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# AN APPRAISAL OF THE QUALITY OF SURFACE WATER IN THE SEVIER LAKE BASIN, UTAH, 1964

by
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# AN APPRAISAL OF THE QUALITY OF SURFACE WATER IN THE SEVIER LAKE BASIN, UTAH, 1964

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## ABSTRACT

Water in 13 mountain streams in the Sevier Lake basin was found to range in concentration of dissolved solids from 60 to about 500 ppm (parts per million) during the 1964 water year. The water is generally of the calcium bicarbonate type and is hard.

Water in the East Fork Sevier River and in the upstream reaches of the main stem of the Sevier River was found to contain a weighted-average concentration of dissolved solids of less than 500 ppm. The dominant ions were calcium, magnesium, and bicarbonate. The observed range in weighted-average hardness of the water was from 142 to 212 ppm expressed as $CaCO_3$. The water is of suitable quality for most uses and has a low to medium salinity hazard and low sodium hazard for irrigation use.

As water moves down the central reaches of the Sevier River the concentration of dissolved solids increases and the water becomes harder. By the time the water reaches the Sevier Bridge Reservoir it contains a weighted-average concentration of 1,700 ppm of dissolved solids, consisting of mostly sodium and chloride ions, and a weighted-average hardness of 595 ppm. Water in this reach of the river is of high to very high salinity hazard and low to high sodium hazard for irrigation use.

Complete use of water from the San Pitch River causes an increase of the concentration of dissolved solids from about 300 ppm at Fairview to about 1,700 ppm below Gunnison Reservoir near Sterling, a distance of less than 40 miles. The water type changes from calcium bicarbonate to sodium chloride in this reach. The water in the San Pitch River is very hard, and the maximum observed hardness was 780 ppm near Sterling. The water in the San Pitch River generally has a low to medium salinity hazard and a low sodium hazard. Releases from the Gunnison Reservoir have a high to very high salinity hazard and a high to very high sodium hazard. These releases, however, are diluted by runoff from Sixmile Creek.

Below the Sevier Bridge Reservoir, the concentration of dissolved solids in the Sevier River is reduced by inflow of water with a low concentration of dissolved solids from Molten and Blue Springs and from wells south of Lynndyl. The weighted-average concentration of dissolved solids in the Sevier River near Delta was 1,330 ppm, and the water was of the sodium chloride type. The water is very hard and near Delta had a weighted-average hardness of 490 ppm. The river water used for irrigation in the lower part of the Sevier River has a low to medium sodium hazard and a high to very high salinity hazard.

Water in all reaches of the Beaver River was found to contain a weighted-average concentration of dissolved solids of less than 500 ppm. The water is mostly of the calcium bicarbonate type. Water in the Beaver River is soft to very hard, and the observed range in weighted-average hardness was from 56 to 188 ppm. For irrigation use the water generally has a low to medium salinity hazard and a low sodium hazard.

A network of water-quality sampling sites is essential to monitor the effects of projects designed to reduce concentrations of dissolved solids in the Sevier, Beaver, and San Pitch Rivers and to properly evaluate effects of importing water to the basin.

No sediment data were obtained during periods of high suspended-sediment concentration and discharge. The sediment data that were obtained probably give a fair indication of sediment-transport characteristics of the streams during most of the time each year, but give a poor indication of the total amount of sediment transported by any stream during the year. Between about July 1 and March 1, suspended-sediment concentrations probably are less than 500 ppm during at least 50 percent of the time and probably are greater than 5,000 ppm less than 5 percent of the time. Most of the sediment discharge each year occurs during a few days of high water discharge. The sediment discharge during any single runoff event that results from an intense thunderstorm may exceed the sum of the sediment discharges during the remainder of the year.

## INTRODUCTION

The Sevier and Beaver River systems are the two major river systems in the Sevier Lake basin in Utah. This report contains an analysis of reconnaissance data collected during the 1964 water year regarding the quality of water in these rivers and their tributaries. The purpose of the reconnaissance was to obtain needed water-quality information for the basin. Corollary purposes were to (1) determine the suitability of surface water for specific uses, (2) determine the need and criteria for a water-quality network, and (3) locate sources of organic pollution to the rivers. Data concerning item 3 are mentioned only briefly in this report and will be discussed in a report to be prepared by the Utah Water Pollution and Control Board. Data collected in connection with the reconnaissance and resulting analyses were reported by Hahl and Cabell (1965).

The lack of information about the chemical quality of surface streams, as well as about other water-quality characteristics of streams in the Sevier Lake basin, prompted the U.S. Geological Survey, as a part of its cooperative program with the Utah Department of Natural Resources, Division of Water Rights, to evaluate the data available as of 1963. These data included no information on water discharge and were collected mainly during the spring and early summer; thus the reconnaissance reported herein was designed to obtain water-quality data for an entire year. The data were collected primarily by the U.S. Geological Survey as part of its cooperative programs with the Division of Water Rights and the Utah Geological and Mineralogical Survey. Applicability and usefulness of the reconnaissance were increased through assistance from the Division of Water Rights, the Utah State Department of Health, the Water Commissioners for the Sevier River, and the Soil Conservation Service and Forest Service of the U.S. Department of Agriculture. These agencies assisted in planning the reconnaissance and selecting sampling sites and provided field assistance and technical services.

The reconnaissance was designed to provide data representative of surface water quality conditions during the 1964 water year[1]. To accomplish this, 70 sampling sites were selected and four sets of data were collected which were representative of the streamflow regimen during late winter, mid-spring, the middle of the irrigation season in the summer, and the postirrigation season in the early fall. Each set of data was obtained during a 4-day period to establish a concurrent basinwide pattern of seasonal water quality.

Of the 70 sites, flow occurred at 62 during at least one of the sampling periods which took place during the period March-September 1964 (plate 1). The sites sampled are listed below by number and name (from Hahl and Cabell, 1965).

1. Mammoth Creek at mouth, near Hatch
2. Sevier River at Hatch
3. Panguitch Creek near Panguitch
4. Sevier River near Circleville
5. Sevier River near Kingston
6. East Fork Sevier River near Antimony
7. Otter Creek above reservoir, near Antimony
8. East Fork Sevier River near Kingston
9. Sevier River below Piute Dam, near Marysvale
10. Sevier River above Clear Creek, near Sevier
11. Clear Creek at Sevier
12. Sevier Valley Canal near Joseph
13. State (Piute) Canal near Redmond
14. Sevier River at Elsinore
15. Vermillion Canal at Glenwood Road, near Richfield
16. Sevier River near Richfield
17. Sevier River at Glenwood Road, near Glenwood
18. South Cedar Ridge Canyon above diversions, near Sigurd
19. Sevier River near Sigurd
20. Lost Creek above diversion, near Aurora
21. Lost Creek at diversion near Aurora
22. Lost Creek at mouth, near Aurora
23. Sevier River at State Highway 63, near Salina
24. Sheep Creek near Salina
25. West Fork Sheep Creek near Salina
26. Sheep Creek at mouth, near Salina
27. Salina Creek above diversions, near Salina
28. Salina Creek at Salina
29. Redmond Canal at Redmond Lake outlet, at Redmond
30. Sevier River at Redmond
31. West View Canal near Axtell
32. Sevier River near Gunnison
33. San Pitch River at Fairview
34. Pleasant Creek near Mount Pleasant
35. San Pitch River at Moroni
36. Manti Creek below lower powerplant tailrace, near Manti
37. San Pitch River near Manti
38. San Pitch River near Sterling
39. San Pitch River at Fayette Canal diversion, near Gunnison
40. Sevier River near Fayette
41. Sevier River near Juab

[1] The 1964 water year is the 12-month period, October 1, 1963 through September 30, 1964.

42. Chicken Creek near Levan
43. Sevier River below Chicken Creek, near Mills
44. Sevier River below Tintic Wash, near Leamington
45. Sevier River near Lynndyl
46. Canal A at DMAD Reservoir, near Delta
46a. Sevier River near Delta
47. Abraham Canal near Delta
48. Drainage ditch near Abraham
49. Sevier River below Gunnison Bend Reservoir, near Delta
50. Sevier River at highway bridge, near Hinckley
51. Sevier River at Deseret
52. Cherry Creek near Jericho
53. Eightmile Creek below diversions, near Holden
54. Chalk Creek near Fillmore
55. Corn Creek near Kanosh
56. Beaver River near Beaver
57. Beaver River at Beaver
58. Beaver River above Dry Creek, at Greenville
59. Beaver River at Adamsville
60. Indian Creek at Adamsville
61. Beaver River at Rockyford Dam, near Minersville

Plate 1 indicates the types of information available for each site. The U.S. Geological Survey performed most of the chemical, a few of the radiological, and all the suspended-sediment analyses. The Utah State Department of Health performed all the biochemical and bacteriological, most of the radiological, and some of the chemical analyses.

## PHYSICAL SETTING

The Sevier Lake basin covers about one-sixth of Utah and lies in the west-central and southwestern parts of the State. The Sevier River is the largest river in the basin. The river heads on the Markagunt Plateau at an altitude of about 10,000 feet and flows less than 20 miles before entering a gently sloping valley that is about 7,000 feet above mean sea level. The valley is about 5 miles wide and is flanked by mountains that rise about 3,000 feet above the valley floor. The Sevier River meanders northward through this valley for 160 miles, then turns southwest and passes through Leamington Canyon. After leaving the canyon the river channel extends through the Sevier Desert for about 70 miles until it reaches the dry bed of the Sevier Lake which lies about 4,500 feet above mean sea level.

The Beaver River heads in the Tushar Mountains at an altitude of about 12,000 feet and within 30 miles reaches the Escalante Valley. The river channel then extends northward through the desert about 80 miles where it joins the Sevier River channel several miles north of Sevier Lake. Prior to settlement of the basin, the lower reach of the Sevier River may have been perennial and the lower reach of the Beaver River probably was ephemeral; but now both reaches are dry because of the diversion of water for irrigation.

Other large tributaries to the Sevier River are the East Fork Sevier River and the San Pitch River. The East Fork Sevier River continually carries water into the Sevier River; however, only intermittent flows reach the Sevier River from the San Pitch River because of diversions for irrigation. The flow of many of the smaller mountain streams in the basin is diverted directly into irrigation systems.

Average annual precipitation on the basin for the period 1931-60 ranged from 25 to 40 inches in the mountains, 8 to 12 inches in the valleys, and 6 to 10 inches in the Sevier Desert (U.S. Weather Bur., 1957, 1965). Approximately two-thirds of the precipitation falls during the period September-May.

The mean annual temperature in the basin for the period 1951-60 ranged from 40.5°F at Bryce Canyon, on the drainage divide of the East Fork Sevier River, to 51.0°F at Delta, in the central part of the Sevier Desert. The lowest temperature recorded at Bryce Canyon was -29°F and the highest recorded at Delta was 106°F (U.S. Weather Bur., 1965).

## CHEMICAL QUALITY OF SURFACE WATER

The concentration of dissolved solids in streams usually varies inversely with water discharge. At low discharges, the concentration of dissolved solids is usually high due to the relatively high concentration of dissolved solids in the ground water which maintains the low flow. At high discharges, the concentration is usually low due to the proportionately greater inflow from overland runoff than from the ground-water sources.

In the upper reaches of a stream, the water has a relatively low concentration of dissolved solids because much of the flow is derived from rainfall or snowmelt that has entered the stream by overland runoff or has been in contact with the soil or rocks for only a short period of time. As water flows downstream, the concentration of dissolved solids usually increases due to inflow of ground water and concentration by evapotranspiration. Superimposed on this natural increase is the increase of dissolved solids caused by water-management practices.

Water in the Sevier Lake basin originates from snow (Feth, Rogers, and Roberson, 1964, p. 20-23) and rain that contain small amounts of dissolved solids. Water in the upper reaches of streams in the basin contains a fairly high concentration of dissolved solids because much of the flow is sustained by ground water which has seeped through soluble rocks and surface material. However, the highest concentrations of dissolved solids in most of the basin result principally from reuse of water. Excess irrigation water that percolates deep into the ground dissolves minerals from the alluvium before it returns to the river. The water in each reach of the river has a characteristic range of concentration of dissolved solids which is related to water discharge and to the concentration of each ion in solution. The relations may vary throughout the year, but they are seasonally repetitive. Discharge from reservoirs tends to contain uniform concentrations of dissolved solids for all rates of discharge because of mixing during storage.

The extremes in concentrations of dissolved solids observed during the reconnaissance are not necessarily the maximum and minimum concentrations that occurred during the 1964 water year. However, the four sets of data at most sites correlate well with water discharge and follow the seasonal pattern of water quality indicated by data obtained from two sites that were sampled throughout the year—Sevier River below Piute Dam, near Marysvale and Sevier River near Lynndyl (U.S. Geol. Survey, 1964, p. 111-112). Therefore, each set of reconnaissance data was assumed to be representative of the streamflow regimen during the season in which the data were collected.

Plate 2 shows the observed extremes in water discharges and corresponding concentrations of dissolved solids. The sampling sites, shown by number on plate 2, are from Hahl and Cabell (1965). The concentrations of individual ions for 27 of the sites sampled are shown by diagrams after Stiff (1951). The two patterns in each diagram indicate the ionic concentrations which correspond to the maximum and minimum discharges observed at the site.

It can be noted from plate 2 that the concentration of each dissolved ion does not increase proportionately as water flows downstream. As the concentrations of ions change, the water may remain suitable for some uses while becoming less suitable for others. Therefore, ionic concentrations in terms of water type are used to describe the water in later discussions of various parts of the basin. Water type is determined by selecting the cation and anion that have the greatest concentrations expressed in equivalents per million. If the next greatest concentration of cation or anion is at least three-fourths that of the largest respective value, it also is listed. The cation with the greatest concentration is listed first, followed by the cation of next greatest concentration; these are followed by the anions similarly listed.

Along with water type, water hardness indicates the usefulness of water. The following classification of hardness is used in this report:

| Classification | Hardness (ppm) |
|---|---|
| Soft | 0-60 |
| Moderately hard | 61-120 |
| Hard | 121-180 |
| Very hard | More than 180 |

Weighted-average[1] concentrations were estimated for 23 sites in the basin (table 1). The estimates were made only for sites where streamflow data were available for the entire 1964 water year and where the observations of concentration of dissolved solids represented the range in discharge occurring at those sites. The data shown in table 1 represent water-quality conditions observed in diversion canals and in the rivers near diversion structures and indicate the type of water available for irrigation. Water-quality data collected from canals represent conditions only during a few months of the year; therefore, in order to describe water quality in the basin more thoroughly, much of the following discussion deals with conditions in the streams and rivers of the basin. To simplify the discussion of water quality in the basin, the rivers are divided into reaches in which the water contains similar concentrations of dissolved solids.

Analysis of the movement of dissolved-solids loads through the basin was not possible from the reconnaissance data. Too little data are available on the volume of water distributed in canals and in the river at key points in the basin, and the chemical-quality data indicate the system is too intricate to permit accurate estimates of the dissolved-solids load entering or leaving given reaches of the rivers.

[1] Weighted average is used to indicate discharge-weighted average. It is computed (usually for a full year) by mutiplying the concentrations given in each analysis by the discharge for the period represented by each analysis, adding the products, and dividing the sum of the products by the sum of the discharges.

**Table 1. — Estimated weighted-average concentrations of dissolved constituents in and properties of water passing selected sites in the Sevier Lake basin during the 1964 water year, and extremes in temperature, coliform bacteria, biochemical oxygen demand, and dissolved oxygen**

| Number on plate 1 | Sampling site | Mean discharge (cfs) | Weighted average: Parts per million | | | | | | | | | Weighted average | | Observed range (maximum/minimum) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Calcium (Ca) | Magnesium (Mg) | Sodium1/ (Na) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Dissolved solids (residue at 180°C) | Hardness as $CaCO_3$: Total | Hardness as $CaCO_3$: Noncarbonate | Specific conductance (micromhos/cm at 25°C) | Sodium-adsorption ratio | Temperature (°F) | Coliform bacteria (MPN) | Biochemical oxygen demand (ppm) | Dissolved oxygen (ppm) |
| 2 | Sevier River at Hatch | 70.6 | 34 | 14 | 8 | 182 | 7 | 2 | 170 | 142 | 0 | 300 | 0.3 | 63/36 | - | - | - |
| 5 | Sevier River near Kingston | 54.8 | 53 | 20 | 27 | 285 | 18 | 15 | 310 | 214 | 0 | 470 | .8 | 62/32 | 4,300/200 | 1.8/0.0 | 10/8.4 |
| 8 | East Fork Sevier River near Kingston | 52.8 | 48 | 20 | 22 | 240 | 31 | 16 | 290 | 202 | 6 | 420 | .7 | 70/32 | 930/75 | 2.5/1.0 | 11/6.3 |
| 9 | Sevier River below Piute Dam, near Marysvale2/ | 104 | 42 | 20 | 32 | 248 | 30 | 14 | 288 | 188 | 0 | 453 | 1.0 | 70/39 | 4,300/9 | 3.4/1.7 | 12/7.0 |
| 10 | Sevier River above Clear Creek, near Sevier | 129 | 44 | 19 | 27 | 220 | 39 | 17 | 290 | 188 | 8 | 440 | .9 | 70/32 | 230/9 | 2.9/1.0 | 11/7.5 |
| 16 | Sevier River near Richfield | 34.0 | 52 | 20 | 38 | 240 | 55 | 29 | 360 | 212 | 15 | 540 | 1.1 | 75/35 | 2,300/75 | 2.9/1.4 | 11/6.1 |
| 19 | Sevier River near Sigurd | 44.2 | 76 | 41 | 80 | 260 | 190 | 86 | 640 | 358 | 145 | 970 | 1.8 | 68/39 | - | - | - |
| 32 | Sevier River near Gunnison | 3/99 | 112 | 67 | 298 | 410 | 320 | 385 | 1,500 | 555 | 219 | 2,150 | 5.5 | 66/34 | 9,300/930 | 2.0/1.1 | 10/7.0 |
| 34 | Pleasant Creek near Mount Pleasant | 16.2 | 45 | 21 | 9 | 220 | 13 | 18 | 212 | 199 | 18 | 380 | .3 | 54/45 | - | - | - |
| 40 | Sevier River near Fayette | 3/101 | 110 | 78 | 344 | 400 | 400 | 460 | 1,700 | 595 | 267 | 2,550 | 6.1 | 79/38 | 7,500/430 | 3.4/1.0 | 10/7.0 |
| 41 | Sevier River near Juab | 108 | 94 | 80 | 330 | 330 | 390 | 430 | 1,600 | 564 | 293 | 2,360 | 6.0 | 75/44 | 210/9 | 2.6/1.0 | 14/6.7 |
| 42 | Chicken Creek near Levan | 6.2 | 57 | 27 | 28 | 265 | 49 | 31 | 341 | 253 | 36 | 570 | .8 | 72/36 | - | - | - |
| 44 | Sevier River below Tintic Wash, near Leamington | 3/160 | 75 | 76 | 308 | 305 | 340 | 385 | 1,400 | 500 | 250 | 2,060 | 6.0 | 73/32 | 2,300/93 | 1.7/0.9 | 10/5.3 |
| 45 | Sevier River near Lynndyl2/ | 4/107 | 66 | 86 | 316 | 281 | 365 | 416 | 1,440 | 517 | 280 | 2,260 | 6.0 | 77/32 | 750/23 | 1.9/0.9 | 12/6.3 |
| 46 | Canal A at DMAD Reservoir, near Delta | 55.3 | 65 | 81 | 310 | 280 | 362 | 408 | 1,410 | 495 | 266 | 2,210 | 6.1 | 74/60 | - | - | - |
| 46a | Sevier River near Delta | 57.0 | 73 | 75 | 270 | 285 | 325 | 360 | 1,330 | 490 | 257 | 1,980 | 5.3 | 75/42 | 2,300/23 | 1.8/1.4 | 9.3/6.4 |
| 47 | Abraham Canal near Delta | 5/53.6 | 65 | 82 | 298 | 262 | 340 | 415 | 1,410 | 499 | 284 | 2,200 | 5.8 | 77/59 | - | - | - |
| 49 | Sevier River below Gunnison Bend Reservoir, near Delta | 3/2.7 | 89 | 99 | 335 | 280 | 410 | 490 | 1,640 | 629 | 400 | 2,400 | 5.8 | 81/39 | 2,300/9 | 3.0/1.0 | 11/5.6 |
| 51 | Sevier River at Deseret | 3/6.5 | 140 | 165 | 540 | 315 | 680 | 880 | 2,720 | 1,030 | 770 | 4,000 | 7.3 | 90/44 | - | - | - |
| 54 | Chalk Creek near Fillmore | 29.1 | 45 | 17 | 7 | 220 | 9 | 5 | 200 | 182 | 2 | 350 | .2 | 63/42 | - | - | - |
| 56 | Beaver River near Beaver | 35.3 | 16 | 4 | 8 | 70 | 12 | 2 | 90 | 56 | 0 | 125 | .5 | 60/35 | - | - | - |
| 59 | Beaver River at Adamsville | 17.9 | 44 | 13 | 29 | 190 | 35 | 24 | 280 | 164 | 8 | 400 | 1.0 | 82/45 | 4,300/930 | 4.2/1.4 | 8.7/6.0 |
| 61 | Beaver River at Rockyford Dam, near Minersville | 17.4 | 49 | 16 | 50 | 230 | 51 | 41 | 370 | 188 | 0 | 540 | 1.6 | 77/56 | 430/93 | 2.2/0.6 | 12/6.3 |

1/ Computed sodium (Na) plus potassium (K) reported as sodium.
2/ Weighted average determined from regular 1964 sampling program.
3/ Estimated.
4/ Discharge of wells pumping into river between sampling site and gaging station not included.
5/ Includes discharge of Midland, Deseret High-Line, Deseret, and Smith Canals near Delta.

## The mountain streams

Some mountain streams in the Sevier Lake basin are tributary to the upper and central reaches of the Sevier River and to its major tributaries, and some enter the Sevier Desert. Water in the mountain streams is runoff derived from rain and snow. In general, high flow in the streams occurs during the spring thaw or during heavy rainstorms, and low flow is sustained by discharge from ground-water sources. A few lakes and reservoirs in the mountains catch some of the runoff. A few streams tributary to the San Pitch River receive trans-basin diversions of water from the Colorado River Basin, and some water is diverted from the East Fork Sevier River into the Colorado River Basin.

The concentration of dissolved solids of water in 13 mountain streams ranged from about 60 to 500 ppm (parts per million). Comparison of the discharge of water and the concentration of dissolved solids showed four relations. Each relation was characteristic of a group of streams, and curves representing the average relation between water discharge and the concentration of dissolved solids for each group of streams are shown in figure 1. The streams (number in parentheses is sampling site on plate 1) included in each group are as follows:

Group I

(27) Salina Creek above diversions, near Salina
(33) San Pitch River at Fairview
(36) Manti Creek below lower powerplant tailrace, near Manti
(42) Chicken Creek near Levan

Group II

(1) Mammoth Creek at mouth, near Hatch
(7) Otter Creek above reservoir, near Antimony
(11) Clear Creek at Sevier

Group III

(3) Panguitch Creek near Panguitch
(56) Beaver River near Beaver

Group IV

(18) South Cedar Ridge Canyon above diversions, near Sigurd
(34) Pleasant Creek near Mount Pleasant
(54) Chalk Creek near Fillmore
(55) Corn Creek near Kanosh

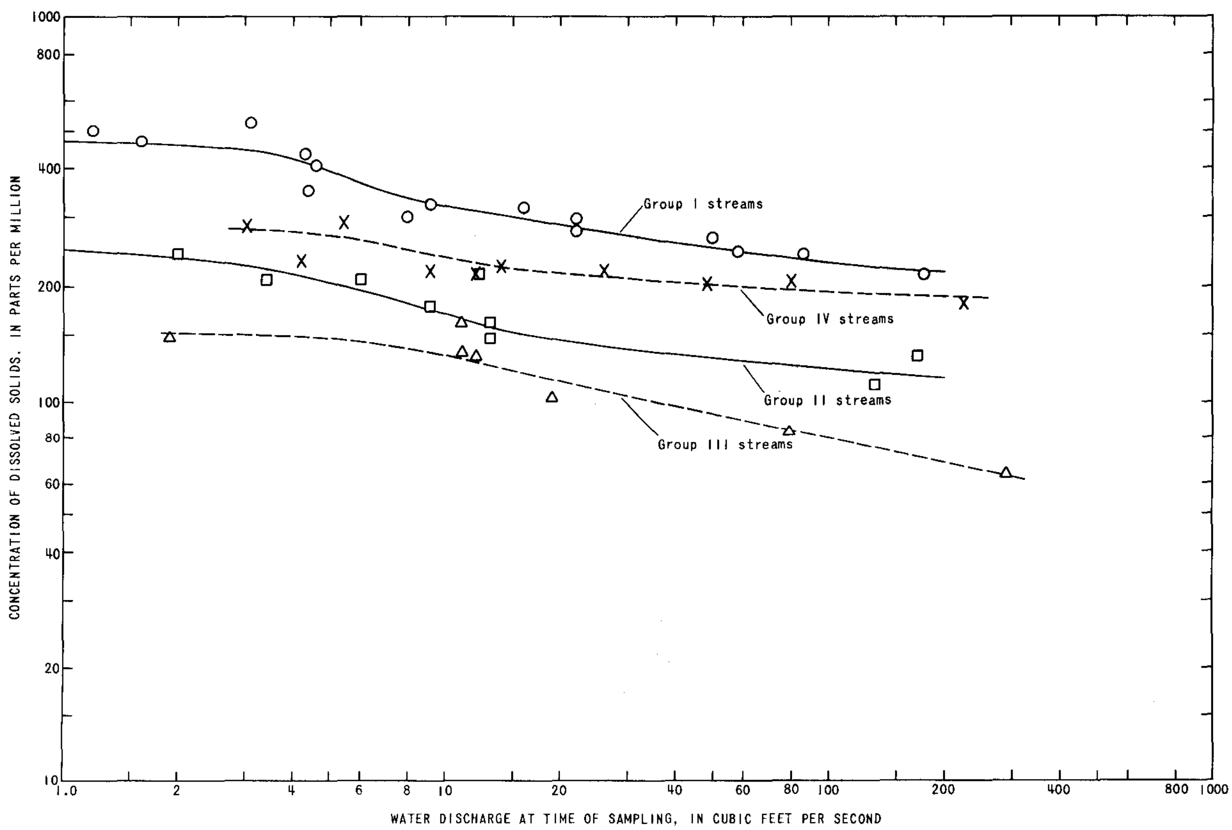


**Figure 1. — Average relation of concentration of dissolved solids to water discharge at sites on mountain streams in the Sevier Lake basin during the 1964 water year.**

Concentrations of individual ions for some streams in each of the four groups are shown on plate 2. Water from mountain streams throughout the basin is generally of the calcium bicarbonate type, although magnesium ions commonly are as plentiful as calcium ions. Thus the water in most of the mountain streams is hard. However, water in Chicken Creek near Levan (Group I) contained mostly calcium, sodium, bicarbonate, and sulfate ions, and water in Salina Creek above diversions, near Salina (also Group I) contained mostly sodium, magnesium, and bicarbonate ions.

The softest water was in the Beaver River near Beaver. The maximum hardness observed in mountain streams during the reconnaissance was 370 ppm in the San Pitch River at Fairview.

Data collected from the 13 mountain streams indicate that dissolved-solids concentrations and ionic concentrations are influenced by local geology. Streams in Groups I and IV drain areas composed mostly of sedimentary rocks, which transmit the water slowly and allow for intimate contact between rocks and water. The water in these streams has a higher concentration of dissolved solids than the water in the streams in Groups II and III which drain areas composed mostly of igneous rocks and coarse conglomerates. These rocks permit more rapid movement of water and reduce the time of contact between rocks and water.

The silica content of water in mountain streams shows a wide range and is probably indicative of the geology of the area. For example, streams draining only volcanic rocks in the Sevier Lake basin contain from 5.7 to 38 ppm silica. Streams draining only sedimentary rocks in the basin contain from 4.8 to 14 ppm silica. The low concentrations of silica for each type of stream occurred during snowmelt runoff when the time of contact between water and rocks is shortest. The volcanic rocks in the basin in general have a higher silica content than the sedimentary rocks, and the high silica content for each type of stream results from solution of silica in decomposed rock. The release of silica seems particularly marked when the rocks of volcanic origin are drained by water that is low in dissolved-solids content and that contains mostly calcium, magnesium, and bicarbonate ions (Clarke, 1924, p. 111).

The ionic ratio of calcium to magnesium in surface water also indicates the effect of geology on water quality. This ratio for natural waters containing low to moderate concentrations of dissolved solids commonly ranges from about 5:1 to about 1:1 (computed from the respective concentrations expressed in equivalents per million) (Hem, 1959, p. 82). Low ratios, on the order of 1:1, may indicate that magnesium silicates or dolomite rocks are being dissolved. A high ratio, on the order of 5:1, would suggest that limestone or other relatively pure calcium carbonate precipitates are being dissolved. Most water from mountain streams of the basin have calcium-magnesium ratios of about 3:1 to about 1:1.

Hahl and Cabell (1965, p. 10-13) reported that water draining the Flagstaff Limestone in South Cedar Ridge Canyon and in the San Pitch River valley at Fairview had calcium-magnesium ratios as low as 1:3. Subsequent resampling indicated that the actual ratio was about 1:1, and the apparent ratio of 1:3 was the result of precipitation of calcium carbonate from the samples during storage.

## The East Fork Sevier River

The East Fork Sevier River receives water from mountain streams along its entire length. Water from the East Fork is diverted into the Paria River in the Colorado River Basin and is also diverted near Antimony to Otter Creek Reservoir where it is held as supplemental storage to Piute Reservoir.

The average relation of the concentration of dissolved solids to water discharge at sites on the East Fork Sevier River is shown in figure 2. Most mountain streams tributary to the East Fork Sevier River were not sampled. However, these tributary streams could be represented in figure 2 by streams in Groups II or III because the relation of concentration of dissolved solids to water discharge for streams in these two groups could evolve, as water moves downstream, to the general relation which was found in the East Fork Sevier River. The dissolved-solids content of water in the East Fork Sevier River more than doubles as the water moves from its headwaters through the main stem to the mouth of the East Fork Sevier River near Kingston. Yet, as listed in table 1, the East Fork Sevier River near Kingston contained a weighted average of only 290 ppm of dissolved solids during the 1964 water year.

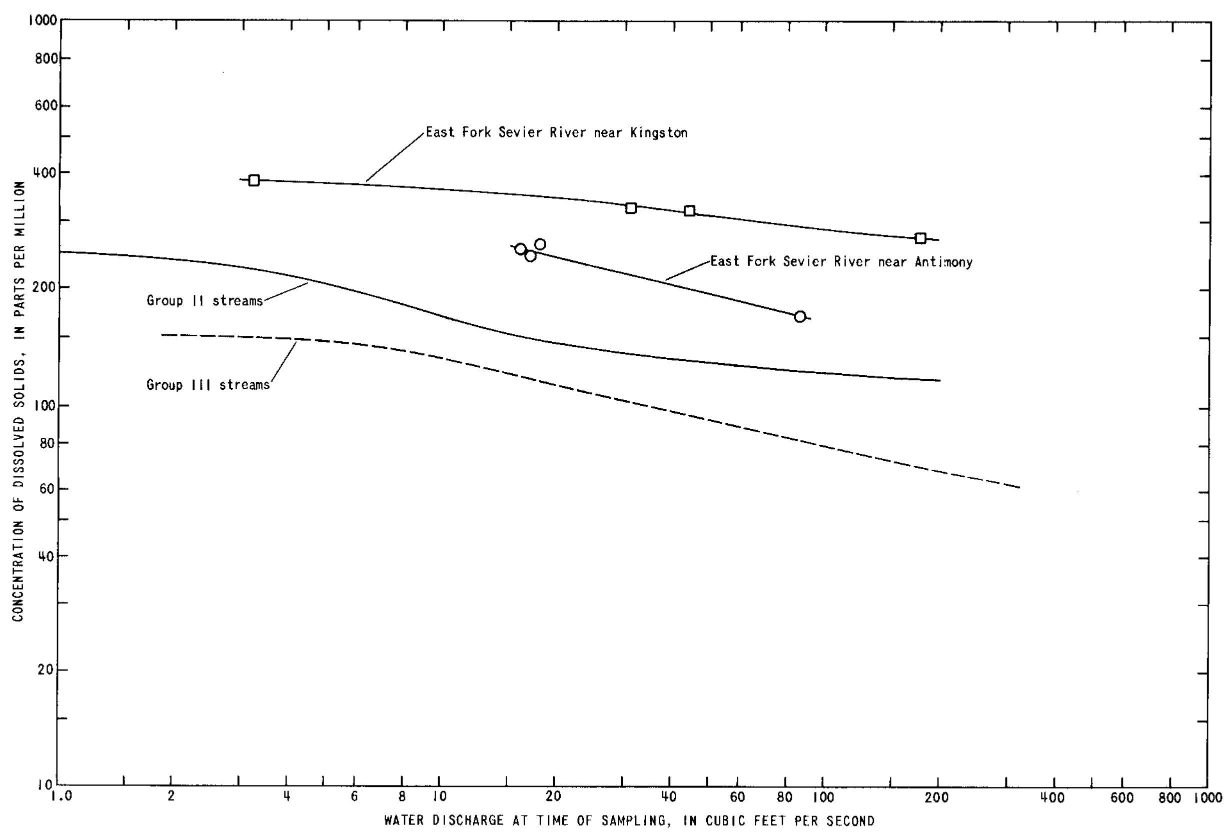


**Figure 2. — Average relation of concentration of dissolved solids to water discharge at sites on the East Fork Sevier River during the 1964 water year.**

Figure 3 illustrates the change in the maximum and minimum concentrations of dissolved solids observed during the 1964 water year as water in the East Fork Sevier River flowed downstream. The lines connecting the points in figure 3 are there only to give the illustration continuity and are neither rate functions nor path functions of concentration as the water moves downstream. The average concentration of dissolved solids of ground water at sites along the East Fork Sevier River, as determined by Carpenter, Robinson, and Bjorklund (1964), is shown for comparison. The relation between the concentration of dissolved solids of ground and surface water is discussed more fully in the following section.

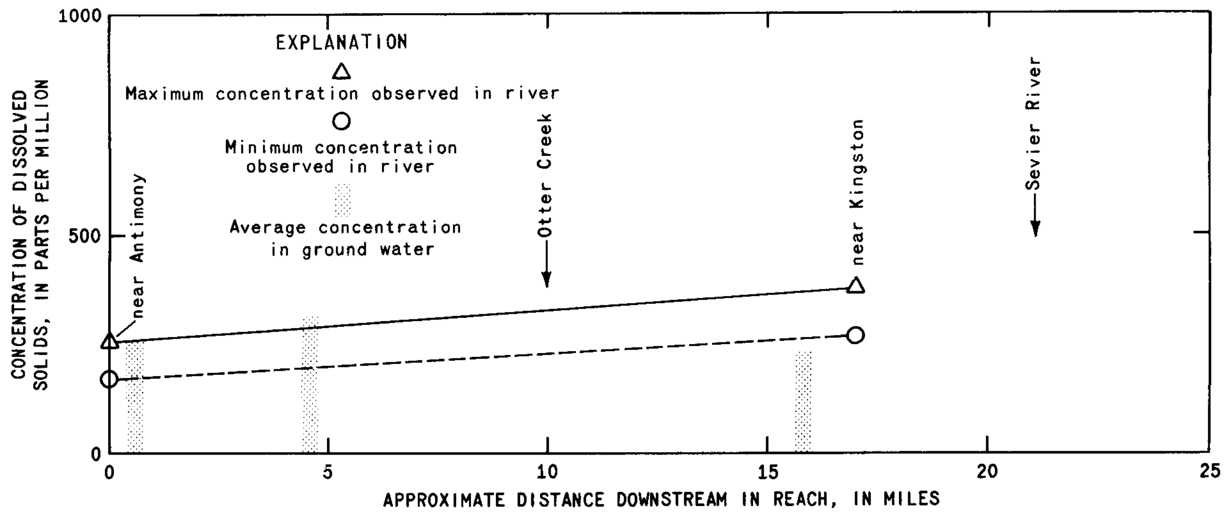


**Figure 3. — Maximum and minimum concentrations of dissolved solids observed in the East Fork Sevier River during the 1964 water year and average concentration of dissolved solids in ground water of the area.**

Estimated weighted-average concentrations of individual ions in the East Fork Sevier River near Kingston are given in table 1, and concentrations for extremes of discharge observed during the reconnaissance are shown on plate 2. The water in the East Fork Sevier River near Kingston is of the calcium magnesium bicarbonate type. The water at this site is very hard, with a maximum hardness of 280 ppm observed during the reconnaissance.

## The Sevier River from Hatch to Richfield

The Sevier River from Hatch to Richfield—the upstream reaches of the Sevier River—receives water from mountain streams and from the East Fork Sevier River. Piute Reservoir lies below the confluence of the East Fork Sevier River with the Sevier River and provides storage for much of the spring runoff from mountains at the south end of the basin. Releases from the reservoir are almost entirely diverted into irrigation canals between Joseph and Richfield.

Figure 4 shows the average relation of concentration of dissolved solids to water discharge at sites in the upper part of the Sevier River basin. A few of the mountain streams tributary to the upstream reaches of the Sevier River were sampled. In general the unsampled tributary streams might be represented in figure 4 by streams in Group II because the relation of concentration of dissolved solids to water discharge for streams in this group could evolve, as water moves downstream, to the general relation which was found in the upstream reaches of the Sevier River. Storage in Piute Reservoir causes mixing of water and results in practically no change in the concentration of dissolved solids as the rate of water released from the reservoir changes. The concentration of dissolved solids of water in the upstream reaches of the Sevier River, although influenced by water-management practices, was found to be less than 500 ppm during the reconnaissance in 1964.

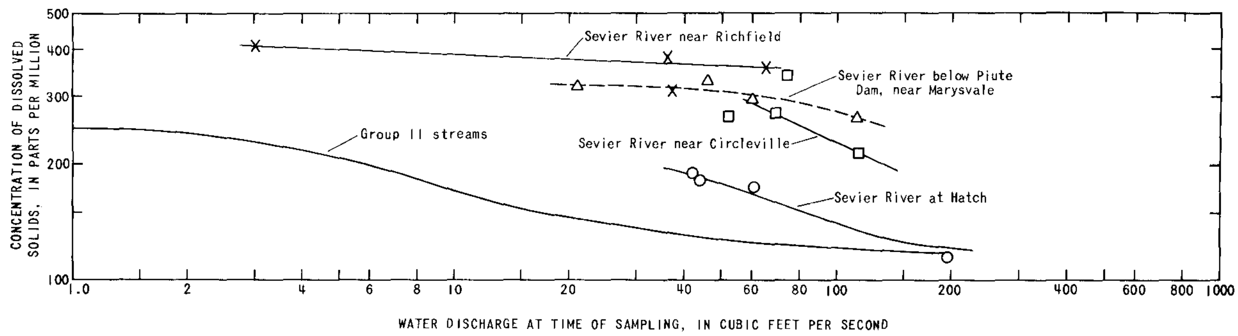


**Figure 4. — Average relation of concentration of dissolved solids to water discharge at sites in the upper part of the Sevier River basin during the 1964 water year.**

Figure 5 illustrates the change in the maximum and minimum concentrations of dissolved solids observed during the 1964 water year as water flowed through the upstream and central reaches of the Sevier River. The histograms in figure 5 indicate the average concentration of dissolved solids in ground water along these reaches of the river. The histograms are after data in Carpenter and Young (1963, p. 33-34) and Carpenter, Robinson, and Bjorklund (1964, p. 27-28). Young and Carpenter (1965, p. 31-33) reported that the Sevier River between Kingston and the Sevier Bridge Reservoir gains water continually from ground-water aquifers that underlie the basin. As streamflow is reduced by lack of discharge from upstream sources or by diversions, the ratio of ground water to surface water is increased and the quality of water remaining in the river approaches that of the ground water. The conclusion by Young and Carpenter is clearly supported by (1) agreement between changes in the maximum concentration of dissolved solids observed in the river and the parallel changes in the histograms in figure 5 and (2) concentrations of individual ions in river water at low flow that parallel ionic concentrations observed in the ground water.

Quantitative measurements of the dissolved-solids load entering and leaving the river are possible only from more detailed data on all inflow and diversions; however, examination of figure 5 shows qualitatively the influence of the concentration of dissolved solids in ground water on the maximum concentration of dissolved solids observed in the river. For example, in the reach from Piute Dam to Sevier there is some ground-water inflow and no diversions. The concentration of dissolved solids averages about the same as that of the surface water; hence there is no change in the concentration of dissolved solids as water flows downstream to Sevier. The next reach, Sevier to Joseph, receives about one-third of its flow from Clear Creek during the spring. The concentration of dissolved solids in water in Clear Creek during periods of high runoff is less than half that in the Sevier River, and the flow of Clear Creek during the spring dilutes the water in the Sevier River. Thus, the minimum concentration of dissolved solids is reduced downstream from the confluence of the two streams. During the remainder of the year, the volume of water from Clear Creek is small compared to the volume in the Sevier River, and the concentrations of dissolved solids of the water in the two streams are almost the same. Therefore, the maximum concentration does not change significantly through this reach.

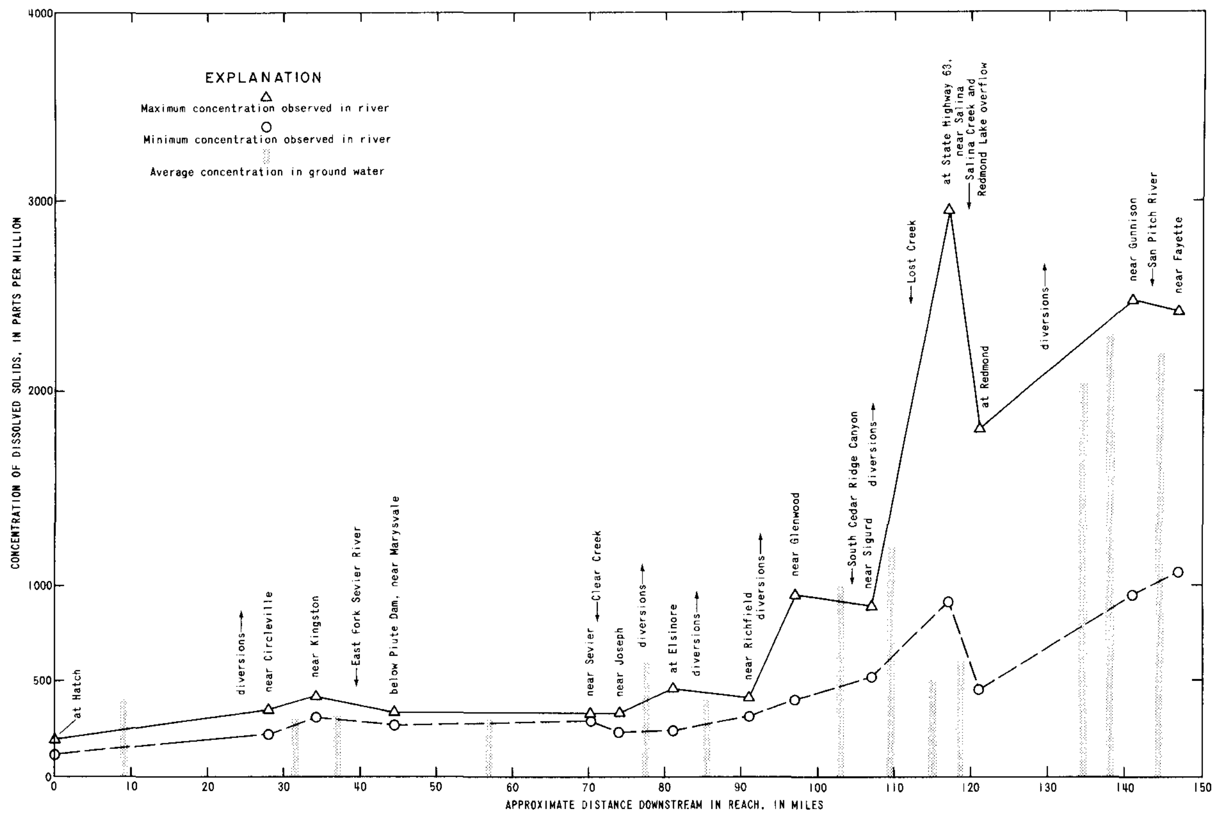


**Figure 5. — Maximum and minimum concentrations of dissolved solids observed at sites in the upstream and central reaches of the Sevier River during the 1964 water year and average concentration of dissolved solids in ground water of the area.**

In the reach between Joseph and Elsinore, large volumes of surface water are diverted. The ground water in this reach has a greater concentration of dissolved solids than does surface water. Therefore, the maximum concentration of dissolved solids increases in this reach of the river. Diversions in the reach between Elsinore and Richfield further reduce the flow in the river; however, most ground water in this reach has a lower concentration of dissolved solids than ground water in the reach between Joseph and Elsinore, and groundwater inflow to the river causes the reduction in the maximum concentration observed.

Concentrations of individual ions for some water in the upstream reaches of the Sevier River are shown on plate 2 and table 1. The water is usually of the calcium bicarbonate type (table 2). Water in this reach of the river is moderately hard to very hard. The maximum hardness observed anywhere in the reach during the reconnaissance was 249 ppm in the Sevier River near Kingston. As the water flows from Hatch to Richfield, the influence of water-management practices on water type can be observed. Storage in Piute Reservoir probably results in release of carbon dioxide dissolved in the water. The release of this gas causes calcium carbonate to precipitate in the reservoir, and the relative concentration of magnesium ions becomes greater although the actual amount of magnesium in solution probably remains constant. Between Joseph and Richfield, return flow from irrigation and discharge from several saline springs result in an increase in the concentration of sodium, sulfate, and chloride ions during periods of low flow.

**Table 2. — Major dissolved ions and average hardness occurring for selected conditions in the upstream reaches of the Sevier River during the 1964 water year**

| | | Water type for selected conditions | | | |
|---|---|---|---|---|---|
| Number on plate 1 | Sampling site | Minimum concentration (high flow) | Weighted-average concentration | Maximum concentration (low flow) | Hardness (weighted average, in ppm) |
| | Sevier River: | | | | |
| 2 | at Hatch | Ca-$HCO_3$ | Ca-$HCO_3$ | Ca-$HCO_3$ | 142 |
| 5 | near Kingston | Ca-$HCO_3$ | Ca-$HCO_3$ | Ca-$HCO_3$ | 214 |
| 9 | below Piute Dam | Ca,Mg-$HCO_3$ | Ca-$HCO_3$ | Ca-$HCO_3$ | 188 |
| 12 | near Joseph (same as Sevier Valley Canal near Joseph) | Ca,Mg-$HCO_3$ | - | Ca-$HCO_3$ | - |
| 14 | at Elsinore | Ca-$HCO_3$ | - | Ca,Na-$HCO_3$ | - |
| 16 | near Richfield | Ca-$HCO_3$ | Ca-$HCO_3$ | Na,Mg-$HCO_3$ | 212 |

## The Sevier River from Richfield to the Sevier Bridge Reservoir

Between Richfield and the Sevier Bridge Reservoir—the central reaches of the Sevier River—water occasionally enters the Sevier River from small tributaries, as return flow from irrigated land, from the San Pitch River (discussed in the following section), and from ground-water aquifers which contain gypsum and halite derived from the weathering of the Arapien Shale of Jurassic age; also, several major diversions are made from this reach of the river. The combined effect of these factors was to increase the 1964 weighted-average concentration of dissolved solids almost five times between Richfield and Fayette (table 1).

Figure 6 shows the average relation of the concentration of dissolved solids to water discharge at sites in the central part of the Sevier River basin and also shows the increase in the concentration of dissolved solids for a given discharge with distance downstream. A few of the mountain streams tributary to the central part of the Sevier River basin were sampled. In general the unsampled tributary streams might be represented in figure 6 by streams in Groups I or IV because the relation of concentration of dissolved solids to water discharge for streams in these two groups could evolve, as water moves downstream, to the general relation which was found in the central reaches of the Sevier River. The estimated 1964 weighted-average concentration of dissolved solids in the Sevier River near Richfield was 360 ppm, whereas in the Sevier River near Fayette the concentration of dissolved solids was 1,700 ppm.

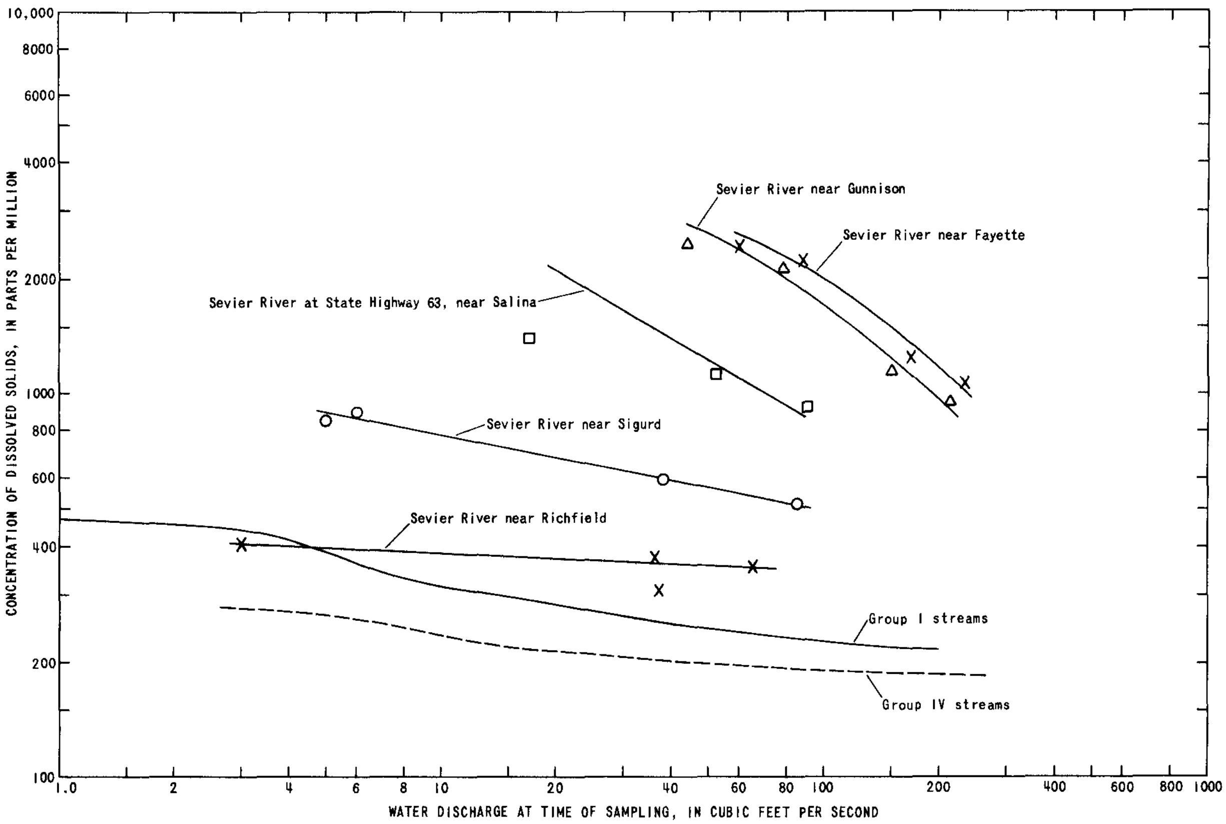


**Figure 6. — Average relation of concentration of dissolved solids to water discharge at sites in the central part of the Sevier River basin during the 1964 water year.**

Figure 5 illustrates the change in the maximum and minimum concentrations of dissolved solids observed during the 1964 water year as water flowed through the central part of the Sevier River basin. Figure 5 shows a sharp increase in the concentration of dissolved solids for low flow near the confluence of Lost Creek and the Sevier River. This increase might be caused by inflow of ground water through the alluvium beneath Lost Creek. Downstream, below the confluence of Salina Creek with the Sevier River and below Redmond Lake, the concentration of dissolved solids decreases sharply. This decrease is due to water entering the Sevier River from Salina Creek, Redmond Lake, and ground-water aquifers. Even though annual discharge data are available for Salina Creek, too much of the flow is diverted to properly evaluate the concentration of dissolved solids at the mouth of the creek for the period of low flow during the spring. Overflow from Redmond Lake consistently supplies water of about 550 ppm of dissolved solids and ground-water inflow contains about 600 ppm of dissolved solids.

The changes in concentration of dissolved solids that occur in most reaches of the Sevier River from Richfield to Fayette are associated with changes in relative concentrations of individual ions. (See plate 2 and table 1.) At Richfield the water is of the calcium bicarbonate type; whereas, at Fayette the water is of the sodium chloride type. Table 3 lists the water type associated with the observed maximum and minimum concentrations of dissolved solids at selected sites in the central reaches of the Sevier River. A rapid change in the relative abundance of ions in solution is apparent from the data in table 3. The increased concentration of ions dissolved in the water is largely associated with the concentration of dissolved solids in ground-water inflow. Water in the central reaches of the Sevier River is hard to very hard, and the maximum hardness of 854 ppm was observed near Fayette.

Return flow from irrigation accounts for part of the increase in dissolved solids in the reach from Richfield to Fayette. The remainder is caused by solution of minerals in the Arapien Shale and in the alluvium which is derived from weathering of the shale. The Arapien, which forms the foothills east of the river and underlies part of the basin, is characterized by a green-gray color and a lack of vegetative cover. It consists of siltstone, sandstone, halite, and gypsum; and the solubility of the latter two minerals is demonstrated by the high concentration of dissolved solids in seepage at the mouth of Lost Creek, whose channel crosses the Arapien Shale.

**Table 3. — Major dissolved ions and average hardness occurring for selected conditions in the central reaches of the Sevier River during the 1964 water year**

| Number on plate 1 | Sampling site | Water type for selected conditions: Minimum concentration (high flow) | Weighted-average concentration | Maximum concentration (low flow) | Hardness (weighted average, in ppm) |
|---|---|---|---|---|---|
| | Sevier River: | | | | |
| 16 | near Richfield | $Ca\text{-}HCO_3$ | $Ca\text{-}HCO_3$ | $Na,Mg\text{-}HCO_3$ | 212 |
| 17 | at Glenwood Road | $Ca,Na\text{-}HCO_3$ | - | $Mg,Ca\text{-}SO_4$ | - |
| 19 | near Sigurd | $Ca,Na\text{-}HCO_3$ | $Ca,Na\text{-}HCO_3,SO_4$ | $Na,Mg\text{-}SO_4$ | 358 |
| 23 | near Salina | Na,Mg-Cl | - | Na-Cl | - |
| 30 | at Redmond | $Na,Ca\text{-}HCO_3$ | - | Na-Cl | - |
| 32 | near Gunnison | $Na\text{-}Cl,HCO_3$ | Na-Cl | Na-Cl | 555 |
| 40 | near Fayette | $Na\text{-}Cl,SO_4$ | Na-Cl | Na-Cl | 595 |

The summer flow in Lost Creek near Aurora is derived from Lost Creek reservoir and from ground-water aquifers. On July 27-28, 1964, field measurements of specific conductance of the water in Lost Creek, which were made upstream from its contact with the Arapien Shale, at a diversion dam about 3 miles above the mouth of the creek, and in the canal below the dam indicated no change in concentration of dissolved solids. The conductance at the three sites was 315 micromhos per centimeter at 25°C. Below the diversion dam the creek channel was dry. However, in the creek channel from about 300 feet below the dam to the confluence with the Sevier River, ground water was seeping into the channel. The specific conductance measured at points down the channel is as follows.

| Distance below diversion dam | Estimated discharge (cfs) | Specific conductance (micromhos/cm at 25°C) | Estimated dissolved solids (ppm) | Temperature (°F) |
|---|---|---|---|---|
| 300 feet | 0.01 | 1,000 | 600 | 53 |
| 360 feet | .01 | 1,100 | 700 | 60 |
| 600 feet | .01 | 1,100 | 700 | 62 |
| 0.8 mile | .1 | 7,500 | 4,700 | 64 |
| 1.2 miles | .1 | 40,000 | 30,000 | 62 |
| 2.6 miles | .2 | 50,000 | [1]38,500 | 62 |

[1] Laboratory analysis.

Comparison of the dissolved ions contained in water from Lost Creek above diversions and at the mouth of the creek (table 4) indicates that the soluble material in the Arapien Shale is sodium chloride and calcium sulfate.

## Table 4. — Concentrations of dissolved ions, in parts per million, at sites on Lost Creek

| Item | Lost Creek | |
|---|---|---|
| | Above diversions | At mouth |
| Date of collection | July 27, 1964 | July 28, 1964 |
| Discharge (cfs) | 17 | 0.2 |
| Silica ($SiO_2$) | 23 | 16 |
| Calcium ($Ca^{++}$) | 28 | 1,110 |
| Magnesium ($Mg^{++}$) | 11 | 238 |
| Sodium ($Na^{+}$) | 10 | 13,100 |
| Potassium ($K^{+}$) | [1]2 | 58 |
| Bicarbonate ($HCO_3^-$) | 147 | 214 |
| Sulfate ($SO_4^=$) | 6.0 | 2,070 |
| Chloride ($Cl^-$) | 7.7 | 21,000 |
| Dissolved solids (residue on evaporation at 180°C) | 157 | 38,500 |

[1] Computed.

Near Redmond, the ground water entering the Sevier River reduces the dissolved-solids content of the river. Downgradient from Redmond, the dissolved-solids content of the river increases due to evapotranspiration and inflow of ground water which has dissolved halite and gypsum derived from weathering of the Arapien Shale.

## The San Pitch River

The San Pitch River receives most of its flow as runoff from the mountains on the east and as water from 13 transmountain diversions from tributaries of the San Rafael and Price Rivers in the Colorado River Basin (U.S. Geol. Survey, 1960 and 1963). During the irrigation season most of the streamflow is diverted in the Sanpete Valley. As a result, the San Pitch River from Moroni to near Manti carries little other than irrigation return flow, and the concentration of dissolved solids increases rapidly as the water flows downstream.

Figure 7 shows the average relation of the concentration of dissolved solids to water discharge at sites on the San Pitch River. The marked change in the average relation between the concentration of dissolved solids and discharge in the San Pitch River near Manti as compared to the other three points sampled on the river, probably occurs because: (1)

during the irrigation and postirrigation seasons, ground water of about 700 ppm of dissolved solids is the source of flow in the river near Manti; (2) during the winter, rain and snowmelt transports some of the dissolved solids accumulated on the land surface to the river; and (3) during the spring, land to be irrigated is inundated, and salts that have accumulated in the soil during the previous irrigation season are flushed into the river.

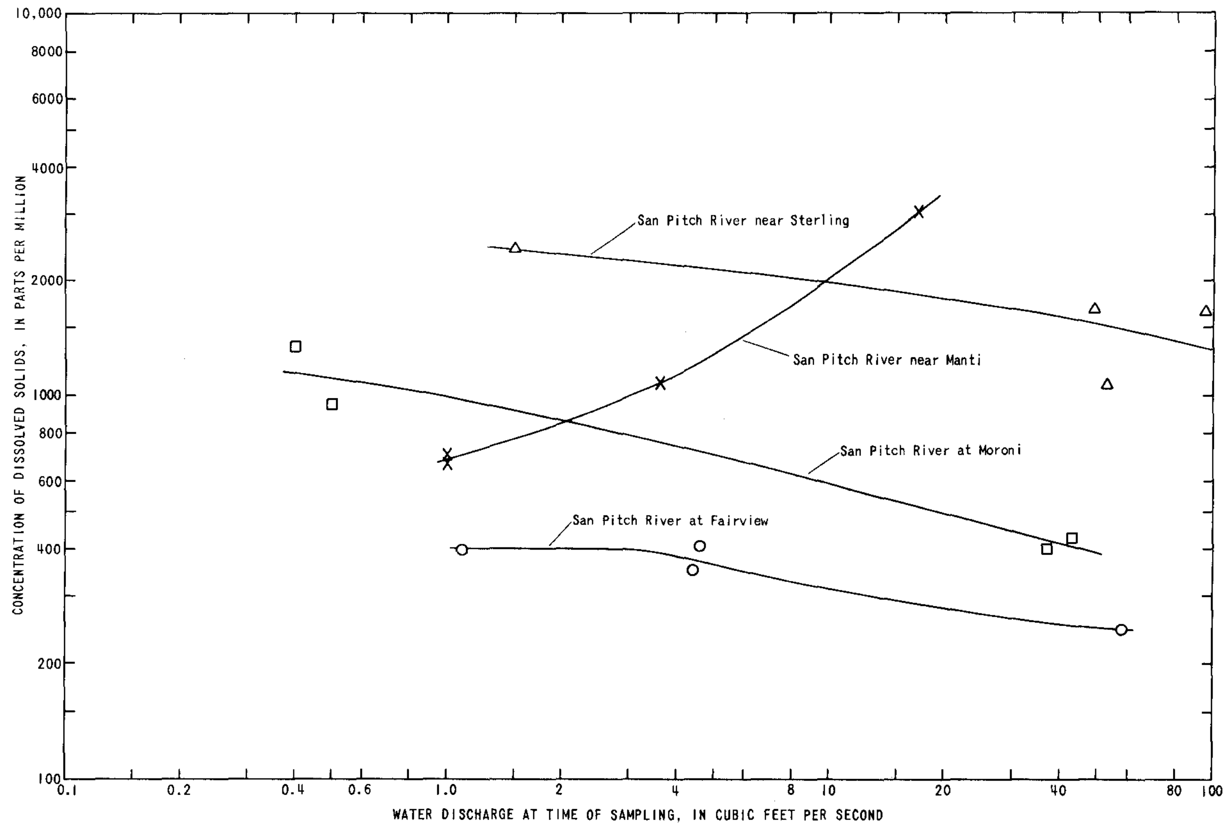


**Figure 7. — Average relation of concentration of dissolved solids to water discharge at sites on the San Pitch River during the 1964 water year.**

Figure 8 illustrates the change in the maximum and minimum concentrations of dissolved solids observed during the 1964 water year as water flowed down the San Pitch River. The few chemical analyses of ground water in the valley (Connor, Mitchell, and others, 1958) indicate that the concentration of dissolved solids in ground water is about the same as the minimum concentration observed in the San Pitch River. This indicates that the chemical quality of water in the San Pitch River is controlled by the diversion and application of surface water in Sanpete Valley and that greater use of ground water might enhance the quality of surface water in the valley. The effect of evapotranspiration and mixing of water in Gunnison Reservoir near Sterling is to reduce the difference in the extremes observed near Manti. Diversions from the San Pitch River and its tributaries at and below Sterling (Sixmile and Twelvemile Creeks) usually keep the lower reach of the river dry. Spring flow and storm runoff from tributaries to the lower San Pitch River do enter the Sevier River west of Gunnison.

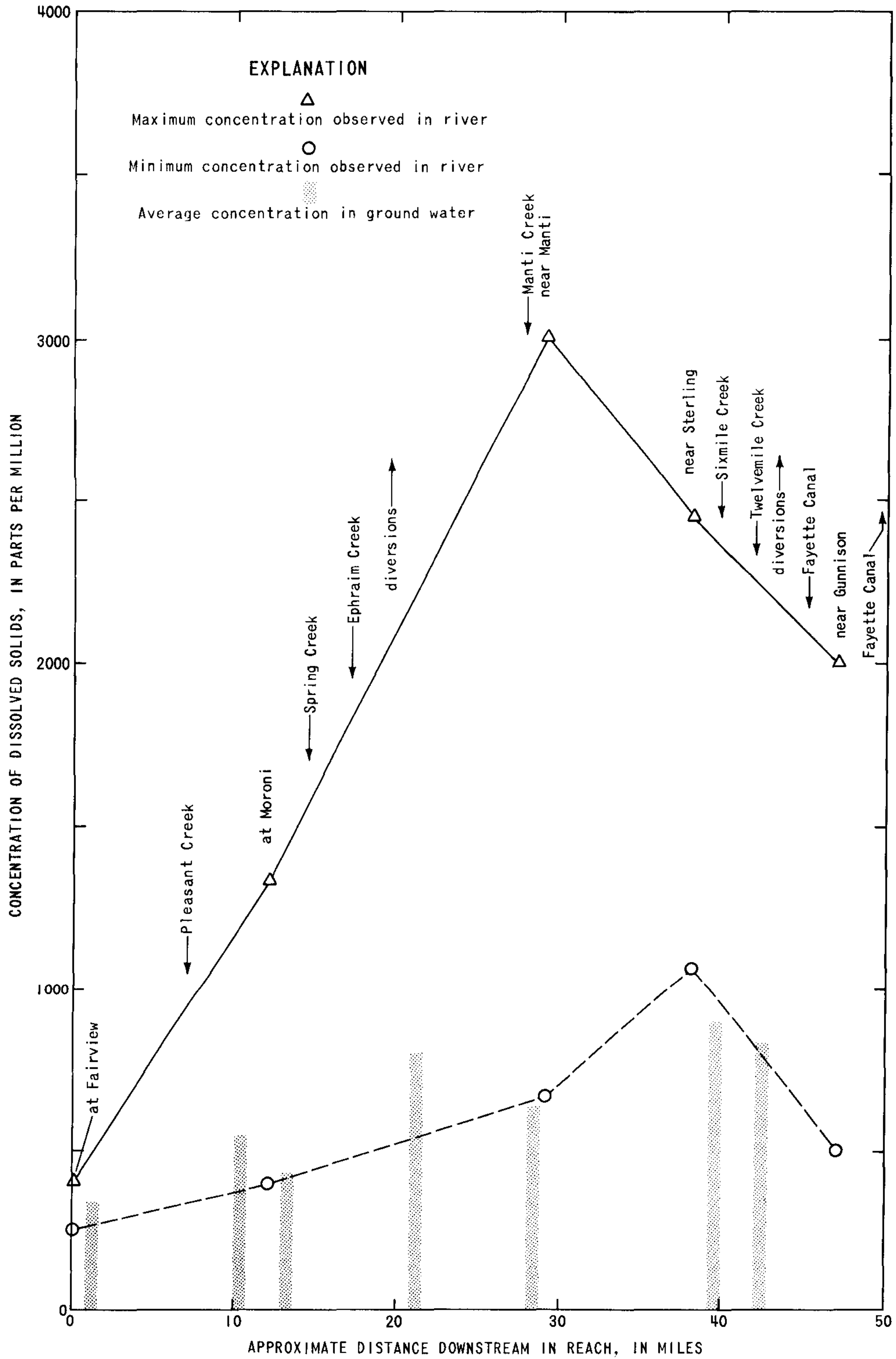


**Figure 8. — Maximum and minimum concentrations of dissolved solids observed in the San Pitch River during the 1964 water year and average concentration of dissolved solids in ground water of the area.**

Concentrations of individual ions in the San Pitch River change with the time of year and as the water flows downstream. Water types for some of the maximum and minimum concentrations shown in figure 8 are illustrated on plate 2 and are listed in table 5. Water in the San Pitch River is very hard; the maximum hardness of 1,540 ppm was observed near Manti. No daily discharge data are available for the San Pitch River; however, as an annual average, water probably leaves the reach of the San Pitch River above Fairview as a calcium bicarbonate type and probably changes to a sodium chloride type near Sterling. The change results from water-management and irrigation practices and from solution of minerals in the alluvium of the lower Sanpete Valley.

**Table 5. — Major dissolved ions occurring for selected conditions in the San Pitch River during the 1964 water year**

| Number on plate 1 | Sampling site | Water type for selected conditions: Minimum concentration (high flow) | Water type for selected conditions: Maximum concentration (low flow) |
|---|---|---|---|
| | San Pitch River: | | |
| 33 | at Fairview | $Ca\text{-}HCO_3$ | $Ca,Mg\text{-}HCO_3$ |
| 35 | at Moroni | $Mg,Ca\text{-}HCO_3$ | $Mg\text{-}SO_4HCO_3$ |
| 37 | near Manti | $Mg\text{-}HCO_3$ | $Mg\text{-}SO_4$ |
| 38 | near Sterling | $Na,Mg\text{-}Cl$ | $Na\text{-}Cl$ |

## The Sevier River from the Sevier Bridge Reservoir to Deseret

The Sevier River from the Sevier Bridge Reservoir to Deseret—the downstream reaches of the Sevier River—receives most of its water as releases from Sevier Bridge Reservoir and as discharge from Molten and Blue Springs located about 1 mile downstream from the reservoir. Downstream from Lynndyl some ground water is pumped into the river. Some of the flow in the downstream reaches of the Sevier River is diverted at Leamington Canyon; the remainder is stored in the DMAD or Gunnison Bend Reservoirs and is subsequently diverted to irrigate land around Delta. Seepage and sewage sustain a small flow in the river between Gunnison Bend Reservoir and Deseret.

Figure 9 shows the average relation of concentration of dissolved solids to water discharge at sites in the lower part of the Sevier River basin. Reconnaissance data indicate that water released from the Sevier Bridge Reservoir contains between 1,500 and 2,000 ppm of dissolved solids. A short distance downstream from the reservoir, inflow to the river from Molten and Blue Springs decreases the concentration of dissolved solids in the river to about 700 ppm during low flow, but has only a slight effect on the concentration of dissolved solids in the river during high flow. (See the curve for Sevier River below Chicken Creek in figure 9.) The discharge of Chase Springs is only about 3 cfs (cubic feet per second) (Bjorklund and Robinson, 1967) and has a negligible effect on the concentration of dissolved solids in the river.

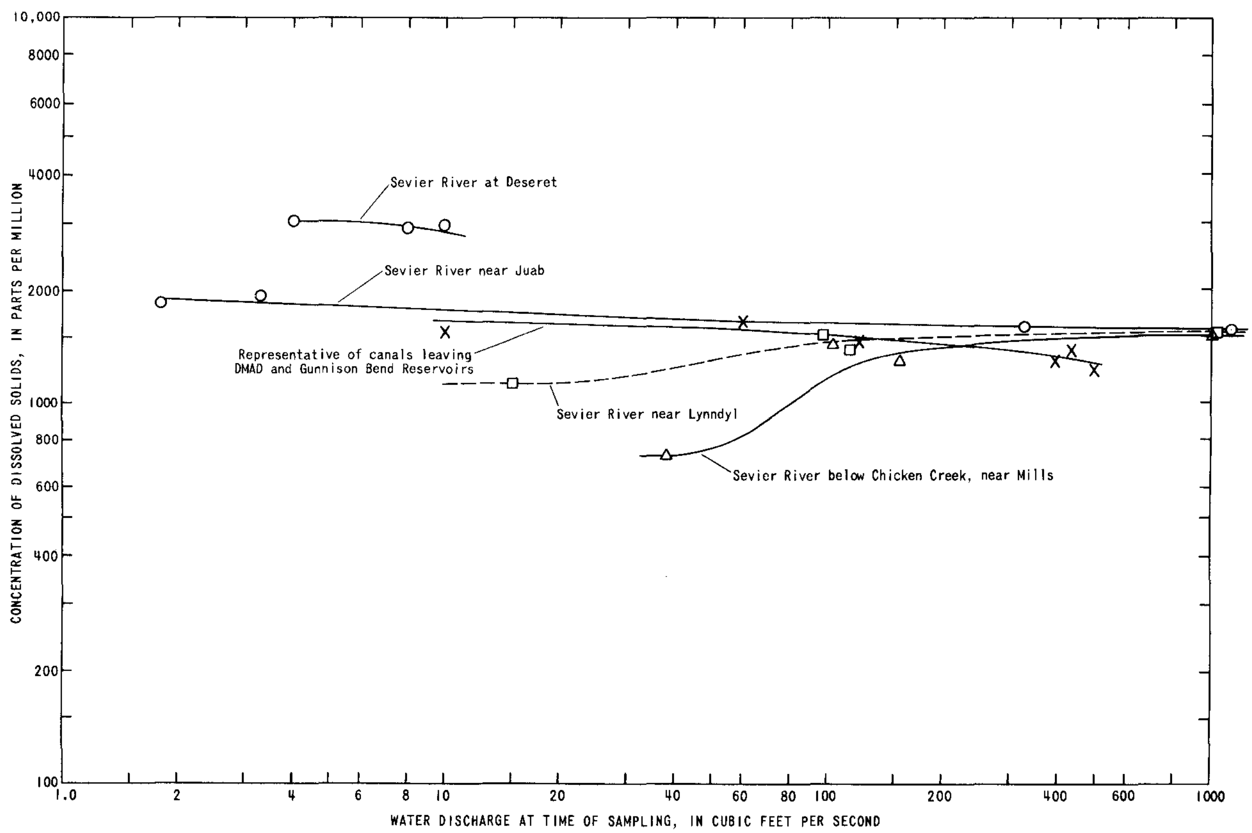


**Figure 9. — Average relation of concentration of dissolved solids to water discharge at sites in the lower part of the Sevier River basin during the 1964 water year.**

The dilution effect of Molten and Blue Springs is still apparent at low flow near Lynndyl even though some of the water having a low concentration of dissolved solids is diverted in Leamington Canyon. Downstream from Lynndyl, ground water is pumped into the river and the mixture is stored in DMAD and Gunnison Bend Reservoirs. The reach of the Sevier River connecting these two reservoirs is used primarily as a canal.

Figure 10 illustrates the change in the maximum and minimum concentrations of dissolved solids observed during the 1964 water year as water flowed through the lower part of the Sevier River basin. The changes in concentrations of dissolved solids between the Sevier Bridge Reservoir and the DMAD and Gunnison Bend Reservoirs are due to several factors—mixing of water in the Sevier Bridge Reservoir, dilution of water by inflow from springs, diversions, and the pumping of water from wells into the river downstream from Lynndyl.

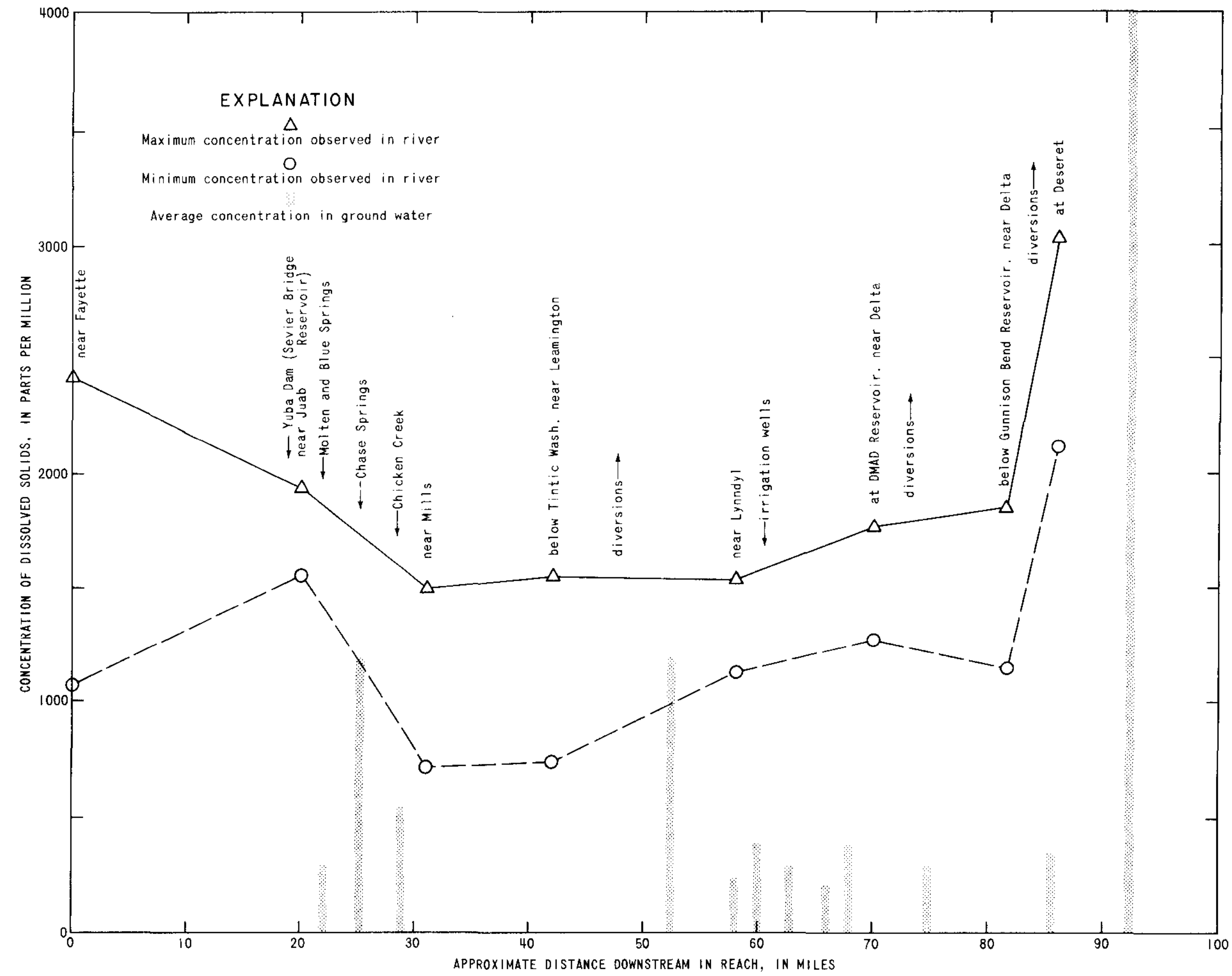


**Figure 10. — Maximum and minimum concentrations of dissolved solids observed at sites in the lower part of the Sevier River basin during the 1964 water year and average concentration of dissolved solids in ground water of the area.**

Water reaching the DMAD and Gunnison Bend Reservoirs during the 1964 water year had a concentration of dissolved solids of about 1,400 ppm (table 1). This represents a 12 percent reduction in the concentration of dissolved solids from water released from Sevier Bridge Reservoir. Mixing in the DMAD and Gunnison Bend Reservoirs further reduced the extremes in the concentration of dissolved solids and restored the inverse relation between concentration of dissolved solids and water discharge.

All the water from the DMAD and Gunnison Bend Reservoirs is taken by canals to irrigate the Sevier Desert between Delta and Deseret. The Sevier River below Gunnison Bend Reservoir receives only drainage from irrigated lands, seepage from the alluvium, and sewage. This mixture of inflow causes the concentration of dissolved solids of the river between Gunnison Bend Reservoir and Deseret to almost double (figure 9). Ground water in the area south of Deseret contains about 4,000 ppm of dissolved solids. This water is seeping through relatively fine sediments, and there is little interchange between the ground water and the water in the river at Deseret.

Concentrations of individual ions in the downstream reaches of the Sevier River are shown on plate 2. The water type remains as sodium chloride and changes only slightly as water flows downstream. The slight change in water type (table 6) is related to inflow of dilute water from Molten and Blue Springs. Water in the downstream reaches of the Sevier River is very hard. Near Delta the maximum hardness was 728 ppm, and at Deseret water in the river contained as much as 1,220 ppm of hardness.

**Table 6. — Major dissolved ions and average hardness occurring for selected conditions in the downstream reaches of the Sevier River during the 1964 water year**

| | Sampling site | Water type for selected conditions: Minimum concentration (high flow) | Weighted-average concentration | Maximum concentration (low flow) | Hardness (weighted average, in ppm) |
|---|---|---|---|---|---|
| | Sevier River: | | | | |
| 40 | near Fayette | Na-Cl,$SO_4$ | Na-Cl | Na-Cl | 500 |
| 41 | near Juab | Na-Cl | Na-Cl | Na-Cl,$SO_4$ | 517 |
| 43 | near Mills | Na-Cl | Na-Cl | Mg,Na-Cl,$HCO_3$ | 490 |
| 44 | near Leamington | Na-Cl | Na-Cl | Mg,Na-Cl,$HCO_3$ | 499 |
| 45 | near Lynndyl | Na-Cl | Na-Cl | Na,Mg-Cl | 1,030 |
| 46a | near Delta | Na-Cl | Na-Cl | Na-Cl | 595 |
| 47 | Abraham Canal near Delta | Na-Cl | Na-Cl | Na-Cl | 564 |
| 51 | Sevier River at Deseret | Na-Cl | Na-Cl | Na-Cl | - |

## The Beaver River

The Beaver River receives most of its flow as runoff from the mountains east of the town of Beaver and as ground-water inflow between Beaver and Rockyford Reservoir. About half of the river's flow is diverted for use above Rockyford Reservoir. The remainder is diverted into canals for use near Minersville and Milford, and flow does not usually occur in the Beaver River downstream from Minersville.

Figure 11 shows the average relation of the concentration of dissolved solids to water discharge at sites on the Beaver River. The greatest concentration of dissolved solids observed during the 1964 water year at the Beaver River near Beaver—the point where the Beaver River emerges from the mountains—was 163 ppm. At this point the weighted-average concentration of dissolved solids for the 1964 water year was estimated to be 90 ppm (table 1). At Adamsville, the river contained more than 500 ppm of dissolved solids during one visit, but the weighted-average concentration of dissolved solids was only 280 ppm. The weighted-average concentration of dissolved solids for the 1964 water year at Rockyford Dam was about 370 ppm.

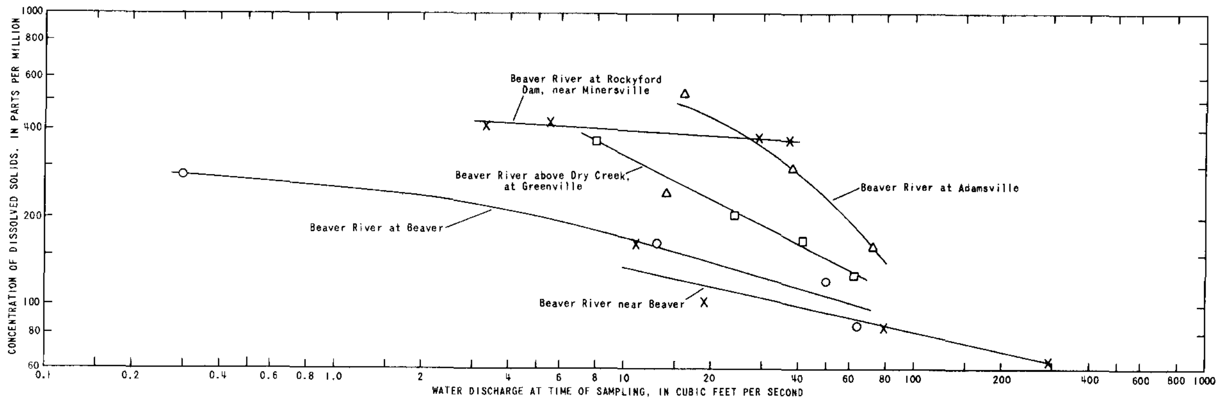


**Figure 11. — Average relation of concentration of dissolved solids to water discharge at sites on the Beaver River during the 1964 water year.**

Figure 12 illustrates the change in the maximum and minimum concentrations of dissolved solids observed during the 1964 water year as water flowed down the Beaver River. The illustration emphasizes the close relation between the concentration of dissolved solids in ground and surface water during periods of low flow and the effect of storage in Rockyford Reservoir. The close relation between the concentrations in ground and surface water is due to the fact that much of the recharge to the ground-water aquifers originates as diversion from the river for irrigation. The increase in the concentration of dissolved solids in the ground water in Beaver Valley in a downstream direction results from recharge from irrigated lands and evapotranspiration where the water table is close to the land surface (Sandberg, 1966, p. 31).

Concentrations of individual ions in the Beaver River are shown on plate 2. Water in the Beaver River is of a calcium bicarbonate type (table 7). The effects of return flow from irrigation and evapotranspiration in Beaver Valley can be seen in the increased quantities of dissolved solids and in the increased hardness of the water at Rockyford Reservoir. Water in the Beaver River is soft to very hard; the maximum hardness of 280 ppm was observed at Adamsville.

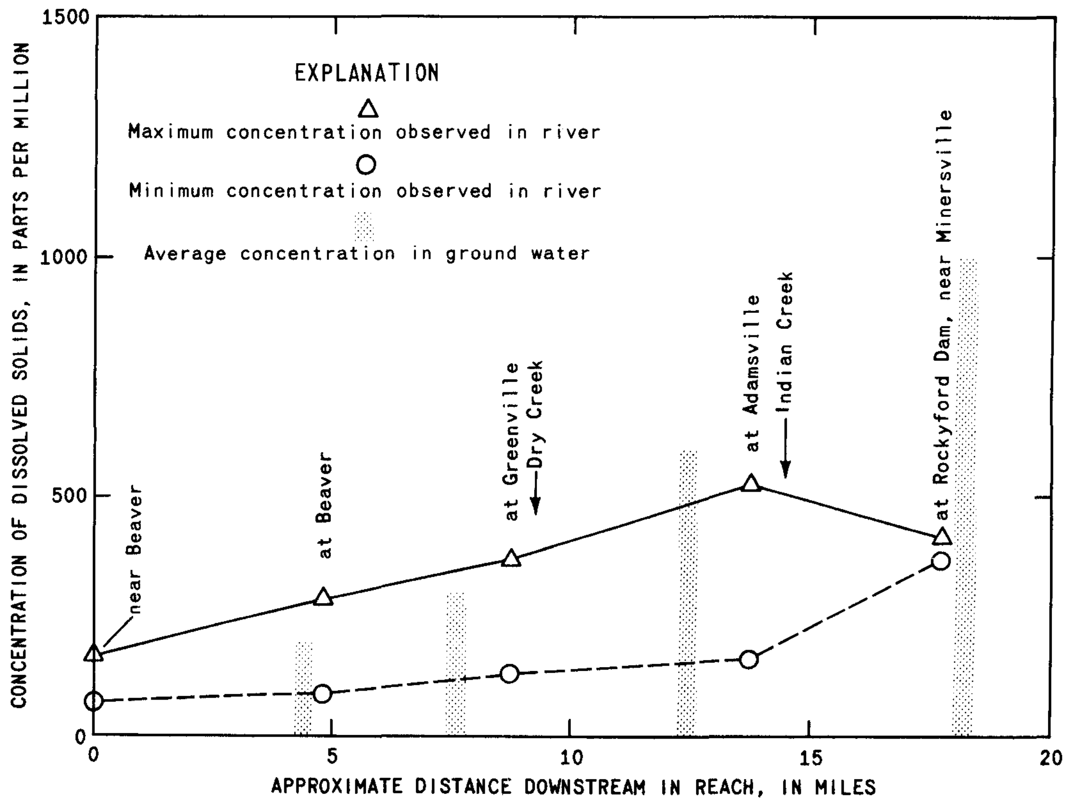


**Figure 12. — Maximum and minimum concentrations of dissolved solids observed in the Beaver River during the 1964 water year and average concentration of dissolved solids in ground water of the area.**

## Table 7. — Major dissolved ions and average hardness occurring for selected conditions in the Beaver River during the 1964 water year

| Number on plate 1 | Sampling site | Water type for selected conditions: Minimum concentration (high flow) | Water type for selected conditions: Weighted-average concentration | Water type for selected conditions: Maximum concentration (low flow) | Hardness (weighted average, in ppm) |
|---|---|---|---|---|---|
| | Beaver River: | | | | |
| 56 | near Beaver | Ca-$HCO_3$ | Ca-$HCO_3$ | Ca-$HCO_3$ | 56 |
| 59 | at Adamsville | Ca-$HCO_3$ | Ca-$HCO_3$ | Ca,Na-$HCO_3$ | 164 |
| 61 | near Minersville | Ca-$HCO_3$ | Ca,Na-$HCO_3$ | Ca,Na-$HCO_3$ | 188 |

## The ephemeral streams

No data were collected as a part of the reconnaissance from the many ephemeral streams that flow from mountains, particularly in the western half of the basin. The ephemeral flow results from heavy rainfall or snowmelt, and consequently the water probably contains less than 500 ppm of dissolved solids at all times.

# WATER QUALITY IN RELATION TO USE

## Irrigation

The major use of water in the Sevier Lake basin is for irrigation. To classify water in terms of its suitability for irrigation, the U.S. Salinity Laboratory Staff (1954, p. 75-82) developed a method that relates the sodium-adsorption ratio to the specific conductance, thus determining the salinity hazard and sodium hazard to plants and soils if the water were used for irrigation. Figure 13 illustrates this method and shows the relative suitability of surface water in the Sevier Lake basin for irrigation.

Line A (figure 13) represents the classification of water in the Sevier River and its tributaries as recorded during the reconnaissance. Water in the mountain streams, the East Fork Sevier River, the upper part of the Sevier River, and the Beaver River is generally represented by values less than 750 micromhos per centimeter and for the most part has low to medium salinity hazard and a low sodium hazard. Water in the central part of the Sevier River and in the San Pitch River is generally represented by values greater than 750 micromhos per centimeter and for the most part has a high to very high salinity hazard and a low to high sodium hazard. Water in the lower part of the Sevier River is similar to that in the central part except that dilution by inflow from Molten and Blue Springs eliminates the condition of high sodium hazard.

Examination of data for sites at or close to major diversions indicates that most water diverted presented either medium salinity and low sodium hazards or high to very high salinity and medium sodium hazards (figure 13). This water seems to be suitable for the crops raised and the soils in the basin.

Area B in figure 13 represents data obtained during a period of low flow in the Sevier River near Salina and near Gunnison, in the Fayette diversion, and in the San Pitch River near Sterling. The waters classified have a very high salinity hazard and a high to very high sodium hazard. Sustained use of this type of water could adversely affect crop production and soil chemistry.

Line C (figure 13) represents drain and sewage water near Delta. Most of the time this water is not suitable for further use.

## Domestic and public supply

The U.S. Public Health Service (1962) has recommended drinking-water standards for domestic and public supply. Table 8 lists the recommended maximum concentrations for selected chemical constituents in drinking water and the maximum concentrations observed in all the mountain streams sampled during the reconnaissance. Reconnaissance data do not necessarily record extremes; therefore, pending detailed analyses of existing and planned domestic supplies, the data indicate that except for the arsenic, lead, and possibly fluoride content of a few mountain streams, most of the water is suitable for domestic and public supply.

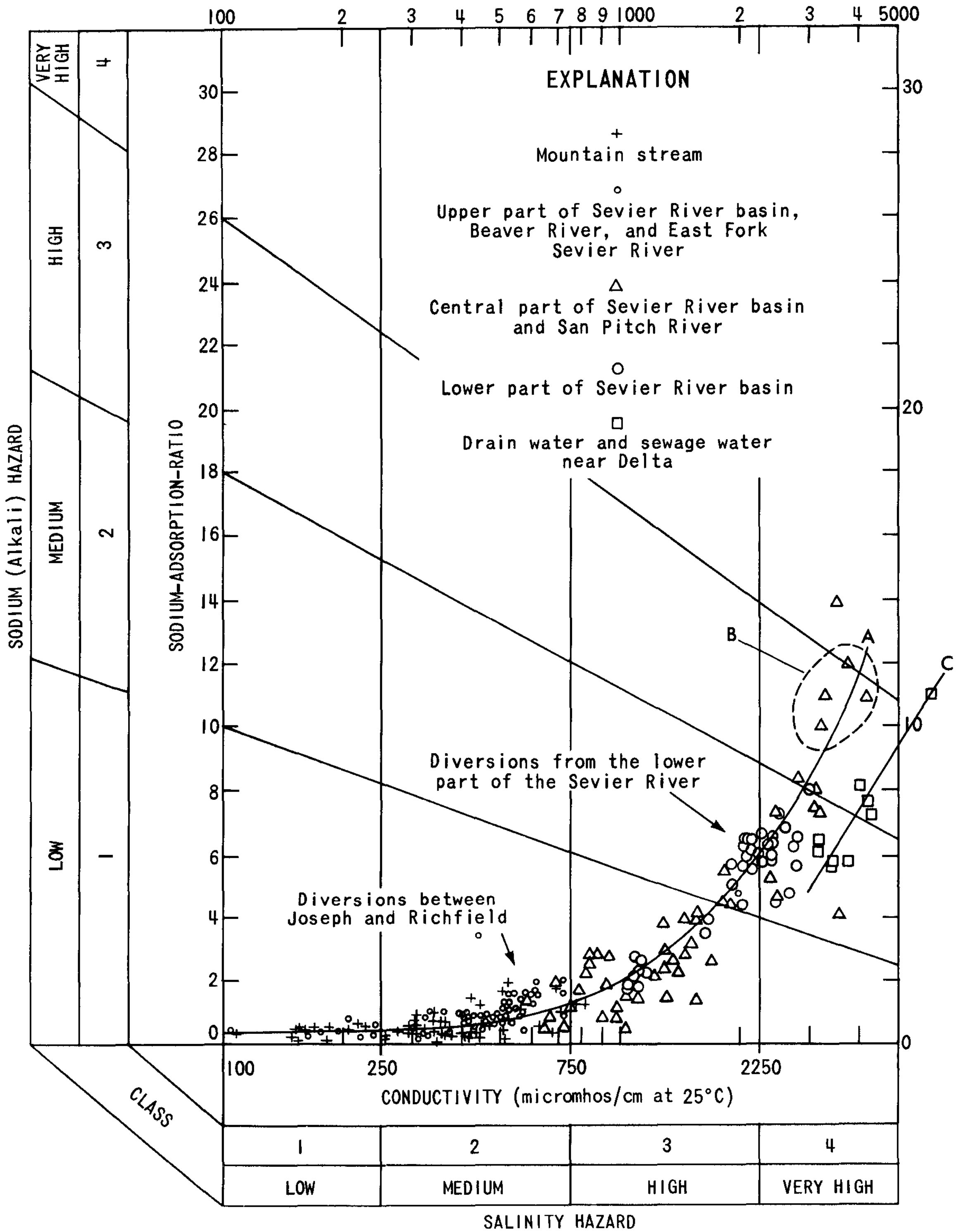


**Figure 13. — Classification of irrigation water in the Sevier Lake basin according to a method developed by the U.S. Salinity Laboratory Staff (1954, p. 75-82).**

Water in the main part of the Beaver River and in the Sevier River above Richfield meets most of the Public Health Service standards for inorganic chemical constituents. However, in the Sevier River below Richfield many of the inorganic chemical constituents exceed Public Health Service standards.

## Table 8. — U.S. Public Health Service (1962) drinking-water standards and maximum concentrations observed during the 1964 reconnaissance in mountain streams of the Sevier Lake basin

PHS standards: Standards are not to be exceeded if more suitable supply is available.

| Item | PHS standards (ppm) | Maximum observed concentrations (ppm) |
|---|---|---|
| Alkyl Benzene Sulfonate (ABS) | 0.5 | 0.00 |
| Arsenic ($As^{+}$) | .01 | .07 |
| Cadmium ($Cd^{++}$) | [1].01 | .001 |
| Chloride ($Cl^{-}$) | 250 | 43 |
| Chromium ($Cr^{+6}$) | [1].05 | .0001 |
| Copper ($Cu^{++}$) | 1.0 | .004 |
| Dissolved solids | 500 | 447 |
| Fluoride ($F^{-}$) | [2].9 | 1.4 |
| Hardness (as $CaCO_3$) | - | 370 |
| Lead ($Pb^{++}$) | [1].05 | .08 |
| Nitrate ($NO_3^{-}$) | 45 | 12 |
| Selenium ($Se^{+4}$) | [1].01 | .004 |
| Silver ($Ag^{+}$) | [1].05 | .01 |
| Sulfate ($SO_4^{=}$) | 250 | 98 |
| Zinc ($Zn^{++}$) | 5.0 | .08 |

[1] Excess of this amount is grounds for rejection of supply.

[2] Optimum value based on average of maximum daily air temperature at Delta. Presence of fluoride in average concentrations greater than two times the optimum value shall constitute grounds for rejection of the supply.

Hardness is often the item that domestic users think of first when water quality is considered. The weighted-average hardness at selected sites in the Sevier Lake basin is shown in tables 1, 2, 3, 6, and 7. Water in the mountain streams ranges from hard to very hard. The upper part of the Sevier River contains moderately hard to very hard water, ranging in weighted-average hardness from 142 ppm at Hatch to 214 ppm near Kingston. This water would require little treatment to make it more suitable for domestic use. Weighted-average hardness in the central part of the Sevier River ranges from 212 ppm near Richfield to 595 ppm near Fayette. The weighted-average hardness at the Gunnison Bend Reservoir is 499 ppm. Water in most of the Richfield-Gunnison Bend Reservoir reach of the river would require extensive treatment to eliminate hardness problems. Hardness of water increases in the lowest parts of the Sevier River, resulting in a weighted-average hardness of 1,030 ppm in the Sevier River at Deseret. This water is extremely expensive to treat.

The upper reach of the Beaver River contains soft water. As water flows downstream the hardness increases; however, diversions near Minersville still carry water that has a weighted-average hardness of only 188 ppm.

Organic concentrations also must be considered along with concentrations of inorganic material in water in the Sevier Lake basin. Organic pollutants in sufficient quantity cause frothing and slimes in some industrial applications and are unsafe in domestic and public supplies. The following standards for the most probable number (MPN) of coliform bacteria and biochemical oxygen demand (BOD) for respective classes of water are listed by the Utah State Department of Health (1965):

| Water class | Coliform bacteria (MPN per 100 milliliters) | BOD (milligrams per liter) | Suitability |
|---|---|---|---|
| A | - | - | All uses including domestic and public supply; requires no treatment. |
| B | $< 50$ | - | All uses including domestic and public supply if chlorinated. |
| C | 50-5,000 | $< 5$ | All uses including domestic and public supply with complete treatment. |
| D | 50-5,000 | 6-25 | All uses except domestic and public supply and irrigation for truck gardens and dairy-cattle pasture. |
| E | - | - | No useful application. |

The ranges in coliform bacteria and BOD observed in the Sevier and Beaver Rivers (table 1) indicate that most of the water is in class C.

### Industry

Water-quality criteria for industrial use vary widely and are discussed in reports by Lohr and Love (1954) and by Bean (1962). With treatment to reduce the hardness and alkalinity[1], most surface water in the upper reaches of the Sevier Lake basin could be used successfully in many industries. However, in the central part of the Sevier River the very high hardness and alkalinity (expressed as $CaCO_3$) would require extensive treatment to make this water suitable for use by many industries.

## WATER-QUALITY NETWORK

Water management in the Sevier Lake basin should be based on consideration of water quality as well as quantity. The reconnaissance data for the Sevier Lake basin as depicted in figures 5, 8, 10, and 12 show a downstream increase in the minimum concentration of dissolved solids. Sampling sites need to be located strategically to monitor water quality under existing conditions of water management and to monitor changes in water quality resulting from new water-management projects.

### Existing water-quality sampling sites

Water-quality sampling sites have been maintained at the Sevier River below Piute Dam, near Marysvale since March 1958 and at the Sevier River near Lynndyl since March 1951.

[1] Alkalinity as $CaCO_3$ equals 0.82 times the concentration of bicarbonate ions in parts per million.

Water-quality data from the Sevier River below Piute Dam, near Marysvale are representative of the quality of water discharged from the upper reach of the Sevier River. The data indicate that thorough mixing of water in Piute Reservoir results in releases that show almost no variation in the concentration of dissolved solids (figure 4). The weighted-average concentration of dissolved solids for the 1964 water year below Piute Reservoir is 288 ppm. As the water moves downstream from Piute Reservoir, no large changes in the concentration of dissolved solids occur until the water passes Richfield.

Data from the Sevier River near Lynndyl provide a good record of water quality in the lower part of the Sevier River. The 1964 weighted-average concentration of dissolved solids at Lynndyl was similar both to releases from the Sevier Bridge Reservoir after mixing with the discharge from springs downstream from the reservoir and to water stored in the DMAD and Gunnison Bend Reservoirs.

Figure 14 shows the relation of the concentration of dissolved solids to water discharge in the Sevier River near Lynndyl during the reconnaissance. The reconnaissance data are represented by squares and the dashed line represents the best relation between these data. The concentrations of dissolved solids obtained as a result of regular sampling at this site during the 1964 water year are also plotted in figure 14. The dashed line could also represent the best relation of the 1964 water year regular sampling-program data with the exception of low flow during the winter months of December-February. Thus, figure 14 demonstrates the applicability of the reconnaissance data for the lower part of the Sevier River. Also, the solid line in figure 14 indicates that extreme conditions during winter were not representated by data collected during the reconnaissance of March to September.

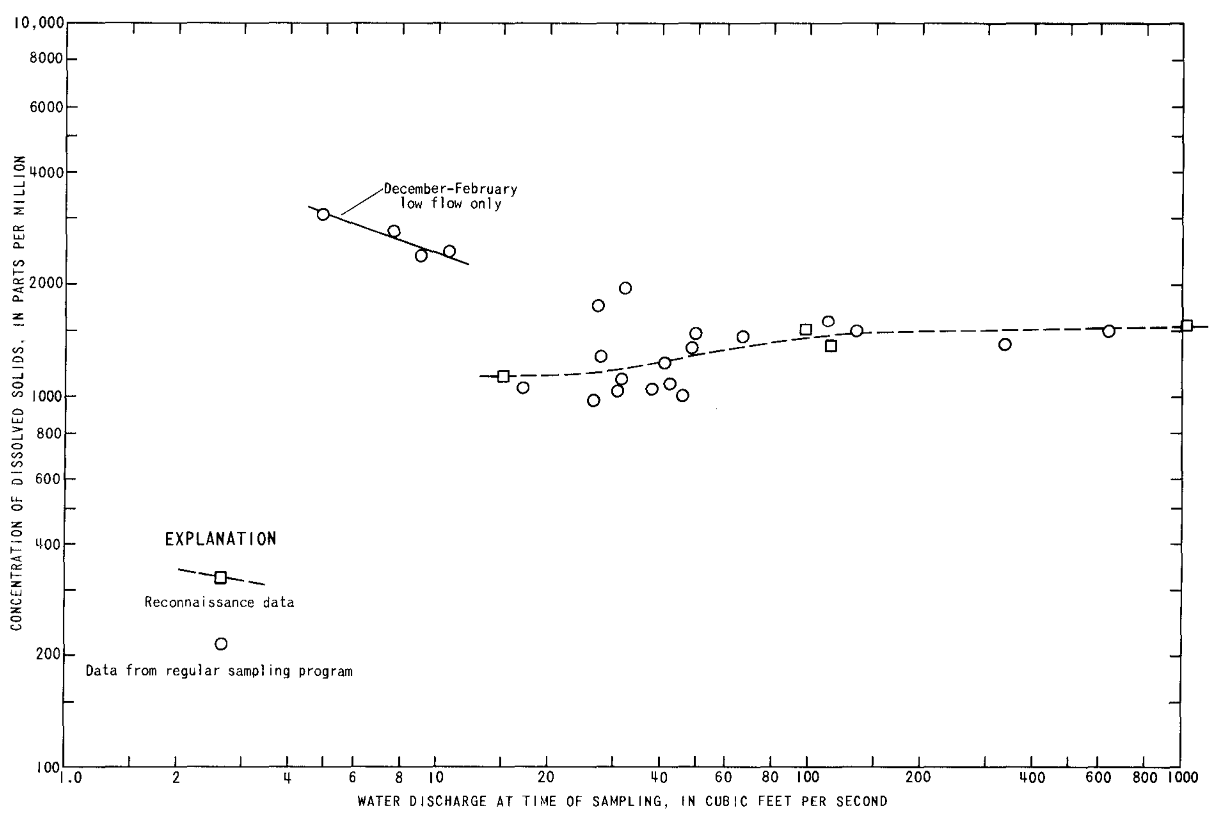


**Figure 14. — Reconnaissance and regularly collected data for the Sevier River near Lynndyl during the 1964 water year.**

Data on the concentrations of dissolved solids and individual constituents collected from the Sevier River near Lynndyl since March 1951 correlate well with water discharge; therefore, chemical characteristics of water in the Sevier River near Lynndyl can be estimated for periods of recorded discharge when little or no chemical data are available.

### Proposed water-quality sampling sites

Adequate monitoring of the variations in the chemical quality of the surface water in the Sevier Lake basin could be achieved by adding the following sites to the data-collection program:

Sevier River near Richfield

Sevier River near Juab

Beaver River below Rockyford Dam, near Minersville

San Pitch River at Gunnison Reservoir outlet, near Sterling

Subsidiary sites could be sampled as water-management studies require. Any attempts to improve chemical quality should include data collection that is sufficient to accurately evaluate the effects of such management. The prospect of importing water to the basin by means of the Central Utah Project makes a prior knowledge of where best to introduce such water of great importance. Changes in water type could be effected by the introduction of such water that would change the value of the introduced water as well as the existing streamflow with regard to its intended use.

## SUSPENDED SEDIMENT

Most of the sediment discharge by streams in arid and semiarid areas is transported during a very short period of time each year. The highest concentrations of suspended sediment and discharges of suspended sediment are characteristic of high-intensity runoff and usually occur as a result of runoff from thunderstorms. Sediment concentration and discharge during snowmelt runoff increase significantly from concentrations and discharges during base flow but are low relative to those during high-intensity runoff from thunderstorms.

In general, concentrations of suspended sediment increase with increasing water discharge, but concentrations of dissolved solids decrease with increasing water discharge. Thus the quality of water, relative to its sediment content, generally is best during periods of low flow; and the quality of water, relative to its chemical content, generally is best during periods of high flow. Further, the range in sediment concentrations generally is much greater than the range in concentrations of dissolved solids; sediment concentrations may range from less than 10 to more than 100,000 ppm during a single day.

The reconnaissance of the Sevier Lake basin was designed primarily to define the chemical quality of water during (1) late winter, (2) peak runoff in the spring, (3) mid-irrigation in the summer, and (4) postirrigation in the early fall. One or more sediment observations were made concurrently with chemical-quality observations at 36 of the 62 sites where chemical-quality data were obtained. Obtaining representative data on the effect of irrigation on the chemical quality of the water required the avoidance of runoff from thunderstorms. Thus the scheduling of data collection resulted in the collection of representative chemical-quality data but resulted in the collection of no sediment data during periods of high sediment concentration and discharge. The sediment data probably give a fair indication of the sediment-transport characteristics of the streams during most of the time each year but give a very poor indication of the total amount of sediment transported by any stream during the year. Of the 119 sediment observations made during the reconnaissance, only one probably represents high-intensity runoff from thunderstorms. Sediment data obtained during the reconnaissance are included in Hahl and Cabell (1965).

The data obtained during the 1964 water year indicate that concentrations of suspended sediment are low for all streams in the basin during most of each year. Between about July 1 and March 1, concentrations probably are less than 500 ppm during at least 80 percent of the time, probably are between 500 and 5,000 ppm during at least 15 percent of the time, and probably are greater than 5,000 ppm less than 5 percent of the time. Although concentrations exceeding 5,000 ppm may occur for only a very small percentage of the time each year, a large part of the total annual sediment discharge may occur during this time.

Between about March 1 and July 1, a large part of the total annual runoff is from snowmelt and results in sustained concentrations of sediment ranging from a few hundred to a few thousand parts per million. During years in which runoff from thunderstorms is low, most of the annual sediment discharge occurs during the period of snowmelt runoff. Data obtained during the reconnaissance are inadequate to show the proportions of annual sediment discharge that result from snowmelt runoff and from thunderstorm runoff.

If data obtained only during July 27-30, 1964, were used as the basis for estimates of sediment discharge during the summer months, these estimates would be much lower than the average sediment discharge that actually occurs during these months. The single observation that may be representative of concentration of suspended sediment and discharge of suspended sediment during thunderstorm runoff was obtained at Sevier River near Circleville on July 28, 1964, and was made on the receding stage of the rise that resulted from a thunderstorm. The observed concentration of suspended sediment was 51,100 ppm at a water discharge of 74 cfs; sediment discharge was at the rate of 10,600 tons per day. During the rising stage, concentrations probably were greater than 100,000 ppm and maximum water discharge was 109 cfs; maximum rate of sediment discharge probably exceeded 25,000 tons per day. The discharge of suspended-sediment during any single runoff event such as this may exceed the discharge of suspended sediment during the entire remainder of the year.

Neither general nor seasonal relations of discharge of suspended sediment or concentration of suspended sediment to water discharge can be established with the few available data. Concentration for any given water discharge on a rising stage usually is much higher than is the concentration at the same water discharge on a falling stage. Also, the concentration for a given water discharge during thunderstorm runoff usually is much higher than is the concentration for the same water discharge during snowmelt runoff. Reliable estimates of annual sediment discharge would require sufficient data to define the relations of sediment discharge to water discharge during rising and falling stages of thunderstorm runoff and snowmelt runoff.

The reconnaissance data were used to make very rough estimates of suspended-sediment yield per square mile of drainage area for a few reconnaissance sites during the 1964 water year. These estimates range from about 5 tons per square mile at East Fork Sevier River near Antimony to about 600 tons per square mile at Chalk Creek near Fillmore. Estimates for three sites on the main stem of the Sevier River ranged from 6 to 12 tons per square mile. These estimates are not reliable as long-term estimates of the average annual yield per square mile but probably approximate the minimum annual yields that would be expected during a long period of time.

Reservoir sedimentation surveys (Subcommittee on Sedimentation, 1965), commonly are an excellent indicator of sediment yield of a drainage area. If the trap efficiency of a reservoir is assumed to be 90 to 100 percent, the quantity of sediment deposited in the reservoir indicates the suspended-sediment yield of the upstream area. The ideal reservoir for the determination of total sediment yield of an area would be one having 100 percent trap efficiency and having no reservoirs, diversions, or other upstream hydraulic structures. Reservoir surveys available for the Sevier Lake basin indicate sediment yields much higher than those estimated from the few reconnaissance data obtained in 1964. Periods between the original survey and a resurvey range in length from 3 to 75 years. The lowest average annual sediment yield was for a reservoir in sec. 33, T. 25 S., R. 1 E., having a drainage area of 5 square miles. According to the survey summary, the reservoir was surveyed in 1865 and was resurveyed in 1940. If a volume weight of 80 pounds per cubic foot is assumed for the measured sediment deposits, the average annual sediment yield of the drainage area was 42 tons per square mile. The highest average annual sediment yield was for a reservoir having a drainage area of 7 square miles and located in sec. 20, T. 35 S., R. 8 W. The reservoir was surveyed in 1926 and was resurveyed in 1940. If a volume weight of 80 pounds per cubic foot is assumed for the deposits, the average annual sediment yield of the drainage area was 5,400 tons per square mile. If the same volume weight is assumed, the average annual sediment yield for the drainage area of Piute Reservoir was about 185 tons per square mile for the period 1910-38, and for the drainage area of Sevier Bridge Reservoir was about 1,000 tons per square mile for the period 1908-32. These data for main stem reservoirs contrast very sharply with the 6 to 12 tons per square mile estimates that result from using reconnaissance data obtained during 1964.

Figure 15 shows the relation of suspended-sediment and of dissolved-solids concentrations to water discharge at two sites. At Sevier River near Circleville, for example, four observations showed concentrations of suspended sediment ranging from 215 to 51,100 ppm at the same time that concentrations of dissolved solids ranged from 214 to 343 ppm. In general, the relation of sediment concentration to water discharge is poor, and the relation of concentration of dissolved solids to water discharge is good to excellent.

In summary, the sediment data obtained as part of the reconnaissance of the Sevier Lake basin give a fair indication of the sediment-discharge characteristics of the streams most of the time, but the data are inadequate to predict the annual suspended-sediment discharges or concentration-duration characteristics of the streams.

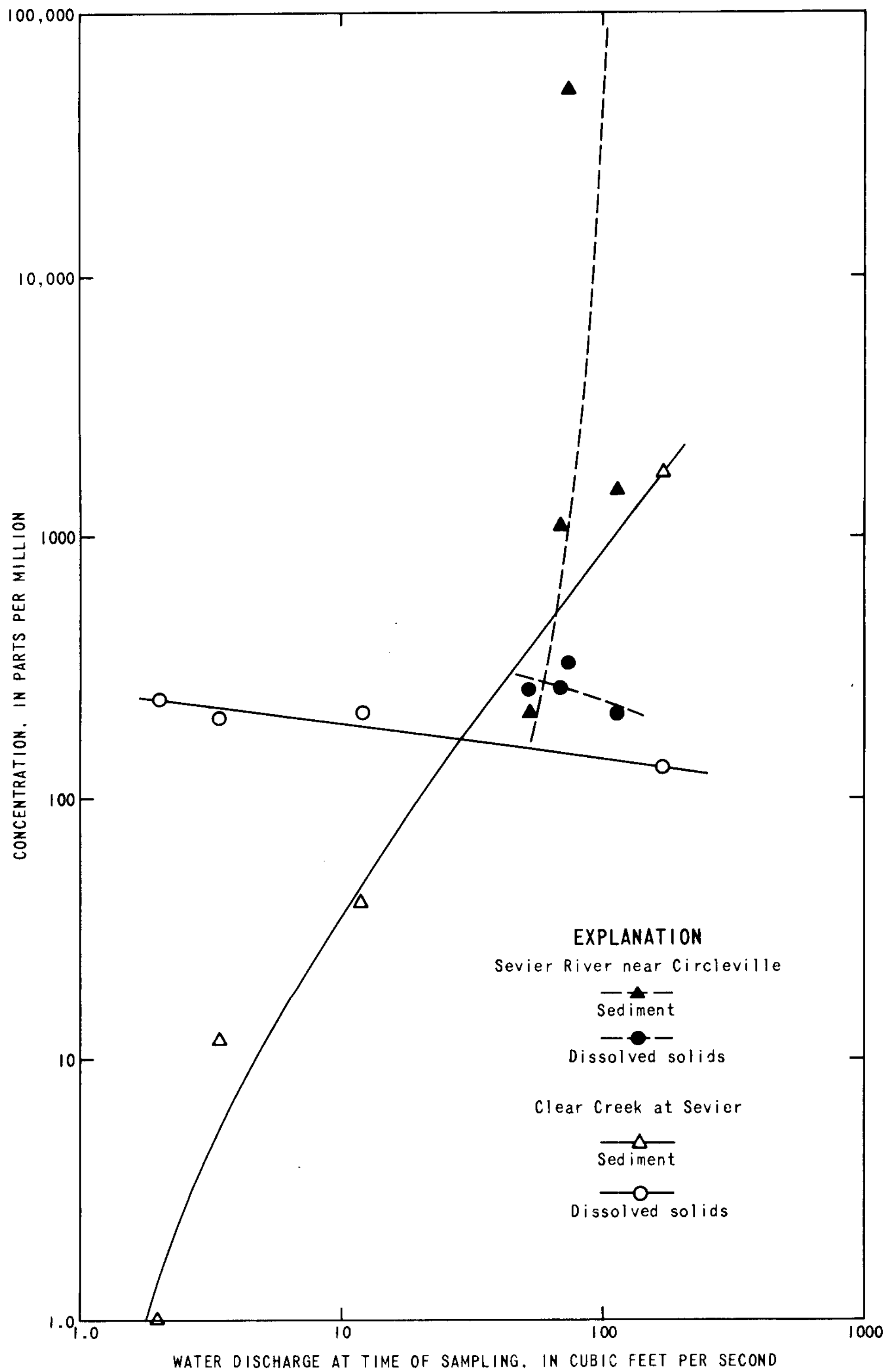


**Figure 15. — Relations of suspended-sediment concentration and dissolved-solids concentration to water discharge at two sites in the Sevier Lake basin during the 1964 water year.**

# CONCLUSIONS

Validity and applicability of the water-quality data collected during the 1964 reconnaissance are indicated by: (1) Correlation between reconnaissance and prior data with respect to water discharge; (2) range in discharge covered by reconnaissance data; (3) effects of inflow and diversions on maximum and minimum concentrations of dissolved solids; and (4) correlation between maximum and minimum concentrations of dissolved solids observed in the rivers of the basin and those observed in ground water.

The concentration of dissolved solids of water increases greatly in a downstream direction in the Sevier and San Pitch Rivers. Adjustment of water-management practices might lead to improved water quality and increased water supply.

Two analyses indicate that the Sevier Valley Canal near Redmond was carrying water of identical chemical character to water which was diverted into the canal near Joseph. Three analyses of water in the Fayette Canal indicate little change in chemical quality between Axtell and Gunnison. The concentration of dissolved solids of the water in the river, on the other hand, had significantly increased in the respective reaches. Water quality might be improved in the central reaches of the Sevier River if the Sevier Valley Canal and other long canals were used as a source of water for irrigation rather than diverting directly from the river. The quality of the water delivered to the lower basin also might be improved if the water entering the Sevier Bridge Reservoir could be conveyed by the Sevier Valley Canal instead of by the river.

The chemical quality of water in the basin could be adequately monitored by continuing the two existing sites and by adding two on the Sevier River and one each on the San Pitch and Beaver Rivers. Other additional sites should be selected for short-term operation to monitor the effects of specific water-management programs on problem reaches of the rivers.

The suspended-sediment data collected as part of the reconnaissance are inadequate to predict either the annual sediment discharge or the concentration-duration characteristics for streams in the basin. Even though these data do not indicate maximum or annual loads, they do give a fair indication of the suspended-sediment discharge characteristics of the streams most of the time and probably represent the minimum annual yield over a long period of time.

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No. 11. Amendments to plan of work and work outline for the Sevier River basin (Sec. 6, P.L. 566), U.S. Department of Agriculture, 1964.

No. 12. Test drilling in the upper Sevier River drainage basin, Garfield and Piute Counties, Utah, by R. D. Feltis and G. B. Robinson, Jr., U.S. Geological Survey, 1963.

No. 13. Water requirements of lower Jordan River, Utah, by Karl Harris, Irrigation Engineer, Agricultural Research Service, Phoenix, Arizona, prepared under informal cooperation approved by Mr. William W. Donnan, Chief, Southwest Branch (Riverside, California), Soil and Water Conservation Research Division, Agricultural Research Service, U.S.D.A., and by Wayne D. Criddle, State Engineer, State of Utah, Salt Lake City, Utah, 1964.

*No. 14. Consumptive use of water by native vegetation and irrigated crops in the Virgin River area of Utah, by Wayne D. Criddle, Jay M. Bagley, R. Keith Higginson, and David W. Hendricks, through cooperation of Utah Agricultural Experiment Station, Agricultural Research Service, Soil and Water Conservation Branch, Western Soil and Water Management Section, Utah Water and Power Board, and Utah State Engineer, Salt Lake City, Utah, 1964.

No. 15. Ground-water conditions and related water-administration problems in Cedar City Valley, Iron County, Utah, February, 1966, by Jack A. Barnett and Francis T. Mayo, Utah State Engineer's Office.

No. 16. Summary of water well drilling activities in Utah, 1960 through 1965, compiled by Utah State Engineer's Office, 1966.

No. 17. Bibliography of U.S. Geological Survey Water Resources Reports for Utah, compiled by Olive A. Keller, U.S. Geological Survey, 1966.

No. 18. The effect of pumping large-discharge wells on the ground-water reservoir in southern Utah Valley, Utah County, Utah, by R. M. Cordova and R. W. Mower, U.S. Geological Survey, 1967.

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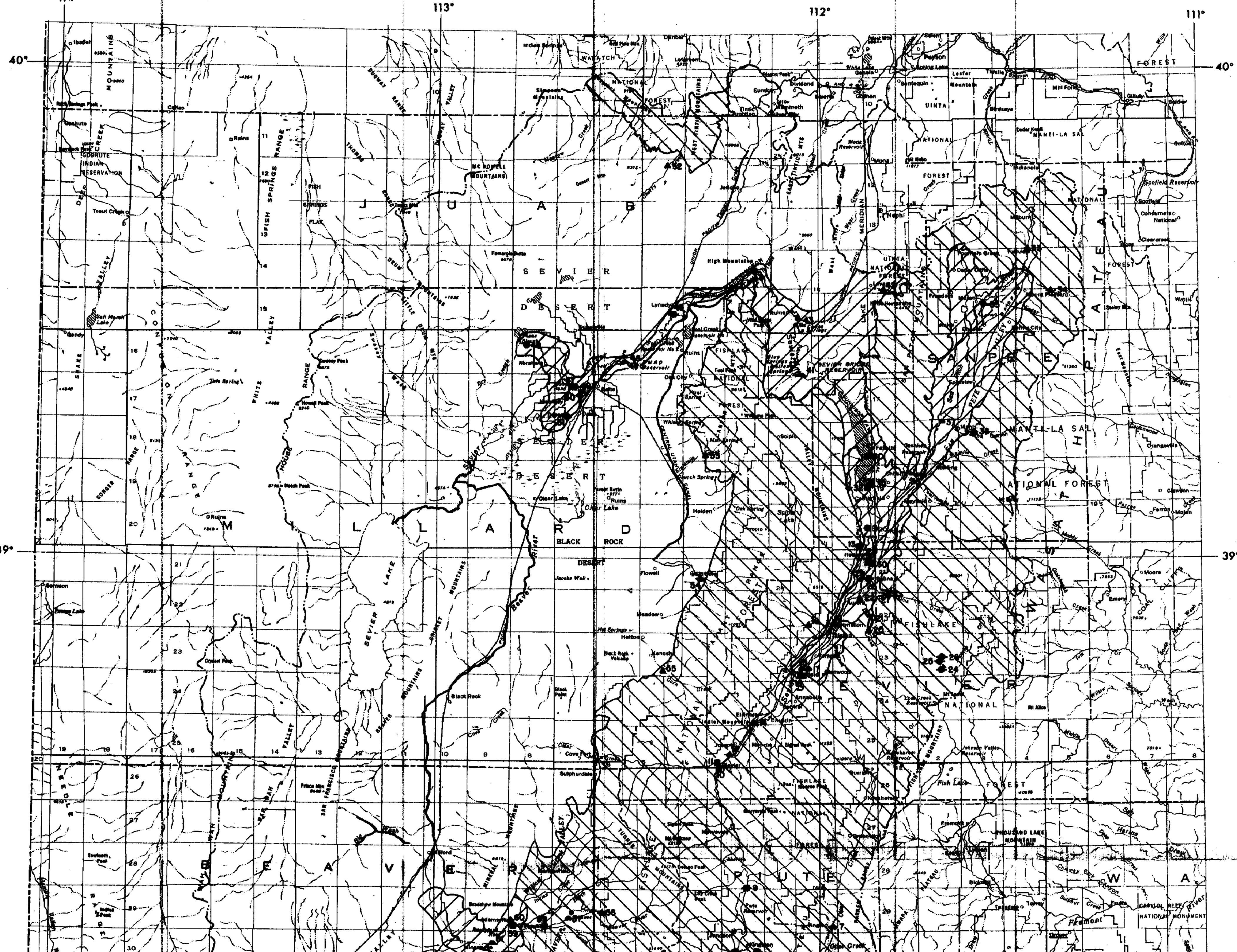


Base from U.S. Geological Survey State Base Map, 1959; scale 1:500,000

10 0 10 20 MILES

Hydrologic data after Hahl and Cabell (1965, pl. 1)

# MAP OF THE SEVIER LAKE BASIN, UTAH, SHOWING SITES FOR WHICH WATER-QUALITY DATA WERE OBTAINED AND AREAS WHERE THE DISSOLVED-SOLIDS CONTENT OF SURFACE FLOW WAS GREATER THAN 500 PARTS PER MILLION AND AREAS WHERE DISSOLVED-SOLIDS CONTENT WAS LESS THAN 500 PARTS PER MILLION DURING THE 1964 WATER YEAR

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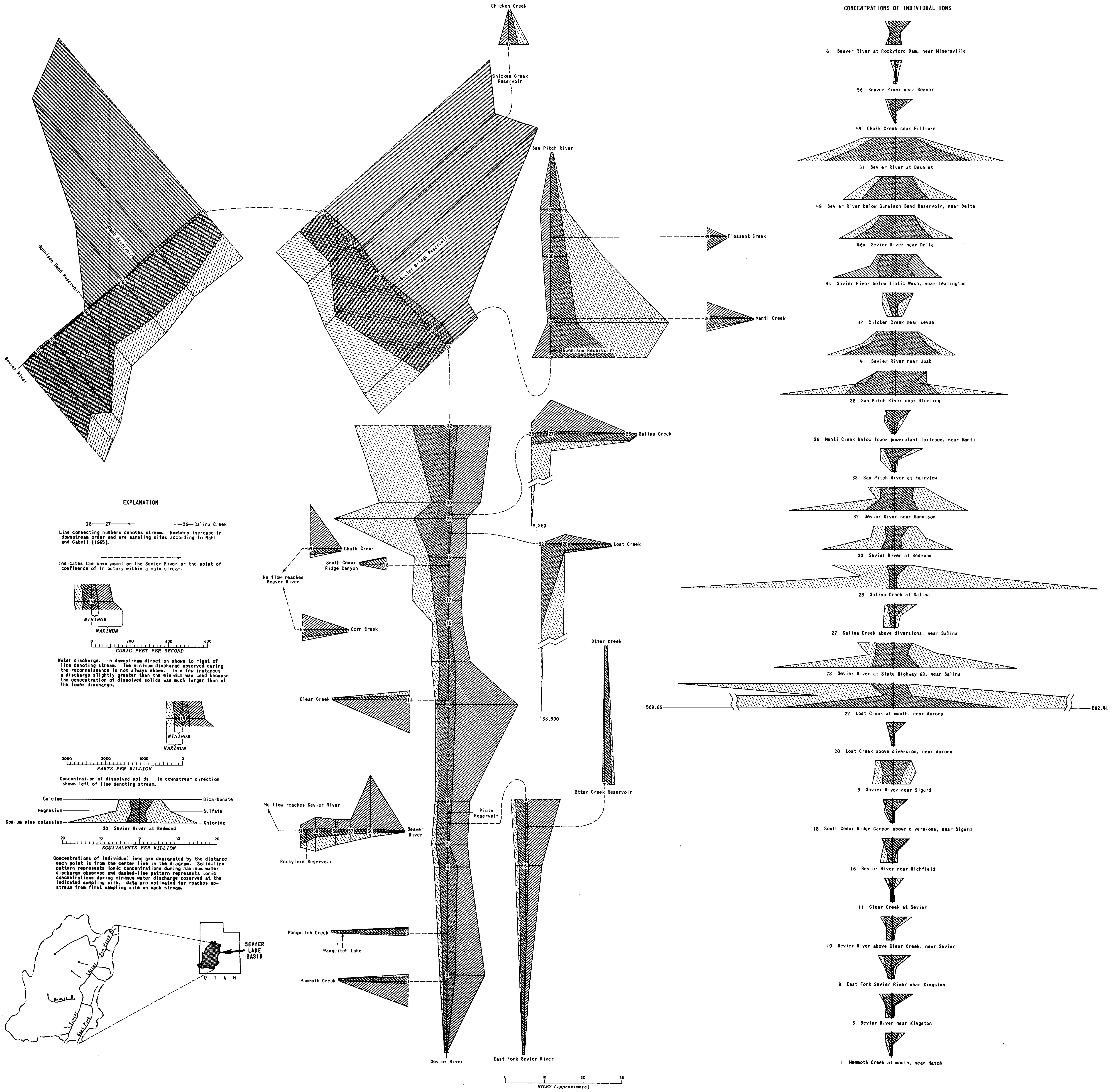


**DIAGRAMS SHOWING EXTREMES IN WATER DISCHARGE AND CORRESPONDING CONCENTRATIONS OF DISSOLVED SOLIDS OBSERVED DURING THE 1964 RECONNAISSANCE IN THE SEVIER LAKE BASIN, UTAH**