals were taken from two groundwater-withdrawal databases developed for the Death Valley regional groundwater flow system (DVRFS) study (Moreo and others, 2003; Moreo and Justet, 2008). Moreo and others (2003) estimate groundwater withdrawals from 1913 to 1998 for the HAs within the Death Valley regional flow system. In an update, Moreo and Justet (2008) estimate groundwater withdrawals for the period 1913–2003. The DVRFS withdrawal databases integrate datasets obtained from: (1) well-log and water-rights databases and pumpage inventories from the Nevada Division of Water Resources (NDWR), (2) data obtained directly from water users, (3) remotely sensed Thematic Mapper imagery, and (4) estimates of potential evapotranspiration (ET). Withdrawals were grouped into three categories: mining, public-supply, and commercial water use; domestic water use; and irrigation water use. Mining, public-supply, and commercial water use were generally estimated from wells that typically are metered. Domestic water use was estimated as the product of the number of domestic wells, which was determined using the NDWR well-log database, and the average annual domestic consumption, which was assumed to be 0.7 acre-ft (Moreo and others, 2003, p. 9). Irrigation water use was estimated as the product of irrigated acreage, which was identified using remote sensing and pumping inventories, and application rate. This rate was estimated by dividing annual crop ET, defined as annual potential ET multiplied by a crop coefficient, by the irrigation efficiency.

A second source of well-withdrawal data used for HAs within Nevada was pumping and crop inventories from the NDWR (http://water.nv.gov; Matt Dillon, NDWR, written commun., 2008). Pumping inventories, available on the NDWR website, have been conducted in 15 HAs generally since the late 1980s, except HAs 162 (1959–2008), 210 (2005–2008), 211 (1989–1991), 212 (1956–2008), 215 and 216 (2001–2008), and 230 (1983–2008). The crop inventories available on the NDWR website, which include estimates of well withdrawals for irrigation, are available only for the years 2006 and 2007. Additional unpublished data from Matt Dillon, NDWR, included withdrawal records for HAs 44, 48, 51 (1996–2006) and 219 (2000–2006),

A third source of well-withdrawal data used for HAs in Nevada was from a compilation of year 2000 groundwater withdrawals for the state of Nevada by Lopes and Evetts (2004). The primary source of data used in this compilation is the previously mentioned pumpage and crop inventories from the NDWR. In the absence of these inventory reports, quarterly and monthly pumpage reports from individuals and geothermal operations were used. If no pumping was reported, well withdrawals for the HA was estimated using Landsat imagery, statistical analysis, and mass-balance calculations.

In addition to these larger inventories and databases, estimates of historical well withdrawals reported in individual HA studies were also used. Auxiliary 4 lists the references and years for which previously reported estimates of well withdrawals were used.

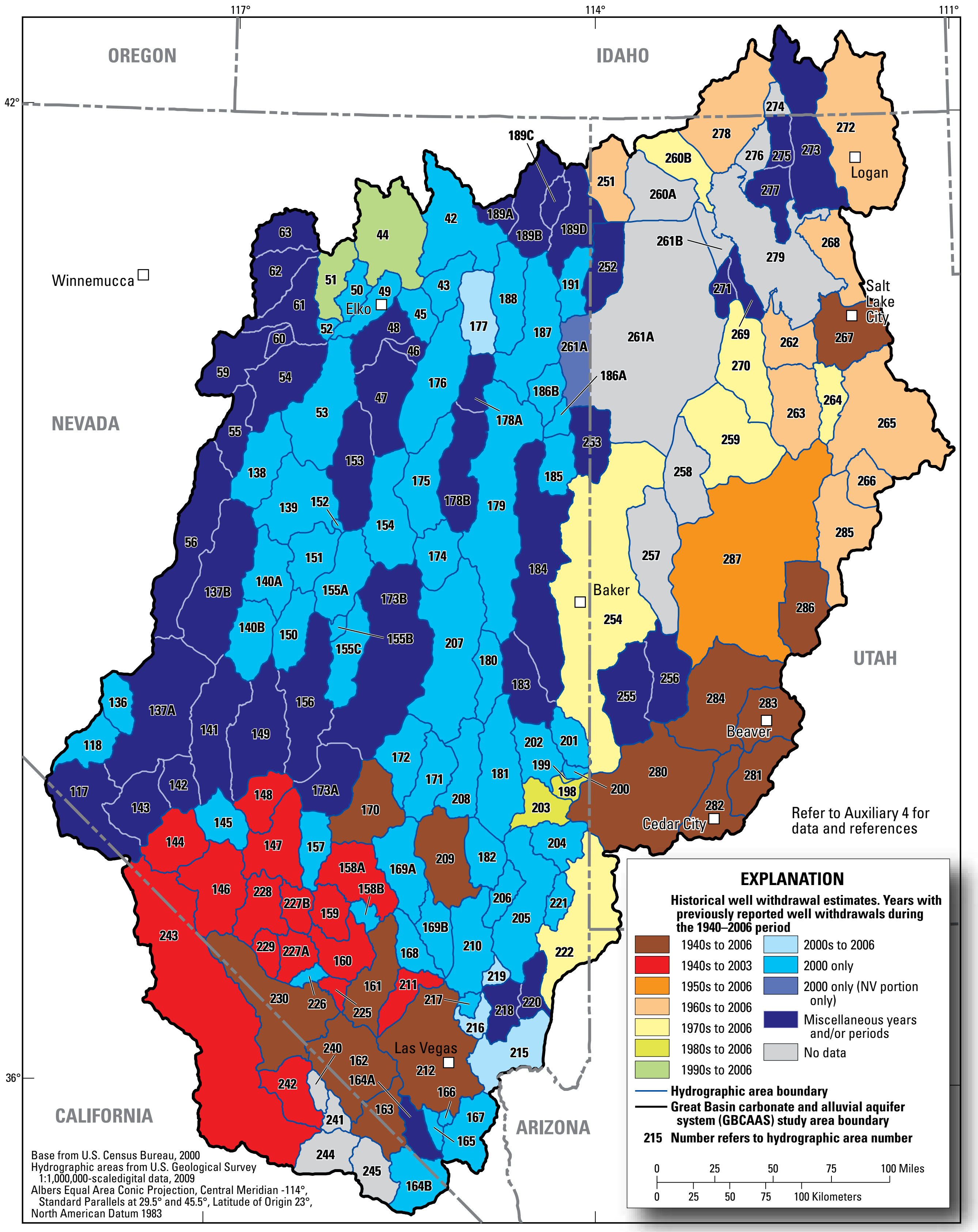

Figure A8–1. Hydrographic areas and time intervals of previously reported historical well-withdrawal estimates during the 1940–2006 period for the Great Basin carbonate and alluvial aquifer system study area.

Methods for Estimating Historical Well Withdrawals

Historical well-withdrawal estimates were developed only for the 78 HAs with more than 500 acre-ft of well withdrawals in the year 2000 (Auxiliary 4). Historical withdrawals were not estimated for the 87 HAs that had less than 500 acre-ft of withdrawals in the year 2000, as these HAs accounted for less than 0.4 percent of the total withdrawals in 2000 (Appendix 7; Auxiliary 4). Because of the differences in sources of historical well-withdrawal data, different methods of interpolating historical well withdrawals were used in different sections of the study area. These methods are described in the following sections.

Hydrographic Areas within Utah

For 19 HAs located entirely within Utah, unpublished data from the U.S. Geological Survey (USGS) Utah Water Science Center were used to develop historical estimates of well withdrawals; the other 12 HAs located entirely within Utah are assumed to have less than 500 acre-ft/yr of withdrawals in 2000 and historical well withdrawals were not estimated for these HAs. A subset of seven of these HAs (267, 280, 281, 282, 283, 284, and 286) has well-withdrawal estimates extending back to the 1930s and 1940s (Auxiliary 4). An inspection of total groundwater withdrawals in these seven HAs indicated that groundwater withdrawal was occurring in most of these seven basins prior to 1940, but that withdrawals began to increase rapidly from the mid-1940s to a peak or plateau during the mid-1970s. On average, 1940 withdrawals for these seven HAs were about 30 percent of the 1970–1979 average annual withdrawals. Therefore, annual withdrawals for HAs that did not have records extending back to 1940 were estimated to increase linearly from 30 percent of the 1970–1979 average in 1940 to the earliest value in their record (Auxiliary 4). In 17 HAs, these estimated withdrawals are less than and increase to about the same amount as the first reported well withdrawals. For Pavant Valley (HA 286) and Sevier Desert (HA 287), however, estimated withdrawals during the 1940s are higher than the subsequently reported well withdrawals beginning in 1946 and 1951, respectively.

Hydrographic Areas That Straddle the Utah-Idaho Border

For the three HAs that straddle the Utah-Idaho border (HAs 272, 273, and 278), assumptions had to be made for well withdrawals from the Idaho portion of these HAs because limited historical well withdrawal data were available. First, for the Utah portion of these HAs, the same linear interpolation methods used for the Utah HAs were applied to these three HAs to estimate the Utah portion of withdrawals for years without previously published estimates (1940–1962 for HA 272; 1940–1994 for HA 273; 1940–1963 for HA 278). Withdrawal estimates for the Utah portion of these HAs were then adjusted in the following ways. For Cache Valley (HA 272), total well withdrawals from 1969 and 1982–1990 (Kariya and others, 1994) were compared to withdrawals for the Utah portion only (USGS Utah Water Science Center data). The comparison indicated that well withdrawals from the Utah portion of Cache Valley accounted for 77 to 85 percent of total Cache Valley well withdrawals in these years. Total withdrawals for Cache Valley, therefore, were estimated by dividing the withdrawals from the Utah portion of the HA by 0.81 for all years except 1969 and 1982–1990 (Auxiliary 4). For Malad-Lower Bear River Area (HA 273), it was assumed that withdrawals from the Idaho portion equaled withdrawals from the Utah portion based on the area of irrigated land being approximately the same. Total withdrawals for Malad-Lower Bear River Area, therefore, were estimated by multiplying withdrawals from the Utah portion (USGS Utah Water Science Center data; Bjorklund and McGreevy (1974) for withdrawals in 1970) by 2 (Auxiliary 4). For Curlew Valley (HA 278), well withdrawals from the Utah portion of the HA (USGS Utah Water Science Center data; Baker, Jr. (1974) for 1964–1972) were compared to total well withdrawals for 1969–1971, for which period Baker, Jr. (1974) reported average withdrawals from the Idaho portion of the HA. The comparison indicated that withdrawals from the Utah portion of Curlew Valley accounted for 54 to 59 percent of total withdrawals from the HA during these years. Total withdrawals for Curlew Valley, therefore, were estimated by dividing the withdrawals from the Utah portion of the HA by 0.57 (Auxiliary 4).

Hydrographic Areas That Straddle the Utah-Nevada Border

For the eight HAs that straddle the Utah-Nevada border (HAs 189D, 222, 251, 252, 261A, 253, 254, and 280), well withdrawals were estimated in the following manner. For the Utah portion of HAs 222, 251, 253 and 254, the same linear interpolation methods used for the Utah HAs were applied to these four HAs to estimate the Utah portion of withdrawals for years with no previously published estimates (1940–1969 for HA 222; 1940–1963 for HA 251; 1940–1968 for HA 253; 1940–1972 for HA 254). Then well withdrawals from the Utah portion of the HA (USGS Utah Water Science Center data) were compared to withdrawals from the Nevada portion of the HA (Lopes and Evetts, 2004) for the year 2000. For Virgin River Valley (HA 222), withdrawals from the Nevada portion for the year 2000 were about 13 percent of withdrawals from the Utah portion; total withdrawals for the HA, therefore, were estimated by adding 13 percent to the Utah portion estimates (Auxiliary 4). For Grouse Creek Valley (HA 251), Deep Creek Valley (HA 253), and Snake Valley (HA 254), withdrawals from the Nevada portion for the year 2000 were only 5 percent or less of withdrawals from the Utah portion; it was assumed, therefore, that withdrawals from the Utah portion closely represented total withdrawals for these HAs (Auxiliary 4). For Pilot Valley (HA 252) and Great Salt Lake Desert-West Part (HA 261A), no withdrawals were reported for the Utah portion, and Lopes and Evetts (2004) reported withdrawals of 320 acre-ft for only the Nevada portion of HA 261A for the year 2000; it was assumed, therefore, that these HAs had less than 500 acre-ft/yr of withdrawals for the year 2000 and historical well withdrawals were not estimated for these HAs. Beryl-Enterprise Area (HA 280) lies mostly within Utah and there were no previous withdrawal estimates from the Nevada portion of the HA. Estimates of withdrawals from the Utah portion of this HA (USGS Utah Water Science Center data), therefore, were assumed to represent total withdrawals from this HA; the same linear interpolation methods used for the Utah HAs were applied to this HA to estimate withdrawals for years with no previously published estimates (1940–1944). Thousand Springs Valley-Montello-Crittenden (HA 189D) lies mostly within Nevada; there were no previously reported estimates of well withdrawals for the Utah portion of the HA. Well-withdrawal estimates for the Nevada portion of this HA are discussed below in the “Method 5: Miscellaneous Reference Years” section of the discussion of Nevada and California well withdrawal estimates.

Hydrographic Areas within Nevada and California

Twenty-three HAs in Nevada and California have historical well-withdrawal estimates that extend back to the 1940s (Auxiliary 4). These include 20 HAs within the Death Valley groundwater flow system, Pahranagat Valley (HA 209), Las Vegas Valley (HA 212), and Mesquite Valley (HA 163) (fig. A8–1). Additionally, 15 other HAs within the Humboldt (7), South-Central Marshes (24), Diamond Valley (27), and Colorado (34) groundwater flow systems have withdrawal estimates for part of the period 1940–2006.

For the 39 HAs in Nevada and California that had more than 500 acre-ft of withdrawals in Nevada in the year 2000 (Lopes and Evetts, 2004; Matt Dillon, NDWR, written commun., 2008; pumpage inventories from NDWR website http://water.nv.gov), but that did not have complete well-withdrawal records from 1940 through 2006, the following methods were used to estimate historical well withdrawals for years with no previously published estimates for the current study. Generally, the methodology used to estimate well withdrawals was the development of yearly ratios between the historical period and a reference year for HAs that had at least partial historical estimates; these yearly ratios were then applied to these HAs for the periods that lacked previously reported estimates of well withdrawals. For the HAs to which this method was applied, the year of the earliest reported withdrawals was used as the reference year. The methods and reference years used are explained in detail below, and the calculations are shown in table A8–1. Except for the determination of yearly ratios for Fish Lake Valley (HA 117), which had an estimate of significant well withdrawals in 1949 (Auxiliary 4), historical estimates of withdrawals for Pahrump Valley (HA 162), Amargosa Desert (HA 230), and Las Vegas Valley (HA 212) were not used in the development of these ratios. These HAs had significant well withdrawals extending back to the 1940s and the use of these HAs in the ratio calculations tended to cause overestimation of withdrawals in the lesser developed HAs.

Table A8–1. 1940–2006 estimated historical well withdrawals for hydrographic areas in Nevada and California that have more than 500 acre-ft of withdrawals in the year 2000 (organized by method).

Method 1: Reference Year 2000

This method was applied to 29 HAs (table A8–1). It is based on historical well-withdrawal estimates from 26 HAs in the Humboldt (7), Death Valley (28), Colorado (34), and Mesquite Valley (36) groundwater flow systems that have a withdrawal estimate for the year 2000 in addition to the estimates reported by Lopes and Evetts (2004). Lopes and Evetts (2004) estimates are less than withdrawal estimates provided by the NDWR (Matt Dillon, NDWR, written commun., 2008) for HAs in the Humboldt groundwater flow system (7) and, therefore, were not used in the following ratio calculation. Historical estimates from each of these 26 HAs were used to develop a multiplication factor that was a ratio of the sum of the withdrawals for each year from 1940 to 2006 for a subset of these HAs to the sum of the withdrawals in 2000 for the same subset (table A8–1). For example, in 1951, 19 out of the 26 HAs have a withdrawal estimate. The multiplication factor for this year was calculated as the sum of withdrawals from these 19 HAs in 1951 divided by the sum of withdrawals from these 19 HAs in 2000. The multiplication factors were then applied to the withdrawal estimates in 2000 for 29 HAs to estimate withdrawals from the periods 1940–1999 and 2001–2006, except for the years in which a withdrawal estimate was reported (Auxiliary 4).

Method 2: Reference Year 1996

This method was applied to three HAs (44, 48, and 51). It is based on historical withdrawal estimates from 26 HAs in the Humboldt (7), Death Valley (28), Colorado (34), and Mesquite Valley (36) groundwater flow systems that have withdrawal estimates for the year 1996. Historical estimates for each of these 26 HAs were then used to develop a multiplication factor that was a ratio of the sum of the withdrawals for each year from 1940 to 2006 from a subset of these HAs to the sum of the withdrawals in 1996 from the same subset (table A8–1). The multiplication factors were then applied to the withdrawal estimates in 1996 for these three HAs to estimate withdrawals from the period 1940–1995 (Auxiliary 4).

Method 3: Reference Year 1998

This method was applied to six HAs (54, 56, 59, 60, 61, and 173A). It is based on historical withdrawal estimates from 31 HAs in the Humboldt (7), Death Valley (28), Colorado (34), and Mesquite Valley (36) groundwater flow systems that have withdrawal estimates from the year 1998. Historical estimates for each of these 31 HAs were then used to develop a multiplication factor that was a ratio of the sum of the withdrawals for each year from 1940 to 2006 from a subset of these HAs to the sum of the withdrawals in 1998 from the same subset (table A8–1). The multiplication factors were then applied to the withdrawal estimates in 1998 for these six HAs to estimate withdrawals from the periods 1940–1997 and 1999–2006, except for the years in which a previous withdrawal estimate was reported (Auxiliary 4).

Method 4: Reference Year 1989

This method was applied to three HAs (198, 199, and 203). It is based on historical withdrawal estimates from 23 HAs in the Death Valley (28), Colorado (34), and Mesquite Valley (36) groundwater flow systems that have withdrawal estimates from the year 1989. Historical estimates for each of these 23 HAs were then used to develop a multiplication factor that was a ratio of the sum of the withdrawals for each year from 1940 to 2006 from a subset of these HAs to the sum of the withdrawals in 1989 from the same subset (table A8–1). The multiplication factors were then applied to the withdrawal estimates in 1989 for these three HAs to estimate withdrawals from the periods 1940–1988 and 1999–2006 (Auxiliary 4).

Method 5: Miscellaneous Reference Years

This method was used to estimate historical withdrawals for five HAs (56, 117, 215, 216, and 189D) that did not fit into the above categories. For HA 56, historical estimates from 22 HAs were used to develop a multiplication factor that was the ratio of the sum of the withdrawals for each year from 1940 to 2006 from a subset of these HAs to the sum of the withdrawals in 1964 from the same subset (table A8–1). These multiplication factors were then applied to the withdrawal estimate in 1964 for HA 56 to estimate withdrawals for the periods 1940–1963 and 1999–2006 (Auxiliary 4).

For HA 117, historical estimates from 23 HAs were used to develop a multiplication factor that was the ratio of the sum of the withdrawals for each year from 1940 to 2006 from a subset of these HAs to the sum of the withdrawals in 1949 from the same subset (table A8–1). These multiplication factors were then applied to the withdrawal estimate in 1949 for HA 117 to estimate withdrawals for the periods 1940–1948, 1970–1988, and 1990 (Auxiliary 4).

For HAs 215 and 216, historical estimates from 25 HAs were used to develop a multiplication factor that was the ratio of the sum of the withdrawals for each year from 1940 to 2006 from a subset of these HAs to the sum of the withdrawals in 2001 from the same subset (table A8–1). These multiplication factors were then applied to the withdrawal estimate in 2001 for HAs 215 and 216 to estimate withdrawals for the period 1940–2000 (Auxiliary 4).

For HA 189D, historical estimates from 18 HAs were used to develop a multiplication factor that was the ratio of the sum of the withdrawals for each year from 1940 to 2006 from a subset of these HAs to the sum of the withdrawals in 1968 from the same subset (table A8–1). These multiplication factors were then applied to the withdrawal estimate in 1968 for HA 189D to estimate withdrawals for the periods 1940–1967 and 1969–2006 (Auxiliary 4). Although HA 189D straddles the Utah-Nevada border, it lies mainly within Nevada, and therefore it is believed that withdrawals from the Nevada portion represent total withdrawals for this HA.

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