Information Series 49

Reconnaissance Field Investigation of SURFACE-WATER SPECIFIC CONDUCTANCE in the Snowmass–Glenwood Springs Area, West-Central Colorado

By Robert M. Kirkham,
Jonathan M. Zook,
and Matthew A. Sares

Colorado Geological Survey / Department of Natural Resources / Denver, Colorado / 1999

Information Series 49

Reconnaissance Field Investigation of Surface-Water Specific Conductance in the Snowmass-Glenwood Springs Area, West-Central Colorado

By Robert M. Kirkham, Jonathan M. Zook, and Matthew A. Sares

DOI: https://doi.org/10.58783/cgs.is49.cyfy9632

State of Colorado, Bill Owens, Governor
Department of Natural Resources, Greg E. Walcher, Director
Colorado Geological Survey, Vicki Cowart, Director
Denver, Colorado
1999

Contents

Figures

Tables

Plate

Acknowledgements

This project was completed through funds from severance taxes, which are derived from the production of oil, natural gas, coal, and minerals in the state of Colorado.

The authors would like to thank Paul von Guerard, David Merritt, and Steve Miller for reviewing this report and making helpful suggestions for its improvement. The authors are solely responsible for any errors in the published report.

Introduction

This report contains the results of a reconnaissance-level field investigation of surface-water quality in the Snowmass-Glenwood Springs area of west-central Colorado. Included in the report are maps and tables that describe the test locations and associated field measurements within the study area (Figure 1). The report is essentially a basic-data report and contains only limited interpretations and conclusions.

Salinity problems in the Colorado River have been well documented during the past several years through numerous investigations by the U.S. Bureau of Reclamation, Colorado River Basin Salinity Control Forum, and U.S. Geological Survey-Water Resources Division. Significant salt loadings to the Colorado River and its tributaries occur in west-central Colorado in the vicinity of the towns of Eagle, Glenwood Springs, and Carbondale. These salt loadings have been associated with dissolution of halite and gypsum within the Pennsylvanian Eagle Valley Evaporite (URS Corporation, 1981; Warner and others, 1985; Eisenhauer, 1986).

In 1993 the Colorado Geological Survey (CGS) initiated a 1:24,000-scale geologic mapping program in the vicinity of Glenwood Springs in west-central Colorado. By the spring of 1995, it was obvious from this geologic mapping that a large part of the area had structurally collapsed during the late Cenozoic Era. In the fall of 1995 the U.S. Geological Survey (USGS) began a geologic mapping program along the Interstate Highway 70 corridor adjacent to areas being mapped by the CGS. Through cooperative work by the CGS and USGS in their respective field areas, the general characteristics and lateral and vertical extent of these actively collapsing areas has been fairly well defined (Kirkham and Widmann, 1997; Kirkham, 1997; Kirkham and others, 1998; Scott and others, 1998). The regional collapse occurring in west-central Colorado is believed to result from dissolution and flowage of evaporitic rocks in the Pennsylvanian Eagle Valley Evaporite.

The initial, large salt loadings to the Colorado River system coincide with the active, regional collapse centers that have been recently discovered by the CGS and USGS. Much of the salt load directly enters the Colorado River via Glenwood and Dotsero Hot Springs (Eisenhauer, 1986). Although no saline hot springs occur along the Roaring Fork River, salinity of the river increases as it crosses the Carbondale collapse center (see Figure 1 for location). Based upon data collected during December 1977, Warner and others (1985) concluded that the base-flow salt load in the Roaring Fork River increased from about 32,700 tons/year at Woody Creek to about 183,000 tons/year at the confluence with the Colorado River. In the same reach, base-flow discharge increased from 105 cubic feet per second (ft^3/s) near Woody Creek to 370 ft^3/s at the confluence with the Colorado River. They attributed the increased salt load in part to tributary inflow, but mostly to direct ground-water discharge into the river. This notable increase in salt load in the Roaring Fork River occurs as the river crosses the Carbondale collapse center.

The CGS undertook this reconnaissance-level investigation for several reasons. The CGS is interested in water quality throughout the state, because geology has an important influence on both surface-water and ground-water quality. The geographic coincidence of the Carbondale collapse center with the marked increase in salinity of streams suggested that dissolution of evaporitic rocks was contributing to or causing both the collapse and salt loading. Geologic studies indicate that the rate and structural style of collapse vary spatially and temporally. By inference, the dissolution rates also vary with location and time. Recognition of saline ground-water and

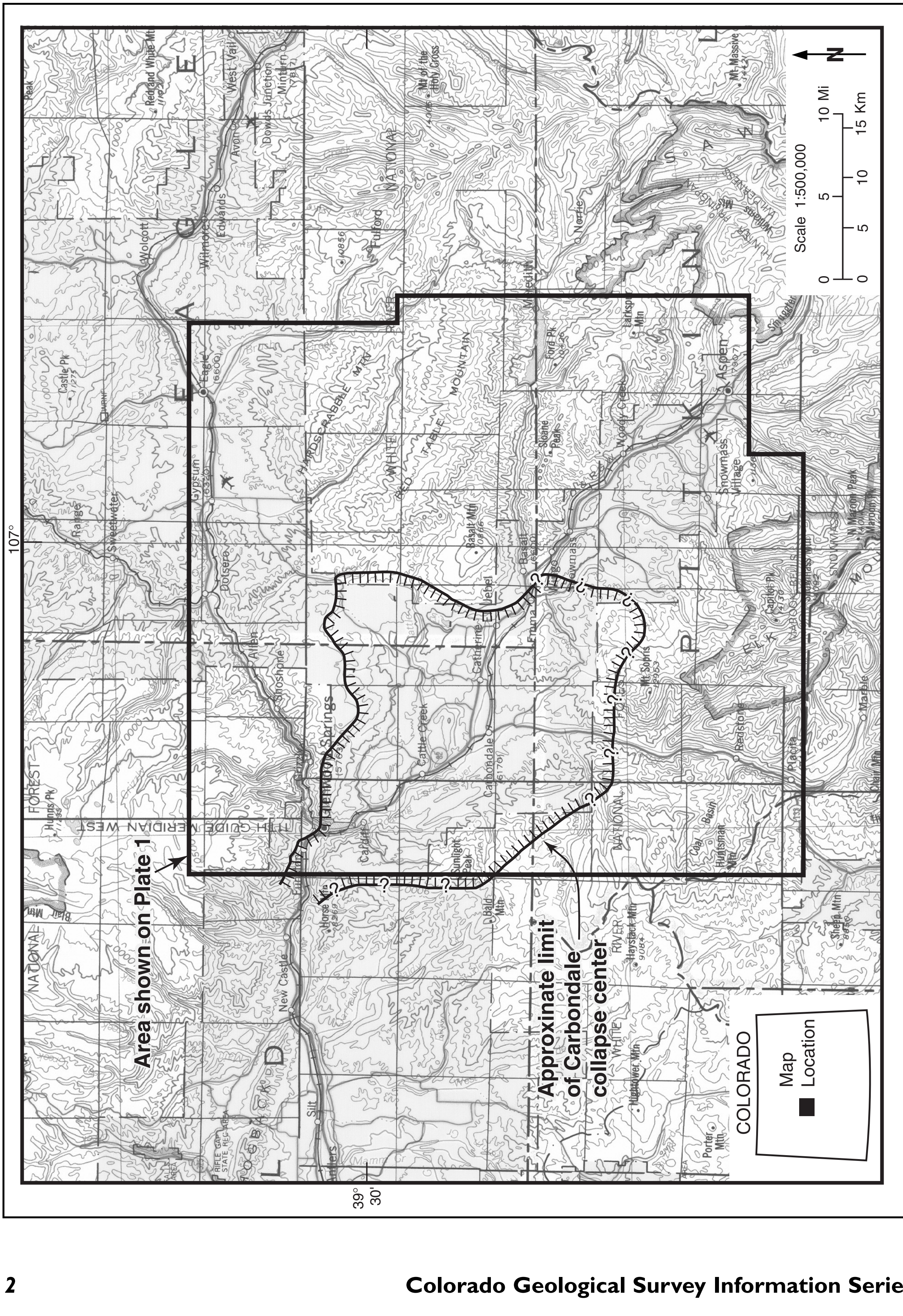


Figure 1. Location map of study area and approximate limits of the Carbondale Collapse Center.

surface-water sources could aid efforts to identify where active dissolution is occurring and to model saline ground-water flow paths. The results of the reconnaissance study could also focus any future, more comprehensive work on these salinity issues.

The primary goal of this investigation was to develop a better understanding of the sources of salinity in the Roaring Fork River and its tributaries in the vicinity of the Carbondale collapse center. To accomplish this goal, the specific conductance, salinity, pH, and temperature of surface water and springs in the area were measured in the field. Field measurements were also collected for the Colorado River in several locations, for several hot springs along the Colorado River, and for a cold spring in Mitchell Creek northwest of Glenwood Springs. Test locations are shown on Plate 1, along with specific conductance data for each site. This information may be used to qualitatively assess the potential significance of individual springs and tributaries to the salinity of the Roaring Fork River, particularly springs that discharge from evaporitic rocks and tributaries that drain basins underlain by evaporitic rocks at or near the surface.

The scope of this reconnaissance surface-water investigation was limited to field measurements. No water samples were collected for laboratory analysis, and discharge rates were not determined for the tested waters.

Data Collection and Methodology

Field measurements of specific conductance, salinity, temperature, and pH were obtained on random point samples at 112 test locations between October 6 and October 16, 1997. Most of the sites and test locations were situated along the Roaring Fork River and its principal tributaries, but several tests were also run on the Colorado River and its tributaries in the vicinity of Glenwood Springs. Both hot and cold springs in the area were tested. Specific conductance, salinity, and temperature were measured using a YSI Incorporated Model 30 instrument. A Myron L Company Model DCH4 instrument was utilized to measure pH. Test locations were plotted on 1:24,000-scale topographic maps while in the field and later digitized in the office.

The identification number for each test location consists of a series of letters followed by a number. The letters refer to the water source being tested (Table 1). For example, "RFR" indicates test locations on the Roaring Fork River. The individual test locations on each water source were assigned a sequential numeric value. Test location number RFR-3 describes the third location at which water was tested on the Roaring Fork River. The test location numbers were assigned chronologically during the investigation, not in an upstream to downstream sequence.

Results and Interpretations

Overview

The following description of the results and interpretations of this field investigation is organized by geographic location. The discussion progresses from upstream to downstream along the Roaring Fork River. Tributaries and springs are discussed based on where their discharge enters the Roaring Fork River. This section concludes with a description of the tests performed on surface waters outside of the Roaring Fork River drainage basin.

Table 1 explains the test location abbreviations for the various water sources investigated. Measured field parameters for each test and a brief description of the test location are given in Table 2 (at the end of this chapter). Figure 2, which follows Table 2, is a graphical representation of the specific conductance at test locations in the Roaring Fork River. It relates the specific conductance of point samples in the river to geographic position. Point samples are susceptible to local variations in the stream and may or may not accurately reflect the character of the entire river at that location.

Roaring Fork River Drainage Basin from Snowmass Creek to the Crystal River

A specific conductance of 399 µS/cm (microSiemens per centimeter) was measured in the Roaring Fork River immediately above its confluence with Snowmass Creek (test location RFR-5). Snowmass Creek, which had a specific conductance of 407 µS/cm at test location SMC-1, had little effect on the Roaring Fork River. Specific conductance of the Roaring Fork River apparently remains fairly constant to the confluence with the Fryingpan River (see RFR-6 and RFR-1 through 3). The Fryingpan River had a specific conductance of 157 µS/cm at the gaging station

Table 1. Explanation of test location abbreviations.

Test Location	Drainage Name
BC	Blue Creek
BG	Barber's Gulch
CBL	Cedar Brook Lake
CC	Cattle Creek
CLC	Coal Creek
COC	Coulter Creek
COR	Colorado River
CPC	Cottonwood Creek
CR	Crystal River
CRHS	Colorado River Hot Springs
CS	Crystal Spring
CSC	Crystal Spring Creek
DG	Dolan Gulch
EC	East Creek
ECC	East Coulter Creek
EJS	El Jebel Spring
ESC	East Sopris Creek
FC	Fisher Creek
FMC	Four Mile Creek
FPR	Fryingpan River
HHS	Hobo Hot Springs
ID	Irrigation Ditch
IHS	Iron Hot Springs
MC	Mitchell Creek
MCS	Mitchell Creek Spring
NC	Nettle Creek
NN	No Name Creek
RC	Red Canyon Creek
RFR	Roaring Fork River
SC	Sopris Creek
SD	Shippee’s Draw
SDS	Shippee’s Draw Spring
SMC	Snowmass Creek
SV	Spring Valley Creek
SVS	Spring Valley Spring
TMC	Three Mile Creek
US	Unnamed Spring
VC	Vapor Caves

below Reudi Reservoir (FPR-2), and it increased only to 200 µS/cm at its mouth (FPR-1). The Fryingpan River may contribute to a lower dissolved solid concentration in the Roaring Fork River, as a point sample well below the inflow from the Fryingpan River had a specific conductance of 320 µS/cm (RFR-4).

Water discharging from Cedar Brook Lake, a spring-fed lake located in landslide deposits derived from Mancos Shale and late Tertiary basalt (Kirkham and others, 1998), had a specific conductance of 213 µS/cm (CBL-1). About one mile downstream of the Cedar Brook Lake discharge, a test location in the Roaring Fork River above Sopris Creek had a specific conductance of 310 µS/cm (RFR-7).

At the confluence of Sopris Creek and the Roaring Fork River, the specific conductance of Sopris Creek was 403 µS/cm (SC-1), which is noticeably lower than values recorded farther upstream on this creek. At the confluence of East and West Sopris Creeks, the specific conductance of East Sopris Creek was 472 µS/cm (ESC-1), West Sopris Creek was 550 µS/cm (WSC-1), and Sopris Creek below the confluence was 492 µS/cm (SC-2). Part, and perhaps much, of the dissolved solids load in Sopris Creek has probably been leached from the extensive outcrops of Mancos Shale that lie within its drainage basin. In spite of the higher specific conductance of Sopris Creek, point samples near the northeast bank of the Roaring Fork River appear to have about the same concentration of dissolved solids above Sopris Creek (310 µS/cm, RFR-7) as below Sopris Creek (311 µS/cm, RFR-8).

The boundaries of the Carbondale collapse center are poorly constrained in this area. The Roaring Fork River probably enters the Carbondale collapse center somewhere near its confluence with Sopris Creek (Figure 1 and Plate 1), and part of the Sopris Creek drainage basin may lie within the collapse center. The collapse center coincides with the area in which evaporite has dissolved or plastically flowed during the late Cenozoic Era, a process continuing to the present. The salt load in the Roaring Fork River generally increases within the collapse center boundaries.

Near Mulford, at the first test location within the Carbondale collapse center (RFR-38), a point sample in the Roaring Fork River had a specific conductance of 363 µS/cm. A spring adjacent to Upper Cattle Creek Road, about 0.75 miles above El Jebel, discharges directly from a bed of gypsum near a prominent, large sinkhole developed in gypsum. Surprisingly, the specific conductance of the spring was only 1,134 µS/cm (EJS-1). It was thought that a spring discharging from a gypsum bed near a sinkhole caused by dissolution would exhibit significantly higher conductivity. Nearby, Blue Creek had a specific conductance of 341 µS/cm where it crosses Upper Cattle Creek Road (BC-1). These surface-water sources of salinity could be partly responsible for the moderate increase in specific conductivity in the Roaring Fork River between Sopris Creek (RFR-8) and Mulford (RFR-38).

Crystal Spring (CS-1) discharges from surficial deposits that overlie basalt and evaporitic rocks. It had a specific conductance of 612 µS/cm. Crystal Spring Creek, at the farthest downstream test location (CSC-2), had a specific conductance of 852 µS/cm. A test location in the Roaring Fork River (RFR-39), which had a specific conductance of 384 µS/cm above the confluence with the Crystal River, perhaps partly reflects the inflow of water from Crystal Spring Creek.

Crystal River Drainage Basin

The Crystal River is a major tributary to the Roaring Fork River. Its drainage basin (361 square miles) comprises about 25 percent of the total area of the Roaring Fork River drainage basin (1,451 square miles).

The Crystal River had a specific conductance of 274 µS/cm above Redstone at the farthest upstream test location on this river (CR-2). Inflows from East Creek and Coal Creek near Redstone had a specific conductance of 243 µS/cm (EC-1) and 430 µS/cm (CLC-1), respectively. Much of the Coal Creek drainage basin is underlain by the Mancos Shale. This basin also contains several coal mines that drain water (Brown, 1990; SeaCrest Group, 1995). These factors may account for the relatively higher conductivity readings at the mouth of Coal Creek.

Of the several hot springs at Penny Hot Springs, one on the west side of the river, had a specific conductance of 3,266 µS/cm (US-2). The specific conductance at a test location in the Crystal River below Penny Hot Springs was 471 µS/cm (CR-3). Further downstream, at a location below the confluence with Avalanche Creek (CR-4), it was 366 µS/cm. Since only point sampling was done during this investigation, test location CR-3 could be affected by relatively unmixed saline waters from Penny Hot Springs. Undoubtedly, though, the discharge of high conductivity water from Penny Hot Springs has an effect on the Crystal River.

The specific conductivity of the Crystal River decreased to 328 µS/cm below Nettle Creek, which, with a specific conductance of only 107 µS/cm (NC-1) was the least saline water tested during this study. Above its confluence with the Roaring Fork River the specific conductance of the Crystal River increased to 360 µS/cm (CR-1), perhaps in part a result of the inflow from Barbers Gulch, which had a specific conductance of 766 µS/cm (BG-1).

Roaring Fork River Drainage Basin from the Crystal River to the Colorado River

In a series of nine closely spaced tests performed on the Roaring Fork River on the inside (northeast bank) of a meander just below the confluence with the Crystal River, the specific conductance consistently ranged from 375 to 387 µS/cm (RFR-21 through 27), except for one test with a specific conductance of 406 µS/cm (RFR-20). A second series of four fairly closely spaced tests was conducted on the Roaring Fork River about 2.5 miles downstream (RFR-28 through 31). Again, these tests were very consistent, with a specific conductance ranging from 394 to 396 µS/cm. These closely spaced tests were conducted to observe the range of local variation in the specific conductivity along the stream and were not related to any particular hydrologic or geologic attribute. The variation observed is generally within the precision of field instrumentation, but elevated specific conductance at RFR-20 may be due to other factors.

Cattle Creek has a large drainage basin in which bold outcrops of evaporitic rocks are common. The Shannon Oil Company Rose #1 well, a 3,060-feet-deep oil test drilled in 1960 in the Roaring Fork valley near the mouth of Cattle Creek, penetrated 60 feet of alluvial gravel, 2,035 feet of gypsum, anhydrite, and clastic and carbonate rocks, and 935 feet of predominantly halite (unpublished lithologic log by American Stratigraphic Company). Drilling stopped in halite, therefore the total thickness of neither the halite or the entire evaporite sequence is known, but the well demonstrates that a thick sequence of evaporitic rock underlies this area. In spite of the widespread and thick deposits of evaporitic rocks in the drainage basin of Cattle Creek, the stream has a specific conductance of only 492 µS/cm at its mouth (CC-1). This value is only 25 percent higher than the specific conductance of the Roaring Fork River above Cattle Creek (see tests RFR-28 through 31). It was hypothesized that specific conductivity values in Cattle Creek would be higher than observed because of the relatively soluble evaporite terrain underlying most of the drainage basin. At the first test site in the Roaring Fork River below Cattle Creek a specific conductance of 404 µS/cm was measured (RFR-19). Approximately 1.2 miles further downstream a point sample had specific conductance of 395 µS/cm (RFR-12), which is identical to the series of tests run on the river above Cattle Creek. There are no significant tributaries to the Roaring Fork between Cattle Creek and test location RFR-12.

The upper reaches of Cattle Creek had conductivity values around 330 µS/cm (CC-2, CC-3). A spring in Shippes Draw, a tributary to Cattle Creek, discharges from surficial deposits that overlie evaporitic rocks in a prominent synclinal sag within Shippes Bowl (Kirkham and others, 1998). This spring had a specific conductance of only 383 µS/cm (SDS-1). The relatively low specific conductance of the spring water probably indicates this water had little residence time in contact with evaporitic rocks or that halite, if formerly present in these rocks, had been removed by earlier dissolution. Near its confluence with Cattle Creek, Shippes Draw had a specific conductance of 513 µS/cm (SD-1). The drainage basin of Coulter Creek is within the Carbondale collapse center, but evaporitic rocks are not exposed in this drainage basin. At its confluence with Cattle Creek, Coulter Creek had a specific conductance of 271 µS/cm (COC-1). Coulter Creek apparently had a diluting effect on Cattle Creek, as the specific conductance of Cattle Creek dropped from 397 µS/cm above the confluence with Coulter Creek (CC-5) to 291 µS/cm below it (CC-4). Below Fisher Creek, which had a specific conductance of 421 µS/cm (FC-1), the specific conductance of Cattle Creek increased to 382 µS/cm. Cattle Creek apparently gains dissolved solids between Fisher Creek and the Roaring Fork River, as specific conductance was 430 µS/cm at the next downstream test location (CC-7) and 492 µS/cm above the Roaring Fork River (CC-1). This reach of Cattle Creek contains prominent outcrops of gypsum.

Fourmile Creek had a specific conductance of 262 µS/cm near the Sunlight ski area (FMC-1). After flowing through a strike valley eroded into the Mancos Shale, its specific conductance increased to 486 µS/cm (FMC-2). Above the confluence with the Roaring Fork River, a specific conductance of 517 µS/cm was measured in Fourmile Creek. Specific conductance tests along the east bank of the Roaring Fork River indicated 395 µS/cm above Fourmile Creek at the bridge near West Bank development (RFR-12) and 429 µS/cm below Fourmile Creek (RFR-17).

Spring Valley, southeast of Glenwood Springs, is a prominent topographic depression thought to be a collapse feature related to dissolution or flowage of underlying evaporitic rocks (Kirkham, 1997; Kirkham and Widmann, 1997). Two springs along the southeastern margin of Spring Valley that issue from landslide deposits had specific conductance values of 401 µS/cm (SVS-1) and 491 µS/cm (SVS-2). The surface flow out the northern end of Spring Valley had a specific conductance of 635 µS/cm (SV-1). After flowing out of Red Canyon, which is eroded into red beds of the Maroon Formation, this stream had a specific conductance of 596 µS/cm at its confluence with the Roaring Fork River (RC-1). Specific conductance tests on the east side of the Roaring Fork River were 429 µS/cm above this inflow (RFR-17) and 434 µS/cm below it (RFR-18).

A short distance below the confluence of the Roaring Fork River with the stream draining Spring Valley, a point sample collected from the west bank of the river below the Glenwood Springs airport had a specific conductance of 860 µS/cm (RFR-16). No known tributaries or springs appear to be associated with this abrupt increase in specific conductance within the Roaring Fork River. This increase was probably due to saline ground water directly discharging into the river at or near this location. Additional studies are needed to better characterize the water quality of this reach of the river.

Another prominent increase in the specific conductance of point samples collected from the southwest bank of the Roaring Fork River was noted near the mouth of Threemile Creek. Immediately upstream of the confluence with Threemile Creek the specific conductance was 595 µS/cm (RFR-37), but downstream of the confluence specific conductance ranged from 735 to 1,550 µS/cm (RFR-11 and RFR-32 through 36). Threemile Creek had a specific conductance of only 255 µS/cm at its mouth (TMC-1), so it apparently was not the source of the saline water. A nearby irrigation ditch (Atkinson Canal), which at the time of this testing was diverted back to the Roaring Fork River immediately above the confluence with Threemile Creek, carried water with a specific conductance of 1,389 µS/cm (ID-1). At first glance it appears that the irrigation ditch is the source of the increased salinity in the river. However, this ditch carried water diverted from the Roaring Fork River only a few hundred feet upstream of its outflow back to the river. Also, one of the tests immediately downstream on the river (RFR-36) had higher specific conductance than the irrigation ditch. Perhaps both the irrigation ditch and river are affected by discharge of saline ground water or by anthropogenic sources related to a nearby subdivision (David Merritt, written commun., 1998). Additional studies will be required to understand the hydrology of this area.

Tests were run on both banks of the Roaring Fork River at the Sunlight bridge, which is located about 0.9 miles downstream of the Threemile Creek area described above. On the west bank of the river, the specific conductance was 503 µS/cm (RFR-13W), while on the east bank it was 481 µS/cm (RFR-13E). At the next downstream test location on the Roaring Fork River (about 0.25 miles below RFR-13W and RFR-13E locations), the specific conductance on the west bank was 496 µS/cm (RFR-10). Measurements were again collected on both sides of the Roaring Fork River at the 7th Street bridge. On the west bank the specific conductance was 482 µS/cm (RFR-15); on the east bank it was 474 µS/cm (RFR-14). This series of tests may reflect the mixing of water in the Roaring Fork River with the above described saline inflows from near the mouth of Threemile Creek. The trend of decreasing specific conductance in this reach may also reflect ground-water inflows of better quality water.

Outside the Roaring Fork River Basin

Several thermal springs along the Colorado River, thought to issue from the Leadville Limestone (Barrett and Pearl, 1978), were tested during this study (YHS-1 and 2; VC-1; CRHS 1, 2, and 3; HHS-1; IHS-1). The specific conductance of these thermal springs ranged from 28,075 to 34,050 µS/cm. These measurements support the interpretations of many prior investigations that have concluded the thermal springs at Glenwood Springs and Dotsero are major sources of salinity to the Colorado River. Thermal springs were the only waters tested in this study that were below pH 7 (slightly acidic).

At a test location in the Colorado River upstream from the thermal springs near Glenwood Springs, the specific conductance of the river was 572 µS/cm on the northwest bank (COR-4) and 585 µS/cm on the southeast bank (COR-3). At a test location on the Colorado River at the Devereux bridge, the specific conductance of the Colorado River was 1,655 µS/cm on the northeast bank (COR-5), but only 520 µS/cm on the southwest bank (COR-6). The vastly different measurements are due to the lack of thorough mixing of the saline thermal spring waters with the river water. This disparate relationship was less noticeable at the Funston rest area on Interstate Highway 70, where on the north bank the specific conductance was 911 µS/cm (COR-8) and on the south bank of the Colorado River it was 665 µS/cm (COR-2). At the bridge over the Colorado River at the Midland Avenue by-pass, the water was somewhat better mixed than upstream at the Funston rest area: on the north bank the Colorado River had specific conductance of 879 µS/cm (COR-7) and on the south bank it was 740 µS/cm (COR-1).

Warm ground water was intercepted in foundation excavations several years ago in a subdivision in west Glenwood Springs on Stoneridge Court. The excavations were made into a prominent ledge of tufa that was dry at the ground surface. The water encountered by these excavations is collected and conveyed by a plastic pipe and discharged to the surface near the middle school. This water had a specific conductance of 3,281 µS/cm (US-3).

A cold spring on Mitchell Creek had a specific conductance of 442 µS/cm (MCS-1). The specific conductance of Mitchell Creek above the spring was 352 µS/cm (MC-2) and 382 µS/cm above Dolan Gulch (MC-1). Dolan Gulch, which drains an area largely underlain by evaporitic rocks, had a specific conductance of 542 µS/cm (DG-1) at its confluence with Mitchell Creek.

A single test was obtained on Cottonwood Creek, an upstream tributary to the Colorado River at the eastern end of Glenwood Canyon. Evaporitic rocks underlie most of this drainage basin. The creek had a specific conductance of 1,032 µS/cm (CPC-1) where it is crossed by Cottonwood Pass road.

Table 2. Field measurements and test descriptions.

Test No.	Drainage	Cond (µS/cm)	Salinity (ppt)	Temp (°C)	pH	Test Location	UTM (X)	UTM (Y)
BC-1	Blue Creek	341	0.2	12.9	8.81	Blue Creek where it crosses Upper Cattle Creek Road	320091	4363228
BG-1	Barbers Gulch	766	0.4	7.5	8.84	Barber's Gulch above confluence with Crystal River	308298	4363080
CBL-1	Cedar Brook Lake	213	0.1	13.3	7.96	Outflow from Cedar Brook Lake at old Hwy 82	323832	4359512
CC-1	Cattle Creek	492	0.2	12.4	7.97	Cattle Creek at Hwy 82	305429	4369688
CC-2	Cattle Creek	332	0.2	5.4	7.74	Cattle Creek near old gaging station below Bowers Gulch	323496	4370331
CC-3	Cattle Creek	333	0.2	7.0	7.92	Cattle Creek at Upper Cattle Creek Road	319646	4369817
CC-4	Cattle Creek	291	0.1	11.3	8.34	Cattle Creek below confluence with Coulter Creek	315883	4370290
CC-5	Cattle Creek	397	0.2	10.8	8.45	Cattle Creek above confluence with Coulter Creek	315926	4370347
CC-6	Cattle Creek	382	0.2	10.6	8.40	Cattle Creek below confluence with Fisher Creek	310420	4369835
CC-7	Cattle Creek	430	0.2	10.4	8.33	Cattle Creek approx. 2.5 miles below confluence with Fisher Creek	306953	4368991
CLC-1	Coal Creek	430	0.2	6.1	8.73	Coal Creek above confluence with Crystal River	306643	4339254
COC-1	Coulter Creek	271	0.1	11.5	8.43	Coulter Creek above confluence with Cattle Creek	315880	4370354
COR-1	Colorado River	740	0.4	8.0	7.93	South bank of Colorado River at Midland Ave. by-pass (opposite COR-7)	297204	4381278
COR-2	Colorado River	665	0.3	8.3	7.94	South bank of Colorado River opposite Funston rest area (opposite COR-8)	298300	4381292
COR-3	Colorado River	585	0.3	7.2	8.24	Southeast bank of Colorado River below west end of railroad tunnel	301288	4380955
COR-4	Colorado River	572	0.3	7.2	8.21	Northwest bank of Colorado River across from COR-3	301218	4380923
COR-5	Colorado River	1,655	0.8	9.2		North bank of Colorado River at Devereaux bridge	299330	4380482
COR-6	Colorado River	520	0.3	8.9		South bank of Colorado River at Devereaux bridge	299269	4380422
COR-7	Colorado River	879	0.4	9.1		North bank of Colorado River on Midland Ave. by-pass (opposite COR-1)	297169	4381353
COR-8	Colorado River	911	0.4	9.6		North bank of Colorado River below Funston rest area (opposite COR-2)	298296	4381333
COR-9	Colorado River	550	0.3	8.5		Colorado River below confluence with No Name Creek	302423	4381299
CPC-1	Cottonwood Creek	1,032	0.5	4.3	8.04	Cottonwood Creek at Cottonwood Pass Road	325126	4381338
CR-1	Crystal River	360	0.2	8.0	8.59	East bank Crystal River above confluence with Edgerton Creek at bridge (County Road 108)	308088	4364204
CR-2	Crystal River	274	0.1	4.8	8.07	Crystal River above confluence with East Creek	306382	4338565

Cond = specific conductance; **µS/cm** = microSiemens per centimeter at 25 deg. C; **ppt** = parts per thousand; **C** = degrees Celsius; **UTM** = Universal Transverse Mercator coordinate.

Table 2. (Continued)

Test No.	Drainage	Cond (µS/cm)	Salinity (ppt)	Temp (°C)	pH	Test Location	UTM (X)	UTM (Y)
CR-3	Crystal River	471	0.2	10.4	7.54	Crystal River below Penny Hot Spring	307800	4344683
CR-4	Crystal River	366	0.1	8.8	8.12	West bank of Crystal River below confluence with Avalanche Creek	307249	4347079
CR-5	Crystal River	328	0.2	8.3	8.08	Crystal River below confluence with Nettle Creek	309118	4352045
CRHS-1	Hot Spring	33,860	21.1	36.9	6.47	Hot spring on south bank of Colorado River east of Glenwood Springs	301143	4380619
CRHS-2	Hot Spring	29,330	17.7	49.9	6.59	Hot spring on south bank of Colorado River east of Glenwood Springs	300913	4380299
CRHS-3	Hot Spring	29,440	17.8	49.2	6.56	Hot spring on south bank of Colorado River east of Glenwood Springs	300825	4380245
CS-1	Crystal Spring	612	0.3	11.2	7.41	Discharge from Crystal Spring	312745	4366508
CSC-1	Crystal Spring Creek	566	0.3	10.9	8.22	Crystal Spring Creek 100 ft below Crystal Spring	312712	4366554
CSC-2	Crystal Spring Creek	852	0.4	12.4	7.68	Crystal Spring Creek 2000 ft above confluence with Roaring Fork River	310407	4364980
CSC-3	Crystal Spring Creek	584	0.3	9.5	8.44	Crystal Spring Creek 30 ft above Hwy 82	311626	4364713
DG-1	Dolan Gulch	542	0.3	9.4	8.42	Dolan Gulch above confluence with Mitchell Creek	296379	4383062
EC-1	East Creek	243	0.1	2.6	8.23	East Creek above confluence with Crystal River	306585	4338922
ECC-1	East Coulter Creek	275	0.1	5.4	8.04	East Coulter Creek above Van Springs Reservoir	321697	4377181
ECC-2	East Coulter Creek	321	0.2	9.3	7.62	East Coulter Creek below Van Springs Reservoir	320028	4375126
EJS-1	El Jebel Spring	1,134	0.6	14.0	7.43	Spring issuing from evaporite on Upper Cattle Creek Road above El Jebel	319890	4363650
ESC-1	East Sopris Creek	472	0.2	6.9	8.72	East Sopris Creek above confluence with West Sopris Creek	322522	4357054
FC-1	Fisher Creek	472	0.2	11.4	8.14	Fisher Creek above confluence with Cattle Creek	310834	4370023
FMC-1	Four Mile Creek	262	0.1	1.7	8.93	Four Mile Creek at Sunlight Ski Area	298516	4363770
FMC-2	Four Mile Creek	486	0.2	3.9	9.18	Four Mile Creek at Dakota watergap	300056	4370469
FMC-3	Four Mile Creek	517	0.2	8.1		Four Mile Creek 3500 ft above confluence with Roaring Fork River	300867	4373174
FPR-1	Fryingpan River	200	0.1	12.2	7.74	Southeast bank of the Frying Pan River above confluence with Roaring Fork River	324851	4359214
FPR-2	Fryingpan River	157	0.1	9.5	7.50	Fryingpan River at gaging station below Reudi dam	342701	4358686
HHS-1	Hobo Hot Spring	28,750	17.4	38.3	6.38	Hobo Hot Spring	299260	4380955

Cond = specific conductance; **µS/cm** = microSiemens per centimeter at 25 deg. C; **ppt** = parts per thousand; **C** = degrees Celsius; **UTM** = Universal Transverse Mercator coordinate.

Table 2. (Continued)

Test No.	Drainage	Cond (µS/cm)	Salinity (ppt)	Temp (°C)	pH	Test Location	UTM (X)	UTM (Y)
ID-1	Irrigation Ditch	1,389	0.7	6.5		Irrigation ditch (Atkinson Canal) southeast of Three Mile Creek	300822	4376243
IHS-1	Iron Hot Spring	34,050	21.0	41.3	6.30	Iron Hot Spring	299308	4380661
MC-1	Mitchell Creek	382	0.2	6.2	8.18	Mitchell Creek above confluence with Dolan Gulch	296414	4383035
MC-2	Mitchell Creek	352	0.2	5.1		Mitchell Creek 30 ft above spring (MCS-1)	296932	4384104
MCS-1	Mitchell Creek Spring	442	0.2	9.2		Spring on east bank of Mitchell Creek	296901	4384068
NC-1	Nettle Creek	107	0.1	6.4	7.78	Nettle Creek above confluence with Crystal River	309137	4351979
NN-1	No Name Creek	264	0.1	5.9		No Name Creek above confluence with Colorado River	302444	4381259
RC-1	Red Creek	596	0.3	8.2		Red Creek above confluence with Roaring Fork River	301901	4374939
RFR-1	Roaring Fork River	405	0.2	12.6	7.81	East bank of Roaring Fork River behind 7-11 store in Basalt	324867	4359144
RFR-2	Roaring Fork River	404	0.2	12.3		East bank of Roaring Fork River 100 ft upstream of RFR-1	324867	4359144
RFR-3	Roaring Fork River	405	0.2	11.9	8.00	West bank of the Roaring Fork River southeast of bridge in Basalt	324849	4359120
RFR-4	Roaring Fork River	320	0.2	12.2	7.95	North bank Roaring Fork River 3,000 ft below confluence with Fryingpan River	324010	4359457
RFR-5	Roaring Fork River	399	0.2	8.2	7.82	Southwest bank Roaring Fork River approx. 50 ft above confluence with Snowmass Creek	328929	4355249
RFR-6	Roaring Fork River	390	0.2	8.4	7.88	Southwest bank Roaring Fork River 1,500 ft below confluence with Snowmass Creek	328314	4355596
RFR-7	Roaring Fork River	310	0.1	11.2	8.23	Northeast bank of Roaring Fork River above confluence with Sopris Creek	322425	4359277
RFR-8	Roaring Fork River	311	0.1	11.2	8.19	Northeast bank of Roaring Fork River 600 ft below confluence with Sopris Creek	321901	4359513
RFR-9	Roaring Fork River	375	0.2	9.9	8.90	East bank Roaring Fork River near Aspen Glen below confluence with Crystal River	306531	4366111
RFR-10	Roaring Fork River	496	0.2	7.9	8.63	West bank of Roaring Fork River at City Park	299913	4379411
RFR-11	Roaring Fork River	1,029	0.5	5.9	8.85	Southwest bank Roaring Fork River 15 ft below confluence with Threemile Creek	300765	4376286
RFR-12	Roaring Fork River	395	0.2	7.7	8.98	East bank of Roaring Fork River 250 ft above County Road 109 bridge	303391	4372260
RFR-13E	Roaring Fork River	481	0.2	7.3		East bank of Roaring Fork River at Sunlight bridge	300187	4377463

Cond = specific conductance; **µS/cm** = microSiemens per centimeter at 25 deg. C; **ppt** = parts per thousand; **C** = degrees Celsius; **UTM** = Universal Transverse Mercator coordinate.

Table 2. (Continued)

Test No.	Drainage	Cond (µS/cm)	Salinity (ppt)	Temp (°C)	pH	Test Location	UTM (X)	UTM (Y)
RFR-13W	Roaring Fork River	503	0.2	8.0		West bank of Roaring Fork River at Sunlight bridge	300142	4377440
RFR-14	Roaring Fork River	474	0.2	8.4		East bank of Roaring Fork River at 7th St. bridge	299846	4379853
RFR-15	Roaring Fork River	482	0.2	7.5		West bank of Roaring Fork River at 7th St. bridge	299783	4379858
RFR-16	Roaring Fork River	860	0.4	8.4		West Bank of Roaring Fork River near airport.	301784	4375242
RFR-17	Roaring Fork River	429	0.2	9.7		East bank of Roaring Fork River above confluence with Red Canyon Creek	301871	4374876
RFR-18	Roaring Fork River	434	0.2	9.2		East bank of Roaring Fork River below confluence with Red Canyon Creek	301855	4374949
RFR-19	Roaring Fork River	404	0.2	10.1		East bank of Roaring Fork River below Cattle Creek	304309	4371117
RFR-20	Roaring Fork River	406	0.2	5.8		North bank of Roaring Fork River below bend near Kiggin	306585	4365903
RFR-21	Roaring Fork River	387	0.2	5.5		North bank of Roaring Fork River 100 ft above RFR-20 near Kiggin	306591	4365868
RFR-22	Roaring Fork River	385	0.2	5.5		North bank of Roaring Fork River 100 ft above RFR-21 near Kiggin	306618	4365836
RFR-23	Roaring Fork River	381	0.2	5.5		North bank of Roaring Fork River 100 ft above RFR-22 near Kiggin	306659	4365824
RFR-24	Roaring Fork River	383	0.2	5.8		North bank of Roaring Fork River 100 ft above RFR-23 near Kiggin	306700	4365822
RFR-25	Roaring Fork River	384	0.2	5.7		North bank of Roaring Fork River 100 ft above RFR-24 near Kiggin	306736	4365833
RFR-26	Roaring Fork River	383	0.2	5.7		North bank of Roaring Fork River 100 ft above RFR-25 near Kiggin	306770	4365857
RFR-27	Roaring Fork River	384	0.2	5.7		North bank of Roaring Fork River 100 ft above RFR-26 at start of river bend near Kiggin	306799	4365894
RFR-28	Roaring Fork River	395	0.2	6.0		West bank of Roaring Fork River, below bend at Asphalt Plant	305108	4368934
RFR-29	Roaring Fork River	396	0.2	6.2		West bank of Roaring Fork River 100 ft above RFR-28	305156	4368893
RFR-30	Roaring Fork River	394	0.2	6.0		West bank of Roaring Fork River 100 ft above RFR-29	305219	4368857
RFR-31	Roaring Fork River	394	0.2	6.1		West bank of Roaring Fork River 100 ft above RFR-30	305274	4368830
RFR-32	Roaring Fork River	735	0.4	6.3		Southwest bank of Roaring Fork River below confluence with Threemile Creek	300721	4376297
RFR-33	Roaring Fork River	816	0.4	6.2		Southwest bank of Roaring Fork River 100 ft below confluence with Threemile Creek	300684	4376288
RFR-34	Roaring Fork River	1,090	0.5	5.9		Southwest bank of Roaring Fork River 100 ft below RFR-33	300625	4376298
RFR-35	Roaring Fork River	968	0.5	6.5		Southwest bank of Roaring Fork River 100 ft below RFR-34	300588	4376310

Cond = specific conductance; **µS/cm** = microSiemens per centimeter at 25 deg. C; **ppt** = parts per thousand; **C** = degrees Celsius; **UTM** = Universal Transverse Mercator coordinate.

Table 2. (continued).

Test No.	Drainage	Cond (µS/cm)	Salinity (ppt)	Temp (°C)	pH	Test Location	UTM (X)	UTM (Y)
RFR-36	Roaring Fork River	1,550	0.8	6.9		Southwest bank of Roaring Fork River above confluence with Threemile Creek	300793	4376281
RFR-37	Roaring Fork River	595	0.3	6.7		Southwest bank of Roaring Fork River 100 ft above RFR-36	300832	4376276
RFR-38	Roaring Fork River	363	0.2	8.5	8.69	North bank of Roaring Fork River at bridge near Mulford	314563	4363157
RFR-39	Roaring Fork River	384	0.2	9.9	8.83	North bank Roaring Fork River above confluence with Crystal River, below Sutank bridge	308004	4365229
SC-1	Sopris Creek	403	0.2	11.0	8.19	Sopris Creek above confluence with Roaring Fork River	322064	4359280
SC-2	Sopris Creek	492	0.2	7.0	8.60	Sopris Creek below confluence of East and West Sopris Creeks	322602	4357498
SD-1	Shippees Draw	513	0.2	8.0	8.06	Shippees Draw at Upper Cattle Creek Road	317279	4371112
SDS-1	Shippees Draw Spring	383	0.2	11.8	8.03	Below spring in Shippees Bowl	318975	4372791
SMC-1	Snowmass Creek	407	0.2	7.4	8.01	Snowmass Creek at Hwy 82 bridge, 50 ft above confluence with Roaring Fork River	328847	4355213
SV-1	Spring Valley	635	0.3	8.2	6.54	[Spring Valley] Creek at NW end of Spring Valley	304862	4376130
SVS-1	Spring Valley Spring	401	0.2	11.9	6.48	Mouth of spring above unnamed reservoir	308684	4372672
SVS-2	Spring Valley Spring	491	0.2	10.6	6.58	Mouth of spring near house below unnamed reservoir	308462	4372561
TMC-1	Three Mile Creek	255	0.1	3.6	8.96	Threemile Creek above subdivision near Cardiff	300715	4375679
TMC-2	Three Mile Creek	269	0.1	4.3	8.93	Threemile Creek 20 ft above confluence with Roaring Fork River	300774	4376252
US-1	Unnamed Spring	726	0.4	9.2	8.63	Unnamed spring southeast of Carbondale	313580	4360403
US-2	Unnamed Spring	3,266	16.0	55.1	6.19	One of the Penny Hot Springs; on west side of Crystal River	307808	4344648
US-3	Unnamed Spring	3,281	1.7	3.0		Pipe discharge of water from sub-division spring on Stoneridge Court	297633	4381774
VC-1	Vapor Caves	30,360	18.3	50.3	6.84	In Vapor Cave; in moat around cave walls	300696	4380262
WSC-1	West Sopris Creek	550	0.3	6.9	8.81	West Sopris Creek above confluence with East Sopris Creek	322385	4357297
YHS-1	Yampah Hot Spring	31,060	19.5	50.0	6.81	Drinking spring east of main Glenwood Springs pool	300524	4380180
YHS-2	Yampah Hot Spring	31,850	19.4	49.6		Main spring next to Glenwood Springs pool	300551	4380177

Cond = specific conductance; **µS/cm** = microSiemens per centimeter at 25 deg. C; **ppt** = parts per thousand; **C** = degrees Celsius; **UTM** = Universal Transverse Mercator coordinate.

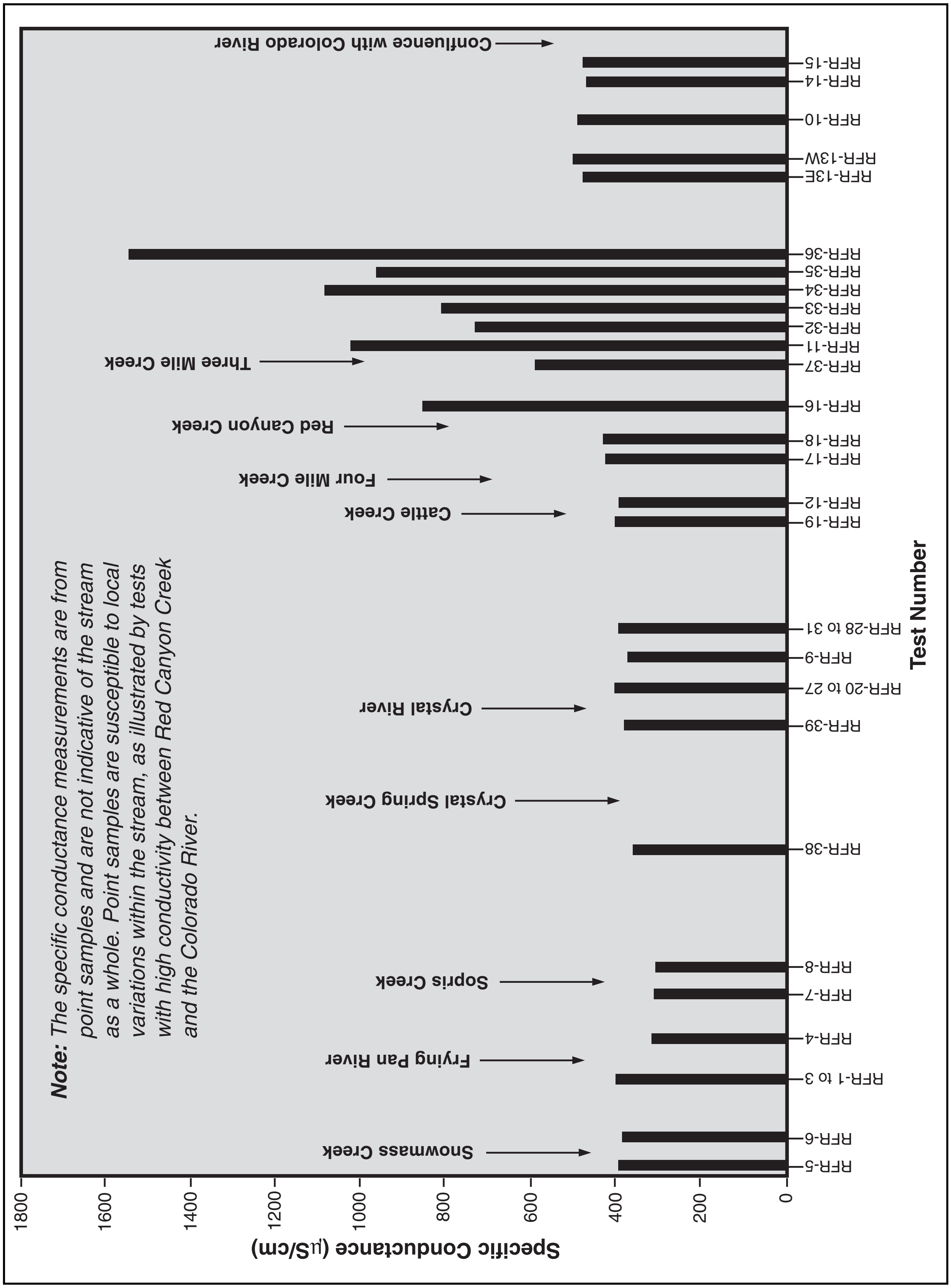


Figure 2. Graph showing specific conductance at test locations in the Roaring Fork River between Snowmass and Glenwood Springs (arrows indicate where various tributaries join the river).

Summary

Specific conductance in the Roaring Fork River was around 400 µS/cm at the confluence with Snowmass Creek at the furthest upstream test site of this study. Downstream of inflows from the Fryingpan River and Cedar Brook Lake, which had specific conductance of about 200 µS/cm each, tests of specific conductance in the Roaring Fork River dropped to around 310 µS/cm. Between Sopris Creek and Fourmile Creek, near the southern edge of Glenwood Springs, specific conductance tests in the Roaring Fork River gradually increased to about 400 µS/cm. From Fourmile Creek to the confluence with the Colorado River, specific conductance of the stream increased to around 480 µS/cm. In this lower portion of the Roaring Fork River, a reach extending from the Glenwood Springs airport downstream past the mouth of Threemile Creek had significantly elevated specific conductance values along the southwestern bank of the river. Specific conductance at test locations in this reach ranged up to 1,550 µS/cm.

The specific conductance data collected during this study indicated that cold springs discharging from evaporite or from surficial deposits overlying evaporite within the Carbondale collapse center had only moderately elevated specific conductance values that ranged from 383 to 1,134 µS/cm. These springs contributed to the salinity loads in surface water in the area, but were probably only minor sources. Streams that drained areas extensively underlain by evaporitic rocks also had moderately elevated specific conductance values that ranged from 492 to 1,032 µS/cm. Streams draining areas underlain by Cretaceous marine shales had somewhat lower specific conductance readings ranging from 255 to 550 µS/cm.

The test locations exhibiting elevated specific conductance in Roaring Fork River near the Glenwood Springs airport and the mouth of Threemile Creek are interpreted to result from the direct discharge of saline ground water to the surface water at discrete locations. This agrees with Warner and others (1985), who suggested a significant part of the increase in the base-flow salt load in the Roaring Fork River between Woody Creek (32,700 tons/year) and Glenwood Springs (183,000 tons/year) was due to saline ground-water discharge to the river. It must be noted that the test locations near Threemile Creek were only from the southwest bank of the Roaring Fork River. These conductivity measurements are not representative of the river as a whole, especially given their departure from test results upstream and downstream of this reach. They are indicative of saline ground water discharging along the southwest bank of the Roaring Fork in this area. The salinity of this ground water is inferred to be from natural processes, but may be influenced by anthropogenic sources.

The substantially lower conductivity values obtained in the Roaring Fork River downstream of the Threemile Creek area could be a result of more thorough mixing of water in the river or dilution effects from less saline ground-water inflows. Nevertheless, conductivity in the Roaring Fork River below Threemile Creek is maintained above 470 µS/cm.

Thermal springs in and near Glenwood Springs had very high specific conductance that was over an order of magnitude higher than any value measured for cold springs or tributary streams in the area. This observation supports the numerous previous investigations that have concluded the thermal springs near Glenwood Springs and Dotsero are major sources of salt loading in this reach of the Colorado River.

A comprehensive investigation is needed to characterize and quantify the significance of the elevated specific conductance detected in the

Roaring Fork River in the vicinity of the Glenwood Springs airport and mouth of Threemile Creek. This investigation should employ discharge measurements, cross-section sampling techniques, and full-suite laboratory analysis of water samples. Laboratory analysis could help in differentiating natural or anthropogenic sources of salt loading to the Roaring Fork River by identifying geochemical signatures of the sources. Oxygen and hydrogen isotope studies would aid in determining the source and relative age of influent saline ground water.

Additional studies are warranted in the Eagle collapse center to evaluate whether cold springs, tributaries, and ground-water discharge play similar roles in that area.

References Cited

Barrett, J.K., and Pearl, R.H., 1978, An appraisal of Colorado's geothermal resources: Colorado Geological Survey Bulletin 39, 224 p.

Brown, S.D., 1990, Mineral appraisal of the White River National Forest, Colorado: U.S. Bureau of Mines Open File Report MLA 9-90, 380 p.

Eisenhauer, R.J., 1986, Characterization of Glenwood Springs and Dotsero Springs source aquifers: U.S. Bureau of Reclamation report REC-ERC-86-1, 35 p.

Kirkham, Bob, 1997, Late Tertiary and Quaternary collapse related to dissolution and flowage of Pennsylvanian evaporitic rocks in the Glenwood Springs area, Colorado: Guidebook for day 2 of the 1997 field trip, Rocky Mountain Cell of the Friends of the Pleistocene, *in* McCalpin, J.P., editor, The active geologic environment of central Colorado: unpublished field trip guidebook for the 1997 Friends of the Pleistocene field trip, Rocky Mountain Cell.

Kirkham, R.M., and Widmann, B.L., 1997, Geologic map of the Carbondale quadrangle, Garfield County, Colorado: Colorado Geological Survey Open-File Report 97-3.

Kirkham, R.M., Widmann, B.L., and Streufert, R.K., 1998, Geologic map of the Leon quadrangle, Eagle and Garfield Counties, Colorado: Colorado Geological Survey Open-file Report 98-3.

SeaCrest Group, 1995, A stream impairment study of aquatic life on Dutch and Coal Creeks: unpublished report prepared for Mid-Continent Resources, 17 p.

Scott, R.B., Lidke, D.J., Shroba, R.R., Hudson, M.R., Kunk, M.J., Perry, W.J., Jr., and Bryant, Bruce, 1998, Large-scale active collapse in western Colorado: interaction of salt tectonics and dissolution, *in* Van Brahana, J., Eckstein, Y. Ongley, L.K., Schneider, R., and Moore, J.E., eds., Gambling with Groundwater—Physical, Chemical, and Biological Aspects of Aquifer-Stream Relations: Proceedings of the Joint Conference of the XXVIII Congress of the International Association of Hydrogeologists and the Annual Meeting of the American Institute of Hydrology, American Institute of Hydrology, St. Paul, Minnesota, p. 195–204.

URS Corporation, 1981, Salinity investigation of Glenwood-Dotsero Springs unit: unpublished report prepared for the U.S. Department of Interior, Water and Power Resources Services, 98 p.

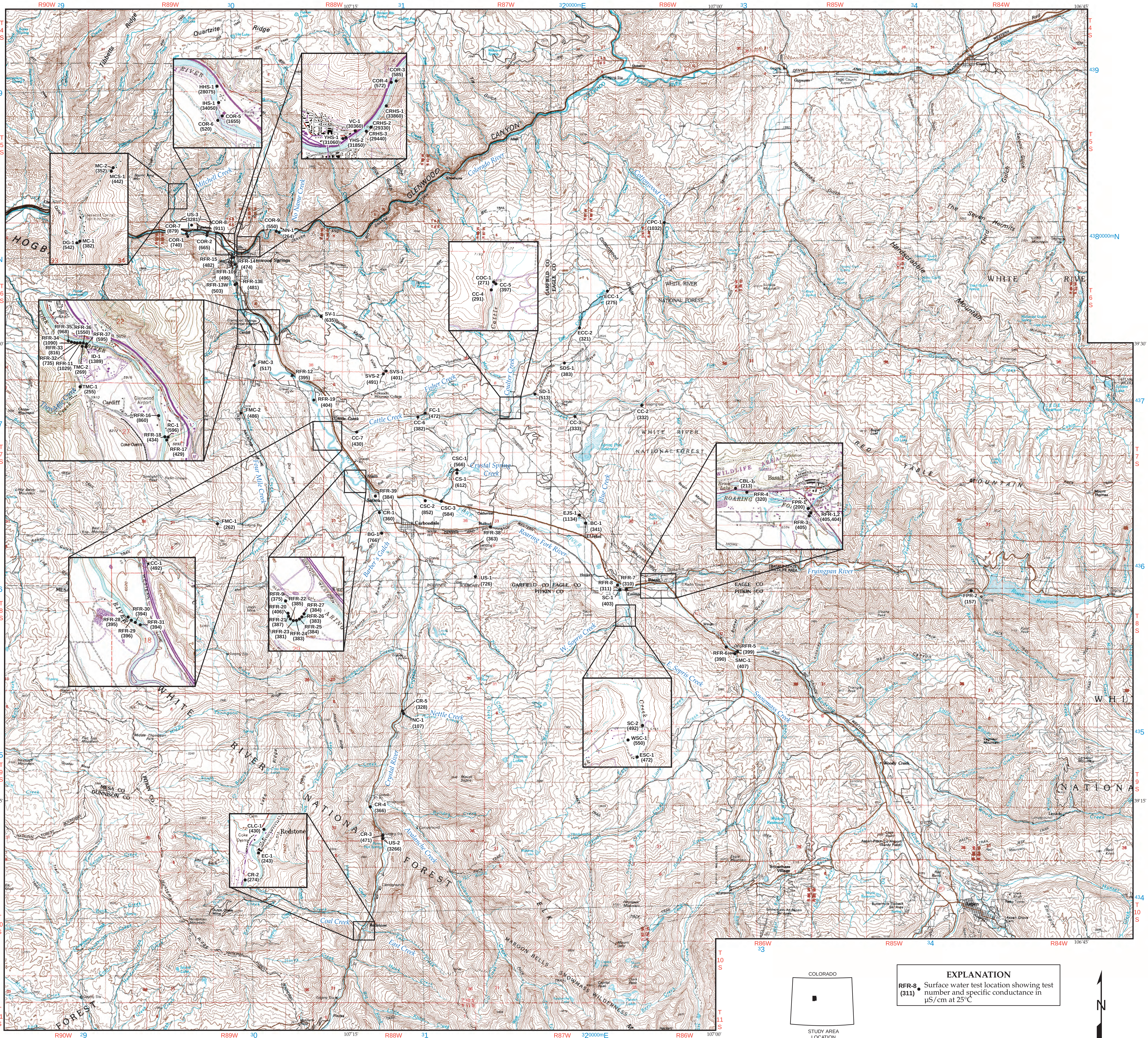
Warner, J.W., Heimes, F.J., and Middleburg, R.F., 1985, Ground-water contribution to the salinity of the upper Colorado River: U.S. Geological Survey Water-Resources Investigation WRI-84-4198, 113 p.

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
DENVER, COLORADO

INFORMATION SERIES 49
PLATE 1
1999

MAP SHOWING TEST LOCATIONS WITH SPECIFIC CONDUCTANCE VALUES, SNOWMASS–GLENWOOD SPRINGS AREA, WEST-CENTRAL COLORADO

Compiled by Jonathan M. Zook



Base composited from U.S. Geological Survey 1:100,000 scale topographic maps: Glenwood Springs (1981), Carbondale (1982), Vail (1980), and Leadville (1983).

Insets from U.S. Geological Survey 1:24,000 scale topographic maps: Basalt (rev. 1987), Carbondale (rev. 1987), Cattle Creek (rev. 1987), Glenwood Springs (rev. 1987), Leon (rev. 1987), and Redstone (rev. 1987).

SCALE 1:24,000 (INSET MAPS)

1 — 1/2 — 0 — 1 MILE

1000 — 0 — 1000 — 2000 — 3000 — 4000 — 5000 — 6000 — 7000 FEET

1 — 0 — 1 KILOMETER

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

SCALE 1:100,000 (BASE MAP)

1 — 0 — 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 KILOMETERS

1 — 0 — 1 — 2 — 3 — 4 — 5 MILES

CONTOUR INTERVAL 50 METERS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

COLORADO

STUDY AREA LOCATION

EXPLANATION

RFR-8 (311) • Surface water test location showing test number and specific conductance in μS/cm at 25°C

N

State of Colorado, Bill Owens, Governor
Department of Natural Resources, Greg E. Walcher, Director
Colorado Geological Survey, Vicki Cowart, Director