Hydrologic Data for Water Years 1978-97 Used in Daily Flow-Routing and River-Operations Models for the Upper Carson River Basin, California and Nevada

By Glen W. Hess

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CONVERSION FACTORS

Multiply	By	To obtain
acre	0.4047	square hectometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per year ($ft^3/s/yr$)	0.02832	cubic meter per second per year
foot (ft)	0.3048	meter
foot per year (ft/yr)	0.3048	meter per year
inch (in.)	25.40	millimeter

Water Year: Refers to the 12-month period October 1 through September 30. The water year is designated by the calendar year in which it ends. Thus, the year beginning October 1, 1996, and ending September 30, 1997, is called the "1997 water year."

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ABSTRACT

The U.S. Geological Survey (USGS) has developed computer models to simulate flow routing and river operations in the upper Carson River Basin. Data are needed for model calibration and initiation, and for comparison of model output with observations. The USGS and other agencies have been operating hydrologic data-collection networks in the upper Carson River Basin for more than 20 years. This report summarizes selected hydrologic data for water years 1978-97 which are necessary to run and test the flow-routing and river-operations models. Specifically, this report describes a data base consisting of records of surface-water flow at 86 gaging stations, precipitation at 5 sites, evaporation at 2 sites, estimates of phreatophyte evapotranspiration for 20 reaches, streamflow forecasts at 3 sites, and estimates of ground-water gain or loss for 33 reaches within the upper Carson River Basin. Until recently (1997), a compilation of these types of water-resources information did not exist. All of the data are available in electronic format.

INTRODUCTION

The Truckee–Carson–Pyramid Lake Water Rights Settlement Act (U.S. Congress, 1990), Public Law (P.L.) 101-618, was legislated to allocate water between California and Nevada in the Truckee River and Carson River Basins (pl. 1, fig. 1) and to develop effective operating criteria. These criteria are being developed using existing decrees, such as the Alpine and Orr Ditch. New criteria also are being developed using negotiations between interested parties within the Truckee River and Carson River Basins. These basins are connected by the Truckee Canal and, consequently, operations in one basin could have a significant impact on the other basin. Effective operations can better coordinate the use of existing water supplies in the basins to meet water demands for uses such as municipal, irrigation, fish, wildlife, and recreation.

Truckee–Carson Program of the U.S. Geological Survey

The Truckee–Carson Program of the USGS was established by the U.S. Department of the Interior to support implementation of P.L. 101-618 by (1) compiling records from a network of multiagency gaging stations to develop a consistent long-term data base that provides reliable information in support of modeling activities in the Truckee River and Carson River Basins, (2) establishing new streamflow and water-quality gaging stations for more complete water-resources information and more consistent support of river operations, and (3) developing an interbasin modeling system to support efficient water-resources planning, management, and allocation.

Many of the planning, management, or environmental-assessment requirements of P.L. 101-618 need a detailed understanding of the hydrologic system. Existing data networks and modeling tools do not provide enough quantitative detail to address the broad spectrum of water-resources issues in the Truckee River and Carson River Basins for P.L. 101-618, particularly for documenting the short- and long-term variability in water supply in these basins. Numerical modeling activities completed by the USGS Truckee–Carson Program include the following components for the Carson River Basin:

- Flow-routing models of the upper Carson River (upstream from Lahontan Reservoir), major tributaries, and lakes/reservoirs (Hess, 1996).
- Models which simulate lake/reservoir and river operations (Hess and Taylor, 1999).

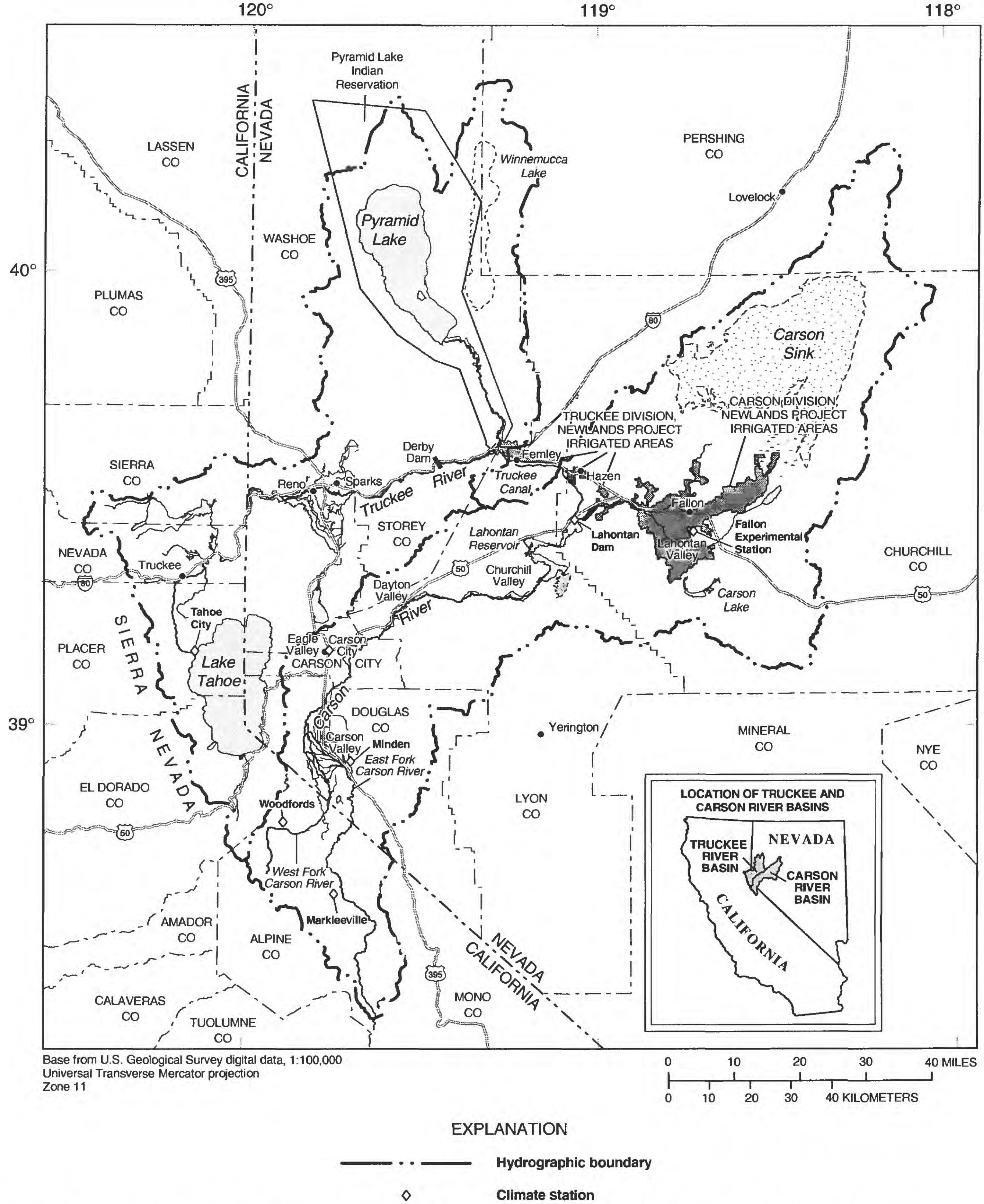

Figure 1. Hydrologic features and climate stations of the Carson River and Truckee River Basins and adjacent areas, California and Nevada.

This modeling system requires standard formats for data exchange and includes programs to enable graphical presentation and statistical analyses. In addition to simulations using flow-routing and river-operations data, simulations using water-quality and precipitation-runoff data can be built into this modular framework.

The flow-routing and river-operations models discussed by Hess (1996, 1997) and Hess and Taylor (1999) include data-management, flow-routing, and river-operations modules. These modules are a part of the Truckee-Carson Program modeling system that is structured to allow integration of newer or more detailed hydrologic-analysis tools. Selected hydrologic data from the expanded network for water years 1978-97 are necessary to run and test the flow-routing and river-operations models.

Users of the comprehensive river-basin models require advanced computer-processing capabilities to better create new scenarios. Knowledge of the complex operational rules in the upper Carson River Basin and data requirements for modeling also are needed to summarize and analyze large volumes of input and output data. An interactive computer program, GENSCN (GENeration and analysis of model simulation SCeNarios), developed by Kittle and others (1998), can be used in conjunction with the river-operations model. GENSCN was developed to create simulation scenarios, analyze results of the scenarios, and compare scenarios. A variety of standard tabular, graphical, and statistical tools are provided in the GENSCN program including animation.

Purpose and Scope

The purpose of this report is to compile and summarize selected water-resources data collected in the upper Carson River Basin, Calif., and Nev., for water years 1978-97. These data are needed to run and test the USGS flow-routing and river-operations models. The selected data are records of surface-water flow at 86 gaging stations, precipitation at 5 sites, evaporation at 2 sites, estimates of phreatophyte evapotranspiration for 20 reaches, streamflow forecasts at 3 sites, and estimates of ground-water gain or loss for 33 reaches within the Carson River Basin. All data are available in electronic format.

The data for this report were compiled from the upper Carson River Basin. This area includes the Carson River headwaters in Alpine County, Calif., and the Carson River to the northeast through Carson Valley and parts of Churchill, Dayton, and Eagle Valleys, Nev., into Lahontan Reservoir (pl. 1). This data-compilation report, along with the river-operations model (Hess and Taylor, 1999), can assist upper Carson River Basin planners and managers in determining trends and changes in surface-water flow.

Acknowledgments

The author gratefully acknowledges the support of many people and agencies who provided data used in this report. Streamflow data were provided by the Office of the U.S. District Court Water Master, also called the Federal Water Master (FWM), Gene Eppler of South Tahoe Public Utility District, Gary Hoffman of Carson City Wastewater Treatment Plant, Carol Grenier, Al Olson and Chuck Vincent of Bureau of Reclamation, Dorothy Timian-Palmer of Carson City Public Utilities, Douglas County Sewer Improvement District, Incline Village General Improvement District, and the Nevada Division of Environmental Protection. Several people within the FWM office, notably Chad Blanchard, Jeff Boyer, Julian Larrouy, Ed Mees, Matthew Setty, and Garry Stone provided data for the Carson River Basin. The National Oceanic and Atmospheric Administration (NOAA) provided precipitation and evaporation data collected in the upper Carson River Basin, and Rebecca Wray of the Natural Resources Conservation Service (NRCS) provided streamflow forecasts.

DESCRIPTION OF DATA

Simulation of Carson River streamflow requires time-series hydrologic data describing river inflows and outflows. These data were compiled from several agencies. Surface-water flow, precipitation, and evaporation data; estimates of phreatophyte evapotranspiration; streamflow forecasts; and estimates of ground-water gain or loss are needed to run and test the flow-routing and river-operations models. Data from selected streamflow gaging stations used in this report, and other hydrologic and climatic data, were compiled by August and others (1992) and Mello (1996). Water years 1978-97 were chosen because hydrologic data were collected at more sites during this period than during previous periods. Additionally, this period represents a wide range of hydrologic conditions.

The flow-routing and river-operations models are formulated using the time-series data-management system called ANNIE (Lumb and others, 1990). This interactive program includes file creation, data-set management, data analysis, and data display. ANNIE is used for management of the daily time-series data, which describes each component of the hydrologic system in the Carson River Basin. Each time series of data is assigned a unique data-set number.

The data and ANNIE are available electronically in several media including compact disk and computer access. Table 1 lists the file names, sizes, and descriptions.

Table 1. Name, size, and description of files used in the daily flow-routing and river-operations models for the upper Carson River Basin, California and Nevada[1]

File name	Size (bytes)	Description
annie2.2	3,425,836	Binary file containing source code for data management system ANNIE (Lumb and others, 1990).
mast.carson.wdm	15,564,800	Binary file created by ANNIE which contains data sets.

[1] For more information, contact Public Information Assistant: phone (775) 887-7649; e-mail <usgsinfo_nv@usgs.gov>. The data base is available in several media, including compact disk and computer access.

Surface-Water Flow

Simulation of streamflow in the upper Carson River Basin requires time-series data to describe surface-water inflows to the river. Inflows at the upstream model boundaries and tributary inflows are required to run the models. Surface-water flows at interior points within the modeled area are required to test the models. The following sections describe the sources and description of each of these required data.

Daily streamflow records for water years 1978-97 are from two USGS gaging stations. The *East Fork Carson River near Markleeville, Calif.* (site 2; pl. 1, table 2), and *West Fork Carson River at Woodfords, Calif.* (site 21), were used as inflows at the upstream model boundaries.

Tributary inflows in the upper Carson River Basin can be separated into two groups: upstream from and downstream from the *Carson River near Carson City, Nev.*, gaging station (site 60; pl. 1). Most of the perennial tributaries are upstream from the Carson City gaging station. These tributaries, with headwaters in the high elevations of the eastern Sierra Nevada, supply most of the tributary inflows to the upper Carson River. Additionally, most of the volume of tributary inflows of tributary drainages from higher altitudes is supplied during the months of December to March. Downstream from the Carson City gaging station, most of the tributaries are ephemeral and normally do not supply large volumes of water to the upper Carson River. Summer thunderstorms, although rare, can provide large volumes of water to these tributaries. For this report, inflows from ephemeral tributaries downstream from the Carson City gaging station were not estimated. Data are not available to use in regression techniques because no ephemeral-tributary gaging stations exist.

In the upper Carson River Basin, few long-term gaging stations on tributaries exist. Available data from these stations were used in regression techniques to estimate daily time series of ungaged tributary inflows in the models. Simple multiple-regression analyses related the independent variables (daily mean streamflows at index gaging stations and annual precipitation at Markleeville and Woodfords, Calif., and Minden Airport, Nev.; table 3) to the dependent variable (gaged-tributary inflows). The USGS gaging stations at *Daggett Creek near Genoa, Nev.*; *Bryant Creek near Gardnerville, Nev.*; and *West Fork Carson River at Woodfords, Calif.* (table 2), were used as index gaging stations. Streamflow data from partial record sites in Carson Valley (table 4) were used for the dependent variable. Separate daily regression equations were developed for each tributary that included one or more of the independent variables (table 5). These equations then were used to estimate daily streamflow for the ungaged tributaries.

Only regression equations for the months of December to March were developed, when most of the tributary runoff occurs. The daily time series of inflow for 11 tributaries were then apportioned to each model reach according to the location of the tributary confluence (table 6). Estimated flow was used for gaged tributaries when no records were available.

For seven tributaries where no long-term gaged records are available, a drainage-area relation was determined to estimate tributary inflows (table 6). Drainage areas were determined using the daily time series of streamflow from *Bryant Creek near Gardnerville, Nev.*, as an index station. The ratio of streamflow of Bryant Creek divided by the drainage area of Bryant

Table 2. Streamflow gaging stations in the upper Carson River Basin data network used in the flow-routing and river-operations models

[Acronyms: CCWUD, Carson City Water Utility Division; DCSID, Douglas County Sewer Improvement District; FWM, U.S. District Court Water Master; IVGID, Incline Village General Improvement District; MGSD, Minden-Gardnerville Sanitation District; STPUD, South Tahoe Public Utilities District; USGS, U.S. Geological Survey. Symbol: ---, not applicable]

Site number (see pl. 1)	Source of data	Station number	Station name	Period of record (water year)	USGS data-set number
1	FWM	---	East Fork Carson River Alpine Reservoir releases, near Markleeville, Calif.	1994-97	425
2	USGS	10308200	East Fork Carson River below Markleeville Creek, near Markleeville, Calif.	1978-97	450
3	USGS	10308800	Bryant Creek near Gardnerville, Nev.	1978-80, 1994-97	460
4	USGS	10309000	East Fork Carson River near Gardnerville, Nev.	1978-97	475
5	FWM	C82	Allerman Canal near Dresslerville, Nev.	1984-97	700
6	USGS	10309025	Indian Creek near Woodfords, Calif.	1987-89	185
7	USGS	10309030	Indian Creek near Paynesville, Calif.	1987-89	195
8	USGS	10309035	Indian Creek above mouth near Gardnerville, Nev.	1994-97	198
9	FWM	C84	Rocky Slough at Dresslerville, Nev.	1982-97	900
10	FWM	C85	Edna Wilslef Ditch near Dresslerville, Nev.	1982-97	1000
11	FWM	C83	Virginia Ditch at Dresslerville, Nev.	1983-97	800
12	USGS	10309050	Pine Nut Creek near Gardnerville, Nev.	1980-97	1350
13	FWM	C86	Company Ditch near Gardnerville, Nev.	1984-97	1200
14	FWM	C88	Henningson Ditch near Gardnerville, Nev.	1983-97	1400
15	FWM	C87	Cottonwood Slough near Gardnerville, Nev.	1983-97	1100
16	MGSD	385814119475101	Minden-Gardnerville Sanitation District effluent near Gardnerville, Nev.	1978-86	1150
17	USGS	10309070	Buckeye Creek near Minden, Nev.	1980-97	1375
18	USGS	10309100	East Fork Carson River at Minden, Nev.	1978-84, 1994-97	1425
19	DCSID	385815119475401	Douglas County Sewage Improvement District effluent discharge near Minden, Nev.	1978-79	1475
20	FWM	C89	Heyburn Ditch near Minden, Nev.	1983-97	1300
21	USGS	10310000	West Fork Carson River at Woodfords, Calif.	1978-97	50
22	FWM	C76	Snowshoe Thompson Ditch No. 2 near Woodfords, Calif.	1984-97	100
23	FWM	---	West Fork Carson River Alpine Reservoir releases near Woodfords, Calif.	1994-97	80
24	FWM	C77	West Fork Carson River at Paynesville, Calif.	1982-94	200
25	STPUD	38450811946280	South Tahoe Public Utility District effluent discharge near Paynesville, Calif.	1982-97	175
26	FWM	C78	Fredericksburg Ditch near Paynesville, Calif.	1982-97	300
27	USGS	10310300	Fredericksburg Canyon Creek near Fredericksburg, Calif.	1981-83, 1988-97	350

Table 2. Streamflow gaging stations in the upper Carson River Basin data network used in the flow-routing and river-operations models—Continued

Site number (see pl. 1)	Source of data	Station number	Station name	Period of record (water year)	USGS data-set number
28	FWM	C79	West Fork Carson River at Dressler Lane near Fredericksburg, Calif.	1982-97	400
29	FWM	C80	Brockliss Slough at Ruhenstroth Dam near Gardnerville, Nev.	1982-97	500
30	FWM	C81	Brockliss Slough at Scossa Box near Gardnerville, Nev.	1982-97	600
31	USGS	1030909020	Cottonwood Slough at State Highway 88 near Minden, Nev.	1994-97	1260
32	USGS	1030909042	Martin Slough at U.S. Highway 395 near Minden, Nev.	1994-97	1259
33	USGS	1030909046	Middle Ditch at Muller Lane near Minden, Nev.	1994-95	1264
34	USGS	1030909048	East Ditch at Muller Lane near Minden, Nev.	1994-95	1263
35	USGS	1030909055	Martin Slough-Heyburn Ditch Return at U.S. Highway 395 near Minden, Nev.	1994-97	1258
36	USGS	1030909060	Heyburn Ditch Return at Slash Bar H Ranch Road at U.S. Highway 395 near Minden, Nev.	1994-95	1256
37	USGS	1030909065	Heyburn Ditch Return at U.S. Highway 395 near Minden, Nev.	1994-95	1257
38	USGS	1030909070	Heyburn Ditch Return near Dangberg Well at U.S. Highway 395 near Minden, Nev.	1994-95	1255
39	USGS	1030909075	Heyburn Ditch Return at Airport Road and U.S. Highway 395 near Minden, Nev.	1994-95	1254
40	USGS	1030909080	Heyburn Ditch Return 0.75 mile south of Johnson Lane at U.S. Highway 395 near Minden, Nev.	1994-95	1253
41	USGS	1030909085	Heyburn Ditch Return 0.25 mile south of Johnson Lane at U.S. Highway 395 near Minden, Nev.	1994-95	1252
42	USGS	1030909090	Heyburn Ditch Return at Johnson Lane and U.S. Highway 395 near Minden, Nev.	1994-95	1251
43	USGS	1030909095	Heyburn Ditch Return at Stephanie Lane near Minden, Nev.	1994-95	1250
44	USGS	1030909710	St. Louis Straight Ditch at State Highway 88 near Minden, Nev.	1994-97	1262
45	USGS	10309110	Home Slough at State Highway 88 near Minden, Nev.	1994-97	1261
46	USGS	10309113	Home Slough at Muller Lane near Minden, Nev.	1994-95	1267
47	USGS	10309117	Home Slough Return at Muller Lane near Minden, Nev.	1994-95	1266
48	USGS	10309118	West Ditch at Muller Lane near Minden, Nev.	1994-95	1265
49	USGS	103103576	West Fork Carson River West Ditch at Muller Lane near Minden, Nev.	1994-95	1269
50	USGS	103103577	West Fork Carson River East Ditch at Muller Lane near Minden, Nev.	1994-95	1268
51	USGS	10310358	West Fork Carson River at Muller Lane near Minden, Nev.	1994-97	1330
52	USGS	10310400	Daggett Creek near Genoa, Nev.	1978-83, 1989-97	650
53	USGS	10310402	East Branch Brockliss Slough at Muller Lane near Minden, Nev.	1994-97	1310
54	USGS	10310403	West Branch Brockliss Slough at Muller Lane near Minden, Nev.	1994-97	1320
55	USGS	10310405	Carson River at Genoa, Nev.	1978-81	675

Table 2. Streamflow gaging stations in the upper Carson River Basin data network used in the flow-routing and river-operations models—Continued

Site number (see pl. 1)	Source of data	Station number	Station name	Period of record (water year)	USGS data-set number
56	USGS	10310447	Ambrosetti Pond near Genoa, Nev.	1992-97	1445
57	USGS	10310448	Ambrosetti Pond Outlet near Genoa, Nev.	1992-97	1446
58	IVGID	390426119460401	Incline Village General Improvement District treatment plant effluent discharge near Carson City, Nev.	1978-85	1435
59	USGS	10310500	Clear Creek near Carson City, Nev.	1989-97	1440
60	USGS	10311000	Carson River near Carson City, Nev.	1978-97	1450
61	FWM	C61	Mexican Ditch near Carson City, Nev.	1978-97	1500
62	CCWUD	---	Carson River municipal diversion at Carson City, Nev.	1991-97	---
63	USGS	10311100	Kings Canyon Creek near Carson City, Nev.	1978-97	1460
64	USGS	10311200	Ash Canyon Creek near Carson City, Nev.	1978-97	1465
65	USGS	10311260	Vicee Canyon Creek near Sagebrush Ranch near Carson City, Nev.	1983-85, 1989-97	1470
66	CCWUD	391036119422401	Carson City Wastewater Treatment Plant effluent discharge at Carson City, Nev.	1978-86	1525
67	USGS	10311300	Eagle Valley Creek at Carson City, Nev.	1985-97	1550
68	USGS	10311400	Carson River at Deer Run Road near Carson City, Nev.	1979-85, 1990-97	1575
69	FWM	C62	Dayton Town (Rose) Ditch near Dayton, Nev.	1978-97	1600
70	FWM	C63	Randall (Dayton) Ditch near Dayton, Nev.	1978-88	1700
71	FWM	C64	Fish Ditch near Dayton, Nev.	1978-97	1800
72	FWM	C65	Baroni Ditch near Dayton, Nev.	1978-97	1900
73	USGS	10311700	Carson River at Dayton, Nev.	1994-97	1950
74	FWM	C66	Rock Point Mill and Cardelli Ditch near Dayton, Nev.	1978-97	2000
75	FWM	C67	Quilici (Ghiglieri) Ditch near Dayton, Nev.	1978-97	2175
76	FWM	C68	Gee Ditch near Dayton, Nev.	1978-97	2000
77	FWM	C69	Koch (Chaves) Ditch near Dayton, Nev.	1978-97	2300
78	USGS	10311875	Carson River near Clifton, Nev.	1992-97	2350
79	FWM	C70A	Houghman and Howard Ditch No. 1 near Fort Churchill, Nev.	1978-97	2650
80	FWM	C70B	Houghman and Howard Ditch No. 2 near Fort Churchill, Nev.	1978-97	2600
81	USGS FWM	10311900 C71	Buckland Ditch near Fort Churchill, Nev.	1978-97	2700
82	FWM	C71A	South Buckland Ditch near Fort Churchill, Nev.	1978-97	2900
83	FWM	C72	Lower Buckland Ditch near Fort Churchill, Nev.	1978-97	2800
84	USGS	10312000	Carson River near Fort Churchill, Nev.	1978-97	2750
85	USGS	10312100	Lahontan Reservoir near Fallon, Nev.	1978-97	3000
86	USGS	10312150	Carson River below Lahontan Dam near Fallon, Nev.	1978-97	3100

Table 3. Climate stations used in the upper Carson River Basin flow-routing and river-operations models

[Data from the National Oceanic and Atmospheric Administration. Abbreviation: USGS, U.S. Geological Survey]

Station name (see fig. 1)	Data type	Period of record (water year)	USGS data-set number
Carson City, Nev.	precipitation	1978-97	8005
Fallon Experimental Station, Nev.	evaporation	1978-97	8062
Lahontan Dam, Nev.	precipitation	1978-97	8015
Markleeville, Calif.	precipitation	1990-97	8045
Minden Airport, Nev.	precipitation	1978-97	8038
Tahoe City, Calif.	evaporation	1978-97	8072
Woodfords, Calif.	precipitation	1978-90	8055

Table 4. Partial-record sites in Carson Valley, California and Nevada, used to estimate tributary inflow to the upper Carson River Basin

Station number	Station name	Period of record (water year)
10308800	Bryant Creek near Gardnerville, Nev.	[a]1961-69, 1976-77, [a]1978-80, [a]1994-97
10310300	Fredericksburg Canyon Creek near Fredericksburg, Calif.	1972-73, 1976-77, 1981-83, [a]1988-97
10310330	Luther Creek near Fredericksburg, Calif.	1976-77, 1981-83, 1989-96
10310360	Jobs Canyon Creek near Minden, Nev.	1976, 1981-83, 1989-97
10310370	Sheridan Creek near Minden, Nev.	1981-83, 1989-96
10310385	Mott Canyon Creek near Minden, Nev.	1969, 1971, 1973, 1976-77, 1981-83, 1987-96
10310400	Daggett Creek near Genoa, Nev.	[b]1965-83, 1989-97
10310410	Genoa Canyon Creek at Genoa, Nev.	1969, 1972, 1976-77, 1981-82, 1988-97
10310415	Sierra Canyon Creek near Genoa, Nev.	1969, 1972, 1976-77, 1981-83, 1989-96
10310500	Clear Creek near Carson City, Nev.	[a]1948-62, 1963-88, [a]1989-97

[a] Continuous streamflow data.

[b] Intermittent pumping of effluent from Lake Tahoe area occurred upstream from gage, Feb. 1969-Nov. 1971.

Table 5. Daily regression equations used to determine tributary inflow from December to March in the upper Carson River Basin

[$Q_{XXXXXXXX}$, daily streamflow for station XXXXXXXX, in cubic feet per second; $P_{Mville/Wood}$ - annual precipitation at Markleeville and Woodfords, Calif. (table 3), in inches; P_{Minden} - annual precipitation at Minden Airport, Nev., in inches; ---, no value determined]

Station number	Station name	Regression equation used to estimate streamflows [1]	Coefficient of determination
10308800	Bryant Creek near Gardnerville, Nev.	$Q_{10308800} = 0.10\ P_{Mville/Wood} + 0.06\ Q_{10310000}$	0.70
10310300	Fredericksburg Canyon Creek near Fredericksburg, Calif.	$Q_{10310300} = -0.05 + 0.24\ P_{Minden} + 0.014\ Q_{10310000}$	.70
10310330	Luther Creek near Fredericksburg, Calif.	$Q_{10310330} = -1.32 + 0.14\ P_{Minden} + 2.04\ Q_{10310400}$	.65
10310360	Jobs Canyon Creek near Minden, Nev.	$Q_{10310360} = -0.81 + 0.18\ P_{Minden} + 0.74\ Q_{10310400}$	.51
10310370	Sheridan Creek near Minden, Nev.	$Q_{10310370} = -0.14 + 0.15\ P_{Minden} + 0.01\ Q_{10310400}$	.38
10310380	Monument Creek near Minden, Nev. [2]	$Q_{10310380} = 1.44 + 0.85\ Q_{10310400}$	---
10310385	Mott Canyon Creek near Minden, Nev.	$Q_{10310385} = 0.27 + 0.11\ P_{Minden} + 0.74\ Q_{10310400}$	.59
10310400	Daggett Creek near Genoa, Nev.	$Q_{10310400} = 1.02 + 0.009\ P_{Minden} + 0.004\ Q_{10310000}$	.53
10310410	Genoa Canyon Creek at Genoa, Nev.	$Q_{10310410} = 0.26 + 0.03\ P_{Minden} + 0.30\ Q_{10310400}$	.37
10310415	Sierra Canyon Creek near Genoa, Nev.	$Q_{10310415} = -0.93 + 0.06\ P_{Minden} + 1.29\ Q_{10310400}$	.85
10310500	Clear Creek near Carson City, Nev.	$Q_{10310500} = -3.29 + 5.62\ Q_{10310400}$	.84

[1] $Q_{10310000}$ - streamflow for station 10310000 West Fork Carson River at Woodfords, Calif.

$Q_{10310400}$ - streamflow for station 10310400 Daggett Creek near Genoa, Nev.

[2] From Maurer (1986, p. 14).

Creek was calculated. This ratio was multiplied by each of the drainage areas of the seven tributaries to determine daily streamflow. Then, these daily time series of ungaged inflows for seven tributaries were apportioned to each model reach by drainage-area relation according to where the tributary flows into the Carson River (table 6).

Surface-water flow data within the modeled area are used to test the models. These daily streamflow data for sites on mainstem streams, tributaries, and irrigation ditches for water years 1978-97 were obtained from several agencies and consolidated into a single Carson River data base (table 2). The locations of all surface-water gaging stations compiled in this data base are shown on plate 1. The map number (pl. 1), source of data, station number, name, period of record, and data-set number are listed in table 2.

The USGS has several gaging stations along the mainstem and tributaries of the Carson River, which typically are operated all year. However, data were not collected at all gaging stations for the entire period of water years 1978-97 (table 2). The FWM operates gaging stations on many irrigation ditches along the Carson River. These stations are used to collect streamflow data only during irrigation season (from about April to October). This gaging-station network is divided into two groups: (1) stations upstream from Carson City, and (2) stations downstream from Carson City. Stations upstream from Carson City were operated to collect streamflow data beginning in the spring of 1982 using continuous stage recorders. Stations downstream from Carson City were operated to collect streamflow data beginning in spring of 1978. However, discontinuous periodic staff-gage readings were used and continue to be used to determine instantaneous

Table 6. Tributary-inflow estimates, by reach, used in the upper Carson River Basin flow-routing and river-operations models

[Symbol: ---, not applicable. Abbreviation: USGS, U.S. Geological Survey]

Stream name	Reach number (see pl. 1)	Tributary or canyon name	Data type	USGS data-set number
East Fork Carson River	1	---	---	---
East Fork Carson River	2	---	---	---
East Fork Carson River	3	Cottonwood Canyon	drainage-area relation	9812
East Fork Carson River	4	Bryant Creek	observed and regression	9810
East Fork Carson River	5	East Fork unnamed tributaries	drainage-area relation	9815
East Fork Carson River	6	Bodie Flat tributary	drainage-area relation	9811
East Fork Carson River	7	---	---	---
East Fork Carson River	8	---	---	---
East Fork Carson River	9	---	---	---
East Fork Carson River	10	---	---	---
East Fork Carson River	11	---	---	---
West Fork Carson River	13	---	---	---
West Fork Carson River	14	---	---	---
West Fork Carson River	15	---	---	---
West Fork Carson River	16	West Fork unnamed tributaries	drainage-area relation	9817
West Fork Carson River	17	---	---	---
West Fork Carson River	18	---	---	---
West Fork Carson River	19	---	---	---
West Fork Carson River	20	---	---	---
West Fork Carson River	21	---	---	---
Carson River	22	---	---	---
Brockliss Slough	23	---	---	---
Brockliss Slough	24	Fredericksburg Canyon Creek	observed and regression	9803
		Luther Creek	regression	9801
		Jobs Canyon Creek	regression	9808
		Sheridan Creek	regression	9806
		Stutler Creek	drainage-area relation	9813
Brockliss Slough	25	Monument Creek	regression	9804
Brockliss Slough	26	Mott Canyon Creek	regression	9809
Brockliss Slough	27	Daggett Creek	observed and regression	9800
Brockliss Slough	28	Genoa Canyon Creek	regression	9807
		Sierra Canyon Creek	regression	9805
Carson River	29	---	---	---
Carson River	30	---	---	---
Carson River	31	Eastern unnamed tributaries	drainage-area relation	9814
		Western unnamed tributaries	drainage-area relation	9816
Carson River	32	Clear Creek	regression	9816

streamflow. Methods for estimating missing daily streamflow data between these periodic staff-gage readings are described by Hess (1996, p. 10-12).

Precipitation and Evaporation

Simulation of streamflow gain or loss due to precipitation, evaporation, and evapotranspiration from phreatophytes require input time-series data. The river-operations model accounts for these gains or losses at each reach.

Daily precipitation and evaporation data for the upper Carson River Basin (table 3) were collected at five precipitation-gage sites and two standard-pan sites operated by NOAA. The evaporation and precipitation data were distributed to each model reach as listed in table 7.

Estimates of Phreatophyte Evapotranspiration

Time-series data of streamflow loss due to evapotranspiration from phreatophytes were estimated. The total monthly evapotranspiration rate for each designated channel reach was estimated by accounting for phreatophyte acreage, annual evapotranspiration rate for typical species, and monthly distribution of annual evapotranspiration (table 8). The approximate extent of phreatophyte coverage and species composition along designated channel reaches of the Carson River were determined during field reconnaissance (Glancy and Katzer, 1976), and from aerial photographs taken in 1994 (Maurer, 1997, pl. 1).

Assuming that phreatophytes can affect streamflow, acreage of phreatophyte coverage within 50 ft of the river banks was estimated. The annual evapotranspiration rate for each typical phreatophyte species was estimated using previous studies as a guideline (Robinson, 1958; Glancy and Katzer, 1976; and Maurer, 1986). The monthly distribution of average annual evapotranspiration rates (data set 2010) was estimated using guidelines described by Duell (1988). The time-series data were applied only to the Carson River downstream from the confluence of the East Fork, West Fork, and Brockliss Slough (reaches 29-48; pl. 1). The evapotranspiration rate, in cubic feet per second per year (table 8), was multiplied by data set 2010 to simulate

Table 7. Evaporation and precipitation stations, by reach, used in the upper Carson River Basin flow-routing and river-operations models

[Data from the National Oceanic and Atmospheric Administration]

Stream name	Reach number (see pl. 1)	Evaporation station	Precipitation station
East Fork Carson River	1	Tahoe City, Calif.	Woodfords /Markleeville, Calif.
East Fork Carson River	2	Tahoe City, Calif.	Woodfords /Markleeville, Calif.
East Fork Carson River	3	Tahoe City, Calif.	Woodfords /Markleeville, Calif.
East Fork Carson River	4	Tahoe City, Calif.	Woodfords /Markleeville, Calif.
East Fork Carson River	5	Tahoe City, Calif.	Woodfords /Markleeville, Calif.
East Fork Carson River	6	Tahoe City, Calif.	Woodfords /Markleeville, Calif.
East Fork Carson River	7	Tahoe City, Calif.	Minden Airport, Nev.
East Fork Carson River	8	Tahoe City, Calif.	Minden Airport, Nev.
East Fork Carson River	9	Tahoe City, Calif.	Minden Airport, Nev.
East Fork Carson River	10	Tahoe City, Calif.	Minden Airport, Nev.
East Fork Carson River	11	Tahoe City, Calif.	Minden Airport, Nev.
West Fork Carson River	13	Tahoe City, Calif.	Woodfords /Markleeville, Calif.
West Fork Carson River	14	Tahoe City, Calif.	Woodfords /Markleeville, Calif.
West Fork Carson River	15	Tahoe City, Calif.	Woodfords /Markleeville, Calif.
West Fork Carson River	16	Tahoe City, Calif.	Woodfords /Markleeville, Calif.

Table 7. Evaporation and precipitation stations, by reach, used in the upper Carson River Basin flow-routing and river-operations models—Continued

Stream name	Reach number (see pl. 1)	Evaporation station	Precipitation station
West Fork Carson River	17	Tahoe City, Calif.	Woodfords /Markleeville, Calif.
West Fork Carson River	18	Tahoe City, Calif.	Minden Airport, Nev.
West Fork Carson River	19	Tahoe City, Calif.	Minden Airport, Nev.
West Fork Carson River	20	Tahoe City, Calif.	Minden Airport, Nev.
West Fork Carson River	21	Tahoe City, Calif.	Minden Airport, Nev.
Carson River	22	Tahoe City, Calif.	Minden Airport, Nev.
Brockliss Slough	23	Tahoe City, Calif.	Minden Airport, Nev.
Brockliss Slough	24	Tahoe City, Calif.	Minden Airport, Nev.
Brockliss Slough	25	Tahoe City, Calif.	Minden Airport, Nev.
Brockliss Slough	26	Tahoe City, Calif.	Minden Airport, Nev.
Brockliss Slough	27	Tahoe City, Calif.	Minden Airport, Nev.
Brockliss Slough	28	Tahoe City, Calif.	Minden Airport, Nev.
Carson River	29	Tahoe City, Calif.	Carson City, Nev.
Carson River	30	Tahoe City, Calif.	Carson City, Nev.
Carson River	31	Tahoe City, Calif.	Carson City, Nev.
Carson River	32	Tahoe City, Calif.	Carson City, Nev.
Carson River	33	Tahoe City, Calif.	Carson City, Nev.
Carson River	34	Tahoe City, Calif.	Carson City, Nev.
Carson River	35	Tahoe City, Calif.	Carson City, Nev.
Carson River	36	Tahoe City, Calif.	Carson City, Nev.
Carson River	37	Fallon Experimental Station, Nev.	Lahontan Dam, Nev.
Carson River	38	Fallon Experimental Station, Nev.	Lahontan Dam, Nev.
Carson River	39	Fallon Experimental Station, Nev.	Lahontan Dam, Nev.
Carson River	40	Fallon Experimental Station, Nev.	Lahontan Dam, Nev.
Carson River	41	Fallon Experimental Station, Nev.	Lahontan Dam, Nev.
Carson River	42	Fallon Experimental Station, Nev.	Lahontan Dam, Nev.
Carson River	43	Fallon Experimental Station, Nev.	Lahontan Dam, Nev.
Carson River	44	Fallon Experimental Station, Nev.	Lahontan Dam, Nev.
Carson River	45	Fallon Experimental Station, Nev.	Lahontan Dam, Nev.
Carson River	46	Fallon Experimental Station, Nev.	Lahontan Dam, Nev.
Carson River	47	Fallon Experimental Station, Nev.	Lahontan Dam, Nev.
Carson River	48	Fallon Experimental Station, Nev.	Lahontan Dam, Nev.

losses due to evapotranspiration from phreatophytes at each reach. Upstream from this confluence, streamflow losses from phreatophyte evapotranspiration were assumed to be indeterminate due to large amounts of irrigation (table 8).

Streamflow Forecasts

Streamflow forecasts were used to determine conditions that may govern the simulation of various reservoir and river operations in the model. Forecasts of flow volume at three gaging stations, *East Fork Carson River near Gardnerville, Nev.; West Fork Carson River at Woodfords, Calif.; and Carson River near Fort Churchill, Nev.* (table 9, pl. 1), were provided by the NRCS (Rebecca Wray, written commun., 1995). These forecasts were divided into three runoff groups—wet, average, or dry years. Runoff groups were defined using data of forecasted flow and long-term, mean runoff at each gaging station from historic USGS streamflow records (1948-97). If the forecast was greater than the long-term mean runoff plus half of the standard deviation, the year was considered wet. If the forecast was less than the mean minus half of the standard deviation, the year was considered dry. All other years were considered average. These runoff groups were used in the operations model to determine inflow and outflow such as the release of water from high-alpine reservoirs and amount of ground-water gain or loss.

Table 8. Estimates of phreatophyte evapotranspiration, by reach, used in the upper Carson River Basin flow-routing and river-operations models

Reach number (see pl. 1)	Phreatophyte area (acres)	Evapotranspiration rate		Typical phreatophytes
		feet per year	cubic feet per second per year	
29	55.9	0.4	0.376	grass, rabbitbrush, and sagebrush
30	66.4	.8	.893	rabbitbrush and sagebrush
31	85.3	.8	1.147	rabbitbrush and sagebrush
32	64.9	.8	.873	rabbitbrush and sagebrush
33	64.9	1.5	1.636	cottonwoods, rabbitbrush, and sagebrush
34	65.0	1.0	1.092	cottonwoods and grass
35	15.9	1.0	.267	cottonwoods and grass
36	17.7	1.0	.298	cottonwoods and grass
37	68.2	2.5	2.866	cottonwoods and willows
38	75.2	2.0	2.528	cottonwoods and sagebrush
39	55.0	2.0	1.849	cottonwoods, grass, and sagebrush
40	45.7	2.0	1.536	cottonwoods, grass, and willows
41	82.5	1.8	2.496	very sparse cottonwoods
42	86.7	1.2	1.749	sparse cottonwoods and rabbitbrush
43	85.7	1.0	1.441	sparse cottonwoods
44	63.9	.5	.537	cottonwoods, rabbitbrush, and sagebrush
45	70.2	.8	.944	rabbitbrush and sagebrush
46	92.0	1.5	2.320	cottonwoods, rabbitbrush, and sagebrush
47	47.1	1.0	.792	cottonwoods and grass
48	39.3	.2	.132	greasewood and sagebrush

Table 9. Streamflow-forecast stations used in the upper Carson River Basin river-operations model

[Data from the Natural Resources Conservation Service. Abbreviation: USGS, U.S. Geological Survey]

Site number (see pl. 1)	Station name	USGS data-set number
4	East Fork Carson River near Gardnerville, Nev.	465
21	West Fork Carson River at Woodfords, Calif.	75
84	Carson River near Fort Churchill, Nev.	2775

Estimates of Ground-Water Gain or Loss

Estimates of ground-water gain or loss are needed for more accurate simulations of streamflow and operations. Ground-water/surface-water interactions in Carson Valley between Woodfords and Carson City (fig. 1) are significant and complex. Depending on the time of year and current irrigation practices, ground water can contribute to gains in surface water or water can be lost from the main channel to the aquifer system. However, the ground-water system is difficult to define by water-balance computations using streamflow data from mainstem and ditch diversion gaging stations because the ditch diversions are usually estimated and returns are mostly ungaged. Additionally, gaging stations are too far apart to adequately define ground-water gain or loss. Where information was available, gain or loss estimates for river reaches in the upper Carson River Basin were made using the results from a ground-water model developed by Maurer (1986) or from low-flow investigations (Clary and others, 1995, p. 556-557; Hess, 1996, p. 12; Bonner and others, 1998, p. 413).

A numerical model used to simulate ground-water movement was applied by Maurer (1986) in Carson Valley to produce a comprehensive characterization of the hydrologic system. Geologic components of the ground-water reservoir were defined and estimates were made of the distribution of hydraulic properties of aquifer materials and water-budget components throughout the valley. The steady-state simulation for water years 1981-83 showed net average annual losses due to surface-water percolation, evapotranspiration, and evaporation. The ground-water model simulated ground- and surface-water inflow and outflow at several points in Carson Valley.

In the river-operations model (Hess and Taylor, 1999), current estimates of ground-water gain or loss are attributed to ground-water/surface-water interactions in Carson Valley. These estimates are based on the results of the ground-water model by Maurer (1986) and, in part, on the NRCS streamflow forecasts. These forecasts were used to determine whether the current simulation year would be classified as dry, average, or wet. In the Carson Valley, estimates of the ground-water gain or loss component for 18 reaches (6-11, 16-22, 24, and 29-32; table 10, pl. 1) are determined by the gain or loss values simulated for wet, dry, or average conditions in the ground-water model (Maurer, 1986) for water years 1981-83. In the river-operations model, each component (ground- and surface-water inflows and outflows) must be specified as a separate data set, if available. Ground-water model data for reaches other than the 18 identified above were not available.

Outside the Carson Valley, estimates of the ground-water gain or loss component for 15 reaches (1-3, 33-44; pl. 1) were calculated using data from low-flow investigations (Clary and others, 1995, p. 556-557; Hess, 1996, p. 12; Bonner and others, 1998, p. 413). Where the annual distribution of ground-water inflow and outflow is variable and could not be described quantitatively, a constant-value time series for the period of simulation was used for the river-operations model. Generally, the magnitude of the ground-water gain or loss values was from 1 to 5 ft^3/s per reach based on the low-flow investigations for the East Fork Carson River near Gardnerville (reaches 1-3) and the Carson River from Carson City to Lahontan Valley (reaches 33-44). Where applicable, estimates of ground-water gain or loss (table 10) from low-flow investigations were applied to each river reach in the operations model.

Table 10. Estimates of ground-water gain or loss, by reach, used in the upper Carson River Basin flow-routing and river-operations models

[Symbol: ---, not applicable. Abbreviation: USGS, U.S. Geological Survey]

Stream name	Reach number (see pl. 1)	Basis of estimate	USGS data-set number
East Fork Carson River	1	Clary and others, 1995	1650
East Fork Carson River	2	Clary and others, 1995	1650
East Fork Carson River	3	Clary and others, 1995	1650
East Fork Carson River	4	---	---
East Fork Carson River	5	---	---
East Fork Carson River	6	Maurer, 1986	9309
East Fork Carson River	7	Maurer, 1986	9310
East Fork Carson River	8	Maurer, 1986	9311
East Fork Carson River	9	Maurer, 1986	9312
East Fork Carson River	10	Maurer, 1986	9313, 9314
East Fork Carson River	11	Maurer, 1986	9315, 9316
West Fork Carson River	13	---	---
West Fork Carson River	14	---	---
West Fork Carson River	15	---	---
West Fork Carson River	16	Maurer, 1986	9317, 9318
West Fork Carson River	17	Maurer, 1986	9319, 9320
West Fork Carson River	18	Maurer, 1986	9321, 9301
West Fork Carson River	19	Maurer, 1986	9323, 9322, 9302
West Fork Carson River	20	Maurer, 1986	9303, 9325, 9324
West Fork Carson River	21	Maurer, 1986	9327, 9326, 9304
Carson River	22	Maurer, 1986	9328, 9329
Brockliss Slough	23	---	---
Brockliss Slough	24	Maurer, 1986	9305
Brockliss Slough	25	---	---
Brockliss Slough	26	---	---
Brockliss Slough	27	---	---
Brockliss Slough	28	---	---
Carson River	29	Maurer, 1986	9329
Carson River	30	Maurer, 1986	9333, 9306
Carson River	31	Maurer, 1986	9334, 9307
Carson River	32	Maurer, 1986	9331, 9330, 9308
Carson River	33	Bonner and others, 1998; Clary and others, 1995; Hess, 1996	1633
Carson River	34	Bonner and others, 1998; Clary and others, 1995; Hess, 1996	1634
Carson River	35	Bonner and others, 1998; Clary and others, 1995; Hess, 1996	1635
Carson River	36	Bonner and others, 1998; Clary and others, 1995; Hess, 1996	1636
Carson River	37	Bonner and others, 1998; Clary and others, 1995; Hess, 1996	1650
Carson River	38	Bonner and others, 1998; Clary and others, 1995; Hess, 1996	1650
Carson River	39	Bonner and others, 1998; Clary and others, 1995; Hess, 1996	1650
Carson River	40	Bonner and others, 1998; Clary and others, 1995; Hess, 1996	1650
Carson River	41	Bonner and others, 1998; Clary and others, 1995; Hess, 1996	1641

Table 10. Estimates of ground-water gain or loss, by reach, used in the upper Carson River Basin flow-routing and river-operations models—Continued

Stream name	Reach number (see pl. 1)	Basis of estimate	USGS data-set number
Carson River	42	Bonner and others, 1998; Clary and others, 1995; Hess, 1996	1650
Carson River	43	Bonner and others, 1998; Clary and others, 1995; Hess, 1996	1650
Carson River	44	Bonner and others, 1998; Clary and others, 1995; Hess, 1996	1650
Carson River	45	---	---
Carson River	46	---	---
Carson River	47	---	---
Carson River	48	---	---

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