RELATIONS OF SPECIFIC CONDUCTANCE TO STREAMFLOW AND SELECTED WATER-QUALITY CHARACTERISTICS OF THE ARKANSAS RIVER BASIN, COLORADO

By Doug Cain

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CONVERSION FACTORS

Inch-pound units used in this report may be converted to International System of Units (SI) by using the following conversion factors:

Multiply inch-pound unit	*By*	*To obtain SI unit*
cubic foot per second	0.02832	cubic meter per second
cubic foot per second per square mile	0.01093	cubic meter per second per square kilometer
foot	0.3048	meter
inch	25.4	millimeter
mile	1.609	kilometer
square mile	2.590	square kilometer
ton, short	0.9072	megagram

Degree Celsius (°C) may be converted to degree Fahrenheit (°F) by using the following equation:

$$°F = 9/5\ (°C+32).$$

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level of 1929."

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ABSTRACT

Areal, seasonal, and long-term variations in the specific conductance of surface and ground water in the Arkansas River basin of Colorado were evaluated, and relations of specific conductance to streamflow and to concentrations of dissolved solids and major ions were determined as part of an effort to develop a comprehensive hydrologic model of the basin. Mean specific conductance of surface and ground water was smallest in the upper basin near the Continental Divide and increased downstream about 50 times to a mean of about 3,800 microsiemens per centimeter at 25 degrees Celsius near the Colorado-Kansas State line. Smallest mean specific conductance occurred during summer runoff, and largest mean specific conductance occurred during spring and fall low flows. Long-term trends in specific conductance were evaluated at 31 surface-water stations and in flow adjusted specific conductance at 24 surface-water stations. Specific conductance increased at 10 stations, decreased at 8 stations, and no trend occurred at 13 stations. Flow-adjusted specific conductance increased at 9 stations, decreased at 5 stations, and no trend occurred at 10 stations.

Logarithmic relations of specific conductance to streamflow were determined for 69 stations using linear-regression techniques. Significant differences in the relations between the irrigation and nonirrigation seasons occurred at 40 of the stations. A regionalization technique was used to relate specific conductance to streamflow, drainage area, mean annual precipitation, percent of irrigated area, and percent of area underlain by shale.

Relations of specific conductance to dissolved-solids concentration were determined for 28 surface-water stations and for ground water in two reaches of the alluvial aquifers along the Arkansas River upstream and downstream from Pueblo. Mean concentrations of sodium, potassium, calcium, magnesium, chloride, fluoride, sulfate, and bicarbonate increase downstream in the Arkansas River and adjacent alluvial aquifers. The percentage of sodium, sulfate, and chloride also increase downstream. Relations of specific conductance to concentrations of major ions were determined for 26 surface-water stations and for ground water in alluvial aquifers along the Arkansas River.

INTRODUCTION

The Arkansas River basin in Colorado (fig. 1) drains an area of about 25,400 square miles in southeastern Colorado. Streamflow is derived primarily from snowmelt in the mountains that flank the upper parts of the basin and, to a lesser extent, from summer thunderstorms that occur primarily on the plains east of Canon City. The primary use of water in the basin is for agriculture, and most of the use occurs on irrigated cropland east of Pueblo. Municipal supply to Pueblo and Colorado Springs also is a substantial water use.

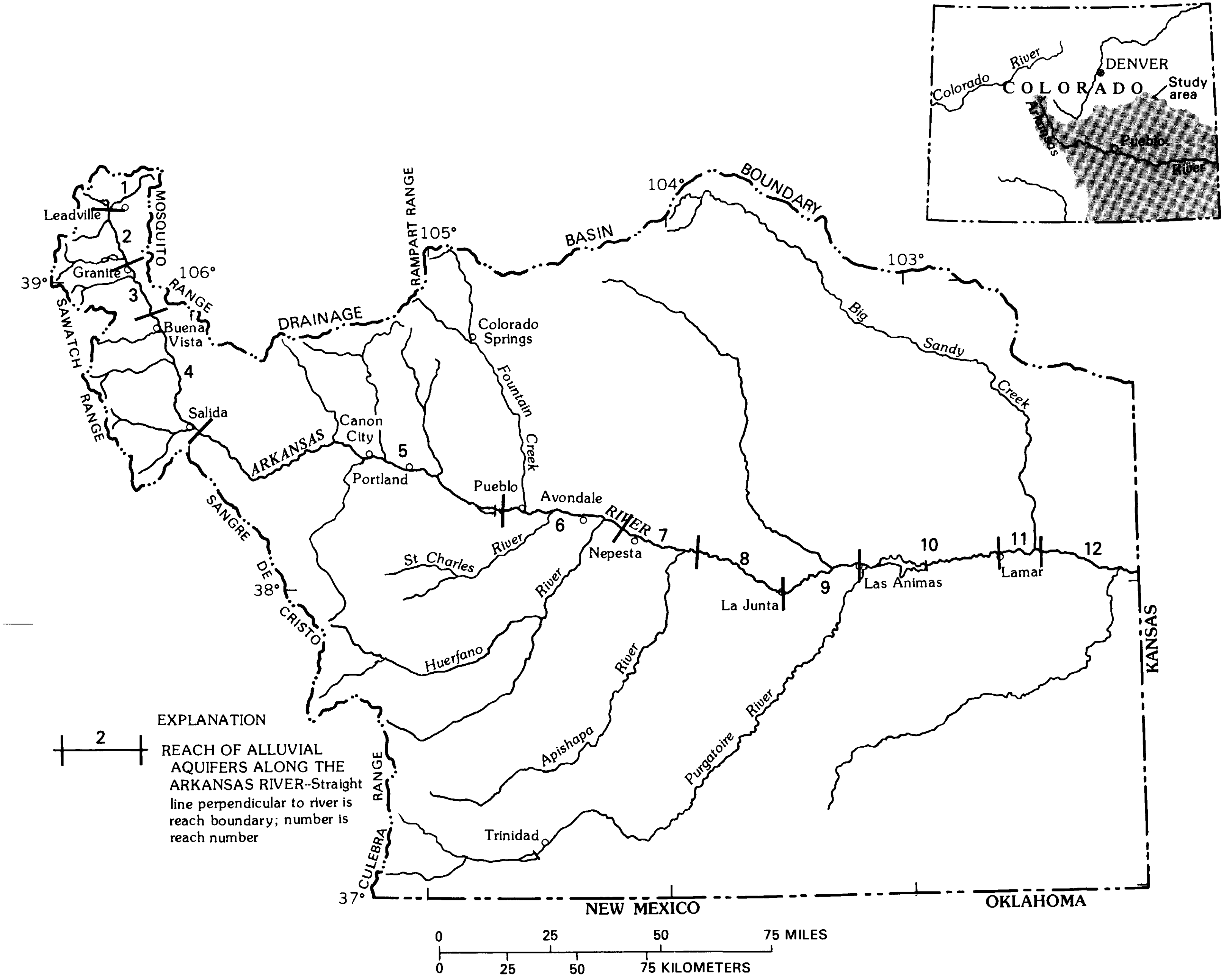

Figure 1.--Location of study area.

Shortages of water for agriculture occur during most years even though there is a complex water-supply system, which includes numerous canals, storage reservoirs, diversions of water from the Colorado River basin and extensive development of the alluvial aquifer adjacent to the Arkansas River between Pueblo and the Colorado-Kansas State line. In the past several years, competition between agricultural, municipal, and industrial uses for available water supplies has increased.

Many studies to describe and evaluate various aspects of water resources in the basin have been made by the U.S. Geological Survey and other investigators, but no recent study has made a basin-wide evaluation of water resources. As competition for water resources has become more intense, a need has developed to evaluate potential changes in water use or water management from a basin-wide perspective. To aid in this evaluation, the U.S. Geological Survey, in cooperation with the Southeastern Colorado Water Conservancy District, is developing a comprehensive hydrologic model of the Arkansas River basin in Colorado that can be used for planning purposes. The model is to include simulation of surface water, ground water, and water quality.

Objective

The objective of this report is to summarize and evaluate statistically the information necessary for development of water-quality components of a comprehensive hydrologic model of the Arkansas River basin in Colorado. Because the model will use specific conductance as its primary water-quality variable, this report summarizes available specific-conductance data and relates that data to streamflow, selected basin characteristics, and concentrations of dissolved solids and major ions. In addition, areal and seasonal variations in specific conductance are described and long-term trends in specific conductance and dissolved-solids loads are evaluated.

Approach

To achieve the objective of the report, an extensive search was made for previously collected water-quality data in the files of the U.S. Geological Survey. About 3,000 additional specific-conductance values were entered into WATSTORE, the computerized National Water Data-Storage and Retrieval System of the U.S. Geological Survey. In addition, about 3,000 specific-conductance values measured by personnel of the Pueblo Board of Water Works at their intake on the Arkansas River upstream from Pueblo were used. A total of about 25,000 specific-conductance measurements and chemical analyses for dissolved solids and major ions, were evaluated in the preparation of this report. The data were summarized statistically, and statistical techniques were used to determine relations of specific conductance to other water-quality and hydrologic variables, including streamflow, concentrations of dissolved solids and major ions, season of the year, and selected basin characteristics.

DESCRIPTION OF STUDY AREA

The headwaters of the Arkansas River are located in the 14,000 foot peaks of the Sawatch Range of central Colorado (pl. 1). Between Leadville and Salida, the river flows through two downfaulted intermontane basins flanked by mountain ranges primarily composed of igneous and metamorphic rocks. The basins are filled with several thousand feet of deposits primarily composed of unconsolidated sand and gravel (Crouch and others, 1984). Glacial deposits overlie the basin-fill deposits in places, and alluvial deposits occur along the Arkansas River and major tributaries. All three deposits have been developed as aquifers. From Salida to Canon City, the Arkansas River generally flows across crystalline bedrock or consolidated sedimentary rocks. East of Canon City, the river changes to a plains stream that has a steadily decreasing gradient. East of Pueblo, the river flows across a several-mile-wide alluvial aquifer underlain by consolidated sedimentary rocks. The alluvial aquifer, especially east of Pueblo, has been developed extensively as a source of irrigation water.

Streamflow in the basin mainly is derived from the melting of snow that accumulates in the mountains during October to May. Precipitation on the plains, which primarily occurs as summer thunderstorms, can contribute substantial quantities of streamflow for short periods. Mean annual precipitation ranges from 10 inches on the plains to more than 40 inches on the high peaks. Streamflow, precipitation, and snowpack data for the Arkansas River basin in Colorado have been summarized by Burns (1985).

Arkansas River streamflow is affected by several diversions from the Colorado River basin that enter the Arkansas River upstream from Buena Vista; by drainage from mines near Leadville; by numerous canal diversions, the largest of which are downstream from Pueblo; by return flows from irrigation; and by pumpage of ground water from alluvial aquifers that are hydraulically connected to the Arkansas River. Streamflow is regulated by several major and numerous minor reservoirs. The water-supply and distribution system in the basin has been described by Abbott (1985).

AREAL VARIATIONS IN SPECIFIC CONDUCTANCE

Large variations in the specific conductance of surface and ground water in the basin have been noted by several investigators (Miles, 1977; Crouch and others, 1984; Cain, 1985). Specific conductance generally is small upstream from Canon City and increases between Canon City and the State line. The increase in specific conductance occurs along with a general decrease in streamflow east of Pueblo. Areal variations in the specific conductance of surface and ground water are described separately in the following two sections.

Arkansas River and Tributaries

Mean values of specific conductance at 72 stations on the Arkansas River and tributaries are shown on plate 1, and the mean values and other statistics are included in table 1 (station 07137500, Arkansas River near Coolidge, Kans., about 2 miles downstream from the Colorado-Kansas State line, is included in tables and text to indicate data for water in the Arkansas River as it flows out of Colorado, but is not included on plate 1). Mean specific conductance ranges from 82 microsiemens per centimeter at 25 degrees Celsius at Halfmoon Creek near Malta to 4,632 microsiemens per centimeter at 25 degrees Celsius at B Ditch Drain near Security. Specific conductance generally is smaller at higher altitude stations (fig. 2) because the areas drained receive larger quantities of precipitation, which has very small specific conductance, and commonly are underlain by igneous and metamorphic rocks, which are less susceptible to chemical weathering than the sedimentary rocks that outcrop on the plains.

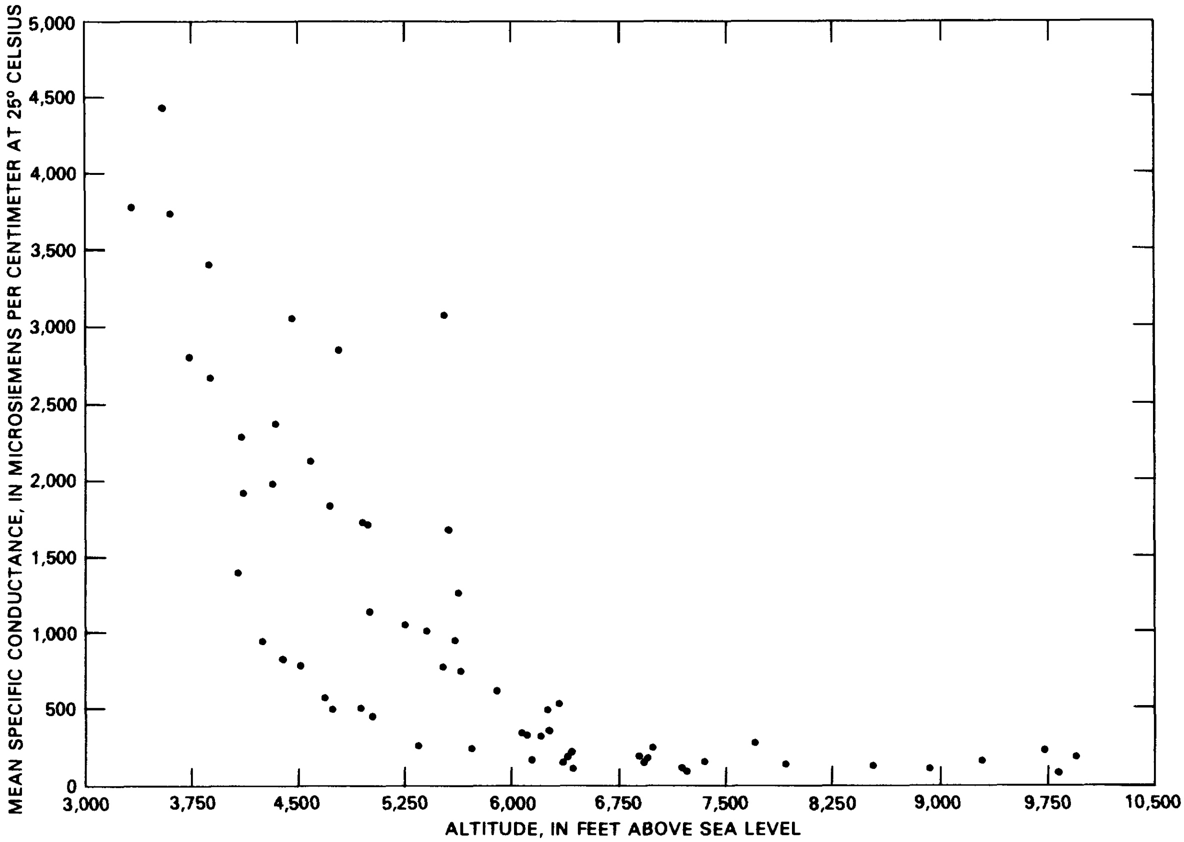

Figure 2.--Relation of mean specific conductance to altitude of surface-water stations.

Table 1.--*Summary statistics for specific conductance*

[μS/cm, microsiemens per centimeter at 25 degrees Celsius;

Station number	Station name	River miles upstream from Coolidge, Kans.	Altitude (feet above sea level)	Drainage area (square miles)	Number of measurements	Period of record
07079200	Leadville Drain at Leadville	-	10,400	-	60	1965-84
07081200	Arkansas River near Leadville	370	9,730	97	135	1968-83
07081800	California Gulch at Malta	-	9,600	-	20	1964-73
07083000	Halfmoon Creek near Malta	365	9,830	24	238	1965-84
07083700	Arkansas River near Malta	363	9,300	228	150	1964-83
07087200	Arkansas River at Buena Vista	332	7,920	611	153	1970-79
07089000	Cottonwood Creek below Hot Springs, near Buena Vista	332	8,532	65	170	1970-83
07091200	Arkansas River near Nathrop	314	7,350	1,060	205	1970-82
07093700	Arkansas River near Wellsville	297	6,883	1,485	62	1970-75
07094500	Arkansas River at Parkdale	261	5,720	2,548	156	1970-82
07094600	South Colony Creek near Westcliffe	-	8,930	6.5	40	1975-78
07094900	Middle Taylor Creek near Westcliffe	-	9,950	3.2	27	1974-78
07096000	Arkansas River at Canon City	251	5,342	3,117	158	1963-77
07096500	Fourmile Creek near Canon City	248	5,254	434	155	1970-83
07097000	Arkansas River at Portland	241	5,022	4,024	77	1970-84
07099100	Beaver Creek near Portland	237	4,993	214	135	1970-81
07099200	Arkansas River near Portland	233	4,940	4,280	228	1964-79
07099215	Turkey Creek near Fountain	-	6,420	13	37	1979-85
07099220	Little Turkey Creek near Fountain	-	6,395	10	31	1979-85
07099230	Turkey Creek above Teller Reservoir near Stone City	-	5,520	63	52	1979-82
07099235	Turkey Creek near Stone City	-	5,400	72	44	1979-83
07099400	Arkansas River above Pueblo	214	4,740	4,670	3,089	1966-82
07099500	Arkansas River near Pueblo	209	4,690	4,686	60	1963-80
07103700	Fountain Creek near Colorado Springs	-	6,110	103	228	1971-84
07103747	Monument Creek at Palmer Lake	-	6,950	26	142	1976-84
07103750	Monument Creek at Monument	-	6,925	29	28	1975-77
07103800	West Monument Creek at Air Force Academy	-	7,180	15	187	1970-83
07103950	Kettle Creek near Black Forest	-	6,980	9.0	112	1976-83
07104000	Monument Creek at Pikeview	-	6,203	204	205	1973-84
07104900	Monument Creek at Cache La Poudre Street, at Colorado Springs	-	5,990	-	42	1976-79
07104905	Monument Creek at Bijou Street, at Colorado Springs	-	5,970	-	52	1979-84
07105500	Fountain Creek at Colorado Springs	-	5,900	392	265	1970-84
07105530	Fountain Creek below Janitell Road, below Colorado Springs	-	5,840	-	74	1975-84
07105780	B Ditch Drain near Security	-	5,724	3.2	46	1981-84
07105800	Fountain Creek at Security	-	5,640	495	226	1970-83

at *surface-water stations*

dashes indicate data not available or applicable]

Specific conductance (μS/cm)						
Mean	Standard deviation	Mini- mum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maxi- mum
811	100	559	754	830	874	990
230	89	70	150	250	290	500
971	189	789	843	904	1,073	1,500
82	17	43	70	87	95	120
156	63	64	100	148	216	320
135	43	50	100	130	175	220
126	23	60	114	130	140	170
151	42	75	114	150	190	250
196	69	75	130	225	251	350
241	73	100	181	243	303	375
107	22	70	90	105	120	140
189	48	50	165	210	220	242
272	67	120	213	301	320	367
1,058	408	400	775	1,050	1,260	3,500
456	155	160	327	478	560	900
1,717	780	160	1,150	1,900	2,400	2,800
506	169	180	353	553	640	950
218	48	145	175	215	260	300
196	51	110	158	180	260	280
778	300	321	438	930	1,025	1,210
1,017	383	390	648	1,030	1,343	1,610
502	174	140	360	515	624	966
571	198	232	427	589	693	1,290
328	108	100	258	330	383	800
171	45	55	145	177	204	250
153	35	100	126	148	180	225
109	24	50	95	110	120	220
249	42	122	230	240	268	385
321	80	122	268	325	370	515
583	177	167	471	578	693	1,030
440	135	130	345	463	535	700
622	228	152	448	625	750	1,280
687	161	240	609	726	801	950
4,632	1,242	2,000	3,790	4,620	5,433	7,540
750	227	100	580	805	925	1,280

Table 1.--*Summary statistics for specific conductance*

Station number	Station name	River miles upstream from Coolidge, Kansas	Altitude (feet above sea level)	Drainage area (square miles)	Number of measurements	Period of record
07105820	Clover Ditch Drain near Widefield	-	5,620	-	46	1981-84
07105825	Fountain Creek below Widefield	-	5,610	-	42	1979-83
07105900	Jimmy Camp Creek at Fountain	-	5,530	66	98	1976-83
07105905	Fountain Creek above Little Fountain Creek, below Fountain	-	5,400	-	100	1975-84
07105920	Little Fountain Creek above Keaton Reservoir, near Fort Carson	-	6,430	11	53	1978-82
07105928	Little Fountain Creek near Fort Carson	-	6,360	12	61	1978-83
07105940	Little Fountain Creek near Fountain	-	5,560	27	45	1979-83
07105945	Rock Creek above Fort Carson	-	6,390	6.9	64	1978-83
07105950	Rock Creek near Fort Carson	-	6,150	7.8	35	1979-85
07105960	Rock Creek near Fountain	-	5,600	17	59	1978-83
07106300	Fountain Creek near Pinon	-	5,005	849	200	1973-84
07106500	Fountain Creek at Pueblo	206	4,725	926	367	1963-84
07107900	Greenhorn Creek near Rye	-	7,220	10	104	1973-80
07108050	Greenhorn Creek near Colorado City	-	5,630	30	116	1973-80
07108900	St. Charles River at Vineland	194	4,585	474	147	1971-83
07109500	Arkansas River near Avondale	187	4,510	6,327	235	1969-83
07116500	Huerfano River near Boone	177	4,450	1,875	77	1976-83
07117000	Arkansas River near Nepesta	165	4,385	9,345	73	1963-80
07117600	Chicosa Creek near Fowler	157	4,335	109	149	1968-76
07118500	Apishapa River at Aguilar	-	6,335	149	43	1979-81
07119500	Apishapa River near Fowler	151	4,317	1,125	249	1963-83
07119700	Arkansas River at Catlin Dam, near Fowler	145	4,246	10,901	77	1968-79
07121500	Timpas Creek at mouth near Swink	123	4,113	496	227	1967-83
07122000	Arkansas River near La Junta	120	4,080	12,000	1,021	1964-67
07122400	Crooked Arroyo near Swink	119	4,100	108	205	1968-83
07123675	Horse Creek near Las Animas	99	3,970	1,265	54	1961-83
07124000	Arkansas River at Las Animas	89	3,884	14,417	372	1945-83
07124050	Middle Fork Purgatoire River at Stonewall	-	7,710	52	803	1978-81
07124200	Purgatoire River at Madrid	-	6,262	550	192	1972-83
07124300	Long Canyon Creek near Madrid	-	6,259	100	123	1972-83
07124410	Purgatoire River below Trinidad Lake	-	6,074	672	67	1977-83
07126200	Van Bremer Arroyo near Model	-	4,960	168	132	1968-84
07126300	Purgatoire River near Thatcher	-	4,790	1,935	142	1968-84
07128500	Purgatoire River near Las Animas	88	3,875	3,503	352	1961-83
07130500	Arkansas River below John Martin Reservoir	68	3,737	18,915	9,274	1951-81
07133000	Arkansas River at Lamar	44	3,597	19,780	350	1963-83
07134100	Big Sandy Creek near Lamar	34	3,545	3,307	180	1968-82
07137500	Arkansas River near Coolidge, Kans.	0	3,331	25,410	509	1963-84

at surface-water stations--Continued

Specific conductance (μS/cm)						
Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
1,351	191	650	1,278	1,390	1,483	1,650
792	185	316	702	823	917	1,160
3,075	654	650	2,800	3,225	3,500	4,000
1,169	332	398	984	1,195	1,360	2,120
111	30	65	88	110	125	210
155	59	65	105	160	193	335
1,688	1,322	200	540	1,050	2,900	5,000
142	33	90	125	140	155	300
162	42	85	130	155	180	255
948	317	230	840	1,040	1,150	1,760
1,139	386	130	851	1,160	1,418	2,400
1,834	794	520	1,300	1,700	2,100	6,000
84	16	50	75	85	93	120
1,264	453	240	900	1,305	1,600	2,200
2,126	905	310	1,500	2,200	2,800	4,000
781	264	190	580	820	963	1,550
3,050	1,847	500	1,400	2,700	5,000	7,000
829	241	280	666	864	1,020	1,200
2,368	762	600	1,800	2,440	3,000	3,950
544	266	168	270	485	825	936
1,984	874	599	1,205	1,870	2,800	4,000
947	309	310	725	1,000	1,200	1,500
1,921	588	530	1,500	1,800	2,200	3,750
1,398	453	252	1,070	1,430	1,710	2,590
2,283	864	870	1,500	2,100	3,100	4,500
4,274	1,294	1,200	3,950	4,275	4,800	8,000
2,662	1,051	570	1,700	2,900	3,500	4,500
276	79	121	211	276	343	460
363	87	151	295	373	432	575
502	104	100	480	522	565	770
349	76	210	295	350	400	490
1,723	352	380	1,550	1,800	2,000	2,300
2,849	1,183	490	1,938	3,000	3,600	6,000
3,393	1,355	580	2,478	3,400	4,408	8,000
2,794	1,105	476	1,780	3,000	3,750	5,180
3,723	1,400	560	2,800	4,000	4,750	8,000
4,423	936	500	4,000	4,600	5,000	6,500
3,770	1,144	475	3,100	4,110	4,500	6,500

Mean specific conductance of the Arkansas River generally increases downstream (fig. 3). The smallest mean specific conductance occurs at Buena Vista rather than farther upstream because of the effects of acid mine drainage from metal mines near Leadville (Moran and Wentz, 1974; Wentz, 1974). Water having smaller specific conductance (such as that from Halfmoon and Cottonwood Creeks) flows into the Arkansas River and dilutes the effects of the upstream mine drainage. Small increases in mean specific conductance occur between Buena Vista and Canon City. Mean specific conductance almost doubles in the 20-mile reach between Canon City and station 07099200 downstream from Portland (table 1), primarily as a result of irrigation return-flows and inflows of saline ground water, and to a lesser extent from tributary inflows. Mean specific conductance increases just downstream from Pueblo because of the effects of tributary inflows having larger specific conductance (fig. 4) and municipal-wastewater discharges (Cain and others, 1980). Farther east, between La Junta and Las Animas, a large increase in specific conductance occurs. The increase is due to irrigation-return flows

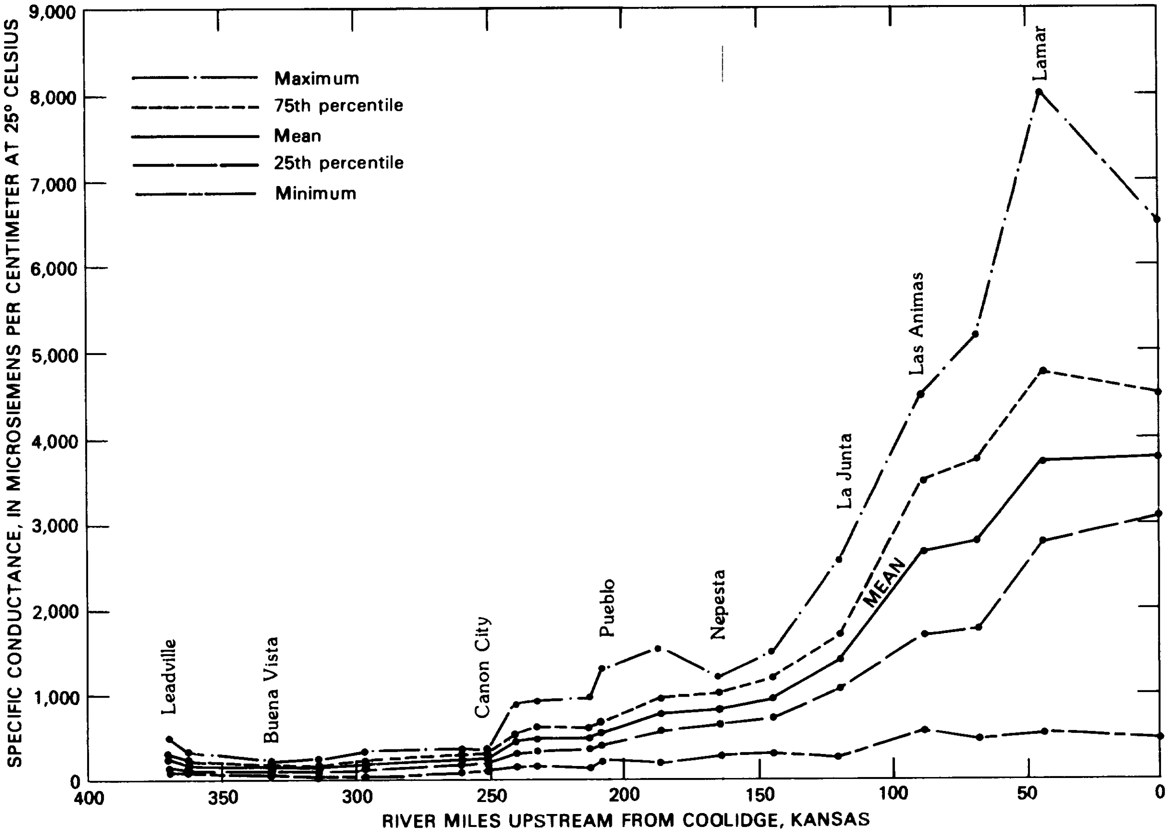

Figure 3.--Downstream increase in specific conductance of the Arkansas River.

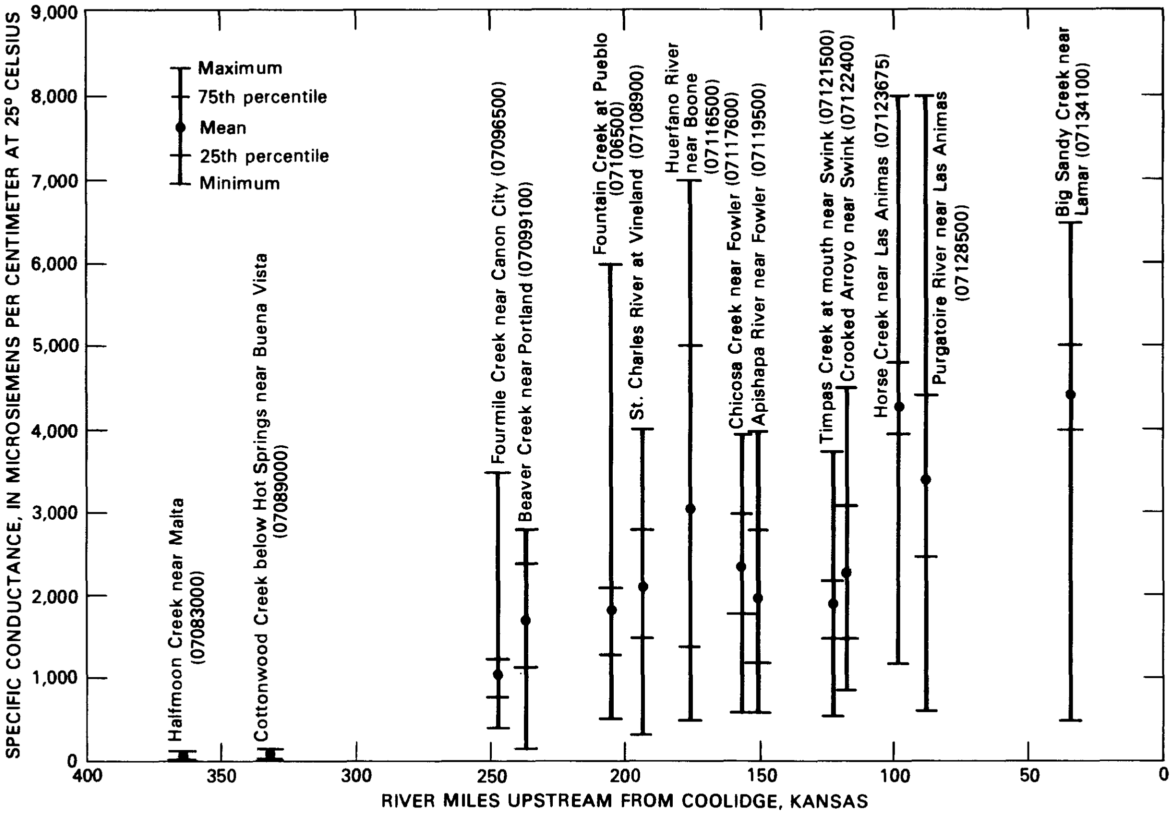

Figure 4.--Specific conductance of Arkansas River tributaries at their mouths.

comprising an increasingly larger part of Arkansas River streamflow. Similar downstream increases in mean specific conductance occur on Fountain Creek and the Purgatoire River (pl. 1).

Ground Water in Alluvial Aquifers along the Arkansas River

Alluvial aquifers along the Arkansas River consist of glacial-outwash and basin-fill deposits north of Salida and valley-fill deposits directly adjacent to the Arkansas River along most of the reach from the headwaters to the Colorado-Kansas State line. Approximate boundaries of the alluvial aquifers are shown on plate 1. In most of the area north of Salida, glacial deposits, as much as 500 feet thick, overlie basin-fill deposits as much as 7,700 feet thick (Crouch and others, 1984). Valley-fill deposits along the Arkansas River upstream from Pueblo are relatively thin (less than 100 feet), narrow (less than 1 mile), and are discontinuous between Canon City and Salida (Crouch and others, 1984). Valley-fill deposits are more extensive east of Pueblo where they form an alluvial aquifer as much as 300 feet thick and 1 to 14 miles wide, with an average width of 3 to 5 miles (Major and others, 1970).

Wells completed in all of the alluvial deposits generally can be considered to be hydraulically connected to the Arkansas River, but wells completed in valley-fill deposits generally are closer to the river and will be more strongly affected by it.

About 350 specific-conductance measurements of ground water from these aquifers were used in this study. These measurements were grouped into the reaches shown in figure 1 for statistical summaries and analyses. Because of the configuration of the alluvial aquifers, most of the measurements of specific conductance east of Pueblo are from wells within 3 miles of the river, but some of the wells north of Salida may be as far as 5 miles from the river. Although the basin-fill deposits north of Salida are several thousand feet thick in places, all but two of the specific-conductance measurements used were from wells less than 200 feet deep. Summary statistics for specific conductance of ground water are given in table 2.

Ground water from alluvial aquifers along the Arkansas River also has a marked downstream increase in mean specific conductance (fig. 5). Reach 2

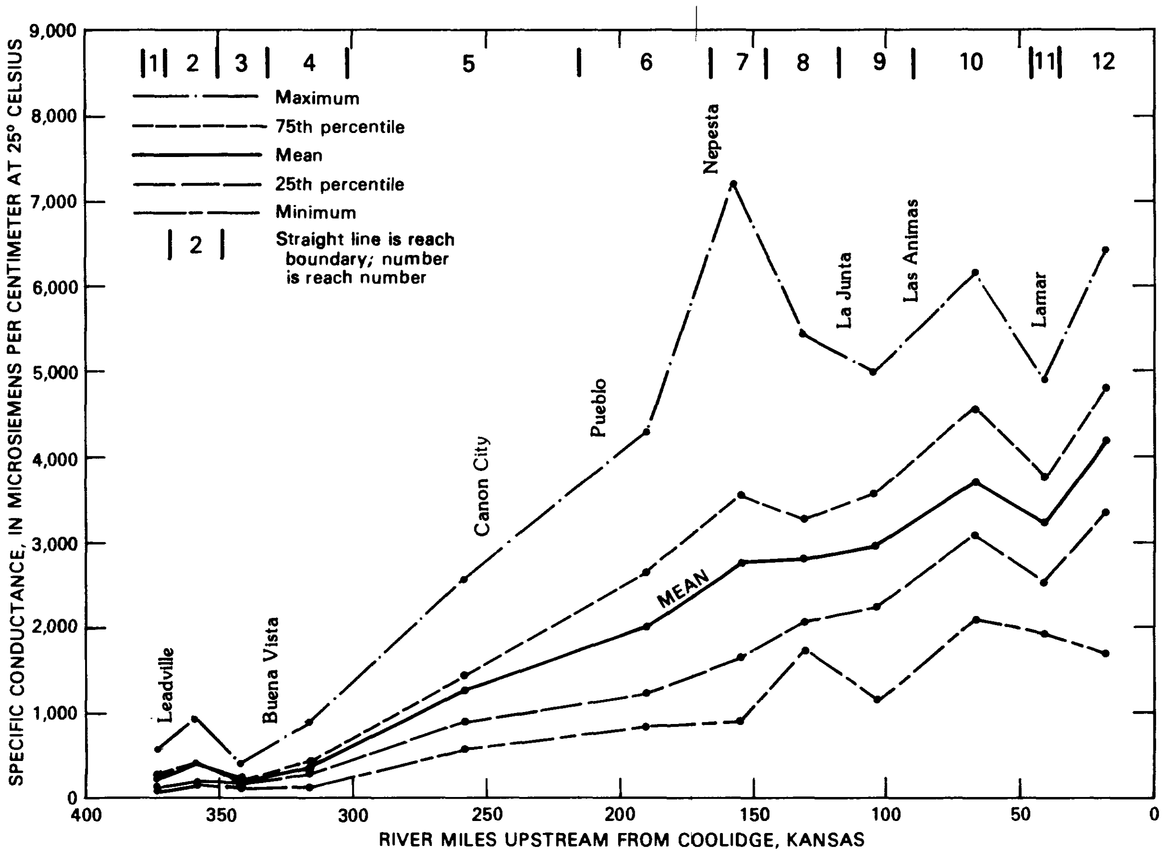

Figure 5.--Downstream increase in specific conductance of ground water in alluvial aquifers along the Arkansas River.

Table 2.--*Summary statistics for specific conductance of ground water in alluvial aquifers along the Arkansas River*

[μS/cm, microsiemens per centimeter at 25 degrees Celsius]

Reach in figure 1	Reach location (miles upstream from Coolidge, Kans.)			Number of measurements	Specific conductance (μS/cm)						
	Downstream end	Midpoint	Upstream end		Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
1	370	375	379	12	209	140	70	107	173	261	594
2	349	360	370	13	381	241	165	202	330	415	950
3	332	341	349	16	189	76	87	147	168	220	384
4	301	317	332	31	386	169	110	295	349	465	889
5	214	258	301	9	1,246	577	555	891	1,120	1,445	2,560
6	165	190	214	22	1,991	999	836	1,218	1,710	2,648	4,280
7	145	155	165	19	2,785	1,673	897	1,660	2,340	3,570	7,220
8	117	131	145	35	2,794	955	1,720	2,070	2,570	3,260	5,430
9	89	103	117	99	2,921	851	1,150	2,230	2,960	3,570	4,990
10	44	67	89	33	3,709	1,050	2,090	3,090	3,580	4,580	6,150
11	34	39	44	21	3,240	837	1,920	2,520	3,220	3,775	4,880
12	0	17	34	41	4,183	1,176	1,670	3,325	4,200	4,820	6,410

near Leadville is affected by mine drainage and has larger specific conductance compared to the upstream and downstream reaches. The mean specific conductance of ground water generally is greater than that of surface water throughout the basin except in the reach between Lamar and the Colorado-Kansas State line where the values of mean specific conductance are similar, probably because much of the Arkansas River streamflow in this reach is ground-water seepage to the river.

SEASONAL VARIATIONS IN SPECIFIC CONDUCTANCE OF THE ARKANSAS RIVER AND TRIBUTARIES

In addition to large areal and downstream variations, specific conductance may change seasonally. Seasonal variations occur at 36 stations where approximately 10 years or more of monthly or more frequent specific-conductance measurements were made. The monthly mean and other statistics for specific conductance at these stations are given in table 17 in the "Supplemental Information" section at the back of the report. Location of the stations are shown on plate 1.

Seasonal variations in specific conductance are similar at the stations on the Arkansas River upstream from Portland (fig. 6). Mean specific conductance generally is largest during March, when ground-water contributions to streamflow are likely to be large. Mean specific conductance generally is smallest during June or July, during the peak of snowmelt runoff. Mean specific conductance is about two to three times as large during March as during June or July at these stations. The difference between 25th and 75th percentiles is largest for most months at the Arkansas River near Malta, probably because of inflow of acid mine drainage from California Gulch, which has a large specific conductance, between this station and the upstream station, Arkansas River near Leadville.

Seasonal variations in specific conductance at the Arkansas River stations downstream from Portland are similar to variations at upstream stations (fig. 7). Mean specific conductance is largest during January to March and smallest during June or July. The difference between the 25th and 75th percentile values during the summer months is large at most of the stations, partly because of regulation by Pueblo and John Martin Reservoirs and because summer thunderstorms contribute water with small specific conductance to the Arkansas River. Duration plots of specific conductance for the three stations on the Arkansas River with the most specific-conductance data are given in figure 8. These plots can be used to estimate the percentage of time that selected specific-conductance values were equaled or exceeded.

Seasonal variations in the specific conductance of Fountain Creek and tributaries are dissimilar (fig. 9). The smallest mean specific conductance may occur during May rather than June or July because snowmelt occurs earlier at the lower altitudes in the Fountain Creek drainage. Largest mean specific conductance may occur during any season, depending on the flow regime and source of flow at a given station.

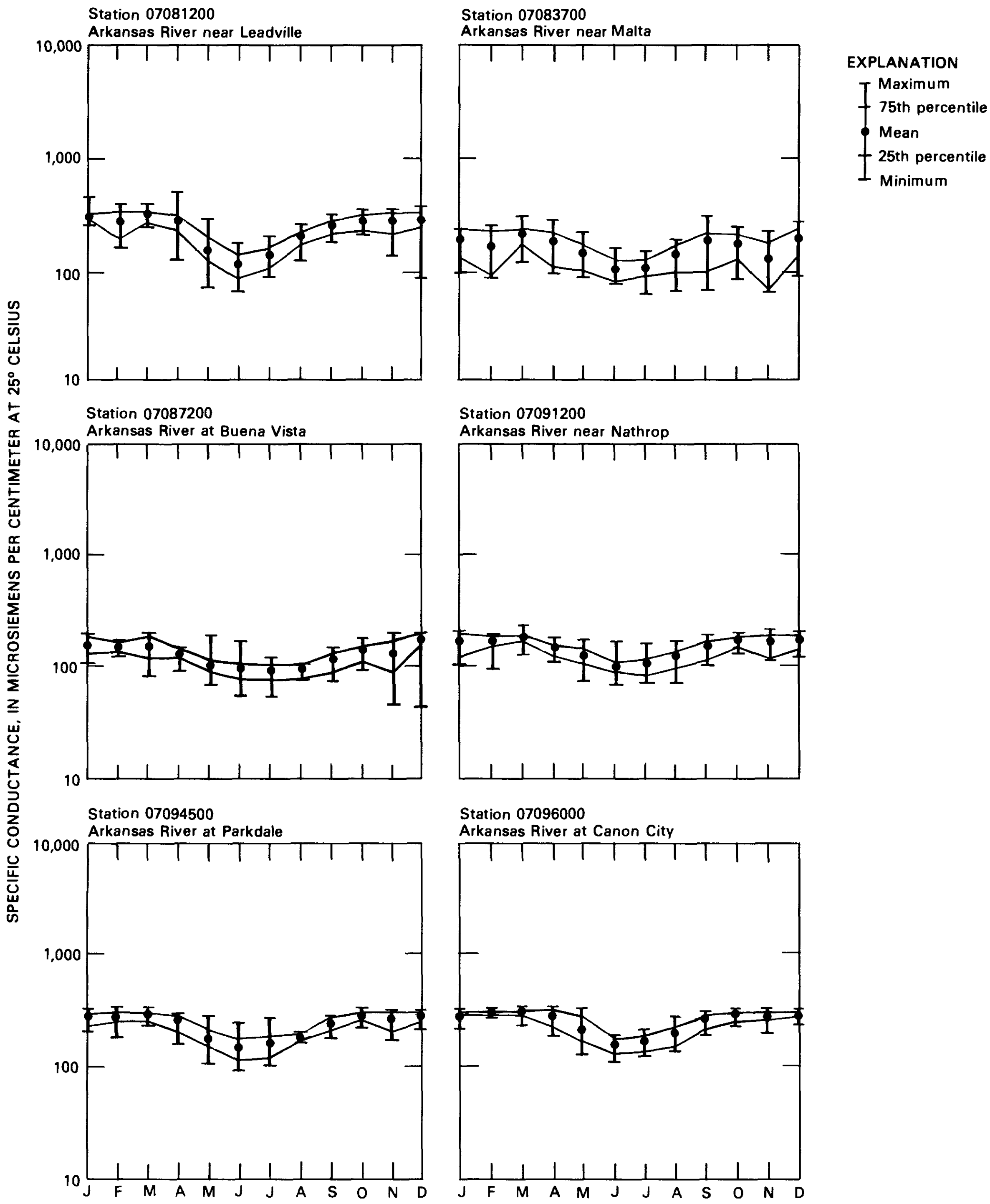

Figure 6.--Seasonal variations in the specific conductance of the Arkansas River upstream from Portland.

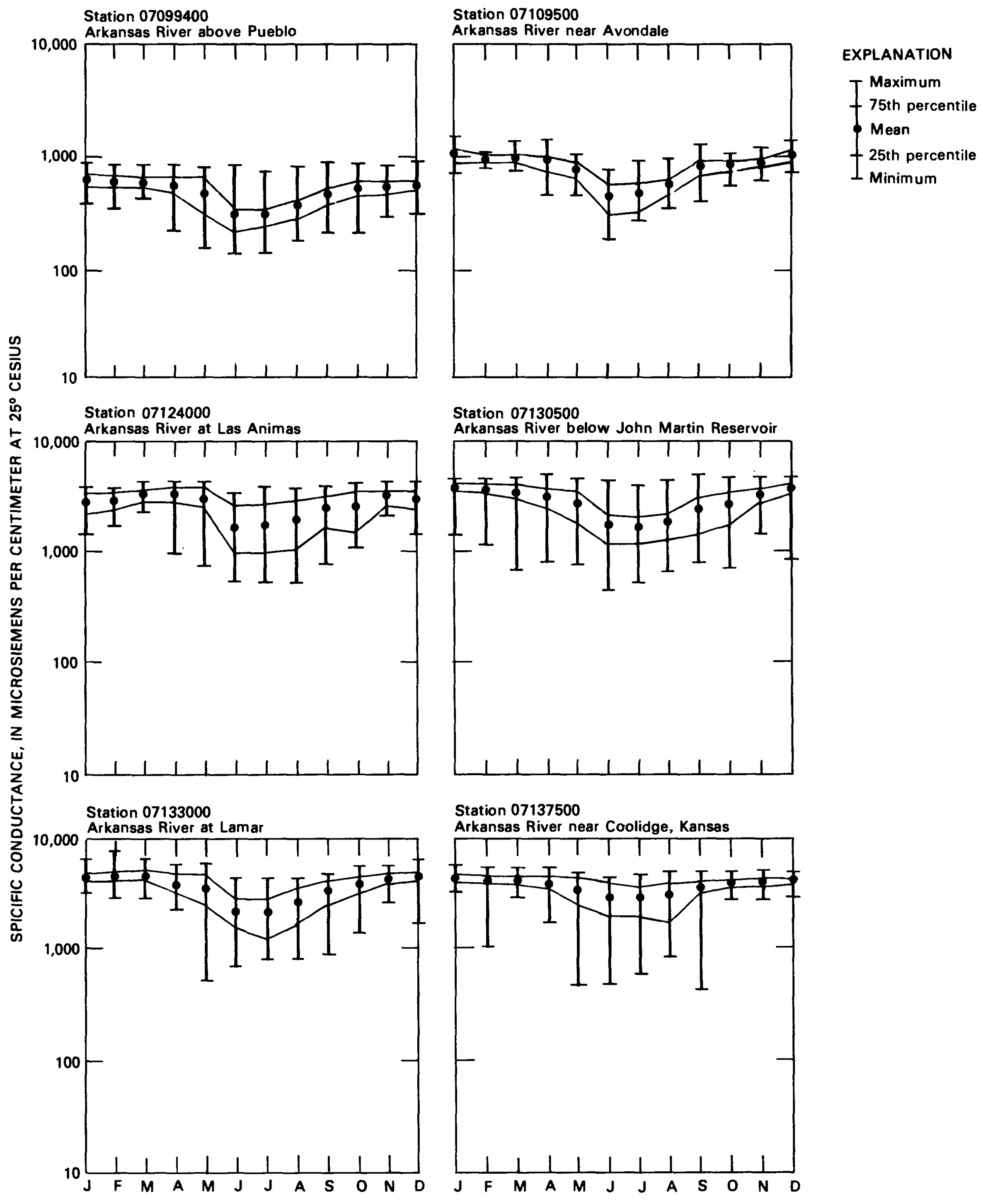

Figure 7.--Seasonal variations in the specific conductance of the Arkansas River downstream from Portland.

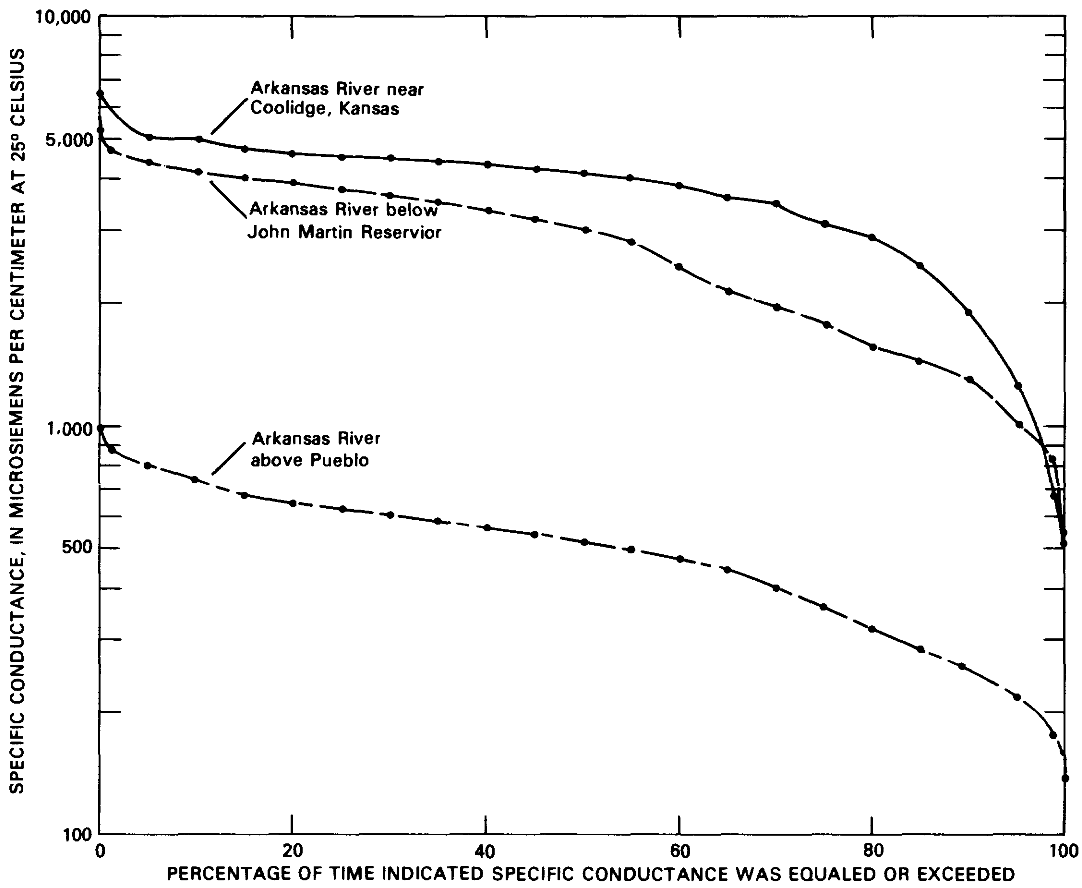

Figure 8.--Duration plot of specific conductance for three stations on the Arkansas River.

Seasonal variations in the specific conductance of the Purgatoire River and tributaries depend on the reach where the station is located (fig. 10). The two stations upstream from Trinidad, the Middle Fork Purgatoire River at Stonewall and the Purgatoire River at Madrid, have seasonal variations similar to stations on the Arkansas River upstream from Portland. Long Canyon Creek near Madrid and Van Bremer Arroyo near Model have small flows except during storm runoff. Base flow is sustained in both streams by ground-water inflow. Mean specific conductance at both stations is smallest during the summer months when thunderstorms are most likely to occur. Purgatoire River near Thatcher and Purgatoire River near Las Animas also have the smallest values of mean specific conductance during the summer months.

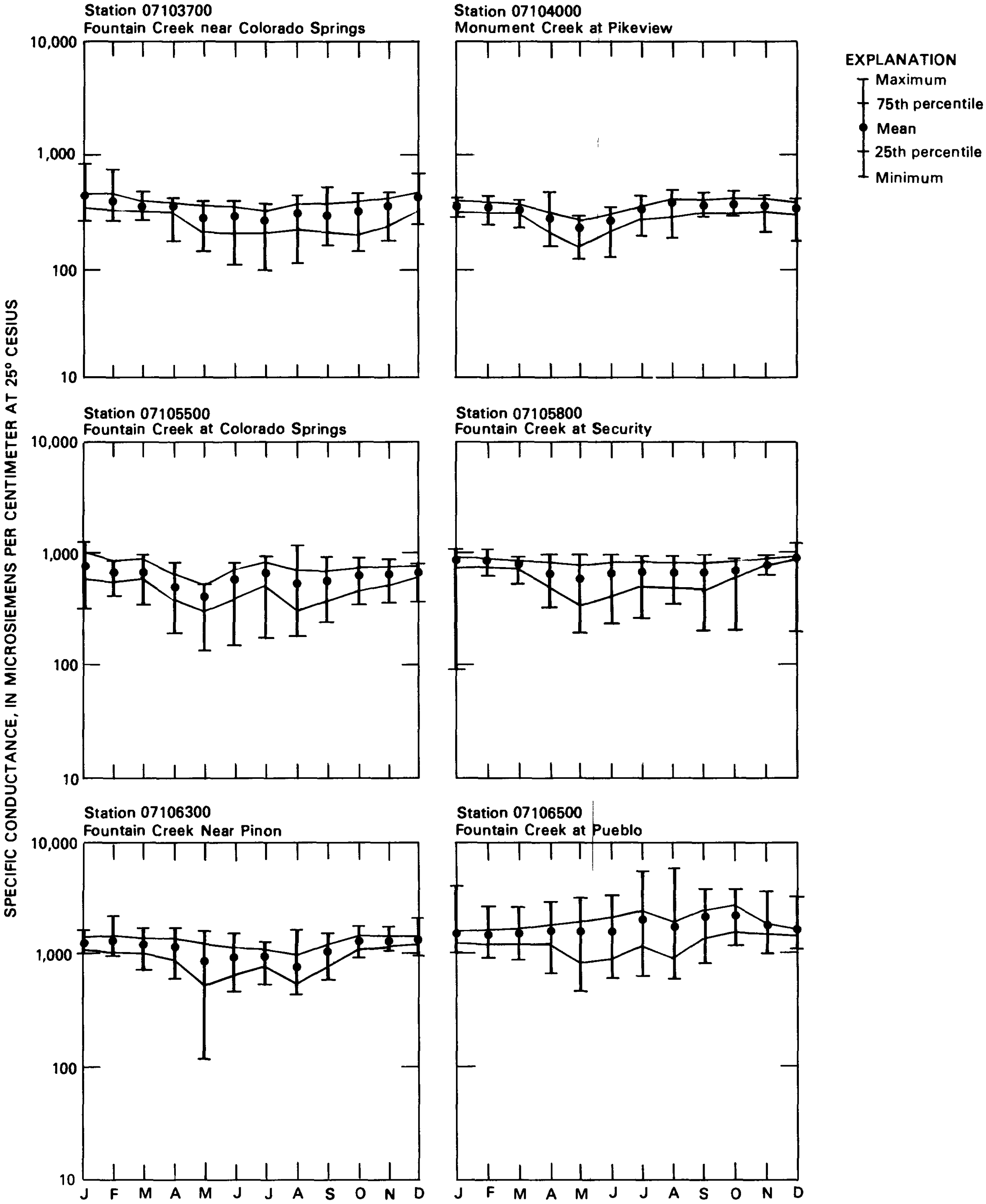

Figure 9.--Seasonal variations in the specific conductance of Fountain Creek and tributaries.

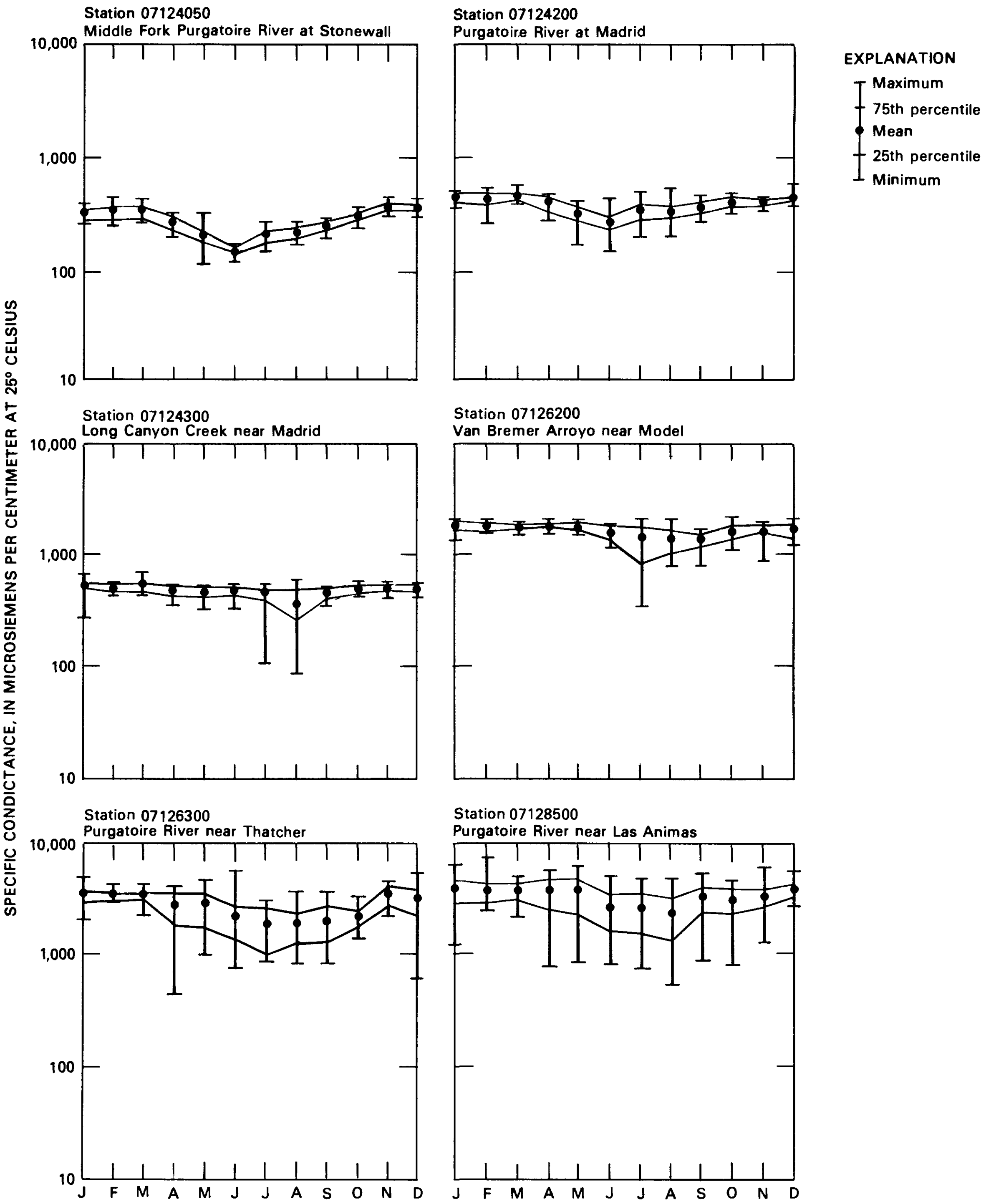

Figure 10.--Seasonal variations in the specific conductance of the Purgatoire River and tributaries.

The next group of six stations includes four headwater tributaries, two each to the Arkansas River and Fountain Creek, and two Arkansas River tributaries whose headwaters are located in the mountains near Pikes Peak, but whose flow has mostly been diverted upstream from the stations where specific conductance was measured (fig. 11). These two stations are Fourmile Creek near Canon City and Beaver Creek near Portland. At both of these stations, mean specific conductance is relatively constant year round, but large variations can occur during a month because of snowmelt or storm runoff. The two headwater tributary streams to the Arkansas River, Halfmoon Creek near Malta and Cottonwood Creek below Hot Springs, near Buena Vista, have similar seasonal variations. Mean specific conductance is largest during March and smallest during June or July. Monthly variation in mean specific conductance is relatively small because these two streams drain areas where the rocks are relatively inert to chemical weathering; thus, base flow does not have much larger specific conductance than does the snowmelt runoff during the summer months. The two headwater stations on Fountain Creek tributaries, Monument Creek at Palmer Lake and West Monument Creek at Air Force Academy, are small streams that are affected somewhat by upstream diversions. Mean specific conductance is smallest at both stations during the May snowmelt runoff and largest during the fall.

The last group of stations evaluated for seasonal variations in specific conductance are on six tributaries to the Arkansas River downstream from Pueblo (fig. 12). The stations all receive base flow from ground-water seepage from the valley-fill aquifer along the Arkansas River. These streams also are subject to sudden flooding from summer thunderstorms and receive surface runoff from irrigation. Because of the many sources of flow, variations in the monthly mean specific conductance are somewhat erratic, but smallest values of monthly mean specific conductance generally occur during the irrigation season.

RELATIONS OF SPECIFIC CONDUCTANCE TO STREAMFLOW

Relations of specific conductance to streamflow can be used to estimate specific conductance from measured or simulated streamflow. These relations have been determined at all stations where sufficient data are available. The effect of basin characteristics on the relations was evaluated to allow estimation of the relation at sites with inadequate specific-conductance or streamflow data.

Determination of Relations at Stations that have Specific-Conductance and Streamflow Data

Relations of specific conductance to streamflow were determined at Arkansas River stations that had at least 50 data pairs of specific conductance and streamflow available. Because fewer data were available at many tributary stations and because relations at many of these stations were needed to estimate the effects of basin characteristics on the relations of specific conductance to streamflow, relations were determined at tributary stations that had 20 or more data pairs. Using these criteria, sufficient data to determine relations of specific conductance to streamflow were available at 19

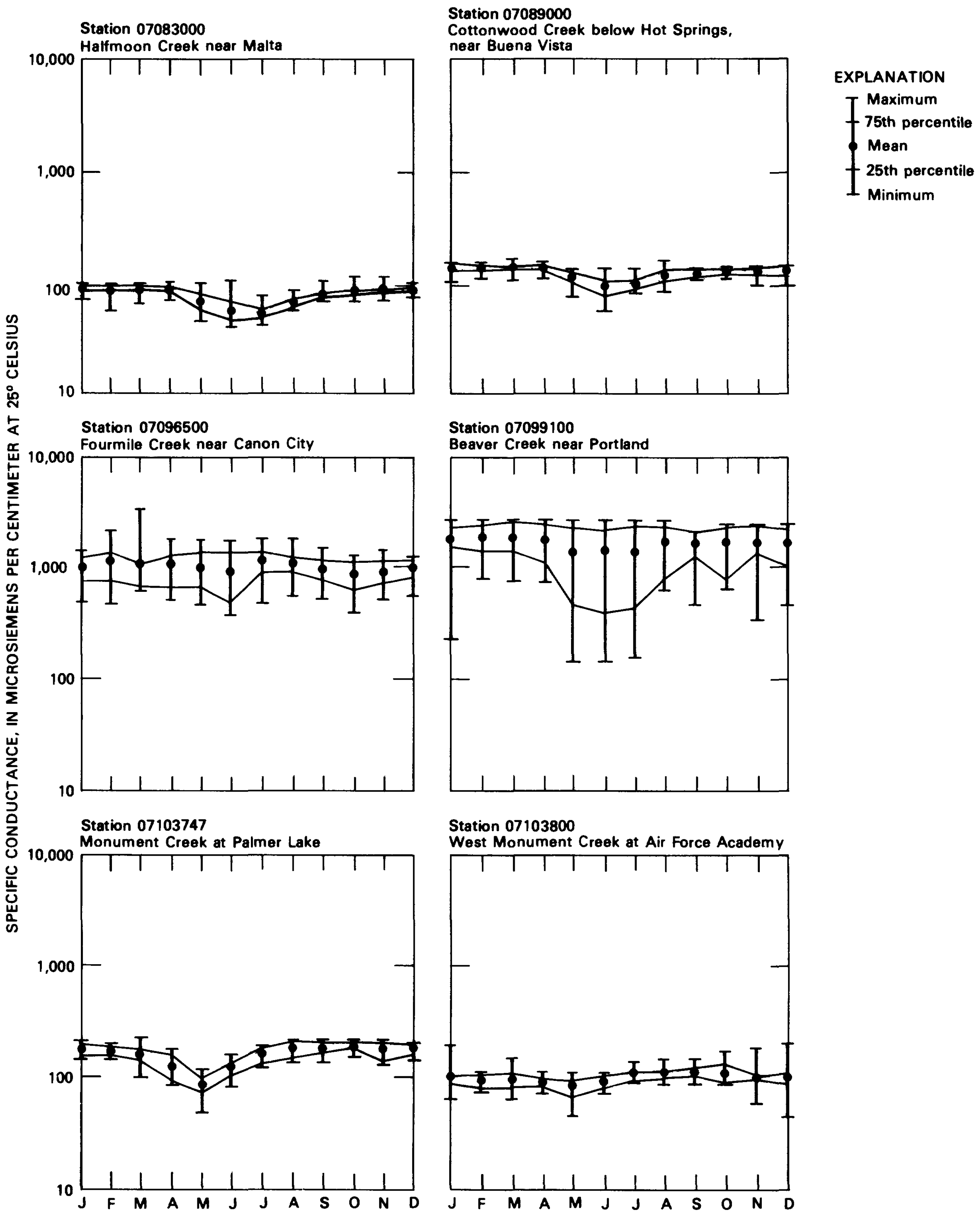

Figure 11.--Seasonal variations in the specific conductance of tributaries upstream from the St. Charles River.

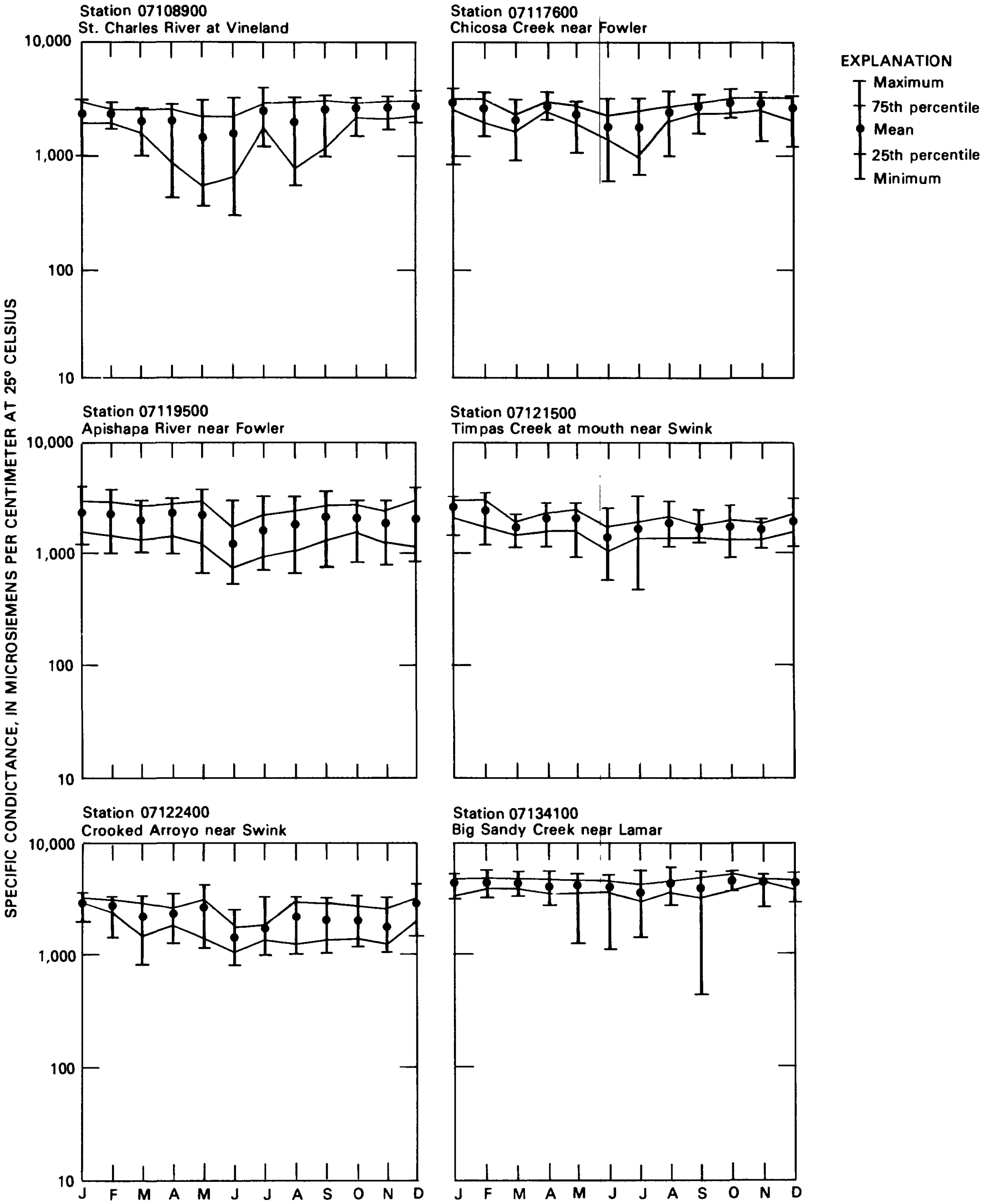

Figure 12.--Seasonal variations in the specific conductance of the St. Charles River and downstream tributaries to the Arkansas River.

Arkansas River stations and at 50 tributary stations. Relations were not determined for the Leadville Drain at Leadville or California Gulch at Malta, which are mine drainages, or for Clover Ditch Drain near Widefield, which primarily is sewage effluent.

Types of Relations Evaluated

Specific conductance may be related to streamflow in several ways depending on the sources of the dissolved ions that contribute to specific conductance and their relative contributions to the total flow and concentration of dissolved solids in a stream. Other investigators (Crawford and others, 1983) have found that water-quality constituents commonly are related to streamflow by one of the following equations:

$$SC_e = a + bQ \qquad \text{linear} \qquad (1)$$

$$SC_e = a + b/Q \qquad \text{inverse} \qquad (2)$$

$$SC_e = a + b\sqrt{Q} \qquad \text{square root} \qquad (3)$$

$$SC_e = a + b\log(Q) \qquad \text{log-linear} \qquad (4)$$

$$SC_e = a + b/(1 + BQ) \qquad \text{hyperbolic} \qquad (5)$$

$$\log(SC_e) = a + b\log(Q) \qquad \text{log-log} \qquad (6)$$

where SC_e = estimated specific conductance, in microsiemens per centimeter at 25 degrees Celsius;
a and b = regression coefficients;
Q = measured streamflow, in cubic feet per second;
B = a constant in the range $0.001/QM < B < 100/QM$; and
QM = mean streamflow, in cubic feet per second.

When determining relations of specific conductance to streamflow for this study, three factors were used for selection: (1) A single type of relation was needed at all stations to simplify formulation of the hydrologic model and to allow comparisons between stations; (2) the relation needed to be applicable to a monthly time-step model; and (3) the relation needed to be usable at stations where data were not available. Of the equations listed in the preceding paragraph, the hyperbolic equation does not meet the third criterion because there is no method to determine the 'B' parameter at stations that have inadequate data. Because of this problem and because it is more difficult to formulate, it was not considered further.

To make an assessment of the applicability of the remaining equations relating specific conductance to streamflow, 36 stations, mostly on the Arkansas River and larger tributaries, were selected. The coefficients of determination (r^2) were calculated for each equation at each station (SAS Institute, Inc., 1982) and are given in table 3. A coefficient of determination of 1.00 indicates that a perfect relation exists between specific conductance and streamflow, and a value of 0.00 indicates that there is no relation between the two. An examination of residual plots also was used to help select among the equations. Residuals are the differences between the specific-conductance values predicted by the regression equations and the

Table 3.--*Coefficients of determination (r^2) at selected streamflow stations for five equations relating specific conductance to streamflow*

[See page 23 for equations]

Station number	Station name	Equations				
		Linear	Inverse	Square root	Log-linear	Log-log
07081200	Arkansas River near Leadville	0.43	0.50	0.58	0.66	0.73
07083000	Halfmoon Creek near Malta	.65	.54	.48	.80	.71
07083700	Arkansas River near Malta	.34	.66	.41	.61	.60
07087200	Arkansas River at Buena Vista	.38	.55	.46	.52	.49
07089000	Cottonwood Creek below Hot Springs, near Buena Vista	.47	.60	.56	.59	.62
07091200	Arkansas River near Nathrop	.48	.64	.61	.69	.72
07094500	Arkansas River at Parkdale	.46	.73	.60	.70	.73
07096000	Arkansas River at Canon City	.58	.72	.73	.80	.78
07096500	Fourmile Creek near Canon City	.20	.41	.31	.45	.45
07099100	Beaver Creek near Portland	.28	.14	.48	.70	.79
07099200	Arkansas River near Portland	.59	.71	.73	.80	.82
07099400	Arkansas River above Pueblo	.55	.37	.62	.61	.61
07103700	Fountain Creek near Colorado Springs	.33	.73	.50	.65	.71
07103747	Monument Creek at Palmer Lake	.32	.34	.60	.80	.67
07103800	West Monument Creek at Air Force Academy	.003	.0001	.001	.01	.01
07104000	Monument Creek at Pikeview	.17	.0028	.28	.28	.30
07105500	Fountain Creek at Colorado Springs	.16	.26	.29	.41	.46
07105900	Jimmy Camp Creek at Fountain	.27	.19	.35	.38	.36
07106300	Fountain Creek near Pinon	.23	.007	.44	.40	.43
07106500	Fountain Creek at Pueblo	.17	.21	.43	.67	.70
07108900	St. Charles River at Vineland	.15	.30	.37	.63	.71
07109500	Arkansas River near Avondale	.37	.50	.49	.57	.58
07117600	Chicosa Creek near Fowler	.12	.27	.26	.37	.34
07119500	Apishapa River near Fowler	.02	.45	.19	.62	.65
07121500	Timpas Creek at mouth near Swink	.44	.62	.57	.61	.66
07122400	Crooked Arroyo near Swink	.56	.08	.69	.68	.63
07124000	Arkansas River at Las Animas	.53	.33	.69	.71	.71
07124200	Purgatoire River at Madrid	.26	.14	.42	.46	.49
07124300	Long Canyon Creek near Madrid	.35	.17	.42	.48	.46
07126200	Van Bremer Arroyo near Model	.17	.05	.26	.28	.35
07126300	Purgatoire River near Thatcher	.09	.0001	.13	.03	.06
07128500	Purgatoire River near Las Animas	.15	.10	.33	.45	.50
07130500	Arkansas River below John Martin Reservoir	.34	.07	.52	.56	.53
07133000	Arkansas River at Lamar	.19	.09	.33	.41	.42
07134100	Big Sandy Creek near Lamar	.25	.02	.24	.15	.15
07137500	Arkansas River near Coolidge, Kans.	.15	.009	.42	.35	.33
	Mean value of coefficients of determination	.31	.32	.44	.52	.53

actual values. Residuals usually are plotted as a function of the predictor variable (streamflow) and other variables that may be of interest (Draper and Smith, 1981). Plots of the relations of specific conductance to streamflow, residuals to streamflow, and residuals to month of the year were made for the 36 stations. An examination of the residual versus streamflow plots using methods described by Draper and Smith (1981, p. 146) was made. A satisfactory residuals plot gives the overall impression of a horizontal band and indicates that the residuals remain relatively constant throughout the range of streamflow. Unsatisfactory plots may have expanding, sloping, or curved bands, indicating an unsatisfactory fit of the equations relating specific conductance to streamflow.

The coefficients of determination can be compared directly for the first four equations being considered, but they should not be used to compare these four equations with the log-log equation (Crawford and others, 1983). Because a single type of model is to be developed for all stations in the basin, a mean coefficient of determination for each type of equation is shown at the bottom of table 3. Based on this mean, the log-linear equation relating specific conductance to streamflow is the best of the first four equations evaluated. This equation also gave the best residual plots at 24 stations and plots as good as other equations at 9 stations.

The log-linear equation then was compared to the log-log equation to determine which gave the best estimates of specific conductance from streamflow. The choice between the log-linear and log-log equations was based on an examination of plots of residual values from the regression because direct comparison of coefficients of determination is not valid when the dependent variable is log-transformed (Crawford and others, 1983). The log-linear equation had better residuals at 6 stations, the log-log equation had better residuals at 13 stations, and there was no appreciable difference at 17 stations. Based on these results, the log-log equation relating specific conductance to streamflow was chosen to estimate specific conductance from streamflow in the Arkansas River basin. An additional reason for selecting the log-log equation is that it predicts positive values of specific conductance for all flows at all 36 stations, whereas the log-linear equation may predict negative values of specific conductance for large streamflow at some stations.

Seasonal Changes in the Relations

During examination of the plots of residuals versus month of the year, seasonal variations in the residuals were noted at several stations. If sufficient data were available, these variations could be removed by determining regression equations of specific conductance to streamflow for each month at each station; however, many of the stations do not have sufficient data.

An alternative to using monthly regressions is to determine separate equations for two seasons. Examination of the residual plots indicated that October through April had a different relation of specific conductance to streamflow than the rest of the year at many stations. Separate regressions could be developed for each period if the relations were significantly different between the periods. The advantage of this approach is that all stations considered for determining the relations of specific conductance to streamflow have sufficient data for seasonal regressions.

To evaluate differences between the seasons, a regression analysis using dummy variables was made (Draper and Smith, 1981, p. 241-250). The term "dummy" indicates that the values of the variable were not measured but were used simply to categorize by season. A dummy variable, Z, was set equal to 1 for the months of October through April, and to 0 for the months of May through September. Using this formulation, the earlier log-log equation relating specific conductance to streamflow of:

$$\log(SC_e) = a + b\log(Q) \text{ becomes:} \tag{6}$$

$$\log(SC_e) = a + b\log(Q) + cZ + dZ\log(Q). \tag{7}$$

where SC, a, b, and Q have the meanings described in the section "Types of Relations Evaluated"; c and d are regression coefficients; and Z is the dummy variable described above.

When the month is from October through April, Z=1, and the equation simplifies to:

$$\log(SC_e) = (a + c) + (b + d)\log(Q) \tag{8}$$

When the month is from May through September, Z=0, and the equation simplifies to our original equation:

$$\log(SC_e) = a + b\log(Q). \tag{6}$$

When simplified, equation 7 can result in four possible relations of specific conductance to streamflow depending on the values of a, b, c, and d, which are determined by the regression. The regression is performed using a stepwise approach (SAS Institute, Inc., 1982, p. 101-110) and includes only variables that are significant at the 0.05 probability level. Thus, the regression analysis determines whether there is significant seasonality in the relation of specific conductance to streamflow. If there is a significant change in the relation between the seasons, then c or d or both will have nonzero values. A schematic diagram of the four possible relations that may result after simplifying equation 7 is shown in figure 13. They are: (A) no difference between seasons ($c = 0$, $d = 0$); (B) the same intercept for both seasons, but a different slope ($c = 0$, $d \neq 0$); (C) the same slope, but a different intercept ($c \neq 0$, $d = 0$); and (D) a different slope and a different intercept for the two seasons ($c \neq 0$, $d \neq 0$).

The regression relations of specific conductance to streamflow for 19 Arkansas River and 50 tributary stations developed using this approach are

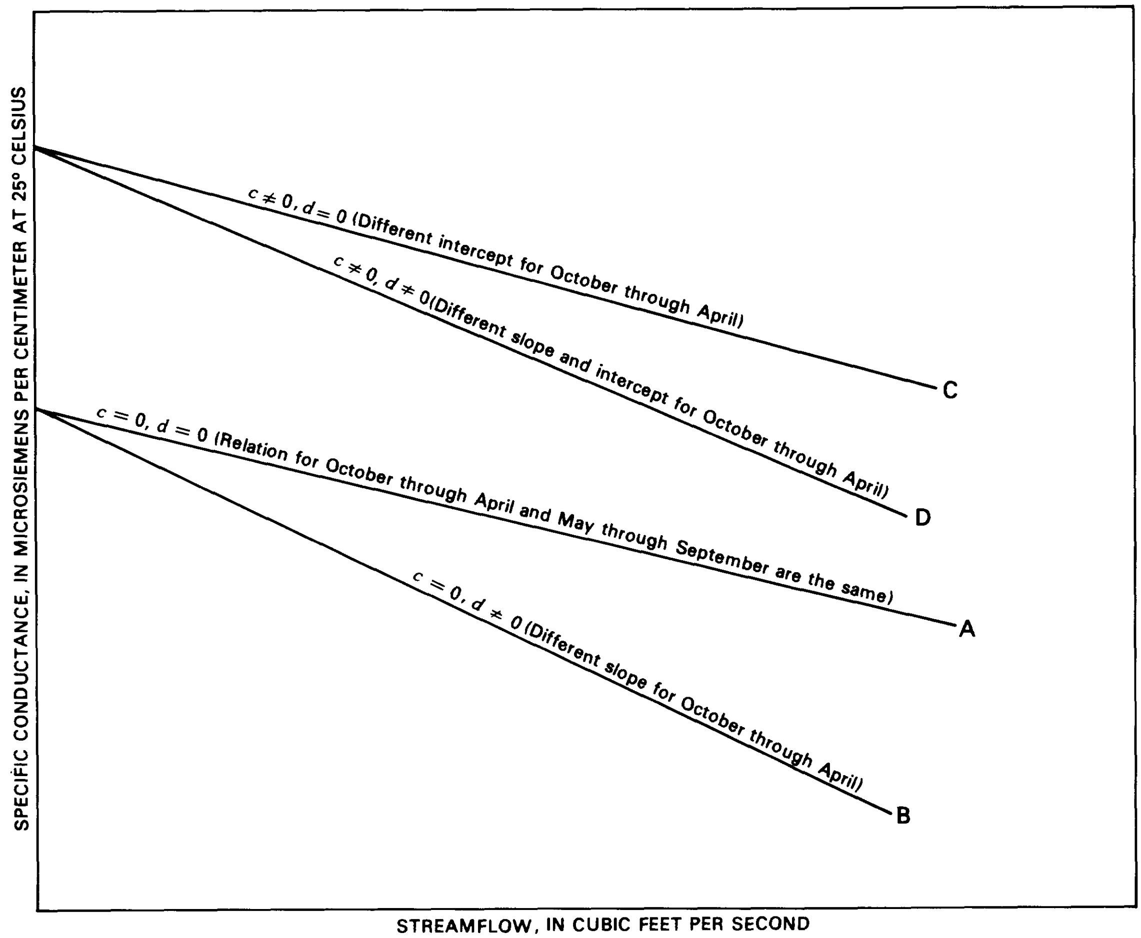

Figure 13.--Four possible relations of specific conductance to streamflow

given in table 4. Also given are the coefficient of determination and the average standard error in percent. All regressions were significant at the 99-percent probability level ($p > F$ was < 0.01). The relations explain between 12 and 88 percent of the variation in the specific-conductance and streamflow data and the mean value is 59 percent. Because both specific conductance and streamflow were log-transformed, the standard error calculated by the program (SAS Institute, Inc., 1982) had to be adjusted. Average percent standard error was computed using the method of Gary Tasker (U.S. Geological Survey, written commun., 1978) and varies from about 10 to 40 percent and has a mean value of 23 percent. Small coefficients of determination or large standard error, which occur at some stations, may be caused by one or more of the following: errors in specific-conductance measurements (especially if specific conductance is less than 200 microsiemens per centimeter at 25 degrees Celsius), several sources of streamflow with differing specific conductance and resultant scatter in the regression relation, or the

Table 4.--*Relations of specific conductance to streamflow*

[SC_e, estimated specific conductance, in microsiemens per centimeter at 25 degrees Celsius; *Q*, measured streamflow, in feet per second; *Z*, dummy variable; dash indicates the coefficient was not included in the regression equation]

Station number	Station name	Number of values	Regression coefficients in the equation $\log(SC_e) = a + b \log(Q) + c Z + dZ \log(Q)$				Coefficient of determination (r^2)	Average standard error (percent)
			a	*b*	*c*	*d*		
07081200	Arkansas River near Leadville	131	2.87	-0.35	-	-	0.73	24
07083000	Halfmoon Creek near Malta	234	2.18	-.22	-0.19	0.18	.74	12
07083700	Arkansas River near Malta	109	2.96	-.36	-	-	.60	26
07087200	Arkansas River at Buena Vista	96	2.63	-.22	-	-	.49	25
07089000	Cottonwood Creek below Hot Springs, near Buena Vista	114	2.39	-.20	-	-	.62	12
07091200	Arkansas River near Nathrop	140	2.64	-.19	.38	-.14	.63	18
07093700	Arkansas River near Wellsville	61	3.46	-.43	-	-	.70	22
07094500	Arkansas River at Parkdale	140	3.18	-.30	.05	-	.75	17
07094600	South Colony Creek near Westcliffe	22	2.02	-.10	.07	-	.82	9.5
07094900	Middle Taylor Creek near Westcliffe	26	2.31	-.16	-	-	.33	29
07096000	Arkansas River at Canon City	155	3.07	-.26	-	.02	.78	13
07096500	Fourmile Creek near Canon City	143	3.44	-.31	-.09	-	.49	27
07097000	Arkansas River at Portland	76	3.61	-.37	-	-	.64	24
07099100	Beaver Creek near Portland	134	3.05	-.30	.09	-	.81	32
07099200	Arkansas River near Portland	226	3.77	-.41	-.32	.14	.85	15
07099215	Turkey Creek near Fountain	35	2.29	-.07	.06	-	.58	15
07099220	Little Turkey Creek near Fountain	27	2.32	-.12	-	-	.69	15
07099230	Turkey Creek above Teller Reservoir near Stone City	35	2.81	-.10	.17	-	.78	22
07099235	Turkey Creek near Stone City	31	2.81	-.22	-	-	.67	27
07099400	Arkansas River above Pueblo	3,088	3.48	-.32	-	-	.61	26
07099500	Arkansas River near Pueblo	59	3.14	-.18	.10	-	.74	19
07103700	Fountain Creek near Colorado Springs	215	2.84	-.36	.04	-	.69	20
07103747	Monument Creek at Palmer Lake	100	2.26	-.20	-	-	.83	13
07103750	Monument Creek at Monument	27	2.18	-.16	-	-	.72	12
07103800	West Monument Creek at Air Force Academy	127	2.04	-.04	-	.08	.12	20
07103950	Kettle Creek near Black Forest	70	2.37	-.05	-	-	.20	16
07104000	Monument Creek at Pikeview	146	2.66	-.17	-.08	.11	.41	22
07104900	Monument Creek at Cache La Poudre Street at Colorado Springs	41	3.05	-.31	-	-	.75	18
07104905	Monument Creek at Bijou Street at Colorado Springs	41	3.08	-.32	-	-	.74	18
07105500	Fountain Creek at Colorado Springs	193	3.11	-.25	-	-	.46	32
07105530	Fountain Creek below Janitell Road below Colorado Springs	60	3.57	-.40	-.40	.25	.70	16
07105780	B Ditch Drain near Security	32	3.50	-.23	-	-	.33	27
07105800	Fountain Creek at Security	212	3.19	-.21	-	.03	.32	32
07105825	Fountain Creek below Widefield	38	3.88	-.50	-.57	.31	.88	10

Table 4.--*Relations of specific conductance to streamflow*--Continued

Station number	Station name	Number of values	Regression coefficients in the equation $\log(SC_e) = a + b \log(Q) + c Z + dZ \log(Q)$				Coefficient of determination (r^2)	Average standard error (percent)
			a	b	c	d		
07105900	Jimmy Camp Creek at Fountain	85	3.56	-0.28	-	-	0.36	26
07105905	Fountain Creek above Little Fountain Creek, below Fountain	86	3.52	-.29	-	0.02	.74	16
07105920	Little Fountain Creek above Keaton Reservoir, near Fort Carson	51	2.06	-.08	-	-	.25	22
07105928	Little Fountain Creek near Fort Carson	44	2.15	-.11	-	-	.45	32
07105940	Little Fountain Creek near Fountain	35	3.18	-.38	-	-	.85	40
07105945	Rock Creek above Fort Carson	47	2.15	-.09	-	-	.33	19
07105950	Rock Creek near Fort Carson	23	2.22	-.12	-	-	.60	17
07105960	Rock Creek near Fountain	38	2.84	-.23	-	-	.64	30
07106300	Fountain Creek near Pinon	194	3.16	-.11	0.16	-	.61	25
07106500	Fountain Creek at Pueblo	282	3.42	-.17	.08	-	.76	20
07107900	Greenhorn Creek near Rye	69	1.99	-.16	-	-	.45	16
07108050	Greenhorn Creek near Colorado City	79	3.08	-.22	-	-	.38	36
07108900	St. Charles River at Vineland	130	3.59	-.29	-	-	.75	29
07109500	Arkansas River near Avondale	219	3.67	-.31	-	.04	.64	24
07116500	Huerfano River near Boone	47	3.59	-.23	-	-	.62	46
07117000	Arkansas River near Nepesta	72	3.40	-.22	-	.05	.62	22
07117600	Chicosa Creek near Fowler	147	3.44	-.26	.05	-	.34	33
07118500	Apishapa River at Aguilar	42	2.84	-.16	-	-	.59	36
07119500	Apishapa River near Fowler	237	3.50	-.27	-	-	.65	28
07119700	Arkansas River at Catlin Dam, near Fowler	76	3.44	-.23	-.35	.21	.56	26
07121500	Timpas Creek at mouth near Swink	207	3.76	-.33	-	.04	.66	18
07122000	Arkansas River near La Junta	61	3.92	-.29	-	-.02	.73	17
07122400	Crooked Arroyo near Swink	184	3.43	-.18	.05	-	.63	24
07123675	Horse Creek near Las Animas	31	3.65	-.15	-	.20	.51	22
07124000	Arkansas River at Las Animas	360	3.85	-.30	-	.06	.74	26
07124050	Middle Fork Purgatoire River at Stonewall	791	2.43	-.09	.07	.11	.66	18
07124200	Purgatoire River at Madrid	169	2.76	-.14	-.15	.16	.59	17
07124300	Long Canyon Creek near Madrid	112	2.61	-.13	.10	.11	.58	20
07126200	Van Bremer Arroyo near Model	129	3.07	-.15	.08	-	.45	20
07126300	Purgatoire River near Thatcher	141	3.40	-.09	.19	-	.31	43
07128500	Purgatoire River near Las Animas	336	3.69	-.21	-	.09	.58	31
07130500	Arkansas River below John Martin Reservoir	9,273	3.77	-.21	-.16	.12	.59	31
07133000	Arkansas River at Lamar	330	3.71	-.20	-	.14	.62	30
07134100	Big Sandy Creek near Lamar	167	3.71	-.15	-	.10	.28	27
07137500	Arkansas River near Coolidge, Kans.	462	3.84	-.20	-.13	.14	.51	29

choice of a log-log relation where another relation might have provided a better fit for a given station.

Areal and Downstream Changes in the Relations

Changes in the relations of specific conductance to streamflow may be evaluated by examining variations of the intercept and slope used to estimate specific conductance from streamflow for the May through September and October through April periods in the simplified forms of equation 7. The intercept, which is the logarithm of expected specific conductance at a streamflow of 1 cubic foot per second gives an approximate indication of expected specific conductance during base flow. The intercept can provide only an approximate indication of baseflow specific conductance because actual base flow at many of the stations in table 4 can be considerably different from 1 cubic foot per second. Large intercepts suggest that base flow may have a large specific conductance. The slope indicates the magnitude of change in specific conductance at different streamflows. Slopes that have large absolute values indicate a large change in specific conductance as streamflow changes and indicate that streamflow consists of water from sources that have large differences in specific conductance. Slope terms that have small absolute values indicate that specific conductance is relatively constant for a large range of streamflow, indicating a common source of streamflow or sources that have similar values of specific conductance.

Intercepts are strongly related to altitude of the station for which the relation was developed (fig. 14), which is not surprising because base flow is sustained by ground water, which generally has smaller specific conductance in the upstream parts of the basin (fig. 5). Slopes of the relations were not similarly related to station altitude, but the absolute values of the slopes for October through April generally were smaller than the slopes for May through September. This difference indicates that there generally is more change in specific conductance for a given change in streamflow during May through September than during the rest of the year. This situation results from snowmelt and rainfall runoff, which have small specific conductance, and base flow, which has larger specific conductance, all contributing significantly to streamflow during May through September; whereas, baseflow is the major component of streamflow from October through April.

Downstream changes in the relations of specific conductance to streamflow at stations on the Arkansas River also are prominent. Relations at 9 of the 19 stations on the Arkansas River for May through September are shown in figure 15 and for October through April in figure 16. During both periods, larger expected values of specific conductance generally will result from the same streamflow at successive downstream stations. Larger slopes occur in the relation for the Arkansas River near Leadville (station 07081200), because of the effects of mine drainage that has larger specific conductance and for the Arkansas River near Portland (station 07099200) because of irrigation-return flows and inflows of saline ground water that have larger specific conductance. Smaller slopes in the relations for the Arkansas River at Lamar (station 07133000) and the Arkansas River near Coolidge, Kans. (station 07137500), result from flows consisting primarily of return flows from

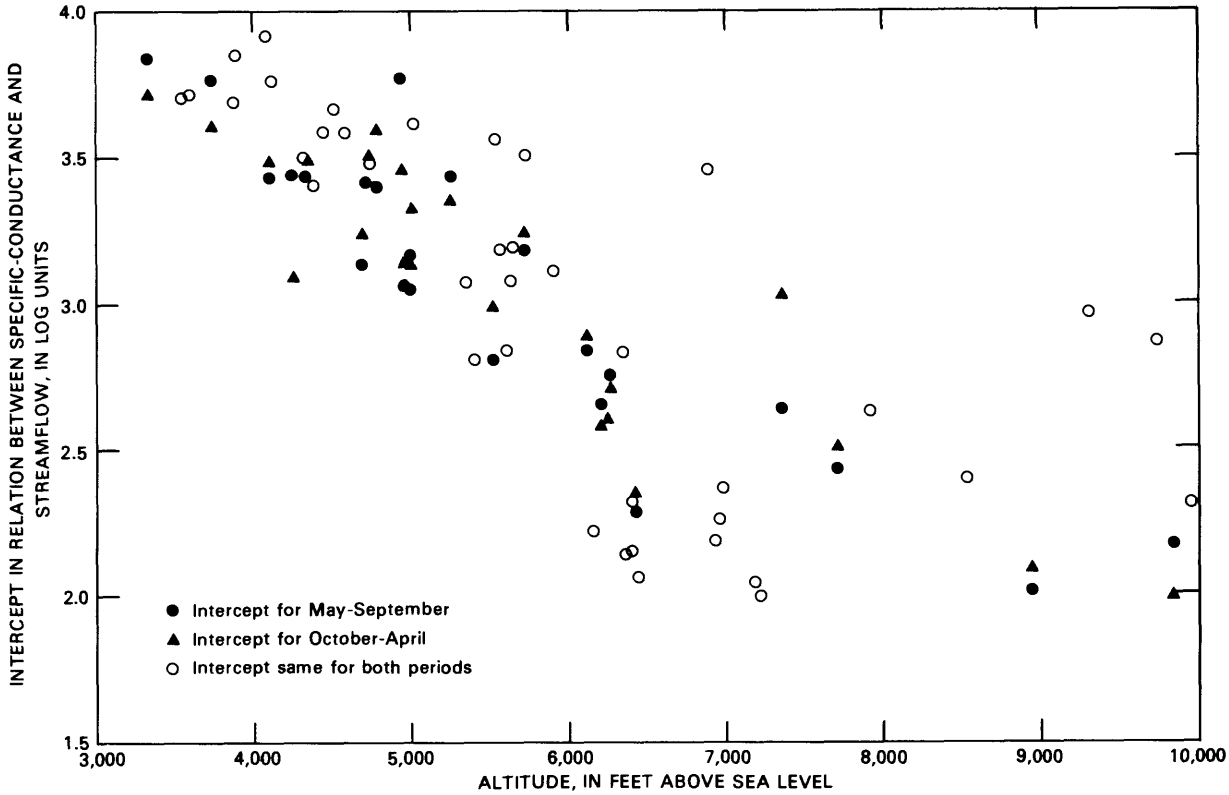

Figure 14.--Relation between intercept in relation of specific conductance to streamflow and altitude of station.

irrigation during much of the year. During May through September, the return flows primarily are surface-water return flow (tail water); during October through April, most of the flow in this reach is ground-water seepage from the alluvial aquifer, another form of irrigation-return flow.

Effect of Basin Characteristics

The effect of basin characteristics on relations of specific conductance to streamflow was evaluated using a technique known as regionalization. Regionalization is a technique for relating hydrologic variables, in this case, the regression coefficients in the equation relating specific conductance to streamflow to climatic and physiographic characteristics of a drainage basin. The results of the regionalization analysis allow estimates of specific conductance to be made at stations that do not have adequate data to develop a direct relation of specific conductance to streamflow. The approach used here is designed to assess the effect of basin characteristics on relations of specific conductance to streamflow at headwater and tributary stations because these stations often lack specific-conductance data.

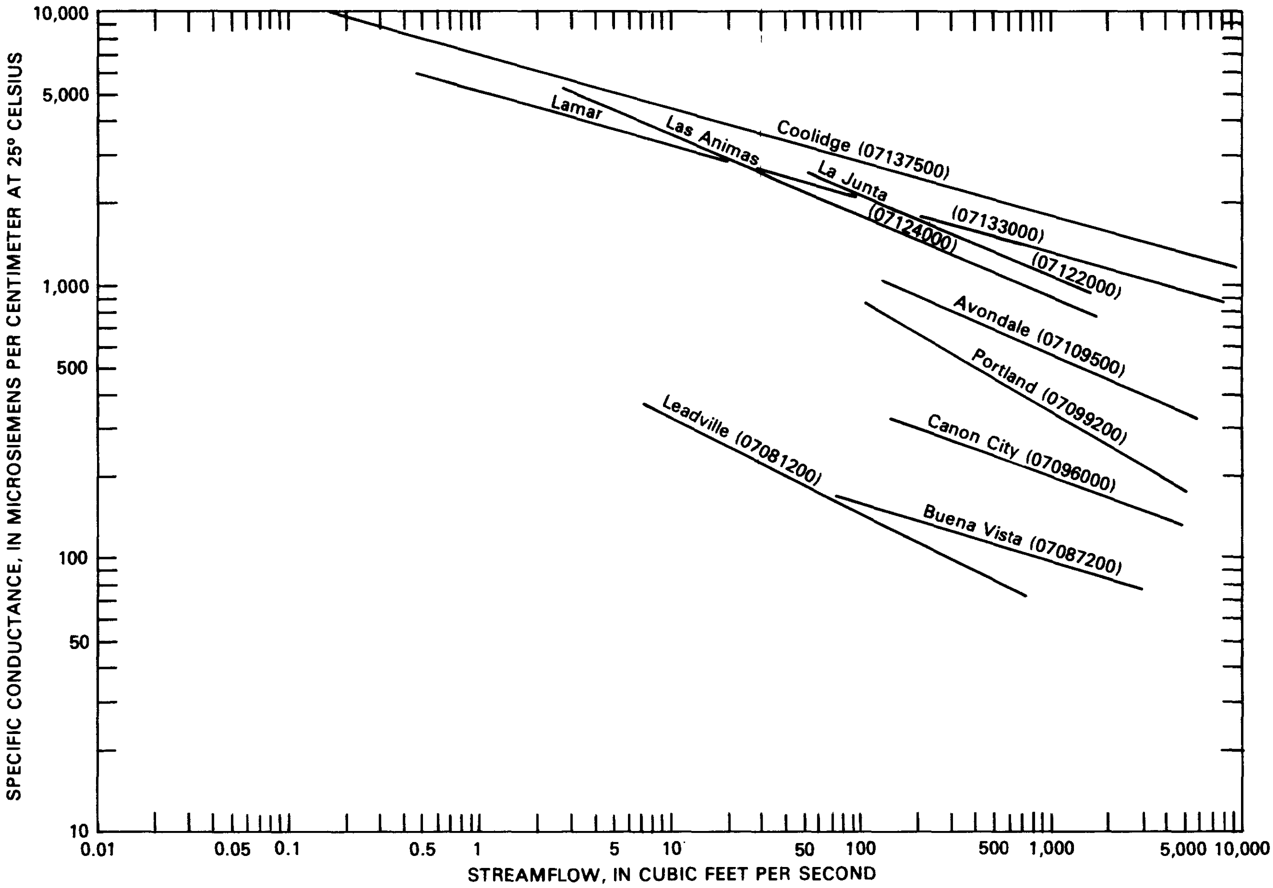

Figure 15.--Relations of specific conductance to streamflow at nine Arkansas River stations for May through September.

Variables Selected for Regionalization Analysis

The dependent variables to be estimated are the coefficients, *a* and *b*, in the equation:

$$\log(SC_e) = a + b \log(Q) \qquad (6)$$

These coefficients need to be estimated for October through April and May through September resulting in four coefficients to determine using regression analysis.

Independent variables chosen for the regionalization analysis were: drainage area, altitude of station, mean annual precipitation at the station, mean annual precipitation on the drainage basin, mean annual runoff at the station, percentage of the drainage basin that is irrigated, percentage of the drainage basin that is underlain by igneous and metamorphic bedrock, percentage of the drainage basin that is underlain by shale bedrock, and the number of metal-mine tunnels and shafts per square mile in the drainage basin.

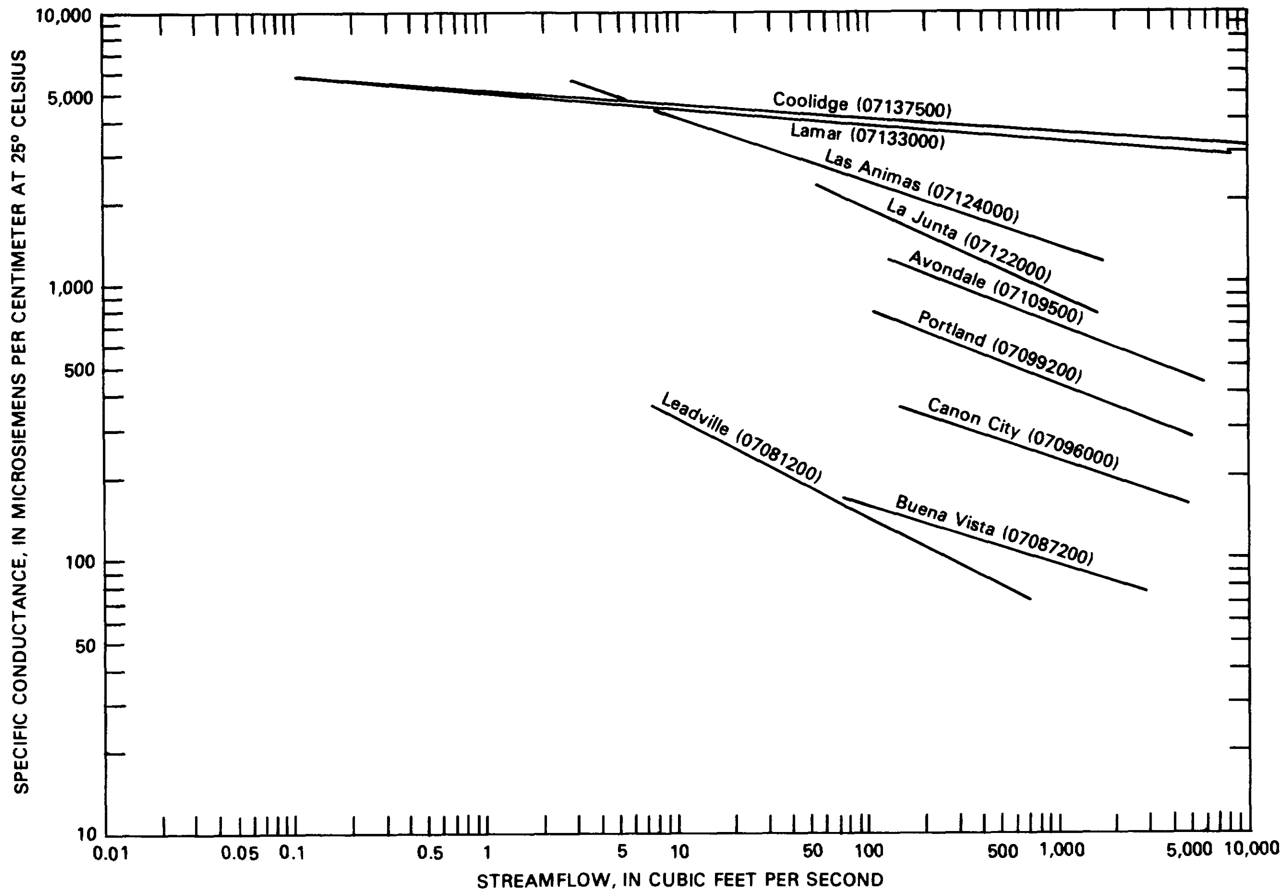

Figure 16.--Relations of specific conductance to streamflow at nine Arkansas River stations for October through April.

These variables were chosen based on relations of mean specific conductance to drainage area, relations of mean specific conductance to altitude (fig. 2), examination of geologic maps, variations in specific conductance of irrigation-return flow (Cain, 1985), and the effects of mine drainage on specific conductance in the basin (Moran and Wentz, 1974; Wentz, 1974). Although other variables may be useful when defining the regression coefficients in the relation of specific conductance to streamflow, these were readily available and were consistent with the needs of the study. The values of the variables for the 37 headwater and tributary stations used in the regionalization analysis are given in table 5. The 37 stations were chosen to provide broad coverage of the basin and to represent tributary or headwater basins of small to moderate size. The results of the regionalization analysis need to be applied only to basins with similar characteristics.

Regionalization Analysis

A stepwise regression-analysis procedure was used to eliminate those independent variables not significant at the 0.05 probability level (SAS

Table 5.--*Summary of regionalization variables for headwater and tributary stations*

Station number	Station name	Drainage area (square miles)	Altitude (feet above sea level)	Mean annual precipitation (inches)		Mean annual runoff (cubic feet per second per square mile)	Percentage of basin irrigated	Percentage of rock type underlying the basin		Number of metal-mine tunnels and shafts per square mile
				At station	On basin			Igneous and metamorphic	Shale	
07081200	Arkansas River near Leadville	97	9,730	17.0	25.6	0.745	3.3	62	0.0	2.19
07083000	Halfmoon Creek near Malta	24	9,830	18.2	27.0	1.208	0.0	100	.0	0.08
07083700	Arkansas River near Malta	228	9,300	12.0	24.5	1.057	4.6	68	.0	1.72
07089000	Cottonwood Creek below Hot Springs, near Buena Vista	65	8,532	17.3	27.2	.851	.0	100	.0	.18
07094600	South Colony Creek near Westcliffe	6.5	8,930	17.6	25.2	.884	.0	0.0	.0	.17
07094900	Middle Taylor Creek near Westcliffe	3.2	9,950	22.5	25.7	.971	.0	.0	38	.31
07096500	Fourmile Creek near Canon City	434	5,254	13.5	15.2	.055	3.2	87	2.6	.01
07099100	Beaver Creek near Portland	214	4,993	12.2	16.5	.041	3.0	61	12	.00
07099215	Turkey Creek near Fountain	13	6,420	15.6	16.6	.164	.0	78	.0	.00
07099220	Little Turkey Creek near Fountain	10	6,395	15.9	17.4	.157	.0	70	.0	.00
07099230	Turkey Creek above Teller Reservoir near Stone City	63	5,520	12.0	15.3	.078	.0	28	14	.00
07103700	Fountain Creek near Colorado Springs	103	6,110	18.7	20.4	.133	.0	73	.0	.00
07103747	Monument Creek at Palmer Lake	26	6,950	17.5	17.0	.253	.0	81	.0	.00
07103750	Monument Creek at Monument	29	6,925	17.5	17.0	.229	.0	74	.0	.00
07103800	West Monument Creek at Air Force Academy	15	7,180	18.9	18.0	.148	.0	87	.0	.00
07103950	Kettle Creek near Black Forest	9.0	6,980	18.1	18.0	.109	.0	.0	.0	.00
07105780	B Ditch Drain near Security	3.2	5,724	15.5	16.2	.584	.0	.0	100	.00
07105900	Jimmy Camp Creek at Fountain	66	5,530	14.9	14.3	.036	4.4	.0	40	.00
07105920	Little Fountain Creek above Keaton Reservoir, near Fort Carson	11	6,430	18.1	20.1	.517	.0	100	.0	.00
07105928	Little Fountain Creek near Fort Carson	12	6,360	17.3	19.6	.390	.0	95	.0	.00
07105940	Little Fountain Creek near Fountain	27	5,560	14.9	17.5	.196	.0	40	51	.00
07105945	Rock Creek above Fort Carson	6.9	6,390	17.1	18.0	.420	.0	90	7.4	.00
07105960	Rock Creek near Fountain	17	5,600	14.7	16.5	.145	.0	32	63	.00
07107900	Greenhorn Creek near Rye	10	7,220	22.7	29.7	.433	.0	89	9.4	.00
07108900	St. Charles River at Vineland	474	4,585	11.0	17.6	.095	3.8	31	64	.00
07116500	Huerfano River near Boone	1,875	4,450	11.0	18.1	.023	3.3	8.2	42	.00
07117600	Chicosa Creek near Fowler	109	4,335	11.0	11.0	.038	2.9	.0	100	.00
07118500	Apishapa River at Aguilar	149	6,335	15.7	23.6	.050	.5	9.3	2.5	.00
07119500	Apishapa River near Fowler	1,125	4,317	11.0	13.1	.026	.3	1.2	58	.00
07121500	Timpas Creek at mouth near Swink	496	4,113	11.0	12.4	.126	4.5	.0	96	.00
07122400	Crooked Arroyo near Swink	108	4,100	11.0	12.3	.102	1.9	.0	100	.00
07123675	Horse Creek near Las Animas	1,265	3,970	11.0	12.0	.008	2.4	.0	79	.00
07124050	Middle Fork Purgatoire River at Stonewall	52	7,710	19.2	22.8	.361	1.3	7.9	15	.00
07124200	Purgatoire River at Madrid	550	6,262	15.0	19.7	.121	1.6	2.0	6.9	.00
07124300	Long Canyon Creek near Madrid	100	6,259	15.8	17.8	.036	.0	.0	.0	.00
07126200	Van Bremer Arroyo near Model	168	4,960	11.8	12.3	.015	2.6	.0	87	.00
07134100	Big Sandy Creek near Lamar	3,307	3,545	14.0	13.7	.003	.5	.0	89	.00

Institute, Inc., 1982). The basin characteristics significant in estimating the intercept (a) for the two time periods were: (1) Drainage area (*DA*); (2) mean annual precipitation at the station (*AP*); (3) percent of the drainage area that is irrigated (*PI*); and (4) percent of the drainage area that is underlain by shale bedrock (*PS*). The only basin characteristic significant in estimating the slope (*b*) for the two periods was the percent of the drainage area that is irrigated (*PI*).

The following regression equations resulted from the regionalization analysis (percent standard error is the standard error of the regression expressed as a percentage of the mean value of the independent variable):

$$a = 3.42 + 0.00017(DA) - 0.062(AP) + 0.096(PI) + 0.0064(PS) \quad (9)$$
for May through September
(r^2 = 0.85, percent standard error=8.7);

$$a = 3.28 + 0.00019(DA) - 0.054(AP) + 0.106(PI) + 0.0062(PS) \quad (10)$$
for October through April
(r^2 = 0.85, percent standard error=8.6);

$$b = -0.128 - 0.034(PI) \quad (11)$$
for May through September
(r^2 = 0.21, percent standard error=64.8); and

$$b = -0.155 - 0.033(PI) \quad (12)$$
for October through April
(r^2 = 0.32, percent standard error=41.2).

RELATIONS OF SPECIFIC CONDUCTANCE TO SELECTED WATER-QUALITY CONSTITUENTS

Although specific conductance is measured easily and numerous values are available, other water-quality constituents are important in many hydrologic studies. Concentrations of dissolved solids are necessary to calculate dissolved-solids loads and mass balances of dissolved solids. Concentrations of major ions are useful in evaluating the suitability of water for a given use, such as for a municipal or irrigation supply.

Dissolved-solids concentrations

To estimate dissolved-solids concentrations from specific conductance, relations of specific conductance to dissolved-solids concentration were determined where data were available. Two types of dissolved-solids concentration data existed at most stations. Dissolved-solids concentration, sum of constituents, is a value calculated from measured major-ion concentrations. Dissolved-solids concentration, residue on evaporation at 180 degrees Celsius, is measured by evaporating a water sample to dryness and drying the residue at 180 degrees Celsius (Fishman and Friedman, 1985).

At stations where both dissolved-solids concentrations were analyzed on the same sample, dissolved-solids concentration, residue on evaporation at 180 degrees Celsius, generally was significantly larger when measured by a Student's *t* test ($p<0.05$). This difference may occur because a rather complete analysis is required to obtain an accurate total when dissolved-solids concentration is calculated as the sum of the ions (Hem, 1985, p. 157). Because of this difference, dissolved-solids concentration, residue on evaporation at 180 degrees Celsius, was used in the determination of relations of specific conductance to dissolved-solids concentration. However, at many stations, many or most of the dissolved-solids analyses were dissolved-solids concentrations, sum of constituents. If sufficient data were available at these stations, a least-squares linear-regression relation between the two dissolved-solids concentrations was determined for the station and the relation was used to estimate dissolved-solids concentration, residue on evaporation at 180 degrees Celsius, from dissolved-solids concentration, sum of constituents. If paired dissolved-solids concentrations at a station were not sufficient to determine a regression relation between the two, a relation between the two using data from all surface-water stations or ground-water sites that had paired data was used to estimate dissolved-solids concentration, residue on evaporation at 180 degrees Celsius, from dissolved-solids concentration, sum of constituents. The relation for surface-water stations was:

$$ROE = -10.8 + 1.07\,SUM \qquad (13)$$
$$(n = 873,\ r^2 = 0.99,\ \text{percent standard error} = 10.1);$$

the relation for ground-water sites was:

$$ROE = -52.2 + 1.09\,SUM \qquad (14)$$
$$(n = 86,\ r^2 = 0.99,\ \text{percent standard error} = 2.7),$$

where *ROE* = dissolved-solids concentration, residue on evaporation, in milligrams per liter; and
SUM = dissolved-solids concentration, sum of constituents, in milligrams per liter.

Using this approach, a total of 2,695 paired measurements of specific conductance and dissolved-solids concentration (2,355 at surface-water stations, 340 at ground-water sites) were available for determining regression relations to estimate dissolved-solids concentrations from specific conductance.

Arkansas River and Tributaries

Least-squares regression was used to determine relations to estimate dissolved-solids concentration from specific conductance at 14 stations along the Arkansas River, 6 stations along Fountain Creek, 4 stations on the Purgatoire River, 2 mine-drainage stations, and 2 stations along tributaries to the Arkansas River. A summary of the regression coefficients and various statistical parameters is given in table 6. All regressions were significant at the 99-percent confidence level. The equation used to estimate dissolved-solids concentration from specific conductance is in the form:

$$DS = a + b(SC_m) \qquad (15)$$

Table 6.--*Relations of specific conductance to dissolved-solids concentration for the Arkansas River and tributaries*

[*DS*, estimated dissolved-solids concentration, in milligrams per liter; SC_m, measured specific conductance, in microsiemens per centimeter at 25 degrees Celsius]

Station number	Station name	Number of values	Regression coefficients in the equation DS = *a* + *b*(SC_m)		Coefficient of determination (r^2)	Standard error (percent)
			a	*b*		
07079200	Leadville Drain at Leadville	26	-111.8	0.90	0.96	2.8
07081800	California Gulch at Malta	13	-218.5	1.07	.96	5.9
07083000	Halfmoon Creek near Malta	167	7.9	.50	.62	14
07083700	Arkansas River near Malta	68	-20.5	.75	.99	11
07086000	Arkansas River at Granite	20	0.2	.63	.97	6.2
07096000	Arkansas River at Canon City	125	-6.2	.64	.96	5.5
07097000	Arkansas River at Portland	53	8.4	.61	.95	7.4
07099200	Arkansas River near Portland	178	-35.0	.73	.97	6.1
07099400	Arkansas River above Pueblo	60	-38.4	.75	.99	4.2
07099500	Arkansas River near Pueblo	47	-57.0	.78	.98	6.6
07103700	Fountain Creek near Colorado Springs	26	7.4	.56	.94	9.2
07105530	Fountain Creek below Janitell Road below Colorado Springs	19	2.1	.61	.94	7.0
07105800	Fountain Creek at Security	29	-21.7	.66	.98	4.2
07105825	Fountain Creek below Widefield	32	-55.9	.72	.90	8.0
07106300	Fountain Creek near Pinon	48	-28.9	.75	.95	9.6
07106500	Fountain Creek at Pueblo	61	-508.8	1.04	.98	7.4
07109500	Arkansas River near Avondale	12	-18.7	.69	.98	5.8
07117000	Arkansas River near Nepesta	49	-71.0	.80	.97	6.4
07119500	Apishapa River near Fowler	49	-438.2	1.14	.99	5.4
07122000	Arkansas River near La Junta	65	-189.3	.94	.99	3.9
07124000	Arkansas River at Las Animas	65	-231.8	.94	.98	5.1
07124050	Middle Fork Purgatoire River at Stonewall	11	-16.5	.63	.91	10
07124200	Purgatoire River at Madrid	10	-.7	.59	.98	4.4
07126300	Purgatoire River near Thatcher	14	-485.1	1.18	.98	8.1
07128500	Purgatoire River near Las Animas	56	-385.0	1.06	.99	3.1
07130500	Arkansas River below John Martin Reservoir	760	-243.8	.97	.97	7.7
07133000	Arkansas River at Lamar	47	-222.3	.98	.95	7.6
07137500	Arkansas River near Coolidge, Kans.	197	-6.5	.92	.83	12

where DS = estimated dissolved-solids concentration, in milligrams per liter;
a and b = regression coefficients; and
SC_m = measured specific conductance, in microsiemens per centimeter at 25 degrees Celsius.

Dissolved-solids concentration is sometimes estimated from specific conductance using the above equation without the intercept (a). This approach was not used during this study because the standard error was larger, especially for stations with large dissolved-solids concentrations. The coefficient of determination (r^2) is more than 0.90, and the standard error is less than 10 percent for most stations in table 6, indicating that dissolved-solids concentration generally can be accurately estimated from specific conductance.

Ground Water in Alluvial Aquifers along the Arkansas River

Least-squares regression was used to determine relations to estimate dissolved-solids concentration from specific conductance for ground water in alluvial aquifers along the Arkansas River. Two relations were determined, one for alluvial aquifers upstream from Pueblo and one for alluvial aquifers downstream from Pueblo. A summary of the regression coefficients and various statistical parameters is given in table 7. Both regressions were significant at the 99-percent confidence level. The equation is the same form as that used for surface-water stations along the Arkansas River and tributaries. The relations, which are based on 340 paired analyses of specific conductance and dissolved-solids concentration, are shown in figure 17.

Table 7.--*Relations of specific conductance to dissolved-solids concentration for ground water in alluvial aquifers along the Arkansas River*

[DS, estimated dissolved-solids concentration, in milligrams per liter; SC_m, measured specific conductance, in microsiemens per centimeter at 25 degrees Celsius]

Area	Number of values	Regression coefficients in the equation $DS = a + b(SC_m)$		Coefficient of determination (r^2)	Standard error (percent)
		a	b		
Alluvial aquifers upstream from Pueblo	80	-122	0.88	0.97	25.1
Alluvial aquifers downstream from Pueblo	258	-459	1.06	.98	6.5

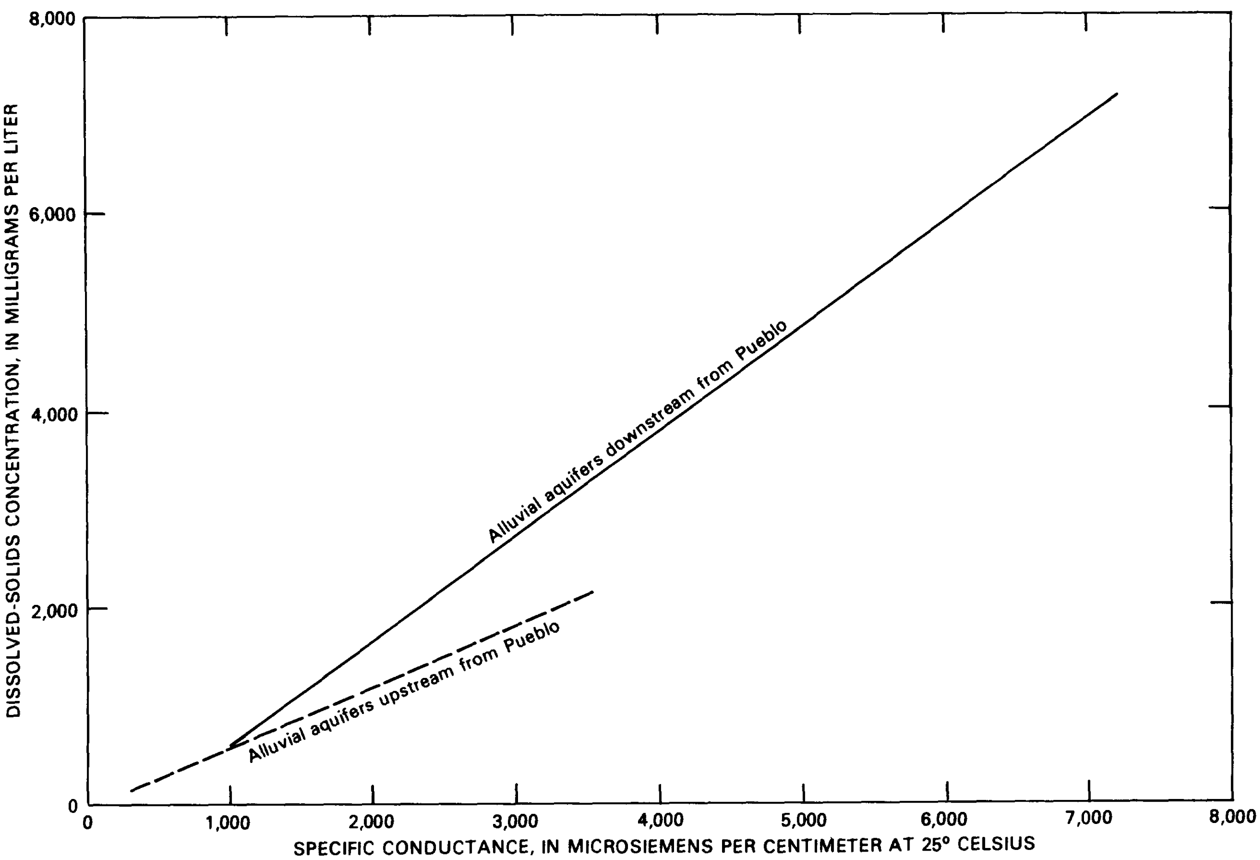

Figure 17.--Relations of specific conductance to dissolved-solids concentration for ground water in alluvial aquifers along the Arkansas River.

Major-Ion Concentrations

Relations of specific conductance to the concentrations of major ions may be used to estimate the concentrations from specific-conductance values. Relations were determined between specific conductance and concentrations of the cations, sodium, calcium, and magnesium, and the anions, chloride, sulfate, and bicarbonate. Although statistically significant relations were determined between specific conductance and the concentrations of potassium and fluoride, the error in these relations generally was large enough to diminish their usefulness for prediction of potassium and fluoride concentrations. Because of this limitation, these relations are not included in this report.

Arkansas River and Tributaries

Relations of specific conductance to major-ion concentrations were developed using least-squares regression for 26 surface-water stations in the Arkansas River basin where at least 10 analyses of specific conductance and major-ion concentrations were available (table 8). Fourteen of the stations

Table 8.--*Relations of specific conductance to major-ion concentrations for stations along the Arkansas River and tributaries*

[SC_m, measured specific conductance, in microsiemens per centimeter at 25 degrees Celsius]

Station number	Station name	Ion	Number of values	Regression coefficients in the equation Ion = a + $b(SC_m)$ a	b	Coefficient of determination (r^2)	Standard error (percent)
07079200	Leadville Drain at Leadville	Sodium	26	-1.05	0.006	0.58	13.1
		Calcium	26	-27.05	.159	.91	5.0
		Magnesium	26	.17	.060	.59	10.0
		Sulfate	26	-176.22	.641	.93	5.1
07081800	California Gulch at Malta	Calcium	13	36.71	.064	.66	9.5
		Magnesium	13	-47.87	.108	.70	26.8
		Sulfate	13	-186.82	.724	.96	5.7
07083000	Halfmoon Creek near Malta	Sodium	127	-0.12	.020	.45	24.5
		Calcium	127	1.08	.102	.68	12.5
		Magnesium	127	.38	.040	.46	19.9
		Sulfate	127	1.13	.052	.31	24.3
		Bicarbonate	127	2.41	.506	.76	10.9
07083700	Arkansas River near Malta	Sodium	33	.68	.017	.83	30.8
		Calcium	33	.88	.103	.99	8.0
		Magnesium	33	-3.17	.058	.97	16.9
		Chloride	33	.62	.009	.82	28.5
		Sulfate	33	-59.44	.518	.97	25.0
07086000	Arkansas River at Granite	Sodium	20	-3.24	.043	.72	37.0
		Calcium	20	-2.56	.127	.94	9.7
		Magnesium	20	1.55	.033	.63	19.6
		Chloride	20	-1.47	.024	.67	35.6
		Sulfate	20	5.35	.141	.73	16.3
		Bicarbonate	20	-8.39	.425	.93	10.0
07096000	Arkansas River at Canon City	Sodium	104	-3.75	.054	.94	8.9
		Calcium	104	2.45	.114	.93	6.5
		Magnesium	104	-1.25	.036	.71	18.7
		Chloride	104	-3.33	.036	.70	24.9
		Sulfate	104	3.37	.098	.73	13.6
		Bicarbonate	104	-10.29	.501	.97	5.0
07097000	Arkansas River at Portland	Sodium	22	-3.27	.057	.93	9.9
		Calcium	22	6.25	.096	.93	7.7
		Magnesium	22	-1.39	.035	.81	16.8
		Chloride	22	-1.50	.022	.82	17.5
		Sulfate	22	-14.61	.264	.92	10.6
		Bicarbonate	22	31.42	.228	.83	11.5
07099200	Arkansas River near Portland	Sodium	171	-5.26	.057	.92	11.3
		Calcium	171	2.24	.109	.95	7.2
		Magnesium	171	-3.13	.041	.92	11.2
		Chloride	171	-1.84	.020	.84	16.9
		Sulfate	171	-44.90	.349	.94	10.7
		Bicarbonate	171	36.28	.219	.86	9.9
07099400	Arkansas River above Pueblo	Sodium	56	-9.98	0.066	0.94	10.7
		Calcium	56	7.60	.099	.92	8.4
		Magnesium	56	-3.84	.044	.89	13.3
		Chloride	56	-2.53	.020	.89	14.4
		Sulfate	56	-70.51	.405	.96	9.5
		Bicarbonate	56	57.97	.177	.79	10.9
07099500	Arkansas River near Pueblo	Sodium	42	-12.74	.073	.96	9.8
		Calcium	42	13.29	.091	.95	6.1
		Magnesium	42	-7.83	.049	.94	11.4
		Chloride	42	-1.75	.019	.71	24.3
		Sulfate	42	-69.97	.411	.97	8.2
		Bicarbonate	42	56.61	.166	.70	13.4

Table 8.--*Relations of specific conductance to major-ion concentrations for stations along the Arkansas River and tributaries*--Continued

Station number	Station name	Ion	Number of values	Regression coefficients in the equation Ion = a + $b(SC_m)$		Coefficient of determination (r^2)	Standard error (percent)
				a	*b*		
07103700	Fountain Creek near Colorado Springs	Sodium	26	-2.15	.069	.92	12.9
		Calcium	26	3.00	.098	.94	9.6
		Magnesium	26	-0.25	.022	.94	10.1
		Chloride	26	-3.75	.054	.74	30.1
		Sulfate	26	6.33	.035	.80	12.8
		Bicarbonate	26	-0.99	.450	.93	11.1
07105800	Fountain Creek at Security	Sodium	29	-13.13	.106	.97	5.4
		Calcium	29	7.33	.066	.91	7.7
		Magnesium	29	-1.16	.024	.97	5.2
		Chloride	29	-11.14	.059	.89	12.9
		Sulfate	29	-6.61	.230	.94	7.5
		Bicarbonate	29	-4.65	.223	.74	17.2
07106300	Fountain Creek near Pinon	Sodium	46	-2.03	.096	.83	17.9
		Calcium	46	1.49	.092	.81	18.8
		Magnesium	46	-4.56	.029	.95	10.9
		Chloride	46	-2.25	.038	.73	25.5
		Sulfate	46	-28.10	.345	.86	17.0
		Bicarbonate	46	30.87	.163	.64	24.3
07106500	Fountain Creek at Pueblo	Sodium	61	-27.52	.114	.96	9.2
		Calcium	61	22.84	.077	.88	12.3
		Magnesium	61	-54.63	.064	.94	16.9
		Chloride	61	18.75	.019	.71	16.3
		Sulfate	61	-341.32	.591	.97	8.8
		Bicarbonate	61	186.33	.040	.27	18.9
07109500	Arkansas River near Avondale	Sodium	14	-18.36	0.085	0.94	14.9
		Calcium	14	17.22	.080	.90	10.0
		Magnesium	14	-1.90	.034	.97	7.2
		Chloride	14	-9.17	.036	.94	16.1
		Sulfate	14	-27.22	.343	.96	9.0
07117000	Arkansas River near Nepesta	Sodium	31	-17.58	.081	.96	8.3
		Calcium	31	11.23	.096	.96	5.7
		Magnesium	31	-7.43	.045	.94	10.4
		Chloride	31	-4.63	.029	.90	13.2
		Sulfate	31	-87.94	.443	.98	6.3
		Bicarbonate	31	67.82	.119	.72	11.4
07119500	Apishipa River near Fowler	Sodium	35	3.66	.052	.88	15.1
		Calcium	35	-76.36	.189	.95	12.8
		Magnesium	35	-16.40	.050	.96	10.5
		Chloride	35	4.77	.015	.79	18.4
		Sulfate	35	-383.59	.733	.99	7.2
		Bicarbonate	35	147.61	.033	.40	15.2
07122000	Arkansas River near La Junta	Sodium	38	-29.22	.093	.95	8.4
		Calcium	38	5.45	.107	.96	5.9
		Magnesium	38	-10.66	.047	.96	7.5
		Chloride	38	-6.12	.027	.85	15.0
		Sulfate	38	-159.35	.536	.98	5.4
		Bicarbonate	38	91.17	.091	.77	9.6

Table 8.--*Relations of specific conductance to major-ion concentrations for stations along the Arkansas River and tributaries*--Continued

Station number	Station name	Ion	Number of values	Regression coefficients in the equation Ion = a + $b(SC_m)$ a	b	Coefficient of determination (r^2)	Standard error (percent)
07124000	Arkansas River at Las Animas	Sodium	52	-62.57	.128	.96	7.7
		Calcium	52	16.29	.095	.92	8.5
		Magnesium	52	-16.65	.045	.91	10.8
		Chloride	52	-11.77	.033	.89	12.5
		Sulfate	52	-246.36	.597	.99	3.3
		Bicarbonate	52	150.88	.037	.54	11.7
07124050	Middle Fork Purgatoire River at Stonewall	Sodium	11	-4.85	.046	.44	46.4
		Calcium	11	4.26	.116	.79	13.3
		Magnesium	11	-1.96	.032	.91	11.3
		Chloride	11	-.27	.006	.56	30.7
		Sulfate	11	-15.57	.188	.82	18.4
07124200	Purgatoire River at Madrid	Sodium	10	-9.43	0.069	0.86	19.5
		Calcium	10	14.18	.084	.93	5.8
		Magnesium	10	-.64	.030	.95	7.4
		Chloride	10	-.65	.008	.77	21.9
		Sulfate	10	-13.63	.157	.73	24.4
07126300	Purgatoire River near Thatcher	Sodium	13	-23.87	.083	.98	8.9
		Calcium	13	-2.18	.097	.95	11.8
		Magnesium	13	-29.87	.077	.98	8.9
		Chloride	13	-4.27	.012	.92	16.6
		Sulfate	13	-243.38	.656	.98	8.8
		Bicarbonate	13	120.41	.049	.60	18.7
07128500	Purgatoire River near Las Animas	Sodium	42	-116.16	.147	.96	9.0
		Calcium	42	56.43	.074	.84	11.5
		Magnesium	42	-33.56	.059	.95	8.6
		Chloride	42	-8.84	.028	.72	22.3
		Sulfate	42	-352.92	.663	.99	4.1
		Bicarbonate	42	168.49	.030	.36	16.4
07130500	Arkansas River below John Martin Reservoir	Sodium	298	-61.04	.131	.92	12.3
		Calcium	298	47.78	.076	.88	10.8
		Magnesium	298	-13.20	.047	.90	13.4
		Chloride	298	-15.84	.036	.83	19.3
		Sulfate	298	-116.68	.548	.93	10.3
		Bicarbonate	298	91.42	.064	.55	22.2
07133000	Arkansas River at Lamar	Sodium	26	-104.07	.160	.97	7.6
		Calcium	26	37.65	.075	.99	3.8
		Magnesium	26	-16.91	.048	.96	8.4
		Chloride	26	-23.56	.040	.99	4.8
		Sulfate	26	-246.54	.621	.98	5.7
		Bicarbonate	26	130.56	.034	.69	11.9
07137500	Arkansas River near Coolidge, Kans.	Sodium	104	-59.67	.142	.88	10.2
		Calcium	104	42.80	.076	.88	8.0
		Magnesium	104	11.49	.036	.74	13.3
		Chloride	104	-22.26	.044	.72	17.5
		Sulfate	104	-48.78	.543	.88	9.2
		Bicarbonate	104	166.45	.023	.26	14.8

are along the Arkansas River, four stations are along Fountain Creek, four stations are along the Purgatoire River, two stations are mine drainages, and two stations are along other tributaries to the Arkansas River. Relations of specific conductance to major-ion concentrations have been developed previously for 19 stations in the basin by Gaydos (1980), but because additional data are available at many of these stations, updated regression relations are included in table 8 for all 26 stations. All the regressions included in table 8 are significant at the 99-percent confidence level. Examples of the relations of specific conductance to major-ion concentrations are shown in figures 18 and 19 for the Arkansas River at Canon City.

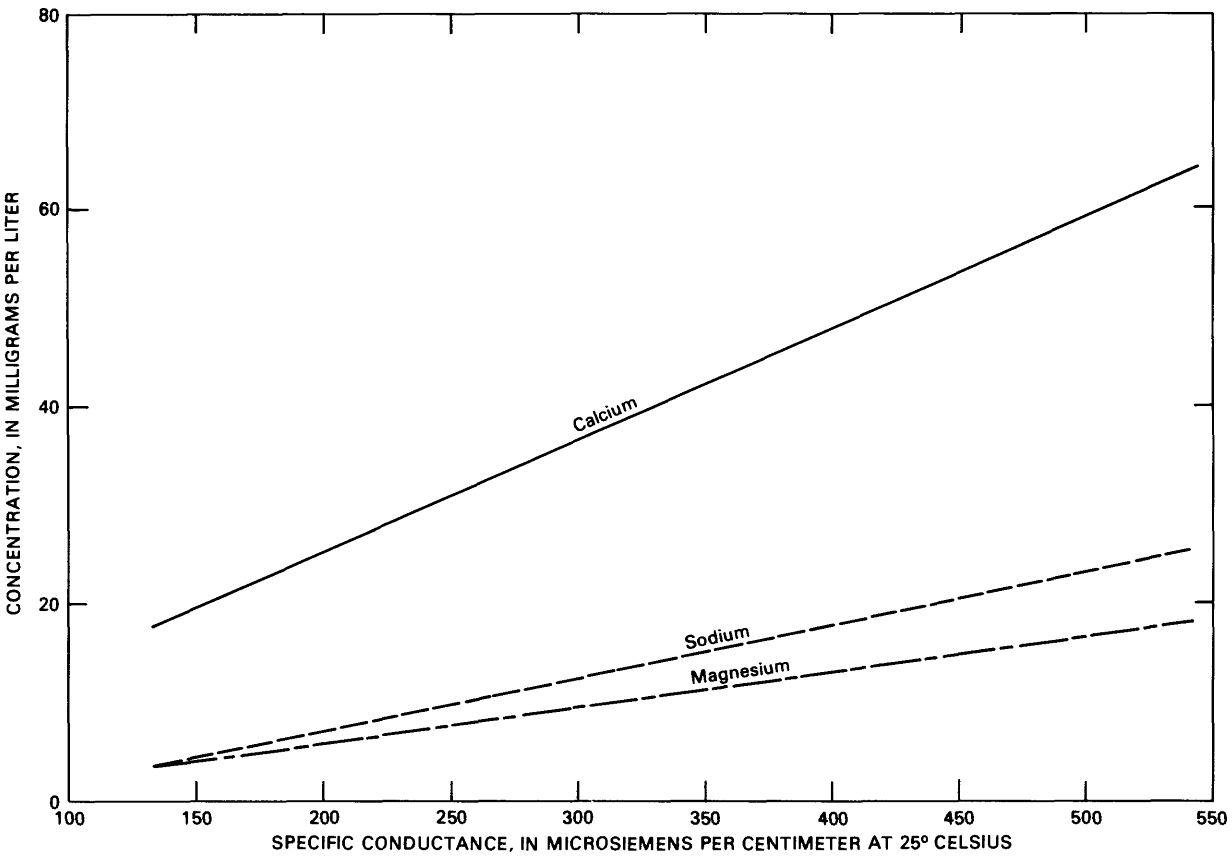

Figure 18.--Relations of specific conductance to major-cation concentrations for the Arkansas River at Canon City.

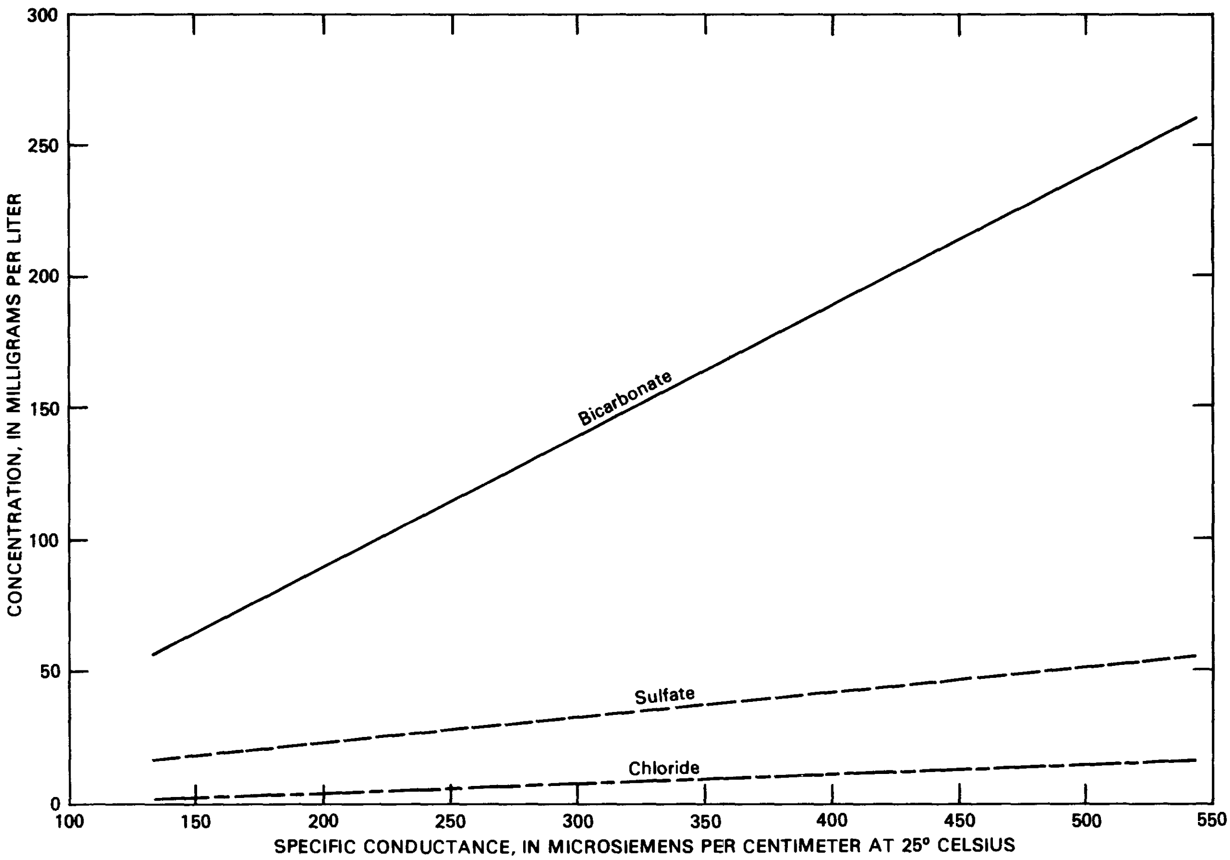

Figure 19.--Relations of specific conductance to major-anion concentrations for the Arkansas River at Canon City.

Ground Water in Alluvial Aquifers along the Arkansas River

Relations of specific conductance to major-ion concentrations were determined for alluvial aquifers in the reaches upstream and downstream from Pueblo using least-squares regression. The regression coefficients and related statistical data for the two reaches are given in table 9. Although all the regressions are significant at the 99-percent confidence level, estimates of chloride concentrations of water in the alluvial aquifers upstream from Pueblo may have considerable error. The relations are plotted in figures 20 and 21.

DISSOLVED-SOLIDS LOADS AT SELECTED ARKANSAS RIVER STATIONS

Dissolved-solids loads were calculated for three Arkansas River stations where daily specific-conductance and streamflow data were available for 10 years or more. The stations are Arkansas River above Pueblo, Arkansas River below John Martin Reservoir, and Arkansas River near Coolidge, Kans.

Table 9.--*Relations of specific conductance to major-ion concentrations for ground water in alluvial aquifers along the Arkansas River*

[SC_m, measured specific conductance in microsiemens per centimeter at 25 degrees Celsius]

Ion	Number of values	Regression coefficients in the equation Ion = $a + b(SC_m)$		Coefficient of determination (r^2)	Standard error (percent)
		a	*b*		
ALLUVIAL AQUIFERS UPSTREAM FROM PUEBLO					
Sodium	80	-5.69	0.064	0.64	89.3
Calcium	80	-3.06	.131	.92	29.5
Magnesium	80	-4.69	.041	.81	62.5
Chloride	80	0.09	.018	.19	192.6
Sulfate	80	-121.41	.496	.85	96.4
Bicarbonate	80	98.65	.131	.38	42.4
ALLUVIAL AQUIFERS DOWNSTREAM FROM PUEBLO					
Sodium	152	-132.70	.150	.88	18.9
Calcium	152	69.37	.077	.70	17.6
Magnesium	152	-18.10	.047	.78	22.2
Chloride	152	-24.35	.037	.76	26.7
Sulfate	152	-292.41	.608	.98	6.9
Bicarbonate	152	189.26	.037	.31	19.0

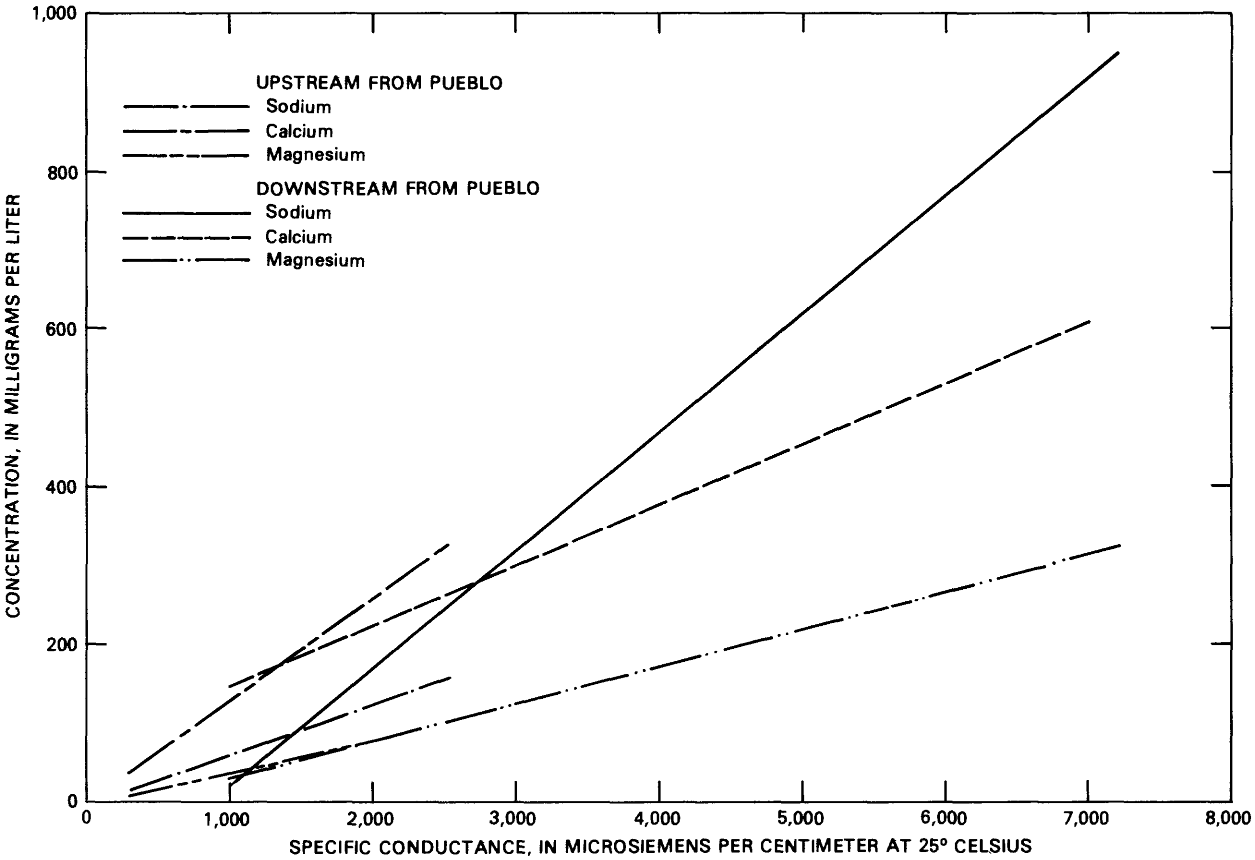

Figure 20.--Relations of specific conductance to major-cation concentrations for ground water in alluvial aquifers along the Arkansas River.

The dissolved-solids loads were calculated from daily specific-conductance and streamflow measurements using the equations relating specific conductance to dissolved-solids concentration that are listed in table 6 for the three stations. The calculated dissolved-solids loads are given in table 10, and a statistical summary of the values is given in table 11. Because the periods of record for the three stations are different, direct comparison of mean values is not appropriate. Comparisons between monthly dissolved-solids loads at the stations can be made using table 11 or figure 22. During periods where the three records overlap (1965-68 and 1976-81), the dissolved-solids load downstream from John Martin Reservoir is about twice the load upstream from Pueblo. Most of the difference between the stations probably is caused by dissolved solids contributed by Fountain Creek and the Purgatoire River. Dissolved-solids loads at Coolidge, Kans., during the period when records overlap, are about 10 percent smaller than those downstream from John Martin Reservoir. However, this difference is caused, in part, by dissolved solids diverted from the river by Frontier Ditch, just upstream from the gage at Coolidge, Kans.

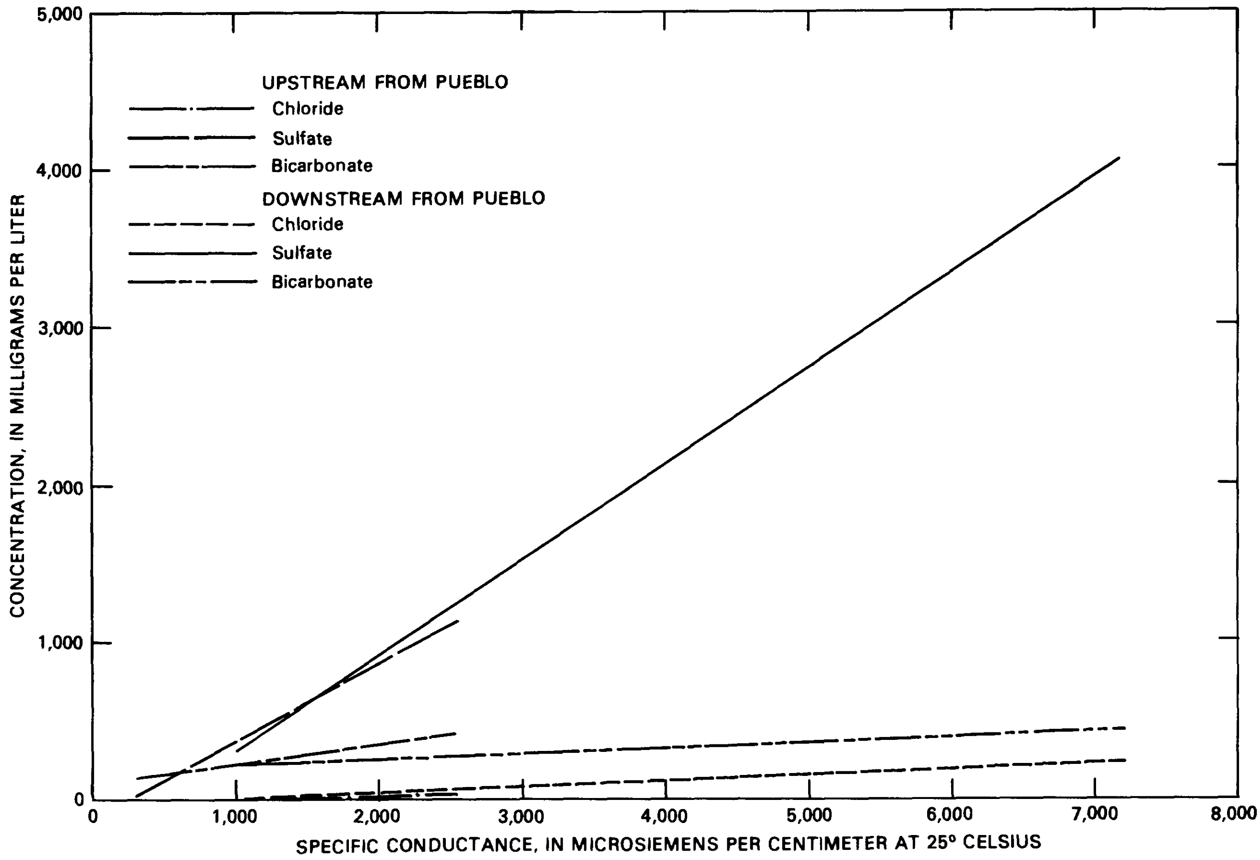

Figure 21.--Relations of specific conductance to major-anion concentrations for ground water in alluvial aquifers along the Arkansas River.

AREAL VARIATIONS IN CONCENTRATION AND PERCENTAGE OF MAJOR IONS

Just as large areal variations in specific conductance occur in the Arkansas River basin, such variations also occur in the concentration of the major ions in water. The major ions discussed are the cations, sodium, potassium, calcium, and magnesium, and the anions, chloride, fluoride, sulfate, and bicarbonate. Variations in the percentage of the ions that make up the total cations or anions also were considered. All percentages given for major ions were calculated as a percentage of total milliequivalents. Fewer data are available for the major ions than for specific conductance, but sufficient data are available to characterize areal variations, especially in the Arkansas River and the adjacent alluvial aquifers.

Table 10.--*Monthly dissolved-solids loads at selected Arkansas River stations*

[Dash indicates data not available]

Year	Month	Calculated load (tons per month) Station 07099400 Arkansas River above Pueblo	Station 07130500 Arkansas River below John Martin Reservoir	Station 07137500 Arkansas River near Coolidge, Kans.	Year	Month	Calculated load (tons per month) Station 07099400 Arkansas River above Pueblo	Station 07130500 Arkansas River below John Martin Reservoir	Station 07137500 Arkansas River near Coolidge, Kans.	Year	Month	Calculated load (tons per month) Station 07099400 Arkansas River above Pueblo	Station 07130500 Arkansas River below John Martin Reservoir	Station 07137500 Arkansas River near Coolidge, Kans.
1952	Jan.	-	1,300	-	1956	Jan.	-	830	-	1960	Jan.	-	860	-
	Feb.	-	1,100	-		Feb.	-	800	-		Feb.	-	970	-
	Mar.	-	1,500	-		Mar.	-	690	-		Mar.	-	890	-
	Apr.	-	85,200	-		Apr.	-	140,000	-		Apr.	-	25,300	-
	May	-	130,000	-		May	-	30,500	-		May	-	168,000	-
	June	-	46,500	-		Jun.	-	28,500	-		Jun.	-	41,600	-
	July	-	34,700	-		Jul.	-	39,300	-		Jul.	-	49,800	-
	Aug.	-	35,500	-		Aug.	-	38,600	-		Aug.	-	5,300	-
	Sept.	-	26,700	-		Sept.	-	11,300	-		Sept.	-	7,400	-
	Oct.	-	15,200	-		Oct.	-	5,800	-		Oct.	-	17,900	-
	Nov.	-	15,400	-		Nov.	-	7,300	-		Nov.	-	13,200	-
	Dec.	-	830	-		Dec.	-	1,800	-		Dec.	-	890	-
1953	Jan.	-	930	-	1957	Jan.	-	530	-	1961	Jan.	-	980	-
	Feb.	-	730	-		Feb.	-	530	-		Feb.	-	1,000	-
	Mar.	-	2,400	-		Mar.	-	460	-		Mar.	-	1,000	-
	Apr.	-	102,000	-		Apr.	-	53,100	-		Apr.	-	106,000	-
	May	-	40,100	-		May	-	28,100	-		May	-	20,500	-
	June	-	41,900	-		Jun.	-	19,700	-		June	-	27,800	-
	July	-	71,700	-		July	-	61,800	-		July	-	45,200	-
	Aug.	-	53,100	-		Aug.	-	53,200	-		Aug.	-	48,400	-
	Sept.	-	12,800	-		Sept.	-	21,800	-		Sept.	-	37,300	-
	Oct.	-	8,100	-		Oct.	-	21,100	-		Oct.	-	42,700	-
	Nov.	-	10,100	-		Nov.	-	1,300	-		Nov.	-	1,800	-
	Dec.	-	620	-		Dec.	-	1,200	-		Dec.	-	1,000	-
1954	Jan.	-	620	-	1958	Jan.	-	1,700	-	1962	Jan.	-	880	-
	Feb.	-	460	-		Feb.	-	1,300	-		Feb.	-	1,000	-
	Mar.	-	550	-		Mar.	-	1,400	-		Mar.	-	1,400	-
	Apr.	-	73,600	-		Apr.	-	5,000	-		Apr.	-	155,000	-
	May	-	26,500	-		May	-	12,200	-		May	-	59,600	-
	June	-	9,100	-		June	-	38,600	-		June	-	48,200	-
	July	-	27,500	-		July	-	49,800	-		July	-	53,800	-
	Aug.	-	74,900	-		Aug.	-	82,500	-		Aug.	-	40,600	-
	Sept.	-	26,900	-		Sept.	-	74,200	-		Sept.	-	11,600	-
	Oct.	-	6,300	-		Oct.	-	52,100	-		Oct.	-	16,600	-
	Nov.	-	5,700	-		Nov.	-	2,100	-		Nov.	-	11,400	-
	Dec.	-	6,300	-		Dec.	-	1,800	-		Dec.	-	1,100	-
1955	Jan.	-	740	-	1959	Jan.	-	2,200	-	1963	Jan.	-	1,200	-
	Feb.	-	470	-		Feb.	-	1,700	-		Feb.	-	970	-
	Mar.	-	2,300	-		Mar.	-	1,700	-		Mar.	-	3,000	-
	Apr.	-	31,300	-		Apr.	-	67,700	-		Apr.	-	106,000	-
	May	-	17,000	-		May	-	89,500	-		May	-	22,700	-
	June	-	41,200	-		June	-	90,700	-		June	-	21,900	-
	July	-	112,000	-		July	-	134,200	-		July	-	11,100	-
	Aug.	-	115,000	-		Aug.	-	136,000	-		Aug.	-	28,300	-
	Sept.	-	90,700	-		Sept.	-	75,100	-		Sept.	-	30,900	-
	Oct.	-	37,500	-		Oct.	-	18,800	-		Oct.	-	10,000	-
	Nov.	-	1,500	-		Nov.	-	1,100	-		Nov.	-	10,300	2,300
	Dec.	-	670	-		Dec.	-	930	-		Dec.	-	3,000	11,600

Table 10.--*Monthly dissolved-solids loads at selected Arkansas River stations*--Continued

Year	Month	Calculated load (tons per month)		
		Station 07099400 Arkansas River above Pueblo	Station 07130500 Arkansas River below John Martin Reservoir	Station 07137500 Arkansas River near Coolidge, Kans.
1964	Jan.	-	990	17,500
	Feb.	-	790	19,400
	Mar.	-	970	15,900
	Apr.	-	50,700	18,800
	May	-	17,800	34,900
	June	-	28,200	55,600
	July	-	18,400	4,000
	Aug.	-	18,600	580
	Sep.	-	10,000	380
	Oct.	-	8,300	1,100
	Nov.	-	6,600	5,700
	Dec.	-	4,000	6,800
1965	Jan.	-	570	6,800
	Feb.	-	3,600	8,300
	Mar.	-	4,100	9,700
	Apr.	-	29,900	5,800
	May	-	26,600	8,600
	June	-	18,700	459,000
	July	-	43,300	90,700
	Aug.	-	110,000	157,000
	Sept.	-	47,800	132,000
	Oct.	10,100	12,000	55,200
	Nov.	13,800	20,400	56,900
	Dec.	16,500	27,600	62,200
1966	Jan.	12,600	22,200	53,000
	Feb.	9,600	56,100	96,700
	Mar.	6,800	20,000	80,700
	Apr.	9,300	52,900	74,200
	May	13,800	90,000	74,800
	June	14,300	85,700	80,800
	July	15,600	110,000	72,808
	Aug.	15,700	52,300	70,000
	Sept.	5,700	48,300	62,700
	Oct.	5,700	26,200	55,300
	Nov.	5,000	4,000	34,200
	Dec.	8,300	1,900	20,600
1967	Jan.	9,600	1,100	40,800
	Feb.	6,300	1,700	38,000
	Mar.	3,700	3,200	31,000
	Apr.	2,200	138,000	78,300
	May	9,100	109,000	91,200
	June	14,600	19,100	70,900
	July	17,500	61,600	53,300
	Aug.	13,600	110,000	79,800
	Sept.	11,800	64,600	71,300
	Oct.	5,300	67,000	68,000
	Nov.	5,800	3,600	41,800
	Dec.	9,000	1,400	40,500

Year	Month	Calculated load (tons per month)		
		Station 07099400 Arkansas River above Pueblo	Station 07130500 Arkansas River below John Martin Reservoir	Station 07137500 Arkansas River near Coolidge, Kans.
1968	Jan.	10,200	690	43,500
	Feb.	7,900	880	36,700
	Mar.	5,300	1,700	19,400
	Apr.	7,200	161,000	87,700
	May	8,300	21,200	25,800
	June	15,200	38,700	42,900
	July	13,200	39,100	23,500
	Aug.	16,700	52,800	47,300
	Sept.	6,700	25,500	12,300
	Oct.	4,400	18,800	-
	Nov.	6,900	8,300	-
	Dec.	6,700	2,000	-
1969	Jan.	6,900	550	-
	Feb.	4,300	2,700	-
	Mar.	3,900	1,000	-
	Apr.	3,000	15,400	-
	May	13,500	111,000	-
	June	21,200	58,700	-
	July	22,900	73,000	-
	Aug.	17,300	43,800	-
	Sept.	9,300	17,400	-
	Oct.	16,000	6,300	-
	Nov.	13,500	1,100	-
	Dec.	11,200	1,000	-
1970	Jan.	11,000	960	-
	Feb.	7,200	900	-
	Mar.	4,900	2,900	-
	Apr.	11,200	49,100	-
	May	21,900	206,700	-
	June	29,700	41,600	-
	July	20,300	63,300	-
	Aug.	14,800	56,200	-
	Sept.	13,300	45,200	-
	Oct.	9,800	29,700	-
	Nov.	9,800	10,200	-
	Dec.	9,800	18,900	-
1971	Jan.	9,400	1,100	-
	Feb.	6,200	1,500	-
	Mar.	7,300	6,700	-
	Apr.	8,600	146,000	-
	May	11,300	34,000	-
	June	22,400	55,200	-
	July	18,100	47,600	-
	Aug.	15,700	35,900	-
	Sept.	9,300	22,100	-
	Oct.	9,100	27,900	-
	Nov.	14,500	6,400	-
	Dec.	13,700	750	-

Year	Month	Calculated load (tons per month)		
		Station 07099400 Arkansas River above Pueblo	Station 07130500 Arkansas River below John Martin Reservoir	Station 07137500 Arkansas River near Coolidge, Kans.
1972	Jan.	12,500	840	-
	Feb.	10,800	850	-
	Mar.	6,700	4,600	-
	Apr.	8,700	103,000	-
	May	12,000	17,200	-
	June	19,700	35,700	-
	July	14,700	33,100	-
	Aug.	12,700	20,400	-
	Sept.	6,800	23,300	-
	Oct.	5,600	8,200	-
	Nov.	10,500	630	-
	Dec.	11,300	530	-
1973	Jan.	10,500	650	-
	Feb.	7,700	550	-
	Mar.	6,500	560	-
	Apr.	9,000	600	-
	May	20,800	82,100	-
	June	25,200	94,500	-
	July	25,000	35,400	-
	Aug.	16,400	30,700	-
	Sept.	9,300	13,500	-
	Oct.	7,200	27,300	-
	Nov.	9,500	5,000	-
	Dec.	11,800	840	-
1974	Jan.	9,100	750	-
	Feb.	7,200	640	-
	Mar.	5,700	1,100	-
	Apr.	5,100	80,300	-
	May	23,700	20,400	-
	June	12,500	32,000	-
	July	12,000	8,400	-
	Aug.	8,400	2,800	-
	Sept.	5,600	920	-
	Oct.	4,500	1,500	-
	Nov.	7,100	1,400	-
	Dec.	6,200	1,500	-
1975	Jan.	8,500	280	-
	Feb.	7,700	350	-
	Mar.	6,800	960	-
	Apr.	9,300	14,800	-
	May	17,900	9,000	-
	June	28,600	22,700	-
	July	25,800	21,800	-
	Aug.	16,500	22,900	-
	Sept.	7,900	6,100	-
	Oct.	5,100	5,800	-
	Nov.	8,500	4,600	-
	Dec.	3,400	350	-

Table 10.--*Monthly dissolved-solids loads at selected Arkansas River stations*--Continued

Year	Month	Calculated load (tons per month) Station 07099400 Arkansas River above Pueblo	Station 07130500 Arkansas River below John Martin Reservoir	Station 07137500 Arkansas River near Coolidge, Kans.
1976	Jan.	3,100	360	9,800
	Feb.	3,600	1,300	8,900
	Mar.	6,100	2,900	9,400
	Apr.	17,000	50,900	16,900
	May	28,400	13,000	12,300
	June	30,300	23,100	8,400
	July	16,600	12,600	4,000
	Aug.	20,900	15,000	14,400
	Sept.	11,600	6,900	2,900
	Oct.	13,100	20,400	3,800
	Nov.	6,700	110	1,800
	Dec.	4,900	100	2,800
1977	Jan.	3,300	100	3,300
	Feb.	3,300	110	3,000
	Mar.	5,400	3,500	4,000
	Apr.	12,100	53,900	14,800
	May	20,600	13,900	13,100
	June	28,500	9,200	7,100
	July	18,200	12,100	2,400
	Aug.	9,700	31,100	13,400
	Sept.	6,000	5,300	2,700
	Oct.	6,300	3,000	580
	Nov.	8,400	4,700	850
	Dec.	8,600	2,100	1,600
1978	Jan.	8,500	820	2,300
	Feb.	6,900	950	1,700
	Mar.	3,900	1,700	2,400
	Apr.	5,500	29,100	7,200
	May	14,500	12,800	8,600
	June	38,100	30,800	25,300
	July	18,500	42,500	18,200
	Aug.	12,100	20,200	10,100
	Sept.	3,800	6,900	2,000
	Oct.	3,700	4,600	630
	Nov.	2,700	3,200	510
	Dec.	2,500	2,500	1,300
1979	Jan.	2,600	1,000	1,100
	Feb.	2,400	280	1,900
	Mar.	9,600	380	3,100
	Apr.	10,300	29,400	3,100
	May	40,400	28,400	2,800
	June	44,400	36,100	9,900
	July	22,500	33,600	11,300
	Aug.	18,200	32,800	3,100
	Sep.	8,200	12,500	990
	Oct.	10,400	6,200	740
	Nov.	11,000	2,700	1,700
	Dec.	2,100	510	2,000
1980	Jan.	2,000	230	5,300
	Feb.	4,400	230	10,200
	Mar.	9,400	250	9,400
	Apr.	20,600	32,000	31,800
	May	83,000	33,200	39,000
	June	73,900	117,300	44,200
	July	25,200	118,000	83,300
	Aug.	23,400	59,700	43,700
	Sept.	13,200	27,700	3,100
	Oct.	10,800	28,000	8,400
	Nov.	6,100	1,400	11,200
	Dec.	2,600	300	22,500
1981	Jan.	2,900	310	23,500
	Feb.	4,100	280	17,800
	Mar.	8,300	420	18,000
	Apr.	12,400	52,700	3,600
	May	17,400	59,900	9,400
	June	39,300	59,900	8,800
	July	24,100	105,400	36,300
	Aug.	19,400	63,300	22,600
	Sept.	12,500	47,500	11,200
	Oct.	9,000	-	-
	Nov.	7,600	-	-
	Dec.	2,800	-	-
1982	Jan.	3,700	-	-
	Feb.	3,700	-	-
	Mar.	7,500	-	-
	Apr.	14,100	-	-
	May	25,100	-	-
	June	43,700	-	-
	July	30,300	-	-
	Aug.	35,900	-	-
	Sept.	19,200	-	-

Table 11.--*Statistical summary of monthly dissolved-solids loads at selected Arkansas River stations*

Month	Number of values	Dissolved-solids load (tons per month) Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
STATION 07099400, ARKANSAS RIVER ABOVE PUEBLO								
January	17	7,400	3,700	2,000	3,200	8,500	10,400	12,600
February	17	6,100	2,400	2,400	3,900	6,300	7,700	10,800
March	17	6,300	1,800	3,700	5,100	6,500	7,400	9,600
April	17	9,700	4,700	2,200	6,400	9,300	12,300	20,600
May	17	22,400	17,500	8,300	12,800	17,900	24,400	83,000
June	17	29,500	15,300	12,500	17,500	28,500	38,700	73,900
July	17	20,000	5,000	12,000	16,100	18,500	24,600	30,300
August	17	16,900	6,200	8,400	13,100	16,400	18,800	35,900
September	17	9,400	3,800	3,800	6,300	9,300	12,100	19,200
October	17	8,000	3,400	3,700	5,200	7,200	10,300	16,000
November	17	8,700	3,300	2,700	6,400	8,400	10,800	14,500
December	17	7,700	4,300	2,100	3,100	8,300	11,300	16,500
All months	204	12,700	10,500	2,000	6,600	9,700	15,700	83,000
STATION 07130500, ARKANSAS RIVER BELOW JOHN MARTIN RESERVOIR								
January	30	1,500	3,900	100	570	830	1,000	22,200
February	30	2,800	10,100	110	520	890	1,300	56,100
March	30	2,500	3,600	250	840	1,500	3,000	20,000
April	30	68,100	46,700	600	29,800	53,000	104,000	161,000
May	30	51,700	50,200	9,000	17,600	28,200	83,900	207,000
June	30	42,100	25,800	9,100	23,000	37,400	50,000	117,000
July	30	52,300	33,900	8,400	31,700	44,200	65,400	134,000
August	30	49,700	33,200	2,800	26,900	42,200	60,600	136,000
September	30	28,600	23,500	920	10,900	22,700	45,700	90,700
October	30	20,300	16,800	1,500	6,300	17,300	27,900	67,000
November	30	5,600	4,900	110	1,500	4,300	8,800	20,400
December	30	2,900	5,800	100	730	1,100	2,000	27,600
All months	360	27,300	35,300	100	1,410	13,100	39,900	207,000
STATION 07137500, ARKANSAS RIVER NEAR COOLIDGE, KANS.								
January	11	18,800	18,800	1,100	3,300	9,800	40,800	53,000
February	11	22,000	27,800	1,700	3,000	10,200	36,700	96,700
March	11	18,500	22,300	2,400	4,000	9,700	19,400	80,700
April	11	31,100	32,700	3,100	5,800	16,900	74,200	87,700
May	11	29,100	29,200	2,800	8,600	13,100	39,000	91,200
June	11	73,900	130,200	7,100	8,800	42,900	70,900	459,000
July	11	36,300	33,400	2,400	4,000	23,500	72,800	90,700
August	11	42,000	46,500	580	10,100	22,600	70,000	157,000
September	11	27,400	43,000	380	2,000	3,100	62,700	132,000
October	9	21,500	28,800	580	690	3,800	55,200	68,000
November	10	15,700	20,700	510	1,500	4,000	36,100	56,900
December	10	17,200	20,200	1,300	1,900	9,200	27,000	62,200
All months	128	29,800	48,700	380	3,400	12,300	42,600	459,000

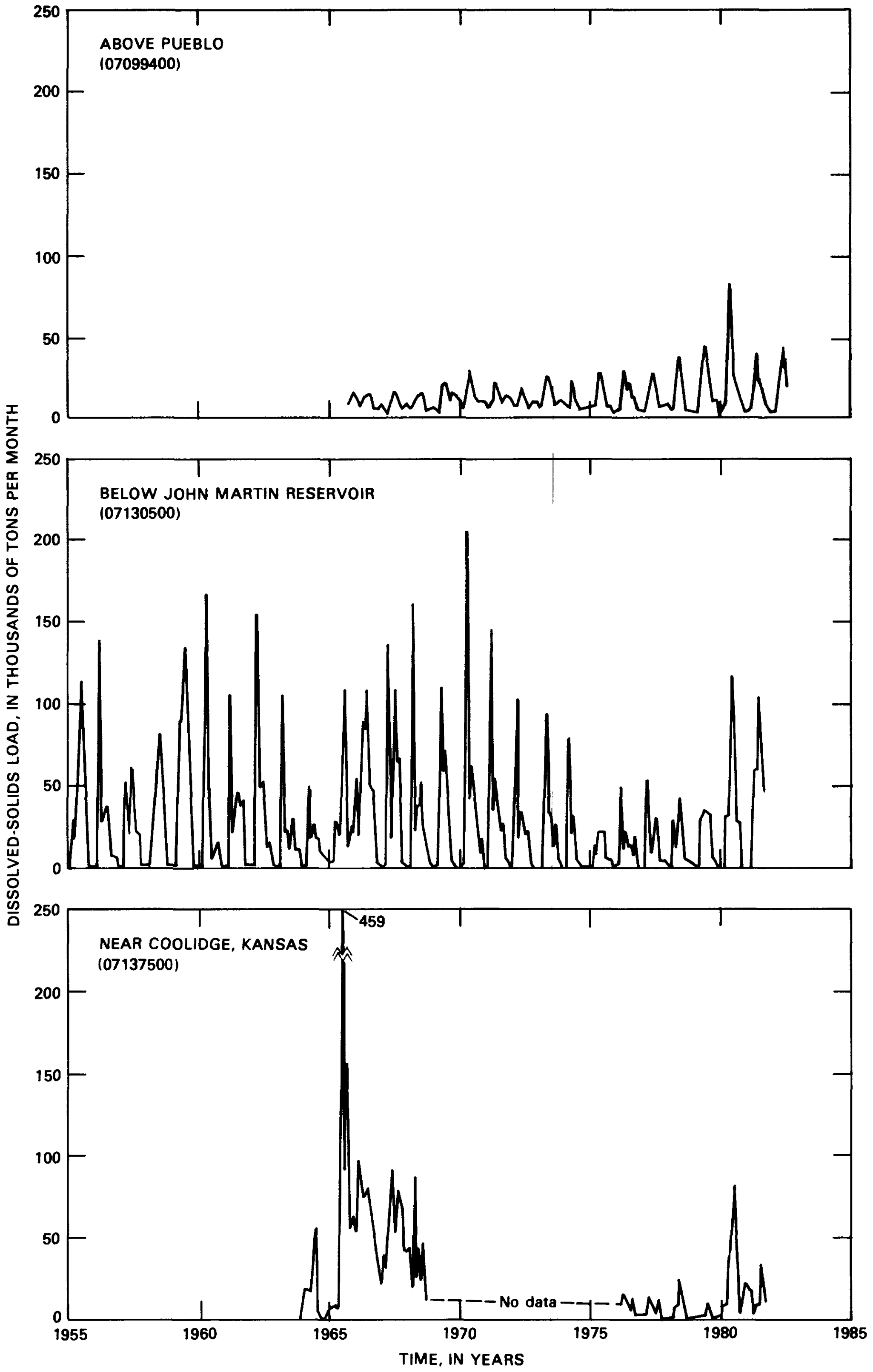

Figure 22.--Monthly dissolved-solids loads at selected Arkansas River stations.

Arkansas River and Tributaries

Sufficient data to make a statistical summary of major-ion concentrations are available at 27 stations, including 15 stations along the Arkansas River, 4 stations along Fountain Creek, 4 stations along the Purgatoire River, 2 mine-drainage stations, and 2 stations on other tributaries near their mouths (table 12). The available major-ion data at all stations cover a broad range of flow conditions, and as such, represent a reasonable approximation of expected conditions. Areal variations in the concentration of major ions and the percentage of the cations or anions that are contributed by each major ion are most pronounced for the stations on the Arkansas River, but similar trends exist for Fountain Creek and the Purgatoire River. Downstream variations in the concentration and percentage of the eight major ions in the Arkansas River are shown in figures 23 to 30.

The mean concentrations of all eight major ions increase downstream. The increases for most of the ions are largest between La Junta and Lamar, corresponding to a large increase in specific conductance (fig. 3) and a large decrease in Arkansas River streamflow (Cain, 1985). According to Cain, much of the Arkansas River flow downstream from La Junta, especially when streamflow is average or less than average, is irrigation-return flow during much of the year. Irrigation-return flow generally will have larger concentrations of major ions than upstream Arkansas River flows.

Variations in the percentage of the various major ions provide information about changes in the relative contribution of each ion to the dissolved solids in the water. Sodium made up an increasingly larger part of the cations downstream, increasing from only about 10 percent near Malta to over 40 percent near the Colorado-Kansas State line. As the percentage of sodium increased, decreases in the percentages of potassium, calcium, and magnesium occurred. These variations affect the suitability of the water for irrigation by increasing the sodium-adsorption ratio from a mean value of about 0.2 near Malta to 5.6 at Coolidge, Kans. Variations in the percentage of anions are characterized by downstream increases in chloride and sulfate and decreases in the percentage of fluoride and bicarbonate. These trends for sulfate and bicarbonate temporarily are reversed in the reach from Arkansas River near Malta, which is affected by mine drainage, to Arkansas River at Canon City where the effects of mine drainage are no longer apparent.

Ground Water in Alluvial Aquifers along the Arkansas River

Sufficient data to make a statistical summary of major-ion concentrations in water in the alluvial aquifers are available for 12 reaches along the Arkansas River (table 13). Downstream variations in the concentration and percentage of major ions in water from alluvial aquifers along the Arkansas River generally are similar to the variations in the Arkansas River (figs. 23-30). However, even though the mean concentrations indicated represent many wells in a given reach, there is considerable variability from reach to reach, and the variations are not as consistent as for the Arkansas River. This variability is caused by the many factors that may affect ground-water quality, including the degree of interaction between surface water and ground

Table 12.--*Summary statistics for major ions at surface-water stations*

Station number	Station name	Number of values	Concentration (milligrams per liter) Mean	Standard devi-ation	Mini-mum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maxi-mum
			SODIUM						
07079200	Leadville Drain at Leadville	27	4.0	0.8	2.4	3.6	4.2	4.6	6.2
07081800	California Gulch at Malta	14	10.1	4.2	5.0	7.2	8.4	13.3	19.0
07083000	Halfmoon Creek near Malta	187	1.5	.5	0.6	1.1	1.5	1.8	3.0
07083700	Arkansas River near Malta	75	3.9	2.7	1.3	2.3	3.5	4.6	21.0
07086000	Arkansas River at Granite	21	4.1	2.8	1.6	2.4	4.1	4.7	15.0
07096000	Arkansas River at Canon City	106	10.9	3.8	3.7	7.0	12.0	14.0	18.0
07097000	Arkansas River at Portland	59	22.9	9.7	5.0	16.0	25.0	28.0	48.0
07099200	Arkansas River near Portland	181	24.4	10.0	5.6	17.0	27.0	32.0	52.0
07099400	Arkansas River above Pueblo	61	30.3	13.2	8.0	18.0	31.0	39.0	72.0
07099500	Arkansas River near Pueblo	50	29.4	14.9	7.0	16.8	30.5	40.3	70.0
07103700	Fountain Creek near Colorado Springs	27	20.7	9.3	5.7	12.0	21.0	25.0	38.0
07105800	Fountain Creek at Security	30	69.2	23.0	15.0	53.8	73.5	86.5	99.0
07106300	Fountain Creek near Pinon	51	92.5	38.5	36.0	56.0	94.0	120.0	170.0
07106500	Fountain Creek at Pueblo	62	199.2	88.6	46.0	130.0	175.0	260.0	500.0
07109500	Arkansas River near Avondale	15	38.5	22.1	17.0	23.0	30.0	68.0	82.0
07117000	Arkansas River near Nepesta	42	48.2	20.9	12.0	32.0	48.5	63.2	91.0
07119500	Apishapa River near Fowler	38	100.4	43.6	24.0	66.0	95.5	145.3	171.0
07122000	Arkansas River near La Junta	45	105.5	42.1	28.0	71.0	110.0	127.5	207.0
07124000	Arkansas River at Las Animas	55	300.0	113.4	56.0	211.0	337.0	376.0	500.0
07124050	Middle Fork Purgatoire River at Stonewall	12	8.5	5.3	2.1	4.6	6.9	11.5	20.0
07124200	Purgatoire River at Madrid	11	15.2	7.7	2.3	7.8	14.0	22.0	26.0
07126300	Purgatoire River near Thatcher	16	153.4	80.3	27.0	98.5	135.0	245.0	270.0
07128500	Purgatoire River near Las Animas	57	387.3	176.2	58.0	236.0	435.0	520.0	721.0
07130500	Arkansas River below John Martin Reservoir	583	302.7	148.8	40.0	155.0	320.0	440.0	653.0
07133000	Arkansas River at Lamar	29	481.5	204.2	57.0	363.0	584.0	636.5	660.0
07137500	Arkansas River near Coolidge, Kans.	159	481.8	161.6	27.0	400.0	560.0	600.0	690.0

Table 12.--*Summary statistics for major ions at surface-water stations*--Continued

Station number	Station name	Number of values	Concentration (milligrams per liter) Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
			POTASSIUM						
07079200	Leadville Drain at Leadville	27	1.3	0.3	0.5	1.1	1.4	1.6	1.8
07081800	California Gulch at Malta	14	3.4	1.1	1.7	2.8	2.9	4.2	5.2
07083000	Halfmoon Creek near Malta	187	0.7	.3	.1	0.5	0.6	0.7	3.6
07083700	Arkansas River near Malta	74	1.1	.8	.4	.7	.9	1.1	4.7
07086000	Arkansas River at Granite	21	1.1	.7	.4	.8	.9	1.1	3.4
07096000	Arkansas River at Canon City	93	1.8	.5	.7	1.4	1.8	2.1	3.4
07097000	Arkansas River at Portland	60	2.4	.7	.8	1.9	2.5	2.9	4.4
07099200	Arkansas River near Portland	175	2.4	.7	1.1	2.0	2.5	2.9	4.5
07099400	Arkansas River above Pueblo	58	2.6	.6	1.3	2.3	2.7	3.0	4.0
07099500	Arkansas River near Pueblo	42	2.6	1.0	.8	2.0	2.5	3.2	7.1
07103700	Fountain Creek near Colorado Springs	27	3.5	.9	1.8	2.5	3.6	4.0	5.3
07105800	Fountain Creek at Security	30	7.2	2.2	.4	6.6	7.6	8.7	10.0
07106300	Fountain Creek near Pinon	50	6.4	1.6	4.0	5.3	6.2	7.4	12.0
07106500	Fountain Creek at Pueblo	62	6.9	1.5	4.3	5.9	6.8	7.7	12.0
07109500	Arkansas River near Avondale	8	3.9	1.1	2.6	2.8	3.9	4.6	5.8
07117000	Arkansas River near Nepesta	34	4.4	1.7	1.6	3.1	4.3	5.4	9.0
07119500	Apishapa River near Fowler	24	5.0	1.3	2.6	4.3	4.7	5.6	8.7
07122000	Arkansas River near La Junta	28	5.9	1.5	2.7	4.8	6.0	6.9	8.2
07124000	Arkansas River at Las Animas	32	5.7	1.0	3.7	5.1	5.7	6.3	8.5
07124050	Middle Fork Purgatoire River at Stonewall	12	1.4	.5	.9	1.0	1.3	1.6	2.7
07124200	Purgatoire River at Madrid	11	1.8	.4	1.1	1.7	1.7	2.2	2.5
07126300	Purgatoire River near Thatcher	16	4.6	1.0	2.8	3.9	4.9	5.1	6.1
07128500	Purgatoire River near Las Animas	26	6.2	1.0	4.5	5.4	6.1	6.9	8.1
07130500	Arkansas River below John Martin Reservoir	189	7.3	1.3	3.1	6.7	7.3	8.0	11.0
07133000	Arkansas River at Lamar	30	8.2	1.7	5.8	7.2	8.2	8.7	14.0
07137500	Arkansas River near Coolidge, Kans.	126	10.8	2.2	5.3	9.7	11.0	12.0	17.0

Table 12.--*Summary statistics for major ions at surface-water stations*--Continued

Station number	Station name	Number of values	Concentration (milligrams per liter) Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
			CALCIUM						
07079200	Leadville drain at Leadville	30	101.6	15.5	55.0	91.0	106.5	110.3	124
07081800	California Gulch at Malta	14	96.5	15.2	84.0	89.8	93.0	96.3	146
07083000	Halfmoon Creek near Malta	189	9.4	2.1	4.5	8.0	10.0	11.0	15
07083700	Arkansas River near Malta	75	21.0	15.4	6.8	13.0	18.0	24.0	95
07086000	Arkansas River at Granite	21	19.1	7.1	10.0	12.0	20.0	22.5	39
07096000	Arkansas River at Canon City	106	33.3	8.0	15.0	27.8	36.5	40.0	45
07097000	Arkansas River at Portland	59	49.1	15.6	20.0	37.0	52.0	60.0	85
07099200	Arkansas River near Portland	181	58.3	18.8	19.0	42.5	63.0	71.0	110
07099400	Arkansas River above Pueblo	58	66.1	19.5	27.0	49.8	70.0	82.0	97
07099500	Arkansas River near Pueblo	51	65.2	22.9	27.0	45.0	69.0	78.0	160
07103700	Fountain Creek near Colorado Springs	31	36.6	12.6	14.0	28.0	40.0	43.0	57
07105500	Fountain Creek at Colorado Springs	15	58.7	17.2	29.0	45.0	64.0	73.0	80
07105800	Fountain Creek at Security	30	58.5	14.8	22.0	51.8	59.5	71.3	88
07106300	Fountain Creek near Pinon	53	91.1	36.3	42.0	64.0	85.0	110.0	260
07106500	Fountain Creek at Pueblo	62	176.5	62.5	48.0	130.0	169.0	232.0	319
07109500	Arkansas River near Avondale	17	65.2	25.3	12.0	44.5	68.0	80.5	110
07117000	Arkansas River near Nepesta	43	85.6	24.9	41.0	64.0	91.0	100.0	124
07119500	Apishapa River near Fowler	36	275.0	149.6	81.0	150.5	216.0	396.5	539
07122000	Arkansas River near La Junta	40	156.0	47.5	67.0	121.0	165.0	186.0	281
07124000	Arkansas River at Las Animas	56	283.8	84.5	94.0	225.3	312.0	357.5	383
07124050	Middle Fork Purgatoire River at Stonewall	12	38.3	10.6	19.0	30.8	42.0	47.3	51
07124200	Purgatoire River at Madrid	11	44.4	9.1	24.0	40.0	47.0	52.0	54
07126300	Purgatoire River near Thatcher	16	205.4	94.3	49.0	150.0	190.0	292.5	350
07128500	Purgatoire River near Las Animas	43	309.2	88.4	128.0	253.0	339.0	361.0	531
07130500	Arkansas River below John Martin Reservoir	550	265.5	89.4	65.0	183.8	287.0	339.0	488
07133000	Arkansas River at Lamar	49	323.8	92.0	91.0	294.0	357.0	380.5	430
07137500	Arkansas River near Coolidge, Kans.	176	339.9	76.9	115.0	310.0	369.5	390.0	450

Table 12.--*Summary statistics for major ions at surface-water stations*--Continued

Station number	Station name	Number of values	Concentration (milligrams per liter) Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
			MAGNESIUM						
07079200	Leadville Drain at Leadville	30	47.9	7.1	36.0	42.8	47.0	51.3	67.0
07081800	California Gulch at Malta	14	53.4	25.0	36.0	42.8	44.5	56.3	136
07083000	Halfmoon Creek near Malta	190	3.6	1.0	1.2	2.9	3.8	4.2	6.8
07083700	Arkansas River near Malta	75	8.5	8.5	2.2	4.5	6.9	8.9	58
07086000	Arkansas River at Granite	21	7.1	2.2	2.9	6.1	7.5	9.1	10
07096000	Arkansas River at Canon City	106	8.5	2.9	3.1	6.4	9.2	10.0	22
07097000	Arkansas River at Portland	59	14.6	5.8	4.7	10.0	16.0	19.0	29
07099200	Arkansas River near Portland	181	18.1	7.2	4.8	12.0	19.0	23.0	38
07099400	Arkansas River above Pueblo	58	22.4	8.9	7.3	14.8	22.5	28.3	46
07099500	Arkansas River near Pueblo	51	19.9	9.9	5.4	11.0	20.0	28.0	46
07103700	Fountain Creek near Colorado Springs	31	7.1	2.7	2.2	5.4	7.8	8.6	12
07105500	Fountain Creek at Colorado Springs	15	14.9	5.3	6.3	10.0	17.0	19.0	22
07105800	Fountain Creek at Security	30	17.2	5.1	4.4	14.0	18.0	21.3	24
07106300	Fountain Creek near Pinon	53	24.5	10.9	8.4	15.5	24.0	32.0	51
07106500	Fountain Creek at Pueblo	62	72.8	50.2	12.0	39.8	51.0	95.5	249
07109500	Arkansas River near Avondale	17	20.9	8.8	11.0	12.0	18.0	30.0	38
07117000	Arkansas River near Nepesta	44	28.0	10.9	9.2	18.5	29.0	35.0	53
07119500	Apishapa River near Fowler	36	77.3	39.6	15.0	49.0	61.5	117.8	148
07122000	Arkansas River near La Junta	42	56.3	20.3	14.0	39.8	60.0	68.3	105
07124000	Arkansas River at Las Animas	56	109.9	40.2	26.0	84.3	113.5	144.0	173
07124050	Middle Fork Purgatoire River at Stonewall	12	7.6	2.8	2.3	5.4	7.7	9.8	12
07124200	Purgatoire River at Madrid	11	10.2	3.2	3.0	9.1	11.0	13.0	14
07126300	Purgatoire River near Thatcher	16	132.6	74.7	20.0	81.5	115.0	210.0	250
07128500	Purgatoire River near Las Animas	43	166.5	65.8	37.0	109.0	182.0	215.0	308
07130500	Arkansas River below John Martin Reservoir	539	117.0	52.5	15.0	65.0	126.0	163.0	219
07133000	Arkansas River at Lamar	49	163.5	56.7	22.0	150.0	190.0	200.0	225
07137500	Arkansas River near Coolidge, Kans.	176	158.2	40.8	33.0	150.0	170.0	180.0	220

Table 12.--*Summary statistics for major ions at surface-water stations*--Continued

Station number	Station name	Number of values	Concentration (milligrams per liter) Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
			CHLORIDE						
07079200	Leadville Drain at Leadville	27	2.6	1.1	0.2	1.8	2.7	3.5	4.0
07081800	California Gulch at Malta	14	6.8	2.9	3.8	4.5	5.7	8.6	14.0
07083000	Halfmoon Creek near Malta	184	0.8	0.6	.0	0.3	0.6	1.1	5.2
07083700	Arkansas River near Malta	75	2.4	2.1	.5	1.4	1.9	2.7	14.0
07086000	Arkansas River at Granite	21	2.6	1.6	.8	1.7	2.8	3.0	8.6
07096000	Arkansas River at Canon City	126	6.6	2.9	1.6	4.3	6.7	8.5	15.0
07097000	Arkansas River at Portland	59	8.5	3.6	1.8	5.3	9.0	11.0	16.0
07099200	Arkansas River near Portland	181	8.6	3.7	1.3	5.7	9.1	11.0	18.0
07099400	Arkansas River above Pueblo	61	9.7	4.1	1.1	6.8	10.0	12.0	19.0
07099500	Arkansas River near Pueblo	50	9.6	5.2	2.1	5.9	9.2	13.0	31.0
07103700	Fountain Creek near Colorado Springs	27	14.1	8.1	3.3	6.2	14.0	17.0	39.0
07105500	Fountain Creek at Colorado Springs	13	19.5	8.3	9.0	12.5	20.0	22.5	42.0
07105800	Fountain Creek at Security	30	35.2	13.5	6.4	27.8	35.0	43.8	62.0
07106300	Fountain Creek near Pinon	51	35.9	16.9	12.0	20.0	37.0	48.0	66.0
07106500	Fountain Creek at Pueblo	62	56.7	17.2	13.0	49.0	59.5	66.0	95.0
07109500	Arkansas River near Avondale	15	15.2	9.4	5.7	7.7	11.0	25.0	34.0
07117000	Arkansas River near Nepesta	52	18.5	8.0	4.5	11.0	18.0	26.0	35.0
07119500	Apishapa River near Fowler	50	32.5	12.4	8.5	23.0	31.5	44.0	53.0
07122000	Arkansas River near La Junta	67	33.7	12.4	9.4	26.0	35.0	40.0	61.0
07124000	Arkansas River at Las Animas	65	79.4	31.6	13.0	53.5	87.0	101.0	140.0
07124050	Middle Fork Purgatoire River at Stonewall	12	1.4	.6	.6	0.8	1.4	2.0	2.4
07124200	Purgatoire River at Madrid	11	2.1	.9	.5	1.3	2.3	2.6	3.7
07126300	Purgatoire River near Thatcher	15	21.5	12.9	4.8	10.0	17.0	36.0	40.0
07128500	Purgatoire River near Las Animas	57	82.2	38.0	3.1	62.5	82.0	113.5	148.0
07130500	Arkansas River below John Martin Reservoir	544	80.8	43.3	2.0	40.0	80.0	120.0	200.0
07133000	Arkansas River at Lamar	66	127.5	43.9	11.0	103.0	149.0	159.0	171.0
07137500	Arkansas River near Coolidge, Kans.	220	139.7	55.0	5.4	100.0	154.5	180.0	230.0

Table 12.--*Summary statistics for major ions at surface-water stations*--Continued

Station number	Station name	Number of values	Concentration (milligrams per liter)						
			Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
			FLUORIDE						
07079200	Leadville Drain at Leadville	27	0.4	.23	0.1	0.2	0.3	0.5	0.9
07081800	California Gulch at Malta	14	.4	.16	.2	.2	.3	.5	.6
07083000	Halfmoon Creek near Malta	181	.1	.10	.0	.1	.1	.2	1.1
07083700	Arkansas River near Malta	74	.3	.15	.1	.2	.2	.2	.9
07086000	Arkansas River at Granite	21	.4	.10	.3	.3	.3	.4	.7
07096000	Arkansas River at Canon City	92	.5	.14	.2	.4	.5	.6	.8
07097000	Arkansas River at Portland	59	.5	.15	.2	.4	.6	.6	.8
07099200	Arkansas River near Portland	173	.6	.21	.2	.5	.7	.8	1.3
07099400	Arkansas River above Pueblo	57	.8	.23	.1	.6	.8	.9	1.3
07099500	Arkansas River near Pueblo	44	.6	.13	.3	.5	.6	.7	.8
07103700	Fountain Creek near Colorado Springs	27	2.8	.57	1.4	2.6	2.8	3.0	4.8
07105800	Fountain Creek at Security	30	2.1	.31	1.6	1.9	2.0	2.2	3.0
07106300	Fountain Creek near Pinon	51	1.8	.54	.9	1.2	1.8	2.2	2.9
07106500	Fountain Creek at Pueblo	62	2.5	.59	.7	2.2	2.5	2.8	4.1
07109500	Arkansas River near Avondale	9	.8	.30	.5	.5	.6	1.1	1.2
07117000	Arkansas River near Nepesta	36	.9	.25	.3	.7	.9	1.1	1.3
07119500	Apishapa River near Fowler	24	.7	.23	.4	.6	.7	.9	1.3
07122000	Arkansas River near La Junta	28	1.0	.20	.6	.8	1.0	1.1	1.3
07124000	Arkansas River at Las Animas	34	1.0	.14	.7	.8	.9	1.1	1.2
07124050	Middle Fork Purgatoire River at Stonewall	12	.3	.10	.2	.2	.2	.3	.5
07124200	Purgatoire River at Madrid	11	.3	.11	.1	.3	.4	.4	.5
07126300	Purgatoire River near Thatcher	16	.5	.06	.3	.4	.5	.5	.5
07128500	Purgatoire River near Las Animas	30	.8	.26	.3	.7	.8	.8	1.8
07130500	Arkansas River below John Martin Reservoir	188	.9	.21	.2	.8	.9	1.0	1.7
07133000	Arkansas River at Lamar	25	1.0	.21	.5	.9	1.0	1.2	1.4
07137500	Arkansas River near Coolidge, Kans.	112	.8	.16	.1	.7	.8	.9	1.1

Table 12.--*Summary statistics for major ions at surface-water stations*--Continued

Station number	Station name	Number of values	Concentration (milligrams per liter) Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
					SULFATE				
07079200	Leadville Drain at Leadville	27	338	63.7	188.0	300	329	375	464
07081800	California Gulch at Malta	14	493	143.0	391.0	415	447	546	946
07083000	Halfmoon Creek near Malta	184	6	1.9	0.6	4	6	7	13
07083700	Arkansas River near Malta	75	50	73.4	10.0	22	34	45	463
07086000	Arkansas River at Granite	21	29	8.9	14.0	20	33	36	43
07096000	Arkansas River at Canon City	127	31	11.5	5.6	24	33	36	126
07097000	Arkansas River at Portland	59	105	46.7	26.0	73	110	130	220
07099200	Arkansas River near Portland	181	135	60.3	30.0	95	140	180	320
07099400	Arkansas River above Pueblo	61	172	77.3	44.0	107	175	230	412
07099500	Arkansas River near Pueblo	50	168	88.8	47.0	97	178	220	480
07103700	Fountain Creek near Colorado Springs	27	18	5.0	9.7	14	19	21	28
07105800	Fountain Creek at Security	30	173	51.1	45.0	140	185	203	240
07106300	Fountain Creek near Pinon	51	310	134.4	120.0	200	300	380	860
07106500	Fountain Creek at Pueblo	62	831	454.2	160.0	478	685	1,178	2,190
07109500	Arkansas River near Avondale	15	202	87.9	86.0	130	200	260	390
07117000	Arkansas River near Nepesta	52	273	102.7	78.0	208	288	355	490
07119500	Apishapa River near Fowler	50	976	551.0	185.0	521	731	1,538	1,940
07122000	Arkansas River near La Junta	67	645	231.8	163.0	482	663	776	1,250
07124000	Arkansas River at Las Animas	66	1,411	531.6	321.0	888	1,600	1,855	2,140
07124050	Middle Fork Purgatoire River at Stonewall	12	39	16.5	11.0	28	37	55	62
07124200	Purgatoire River at Madrid	11	43	19.1	14.0	24	47	53	72
07126300	Purgatoire River near Thatcher	16	1,151	631.2	160.0	703	990	1,850	2,000
07128500	Purgatoire River near Las Animas	57	1,883	763.7	412.0	1,225	2,140	2,465	3,070
07130500	Arkansas River below John Martin Reservoir	545	1,353	628.3	91.0	779	1,330	1,910	2,640
07133000	Arkansas River at Lamar	66	2,141	698.1	299.0	1,908	2,475	2,610	2,720
07137500	Arkansas River near Coolidge, Kans.	218	1,985	622.2	116.0	1,608	2,295	2,413	2,720

Table 12.--*Summary statistics for major ions at surface-water stations*--Continued

Station number	Station name	Number of values	Concentration (milligrams per liter) Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
					BICARBONATE				
07079200	Leadville Drain at Leadville	33	140.1	14.6	106	133	140	144	171
07081800	California Gulch at Malta	17	21.6	21.5	0	2	22	32	77
07083000	Halfmoon Creek near Malta	140	44.0	9.7	19	37	47	51	60
07083700	Arkansas River near Malta	39	57.7	19.5	17	44	62	76	87
07086000	Arkansas River at Granite	21	63.9	23.9	26	54	64	75	136
07096000	Arkansas River at Canon City	127	127.2	34.2	55	104	141	153	190
07097000	Arkansas River at Portland	23	147.0	40.0	57	120	160	180	210
07099200	Arkansas River near Portland	173	150.1	39.4	60	121	168	180	212
07099400	Arkansas River above Pueblo	60	163.9	37.4	84	129	177	192	212
07099500	Arkansas River near Pueblo	43	153.0	36.9	80	122	154	185	209
07103700	Fountain Creek near Colorado Springs	38	156.5	52.8	49	134	170	186	266
07105500	Fountain Creek at Colorado Springs	13	174.9	30.1	101	160	185	190	214
07105800	Fountain Creek at Security	30	169.4	55.9	52	134	160	221	258
07106300	Fountain Creek near Pinon	47	189.3	76.2	68	113	194	258	330
07106500	Fountain Creek at Pueblo	62	266.0	58.4	116	236	293	307	342
07109500	Arkansas River near Avondale	6	128.2	32.8	98	103	117	159	182
07117000	Arkansas River near Nepesta	43	165.2	33.5	99	140	175	188	234
07119500	Apishapa River near Fowler	50	214.1	43.2	116	186	216	244	322
07122000	Arkansas River near La Junta	66	223.7	39.5	121	196	232	254	288
07124000	Arkansas River at Las Animas	65	256.3	42.4	158	229	262	287	328
07124050	Middle Fork Purgatoire River at Stonewall	7	119.4	30.8	56	110	130	140	150
07124200	Purgatoire River at Madrid	9	144.7	52.6	77	98	150	200	220
07126300	Purgatoire River near Thatcher	16	221.7	62.6	106	186	198	257	349
07128500	Purgatoire River near Las Animas	57	269.4	53.6	162	236	270	307	434
07130500	Arkansas River below John Martin Reservoir	742	256.8	86.5	114	191	238	306	644
07133000	Arkansas River at Lamar	67	286.8	54.8	129	266	295	328	390
07137500	Arkansas River near Coolidge, Kans.	183	254.4	46.2	132	228	260	288	360

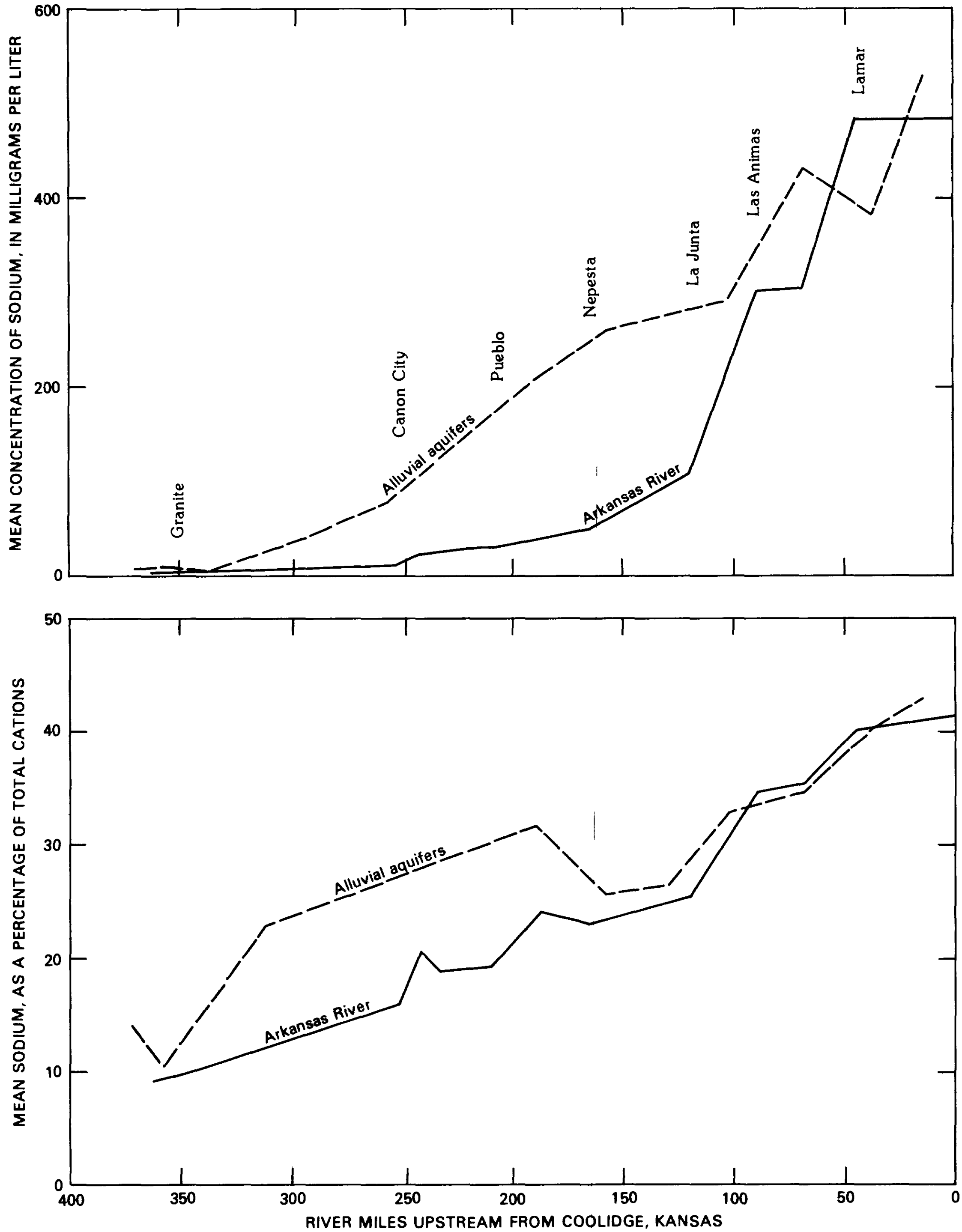

Figure 23.--Downstream variations in the mean concentration of and mean percentage of dissolved sodium in the Arkansas River and adjacent alluvial aquifers.

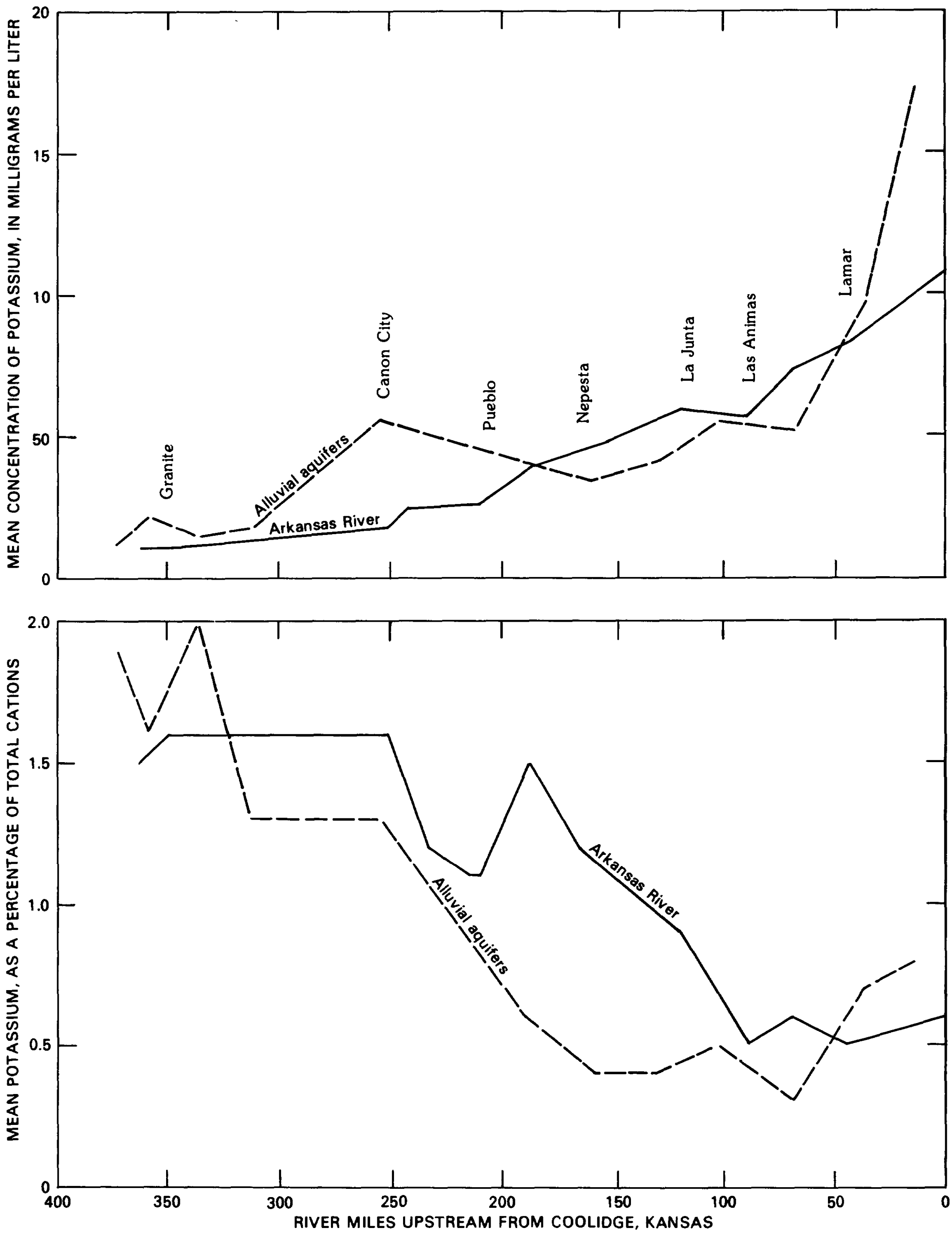

Figure 24.--Downstream variations in the mean concentration of and mean percentage of dissolved potassium in the Arkansas River and adjacent alluvial aquifers.

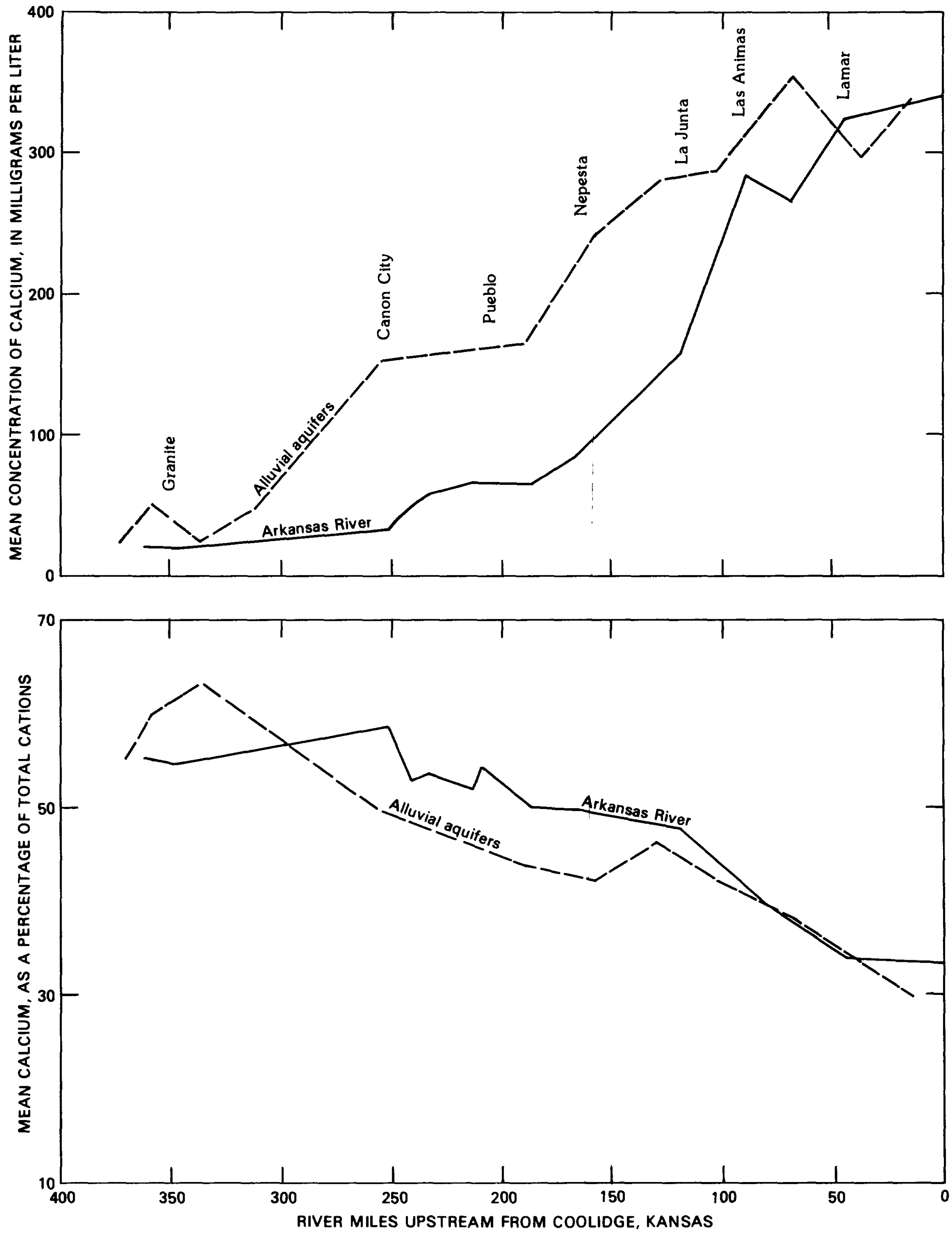

Figure 25.--Downstream variations in the mean concentration of and mean percentage of dissolved calcium in the Arkansas River and adjacent alluvial aquifers.

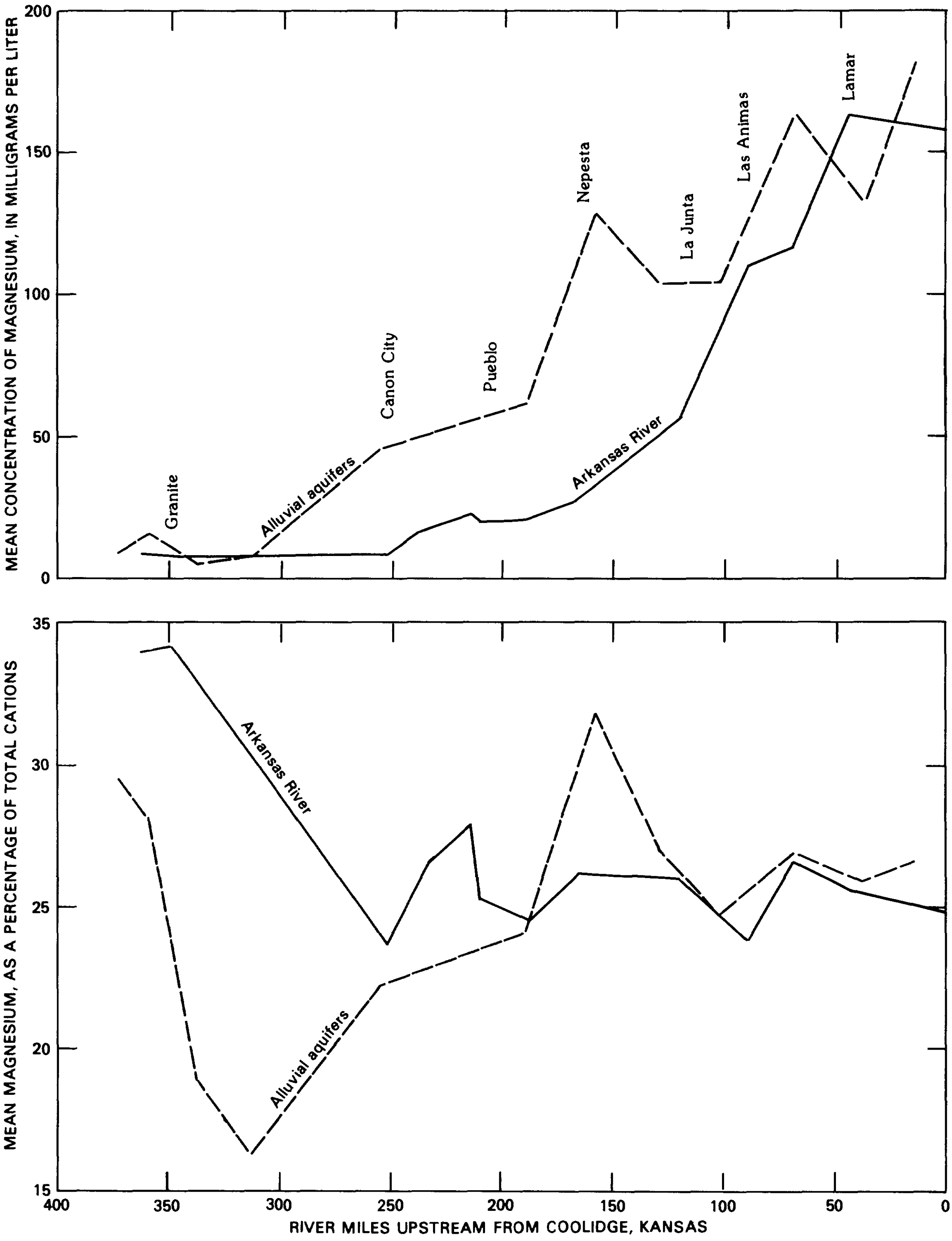

Figure 26.--Downstream variations in the mean concentration of and mean percentage of dissolved magnesium in the Arkansas River and adjacent alluvial aquifers.

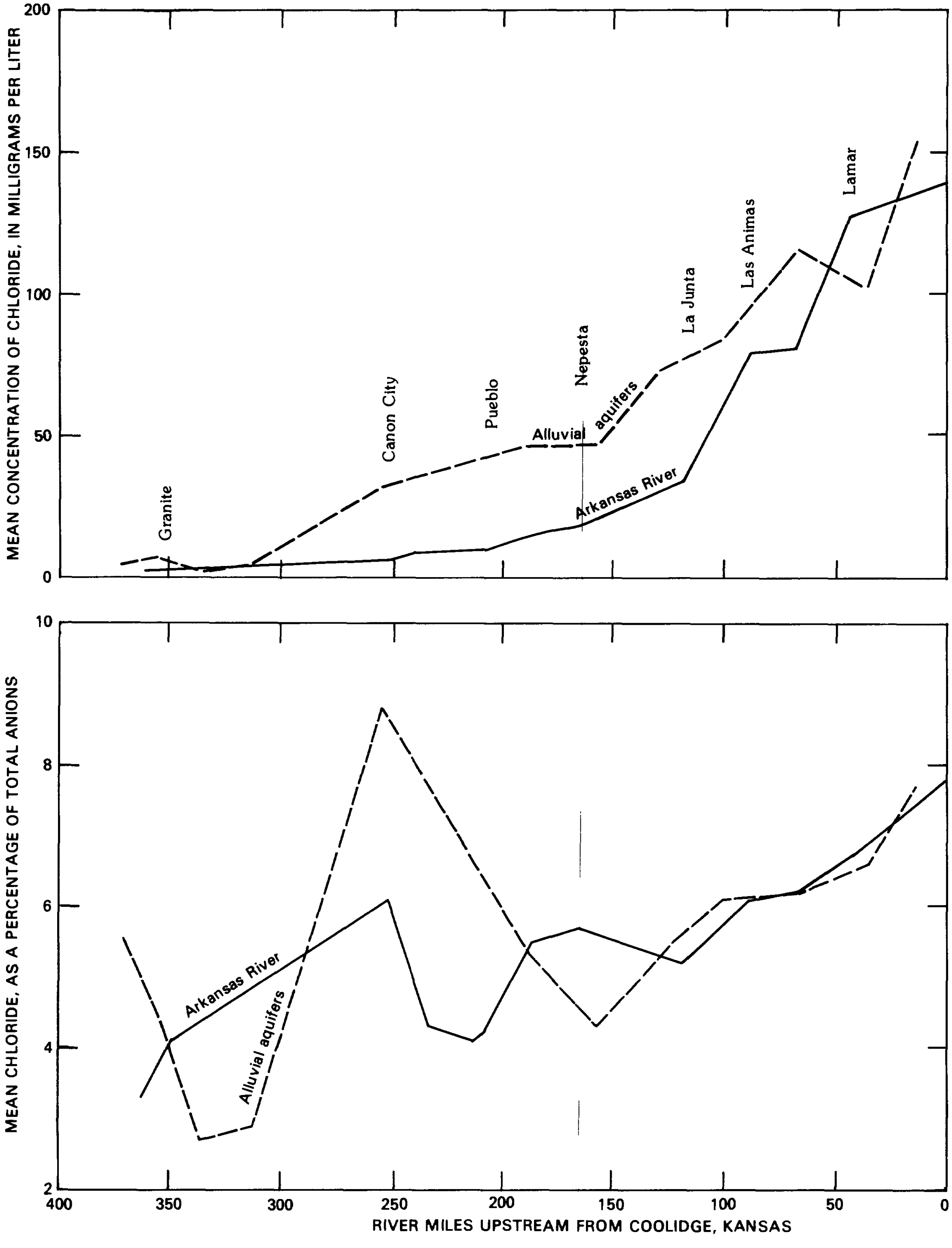

Figure 27.--Downstream variations in the mean concentration of and mean percentage of dissolved chloride in the Arkansas River and adjacent alluvial aquifers.

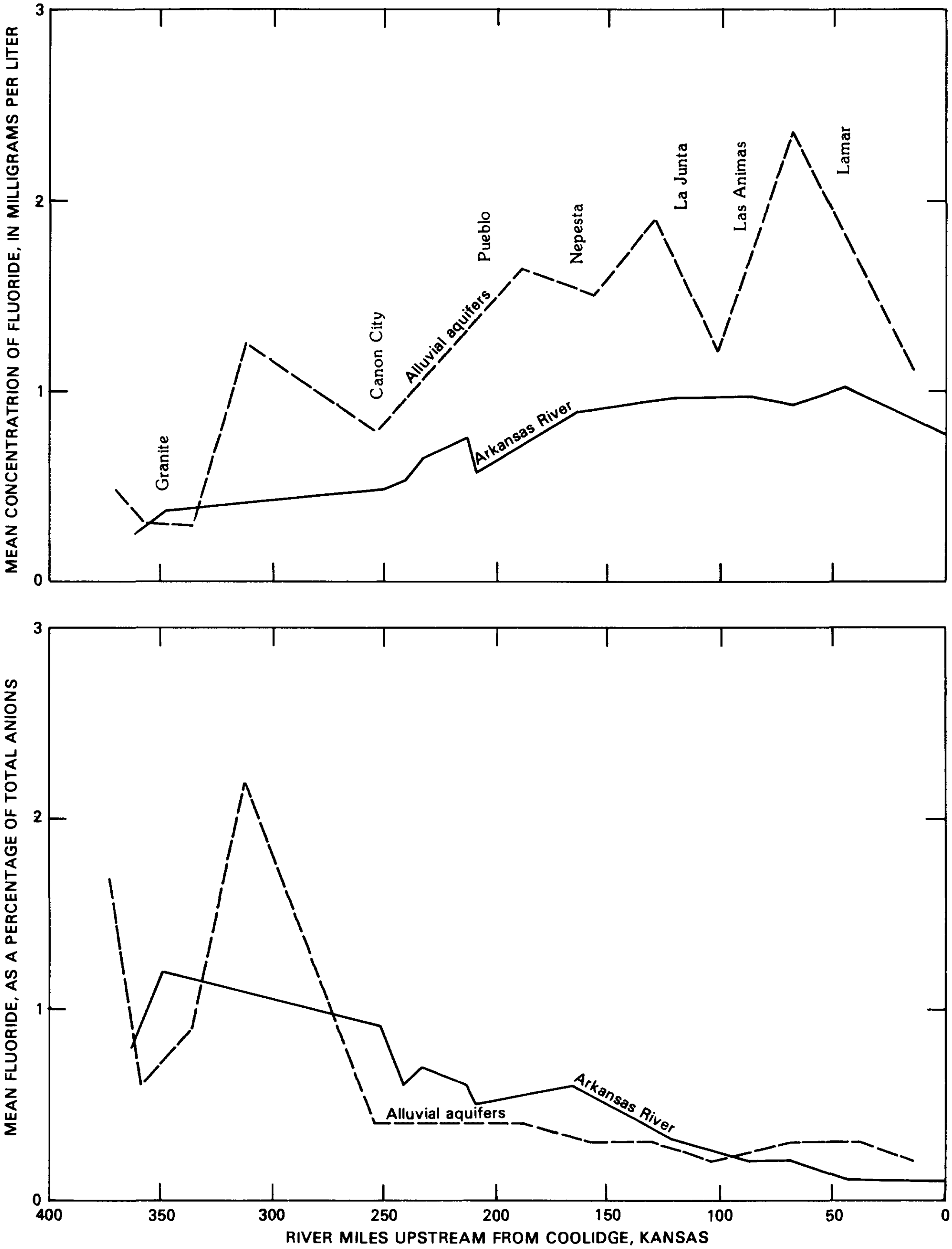

Figure 28.--Downstream variations in the mean concentration of and mean percentage of dissolved fluoride in the Arkansas River and adjacent alluvial aquifers.

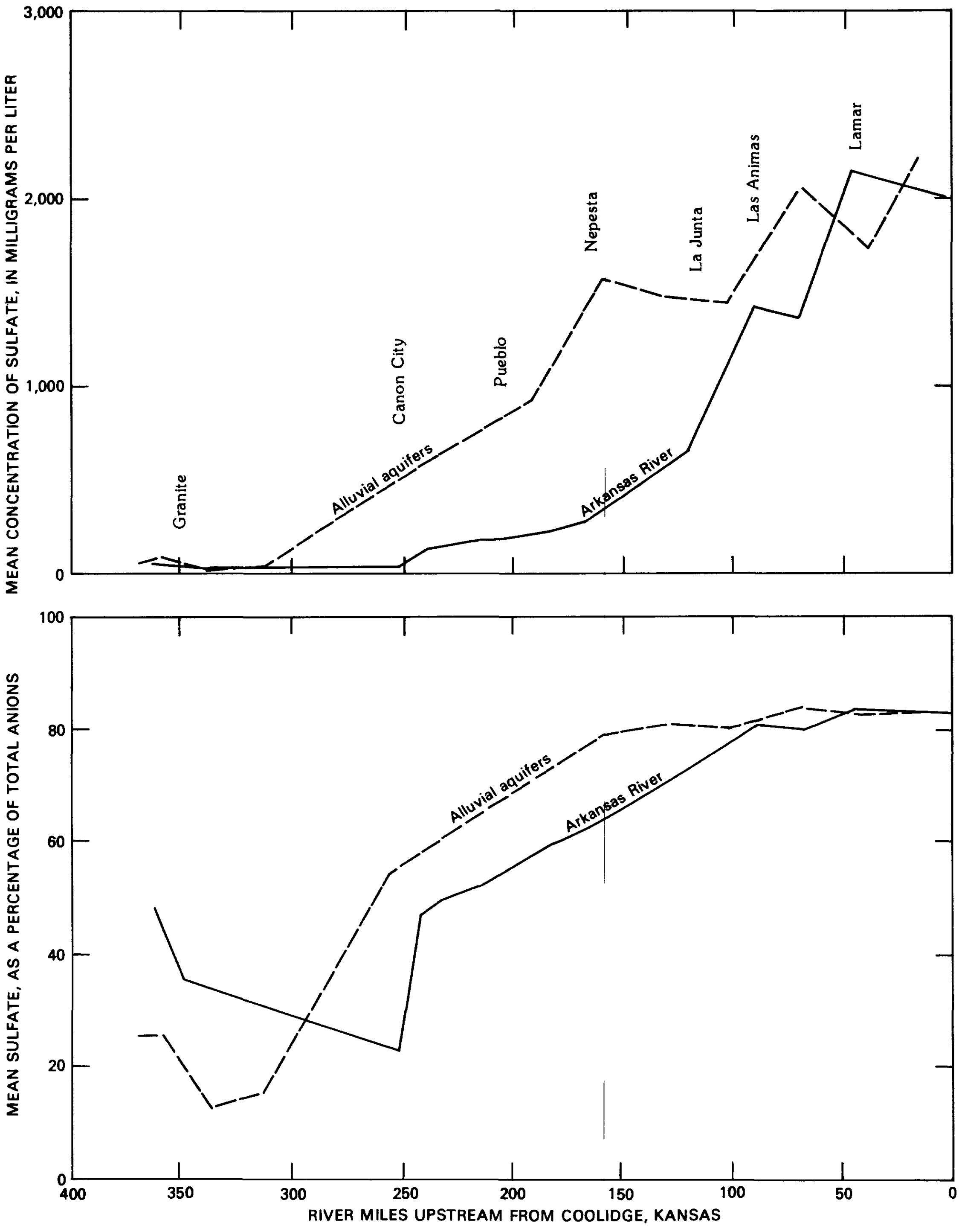

Figure 29.--Downstream variations in the mean concentration of and mean percentage of dissolved sulfate in the Arkansas River and adjacent alluvial aquifers.

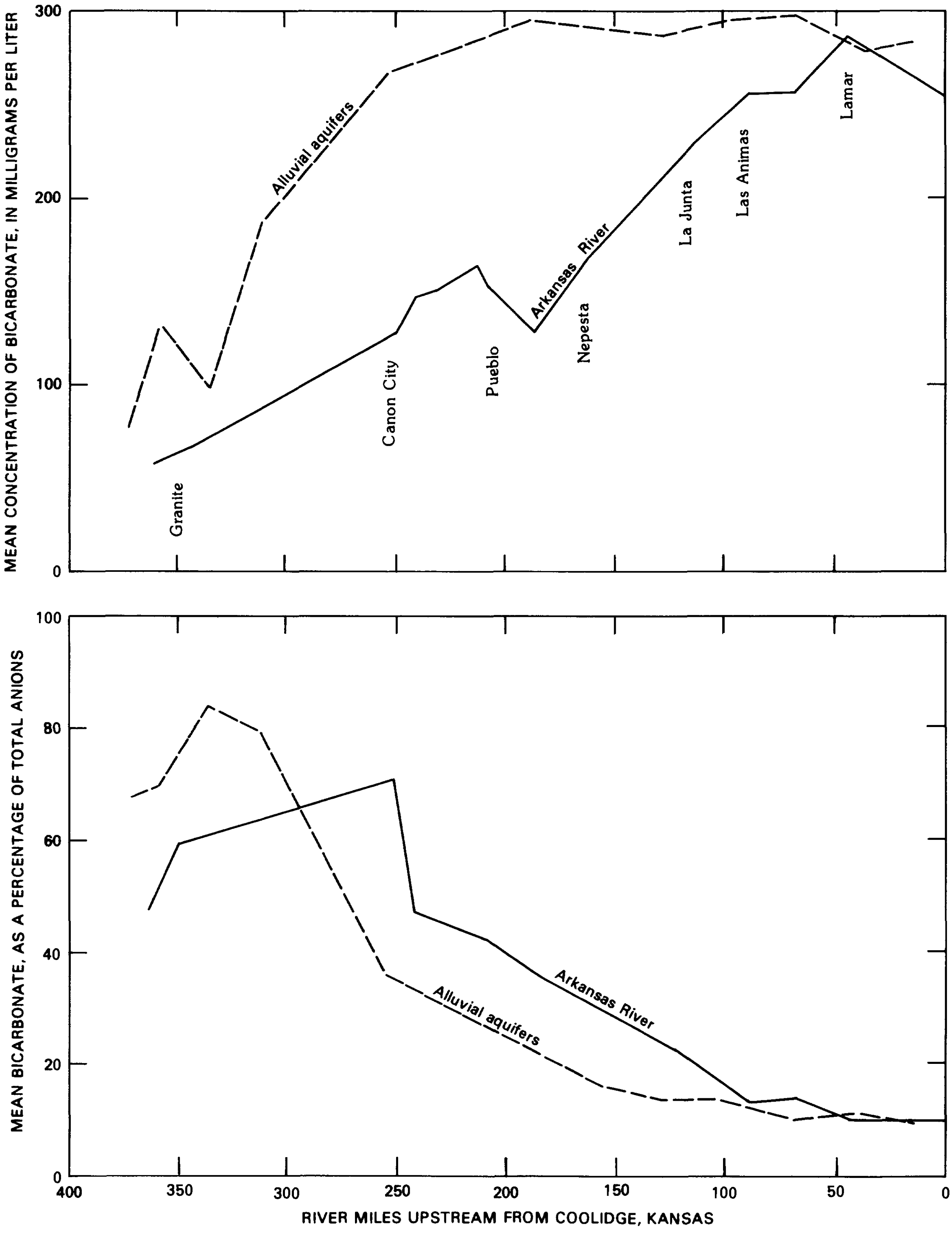

Figure 30.--Downstream variations in the mean concentration of and mean percentage of dissolved bicarbonate in the Arkansas River and adjacent alluvial aquifers.

Table 13.--*Summary statistics for major ions in ground water in alluvial aquifers along the Arkansas River*

Reach in figure 1	Reach location (miles upstream from Coolidge, Kans.)			Number of values	Concentration (milligrams per liter)						
	Downstream end	Mid-point	Upstream end		Mean	Standard deviation	Mini-mum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maxi-mum
					SODIUM						
1	370	375	379	12	5.8	7.0	1.8	2.0	4.1	5.8	27
2	349	360	370	13	8.7	6.2	1.8	3.6	6.6	14.0	21
3	332	341	349	16	6.7	3.3	2.1	4.8	5.8	7.6	14
4	301	317	332	31	22.6	30.3	1.9	7.8	12.0	26.0	140
5	214	258	301	9	79.1	36.4	29.0	62.5	65.0	91.5	161
6	165	190	214	22	206.9	146.0	43.0	65.5	187.0	341.3	507
7	145	155	165	19	257.1	198.9	57.0	109.0	212.0	395.0	745
8	117	131	145	35	275.9	191.3	109.0	156.0	191.0	312.0	775
9	89	103	117	99	289.6	132.7	83.0	180.0	260.0	396.0	706
10	44	67	89	33	429.8	204.1	151.0	258.5	385.0	598.5	919
11	34	39	44	21	380.0	118.4	235.0	278.5	342.0	455.5	625
12	0	17	34	41	527.7	211.4	99.0	381.5	491.0	669.0	1,000
					POTASSIUM						
1	370	375	379	12	1.2	0.3	0.7	0.9	1.1	1.4	1.7
2	349	360	370	13	2.1	1.4	.7	1.0	1.8	3.5	4.5
3	332	341	349	16	1.4	.5	.6	1.1	1.4	1.8	2.4
4	301	317	332	31	1.7	.8	.6	1.0	1.8	2.2	3.7
5	214	258	301	7	5.5	1.9	3.3	4.1	5.1	6.8	9.2
6	165	190	214	11	4.1	1.5	2.1	2.8	4.1	4.7	7.1
7	145	155	165	7	3.4	1.7	.6	2.3	3.4	5.3	5.4
8	117	131	145	15	4.1	1.7	2.0	2.3	3.8	5.6	6.5
9	89	103	117	84	5.5	1.9	1.7	3.8	5.7	6.7	11.0
10	44	67	89	15	5.2	2.4	2.8	3.6	3.9	6.5	12.0
11	34	39	44	9	9.6	3.3	6.5	6.6	8.1	13.0	15.0
12	0	17	34	27	17.2	30.7	5.8	8.9	12.0	14.0	170.0
					CALCIUM						
1	370	375	379	12	23.3	17.0	7.6	11.3	17.5	32.3	69
2	349	609	370	13	51.5	39.9	19.0	25.0	43.0	49.5	160
3	332	341	349	16	24.5	10.7	12.0	17.3	21.5	29.3	52
4	301	317	332	31	46.7	22.7	9.4	31.0	49.0	59.0	96
5	214	258	301	9	152.0	95.7	55.0	65.0	140.0	193.0	357
6	165	190	214	16	164.8	62.4	71.0	122.3	146.0	205.0	277
7	145	155	165	10	241.3	78.9	120.0	159.0	248.5	299.0	369
8	117	131	145	19	277.8	55.4	198.0	240.0	269.0	305.0	441
9	89	103	117	85	288.5	82.7	110.0	222.5	285.0	350.0	490
10	44	67	89	18	353.1	57.7	236.0	327.0	361.0	386.0	469
11	34	39	44	12	297.1	117.6	152.0	181.0	293.0	411.0	505
12	0	17	34	28	338.6	60.9	216.0	300.3	342.0	360.0	513

Table 13.--*Summary statistics for major ions in ground water in alluvial aquifers along the Arkansas River*--Continued

Reach in figure 1	Reach location (miles upstream from Coolidge, Kans.) Downstream end	Mid-point	Upstream end	Number of values	Concentration (milligrams per liter) Mean	Standard deviation	Mini-mum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maxi-mum
					MAGNESIUM						
1	370	375	379	12	8.2	7.1	2.2	3.3	5.7	11.8	27
2	349	360	370	13	15.6	15.1	3.6	6.9	10.0	15.5	55
3	332	341	349	16	4.7	3.0	1.5	2.8	3.7	6.2	12
4	301	317	332	31	7.5	5.2	.1	3.0	6.8	11.0	20
5	214	258	301	9	45.1	34.9	13.0	20.0	42.0	52.0	129
6	165	190	214	16	61.4	31.1	30.0	40.0	52.5	79.3	131
7	145	155	165	10	128.8	89.3	39.0	53.0	109.5	195.8	326
8	117	131	145	19	103.7	24.0	72.0	84.0	92.0	122.0	156
9	89	103	117	85	103.9	36.5	39.0	80.5	100.0	120.0	220
10	44	67	89	18	163.4	67.4	79.0	115.0	140.0	211.3	289
11	34	39	44	12	132.2	56.3	49.0	98.3	124.5	176.0	224
12	0	17	34	28	181.8	63.4	71.0	134.5	171.0	236.0	320
					CHLORIDE						
1	708	375	379	12	4.4	5.8	0.3	0.5	0.9	9.2	18.0
2	349	360	370	13	6.8	7.8	1.0	1.6	2.5	13.0	23.0
3	332	341	349	16	1.9	1.8	.8	0.9	1.3	2.3	8.2
4	301	317	332	31	5.1	9.4	.6	1.1	2.3	4.3	49.0
5	214	258	301	9	31.8	37.0	4.4	11.5	18.0	56.0	99.0
6	165	190	214	22	46.3	26.4	13.0	27.3	41.5	59.3	119.0
7	145	155	165	19	46.9	22.2	20.0	34.0	42.0	54.0	123.0
8	117	131	145	35	73.1	40.8	32.0	47.0	55.0	92.0	204.0
9	89	103	117	99	83.9	34.3	27.0	58.0	82.0	109.0	170.0
10	44	67	89	33	115.8	55.8	48.0	74.5	95.0	159.0	250.0
11	34	39	44	21	101.9	34.9	50.0	76.0	101.0	117.0	189.0
12	0	17	34	41	154.1	59.6	70.0	110.0	137.0	204.5	290.0
					FLUORIDE						
1	708	375	379	12	0.5	0.78	0.1	0.1	0.3	0.6	2.9
2	349	360	370	13	.3	.23	.1	0.2	0.2	0.5	.8
3	332	341	349	16	.3	.14	.1	0.2	0.3	0.4	.6
4	301	317	332	31	1.2	1.59	.5	0.6	0.8	1.2	9.4
5	214	258	301	8	.8	.18	.6	0.7	0.8	0.8	1.2
6	165	190	214	10	1.6	.98	.7	0.9	1.2	2.6	3.6
7	145	155	165	6	1.5	.53	.9	1.1	1.4	2.0	2.3
8	117	131	145	10	1.9	1.23	.7	1.2	1.3	2.5	4.6
9	89	103	117	76	1.2	.68	.6	0.9	1.1	1.3	5.5
10	44	67	89	10	2.4	2.46	.7	1.0	1.4	3.2	8.9
11	34	39	44	6	1.6	.48	1.1	1.3	1.5	1.9	2.5
12	0	17	34	21	1.1	.81	.4	0.7	0.9	1.2	4.2

Table 13.--*Summary statistics for major ions in ground water in alluvial aquifers along the Arkansas River*--Continued

Reach in figure 1	Reach location (miles upstream from Coolidge, Kans.)			Number of values	Concentration (milligrams per liter)						
	Downstream end	Mid-point	Upstream end		Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
					SULFATE						
1	370	375	379	12	32	46	4	8	17	36	170
2	349	360	370	13	84	156	4	9	21	58	530
3	332	341	349	16	11	7	2	6	9	16	25
4	301	317	332	31	32	43	5	12	17	23	190
5	214	258	301	9	469	447	71	91	450	618	1,490
6	165	190	214	22	922	665	234	449	674	1,318	2,580
7	145	155	165	19	1,566	1,330	326	707	1,190	1,910	5,420
8	117	131	145	35	1,465	613	770	995	1,270	1,700	3,220
9	89	103	117	99	1,434	520	430	990	1,400	1,830	2,770
10	44	67	89	33	2,052	650	1,020	1,650	1,970	2,490	3,470
11	34	39	44	21	1,728	561	868	1,275	1,740	1,990	2,810
12	0	17	34	41	2,213	636	668	1,790	2,300	2,670	3,400
					BICARBONATE						
1	370	375	379	12	77.3	38.4	27	45	71	111	149
2	349	360	370	13	132.6	46.8	48	107	137	180	194
3	332	341	349	16	97.9	37.4	51	74	88	120	182
4	301	317	332	31	186.2	77.0	32	136	193	247	342
5	214	258	301	9	266.8	56.3	192	216	263	303	366
6	165	190	214	22	295.6	61.1	189	259	306	324	432
7	145	155	165	19	291.4	70.3	170	244	290	352	414
8	117	131	145	34	288.1	51.9	184	254	282	336	394
9	89	103	117	76	294.8	72.0	115	258	289	353	497
10	44	67	89	33	297.8	68.3	180	251	292	336	458
11	34	39	44	21	278.8	44.5	202	237	288	314	354
12	0	17	34	30	283.6	61.3	159	254	299	329	388

water, the effects of mine drainage and geothermal waters north of Salida, varying composition of the alluvial materials with which the water is in contact, possible discharge of water from underlying bedrock aquifers into the alluvial aquifers, variability in the salinity of irrigated soils overlying alluvial aquifers east of Pueblo, and variability in the composition of bedrock underlying the alluvial aquifers.

LONG-TERM TRENDS IN SPECIFIC CONDUCTANCE AND DISSOLVED-SOLIDS LOADS

Trends in the volume of annual streamflow for periods of 12 to 70 years at several stations in the Arkansas River basin have been documented by Burns (1985). Because specific conductance and dissolved-solids loads are related to streamflow, these trends in streamflow indicate that long-term trends in specific conductance and dissolved-solids loads in the Arkansas River basin also may have occurred.

Specific Conductance

Long-term trends in specific conductance in the Arkansas River basin were evaluated using two nonparametric statistical procedures (Hirsch and others, 1982; Crawford and others, 1983). The first procedure, the seasonal rank sum, tests for changes before and after events that are suspected of causing water-quality changes or for changes before and after an interruption in the record at a station. The second procedure, the seasonal Kendall, tests for time trends in water-quality constituents in a continuous record in the absence of a specific event suspected of causing a change. Both of the procedures are designed to take into account seasonal and flow-related changes in water-quality, which occur in the Arkansas River and tributaries.

Arkansas River and Tributaries

Approximately 10 years or more of at least monthly measurements are required to use these statistical procedures. Sufficient data were available at 31 stations on the Arkansas River and tributaries to apply these techniques. The available record varied from 10 to 26 years at these stations.

Station 07099400, Arkansas River above Pueblo

Station 07099400, Arkansas River above Pueblo, was evaluated separately from other stations in the basin because changes in specific conductance at this station may be caused by a definable change in water management. Pueblo Reservoir, which is immediately upstream from the station, began storing water in January 1974. This change is likely to have caused changes in the distribution of specific-conductance values at this station. Changes in water management have occurred near other stations in the basin, but either sufficient data are not available to examine these changes, or the changes have been implemented gradually and cannot be evaluated before and after the change occurred. Because a specific event that had a definite date occurred just upstream from the Arkansas River above Pueblo station, the seasonal rank-sum procedure was used to determine if a change in specific conductance occurred.

The procedure was used to evaluate unadjusted specific conductance and specific conductance adjusted using the relation of specific conductance to streamflow shown in table 4 for the Arkansas River above Pueblo (station 07099400). Flow-adjusted specific conductance is the unadjusted specific conductance minus the expected specific conductance predicted from the relation of specific conductance to streamflow. Flow adjustment is an attempt to remove variations in specific conductance caused by streamflow, thus allowing the effects of other variables on specific conductance to be evaluated. To reduce problems of serial correlation in the daily specific conductance data at this station, the test was made on data from the fifteenth day of each month. Highly significant ($p<0.01$) changes have occurred in unadjusted specific conductance and significant ($p<0.1$) changes have occurred in flow-adjusted specific conductance. The results of the procedure indicate an increase in specific conductance of about 115 μS/cm and an increase in flow-adjusted specific conductance of about 9 percent.

The shift in flow-adjusted specific conductance detected by the seasonal rank-sum procedure (Crawford and others, 1983) indicated that a different relation of specific conductance to streamflow probably existed before storage of water in Pueblo Reservoir. When this relation was developed earlier (table 4), data from the entire period of record were grouped together, and the following relation was determined for the entire year:

$$\log(SC_e) = 3.48 - 0.32 \log(Q) \qquad (16)$$

To determine if different relations need to be used for the periods before and after storage began in Pueblo Reservoir, another dummy-variable regression analysis was made. In this analysis, the dummy variable, Z, was included to categorize by season, and an additional dummy variable, S, was used to separate data collected before and after storage began in Pueblo Reservoir. The dummy variable Z was assigned the same values as in the section entitled, "Seasonal Changes in the Relations," and the dummy variable S was assigned a value of 0 for data collected before storage began in Pueblo Reservoir and a value of 1 for the data after storage began. The relation of specific conductance to streamflow, including both dummy variables, is:

$$\log(SC_e) = a + b \log(Q) + cZ + dZ \log(Q) + eS + fS \log(Q) \qquad (17)$$

where a, b, c, d, e, and f are coefficients determined using regression analysis. The regression analysis again was performed using a stepwise approach (SAS Institute, Inc., 1982, p. 101-110) and included only coefficients significant at the 0.05 probability level. All six coefficients were found to be significant, indicating that different relations need to be used for both seasons and before and after the beginning of storage. The four relations that result after simplifying equation 17 to the form of equation 6 are given in table 14 and shown in figure 31.

Table 14.--*Relations of specific conductance to streamflow for station 07099400, Arkansas River above Pueblo, before and after the beginning of storage in Pueblo Reservoir during January 1974*

[S, Z, dummy variables; SC_e, estimated specific conductance, in microsiemens per centimeter at 25 degrees Celsius; Q, measured streamflow, in cubic feet per second]

Season	Number of values	S	Z	Regression coefficients in the equation $\log(SC_e) = a + b \log(Q)$: a	b	Coefficient of determination (r^2)	Average standard error (percent)
BEFORE STORAGE IN PUEBLO RESERVOIR							
October - April	1,114	0	1	3.09	-0.15	0.14	19
May - September	735	0	0	3.46	-.33	.70	19
AFTER STORAGE IN PUEBLO RESERVOIR							
October - April	695	1	1	3.04	-0.11	0.12	17
May - September	541	1	0	3.54	-.32	.40	36

Other stations on the Arkansas River and tributaries

Long-term trends in specific conductance at the other 30 stations were evaluated using the seasonal Kendall procedure (Hirsch and others, 1982; Crawford and others, 1983). Specific conductance was examined at all 30 stations and flow-adjusted specific conductance was examined at stations where no trend in streamflow was detected by Burns (1985). The test procedure indicates whether a trend is occurring at a given probability level and provides an estimate of the magnitude of the trend. Flow adjustment of the specific-conductance data at all stations was made using log-log relations between specific conductance and streamflow. Seasonality in the relations was not used in the flow adjustment because the trend procedure only compares values from the same months of the year at any station, so seasonality is incorporated in the procedure. To reduce problems of serial correlation in the daily specific conductance data at station 07130500, Arkansas River below John Martin Reservoir, the test was made on data from the fifteenth day of each month.

A summary of the results from the application of the seasonal Kendall procedure to specific-conductance data on the Arkansas River and tributaries

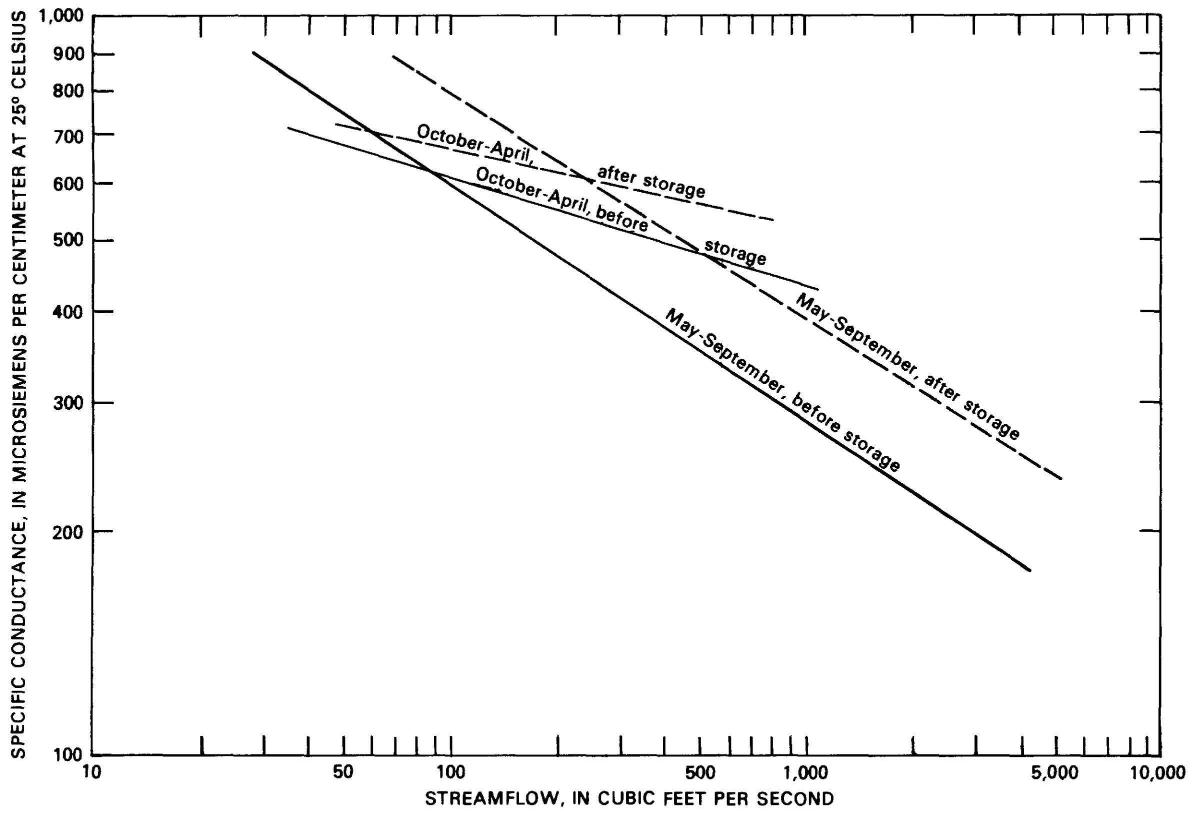

Figure 31.--Relations of specific conductance to streamflow for station 07099400, Arkansas River above Pueblo, before and after the beginning of storage in Pueblo Reservoir during January 1974.

is given in table 15. Trends in specific conductance are shown in figure 32, and trends in flow-adjusted specific conductance are shown in figure 33. The magnitude of the trends in specific conductance and flow-adjusted specific conductance are given in percent per year in table 15 for ease of comparison between stations. Percent per year is the slope of the trend divided by the average specific conductance (table 1) and multiplied by 100.

Trends of increasing specific conductance have occurred at eight stations in Colorado (fig. 32) and at station 07137500 near Coolidge, Kans. No significant trend ($p>0.10$) has occurred at 13 stations, and a decreasing trend occurred at 8 stations. Because specific conductance is related to streamflow, changes in specific conductance may be caused by changes in streamflow. A period of generally low flow occurred during the late 1970's and a period of high flow, especially at stations where much of the flow was snowmelt runoff, occurred during the 1980's. This situation probably explains decreasing trends at stations where the period of record only includes the last 10 to 12 years, such as most of the stations on Fountain Creek. Flow-adjusted specific conductance did not have a significant trend or had an increasing trend at most of these stations, as can be seen in table 15. Causes of increases in

Table 15.--*Summary of results of the seasonal Kendall trend procedure*

[Dash indicates no significant trend was found; asterisk indicates test not made because of trend in streamflow detected by Burns (1985, p. 66); HS, highly significant ($p<0.01$); S, significant ($p<0.10$); NS, not significant ($p>0.10$)]

Station number	Station name	Period of specific-conductance data used in trend procedure	Specific-conductance trend: Slope of trend (percent per year)	Specific-conductance trend: Significance of trend	Flow-adjusted specific-conductance trend: Slope of trend (percent per year)	Flow-adjusted specific-conductance trend: Significance of trend
07081200	Arkansas River near Leadville	1969-1983	2.0	HS	1.8	HS
07083000	Halfmoon Creek near Malta	1965-1984	0.3	S	-	NS
07089000	Cottonwood Creek below Hot Springs, near Buena Vista	1974-1983	-	NS	*	*
07091200	Arkansas River near Nathrop	1971-1982	-	NS	-	NS
07094500	Arkansas River at Parkdale	1971-1982	.8	S	-	NS
07096500	Fourmile Creek near Canon City	1971-1983	-	NS	-	NS
07099100	Beaver Creek near Portland	1971-1981	7.8	HS	3.4	HS
07099200	Arkansas River near Portland	1965-1979	-.6	S	-2.0	HS
07103700	Fountain Creek near Colorado Springs	1972-1984	-2.3	HS	-	NS
07103800	West Monument Creek at Air Force Academy	1971-1983	-2.1	HS	-2.1	HS
07104000	Monument Creek at Pikeview	1973-1984	-	NS	4.0	HS
07105500	Fountain Creek at Colorado Springs	1975-1984	-6.8	HS	-1.8	S
07105800	Fountain Creek at Security	1971-1983	-	NS	1.8	HS
07105905	Fountain Creek above Little Fountain Creek, below Fountain	1975-1984	-4.8	HS	-	NS
07106300	Fountain Creek near Pinon	1973-1984	-2.1	HS	-	NS
07106500	Fountain Creek at Pueblo	1971-1984	-1.5	HS	1.0	HS
07109500	Arkansas River near Avondale	1969-1983	1.7	HS	.8	S
07119500	Apishapa River near Fowler	1964-1983	1.0	S	*	*
07121500	Timpas Creek at mouth near Swink	1967-1983	-	NS	-	NS
07122400	Crooked Arroyo near Swink	1969-1983	1.0	S	-.6	S
07124000	Arkansas River at Las Animas	1962-1983	-	NS	-	NS
07124200	Purgatoire River at Madrid	1972-1983	-	NS	1.0	S
07124300	Long Canyon Creek near Madrid	1972-1983	-	NS	1.6	HS
07126200	Van Bremer Arroyo near Model	1969-1979	-	NS	-1.0	S
07126300	Purgatoire River near Thatcher	1969-1983	-	NS	-	NS
07128500	Purgatoire River near Las Animas	1964-1983	0.9	S	*	*
07130500	Arkansas River below John Martin Reservoir	1952-1978	-.5	HS	*	*
07133000	Arkansas River at Lamar	1969-1983	-	NS	*	*
07134100	Big Sandy Creek near Lamar	1969-1982	-	NS	*	*
07137500	Arkansas River near Coolidge, Kans.	1964-1984	.5	S	*	*

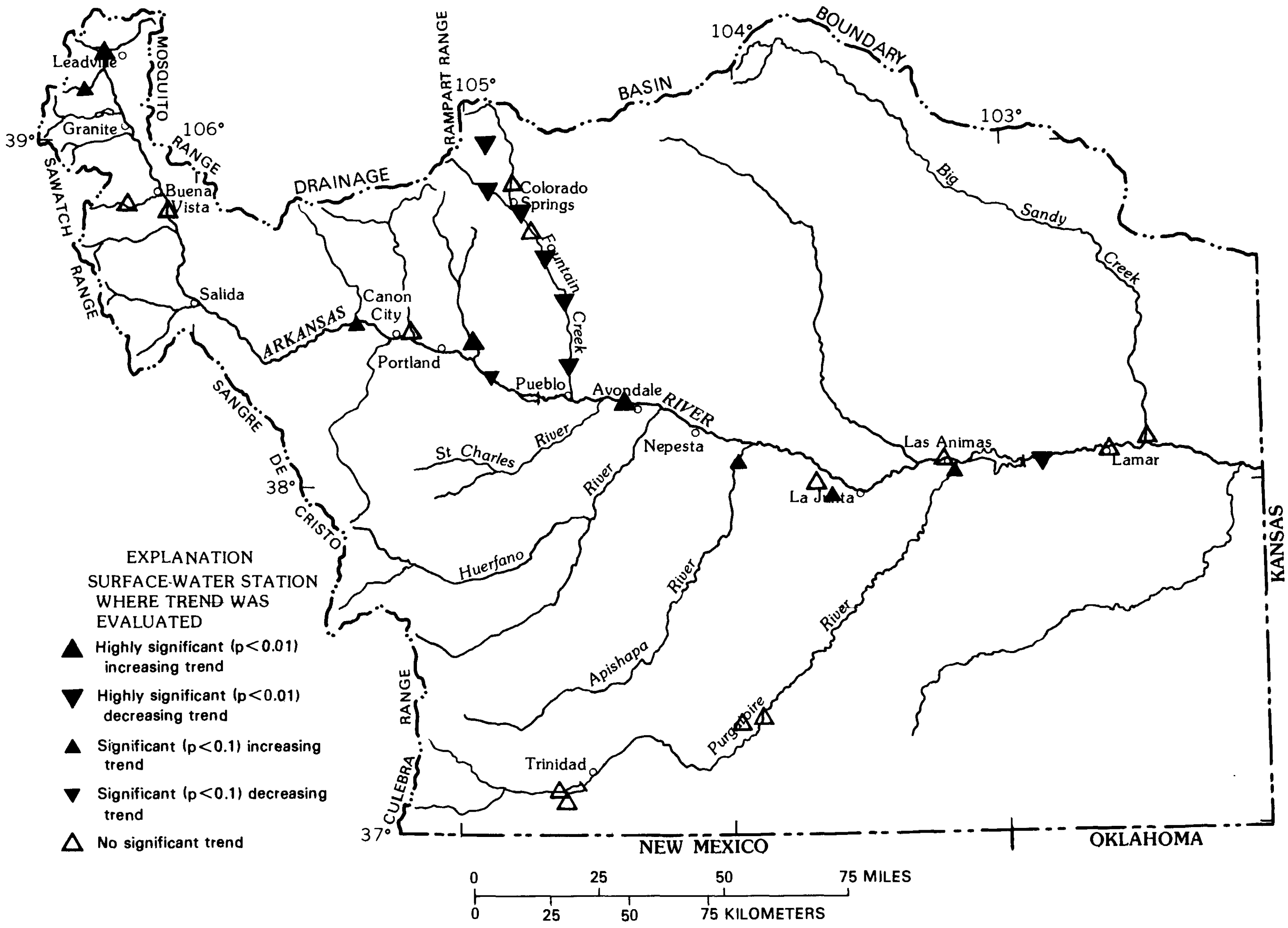

Figure 32.--Long-term trends in specific conductance of the Arkansas River and tributaries.

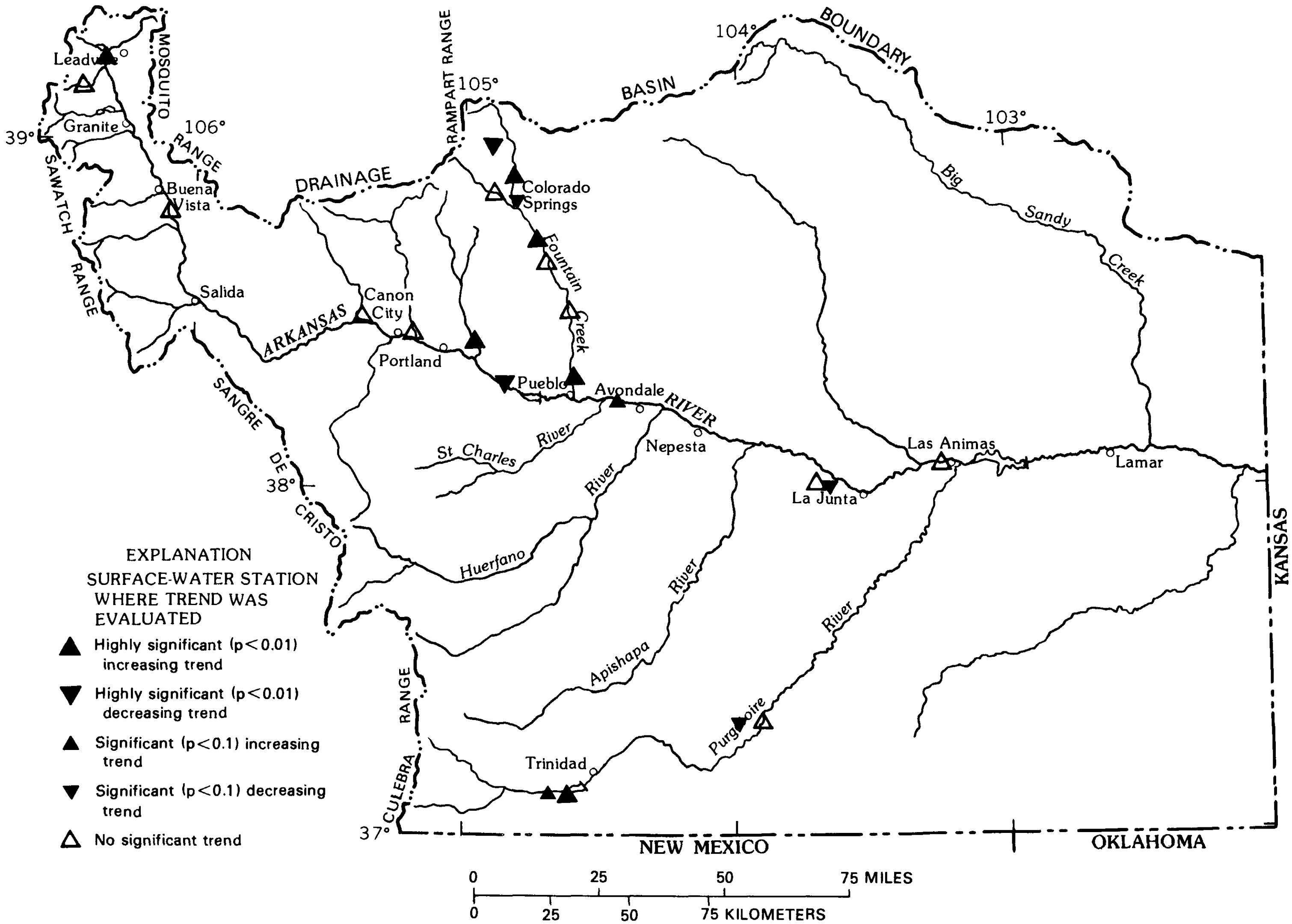

Figure 33.--Long-term trends in flow-adjusted specific conductance of the Arkansas River and tributaries.

specific conductance of Halfmoon Creek near Malta, the Arkansas River near Leadville, and the Arkansas River at Parkdale are not known, but the increase at the Arkansas River near Avondale probably resulted from the increase in specific conductance of water released from Pueblo Reservoir. The increase in specific conductance of the Arkansas River near Coolidge, Kans., probably is related to decreases in streamflow at this station.

Long-term trends in flow-adjusted specific conductance have occurred at 13 stations (fig. 33). No significant trend was recorded at 10 stations and 7 stations were not evaluated because of trends in streamflow. Of the 13 stations where trends occurred, 8 stations had significant increases and 5 stations had significant decreases. Trends in flow-adjusted specific conductance indicate a change in the relation of specific conductance to streamflow (Crawford and others, 1983). In effect, this change means that at the same streamflow, different values of specific conductance may be expected at different times during the period of record. Trends of this sort commonly might be expected to result from other than natural causes, such as increased diversions, construction of reservoirs, or increased effluent discharges.

Trends of increasing flow-adjusted specific conductance at several stations along Fountain Creek or Monument Creek may be related to increasing urbanization, which has resulted in increases in effluent discharges in the Colorado Springs area (Edelmann and Cain, 1985). Reasons for increase in flow-adjusted specific conductance of the Arkansas River near Leadville are not known. The only increase in flow-adjusted specific conductance for the Arkansas River downstream from Pueblo occurred at Avondale, about 20 miles downstream from Pueblo Reservoir, where the relation of specific conductance to streamflow had been altered by storage of water. This station also is about 10 miles downstream from the confluence of Fountain Creek and the Arkansas River. Fountain Creek at Pueblo, which is near the mouth, had an increasing trend in flow-adjusted specific conductance. A decrease in flow-adjusted specific conductance occurred at the Arkansas River near Portland, and no trend was noted at three stations (near Nathrop, at Parkdale, and at Las Animas).

Ground Water in Alluvial Aquifers along the Arkansas River

Fewer data are available for evaluating long-term trends in the specific conductance of ground water in alluvial aquifers along the Arkansas River. No wells have been sampled routinely over a period of several years, but water from wells in two areas of the alluvial aquifer downstream from Pueblo have been sampled at least two times during a period that lasted more than 10 years. The first area is between La Junta and Las Animas, where dissolved-solids concentrations in water from 22 wells sampled in 1972 and again in 1982 have been compared (Konikow and Person, 1985). Because dissolved-solids concentration and specific conductance are directly related, inferences about long-term trends in dissolved-solids concentration can be extended to specific conductance. Nonparametric statistical procedures indicated no significant trend in dissolved-solids concentration between 1972 and 1982 for this area. The second area is just west of Holly (pl. 1), about 5 miles from the Colorado-Kansas State line. In this area, the specific conductance of seven wells was measured between 1956 and 1965 and again during 1978 (Cain, 1985);

no significant trend in specific conductance was detected. Although these two areas are small and definitive conclusions cannot be made about the entire alluvial aquifer, the lack of trend indicates that specific conductance or concentrations of dissolved solids have been stable in areas of the alluvial aquifer downstream from Pueblo.

Dissolved-Solids Loads

Long-term trends in monthly dissolved-solids loads were evaluated using nonparametric statistical procedures. The seasonal Kendall procedure was used for the Arkansas River below John Martin Reservoir. The seasonal rank-sum test was used for the Arkansas River above Pueblo to evaluate trends in dissolved-solids loads before and after storage of water in Pueblo Reservoir and also was used for the station, Arkansas River near Coolidge, Kans., where there is a 7-year break in the daily specific-conductance record. The results of the procedures are summarized in table 16. No significant trend occurred in the dissolved-solids load of Arkansas River above Pueblo, even though a significant trend occurred in both specific conductance and flow-adjusted specific conductance. The lack of trend is not unexpected because storage of water in Pueblo Reservoir has resulted only in mixing of the inflow with stored water and additional evaporation, and no new sources or sinks of dissolved solids have been established. A significant decrease in dissolved-solids load has occurred at both the Arkansas River below John Martin Reservoir and the Arkansas River near Coolidge, Kans. Both stations had significant trends of decreasing streamflow (Burns, 1985), which probably account for much of the decreased dissolved-solids loads.

SUMMARY

Specific conductance in the Arkansas River basin varied areally and seasonally. The specific conductance of surface and ground water was smallest upstream from Canon City and increased downstream. Mean specific conductance increased by about 50 times from the headwaters of the Arkansas River to the Colorado-Kansas State line. A similar increase in the specific conductance of water from alluvial aquifers along the Arkansas River also was measured. Mean specific conductance at stations that received runoff from snowmelt was smallest during May, June, or July. At stations where the highest flows usually were caused by rainfall runoff, mean specific conductance was smallest during July or August. Largest mean specific conductance occurred at most stations during the low-flow months during spring or fall.

Relations of specific conductance to streamflow were determined for 19 stations on the Arkansas River and for 50 stations on tributary streams. A log-log equation was chosen as the most appropriate of six equations evaluated to represent the inverse relation of specific conductance to streamflow. The relations were determined using least-squares linear regression; seasonal changes in the relations between the irrigation and nonirrigation seasons were determined using dummy-variables in the regression analysis. Significant seasonal trends in the relations existed at 40 of the 69 stations.

Table 16.--*Summary of results of trend test for monthly dissolved-solids loads at selected stations*

[Dash indicates no trend or not applicable (see footnotes); HS, highly significant ($p<0.01$); NS, not significant ($p>0.10$)]

Station number	Station name	Trend procedure used	Period(s)	Trend in monthly dissolved-solids load: Slope of trend[1] (percent per year)	Change between periods[2] (percent of mean)	Significance of trend
07099400	Arkansas River above Pueblo	Seasonal rank sum	1966-74 1974-83	-	-	NS
07130500	Arkansas River below John Martin Reservoir	Seasonal Kendall	1952-83	-0.16	-	HS
07137500	Arkansas River near Coolidge, Kans.	Seasonal rank sum	1964-69 1976-82	-	-111	HS

[1]Applies to seasonal Kendall procedure.
[2]Applies to seasonal rank-sum test, mean of data from both periods.

A regionalization procedure was used to estimate the effect of basin characteristics on the relations of specific conductance to streamflow. Of nine climatic or physiographic variables evaluated in the regionalization analysis, only drainage area, mean annual precipitation at the station, percent of the drainage area that was irrigated, and percent of the drainage area underlain by shale bedrock were found to be useful in estimation of specific conductance.

Relations of specific conductance to dissolved-solids concentration were determined for surface and ground water. Relations were determined for 28 surface-water stations and for ground water in the alluvial aquifers upstream and downstream from Pueblo. Relations of specific conductance to major-ion concentrations were determined for 26 stations along the Arkansas River and tributaries and for water from alluvial aquifers along the Arkansas River in reaches upstream and downstream from Pueblo.

Dissolved-solids loads were calculated for three stations, Arkansas River above Pueblo, Arkansas River below John Martin Reservoir, and Arkansas River near Coolidge, Kans., using daily specific-conductance measurements, daily streamflow, and the relations of specific conductance to dissolved-solids concentration for these stations. Trends in dissolved-solids loads were evaluated using nonparametric statistical procedures. No change in dissolved-solids load was observed downstream from Pueblo Reservoir after storage began, but significant decreases in dissolved-solids load have occurred downstream from John Martin Reservoir and at the station near Coolidge.

Mean concentrations of sodium, potassium, calcium, magnesium, chloride, fluoride, sulfate, and bicarbonate increase downstream in the Arkansas River and in adjacent alluvial aquifers. Sodium comprised an increasingly larger percentage of the cations downstream, and sulfate and chloride comprised an increasingly larger percentage of the anions downstream.

At stations where 10 years or more of specific-conductance data were available, long-term trends in specific conductance and flow-adjusted specific conductance were evaluated using nonparametric statistical procedures. Significant increasing trends in specific conductance, flow-adjusted specific conductance, and changes in the relations of specific conductance to streamflow were observed downstream from Pueblo Reservoir after the beginning of storage in 1974. Trends in specific conductance and flow-adjusted specific conductance were evaluated at 30 other stations. Increases in specific conductance occurred at 9 stations, decreases occurred at 8 stations, and no change was observed at 13 stations. Increases in flow-adjusted specific conductance occurred at 8 stations, decreases occurred at 5 stations, and no change was observed at 10 stations; 7 stations were not evaluated because of trends in streamflow.

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SUPPLEMENTAL INFORMATION

Table 17.--*Monthly statistics for specific conductance at selected surface-water stations*

[Specific conductance in microsiemens per centimeter at 25 degrees Celsius]

Station number	Station name	Month	Number of measurements	Specific conductance: Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
07081200	Arkansas River near Leadville	Jan.	11	301	49	260	273	280	305	440
		Feb.	10	277	78	160	197	295	338	395
		Mar.	10	313	43	260	287	303	327	400
		Apr.	11	274	101	130	220	260	300	500
		May	11	147	63	72	108	130	180	290
		June	14	110	35	70	82	104	127	185
		July	12	131	35	95	105	120	149	210
		Aug.	9	193	39	130	170	190	222	260
		Sept.	11	251	43	185	220	265	280	320
		Oct.	12	265	46	215	224	252	310	360
		Nov.	12	261	73	140	202	280	327	360
		Dec.	12	268	70	90	244	268	315	370
07083000	Halfmoon Creek near Malta	Jan.	17	93	8	75	90	95	99	105
		Feb.	21	93	12	60	93	95	100	103
		Mar.	17	95	8	70	91	97	100	105
		Apr.	19	90	8	74	88	90	95	107
		May	23	71	15	49	60	65	81	102
		June	21	60	19	43	49	55	70	110
		July	20	56	10	45	50	52	61	80
		Aug.	20	72	10	60	63	70	78	90
		Sept.	19	84	8	75	78	82	89	110
		Oct.	21	89	11	72	84	86	92	120
		Nov.	18	92	10	75	87	90	95	120
		Dec.	22	92	5	82	89	91	94	105
07083700	Arkansas River near Malta	Jan.	12	181	54	98	130	200	231	240
		Feb.	9	159	69	90	90	147	220	260
		Mar.	11	212	58	125	185	225	240	320
		Apr.	10	176	63	100	108	168	222	290
		May	13	138	48	92	100	128	170	225
		June	18	104	26	80	80	96	125	162
		July	13	107	26	64	93	105	125	155
		Aug.	11	139	44	70	100	160	175	195
		Sept.	14	186	77	72	100	208	221	310
		Oct.	15	171	55	89	130	180	214	250
		Nov.	11	130	63	68	70	90	175	230
		Dec.	13	196	61	95	144	220	245	270
07087200	Arkansas River at Buena Vista	Jan.	13	168	31	120	140	165	200	215
		Feb.	10	163	15	140	151	165	176	180
		Mar.	13	165	42	90	125	180	200	220
		Apr.	11	146	19	100	130	150	160	160
		May	17	113	36	75	95	100	120	200
		June	16	104	35	60	80	99	110	180
		July	16	95	21	60	80	100	110	130
		Aug.	9	100	11	85	85	105	110	110
		Sept.	12	123	24	80	96	131	140	155
		Oct.	10	149	28	100	120	155	164	193
		Nov.	13	140	52	50	92	175	180	215
		Dec.	13	181	41	50	180	180	205	210
07089000	Cottonwood Creek below Hot Springs, near Buena Vista	Jan.	14	143	17	110	134	145	160	160
		Feb.	11	141	11	118	135	140	150	160
		Mar.	11	143	16	115	140	140	145	170
		Apr.	12	144	13	120	136	140	157	162
		May	17	119	16	80	105	120	130	140
		June	19	94	25	60	80	82	110	140
		July	16	102	15	87	90	98	111	140
		Aug.	11	123	21	90	110	120	140	165
		Sept.	17	128	10	115	119	129	140	140
		Oct.	13	133	8	120	127	135	140	145
		Nov.	13	132	14	100	122	130	142	150
		Dec.	16	135	16	104	120	142	149	150

Table 17.--*Monthly statistics for specific conductance at selected surface-water stations*--Continued

Station number	Station name	Month	Number of measurements	Specific conductance: Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
07091200	Arkansas River near Nathrop	Jan.	18	174	38	113	130	180	206	220
		Feb.	16	173	31	103	164	180	195	205
		Mar.	15	194	29	140	180	200	200	250
		Apr.	11	150	24	115	128	160	160	190
		May	19	131	29	80	110	130	150	187
		June	24	108	26	75	92	100	114	175
		July	26	109	27	78	85	102	120	170
		Aug.	12	123	31	76	105	125	140	180
		Sept.	18	158	33	110	120	180	183	200
		Oct.	18	181	25	140	166	185	201	210
		Nov.	15	174	39	120	122	180	200	225
		Dec.	13	182	28	135	152	190	200	220
07094500	Arkansas River at Parkdale	Jan.	12	284	40	220	242	285	314	355
		Feb.	10	296	51	191	274	300	330	375
		Mar.	10	303	31	255	275	305	317	360
		Apr.	12	271	53	170	220	300	303	330
		May	12	188	54	115	160	180	221	310
		June	24	157	43	100	120	142	185	280
		July	19	174	53	115	130	160	200	300
		Aug.	9	195	16	180	180	190	212	220
		Sept.	15	261	38	200	230	265	300	305
		Oct.	12	311	33	255	282	317	335	375
		Nov.	9	277	54	200	220	280	320	350
		Dec.	12	305	37	240	275	320	334	350
07096000	Arkansas River at Canon City	Jan.	16	311	22	242	301	314	323	338
		Feb.	11	317	15	300	300	318	328	345
		Mar.	15	321	26	258	306	315	340	364
		Apr.	13	305	52	209	248	328	345	367
		May	12	226	73	140	172	199	295	361
		June	13	165	27	120	138	170	189	206
		July	13	176	31	139	149	162	204	238
		Aug.	14	215	48	156	168	211	247	307
		Sept.	10	283	38	225	250	279	316	340
		Oct.	16	313	29	270	282	318	340	356
		Nov.	15	304	37	222	280	311	324	361
		Dec.	10	316	18	280	305	316	330	340
07096500	Fourmile Creek near Canon City	Jan.	13	1,047	293	540	805	1,050	1,300	1,500
		Feb.	10	1,204	496	510	825	1,160	1,450	2,300
		Mar.	14	1,134	754	670	700	875	1,125	3,500
		Apr.	12	1,103	411	550	702	1,150	1,405	1,900
		May	11	1,056	434	510	720	950	1,500	1,900
		June	16	978	495	400	486	1,060	1,412	1,850
		July	15	1,181	352	520	1,010	1,200	1,450	1,900
		Aug.	12	1,138	331	600	952	1,100	1,262	1,900
		Sept.	13	1,004	287	560	805	1,000	1,175	1,600
		Oct.	12	918	293	420	640	925	1,156	1,320
		Nov.	14	929	254	540	779	850	1,200	1,500
		Dec.	13	1,038	233	600	860	1,100	1,225	1,300
07099100	Beaver Creek near Portland	Jan.	11	1,862	734	250	1,580	2,000	2,400	2,800
		Feb.	10	1,948	618	850	1,437	2,050	2,525	2,800
		Mar.	9	1,906	706	800	1,475	1,750	2,750	2,800
		Apr.	10	1,815	761	800	1,156	1,675	2,588	2,800
		May	16	1,486	914	160	477	1,550	2,325	2,800
		June	13	1,528	926	160	407	1,900	2,200	2,800
		July	15	1,484	960	170	460	1,600	2,500	2,800
		Aug.	10	1,792	781	700	869	1,975	2,406	2,800
		Sept.	9	1,750	578	500	1,375	2,000	2,150	2,200
		Oct.	10	1,784	768	700	819	2,010	2,463	2,600
		Nov.	11	1,769	798	380	1,430	1,800	2,500	2,600
		Dec.	11	1,781	669	520	1,100	2,000	2,300	2,650

Table 17.--*Monthly statistics for specific conductance at selected surface-water stations*--Continued

Station number	Station name	Month	Number of measurements	Specific conductance: Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
07099200	Arkansas River near Portland	Jan.	19	624	67	471	600	630	670	750
		Feb.	16	632	58	520	583	645	678	721
		Mar.	18	623	100	464	575	600	661	850
		Apr.	19	587	118	380	510	580	708	850
		May	18	378	106	220	306	373	410	640
		June	23	265	82	180	200	254	302	520
		July	20	295	105	203	218	266	312	600
		Aug.	20	377	101	467	335	302	260	601
		Sept.	18	550	108	383	465	548	629	771
		Oct.	21	628	122	440	543	638	712	950
		Nov.	20	587	112	315	537	585	669	750
		Dec.	16	614	45	550	580	605	655	696
07099400	Arkansas River above Pueblo	Jan.	281	619	113	385	530	608	701	916
		Feb.	268	614	110	365	530	613	675	866
		Mar.	257	598	91	435	533	600	639	864
		Apr.	269	564	133	230	480	560	654	875
		May	268	472	190	160	300	453	635	836
		June	255	314	173	140	210	250	320	859
		July	252	319	141	150	235	278	340	765
		Aug.	257	372	143	190	280	333	400	844
		Sept.	246	475	153	225	384	450	545	936
		Oct.	254	537	130	226	460	520	620	912
		Nov.	236	545	122	310	466	540	605	870
		Dec.	246	579	120	330	514	570	621	966
07103700	Fountain Creek near Colorado Springs	Jan.	21	417	129	270	337	380	455	800
		Feb.	14	400	127	276	324	359	463	750
		Mar.	17	351	54	277	313	342	377	475
		Apr.	26	338	56	180	310	347	381	425
		May	18	263	81	150	200	246	348	380
		June	18	276	91	112	208	287	347	400
		July	21	258	75	100	200	270	313	380
		Aug.	24	302	97	120	225	302	382	451
		Sept.	19	284	103	167	211	252	370	545
		Oct.	16	308	104	148	195	340	395	470
		Nov.	17	344	99	188	243	350	420	495
		Dec.	17	419	112	259	342	416	472	700
07103747	Monument Creek at Palmer Lake	Jan.	10	196	24	162	172	195	215	230
		Feb.	8	190	17	165	176	193	198	220
		Mar.	11	168	40	110	155	162	192	250
		Apr.	13	134	35	94	100	119	170	195
		May	15	93	20	55	79	86	105	130
		June	12	132	23	92	117	125	147	175
		July	12	181	26	140	149	190	204	210
		Aug.	17	199	31	152	162	204	230	240
		Sept.	14	201	28	148	184	205	221	242
		Oct.	9	208	22	170	198	200	227	240
		Nov.	9	188	35	145	150	190	221	238
		Dec.	12	191	20	158	175	185	211	220
07103800	West Monument Creek at Air Force Academy	Jan.	21	111	29	70	95	108	112	210
		Feb.	8	103	15	82	86	105	115	120
		Mar.	13	102	24	70	88	92	120	160
		Apr.	19	98	11	80	90	100	105	120
		May	12	89	20	50	71	95	100	120
		June	12	100	13	80	89	100	114	120
		July	14	116	15	99	103	120	120	145
		Aug.	18	120	16	95	110	116	120	160
		Sept.	17	122	18	95	111	118	132	160
		Oct.	15	117	28	95	95	105	145	190
		Nov.	20	110	27	65	106	110	114	200
		Dec.	18	112	34	50	96	107	120	220

Table 17.--*Monthly statistics for specific conductance at selected surface-water stations*--Continued

Station number	Station name	Month	Number of measurements	Specific conductance: Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
07104000	Monument Creek at Pikeview	Jan.	15	355	41	305	310	360	393	420
		Feb.	13	345	55	245	317	360	382	430
		Mar.	15	327	54	240	293	325	365	405
		Apr.	25	276	80	158	205	288	305	480
		May	15	214	57	122	148	233	265	295
		June	22	260	60	132	225	246	310	360
		July	19	328	65	200	280	338	369	436
		Aug.	23	368	84	196	290	360	415	515
		Sept.	20	367	53	300	321	360	397	480
		Oct.	12	368	63	300	305	357	430	485
		Nov.	13	352	72	218	329	348	417	445
		Dec.	13	333	79	178	300	350	380	428
07105500	Fountain Creek at Colorado Springs	Jan.	22	801	287	350	603	725	1,024	1,280
		Feb.	15	691	152	460	570	652	884	900
		Mar.	22	734	209	360	625	709	950	1,050
		Apr.	28	512	185	200	385	487	646	900
		May	24	426	139	152	309	466	540	580
		June	27	594	209	164	431	635	800	875
		July	28	687	232	190	531	700	880	1,010
		Aug.	28	548	265	195	320	548	697	1,250
		Sept.	24	574	203	260	409	597	711	955
		Oct.	13	663	194	372	512	660	785	965
		Nov.	18	660	168	394	552	630	800	940
		Dec.	16	702	127	400	640	706	818	860
07105800	Fountain Creek at Security	Jan.	18	862	237	100	787	937	1,000	1,150
		Feb.	10	891	125	680	831	887	944	1,150
		Mar.	21	829	95	580	773	850	900	980
		Apr.	21	691	214	360	530	680	895	1,000
		May	20	584	242	212	370	565	818	1,020
		June	21	671	262	260	437	690	911	1,025
		July	25	698	220	280	547	700	907	1,000
		Aug.	27	692	195	380	520	680	893	1,000
		Sept.	18	693	236	220	490	735	870	1,000
		Oct.	13	738	205	220	619	777	912	950
		Nov.	16	879	97	680	823	905	950	1,010
		Dec.	16	946	225	220	906	974	1,037	1,280
07106300	Fountain Creek near Pinon	Jan.	10	1,370	225	1,120	1,170	1,300	1,565	1,750
		Feb.	8	1,437	456	1,040	1,067	1,345	1,600	2,400
		Mar.	14	1,286	255	800	1,108	1,275	1,460	1,825
		Apr.	20	1,214	337	680	952	1,150	1,515	1,850
		May	18	933	460	130	551	930	1,307	1,750
		June	19	998	347	520	750	960	1,210	1,700
		July	21	1,012	227	600	873	950	1,190	1,420
		Aug.	36	826	307	490	575	705	1,053	1,770
		Sept.	17	1,127	321	680	840	1,090	1,405	1,700
		Oct.	10	1,442	278	1,025	1,230	1,420	1,631	1,950
		Nov.	12	1,462	189	1,210	1,332	1,445	1,578	1,900
		Dec.	15	1,499	288	1,080	1,340	1,475	1,600	2,300
07106500	Fountain Creek at Pueblo	Jan.	23	1,656	614	1,150	1,350	1,520	1,675	4,220
		Feb.	25	1,574	376	1,000	1,295	1,500	1,800	2,810
		Mar.	28	1,594	391	950	1,320	1,648	1,800	2,780
		Apr.	38	1,764	557	730	1,338	1,665	2,000	3,090
		May	34	1,589	696	520	910	1,635	2,100	3,380
		June	39	1,618	728	680	975	1,250	2,300	3,500
		July	35	2,181	1,216	700	1,300	1,900	2,700	5,800
		Aug.	31	1,830	1,256	630	1,000	1,600	2,100	6,000
		Sept.	33	2,250	799	900	1,560	2,400	2,800	4,000
		Oct.	25	2,320	770	1,270	1,715	2,100	2,995	4,000
		Nov.	29	1,857	479	1,100	1,605	1,850	2,000	3,740
		Dec.	27	1,768	414	1,240	1,550	1,660	1,800	3,460

Table 17.--*Monthly statistics for specific conductance at selected surface-water stations*--Continued

Station number	Station name	Month	Number of measurements	Specific conductance: Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
07108900	St. Charles River at Vineland	Jan.	10	2,289	686	1,000	1,950	2,250	2,993	3,200
		Feb.	9	2,276	380	1,850	2,025	2,185	2,550	3,000
		Mar.	8	1,977	547	1,040	1,636	1,950	2,510	2,700
		Apr.	15	1,962	903	440	830	2,400	2,600	2,900
		May	19	1,416	998	370	520	870	2,200	3,150
		June	15	1,547	943	310	640	1,420	2,250	3,250
		July	12	2,532	845	1,250	1,900	2,350	3,000	4,000
		Aug.	16	1,999	1,023	560	725	2,175	2,975	3,300
		Sept.	12	2,385	995	1,030	1,168	2,875	3,150	3,500
		Oct.	9	2,621	489	1,580	2,300	2,800	2,945	3,200
		Nov.	12	2,647	519	1,710	2,125	2,800	3,075	3,250
		Dec.	10	2,740	566	2,000	2,300	2,700	3,100	3,800
07109500	Arkansas River near Avondale	Jan.	14	1,075	200	750	916	1,088	1,200	1,550
		Feb.	11	971	77	850	900	960	1,020	1,120
		Mar.	13	977	170	760	900	960	1,070	1,400
		Apr.	23	897	207	475	740	925	1,000	1,450
		May	24	775	163	480	642	767	900	1,050
		June	26	433	165	190	312	375	557	800
		July	16	473	180	280	334	425	594	950
		Aug.	26	562	160	360	454	510	647	975
		Sept.	28	824	207	410	700	845	984	1,315
		Oct.	21	830	131	570	760	810	935	1,100
		Nov.	17	896	132	625	815	890	975	1,180
		Dec.	16	1,048	163	750	912	1,050	1,160	1,380
07117600	Chicosa Creek near Fowler	Jan.	10	2,734	801	870	2,456	2,800	3,175	3,900
		Feb.	10	2,561	737	1,500	1,900	2,725	3,125	3,600
		Mar.	11	1,942	622	925	1,600	1,800	2,230	3,100
		Apr.	12	2,722	364	2,175	2,430	2,750	2,815	3,600
		May	14	2,311	547	1,100	1,963	2,375	2,750	3,050
		June	16	1,737	651	600	1,444	1,500	2,238	3,200
		July	18	1,727	832	700	965	1,650	2,475	3,200
		Aug.	16	2,448	672	1,000	2,063	2,420	2,808	3,700
		Sept.	12	2,633	537	1,600	2,410	2,725	3,000	3,500
		Oct.	10	2,925	553	2,200	2,400	2,900	3,350	3,950
		Nov.	12	2,825	692	1,350	2,575	3,000	3,338	3,600
		Dec.	8	2,594	755	1,200	2,075	2,800	3,263	3,400
07119500	Apishapa River near Fowler	Jan.	19	2,423	861	1,290	1,600	2,300	3,000	4,000
		Feb.	19	2,261	939	1,070	1,500	1,900	2,900	3,900
		Mar.	17	1,988	693	1,100	1,360	1,850	2,650	3,070
		Apr.	21	2,346	733	1,040	1,515	2,600	2,880	3,300
		May	20	2,185	977	725	1,263	2,525	3,045	3,800
		June	22	1,284	847	599	725	890	1,655	3,000
		July	30	1,631	793	775	1,038	1,280	2,350	3,300
		Aug.	23	1,813	854	700	1,100	1,500	2,500	3,250
		Sept.	23	2,169	753	830	1,400	2,250	2,800	3,700
		Oct.	16	2,107	703	905	1,615	2,175	2,810	3,100
		Nov.	20	1,829	719	875	1,233	1,650	2,400	3,100
		Dec.	19	2,069	1,034	950	1,160	1,600	3,100	4,000
07121500	Timpas Creek at mouth near Swink	Jan.	17	2,668	574	1,600	2,175	2,600	3,200	3,500
		Feb.	17	2,393	733	1,400	1,875	2,200	3,150	3,750
		Mar.	20	1,768	310	1,250	1,541	1,725	2,000	2,400
		Apr.	19	2,103	494	1,280	1,700	2,200	2,500	3,000
		May	19	2,109	542	1,000	1,700	2,100	2,600	3,000
		June	22	1,450	478	625	1,113	1,475	1,775	2,700
		July	26	1,754	608	530	1,462	1,700	2,025	3,400
		Aug.	16	1,908	552	1,250	1,493	1,790	2,275	3,100
		Sept.	21	1,729	315	1,400	1,500	1,600	1,875	2,600
		Oct.	15	1,798	481	1,000	1,350	1,920	2,150	2,800
		Nov.	19	1,673	277	1,250	1,400	1,700	1,930	2,100
		Dec.	16	1,972	553	1,250	1,662	1,725	2,360	3,200

Table 17.--*Monthly statistics for specific conductance at selected surface-water stations--Continued*

Station number	Station name	Month	Number of measurements	Specific conductance: Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
07122400	Crooked Arroyo near Swink	Jan.	15	3,117	441	2,100	3,000	3,200	3,400	3,700
		Feb.	16	2,815	630	1,500	2,500	3,049	3,200	3,500
		Mar.	19	2,198	837	875	1,510	2,000	3,000	3,500
		Apr.	15	2,424	609	1,350	2,050	2,300	2,700	3,700
		May	14	2,618	1,028	1,250	1,500	2,950	3,400	4,400
		June	20	1,474	519	870	1,100	1,300	1,856	2,600
		July	19	1,869	606	1,090	1,500	1,750	2,000	3,400
		Aug.	16	2,209	926	1,100	1,313	2,100	3,200	3,500
		Sept.	19	2,068	762	1,140	1,500	1,800	3,000	3,400
		Oct.	15	2,103	691	1,300	1,500	1,900	2,800	3,500
		Nov.	19	1,882	785	1,150	1,300	1,500	2,600	3,500
		Dec.	18	3,028	814	1,600	2,275	3,200	3,500	4,500
07124000	Arkansas River at Las Animas	Jan.	24	2,904	719	1,500	2,250	3,000	3,500	4,000
		Feb.	28	3,009	621	1,780	2,450	3,250	3,500	3,800
		Mar.	23	3,403	496	2,400	3,000	3,500	3,700	4,500
		Apr.	39	3,345	866	1,020	2,900	3,500	4,000	4,500
		May	39	3,077	995	800	2,600	3,400	3,800	4,500
		June	41	1,707	908	590	947	1,400	2,500	3,700
		July	42	1,843	1,028	570	1,000	1,435	2,800	3,950
		Aug.	34	2,070	1,072	580	1,098	1,750	3,062	4,000
		Sept.	35	2,543	882	840	1,880	2,600	3,250	4,030
		Oct.	21	2,644	1,033	1,200	1,600	2,560	3,700	4,250
		Nov.	23	3,311	566	2,300	2,980	3,330	3,700	4,500
		Dec.	23	3,013	805	1,500	2,470	3,000	3,750	4,500
07124050	Middle Fork Purgatoire River at Stonewall	Jan.	74	322	40	267	281	325	352	403
		Feb.	85	339	51	258	288	351	375	460
		Mar.	67	333	38	277	297	324	366	434
		Apr.	51	261	37	209	226	259	297	329
		May	82	202	43	121	177	202	213	336
		June	61	151	11	125	142	151	159	170
		July	84	204	30	159	188	197	225	272
		Aug.	70	220	27	179	196	222	238	276
		Sept.	60	253	24	202	237	248	274	293
		Oct.	47	309	38	248	292	314	339	372
		Nov.	60	376	34	319	349	377	404	455
		Dec.	62	363	33	311	331	369	385	439
07124200	Purgatoire River at Madrid	Jan.	11	449	43	375	400	460	490	500
		Feb.	12	415	79	265	369	425	480	530
		Mar.	16	455	43	390	422	460	480	560
		Apr.	8	389	67	280	327	402	452	468
		May	23	305	60	170	265	300	360	408
		June	25	257	58	151	220	260	295	420
		July	27	344	87	200	280	330	390	490
		Aug.	22	331	65	205	290	325	364	520
		Sept.	13	370	58	280	320	380	410	460
		Oct.	13	419	46	320	375	435	450	460
		Nov.	12	399	36	340	365	405	431	443
		Dec.	10	427	55	385	397	410	433	575
07124300	Long Canyon Creek near Madrid	Jan.	11	539	106	300	520	550	588	730
		Feb.	9	538	44	480	493	558	571	600
		Mar.	7	570	96	480	500	565	580	770
		Apr.	10	509	72	385	444	538	562	580
		May	10	484	68	360	442	495	550	562
		June	15	516	59	360	480	530	565	580
		July	15	451	132	120	420	490	520	600
		Aug.	14	396	172	100	264	415	541	650
		Sept.	8	508	60	380	482	525	550	565
		Oct.	9	545	49	480	500	540	585	630
		Nov.	8	551	43	460	527	565	580	588
		Dec.	7	525	51	480	490	490	590	600

Table 17.--*Monthly statistics for specific conductance at selected surface-water stations*--Continued

Station number	Station name	Month	Number of measurements	Specific conductance: Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
07126200	Van Bremer Arroyo near Model	Jan.	12	1,922	234	1,500	1,737	1,975	2,118	2,200
		Feb.	12	1,858	156	1,700	1,700	1,835	2,000	2,180
		Mar.	9	1,867	107	1,625	1,835	1,900	1,930	2,000
		Apr.	10	1,963	156	1,700	1,837	2,005	2,078	2,200
		May	8	1,906	145	1,650	1,812	1,900	2,038	2,100
		June	16	1,663	245	1,250	1,472	1,640	1,900	2,000
		July	14	1,448	578	380	910	1,600	1,888	2,200
		Aug.	10	1,490	397	850	1,153	1,510	1,725	2,200
		Sept.	10	1,433	300	875	1,280	1,550	1,607	1,800
		Oct.	9	1,747	338	1,200	1,500	1,700	2,000	2,300
		Nov.	12	1,712	366	950	1,712	1,775	1,975	2,100
		Dec.	10	1,797	285	1,300	1,500	1,837	2,025	2,200
07126300	Purgatoire River near Thatcher	Jan.	13	3,738	860	2,200	3,095	3,660	4,200	5,300
		Feb.	9	3,611	474	3,000	3,225	3,500	3,900	4,500
		Mar.	11	3,626	654	2,400	3,325	3,900	4,000	4,400
		Apr.	10	2,902	1,228	490	1,910	3,095	4,025	4,300
		May	10	3,076	1,295	1,100	1,828	3,275	3,900	5,000
		June	17	2,317	1,255	808	1,460	2,010	2,950	6,000
		July	13	1,962	914	950	1,035	2,000	2,870	3,300
		Aug.	16	2,038	800	900	1,338	1,850	2,575	3,950
		Sept.	10	2,135	970	900	1,413	1,915	3,075	3,900
		Oct.	11	2,359	594	1,500	1,900	2,300	2,700	3,500
		Nov.	14	3,740	915	2,400	3,000	3,400	4,775	5,000
		Dec.	8	3,321	1,565	670	2,250	3,500	4,125	6,000
07128500	Purgatoire River near Las Animas	Jan.	27	4,001	1,214	1,300	3,000	3,900	4,800	6,750
		Feb.	25	3,888	1,175	2,600	3,000	3,600	4,550	8,000
		Mar.	23	3,814	819	2,300	3,300	3,900	4,410	5,300
		Apr.	33	3,932	1,515	850	2,650	4,410	5,000	6,000
		May	41	3,885	1,675	920	2,360	4,700	5,000	6,500
		June	40	2,622	1,181	900	1,725	2,375	3,618	5,000
		July	39	2,637	1,156	800	1,620	2,600	3,750	5,000
		Aug.	27	2,394	1,200	580	1,400	2,200	3,330	5,000
		Sept.	30	3,430	1,240	950	2,563	3,450	4,400	5,500
		Oct.	23	3,163	1,080	900	2,400	3,200	4,030	5,000
		Nov.	22	3,447	1,052	1,400	2,708	3,450	4,000	6,500
		Dec.	22	4,022	799	2,850	3,425	3,910	4,535	6,000
07130500	Arkansas River below John Martin Reservoir	Jan.	700	3,805	652	1,500	3,500	3,950	4,250	4,810
		Feb.	643	3,734	662	1,200	3,500	3,860	4,180	4,800
		Mar.	721	3,487	791	700	3,100	3,610	4,040	4,840
		Apr.	797	3,072	789	850	2,550	3,220	3,595	5,180
		May	844	2,746	948	800	1,900	2,800	3,537	4,690
		June	820	1,807	879	476	1,200	1,500	2,100	4,590
		July	856	1,690	717	575	1,180	1,500	2,000	4,090
		Aug.	848	1,866	821	700	1,310	1,620	2,207	4,620
		Sept.	823	2,409	985	835	1,480	2,210	3,230	5,000
		Oct.	837	2,684	984	750	1,800	2,800	3,590	4,830
		Nov.	687	3,296	693	1,500	2,920	3,410	3,740	4,830
		Dec.	698	3,676	713	900	3,277	3,860	4,152	4,870
07133000	Arkansas River at Lamar	Jan.	21	4,791	713	3,500	4,350	4,640	5,100	6,750
		Feb.	27	4,873	944	3,000	4,400	4,960	5,300	8,000
		Mar.	26	4,924	921	3,100	4,500	4,890	5,500	7,000
		Apr.	36	4,073	850	2,400	3,425	3,885	4,785	6,000
		May	39	3,615	1,373	560	2,600	3,300	4,970	6,250
		June	40	2,272	941	750	1,600	2,200	2,800	4,530
		July	31	2,278	1,151	856	1,280	1,900	3,000	4,600
		Aug.	32	2,746	1,160	867	1,758	2,825	3,950	4,500
		Sept.	29	3,465	1,053	964	2,700	3,500	4,375	5,000
		Oct.	22	4,033	1,052	1,500	3,350	4,150	4,812	5,900
		Nov.	29	4,531	764	2,800	4,180	4,580	5,100	6,000
		Dec.	18	4,742	1,148	1,800	4,390	4,520	5,300	7,000

Table 17.--*Monthly statistics for specific conductance at selected surface-water stations*--Continued

Station number	Station name	Month	Number of measurements	Specific conductance						
				Mean	Standard deviation	Minimum	Twenty-fifth percentile	Median	Seventy-fifth percentile	Maximum
07134100	Big Sandy Creek near Lamar	Jan.	14	4,536	731	3,400	3,575	4,900	5,000	5,500
		Feb.	13	4,677	700	3,400	4,150	4,600	5,100	6,000
		Mar.	15	4,607	623	3,500	4,200	4,600	5,000	5,500
		Apr.	15	4,330	825	3,000	3,700	4,600	4,900	5,800
		May	22	4,373	980	1,400	3,850	4,500	5,000	5,500
		June	19	4,204	943	1,200	4,000	4,300	4,750	5,500
		July	17	3,749	992	1,590	3,150	3,750	4,375	6,000
		Aug.	16	4,581	841	3,000	4,050	4,600	5,000	6,500
		Sept.	14	4,082	1,628	500	3,313	4,300	5,275	6,000
		Oct.	8	4,912	795	4,000	4,075	5,000	5,750	6,000
		Nov.	15	4,850	564	3,000	4,900	5,000	5,000	5,500
		Dec.	12	4,617	723	3,400	3,975	4,850	5,000	5,800
07137500	Arkansas River near Coolidge, Kans.	Jan.	25	4,579	614	3,500	4,190	4,600	4,995	6,500
		Feb.	40	4,343	861	1,200	4,200	4,485	4,845	6,000
		Mar.	35	4,462	649	3,100	4,100	4,430	4,700	6,010
		Apr.	50	4,064	856	1,880	3,692	4,200	4,600	6,000
		May	59	3,544	1,341	512	2,620	4,050	4,600	5,200
		June	45	3,006	1,143	530	2,070	3,000	4,125	4,700
		July	59	2,919	1,109	661	2,100	2,900	3,740	5,200
		Aug.	57	3,161	1,285	900	1,830	3,500	4,200	5,500
		Sept.	42	3,808	1,163	475	3,600	4,120	4,500	5,500
		Oct.	37	4,201	528	3,050	3,945	4,184	4,500	5,500
		Nov.	31	4,290	614	3,000	3,900	4,320	4,750	5,800
		Dec.	29	4,353	446	3,160	4,090	4,310	4,500	5,430

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