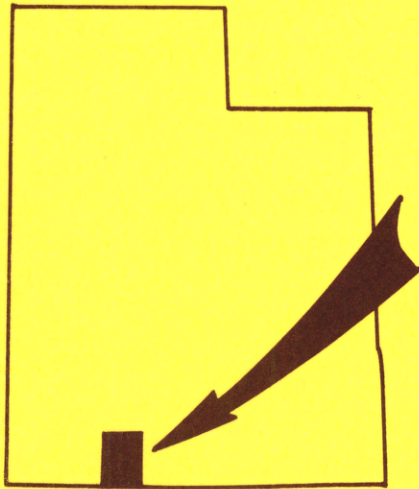
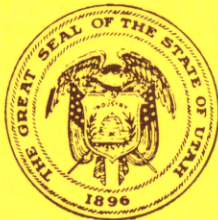


WATER-RESOURCES BULLETIN 5
1964

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY
affiliated with
THE COLLEGE OF MINES AND MINERAL INDUSTRIES
University of Utah, Salt Lake City, Utah



RECONNAISSANCE OF
WATER RESOURCES
OF A PART OF
WESTERN KANE COUNTY,
UTAH



Prepared by
Utah Engineering Experiment Station
University of Utah

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August 1966

Errata sheet for

"Reconnaissance of water resources of a part of
western Kane County, Utah" by Harry D. Goode
Water-Resources Bulletin 5, published
by Utah Geological and Mineralogical Survey,
and Utah Water and Power Board - August 1964

Figure 1, p. 16, Index map - Reference to area covered by
figure 9 should read figure 3.

Figure 5A, p. 23, second line - should read "underlain" instead
of "overlain".

Page 28, first column, 2nd paragraph, line 9 - Insert comma
after Kanab Creek.

Table 3, p. 29, First spring under Upper Kanab Creek should
be (C-38-5) 23 dc instead of 23 cd.

Table 3, p. 30, spring (C-42-6) 9bbd in main canyon of Lower
Kanab Creek - Approximate altitude should be "5360"
instead of "5880".

Table 4, p. 45, M-C & S Corp. wells 3 and 4 were used for
cooling, not PS
M-C & S Corp. wells 1 and 2 were used for PS, not cooling.

Table 5, p. 46, Logs of Nevada Power Co. wells, (C-39-5) 18 bqd
and (C-39-5) 30 bdc, show altitude as 6600+. Altitude
of (C-39-5) 18 bcd is about 6900 and altitude of (C-39-5)
30 bdc is about 6850.

Table 7, p. 49, Second listing of Nevada Power Co. well
#2 should read (C-39-5) instead of (C-30-5).

Figure 3, geologic map, in pocket - Change box for Wasatch
Formation in Explanation to read "Tw" instead of "Tu".

WATER-RESOURCES BULLETIN 5

RECONNAISSANCE OF WATER RESOURCES OF A PART OF WESTERN KANE COUNTY, UTAH

*by Harry D. Goode
Department of Geology
University of Utah*



Upper Kanab Creek about one mile below headwaters spring (Text pages 28 and 41). In background are Pink Cliffs of the Wasatch Formation.

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PLATE 1



Headwaters spring upper Kanab Creek. Spring is flowing about 250 gallons per minute (Text pages 28 and 41).



Headwaters spring upper Kanab Creek with Pink Cliffs in background behind trees.

Lower Kanab Creek where crossed by bridge of US 89 (Text page 35).

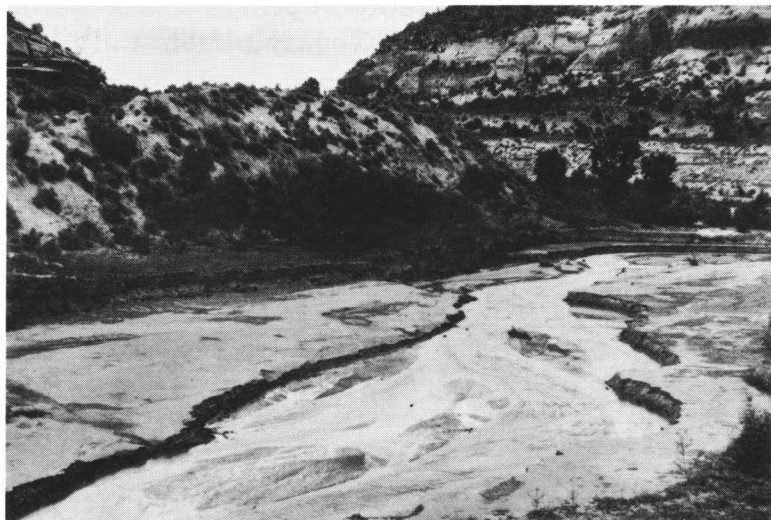
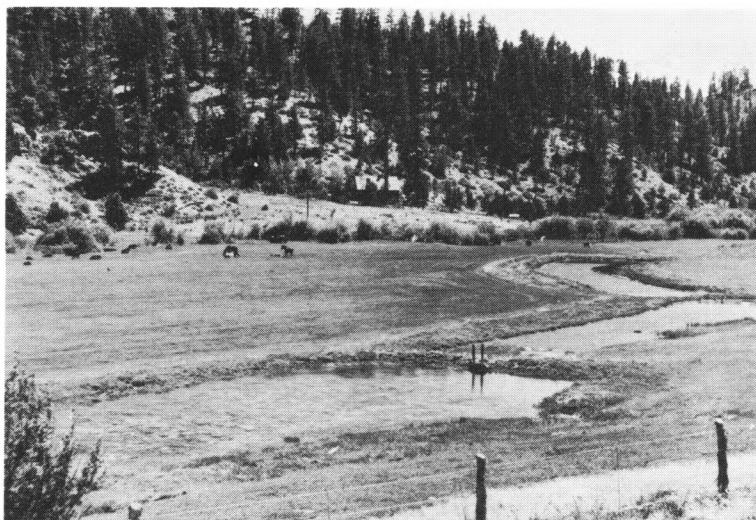


PLATE 2



Headwaters spring
Long Valley Creek,
East Fork of
Virgin River
(Text page 38).
Spring is about one
quarter of a mile
north of junction of
US 89 and U 136.



Springs and ponds
on Major property,
Long Valley Creek,
East Fork of
Virgin River
(Text page 38).
Springs are about three
quarters of a mile south-
west of junction of
US 89 and U 136.



Mound of tufa built
by springs of Hidden
Lake, Long Valley.
Hidden Lake is
behind trees in center
of picture, and tufa
forms flat-topped mound
across center of picture
(Text page 39).

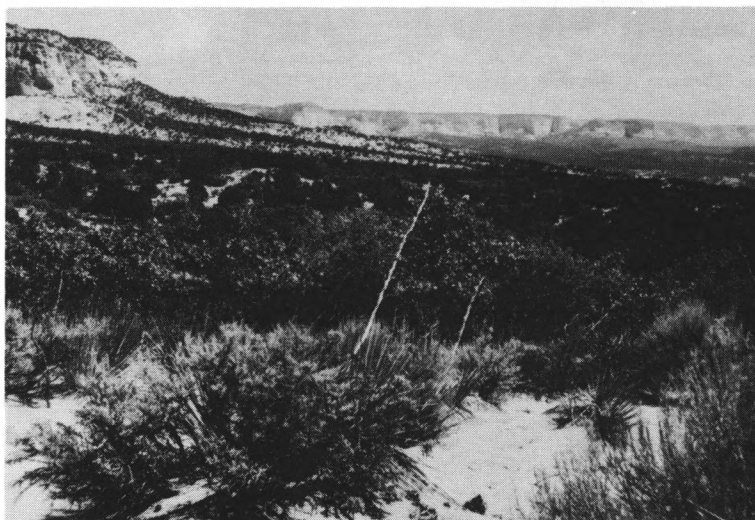
PLATE 3

Parshall flume and
stilling pond at mouth
of Calf Pasture Hollow
(Text pages 15 and 40).



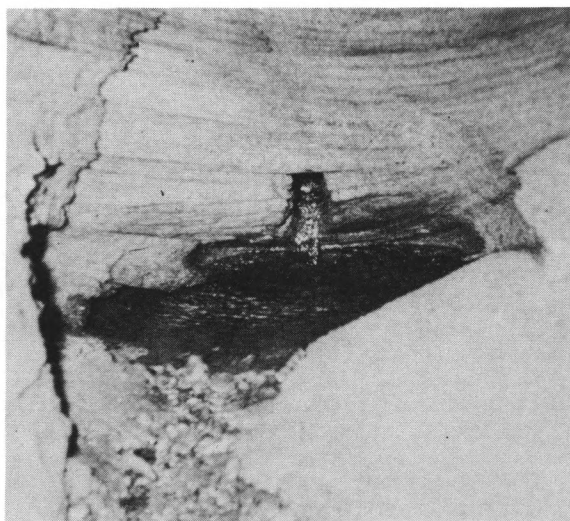
White Cliffs of Navajo
Sandstone capped by
Carmel Formation.
Rolling slope below
cliffs and in fore-
ground is composed
of Navajo Sandstone
and makes up a vast
recharge area for the
upper member of the Navajo

(Table 1 and text
pages 53 and 54).



Main spring of Alton
town supply. Opening at
end of tunnel in sandstone
is about 4 inches wide.
Spring was flowing 4 to
5 gallons per minute
in July, 1963

(Text page 58).



RECONNAISSANCE OF WATER RESOURCES OF A PART OF WESTERN KANE COUNTY, UTAH

*by Harry D. Goode
Department of Geology
University of Utah*

ABSTRACT

This reconnaissance study of the water resources of about 850 square miles of western Kane County in southern Utah was undertaken by the Engineering Experiment Station of the University of Utah to promote development of the coal deposits of southern Utah, which could be used to produce electricity if adequate water supplies are available. More than 100 springs were visited and recorded, 29 samples of spring and well water were chemically analyzed, and the collected and other available data were

evaluated to provide recommendations for developing the water supplies.

The area is underlain by sedimentary and volcanic rocks that range in age from Triassic to Recent; sedimentary rocks are the most abundant and consist principally of sandstone, shale, and limestone. The lithologies and water-bearing properties of the rocks are generalized below:

Principal geologic formations of western Kane County

Age	Formation	Thickness in feet	Lithology	Water-bearing properties
Quaternary	Surficial deposits and lava	A few to 50 feet	Alluvial sand; dunes; basalt flows	Of local significance only--a few springs in basalt
Tertiary	Brian Head and Wasatch	500 to 1,000	White, red, and pink limestone and siltstone	Springs on plateaus and in steep cliffs--50 to 500 gpm
Cretaceous	Kaiparowits, Wahweap, and Straight Cliffs	1,300 to 2,000	Interbedded sandstone, siltstone, and claystone	Springs occur at many contacts where sandstone is above and claystone below--1 to 500 gpm
	Tropic and Dakota	500 to 1,300	Shale and coal over conglomerate	Springs 2 to 20 gpm in Sink Valley
Jurassic	Winsor, Curtis, Entrada	400 to 500	Fine sandstone and gypsum	Probably not water bearing
	Carmel	150 to 200	Limestone and shale	Springs of 1 to 5 gpm of water of rather poor quality
Jurassic and Triassic(?)	Navajo (including Lamb Point Tongue)	1,200 to 2,000 (including 400 to 500 for Lamb Point Tongue)	Massive, cross-bedded, porous sandstone	Both members yield water to springs and wells--a few to 1000 gpm
Triassic(?)	Kayenta (including Tenney Canyon Tongue)	75 to 500 (Tenney Canyon about 100 ft in Johnson Wash)	Mudstone, siltstone, sandstone	Acts as an aquiclude to hold water in overlying Navajo

The rocks of western Kane County dip 1° to 2° to the north or northeast, and the more resistant sandstone and limestone formations have formed vast northeastward-dipping plateaus that are arranged in a staircase structure; the older resistant rocks form steep risers and treads in the southern part of the area and successively younger resistant rocks form risers and treads northward. This simple structure is cut by the northeast-trending Sevier fault zone which is upthrown on the east and has created a zone of weakness which has guided in part the principal south-flowing stream, the East Fork of the Virgin River.

Although 20 to 25 inches of precipitation falls on the Paunsaugunt Plateau and 30 to 40 inches falls on the Markagunt Plateau, both of which drain northward to the Sevier River, most of western Kane County is semiarid and receives 16 inches or less precipitation annually. Thus the only southward-draining streams that maintain perennial flow for appreciable portions of their length receive their

flow during dry periods of the year from ground water, some of which comes from precipitation that falls on the northward-draining plateaus but seeps southward because the water table is drained by springs along the steep southward-facing Pink Cliffs. Upper Kanab Creek, Stout Canyon, Right Fork of Lydias Canyon, and possibly Long Valley Creek receive some water from springs near the Pink Cliffs, but these and other streams, such as lower Kanab Creek, Calf Pasture Hollow, and Johnson Wash, probably receive most of their base flow from springs that are fed by local precipitation.

Among the major springs that supply water to streams and their estimated present yields (including non-beneficial use) and potentials under full development by wells are (figures are in cubic feet per second, cfs, or about 450 gallons per minute):

Spring or area	Flow	Potential
Headwaters - Upper Kanab Creek	1 cfs	2 to 3 cfs
Scattered spring areas - Upper Kanab	2 to 4 cfs	4 to 6 cfs
Rush Hollow springs - Tributary to Upper Kanab	0.3 cfs	0.3 to 0.6 cfs
Aggregate of Sink Valley springs	1 cfs	3 to 4 cfs (possibly 8 to 10 cfs)
Headwaters springs - Lower Kanab	1 cfs	not estimated
Three Lakes Canyon	0.7 to 1.5 cfs	not estimated
Headwaters - Long Valley Creek	1 cfs	2 to 3 cfs
McDonald and Le Vanger Lakes	0.5 cfs	not estimated
Headwaters and adjacent springs - Stout Canyon	2 cfs	4 to 6 cfs
Springs near mouth of Stout Canyon	0.4 cfs	1 to 2 cfs
Four spring areas in Right Fork - Lydias Canyon	1 cfs	2 to 3 cfs
Big Spring in Lydias Canyon	1 cfs	2 to 3 cfs
Hidden Lake	0.6 cfs	not estimated
Springs along Johnson Wash	1 to 2 cfs	3 to 4 cfs

The potentials of springs feeding existing lakes have not been estimated because appreciable development by wells probably would cause the lakes to dry up. Development to the higher potential in any area may result in withdrawals at a rate exceeding natural recharge and therefore water tables will be lowered. So long as this possible effect is recognized in advance by those planning development, it can be considered as part of the cost of development.

Chemical quality of waters from springs and wells in western Kane County may be evaluated on the total dis-

solved solids and hardness reported in analyses of those waters. Recommended limit for total dissolved solids for public or domestic supply is 500 ppm (parts per million), but water containing up to 900 ppm may be acceptable for generation of power. Water with a hardness in the range of 61 to 120 ppm is moderately hard, 121 to 200 is hard, and over 200 is very hard. As will be seen from the following tabulation, all sampled waters were hard to very hard; 18 of the 27 sampled springs had not more than 465 ppm total solids; but all wells except the Kanab City and Clay Flats wells, both in the Navajo Sandstone, yield water containing at least 750 ppm total solids.

(parts per million)		Drainage	Sample Nos. ✓	Formations
Total solids	Hardness			
145-200	124-140	East Fork and lower Kanab	0-4, 7; A-7; Kanab City	Wahweap and Navajo
200-380	165-335	East Fork, upper Kanab, Sevier	A-1, 2, 3, 6; 0-2, 3, 9, 10, 11, 17; S-1; Clay Flats	Wasatch, Kaiparowits, Wahweap, Navajo
415-465	275-380	East Fork, upper Kanab, Sink Valley	A-4, 5, 8; 0-19	Kaiparowits, Tropic
510-565	360-405	East Fork	0-1, 5, 8, 16	Wahweap, Straight Cliffs, Tropic
650-810	525-600	East Fork, Johnson	0-12, 13, 15; No. Orderville, Johnson Canyon	Alluvium, Wahweap, Carmel
900-2700	300-1800	East Fork, upper Kanab, Johnson	0-16, 14, 18; Johnson #1; Nev. Pwr. #1, #2; Mt. Carmel	Alluvium, Straight Cliffs, Winsor(?), Curtis(?), Carmel, Navajo

✓ Springs: 0-4, A-7, S-1 for Order 4, Alton 7, Sevier 1 in Table 6
Wells: By name in Table 6 or 7

This reconnaissance study concludes that the water resources of western Kane County might be developed for industry by 1) removing water that is now in storage in deep sandstone aquifers, such as the two members of the Navajo Sandstone that probably contain more than 5,000,000 acre-feet at depths to as much as 3000 feet in the northern part of the area, 2) developing springs that rise from the Tropic Shale in Sink Valley and from the Cretaceous sandstone in upper Kanab Creek, 3) developing and diverting springs in the Cretaceous sandstones and in the Wasatch Formation in Long Valley or in the tributaries of Long Valley, 4) developing additional wells in Three Lakes Canyon, possibly at the expense of drying up the lakes, or 5) build-

ing dams to store flood- and spring-runoff water. Of these choices, the development of the Navajo Sandstone by deep wells might produce the largest quantities of water but at rather high cost; the developing of springs in Sink Valley or in the vicinity of upper Kanab Creek would probably yield smaller quantities of water but at less cost if existing rights can be satisfied economically; the developing of springs in Long Valley or its tributaries or in Three Lakes Canyon could be costly for power generation because they are distant from the coal supplies in the Tropic Shale and because purchase of existing rights may be expensive; and the building of dams at present seems the least economical way of developing water.

In anticipation that the demand for water in western Kane County will increase and because I recognize that these suggestions about future development of water resources are based principally on single observations because no long-term water records are available, I recommend that there be established a program of data collection to include:

- 1) Periodic measurements (say weekly) of flow of Long Valley, Stout, Lydias Canyon, and Muddy Creeks to supplement the present measurements of diversions on the East Fork of the Virgin River.
- 2) Automatic gaging station on the East Fork about one mile below Mt. Carmel Junction
- 3) Periodic measurements of diversions from upper and lower Kanab Creeks
- 4) Periodic measurements of lower Kanab Creek below diversions
- 5) Periodic measurements of flow of Johnson Wash
- 6) Periodic observations of flood gage at the Elbow on upper Kanab Creek
- 7) Periodic measurements of flow of major springs such as Hidden Lake, Big Spring in Lydias Canyon, headwaters springs in Long Valley, and in upper Kanab and lower Kanab Creeks
- 8) Periodic measurements of water levels in a few wells to form nucleus of a future observation-well network.

Most of the measurements above probably could be undertaken as part of the responsibilities of the irrigation companies or the river commissioner of the East Fork, but the measurements of stream flow of the East Fork and of Kanab Creek and Johnson Wash and the measurements of water levels in wells should be incorporated in the cooperative program between the U.S. Geological Survey and the Utah State Engineer.

INTRODUCTION

Background of the project and purpose and scope

This reconnaissance study of the water resources of a part of Kane County was undertaken by the Engineering Experiment Station of the University of Utah as one of a series of many projects designed to study and promote the mineral resources of the State of Utah.

Kane County and other parts of southwestern Utah have extensive and essentially unexploited deposits of subbituminous and high volatile bituminous coal (Robison, 1963, p. 26-27). One way of exploiting these deposits would be by coal-fired electric-generating plants. Such plants consume water at the rate of 1,500 gpm (gallons per minute) for each 100,000 KW generating unit. In an area where essentially all surface water was appropriated long ago, the right to use 7,000 acre-feet of water a year, the amount a 3-unit plant would require, can be obtained only by acquiring and subsequently transferring existing rights to

such use or by developing unappropriated water that may be in storage underground. To my knowledge no attempt has been made to buy and subsequently to transfer existing rights to large quantities of water in western Kane County, but an attempt to obtain water from underground sources near Alton was made by Nevada Power Company in 1961 to 1963. The power company drilled two holes to depths of about 1400 and 1600 feet but about 1000 or 1500 feet short of the base of the target formation, the Navajo Sandstone, and did not obtain sufficient water at the final depth for the attempt to be considered even moderately successful. The time required and the reported cost of \$200,000 for the drilling caused the power company to turn its effort to other localities for the generation of power.

This very evident dependence of a major industry on a suitable water supply suggested to the University of Utah that a reconnaissance study of the water resources in the vicinity of the coal deposits of western Kane County could be useful in planning future development of coal-fired electric-generating plants or of other industry in that area.

This study, then, was undertaken to make a reconnaissance of the water resources of a part of western Kane County. The investigation resulted in records of more than 100 springs (out of perhaps 5 or 10 times that number within the area), chemical analyses of 29 samples of spring and well water, logs of most of the wells within the area, and many spot measurements of surface water that help in an evaluation of use and disposal of the surface water. In addition, the report contains chemical analyses of samples of well water collected and analyzed by Nevada Power Company; chemical analyses, well logs, and yield data supplied by Merritt-Chapman and Scott Corporation for their wells near Glen Canyon Dam; and a driller's log and yield data supplied by the National Park Service for a well in the Glen Canyon Recreation Area.

By-products of the investigation were short studies of the public water supplies of Alton, Orderville, and Mt. Carmel. One unsuccessful attempt was made to visit the Glendale water supply, and the only work done on the Kanab supply was study of the logs of its wells.

As with many reconnaissance investigations, the conclusions reached were based on the few records enumerated above and on on-the-spot evaluations. No long-term and exceedingly few short-term or spot-measurement records were available to aid in the study. Irrigation has been practiced since the earliest settlers reached the area almost 100 years ago, yet no records of water diversions were available in the Kanab area, only a few spot measurements in the Alton area, and only records since 1961--when a river commissioner was appointed--in the Glendale-Orderville-Mt. Carmel area. Without the necessary long-term records, the conclusions reached here are founded on shaky ground, for they must be based on much speculation garnished by a few facts. Yet development does not wait on ungathered information--we must make some evaluation and proceed from there. If the evaluation presented here is substantiated as further facts are accumulated, its worth will be proved; if some of its conclusions must be modified after more data are collected, the evaluation will at least have provided a base for the necessary modifications.

Acknowledgments

I am indebted to many individuals and to officials in the communities of Kane County, without whose wholehearted help and active cooperation this work would have been much less complete.

In Alton, Bishop Gail Heaton and Mrs. Heaton extended the hospitality of their home and aided greatly with their personal knowledge of the local people and of the area; Mr. Allen Cox arranged a visit to the Alton springs and explained the water system that serves Alton; Mayor Bruce Hoyt arranged the first trip in the Alton area and helped with geographic names; and Mr. Lloyd Heaton described the Alton irrigation system and obtained a few measurements of ditch water. These people and other land owners, notably Mr. Preston Swapp and Mr. Cecil Pugh, permitted free access to their lands for appraisal of the water supplies and gave freely of their knowledge of the occurrence of water.

In the Orderville-Glendale area, Mr. W. R. Heaton, Assessor for Kane County, provided much information and arranged for several meetings with local water users; Mr. Charles Hepworth, River Commissioner for the East Fork of the Virgin River, made available numerous records and showed me the full irrigation system between the headwaters of Long Valley Creek and Mt. Carmel; Mr. Henry Carroll spent two long half days escorting me to many large and small springs on his extensive properties; Mr. Lyle Chamberlain allowed access to Hidden Lake and pointed out other springs on his property; Mr. Cornell Chamberlain showed me several springs in Lydias Canyon and carefully explained the development of areas where the only surface indication of water was vegetation; Mr. Orson Young provided information and help with visits to the springs that provide the Orderville public supply; and Mr. Earl Sorensen not only gave information about springs in Sink Valley but helped immeasurably when I was unfortunate enough to get stuck off the highway in a borrowed jeep.

The information on the wells in the Glen Canyon area was made available by Messrs. Don Dewar and Phil Smith of Merritt-Chapman and Scott Corp. and by Mr. James Eden of the National Park Service. The information on the Mt. Carmel water system was supplied by Mr. Tharon Salter.

Others whose interest and encouragement helped the project were Mr. Merrill McDonald, Chairman, Kane County Commission; Mr. Hans Chamberlain, member, Kane County Commission; and Mr. Neldon Robinson, rancher, of Kanab. Of special help was Mr. Dwain Haacke, Unit Conservationist, Soil Conservation Service, Kanab. Mr. Haacke generously made available aerial photographs of the Alton area and his files on the Elbow dam site.

The Utah State Engineer made available records of wells and provided a current meter for measuring stream flow, and the U.S. Geological Survey made available some records of flood flows.

I am also indebted to Mr. James Zornes and Mr. William Smirl of Nevada Power Company who provided information on the wells drilled by the power company and analyses of water samples collected and analyzed by them.

The chemical analyses of water samples collected during the field work were done by Mr. M. Elmer Christensen, State Chemist; and the typing of the manuscript in its final form was done by Mrs. Alice Aikens. Mrs. Abby Eldredge, of the Water and Power Board, drafted some of the illustrations. Mr. Creighton Gilbert, of the U. S. Department of Agriculture Sevier River Basin Field Party in Richfield, provided ideas on the southward diversion of water by springs, and Mr. Harold Brown, of the same office, supplied some streamflow data.

Finally, I am indebted to Dr. Wm. Lee Stokes, Head of the Department of Geology of the University of Utah, who first suggested a study of the water problems in western Kane County, and to Dr. Ray E. Marsell, of the Utah Water and Power Board, who reviewed the manuscript. Doctor Marsell provided many valuable suggestions that helped to remove errors and to fill some gaps. Errors that remain are mine.

Location, method of investigation, and plan of the report

The area studied is in western Kane County in southern Utah (fig. 1). The area shown on figure 3 is about 850 square miles and includes Ranges 4 1/2, 5, 6, and 7 West and about two-thirds of Range 8 West, from the northern boundary of Kane County to the Arizona border, a north-south distance of about 35 miles. The greater part of the time of this investigation was spent in the headwaters area of the East Fork of the Virgin River and in upper Kanab Creek, an area of perhaps 200 square miles, and a smaller part was spent in traverses along lower Kanab Creek, Johnson Wash, and the Markagunt Plateau.

It was noted in the acknowledgments that I am indebted to many people for help with this work, for without their help much information now presented here would be lacking. Yet most of the investigation involved visiting the individual springs, recording them, and measuring and sampling some of them. The field work was done between July 3 and August 31, 1963, when I visited the areas by truck, on horseback, or on foot.

The yields of some springs, ditches, and small streams were measured by bucket and stopwatch, by a 90° V-notch weir, or by a 3-inch Parshall flume. Standard tables were used to determine flow through the weir and flume. The flow of larger streams was measured by a type-A current meter that had been calibrated by the U.S. Bureau of Standards. The yields of many springs, especially the spring areas that resulted in flooded meadows, were not readily measured so their flow was estimated. Yields of single, free-flowing springs and some seeps were estimated visually and may be in error by 50 to 100 percent; yields of large flooded-meadow areas were estimated by adding to the estimated or measured downstream yield of these areas a factor based on the evapotranspiration from the flooded areas. Bagley (1963, fig. 3) indicates that the potential evapotranspiration rate in the belt in which most flooded meadows occur is 21 to 24 inches. This evapotranspiration rate presumably was based on a growing season of 7 to 8 months, or about two-thirds of a year. A spring capable of maintaining wet meadows during summer would be flowing at a rate in excess of evapotranspiration and

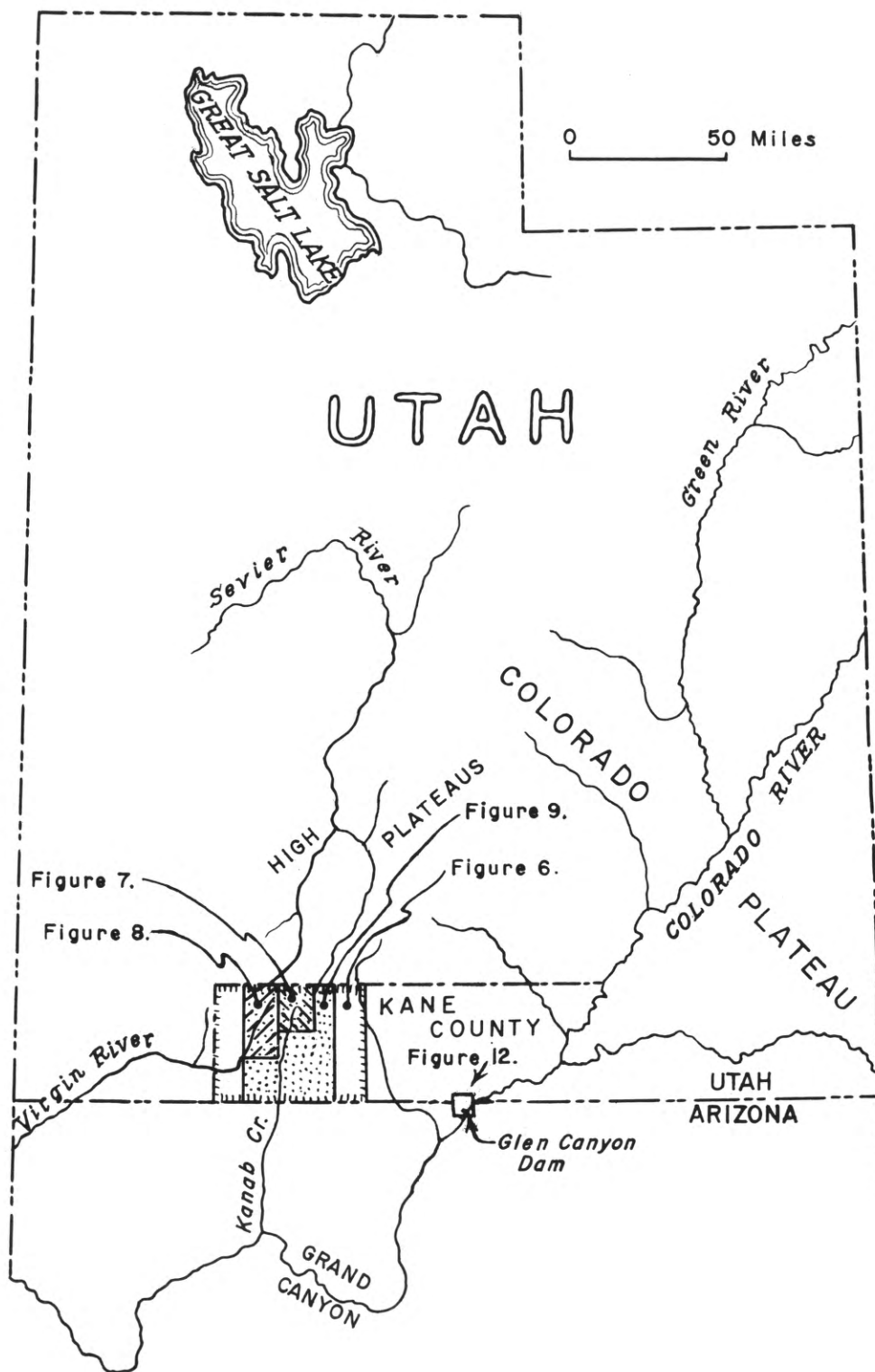


Figure 1.—Index map of Utah and northern Arizona showing areas covered by other figures in this report.

would flow or tend to flow 12 months a year. Therefore, in order to equate an evapotranspiration rate of about 2 feet for 8 months to spring flow for 12 months, a factor of 3 acre-feet per acre was used. Areas of flooded meadows were measured on aerial photographs, multiplied by 3 to obtain evapotranspiration, and this result was added to any estimated or measured downstream flow to obtain total yield. This method resulted in estimates that give a reasonable base for comparing yields.

The estimates of potential of spring areas after development by wells are essentially considered guesses that were arrived at by evaluating not only total yield but also the distribution of orifices and whether the spring areas were gravity or artesian (see figure 5). Some spring areas, such as those at the head of Rush Hollow, consisted of many small gravity springs yielding 2 to 5 gpm, and development probably would have to be concentrated in a few of the most favorable areas, so that the total development might not be able to double the present yield; other spring areas appeared to have much greater potential than indicated by present yields—for example, the springs in Sink Valley represent the overflowing of a near-surface artesian aquifer that may be more extensive and have greater potential than can be guessed from the present yields of the springs in the valley. All estimates of potential yields were based on the presumed ability of wells to withdraw water from the particular locations, and no consideration was given to keeping the estimates of potential yield within limits that might be imposed by annual recharge; thus withdrawal of water at the rate indicated by the maximum potential yield may result in appreciable lowering of water tables in the areas developed. Such lowering of water tables is not necessarily a bad result from development by wells but rather may be looked upon as one of the costs of development, something that must be considered at the time development is planned.

The locations of springs and seeps were plotted in the field on aerial photographs and were later transferred to the available topographic maps or, for the area around Alton, to the sketch map I prepared from aerial photographs.

Geologic field work consisted only of attempting to identify the formation from which a spring was issuing. Most springs were so obscured by tufa deposits, by moss or other vegetative growths, or by surficial deposits that the underlying bedrock could be determined only approximately. The geologic map (Hintze 1963) from which most of the geologic map that accompanies this report was prepared, did not become available until field work on this project was completed.

Water samples for chemical analysis were collected in polyethylene bottles that were thoroughly rinsed in the water sampled. The samples were analyzed by the Utah State Chemist, of the State Department of Agriculture.

Because this investigation could be no more than a reconnaissance, many areas were skipped completely, yet others, such as Calf Pasture Hollow, were probably given more attention than their low yields might warrant. The treatment of the areas, therefore, tends to be spotty, and in no way can the investigation pretend to be comprehensive. Despite these deficiencies, I believe that a fair,

though certainly not quantitative, appraisal of the water supply is presented.

Because of the extremely close relationship between surface water and ground water, the material presented here follows the plan used by the Burton Decree (1925) in its allocation of water rights. The principal streams and tributaries are discussed in downstream order. Treated first is Kanab Creek, which for hydrologic consideration is divided into upper and lower parts, and then the discussion covers the East Fork of the Virgin River from its headwaters as Long Valley Creek to below Mt. Carmel Junction where it enters Parunuweap Canyon. Also included are summary discussions of the proposed reservoir sites at the Elbow on Kanab Creek and at Dry Wash above Glendale.

Numbering system used to identify springs and wells in Utah

The numbers used in this report to identify springs and wells in Utah indicate the spring or well location by land subdivision according to a coordinate numbering system that was devised cooperatively by the Utah State Engineer and G. H. Taylor of the U.S. Geological Survey about 1935. The system is illustrated in figure 2. The coordinate number used to designate location of a well or spring comprises letters and numbers that designate consecutively the quadrant and township (shown together in parentheses by a capital letter designating the quadrant in relation to the base point of the Salt Lake Base and meridian, and numbers designating the township and range); the number of the section; the quarter section (designated by a letter); the quarter of the quarter section; the quarter of the quarter-quarter section; and, finally, the particular spring or well within the 10-acre tract (designated by a number). By this system the letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quadrants of the standard base and meridian system of the General Land Office, and the letters a, b, c, and d designate, respectively, the northeast, northwest, southwest, and southeast quarters of the section, of the quarter section, and of the quarter-quarter section. This coordinate number can be used to identify either wells or springs because it designates location, and the usage of the number in the text or table will show whether the number refers to a well or spring. Thus, the expression, well (B-2-2)12dcd-2, refers to well 2 in the SE1/4SW1/4SE1/4, sec. 12, T. 2 N., R. 2 W., the letter B showing that the township is north of the Salt Lake Base Line and the range is west of the Salt Lake Meridian; and, similarly, the expression spring (D-3-2)34bca-1, refers to spring 1 in the NE1/4SW1/4NW1/4 sec. 34, T. 3 S, R. 2 E.

Geology and physiography

The area studied is a dissected canyonlands area of the Colorado Plateau, and lies at and south of the southern margin of the High Plateaus of Utah and north of the Grand Canyon in Arizona (fig. 1). Its rocks, principally sandstone, shale, and limestone, range in age from Triassic to Recent. The formations of the area with their lithologic characteristics and waterbearing properties are given in table 1, and a geologic map of the area is on figure 3.

Figure 2.—Numbering system used to designate springs and wells in Utah

Table 1.—Generalized description and water-bearing properties of rocks in a part of western Kane County, Utah.

Sources: Gregory, 1945, 1950, and 1951; Cashion, 1961; Detterman, 1956a and 1956b; Detterman and Hackman, 1957; Hackman, 1957; Marine, 1963; Pomeroy, 1958; and Wilson, 1958

System	Series	Formation	Map symbol Fig. 3	Thickness (feet)	Description	Distribution	Water-bearing properties
QUATERNARY	Recent	Alluvium, colluvium, and wind-blown deposits	Qal	0 to 30	Alluvium of coarse and fine materials from the many varied kinds of bedrock, colluvium of the same kind, and wind-blown deposits principally of silt and sand. Particularly distinctive are the "cascade deposits" in valleys below eroding pink cliffs. These deposits are dominated by vari-colored fragments from the Wasatch Fm. Generally these are angular, fresh, and are markedly sized from huge boulders near the outcrop to pebbles a mile or so farther downstream.	Alluvium, generally deeply dissected, fills major valleys and some tributaries probably to 50 ft thick; colluvium of resistant rocks commonly covers slopes formed on less resistant rocks such as shales; wind-blown deposits cover many terraces and benches. Include some pediment deposits south of Orderville.	Alluvium has been penetrated by few wells but coarse alluvium in major valleys should yield water for moderate irrigation - say to 1 cfs. The yields of wells in alluvium would probably be supported by upstream irrigation. Colluvium and windblown deposits are nowhere thick enough to yield appreciable water but they should absorb water for recharging underlying aquifers.
	Pleistocene(?) and Recent	Spring deposits; calcareous tufa	Qsd	0 to 50	Spongy, porous, generally iron-stained tufa deposited and being deposited by springs	Principal deposit occurs at Hidden Lake on US 89 two miles north of Glendale. Also occurs at many other existing and now dry springs throughout area	
	Pleistocene and Recent(?)	Basic intrusive and extrusive rocks	Qb		Flows, craters, and (near Alton) a dike of basic igneous rock	Partly fill some canyons, form terraces and peaks	A few springs from the basalt are reported on Spencer Bench, and the basalt on Black Mountain may supply some water to the only one of the Flax Lakes that contained water in July, 1963.
	Pleistocene(?)	Alluvial conglomerate	Qac	20 to 50	Rounded fragments of sandstone, pink limestone, chert, and volcanic rock from pebble to large boulder size in matrix of medium- to fine-grained sandstone	Patches on or near walls of present canyons. Overlies Cretaceous, Jurassic, and Triassic rocks and is overlain by basalt flows	Iron stains near base suggest unit was water bearing in past but present exposures are not known to yield water.
TERTIARY	Miocene(?)	Brian Head Formation (Wasatch "white beds" of Gregory, 1951)	Tw	0 to 300	White limestone and sandstone with gray conglomerate and volcanic sediments	Exposed only in the northern part of the area where it overlies exposures of the Wasatch Formation	On the Markagunt Plateau and in the upper reaches of Long Valley Creek limestones of this formation yield water to springs and seeps.
	UNCONFORMITY						
	Eocene	Wasatch Formation (Pink Cliffs)	Tw	500 to 800 (0 to 800; Gregory, 1951 p.45)	Consists principally of pink, red, and white limestones with interbedded sandstone and siltstone and generally with one or more conglomerate beds at or near the base. The conglomerate consists of rounded pebbles of chert, sandstone, quartz, limestone, and petrified wood in a matrix of coarse- to medium-grained, grayish-brown sandstone. The weathering of the limestone beds into vertical "turrets" makes the information especially distinctive.	Generally occupies the edges of plateaus where its Pink Cliffs can be recognized for great distances. The formation is characterized by intricate systems of vertical joints that control both external weathering and presumed internal vertical solution channels	Yields water to seeps and springs in headwaters of East Fork of the Virgin River and probably is a reservoir rock that yields its water through vertical joints to underlying formations which in turn yield water to springs. Yields of 50 gpm to 1 cfs are common from the springs in upper Long Valley.
	UNCONFORMITY						
CRETACEOUS	Upper Cretaceous	Kaiparowits Formation	Kk	650 to 750	Greenish-gray to dark-gray sandstone and siltstone with gray claystone. Has a few thin shelf-like benches but is generally a slope former. Sparse limestone beds and conglomerate beds occur near the base. Conglomerate of round, subangular and angular pebbles to 2 inches in diameter of quartz, variegated quartzite, black chert, and sandstone partly covers erosion surface in underlying Wahweap	Forms slopes under the Wasatch Pink Cliffs. Hard sandstone cemented by iron oxide forms benches 2 to 5 ft thick	Yields water to springs in many localities below Pink Cliffs and in other localities where overlying Wasatch has been eroded. In gross aspect - the repetition of thin to thick sandstone beds separated by shale or clay beds - these 3 formations are so similar that identification of a particular unit, unless it is near the top or base of the sequence, is extremely difficult. In these 3 formations the common occurrence of water as springs or seeps is at the contact between overlying sandstone and underlying shale or clay. The sandstone permits passage of water through joints or through interstitial openings, the shale becomes saturated and rejects additional water which comes to the surface. Springs with yields of 1 to 5 gpm are common throughout the sequence, and in Hidden Lake and Lydias Canyon there are springs that yield about 1 cfs each.
	UNCONFORMITY						
		Wahweap Sandstone	Kw		Sandstone and sandy shale in massive, uniform lensatic beds a few to a few tens of feet thick. Prominent are massive cross-bedded cream to buff colored sandstone beds 10 to 20 ft thick of fairly well rounded grains of quartz	Forms cliffs that are generally not so continuous as the cliffs formed by underlying Straight Cliffs	
		Straight Cliffs Sandstone	Ksc	700 to 1250	Principally sandstone beds more than 10 ft thick; thinner sandstones 35%; calcareous, argillaceous, and carbonaceous shale 5%. Mostly medium-grained sandstone of clear quartz cemented by lime and iron, and with many conglomerate lenses 1 to 6 ft thick. Pebbles are subangular to angular quartz, quartzite, and chert with iron concretions. Shale lenses are vari-colored and 3 to 20 ft thick. Contains highly fossiliferous beds 4 to 6 ft thick	Prominent cliff former in the vicinity of Orderville and westward	
		Tropic Shale		500 to 1250	Principally dark-gray shale with thin sandstone beds and with important coal beds in the lower 200 to 400 ft of the sequence	Slope-forming beds make up the floors of upper Kanab Creek and Sink Valley and form low hills west of Mt. Carmel	The Tropic yields 2 to 20 gpm to springs in Sink Valley, but is not known to yield appreciable water elsewhere. The water in Sink Valley may be coming from underlying formations through an unconfirmed fault or fold.
			Kdt				
	UNCONFORMITY						
JURASSIC	Upper Jurassic	Winsor Formation	Jw	180 to 300	White and red banded sandstone and very subordinate conglomerate. Beds less than 2 ft thick, predominantly of subangular to angular quartz sand less than 1/4 mm in diameter	Occurs in the valleys of Meadow Creek and Muddy Creek in western part of area, and probably crops out north of the Elbow	Not known to be water bearing.
	Upper Jurassic	Curtis Formation	Ju	40 to 60	Massive gypsum bed 15 to 30 ft thick overlain by fossiliferous limestone conglomerate	In valleys of Muddy Creek and Meadow Creek and probably north of the Elbow	Not known to be water bearing.
	Upper Jurassic	Entrada Sandstone		160 to 240	Friable evenly bedded variegated sandstone impregnated with gypsum	Occurs on the Glendale Bench and in Muddy Creek where it has eroded to loose sand	If this formation bears water, its gypsum content should impair the quality. This formation erodes so readily that it has covered areas such as the Glendale Bench with loose sand. This sand should be a good recharging medium for underlying formations.
	Middle and Upper Jurassic	Carmel Formation	Jc	150 to 200	Thin regular beds of marine limestone and shale or siltstone. Limestone thickens westward. Limestone and siltstone beds are characteristically ripple marked	Caps the white cliffs of the Navajo Sandstone west of Johnson Wash and forms rim rock of the Glendale Bench	Springs and seeps from jointed and fractured limestone yield 1 to 5 gpm in canyons cut into Glendale Bench. Provides the base flow of the uppermost part of lower Kanab Creek. (Water generally does not flow over the limestone between upper and lower Kanab Creek, but seeps for some distance below the limestone provide base flow below the limestone.)
	UNCONFORMITY						
TRIASSIC(?) AND JURASSIC	Upper Triassic(?) and Jurassic	Navajo Sandstone, upper massive member	Jtn	1200 to 1500	Massive, cross-bedded, white, red, or brown sandstone. Forms massive cliffs that are in places broken into blocks by vertical joints. Is divided by the Tenney Canyon Tongue of the Kayenta Formation into a thick upper member and a thinner lower member, the Lamb Point Tongue. Both members consist of well-rounded quartz sand cemented lightly to firmly by lime and iron oxides. Interstitial pore space is reported to be 12 to 20 percent of volume	Forms the White Cliffs that are prominent in central part of the area. On west side of the Glendale Bench the Navajo forms the Elkheart Cliffs	The lower part of the upper member and the Lamb Point Tongue yield water to springs and seeps in Three Lakes Canyon, in lower Kanab Creek, in Johnson Wash, and in many other places outside the area. Supplies water to wells used by Kanab City. Probably is the best potential aquifer and may be expected to give highest yields to wells in areas where it is well jointed. In this region it has been tested only by shallow wells in its area of outcrop.
		Navajo Sandstone, Lamb Point Tongue	Tnl	400 to 500			
TRIASSIC	Upper Triassic(?)	Kayenta Formation, Tenney Canyon Tongue	Tkt	0 to 300 (is about 100 ft thick in Johnson Wash)	Sandstone, mudstone, and siltstone with subordinate limestone and conglomerate. Generally well cemented by calcite and iron oxide. Is divided into a lower principal member and an upper member, the Tenney Canyon Tongue, which separates the two members of the Navajo Sandstone	Crops out in lower Kanab Creek and in Johnson Wash. Probably underlies whole area north of Vermilion Cliffs	Is only slightly permeable and acts effectively as a barrier to movement of water. Springs and seeps in overlying Navajo yield their water at contact with the Tenney Canyon Tongue or with the main member of the Kayenta.
		Kayenta Formation lower member	Tk	75 to 200			
	Middle(?) and Upper Triassic(?)	Undifferentiated older rocks	Tu				

In general the rocks dip 1° to 2° to the north or northeast except where the great northward- and northeastward-trending Sevier fault has broken and tilted blocks adjacent to it (fig. 3). Lateral erosion by streams has stripped the softer of the dipping rocks and has left extensive step-like platforms of resistant rock bordered at their southern margins by steep cliffs. In many places, swift southward-flowing main streams and their lesser lateral tributaries have dissected even the resistant rocks and have formed canyons several hundred to more than a thousand feet deep.

Lateral erosion by the southward-flowing streams that head below the Pink Cliffs of the Paunsaugunt Plateau has carved huge parklike areas that early geologists called "amphitheaters" (Gregory, 1951, p. 87), of which the Alton Amphitheater is the principal example in the area of study. Many tributaries that head in the Pink Cliffs of the Paunsaugunt and Markagunt Plateaus begin in small amphitheaterlike alcoves gouged a few hundred feet deep and wide to expose sheer walls of the Pink Cliffs. Gregory (1951, p. 103) attributes these alcoves to "the snow and rain that fall directly into the canyon and the frost and atmospheric acids. The transporting agents are intermittent and ephemeral streams of short length." Some of these alcoves, such as those at the heads of Water and Rush Hollows in the upper Kanab drainage (fig. 7), are the sites of rather large spring areas which may have helped in forming the alcoves by ground-water sapping.

Superposed on this simple but well-dissected staircase structure of northeastward-dipping rocks is the great Sevier fault zone that runs diagonally northeastward across the area and which in part has guided the erosion by the East Fork of the Virgin River. Displacement on this fault ranges from 100 to about 2000 feet (Gregory, 1950, p. 144) with the west side down. Throughout most of its length the fault is marked by a prominent escarpment such as the Elkhart Cliffs east of Mt. Carmel. In most places the scarp is a true fault scarp but eroded backward to a greater or lesser degree from the fault itself. However, north of Alton rapid headward erosion by tributaries of Kanab Creek has removed much of the Cretaceous rock on the up-thrown side of the fault, and the pink rocks of the Wasatch Formation have been left at a high elevation on the down-thrown side of the fault so that they form an obsequent fault-line scarp several hundred feet high. Although Gregory correctly illustrated this fault-line scarp along the Sevier fault (Gregory, 1951, fig. 81-b, p. 145), he did not mention the scarp reversal and he did not call the feature a fault-line scarp.

In a few places within the area and in many places nearby, the dipping sedimentary rocks are covered by volcanic rocks, principally basalt. This basalt is younger than the principal fault movements for it is not cut by them, and it is younger than the principal canyon cutting for it fills or partly fills many canyons. Sparsely distributed areally but of interest in this report are the spring deposits of calcareous tufa. These deposits consist of brown or tan spongy calcareous material laid down at the orifices of springs whose waters contain appreciable calcium carbonate. By far the largest deposit of tufa is around Hidden Lake on US 89 about 2 miles north of Glendale.

WATER RESOURCES

The hydrologic cycle and relations between ground water, springs, and surface water in western Kane County

The hydrologic cycle describes the movement of water from the vast reservoir of the sea, to the atmosphere, then through precipitation to the earth, where it flows over and under the surface as surface runoff or ground water that sooner or later returns to the sea, or returns directly to the atmosphere as evaporation from surfaces of fresh water or as transpiration from plants.

Essentially all water is derived from precipitation as rain or snow. Of the precipitation that falls as rain, some is used directly by plants or is evaporated, some becomes soil moisture and is used eventually by plants, some runs over the ground and is stored temporarily in rivers or lakes or reservoirs before it finally reaches the sea, and some seeps downward to the ground-water table where it remains in storage or slowly moves down gradient until it comes to the surface as a spring or a seep at a lower elevation. Precipitation that falls as snow follows the same pattern as rain except that some snow remains in surface storage in winter and then becomes melt water in the spring or early summer. This melt water becomes available in the early growing season and supplements springtime precipitation. Where snow melt is abundant, storage of such water in reservoirs makes it available for year-round use. A large amount of snow falls on permanent glaciers in arctic or high mountain areas and becomes long-term storage.

Water that runs off over the land or reaches the sea after slow percolation through the ground carries with it soluble minerals that, during the vast span of geologic time, have made the sea salty; and in most parts of the oceans, sea water contains about 35,000 parts per million (ppm) total dissolved solids. Yet this tremendous body of salty water is bit-by-bit transformed to freshwater vapor by the natural distillation of evaporation, and when this water vapor is precipitated as rain or snow, it is fresh. New precipitation is not totally devoid of dissolved minerals, however, for by the time it reaches the earth's surface it has picked up a few parts per million of solids from the atmosphere.

Those are the broad features of the hydrologic cycle; its variations from area to area are dependent on the climate of the particular area. In hot arid climates, local precipitation does not equal evaporation so vegetation is scant, and only intense storms produce runoff; in hot humid climates, precipitation may exceed evaporation many fold so vegetation is luxurious and runoff is plentiful. But in all climates there are definite relationships between precipitation, temperature, transpiration, evaporation, runoff, and the acceptance or rejection of water by the soil and underlying rocks. For areas whose precipitation, temperature, and rates of evaporation and transpiration are the same, runoff is largely dependent on the porosity and permeability of the rocks over which the runoff moves. Highly porous and permeable rocks will absorb large quantities of runoff and will hold it in storage where the regional water table is below the level of water in the stream, as it generally is in arid climates, or later will

slowly return the water to the stream where the water table is above the stream, as it is in humid climates. These two conditions are illustrated by sketches in figure 4: the arid and semiarid condition as series A and the humid condition as series B. The fundamental difference is that in humid areas the water table is high enough to discharge water to the stream and thus maintain its base flow, whereas in arid or semiarid areas streams go dry because the water table during dry periods is far below their channels.

The general relations between streams and ground water as illustrated in figure 4 hold true where the underlying rocks are homogeneous and are reasonably porous everywhere. In other words, water that seeps into the ground seeks the regional water table, which is close to the surface where the climate is humid and generally deeper where the climate is arid or semiarid. Where the rocks have different porosities in different places, they will absorb water in some places and reject it in others. Under such conditions, concentrated flows of ground water come to the surface as springs in certain favorable localities. Obviously in any region the abundance of springs and their total discharge are directly related to the overall precipitation, but if the topographic, as well as the geologic, conditions are favorable, a porous rock that has a large outcrop area may absorb large quantities of water even in an arid climate and then may concentrate the discharge of the whole aquifer (the water-bearing rock body) at just a few springs. Still other aquifers may receive recharge in areas where precipitation is great and make water available in distant areas where there is less precipitation. For example, in South Dakota the Dakota Sandstone receives recharge in the Black Hills and yields water to artesian wells in the desert east of the Black Hills (Tolman, 1937, p. 362).

In western Kane County, some rocks such as the Wasatch Formation, some Cretaceous sandstones, and the Navajo Sandstone are highly porous and tend to absorb water; other rocks such as the Tropic Shale and other unnamed shales in the Cretaceous sequence are relatively impervious and act as barriers to the movement of water. Faults also can control the movement of water: some act as conduits because they are highly permeable; others act as barriers if they are filled with impermeable gouge. The sketches in figure 5 illustrate some of the different conditions under which water may be brought to the surface as springs; these sketches are generalized and do not attempt to cover all varieties of springs, but rather to illustrate the most common types in western Kane County, as represented by the 100-odd springs listed in table 3. No attempt is made here to come up with a comprehensive classification of the springs in western Kane County, because the precise factors that caused most springs were obscured by tufa deposits or vegetation. However, the surrounding topographic and geologic conditions put certain limitations on the possible causes, and I feel therefore that the great majority of springs in western Kane County falls into one of the categories illustrated here. Probably most springs in the Cretaceous sandstones are of the contact variety, that commonly occur where a water table is perched above an impermeable bed of clay or shale; most such springs would be fed by local precipitation on the immediate watershed. Most springs at the edges of valleys, such as along the north side of Lydias Canyon, are probably of the contact variety. Springs that are localized by faults may be more common than can be indicated with certainty by this

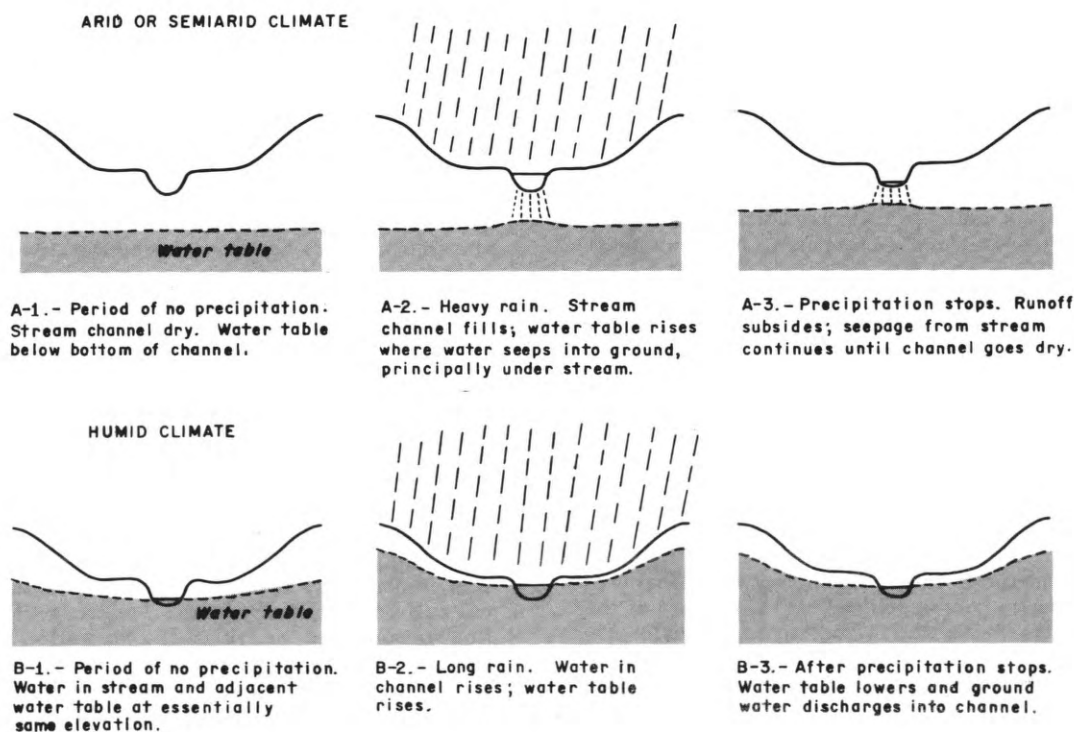
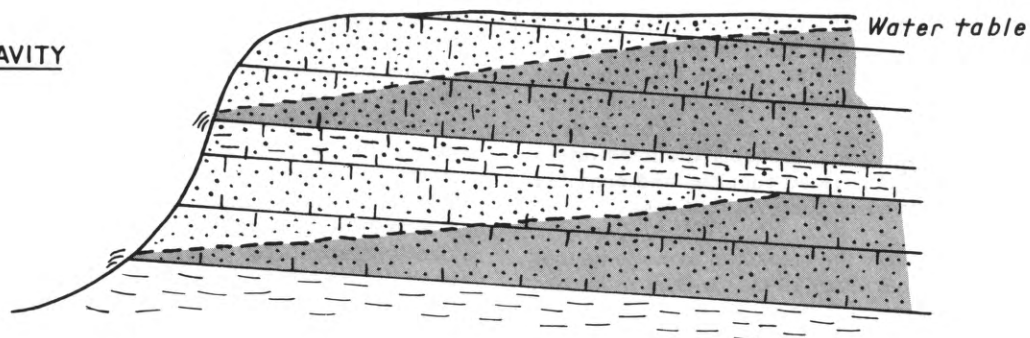


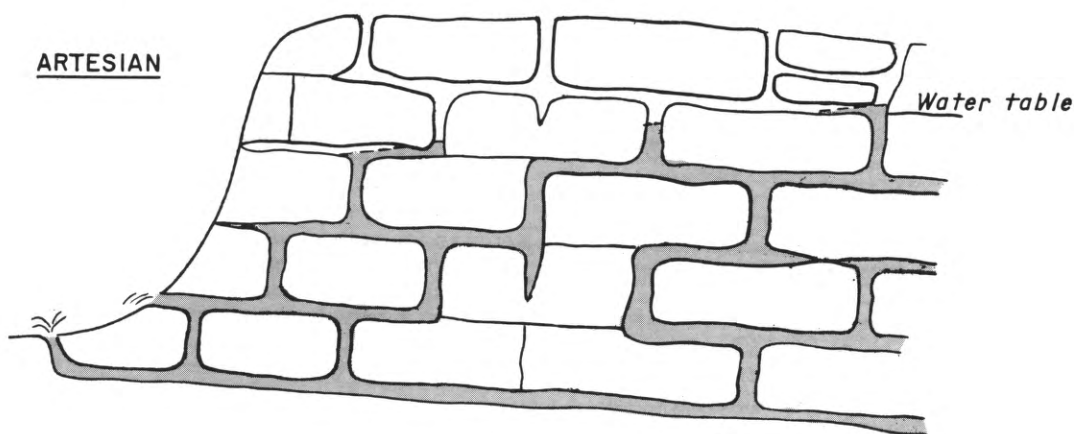
Figure 4.—Profile sketches to illustrate relation of streams to water table:
A-1, 2, 3,- arid or semiarid climate; B-1, 2, 3- humid climate.

GRAVITY

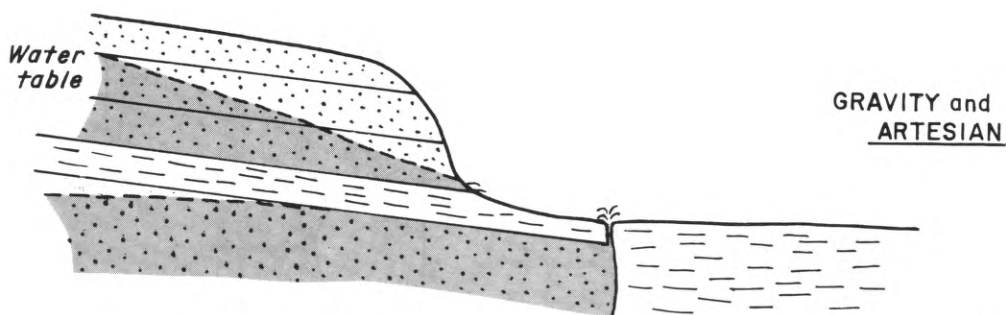


- A. Contact springs. Highly porous, jointed sandstone beds separated by a slightly permeable bed of jointed siltstone and overlain by impermeable shale.

ARTESIAN



- B. Conduit springs in cavernous limestone. One spring is part way up cliff face and the other is at base of cliff. Both springs are under artesian pressure.



- C. Fissure spring along a fault and a contact spring. Fault brings porous sandstone against impermeable shale, and shale overlying sandstone confines water in lower aquifer and so provides artesian pressure to bring water to surface.

Figure 5.—Profile sketches to illustrate the most common types of springs in western Kane County.

investigation; the springs that supply Orderville are on a fault and the springs that rise in Sink Valley may be on a fault that permits the water to rise through the otherwise impermeable Tropic Shale. Springs that are supplied by water tables in cavernous limestone probably occur in or close to the Wasatch Formation. Probably the headwaters spring for upper Kanab Creek is so supplied and possibly also the headwaters spring of Long Valley Creek.

In western Kane County the measured average annual precipitation ranges from about 12–3/4 inches at Kanab, through almost 15 inches at Orderville, to about 16–1/3 inches at Alton (table 2), and the estimated normal annual precipitation ranges from less than 12 inches along the Arizona border to more than 25 inches on the Paunsaugunt Plateau above Alton and to about 40 inches near Navajo Lake on the Markagunt Plateau (figure 6). In general, the line indicating 20 inches or more follows the 7,500-foot topographic contour, so the area below that contour would be considered semiarid. In the more humid area above 7,500 feet the porous limestones of the Wasatch and the porous Cretaceous sandstones crop out and receive recharge; below 7,500 the Navajo Sandstone crops out and can readily receive the small available recharge where it is exposed at the surface or is overlain by dunes.

In the area below the 7,500-foot contour most streams would be expected to dry up in the summer after complete melting of snow at the higher elevations. Without having made a statistical count, I feel sure that many streams of western Kane County do dry up, yet in July of 1963, after a very dry spring and after a winter which produced so little snow that there was no spring runoff, there was water flowing in upper Kanab Creek above Alton, in lower

Kanab Creek at US 89, and in the East Fork of the Virgin River and many of its tributaries at least as far downstream as Orderville. Under similar conditions of low rainfall and little or no water from snow storage, streams in most other semiarid areas would have dried up. But during this period of deficient precipitation the streams mentioned above were being supplied by water issuing from seeps and springs, principally from bedrock. Table 3 records all springs and seeps visited during this investigation, about 100 in all. The spring water supplying base flow was not coming from the alluvium of the stream valleys because in most areas the alluvium is too thin or too deeply dissected to supply water for long periods without replenishment. Instead, this water was coming from springs and seeps in the exposed or underlying bedrock.

Because of the great differences in the rocks, the springs and seeps supply abundant water only in certain localities and, as a consequence, streams are perennial only in certain reaches. For example, upper Kanab Creek and some of its tributaries have contact springs (fig. 5) from place to place at the sides of the valleys from the headwaters to within about 3 or 4 miles of Alton, at about where the Tropic Shale becomes prominent in the valley (fig. 7 and fig. 3). From that area to the Elbow, a distance of about 15 miles, the valley of Kanab Creek is underlain principally by shale and other fine-grained rocks, and the principal supply of base flow for Kanab Creek in this reach comes from return flow from irrigation below Alton. The supply from irrigation is intermittent and not abundant; hence, much of Kanab Creek between Alton and the Elbow is dry for long periods.

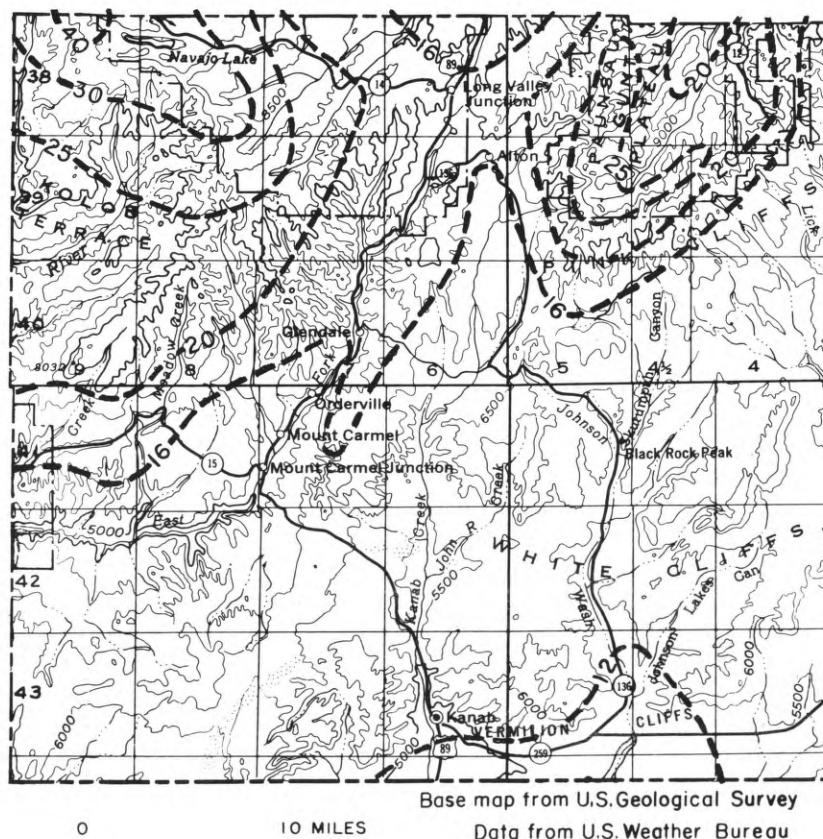


Figure 6.—Map of western Kane County, Utah, showing normal annual precipitation in inches.

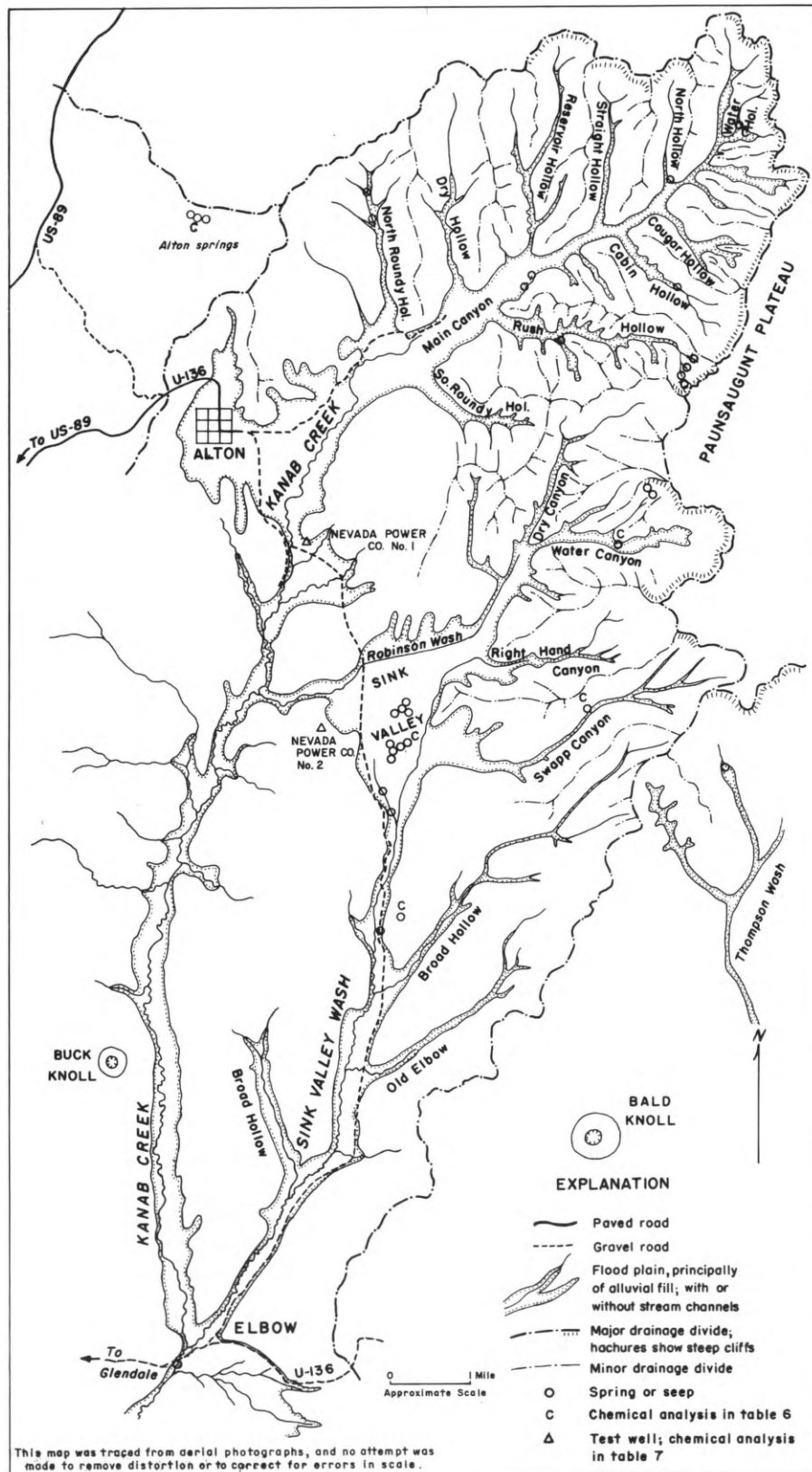


Figure 7.—Sketch map of upper Kanab Creek and Sink Valley showing selected springs and test wells.

Table 2-A.—Precipitation at Alton, Kanab, and Orderville, Utah.

Annual precipitation at Alton, 1916 to 1962; at Kanab, 1903 to 1962; and at Orderville, 1910 to 1962.
 Source: Department of Agriculture, Weather Bureau, Climatic Summary of the U.S.

<u>Year</u>	<u>Alton</u>	<u>Kanab</u>	<u>Orderville</u>
1903	--	15.92	--
1904	--	8.61	--
1905	--	18.90	--
1906	--	20.70	--
1907	--	--	--
1908	--	--	--
1909	--	--	--
1910	--	--	13.80
1911	--	--	16.40
1912	--	15.26	17.45
1913	--	11.59	16.58
1914	--	15.12	18.87
1915	--	11.85	16.22
1916	28.40	--	24.36
1917	12.22	--	13.41
1918	22.33	--	15.62
1919	12.15	--	11.21
1920	17.91	11.22	15.97
1921	20.10	--	18.75
1922	13.33	14.77	16.29
1923	11.45	12.35	11.72
1924	11.61	7.29	9.00
1925	17.33	11.44	14.52
1926	16.59	12.75	10.18
1927	20.27	18.00	19.29
1928	11.85	8.91	7.76
1929	14.80	9.87	10.20
1930	14.58	13.34	15.46
Av 1916-1930	16.35	Av 1875-1930 12.63	Av 1910-1930 14.95
Source: U.S. Department of Commerce, Weather Bureau, Climatic Summary of the U.S.			
1931	15.84	13.55	14.98
1932	18.73	13.72	16.43
1933	13.31	10.48	11.95
1934	14.86	11.06	9.87
1935	13.78	11.31	14.54
1936	19.47	13.95	18.79
1937	17.89	13.28	17.57
1938	17.32	14.08	14.42
1939	15.35	14.34	16.00
1940	16.37	19.03	20.58
1941	22.39	20.29	24.06
1942	10.96	9.05	9.91
1943	16.20	14.11	15.53
1944	11.42	9.59	12.16
1945	18.15	11.85	14.28
1946	18.44	13.90	13.40
1947	14.63	9.83	11.04
1948	12.15	9.82	13.01
1949	21.27	14.90	20.15
1950	9.73	7.25	8.27
1951	20.32	14.26	16.13
1952	18.30	13.59	14.34
Mean 1931-52	16.20	12.88	14.91
1953	7.45	8.75	9.57
1954	17.20	14.30	16.38
1955	14.14	9.16	11.29
1956	5.48	5.43	6.50
1957	25.44	17.37	24.62
1958	19.24	14.63	17.57
1959	13.52	9.31	10.57
1960	6.93	10.37	12.08
1961	14.81	8.93	12.76
1962	14.60	10.50	15.44
1963	15.63	11.87	13.81

Table 2-B.—Precipitation at Alton, Kanab, and Orderville, Utah.

Monthly precipitation at Alton, Kanab, and Orderville, October 1961 through December 1963.
Source: U.S. Department of Commerce, Weather Bureau, Climatological Data for Utah.

Monthly Total											
<u>Alton</u>	<u>1961</u>										<u>1962</u>
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
	.49	1.65	1.38	2.24	4.83	1.55	T	.42	.28	.39	.11
	<u>1962</u>										<u>1963</u>
	1.10	.20	.46	.78	1.51	1.63	1.76	.06	.24	.38	4.81
	<u>1963</u>										
	.68	1.44	.03								
<u>Kanab</u>	<u>1961</u>										<u>1962</u>
	.23	.95	.50	1.22	3.27	.55	.04	.40	.17	.04	.15
	<u>1962</u>										<u>1963</u>
	1.24	.34	.54	.82	1.23	.59	.89	.02	.14	.09	3.75
	<u>1963</u>										
	1.21	1.69	.01								
<u>Orderville</u>	<u>1961</u>										<u>1962</u>
	.37	1.52	.69	2.10	4.32	1.64	.05	.78	3.19	.05	.27
	<u>1962</u>										<u>1963</u>
	1.00	.03	.49	1.11	1.66	.88	1.16	T	T	.08	4.64
	<u>1963</u>										
	1.19	.91	.02								

Table 2-C.—Precipitation at Alton, Kanab, and Orderville, Utah.

Daily precipitation at Alton, Kanab, and Orderville, June 1 through August 31, 1963.

June			July			August			June			July			August		
<u>Alton</u>			<u>Kanab</u>			<u>Order-</u>			<u>ville</u>								
1	.10	-	.05	.14	-	.02	T	-	-	-	T	-	-	-	-	-	-
2	T	-	.19	.04	-	.25	F	-	-	-	-	-	-	-	-	-	-
3	.06	-	.38	-	-	.33	-	-	-	-	-	-	-	-	-	.45	-
4	-	-	T	.05	-	.06	-	-	-	-	-	-	-	-	-	-	-
5	T	-	1.18	-	-	.10	-	-	-	-	-	-	-	-	-	2.52	-
6	.02	-	.34	-	-	.82	-	-	-	-	-	-	-	-	-	-	-
7	-	-	.11	-	-	T	-	-	-	-	-	-	-	-	-	-	-
8	-	-	T	-	-	.34	-	T	-	-	-	-	-	-	-	-	-
9	-	.06	-	-	.01	-	-	T	-	-	-	-	-	-	-	-	-
10	.02	.04	T	-	.04	-	-	.05	-	-	-	-	-	-	-	-	-
11	-	-	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	.04	-	.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	T	-	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	T	-	-	.02	-	-	-	-	-	-	-	-	-	-	-
16	-	-	T	-	-	-	-	-	-	-	-	-	-	-	-	.32	-
17	-	-	.17	-	-	.14	-	-	-	-	-	-	-	-	-	.32	-
18	-	-	.21	-	-	.50	-	-	-	-	-	-	-	-	-	.04	-
19	-	-	T	.05	-	-	-	-	-	-	-	-	-	-	-	.28	-
20	T	.28	.03	-	.02	.02	-	T	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	T	-	-	-	-	-	-	-	-	-
22	-	-	.03	-	.02	.01	-	.03	-	-	-	-	-	-	-	.07	-
23	-	-	.16	-	-	-	-	-	-	-	-	-	-	-	-	.38	-
24	-	-	.99	-	-	.32	-	-	-	-	-	-	-	-	-	-	-
25	-	-	.09	-	-	.11	-	-	-	-	-	-	-	-	-	.05	-
26	-	-	.12	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	-	-	.25	-	-	.02	-	-	-	-	-	-	-	-	-	.10	-
30	-	-	.36	-	-	.37	-	-	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	.32	-	-	-	-	-	-	-	-	-	.38	-

In general, the springs that supply the base flow in upper Kanab Creek and the base flow in the East Fork of the Virgin River and its tributaries come from the limestones of the Wasatch Formation, and from sandstone beds above silt or clay in the Kaiparowits, Wahweap, and Straight Cliffs Sandstones (fig. 3). The Tropic Shale does not normally yield appreciable water, but in Sink Valley numerous small springs and seeps issue from the Tropic, possibly along an unproved fault.

The base flow for lower Kanab Creek, at least above the point where the creek is crossed by US 89, comes from springs in the Navajo Sandstone. Many springs in Kanab Canyon yield water at the contact between the upper massive member of the Navajo and the underlying Tenney Canyon Tongue of the Kayenta; the headwaters springs rise higher up in the upper massive member of the Navajo. Other springs in Three Lakes Canyon, a tributary of lower Kanab Creek support lakes in that canyon. These springs and the Kanab City wells in the same canyon get water from the upper massive member or the Lamb Point Tongue of the Navajo Sandstone, probably localized by a fault (fig. 3).

Springs and surface water

Upper Kanab Creek and tributaries

Upper Kanab Creek is perennial only in its upper reaches; for most of its nearly 20 miles of length it flows only during spring runoff or after an extensive rainfall. The total yield of the springs (fig. 7) in upper Kanab Creek and its tributaries may be 1 to 2 cfs more than the 3 to 5 cfs normally available for diversion into the Alton Farmers Association irrigation system because an appreciable part of the yield is used to support wet meadows or to irrigate pasture lands in the side and main canyons and therefore does not become base flow in the main canyon.

The springs of upper Kanab Creek and its tributaries issue from Upper Cretaceous sandstones and siltstones and possibly, but certainly to a much lesser degree, from the Wasatch Formation. The uppermost of these springs appear in the Cretaceous sandstones and siltstones within a few tens or a couple of hundred feet below the base of the Pink Cliffs. They are more abundant and yield more water below deeply dissected steep cliffs than they do below rounded or less-steep exposures of the Wasatch. Whether the steepness of the cliffs promotes the yield of water or the steepness is due to sapping because of a relative abundance of water is not known. In some areas in the Kanab drainage sapping is probably a contributor to fast erosion, as it is at the head of Lydias Canyon (as described below).

This investigation included traverses through the main canyon of upper Kanab Creek, through South Roundy, Rush, Cabin, and Water Hollows southeast or east of main canyon, and through North Roundy and Dry Hollows northwest of main canyon. Not investigated were Reservoir, Straight, North, Dry, Cougar, and the unnamed hollow north of Cougar Hollow.

Among the southeast hollows, those that head in the steep Pink Cliffs on the west side of the Paunsaugunt Plateau yield more water than those whose heads are not steep

or do not breach the west edge of the plateau. For example, both Water Hollow and Rush Hollow, whose heads are in very steep Pink Cliffs, yield appreciably more water than do Cabin Hollow or South Roundy Hollow. The head of Cabin Hollow is much less steep than the heads of Water or Rush Hollows, and South Roundy Hollow does not head in the Pink Cliffs of the plateau.

In general, the southeast hollows that head in the Pink Cliffs yield more water than the northwest hollows that do not head in the Pink Cliffs, although Reservoir Hollow, one of those not investigated, is reported to have springs.

The largest single spring in the upper Kanab drainage is the headwaters spring (C-38-5)23cd, whose water gushes out of one principal orifice and many smaller springs. The water from the principal orifice produced a stream 5 to 6 inches in diameter and rose about 6 inches above the tufa-lined hole. The estimated yield of this principal orifice is 250 to 300 gpm, and the total yield of the spring area probably is more than 1 cfs. At least three other unrecorded spring areas in sections 23 and 19 provide additional water for upper Kanab Creek. These areas all supply flooded meadows as well as their contributions to Kanab Creek. Measurements of meadow areas on aerial photographs suggest that a total of 30 to 40 acres is kept flooded by water in the uppermost reaches of Kanab Creek. In addition, this water undoubtedly supports much additional vegetation beyond the flooded areas. Salvage of the water lost by evapotranspiration from the flooded areas at the head of upper Kanab Creek alone might recover 60 to 80 gpm; development by wells of the water in the principal spring areas that contribute to upper Kanab Creek and in Rush Hollow, Cabin Hollow, and Robinson Creek might increase the yield to 8 to 10 cfs, but the yield of the wells would be at the expense of Kanab Creek and the flooded meadows, and the indigenous vegetation would have to depend on local precipitation. Plans for development by wells would have to include ways of satisfying present rights to surface flow.

Rush Hollow on August 29, 1963 had essentially continuous flow from its three principal alcoves almost to its mouth. On that date, a ditch supplying water to a meadow about one-third mile from the mouth was flowing 90 gpm, and the aggregate yield of the many springs and seeps of the alcoves was 125 to 150 gpm about one-quarter mile below the alcoves. Although there were many orifices yielding water in the steep alcoves immediately below the Pink Cliffs, the springs were catalogued as only one in each alcove (table 3).

Cabin Hollow, unlike Rush Hollow, does not yield water immediately below the Pink Cliffs, probably because erosion has not removed material below the cliffs. Whether this lack of removal is due to the lack of sapping by ground water, which could have prepared the material of Rush Hollow for removal, or to some other unrecognized cause is not clear. At any rate, the only spring areas in Cabin Hollow are more than half a mile from the Pink Cliffs on two sides of a small tufa ridge in the center of the hollow. These two areas yielded 30 gpm, in addition to supporting a flooded area of about 10 acres.

Robinson Creek, the tributary of upper Kanab Creek whose mouth is about 3 miles south of Alton, has two principal branches, Dry Canyon and Water Canyon. The head

Table 3.—Records of selected springs in western Kane County, Utah.

Most springs recorded here are in the drainages of Kanab Creek and East Fork of the Virgin River.

Abbreviations used and further explanation of some columns in this table: * in any column = additional information in Remarks. Sub-drainage: Hol = Hollow; trib = tributary. Topography: trib = tributary. Spring number: see text for description of numbering system. Approx. altitude: Altitudes from topographic maps in feet above mean sea level. Kind of rock: clst = claystone; Fm = Formation; ls = limestone; Prob. = Probably; Sh = Shale; slt = siltstone; Ss or ss = sandstone. Openings: Spr(s) = Spring(s); yds = yards. Improvements, accommodations, or use of water: ck = creek; col. box = collection box; dist. = distribution; dom = domestic. Flow: E = Estimated; M = measured; cfs = cubic feet per second; gpm = gallons per minute; pt = pint; qt = quart; < = less than. Remarks: C = chemical analysis in Table 6; MP = measuring point; Temp(s) = temperature(s)

Sub-drainage	Owner, name of spring, or further description	Topography	Spring number	Nearby town	Date of Record	Approx. altitude	Kind of rock	Openings	Improvements, accommodations, or use of water	Flow	Temp °F	Remarks
UPPER KANAB CREEK												
Main canyon	Headwaters spring	Broad meadow under Pink Cliffs	(C-38-5) 23cd	Alton	7/ 3/63	8400	Prob. Cretaceous ss	One bubbling; many seeps	Feeds meadow, drains to creek	250 gpm E*	45	C; Total yield from area about 1 cfs.
Main canyon	East side mouth North Hollow	End of ridge	(C-38-5) 27ad	Alton	7/ 3/63	8000	Prob. Cretaceous ss	Seeps	Waters meadow, drains to creek	15-25 gpm E		
Cabin Creek		Both sides tufa ridge	(C-38-5) 34da	Alton	8/29/63	7800	Prob. Cretaceous ss	Springs & seeps	Waters meadow	30 gpm M	43	Temp measured at south spring.
Main canyon		East side of valley	(C-38-5) 33ca	Alton	7/ 3/63	7600	Prob. Cretaceous ss	Seeps	Waters meadow	5-10 gpm E	48	
Main canyon		East side of valley	(C-38-5) 33cb	Alton	7/ 3/63	7600	Prob. Cretaceous ss	Seeps	Waters meadow	5 gpm E	48	
Rush Hollow	North alcove	Below Pink Cliffs	(C-39-5) 3ad	Alton	8/29/63	8400	Cretaceous ss	Many sprs & seeps	Feeds into creek	50-60 gpm E		MP-200 yds below springs.
Rush Hollow	Middle alcove	Below Pink Cliffs	(C-39-5) 3da-2	Alton	8/29/63	8400	Cretaceous ss	Many sprs & seeps	Feeds into creek	30 gpm M		MP-250 yds below springs.
Rush Hollow	South alcove	Below Pink Cliffs	(C-39-5) 3da-1	Alton	8/29/63	8400	Cretaceous ss	Many sprs & seeps	Feeds into creek	50 gpm M	45	C; Slight iron taste; MP-300 yds below springs.
Rush Hollow	Pipe Spring (Heaton Bros)	SW corner east-trending ridge	(C-39-5) 4ac	Alton	8/29/63	7600	Cretaceous ss	Seeps	Pipe; drains into meadow	1 gpm M	50	
North Roundy Hol		West side of canyon	(C-38-5) 30ddb	Alton	8/22/63	7800	Cretaceous ss	Seep	Supports wire grass	< pt/min E		
North Roundy Hol		Bottom of canyon	(C-38-5) 30ddd	Alton	8/22/63	7700	Cretaceous ss	Seeps	Supports grass in canyon	2-3 gpm E		
Robinson Hollow	Main spring, Water Canyon	Bottom of valley	(C-39-5) 15ac	Alton	7/ 6/63	7700	Prob. Cretaceous ss	One	Feeds into creek	28 gpm M	44	C; 23 gpm at 45° on 8/19/63; tufa deposits.
Robinson Hollow	North fork Water Canyon	Below Pink Cliffs	(C-39-5) 10dda	Alton	7/ 6/63	8500	Cretaceous slt	Seeps	Feeds into creek	4 gpm M		MP-100 ft below seeps.
Robinson Hollow	North fork Water Canyon	Below Pink Cliffs	(C-39-5) 10dac	Alton	7/ 6/63	8500	Cretaceous slt	Seeps	Feeds into creek	4 gpm M		MP-150 yds below seeps.
SINK VALLEY												
Swapp Canyon	Stock spring	North side of canyon	(C-39-5) 22caa	Alton	7/ 9/63	7700	Prob. Cretaceous ss		Col. box, pipe, tank; - stock	1 gpm M	52	C; Sampled 8/21/63, 58°.
Main valley	Cecil Pugh	Broad valley	(C-39-5) 20ccc	Alton	8/26/63	6850	Tropic Shale	Seeps	Head box	2-3 gpm E		
Main valley	Sorensen ranch	Broad valley	(C-39-5) 29bac	Alton	7/ 9/63	6800	Tropic Shale		Head box, pipe; dom	1/2 gpm E	51	C; Sampled 8/21/63, 56°.

Table 3.—Records of selected springs in western Kane County, Utah..(continued).

Sub-drainage	Owner, name of spring, or further description	Topography	Spring number	Nearby town	Date of Record	Approx. altitude	Kind of rock	Openings	Improvements, accommodations, or use of water	Flow	Temp of	Remarks
SINK VALLEY - Continued												
Main valley	Swapp ranch (old homestead)	Broad valley	(C-39-5) 29bba	Alton	8/26/63	6800	Tropic Shale		Small ditch; - water in pond	1-2 gpm E	*	Pond 67°.
Main valley	Swapp ranch	Broad valley (small mounds)	(C-39-5) 29bbb-1	Alton	8/26/63	6800	Tropic Shale	Three or more		1 gpm E		Bog deposits.
Main valley	Swapp ranch	Broad valley	(C-39-5) 29bbb-2	Alton	8/26/63	6800	Tropic Shale	Seeps	Ditch as drain	2-3 gpm E		
Main valley	Swapp ranch	Broad valley	(C-39-5) 29bbc	Alton	8/26/63	6800	Tropic Shale	Two	Ditch as drain	3-4 gpm E	50	
Main valley	Swapp ranch	Broad valley	(C-39-5) 29bca	Alton	8/26/63	6800	Tropic Shale & slt	Two	Ditches as drains	6-8 gpm E	50	
Main valley	Swapp ranch	Broad valley	(C-39-5) 29bcb	Alton	8/26/63	6800	Tropic Shale	One	Pipe to house for domestic use	3-4 gpm E	50	
Main valley	Swapp ranch	Broad valley (3 bogs)	(C-39-5) 29bcc	Alton	8/26/63	6800	Tropic Shale	Three	Supports grasses	2-3 gpm E		
Main valley	Entrance Swapp Canyon Rd.	West side of valley	(C-39-5) 30dda	Alton	8/21/63	6800	Tropic Shale	?	Dam with reservoir	20 gpm E		
Main valley	Swapp ranch	West side of valley at ridge	(C-39-5) 32bbc	Alton	8/26/63	6800	Tropic Shale	Two	Dams - 2 ponds	15-20 gpm E	52	
Unnamed trib	Preston Swapp	Bottom & side of gully	(C-40-5) 5bcd	Alton	8/21/63	6850	Tropic Shale	Several + seeps		3 gpm E*	50	C; 1/2 gpm M in gully 1/2 mile downstream.
Main valley	At edge of U-136	East side of valley	(C-40-5) 6daa	Alton	8/21/63	6800	Tropic Shale	Seep		<pt/min E		
LOWER KANAB CREEK												
Threemile Hollow	Glendale Bench	Bottom of canyon	(C-40-6) 33bca	Glen-dale	8/15/63	6200	Carmel Fm - Sh, ls	Seeps	Stock-watering	<qt/min E		
Threemile Hollow	Glendale Bench	Bottom of canyon	(C-40-6) 33bcd	Glen-dale	8/15/63	6180	Carmel Fm - Sh over clay	Seeps	Stock-watering	<pt/min E		
Threemile Hollow	Glendale Bench	Bottom of canyon	(C-40-6) 33cba	Glen-dale	8/15/63	6160	Carmel Fm - Sh over clay	Seeps	Stock-watering	<qt/min E		
Fourmile Hollow	Glendale Bench	Bottom of canyon	(C-40-6) 33dbd	Glen-dale	8/15/63	6100	Carmel Fm - Sh over clay	Seeps	Stock-watering	<qt/min E		
Main canyon	At Elbow	Below waterfall	(C-40-6) 35ac	Glen-dale	9/ 3/63	6300	Carmel Fm - Sh, ls over clay	Seeps	Base flow for ck	10-50 gpm E		
Main canyon	Headwaters spring	Bottom of canyon	(C-42-6) 4cbc	Kanab	8/26/63	5380	Navajo Ss	Seeps	Feeds into Kanab Ck	300-400 gpm		Spring reported by Neldon Robinson.
Main canyon	Near mouth Red Canyon	East side of canyon	(C-42-6) 9bbd	Kanab	8/26/63	5880	Navajo Ss	Seeps	Feeds into Kanab Ck	200-300 gpm	72	Spring reported by Neldon Robinson.
Unnamed trib	Big Lake springs	West of Kanab Creek	(C-42-6) 17caa	Kanab	8/26/63	5350	Navajo Ss	Seeps	Ditch feeds into Kanab Creek	100-125 gpm E	60	Lower spring area also yields about 100 gpm.
Main canyon		West side Kanab Creek	(C-42-6) 17dac & ddb	Kanab	8/26/63	5350	Navajo Ss	Seeps	Small ditch drains into creek	25 gpm	57	C; Sampled at point yielding 3 gpm.
Main canyon		West side canyon wall	(C-42-6) 20aac	Kanab	8/20/63	5375	Navajo Ss contact Tenney Canyon	Seeps	Stock-watering facilities	10-50 gpm E		

Table 3.—Records of selected springs in western Kane County, Utah..(continued).

Sub-drainage	Owner, name of spring, or further description	Topography	Spring number	Nearby town	Date of Record	Approx. altitude	Kind of rock	Openings	Improvements, accommodations, or use of water	Flow	Temp of	Remarks
LOWER KANAB CREEK - Continued												
Main canyon		East side canyon wall	(C-42-6) 28bba	Kanab	8/20/63	5400	Navajo Ss contact Tenney Canyon	Seeps	Feeds into Kanab Ck	10-50 gpm E		
Three Lakes Canyon	Upper lake	West side canyon	(C-42-6) 19cdd	Kanab	8/26/63	5460	Navajo Ss contact Tenney Canyon			100-200 gpm E		
Three Lakes Canyon	Middle lake	West side canyon	(C-42-6) 30baa	Kanab	8/26/63	5450	Navajo Ss contact Tenney Canyon			100-200 gpm E		
Three Lakes Canyon	Lower lake	West side canyon	(C-42-6) 30bda	Kanab	8/26/63	5425	Navajo Ss contact Tenney Canyon		Picnic ground	100-200 gpm E		
EAST FORK VIRGIN RIVER												
Long Valley Creek	Alton east spring	Hillside	(C-38-6) 25ccc-2	Alton	7/ 8/63	7600	Cretaceous ss		Culvert, col. tunnel	1 gpm E	48	Alton town supply.
Long Valley Creek	Alton main spring	Hillside	(C-38-6) 25ccc-1	Alton	7/ 9/63	7600	Cretaceous ss	Spr & seeps	Culvert, col. tunnel	4-5 gpm M	47	C; Alton town supply.
Long Valley Creek	Alton west spring	Hillside	(C-38-6) 26ddd	Alton	7/ 8/63	7600	Cretaceous ss		Col. box	< 1 gpm E	49	Alton town supply.
Long Valley Creek	Near Long Valley Jct.	Gully west of highway	(C-38-6) 27bad	Long V. Jct.	8/ 1/63	7375	Alluvium near base Brian Head			< 1 gpm E		
Long Valley Creek	Unnamed trib	Center of valley	(C-38-6) 35bcc	Long V. Jct.	8/23/63	7240	Possibly Brian Head Fm	Seep	Dam & col. box	1 gpm E		
Long Valley Creek	Upper LeVanger Lake	Center of valley	(C-39-6) 10a	Alton	8/28/63	7053	*Brian Head Fm		Lake covers about 10 acres	25-50 gpm E		*Altitude printed on USGS map.
Long Valley Creek	Lower LeVanger Lake	Center of valley	(C-39-6) 10c	Alton	8/28/63	7044	*Pink Cliffs		Lake covers 10-15 acres	25 gpm E		*Altitude printed on USGS map; Lake very shallow & drying.
Long Valley Creek	Below lower LeVanger Lake	Center of valley	(C-39-6) 9ddd	Alton	8/28/63	6980	Pink Cliffs		Pipe & small pond	3-4 gpm E	50	
Long Valley Creek	McDonald Lake	Center of valley	(C-39-6) 16a	Alton	8/28/63	6950	Pink Cliffs		Dam; - lake covers about 25 acres	100-200 gpm E		Recreation plus stock.
Long Valley Creek	Headwaters spring	East edge of valley	(C-39-6) 9cca	Alton	8/28/63	6960	Pink Cliffs	One ?	Diversion ditch; feeds into creek	1 + cfs E		Diversion ditch takes about half of yield.
Long Valley Creek	Major property	West side of valley	(C-39-6) 17dbd	Alton	8/14/63	6870	Pink Cliffs	Two or more	Collection flume 3 ponds	100-150 gpm E	50	C.
Long Valley Creek	Farrell & Ronald Spencer	Center of valley	(C-39-6) 30cad	Glen-dale	8/14/63	6520	Lower Pink Cliffs	?	Three ponds	10-20 gpm E		
Long Valley Creek	Howard Spencer(?)	Center of valley	(C-39-7) 36adb	Glen-dale	8/14/63	6390	Prob. Cretaceous ss		Two ponds to store water	20-30 gpm E		
Long Valley Creek	West side US 89	West wall of valley	(C-39-7) 36aca	Glen-dale	7/20/63	6400	Cretaceous slt & ss	Seeps	Drains into creek	15 gpm M	57	MP about 20 ft below seeps
Long Valley Creek	Campground on US 89	West side of valley	(C-39-7) 36acb	Glen-dale	7/20/63	6400	Prob. Cretaceous slt		Pipe & faucet, col. box	0.8 gpm M	57	C.
Stout Canyon	Headwaters spring	Along creek	(C-39-6) 7bcb	Glen-dale	7/27/63	6950	Cretaceous ss & slt	Seeps for 200 yds	Total flow of head of Stout Creek	160 gpm M	54	C; MP about 400 yds below first seep.

Table 3.—Records of selected springs in western Kane County, Utah..(continued).

Sub-drainage	Owner, name of spring, or further description	Topography	Spring number	Nearby town	Date of Record	Approx. altitude	Kind of rock	Openings	Improvements, accommodations, or use of water	Flow	Temp °F	Remarks
EAST FORK VIRGIN RIVER - Continued												
Stout Canyon	Shingle Mill	Near head of canyon	(C-39-7) 16baa	Glen-dale	8/28/63	7600	Cretaceous ss	One		3 gpm E	48	
Stout Canyon	Shingle Mill	Width of valley	(C-39-7) 16abd	Glen-dale	8/28/63	7450	Cretaceous ss	Several	Supports meadow	20-30 gpm E	48	
Stout Canyon	Shingle Mill	Width of valley	(C-39-7) 16da	Glen-dale	8/28/63	7300	Cretaceous ss	Many	Supports meadow	40-50 gpm E	46	
Stout Canyon	Shingle Mill	Width of valley	(C-39-7) 15cbc	Glen-dale	8/28/63	7200	Cretaceous ss	Several	Supports meadow	40-50 gpm E		
Stout Canyon	Shingle Mill-Old Wagon Spr	Width of valley	(C-39-7) 15cca	Glen-dale	8/28/63	7150	Cretaceous ss	Many	Floods meadow	75-100 gpm E	48	C; Tufa deposits.
Stout Canyon	Shingle Mill	South side canyon	(C-39-7) 26abb-2	Glen-dale	8/28/63	6550	Cretaceous ss	Seeps		*		Yield varies reports Henry Carroll.
Stout Canyon	Shingle Mill	North side canyon	(C-39-7) 26abb-1	Glen-dale	8/28/63	6550	Cretaceous ss	Seeps	Supports meadow	4-5 gpm E*	51	Yield constant reports Henry Carroll.
Stout Canyon	Near mouth Shingle Mill	East side of creek	(C-39-7) 26add	Glen-dale	8/28/63	6400	Cretaceous ss	Many	Floods meadow & drains to creek	200-300 gpm E		
Stout Canyon	1.2 miles above mouth	Hillside east of road	(C-39-7) 26daa	Glen-dale	7/20/63	6400	Cretaceous ss			1 gpm E		
Stout Canyon	0.9 to 1.1 miles above mouth	Hillside east of road	(C-39-7) 26dad	Glen-dale	7/20/63	6375	Cretaceous ss	Several	Flows into creek	15 gpm E		
Stout Canyon	0.7 mile above mouth	Hillside east of road	(C-39-7) 26dda	Glen-dale	7/20/63	6375	Cretaceous ss		Flows into creek	6-1/2 gpm M		
Stout Canyon	0.55 mile above mouth	Hillside	(C-39-7) 25ccc	Glen-dale	7/25/63	6350	Cretaceous ss			1 gpm E		
Stout Canyon	Currant Spring, Currant Canyon	Bottom of shallow gully	(C-39-7) 21acb	Glen-dale	7/26/63	7650	Prob. Cretaceous ss	Seeps	Used by local grass	< 1 gpm E	59	
Stout Canyon	Hidden Spring, Currant Canyon	West side valley bottom	(C-39-7) 27bbb	Glen-dale	7/26/63	7000	Alluvium - Ss crops out 50 ft west			2 gpm E	48	
Stout Canyon	Currant Canyon	Both sides of creek	(C-39-7) 26ccb	Glen-dale	7/26/63	6600	Cretaceous ss	Several	Waters meadow - drains to creek	15-20 gpm E	48	
Stout Canyon	Currant Canyon	South side canyon	(C-39-7) 26cdc	Glen-dale	7/26/63	6475	Cretaceous ss	Several	Waters mound - drains to creek	10 gpm E	52	C; Tufa deposits.
Stout Canyon	Mouth of Currant Canyon	South side Currant Canyon	(C-39-7) 35aab	Glen-dale	7/26/63	6350	Cretaceous ss	Seeps	Flows into creek	5-10 gpm E		
Stout Canyon Main valley	0.4 mile above mouth Near confluence Stout Creek	Hillside east of creek Hillside west of highway	(C-39-7) 36bbb (C-39-7) 36cbb	Glen-dale Glen-dale	7/25/63 7/20/63	6350 6250	Prob. Cretaceous ss Cretaceous ss	Seep Seeps	Flows into creek Flows into creek	1 gpm E 5 gpm M	71	
Main valley	Hidden Lake spring	Tufa mound on ridge west side Long Valley	(C-40-7) 11bbb	Glen-dale	7/23/63	6010	Cretaceous ss	Not known	Supports lake; overflow used for irrigation or goes into ck	250 gpm*M	69-74	C; Said to be unfit for fish culture; plus leakage of about 100 gpm.
Right Fork Lydias	Headwaters - east branch	On rounded nose of Pink Cliffs	(C-39-7) 17cda	Glen-dale	8/27/63	7900	Pink Cliffs	Sprs & seeps	Supports meadow; drains to creek	10-15 gpm E	49	Tufa & moss deposits.

Table 3.—Records of selected springs in western Kane County, Utah..(continued).

Sub-drainage	Owner, name of spring, or further description	Topography	Spring number	Nearby town	Date of record	Approx. Kind of altitude rock	Openings	Improvements, accommodations, or use of water	Flow	Temp of	Remarks
EAST FORK VIRGIN RIVER - Continued											
Right Fork Lydias	East Branch	Width of valley plus side tributaries	(C-39-7) 17c & 20b	Glen-dale	8/27/63	7500- Pink Cliffs & underlying Cretaceous ss	Many	Floods 20-25 acres; drains to creek	1 cfs E*		Probably greatest potential yield in Right Fork.
Right Fork Lydias	Between east & middle branches	Nose of ridge	(C-39-7) 20bcc	Glen-dale	8/27/63	7350 Cretaceous ss	Seeps	Supports meadow; drains to creek	15-25 gpm E		
Right Fork Lydias	Middle branch	Width of valley	(C-39-7) 18dd & 19aa	Glen-dale	8/27/63	7550- Prob. Cretaceous ss	Seeps	Supports 15-20 acres meadow; drains to creek	100 gpm E		
Right Fork Lydias	East Branch	Width of valley	(C-39-7) 20cb & 20cc	Glen-dale	8/27/63	7200 Cretaceous ss on clay	Seeps	Supports Ponderosa & short-needle pines	10-20 gpm E		
Right Fork Lydias	East trib of west branch	Width of valley	(C-39-7) 19ba	Glen-dale	8/27/63	7500- Cretaceous ss 7650	Seeps	Supports 10-20 acres meadow; drains to creek	50-100 gpm E		
Right Fork Lydias	West trib of west branch	Width of valley	(C-39-7) 19bb	Glen-dale	8/27/63	7500- Cretaceous ss 7650	Seeps	Supports 15-20 acres meadow; drains to creek	100-150 gpm E	48*	Temp measured on west side.
Left Fork Lydias	Trough Spring	Near top of ridge	(C-39-8) 25cbd	Glen-dale	7/29/63	7800 Prob. Cretaceous ss	Two or more seeps	Pipe & stock trough	1-2 qts/min E	47	Clear, good taste.
Left Fork Lydias	Chokecherry Spring	Above flat area on hill	(C-39-8) 25dca	Glen-dale	7/29/63	7500 Cretaceous clay in seep	Seeps		2 qts/min E	45	C; Clear, good taste.
Left Fork Lydias	Aspen Spring area	Both sides of valley	(C-39-7) 30bcc	Glen-dale	7/29/63	7280 Prob. Cretaceous ss	Several	Waters meadow & stock	15-20 gpm E	52*	C; Temps: East 57°, center 56°, west 50, 52, 54°.
Left Fork Lydias	Birch Spring	South side canyon	(C-39-7) 31bac	Glen-dale	7/29/63	7120 Cretaceous ss		Supports Ponderosa & wire grass	None visible		
Lydias Canyon	Unnamed trib to north		(C-40-7) 3ccc	Glen-dale	7/29/63	6200 Prob. Cretaceous ss		Feeds into 2 small reservoirs	25 gpm E		
Lydias Canyon	Dr. Thomas' NE & SE sprs	East side trib canyon	(C-40-7) 11cbc	Glen-dale	7/17/63	6100 Cretaceous ss	Seeps	2 drains & pipes; dom	1-2 gpm E		
Lydias Canyon	Dr. Thomas' West spring	West side trib canyon	(C-40-7) 10dad	Glen-dale	7/17/63	6100 Cretaceous ss	Seeps	Drain, pipeline, storage tank; dom	3-1/2 gpm M	56	C.
Lydias Canyon	Big Spring	Center of valley	(C-40-7) 10dda	Glen-dale	7/17/63	5950 Prob. Cretaceous ss		Col. area, 6-inch pipe	400-500 gpm E	57	C; Slight sulfur odor.
Main valley	Glendale Water System	East side Long Valley	(C-40-7) 14acc	Glen-dale	9/ 3/63	5860 Prob. Cretaceous ss		Pipeline, storage tank, dist. system	0.15 cfs*		Allowed by Burton decree, not checked.
Dry Wash	Right fork	Bottom of gully	(C-40-6) 7dab	Glen-dale	7/22/63	6400 Prob. Cretaceous ss	Seep	Drains to creek	2-3 gpm E	57	C; Iron taste.
Spring Hollow	Glendale Bench	Bottom of canyon	(C-40-7) 25adb	Glen-dale	7/31/63	6280 Ls, Carmel Fm	Seeps	Used by stock	5 gpm E	*	C; 58° north, 57° east.
Stewart Creek	Glendale Bench	Bottom of canyons*	(C-40-7) 36ccb	Order-ville	7/31/63	6400- Ls, Carmel 6450 Fm	Seeps*	Used by stock	1-2 gpm E*		Evidence of more water in past; seeps in two canyons.

Table 3.—Records of selected springs in western Kane County, Utah..(continued).

Sub-drainage	Owner, name of spring, or further description	Topography	Spring number	Nearby town	Date of record	Approx. altitude	Kind of rock	Openings	Improvements, accommodations, or use of water	Flow	Temp of	Remarks
EAST FORK VIRGIN RIVER - Continued												
Unnamed trib	Orderville main spring	Center of broad canyon	(C-40-7) 27cdd	Order-ville	7/18/63	5800	Valley fill - on Cretaceous ss		Col. box, pipeline	60 gpm M	54	C; Orderville town supply.
Main valley	Proposed new spring	Hillside - west side of Long Valley	(C-40-7) 34bad	Order-ville	7/19/63	5750-5775	Cretaceous ss	Several seeps		*	60	C; Potential yield 20-30 gpm.
Main valley	Orderville middle spring	West side of valley	(C-40-7) 34bda	Order-ville	7/18/63	5700	Cretaceous ss		Col. box, pipeline	10 gpm E		Orderville town supply.
Main valley	Orderville south spring	West side of valley	(C-40-7) 34bdc	Order-ville	7/16/63	5650	Cretaceous ss		Col. box, pipeline*	12 gpm M	58	C; Installed 1962-63; Orderville town supply.
Calf Pasture Hol		Near waterfall	(C-40-7) 28abd	Order-ville	8/12/63	5920	Cretaceous ss on blue clay	Seeps	Drain into creek	5 gpm E*	57	M 3 gpm; E 2 additional.
Calf Pasture Hol		Bottom of canyon	(C-40-7) 28adc	Order-ville	8/12/63	5850	Cretaceous ss	Seeps	Drain into creek	2-3 gpm E	52	C.
Calf Pasture Hol		Bottom of canyon	(C-40-7) 28dba	Order-ville	8/12/63	5850	Cretaceous ss		Drain into creek	4 gpm E	64	
Calf Pasture Hol		Bottom of canyon	(C-40-7) 33aad	Order-ville	8/13/63	5650	Ss west wall; covered east wall	Seeps	Drain into creek			
Calf Pasture Hol		Bottom of canyon	(C-40-7) 33ada	Order-ville	8/13/63	5620	Cretaceous ss stained black at top	Seeps	Drain into creek	5 gpm E	54	
Calf Pasture Hol		NE side of canyon	(C-40-7) 34bcb	Order-ville	8/13/63	5580	Cretaceous ss	Seeps	Drain into creek	1-2 gpm E	58	C.
Red Hollow	Glendale Bench	Bottom of canyon	(C-41-7) 11bad	Order-ville	7/31/63	6520	Slt & cist, Carmel Fm		Used by stock	2 gpm E	58	C.
Muddy Creek		Bottom of canyon	(C-40-8) 2 & (C-39-8)35	Mt. Carmel	8/16/63	6375-6600	Cretaceous ss on shale	Many seeps	Drain into creek	300 gpm E		
OTHER DRAINAGES												
Thompson Wash	Near head of canyon	Center of valley	(C-39-5) 26bad	Alton	8/21/63	8000	Prob. Cretaceous ss	Several	Support meadow	4-5 gpm E*	49	Vegetation suggests potential yield is greater.
Sevier River	Strawberry Creek	West side of valley	(C-38-7) 30dcb	Long V. Jct.	7/20/63	8300	Prob. ls of Brian Head Fm	One	Boards around spring; forms creek	28 gpm M	43	C.

of dry Canyon barely breaches a corner of the Pink Cliffs, and this canyon has no visible springs, although lush growths of vegetation, particularly scrub oak, suggest that ground water in limited quantities is close to the surface. Water Canyon, on the other hand, has several springs whose aggregate yield was measured at 50 gpm. The largest single spring in this canyon is here called Main Spring, Water Canyon, (C-39-5)15ac. It yielded 28 gpm of 44° water on July 6, 1963, and 23 gpm of 45° water on August 19, 1963. There is no development at the spring itself but sometime in the summer of 1963, during the interim between the two measurements, a pipeline was installed about half a mile downstream from the spring. This pipe recovers the flow at that point and carries the water down canyon, past an influent, or losing, reach of the stream channel, for about three quarters of a mile, where it is used for watering stock.

Further development of this spring and other springs and seeps in the canyon could result in less use of this water by non-beneficial riparian vegetation.

Sink Valley Wash and tributaries

Sink Valley Wash has perennial flow only in the vicinity of the springs in Sink Valley, and none of its tributaries has perennial flow to its mouth.

Sink Valley is so named because springs that rise through the Tropic Shale have opened holes and made bogs into which stock animals can sink and become stranded.

Most of the 11 springs or spring areas that were visited in the main part of Sink Valley yield about 2 to 4 gpm, and two, (C-39-5)30dda and (C-39-5)32bbc, yield about 15 to 20 gpm. The total flow of the springs in Sink Valley is probably only 60 to 80 gpm but they support appreciable bog land and in all probability their yield is about 1 cfs. These springs rise in an area where the Tropic is covered by thin alluvium and by bog deposits, but in some of the springs the black clay that is typical of the Tropic is only a few feet below the surface.

Water that rises through the generally slightly permeable Tropic Shale is not readily accounted for. A possible explanation for the water in Sink Valley is that it is coming from the underlying Dakota Formation and is rising to the surface along a previously unrecognized fault. The presence of such a fault was not verified, but in the northern part of Sink Valley, a north-trending low scarp, whose east side is up, is on line with the general lineation of the springs and may be the surface expression of such a fault.

Development of this spring area by shallow or moderately deep wells should result in a yield of 3 to 4 cfs and might result in a yield of 8 to 10 cfs if the source of the water is as extensive as spring (C-40-5)5bcd, which is a mile south of the springs in Sink Valley, suggests it may be. This spring is in the Tropic Shale and yields about 3 gpm from several orifices. Chemical analyses of the water from this spring and of the water from the Sorensen spring, (C-39-5)29bac, in Sink Valley suggest that both waters are from the same source (table 6). An overfull aquifer that extends for a couple of miles could well yield 8 to 10 cfs. Development of this aquifer would stop the flow of the springs and would dry up the land surface in Sink Valley.

During August 1963 a traverse up the Old Elbow revealed no springs in that canyon. Broad Hollow, north of Old Elbow, was visited at the same time, and there was no flow at its mouth.

Swapp Canyon, like the other tributaries to Sink Valley Wash, has no perennial flow to its mouth, but in July 1963 it had a flow in its middle reaches of about 13 gpm from uncatalogued springs near the top of the Tropic Shale. On the north side of Swapp Canyon about 3 miles from U 136 is a spring, (C-39-5)22caa, that is worth mentioning because it is exceptionally well developed and well protected although its yield is only 1 gpm. Development consists of a drain and a pipeline to a storage tank that holds about 1000 gallons. The storage tank feeds into a stock-watering trough. The spring area is protected by barbed wire strung on steel fence posts.

Lower Kanab Creek

Lower Kanab Creek and upper Kanab Creek form a connected drainage system (fig.3), but the sources of base flow for the two sections of the system are different, and normally only spring runoff and flood waters provide a continuous flow of water from the head of Kanab Creek through its lower reaches. Thus for most of any year the flow of upper Kanab Creek does not go below the Elbow, and base flow in lower Kanab Creek is maintained by springs that rise below the Elbow.

During 1963 lower Kanab Creek at US 89 was observed to flow between 2 and 5 cfs on July 5 and 30, and on August 18 and 26. During the same period the Elbow was dry on July 6, 7, and 30 and on August 21 and 26, but was flowing 50-100 gpm on August 19. In August, two floods, probably on the 18th and 24th, passed the Elbow, and the flow observed at the Elbow on August 19 was the result of the earlier flood. The flood of August 24 was reported by the U.S. Geological Survey at 288 cfs at the Elbow. The two July observations of the flow in lower Kanab Creek were made when there had been little or no precipitation in the area for about six weeks (table 2-C), so all flow can be attributed to springs below the Elbow, and none to any discharge from upper Kanab Creek.

The springs that supply the base flow for lower Kanab Creek are in the Navajo Sandstone. The headwaters springs, (C-42-6)4cbc and (C-42-6)9bbd, were not visited during this investigation, but their probable flow of more than 1/2 cfs each is indicated by the flow of upper Kanab Creek above the Big Lake springs, (C-42-6)17caa. Below Big Lake springs many other springs yield water principally from the lower contact of the upper massive member of the Navajo, above the Tenney Canyon Tongue of the Kayenta.

Three Lakes Canyon is a well-watered tributary that joins lower Kanab Creek about half a mile above the US 89 bridge across Kanab Creek. Three principal spring areas, (C-42-6)18cdd, (C-42-6)30baa, and (C-42-6)30bda, support the three lakes for which the canyon is named. These spring areas are estimated to yield 100 to 200 gpm each but they may be capable of yielding appreciably more. These springs are probably controlled by a northward extension of the fault at the lower end of Three Lakes Canyon. This fault has been traced only to about half a mile south of Three Lakes, but its displacement there and the very

presence of Three Lakes Canyon indicate that fracturing, if not actual displacement, continues northward beyond Three Lakes.

Development of this area consists of the two Kanab City wells about a mile north of Three Lakes. It is not known whether or not these wells have in the past affected water levels in the lakes, but the brimfull condition of the lakes in 1963 suggests that pumping the wells has had no appreciable effect on them. Undoubtedly more water could be developed from this area if additional wells were constructed, but an appreciably greater drain on the groundwater body probably would result in lowering the lake levels or in drying up the lakes completely.

East Fork of the Virgin River and tributaries

Summary of yield and potentials

The East Fork of the Virgin River and its tributaries above Mt. Carmel Junction drain an area of about 150 square miles (fig. 8). The principal tributaries that provide water to the East Fork in this reach are Long Valley Creek, Stout Canyon Creek, Lydias Canyon Creek, and Muddy Creek; lesser tributaries may supply appreciable spring runoff but little or no perennial flow. Essentially all water of the system is used within the area during irrigation seasons of dry years, and only spring runoff or flood water reaches the head of Parunuweap Canyon a mile below Mt. Carmel Junction. No records of stream flow are available for this reach of the East Fork, but it has been estimated (Bagley, Criddle, and Higginson, 1959, fig. 11) that the East Fork yields 25,000 acre-feet at its confluence with the North Fork. The total drainage area of the East Fork is about 400 square miles, and the part above Mt. Carmel Junction is in an area where the yield is appreciably greater than it is in the downstream reaches (Bagley, Criddle, and Higginson, 1959, fig. 4). Therefore it would not be unreasonable to believe that at least 50 percent or 12,000 to 13,000 acre-feet of the total flow of the East Fork comes from the 150 square miles above Mt. Carmel Junction. This estimate of downstream yield of the area is in close agreement with the total withdrawals of about 12,600 acre-feet for this reach of the East Fork as permitted under the Burton Decree of 1925.

If we add to this estimate of downstream yield the amount that Bagley, Criddle, and Higginson (1959, table 36) estimated as the amount consumed by irrigated crops, 2119 acre-feet, and by vegetation on valley floor, 127 acre-feet, we can estimate that the water crop of the East Fork above Mt. Carmel Junction, exclusive of that used by natural evapotranspiration on the hillsides, is about 15,000 acre-feet. These estimates indicate that by far the largest part of the water crop moves out of the area as surface flow by the East Fork and a smaller part is consumed by irrigated crops within the area.

In addition to the water accounted for above, springs in some areas, such as the Right Fork of Lydias Canyon, yield fair quantities of water that is used in the immediate vicinity. Development of many of the spring areas by wells could increase the yields of the springs and not only satisfy existing rights but also provide water for other uses. There is little doubt that development of the larger springs and spring areas in Long Valley Creek, Stout Canyon, and

Lydias Canyon and the salvage of water now going to non-beneficial use could increase the present yield and might make available for other use about 10 cfs (about 7,000 acre-feet a year).

Diversions and base flow

The East Fork of the Virgin River is a perennial stream from its headwaters spring near the junction of highways US 89 and U 136 to the diversions of the Mt. Carmel Irrigation Co. south of Orderville (fig. 8).

From the headwaters of the East Fork and its tributaries and including the diversions of the Mt. Carmel Irrigation Co., the Burton Decree allows almost 25 cfs of Class 1 diversions (rights prior to 1891) and 5 cfs of Class 2 diversions (rights between January 1, 1891 and March 12, 1903). Nearly all these rights permit withdrawals from April 1 to November 1, and, based on a duty of water of 60 acres for 1 cfs (or about 7 acre-feet per acre) (Burton 1925), these rights should permit irrigation of almost 1,700 acres. Although withdrawals at the rates allowed should result in total withdrawals of about 12,600 acre-feet, the River Commissioner's Report for 1962 shows that during the irrigation season of 1962, the water delivered under these rights was as follows:

<u>"Owner</u>	<u>Acre-feet</u>
Mt. Carmel East	630.46
Glendale East	1196.52
Glendale West	1030.26
Orderville	1395.14
C. W. Brinkerhoff	226.
Lyle Chamberlain	72.
Mt. Carmel West	1069.20
Henry Carroll	142.
Merrill McDonald	40.
Fred R. Major	70.
Duncan McDonald	92.
Howard Spencer	65.
Grant Heaton	620.
Total	6648.58"

Presumably, all water available was delivered, so the small amount delivered, about 53 percent of the rights allowed by the Burton Decree, must be attributed to a decrease in supply, probably as a result of the deficient precipitation since 1958, the last year when the annual precipitation was at average or above at any of the three stations in western Kane County (table 2). The natural base flow of the East Fork is supplied by many seeps and springs along its main stem and is supplemented by contributions from the principal tributaries, Long Valley, Stout Canyon, Lydias Canyon, and Muddy Creeks, and from many minor tributaries. Return flow from irrigation also contributes to the natural base flow in many reaches of the East Fork, and probably supplies intermittent flow to the East Fork below the diversions of Mt. Carmel Irrigation Co. The springs reported in the valley of the main stem between Glendale and Orderville were not investigated, but most springs of major tributaries and some springs in minor tributaries were investigated in detail and will be discussed in downstream order.

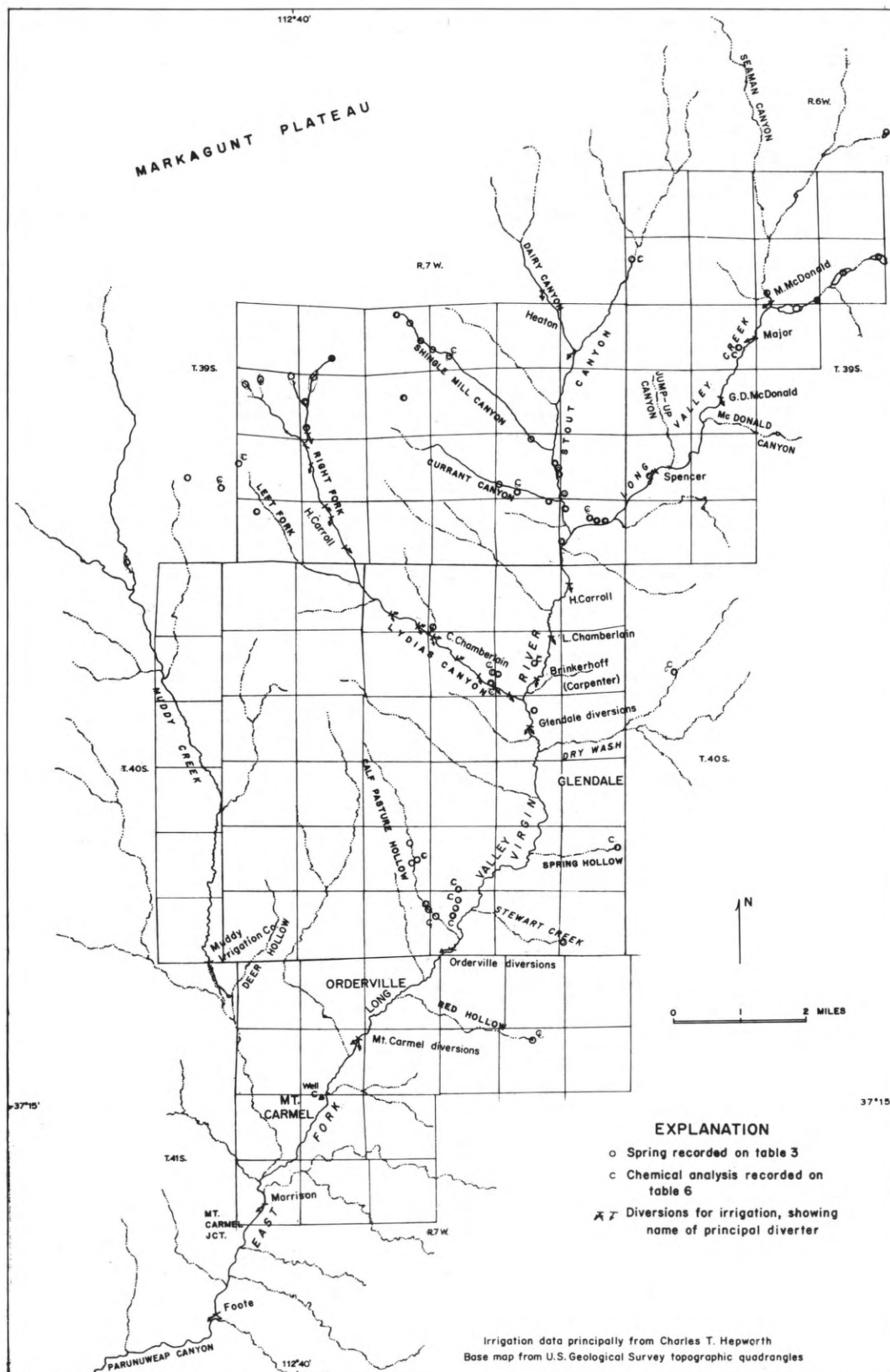


Figure 8.—Map of the East Fork of the Virgin River and tributaries showing springs and principal diversions.

Long Valley Creek

The "upper part of the East Fork is known as Long Valley Creek," says the Burton Decree (Burton 1925), but the decree does not indicate how far the "upper part" extends. In this report, Long Valley is considered to extend almost to Long Valley Junction, and Long Valley Creek includes the waters from the headwaters spring, (C-39-6)9cca, and other tributary waters down to the confluence of Long Valley with Stout Canyon (fig. 8).

The tributaries of Long Valley include Seaman Canyon, the unnamed canyon through which U 136 passes eastward from US 89, and many other small valleys. Although some springs are reported to rise in Seaman Canyon and other springs rise in a few other areas north of the headwaters spring, the waters from these springs are used locally, and no perennial flow passes through Long Valley immediately north of the headwaters spring, hence the springs north of the headwaters do not contribute to the base flow of Long Valley Creek. On the other hand, the springs in the valley traversed by U 136 eastward from Long Valley support three small lakes, the upper and lower LeVanger Lakes and McDonald Lake, and it is likely that in years wetter than the dry year of 1963 overflow from these lakes contributes to the flow of Long Valley Creek.

Even without overflow from these lakes, the beginning of Long Valley Creek is auspicious because about 1 cfs of water rises from a spring area that probably covers only a few square feet, but whose dimensions are obscured by the pond that has backed up behind the first diversion from the spring. From this beginning, Long Valley Creek gains water down to its confluence with Stout Canyon where the flow as measured 5 times in 1963 ranged from 5.06 cfs on April 30 to 3.14 cfs on August 13 (table, next column). This gain in the base flow comes from springs in Long Valley and probably to some degree from seeps or underflow contributions from tributaries such as McDonald Canyon and Jump-up Canyon. This gain in base flow exists despite several diversions from the creek for irrigation.

Only a few of the contributing springs have been catalogued (table 3), but notable among these are (C-39-6)17dbd, (C-39-6)30cad, and (C-39-7)36adb, all of which support two or more small ponds as well as contributing their overflow to Long Valley Creek. Development of these springs by wells probably could double or triple their yields without ill effects other than stopping the flow of the springs themselves.

Stout Canyon Creek and tributaries

To its confluence with Long Valley Creek, Stout Canyon Creek brings about the same amount of water as Long Valley Creek, the major tributary of the East Fork of the Virgin River. In fact, diversions from Long Valley Creek to reduce its flow during the irrigation season that measurements made at the confluence in 1963 by U. S. Department of Agriculture and by me all show Stout Creek contributing more water than Long Valley Creek:

Measured by:		Stout Creek	Long Valley Creek
USDA	April 30	7.19 cfs	5.06 cfs
	May 9	6.79	4.2
	May 24	6.24	4.01
Author	July 25	4.67	3.92
	Aug 13	4.16	3.14

The headwaters spring area, (C-39-6)7bcb, of the main stem of Stout Canyon is 1-3/4 miles upstream from the confluence with Dairy Canyon, and almost 4 miles below the head of Stout Canyon at the south margin of the Markagunt Plateau. This spring area stretches for about 200 yards principally along the west side of the creek. As measured on July 27, the flow began below a dry reach of the stream and increased to about 25 gpm in 50 yards. At the first road crossing, about 0.3 miles downstream, the flow increased to 160 gpm (.35 cfs). Other springs (not recorded) contributed more water, and one mile farther downstream (0.4 mile above confluence with Dairy Canyon) the measured flow was 1.84 cfs.

Dairy Canyon was not investigated, but its creek yields an estimated 1 cfs, and aerial photographs show several probable spring areas between its mouth and the Pink Cliffs at its head. Likely, Dairy Canyon has spring areas similar to those in Shingle Mill Canyon, described below.

The headwaters spring, (C-39-7)16baa, for Shingle Mill Canyon yields about 3 gpm of 48° water from Cretaceous sandstone. This trickle does not reach the next spring area, (C-39-7)16abd, which fills the valley at about 7450 feet and yields an estimated 20 to 30 gpm. Three other flooded-meadow spring areas fill the width of the canyon and yield 50 to 100 gpm each between 7300 and 7150 feet, yet the yields of these areas plus the yield of a side canyon to the southwest at about 1.8 miles above the mouth of Shingle Mill are insufficient to maintain flow throughout the canyon. Thus, most of the yield of Shingle Mill is used by riparian vegetation within the canyon, and only 5 to 10 gpm of base flow normally reaches the main stem of Stout Canyon.

In Currant Canyon, the next tributary of Stout Canyon south of Shingle Mill Canyon, the springs near the head of the canyon, Currant Spring and Hidden Spring, have trifling yields of 1 to 2 gpm, but farther downstream are springs and seeps that provide a total yield at the mouth of Currant Canyon of about 100 gpm, part of which is evaporated or transpired from a swamp and part of which reaches Stout Creek. Many of the water-yielding areas in Currant Canyon are seeps that support grass, principally on the southeast side of the canyon bottom. Only two of these areas, (C-39-7)26ccb and (C-39-7)26cdc, both of which yield more than 10 gpm, have been designated springs.

Between the mouth of Shingle Mill Canyon and the confluence of Stout Canyon with Long Valley there are many spring areas along the main stem of Stout Canyon itself. Six of these areas that yield from 1 gpm to about 200 gpm have been catalogued (table 3). All these springs yield water on the east side of Stout Canyon where the Cretaceous rocks dip northeastward away from the canyon.

Development by wells of several of the largest of these areas, for example Stout Canyon above Dairy Canyon, the spring areas in Shingle Mill, and (C-39-7)26add near the mouth of Shingle Canyon, could double or triple their present yields.

Hidden Lake

The spring that supplies Hidden Lake, (C-40-7)11ddb, yields enough water, probably from sandstone of the Wahweap Formation, to support a lake of about one acre, to maintain lush vegetation surrounding the lake, and to provide an overflow from the lake of about 250 gpm and seepage from the tufa surrounding the lake of about 100 gpm. This spring has built a hollow dome-like mound as the basin in which Hidden Lake lies. This mound is of tufa, a soft, spongy, slightly porous limestone, and is nearly 50 feet high. It now covers 3 or 4 acres, but at some time in the past the mound may have been much more extensive for a deposit of similar tufa covers a ridge about one-quarter mile south of Hidden Lake. At the present time the two exposures of tufa are separated by the valley cut by the East Fork of the Virgin, but they may have been connected when the East Fork was flowing at a higher level.

Hidden Lake has been reported to yield warm water in winter and cool water in summer, but I could find no records of temperatures to support the report. Around the periphery of the lake I measured temperatures of 69° to 74° in July, and I believe the temperature was perhaps 20° lower near the orifice of the spring, which probably is 50 to 75 feet below the surface. In wintertime, water of 50° or less could give the impression of being much warmer if the spring provides sufficient circulation to keep the small surface of the lake from freezing.

The water in Hidden Lake is reported also to be incapable of supporting fish, although the outflow from the lake successfully supported fish. The chemical analysis of the water from this spring (table 6) does not indicate that the water might be lethal to fish, but it is possible that the water as it issues from the spring contains little oxygen, and the small surface area of the lake may inhibit absorption of enough oxygen to support fish.

Lydias Canyon Creek and tributaries

The total potential yield from the base flow of Lydias Canyon may be even greater than the 4 to 5 cfs which appears to be about normal for Stout Canyon, but use of the water by riparian vegetation and development of the water for irrigation within the canyon have reduced the flow so that its estimated yield to the East Fork of the Virgin River is less than 2 cfs. The areas of greatest potential in Lydias Canyon are the extreme heads of the branches of Right Fork and the big spring half a mile above the mouth of the canyon. Although the high springs in Left Fork, such as Trough Spring, (C-39-9)25cbd, and Chokecherry Spring, (C-39-8)25dca, are of interest because they are about 50 and 300 feet, respectively, below the top of a narrow ridge, yields are less than 1 gpm, and there are no springs in Left Fork that are comparable to the springs in the flooded meadows of Right Fork.

Headwaters of Right Fork of Lydias Canyon

The four branches of the Right Fork of Lydias Canyon head below four alcoves cut into the Pink Cliffs of the Markagunt Plateau. The easternmost branch of Right Fork is fed in part by a spring in the Pink Cliffs, (C-39-7)17cda, but all branches receive appreciable water, amounting to an aggregate estimated at about 1-1/2 cfs, from Upper Cretaceous rocks that begin below the Pink Cliffs and continue through a vertical interval of about 150 feet in the west and middle branches and about 300 feet in the east branch. These spring areas, of which the one in the East Branch, (C-39-7)17c and 20b, is the largest, support flooded meadows on slopes of 500 to 600 feet to the mile. The wettest parts of these meadows are avoided by cattle which have worn paths beside them to reach better grazing at the heads. Much of this water is consumed by the vegetation in the spring areas because the yields of these areas were measured at only 375 gpm or not quite 0.85 cfs at the confluence of the major branches of Right Fork in the northwest corner of sec. 29, T. 39 S., R. 7W.

In the east branch of Right Fork the water comes out of the ground at the edges of each tributary swale coming into the main valley, and dead trees at the edges of the wet area suggest that the valley is actively widening due to sapping by this water. Some of these trees evidently started to grow when the spring areas were topographically below their roots. Growth of the spring areas by sapping later permitted the flow of water to begin at a higher elevation and so flood or drown the root systems of these trees.

Development of the spring areas in Right Fork by wells might increase the yield to 2 to 3 cfs which would be ample to supply present beneficial uses and to provide 1 to 2 cfs for other new uses.

Other springs in Lydias Canyon

Big Spring, (C-40-7)10dda, is of interest because its yield of about 1 cfs is rather high among the springs of the area and because its water is appreciably softer than most spring waters of the area; the springs developed for Dr. Thomas on the slopes of a canyon tributary to Lydias Canyon north of Big Spring are of interest because they were developed in areas that did not naturally yield water to the surface.

Big Spring rises at about the center of the alluvial valley in Lydias Canyon, possibly along an unrecognized fault. Water from this spring has a hardness of 140 ppm (parts per million) and contains 180 ppm total dissolved solids (table 6); this water, therefore, is less mineralized than any other spring or well water recorded in this report (tables 6 and 7) except the water from the campground spring on US 89, which contains 145 ppm total solids (table 6). No faults are shown on Cashion's map of the area that includes Lydias Canyon (Cashion, 1961), and I recognized no displacement of Cretaceous rocks on the two sides of the canyon, but I did observe that the dip of the rocks appears to change at the canyon. From the road on the Glendale Bench opposite the mouth of Lydias Canyon

I saw that the rocks on the south side of the canyon dip about 1° to the northeast whereas the rocks on the north side of the canyon dip about 2°. Possibly this change in dip marks a buried fracture that acts as a conduit to bring artesian water from some depth. Development of this spring by a well probably would double or triple its yield.

Dr. Thomas' springs, (C-40-7)11cbc and (C-40-7)10dad, are on the east and west sides, respectively, of a short north-trending canyon tributary to Lydias Canyon. These springs yield about 1 and 3-1/2 gpm of hard, but otherwise good quality water. According to Mr. Cornell Chamberlain, who developed these springs, there was no indication of even dampness at the land surface although he was confident that water must be close to the surface because there were good stands of water birch (Betula occidentalis) at both locations. In order to develop the west spring, (C-40-7)10dad, Mr. Chamberlain bulldozed a trench about 6 to 8 feet deep in the hillside, laid in and gravel packed a 4-inch perforated aluminum pipe as a drain, and installed a storage tank 16 feet long, 3 feet in diameter. This area was yielding a measured 3-1/2 gpm in July 1963. The two smaller spring areas grouped as (C-40-7)11cbc were yielding 1 to 2 gpm on the same day. The water supporting these spring areas is coming from Cretaceous sandstones and its ultimate source is the precipitation that falls on the adjacent ridges.

Calf Pasture Hollow

Calf Pasture Hollow drains about 2-1/4 square miles and its creek joins the East Fork about half a mile north of Orderville. Calf Pasture Hollow, like other canyons in the area, gets its base flow from springs.

On July 18, 1963, after a long period of dry weather, the measured flow at the mouth of the creek in Calf Pasture was 82 gpm. During the period of August 12 to 14, after rainy weather during the first week of August (table 2-C), the flow of the creek ranged from 105 to 150 gpm. Daily morning and late afternoon measurements for those dates follow:

August 12 - 10:30 A	120 gpm
6:30 P	105
13 - 9:15 A	130
5:00 P	105
14 - 8:30 A	150
6:30 P	125

Although there was only a trace of rain during the August 12 to 14 period, the creek showed a decrease in flow during each day but an increase in day-to-day flow. The decrease in flow during daytime hours can be attributed to evaporation and to transpiration; the increase in day-to-day flow probably is due partly to effluence from alluvium and partly to a delayed increase in yield from bedrock springs, due to slow recharge from rainfall.

The rains during the first week of August saturated the banks of Calf Pasture creek and thus put water into the small alluvial ground-water reservoir in the canyon bottom. This water not only began to return to the stream after the flow went below the high water of the rainy period but the saturation of the alluvium also prevented some spring water from returning to the ground in reaches that normally take water from the stream. Yet these effects should be decreasing rather than increasing--in other words, they should result

in a higher base flow after the runoff stopped, but this base flow should decrease with time. Therefore, the explanation for the day-to-day increase in base flow probably lies in the springs that provide the normal base flow. These bed-rock springs receive their recharge from the local drainage area but the rain that provides the recharge requires time--evidently on the order of a few days--to percolate deep enough to affect the flow of the springs. Thus the total increase and the day-to-day increase in the flow of Calf Pasture creek can be attributed to the rain of the first week in August through its saturation of the alluvial ground-water reservoir and its slow recharge to the reservoirs that feed the springs.

The springs in Calf Pasture Hollow were catalogued in perhaps more detail than were the springs in most other canyons, and from this cataloging I can make a few generalizations that apply to the springs in general.

Many of the springs in Calf Pasture rise in the creek bed yet, although their yields are only a few gallons a minute, their presence can be detected by the colored algae that grow in them, and it can be verified by comparing the temperatures of the always (at least in summer-time) cooler waters of the springs with the warmer waters in the creek.

The coloring of the spring areas by algae is quite marked. In most areas it is light yellowish brown but in other areas it is deep reddish brown. These "rusty" spots of color are typical of most of the spring areas and call attention to them in areas where surface water might mask their presence. Temperatures measured at five springs in Calf Pasture were 52°, 54°, 57°, 58°, and 64°F whereas temperatures in the creek were 70° to 80°.

Muddy Creek

The ditch below the mouth of Deer Hollow was flowing about 1 cfs on August 16, 1963 and presumably was carrying the full flow of Muddy Creek. At this point the water was turbid with sediment but about 7 miles upstream, near the top contact of the Tropic Shale, Muddy Creek was also flowing at about 1 cfs and was clear. The reasonably constant flow of Muddy Creek in this reach suggests that there is little or no loss to seepage or to evapotranspiration across the Tropic Shale. This reach is singularly free of vegetation at stream level because the exposed shale evidently does not support plant growth, whereas in the higher reach across the water-yielding Straight Cliffs Sandstone, vegetation is readily supported by the porous fill in the valley bottom.

Most of the downstream base flow across the Tropic Shale comes from springs in the Straight Cliffs Sandstone. Seeps yield water for about three-quarters of a mile upstream from the top of the Tropic to the top of the Straight Cliffs but above the Straight Cliffs the base flow in August was only a trickle. Probably additional springs and seeps occur in the Wahweap and Kaiparowits Sandstones but their yield is not sufficient to provide appreciable flow so they were not investigated.

Tributaries east of the Sevier Fault:
Spring Hollow, Stewart Creek, Red Hollow

Springs in the Carmel Formation near the heads of Spring Hollow, Stewart Creek, and Red Hollow, (C-40-7)25adb, (C-40-7)36ccb, and (C-41-7)11bad, respectively, yielded from 1 gpm in Stewart Creek to about 5 gpm in Spring Hollow when visited in July 1963. These tiny yields supplied drinking water for a few cattle that were grazing in the vicinity.

Traverses up Spring Hollow and Stewart Creek revealed no water coming from the lower exposed parts of the massive upper member of the underlying Navajo Sandstone, and a traverse down Red Canyon to the top of the dry waterfall about 150 feet below the top of the Navajo revealed no water coming from the upper part of the Navajo. Presumably any water that gets into the Navajo in this area moves northeastward down dip from the area. The evidence here might suggest that the massive upper member of the Navajo does not contain water, but it seems more likely that the upper parts of the upper member are dry and that if the base of the upper member were exposed, as it is farther south in Three Lakes Canyon, it might be found to be water bearing.

Johnson Wash

The creek in Johnson Wash is ephemeral above the outcrops of the Lamb Point Tongue of the Navajo Sandstone about six miles north of its mouth. Below that point the springs that issue from the Lamb Point would probably provide perennial flow if they were not diverted for other uses. On August 26, 1963, after a period of appreciable rainfall (table 2), the stream in Johnson Wash was flowing about 1 cfs at Johnson, but was dry about 15 miles farther upstream. Likely most of the flow at that time was from prior rainfall; probably Johnson Wash is dry throughout its length at many times during most summers. The U.S. Geological Survey has reported a flood on August 19, 1963 which was estimated at 1540 cfs about 1 mile above US 89.

No inventory was made of the springs in Johnson Wash but a cursory upstream examination showed that the springs begin at Johnson, where the base of the Lamb Point Tongue is in contact with the Kayenta, and continue intermittently for about four miles upstream, where the top of the Lamb Point Tongue disappears below the surface. A strong fault follows Johnson Wash but the springs appear to be controlled by the lithology rather than the structure of the rocks.

Development of these springs by wells probably would increase their present yield, estimated at 1 to 2 cfs, to 3 or 4 cfs.

Trans-divide migration of ground water as a source of some of the water in springs

The base flow of the East Fork of the Virgin River and of upper and lower Kanab Creek comes from springs. These springs are in many formations almost throughout the whole geologic section; they begin at the Lamb Point Tongue of the Navajo Sandstone and continue with interruptions up to the Brian Head Formation.

Most of these springs receive their supply from deep percolation of precipitation that falls on the adjacent higher areas within the local watershed, but many springs in the cliffs close to the divide between northward- and southward-flowing surface drainage probably are fed in part by water that falls on the higher Markagunt and Paunsaugunt Plateaus to the north, on areas whose surface drainage is tributary to the Sevier River. Movement of ground water from a higher surface-drainage area to a lower surface drainage is a natural phenomenon that can occur wherever the water table is high enough to intersect the land surface. Obviously a high water table will intersect a lower land surface at points below its intersection with a high land surface and, in an area of uneven slopes, such as a gently-sloping plateau faced by cliffs, the water table will intersect the steeper or cliff side below the shallower or plateau side (fig. 9). In time, drainage of the ground-water body may result in actual migration of the ground-water divide and displace it from the surface-water divide, but such migration will occur only if the discharge to the lower drainage exceeds the discharge to the upper drainage and succeeds therefore in differentially lowering the water table. As the water table lowers on the steep side, the gradient steepens and the divide migrates.

In western Kane County, the water table is high under the Markagunt and Paunsaugunt Plateaus, because both areas receive good quantities of precipitation (fig. 6), and both are underlain largely by the jointed and water-receptive Wasatch Formation (fig. 3). It is evident that springs rise along many cliffs that cut these plateaus, and the question of how much of this spring water in the south-facing cliffs is derived by ground-water capture from the natural surface drainage to the north is one that has come up before. Thomas and Wilson (1960, and a longer unpublished manuscript in press) have concluded that the principal source of water for Cascade Spring on the North Fork of the Virgin River is outflow from Navajo Lake on the Sevier drainage. Gilbert and Brown (written communication, 1963) of the Soil Conservation Service have speculated that trans-divide migration of ground water may account for the Virgin River drainage having an apparently higher runoff-precipitation ratio than the headwaters of the Sevier River. The question of how much ground water migrates from the drainage of the Sevier to the drainage of the Virgin and Kanab cannot be answered until detailed work has been done in the several areas, but some of the areas where trans-divide migration probably occurs will be mentioned here, and one area--at the heads of Right Fork and Shingle Mill--will be discussed in some detail.

Upper Kanab Creek - main canyon

The headwaters spring of upper Kanab Creek, (C-38-5) 23cd, probably is supplied from Cretaceous sandstone which receives its water from the overlying Wasatch. The base of the Pink Cliffs is concealed, and the principal orifice of the spring is covered with calcareous tufa and moss, so that the direct source is not readily visible. This spring is directly below the Pink Cliffs which here are about 700 to 800 feet high.

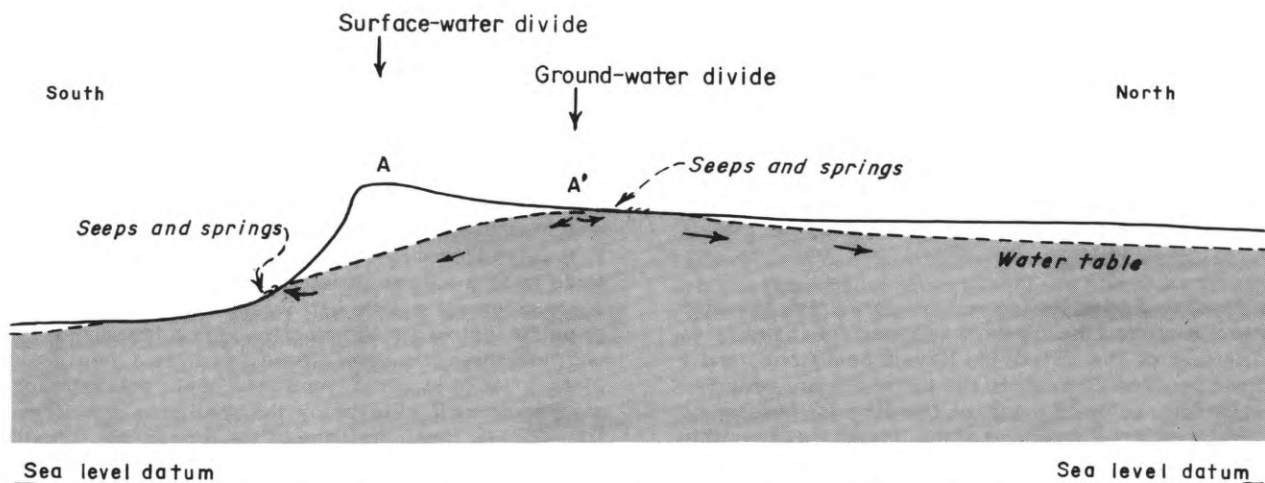


Figure 9.—Sketch profile showing how ground-water divide is displaced by draining. Arrows show general direction of movement of ground water after displacement of divide.

The main orifice yields a fountain of water that bubbles about 6 inches out of the ground at a rate of about 250 gpm, and other seeps and smaller springs in the flooded meadow that surrounds the main orifice yield an estimated 1 cfs (or about 450 gpm).

This water, which issues from the ground under pressure, could not be supplied completely from the precipitation that falls on the overlying rocks within the watershed because 1) the overlying slope is a cliff which is too precipitous to absorb water readily and 2) the bedding in the overlying rocks dips toward the northeast, away from the drainage area. In other words, the water for this spring area, then, evidently is coming out of the rocks updip and under such a great hydraulic head that the source of the water must be the adjacent plateau. (See also figure 5.)

Upper Kanab Creek - Rush Hollow

The three alcoves that are at the head of Rush Hollow all supply water to the creek in Rush Hollow. In both the south and middle alcoves, spring areas (C-39-5)3da-1 and 3da-2, respectively, water comes from Cretaceous sandstone and siltstone beginning 100 to 200 feet below the base of the Pink Cliffs and continuing from other horizons through a vertical distance of more than 100 feet. In the left fork of the south alcove, water issued from at least three different horizons in a vertical distance of 50 to 100 feet. In one horizon the water was issuing from a sandstone above a gray shale that had become stained purple, presumably from algae in the water.

In the south alcove the base of the Pink Cliffs is well exposed because the underlying Cretaceous rocks form a cliff, reasonably continuous with the Pink Cliffs. The slopes here are so steep that direct measurements of thickness could be made only by experienced mountain climbers. As in the headwaters of main canyon, the waters issue updip but are seeps or flows of 2 to 5 gpm. Here the slopes are too steep to absorb direct precipitation and the storage area between the springs and the topographic divide is too small to yield the 130 gpm that was partly measured and partly estimated as the yield of these springs. Thus

these springs must be fed largely by water that falls on the adjacent plateau.

Shingle Mill and Right Fork of Lydias Canyon

The heads of Shingle Mill and Right Fork are about one mile apart at the south edge of the Markagunt Plateau (figs. 10 and 8). Both have extensive spring areas that maintain flooded meadows: Shingle Mill at about 7,150, 7,200, 7,300, and 7,450 feet, plus a small spring at about 7,650; Right Fork at 7,350 to 7,700 feet, plus a small flooded area at 7,900 (fig. 10). The rim of the plateau above the springs ranges from about 8,000 to 8,500 feet. Surface water in ponds and springs on the plateau is at about 8,000 feet and lower.

Profiles A-A' up Right Fork and B-B' up Shingle Mill (fig. 11) show possible relations between the springs in the canyons and water on the plateau. In Shingle Mill the highest large spring is at about 7,450 feet, 500 feet below the water on the plateau. Even the highest spring, which yields only a trickle of 3 gpm, is 300 feet below the water on the plateau. Here there is a clear suggestion that the ground-water divide between Shingle Mill and Swains Creek to the north is appreciably north of the topographic divide. But profile A-A' through Right Fork doesn't completely support this idea. The headwaters spring of Right Fork is at about 7,900 feet. If it is being fed by the same ground-water body as the surface water in Swains Creek--and there is no reason to doubt that it is--then the gradient toward the south is about 100 feet or less per mile, or the 500-foot high mesa between Right Fork and Swains Creek is holding up a locally-high water table. In either case the ground-water divide is not necessarily displaced north of the topographic divide.

None of this evidence is positive proof that the southward-flowing streams that head in the cliffs around the high plateaus are actually capturing water that fell north of the topographic divide, but the geologic and hydrologic conditions favor this explanation for the high-yield springs under the Pink Cliffs. Still to be determined are the ratio of captured to normal yield and the amount of displacement of the ground-water divide.

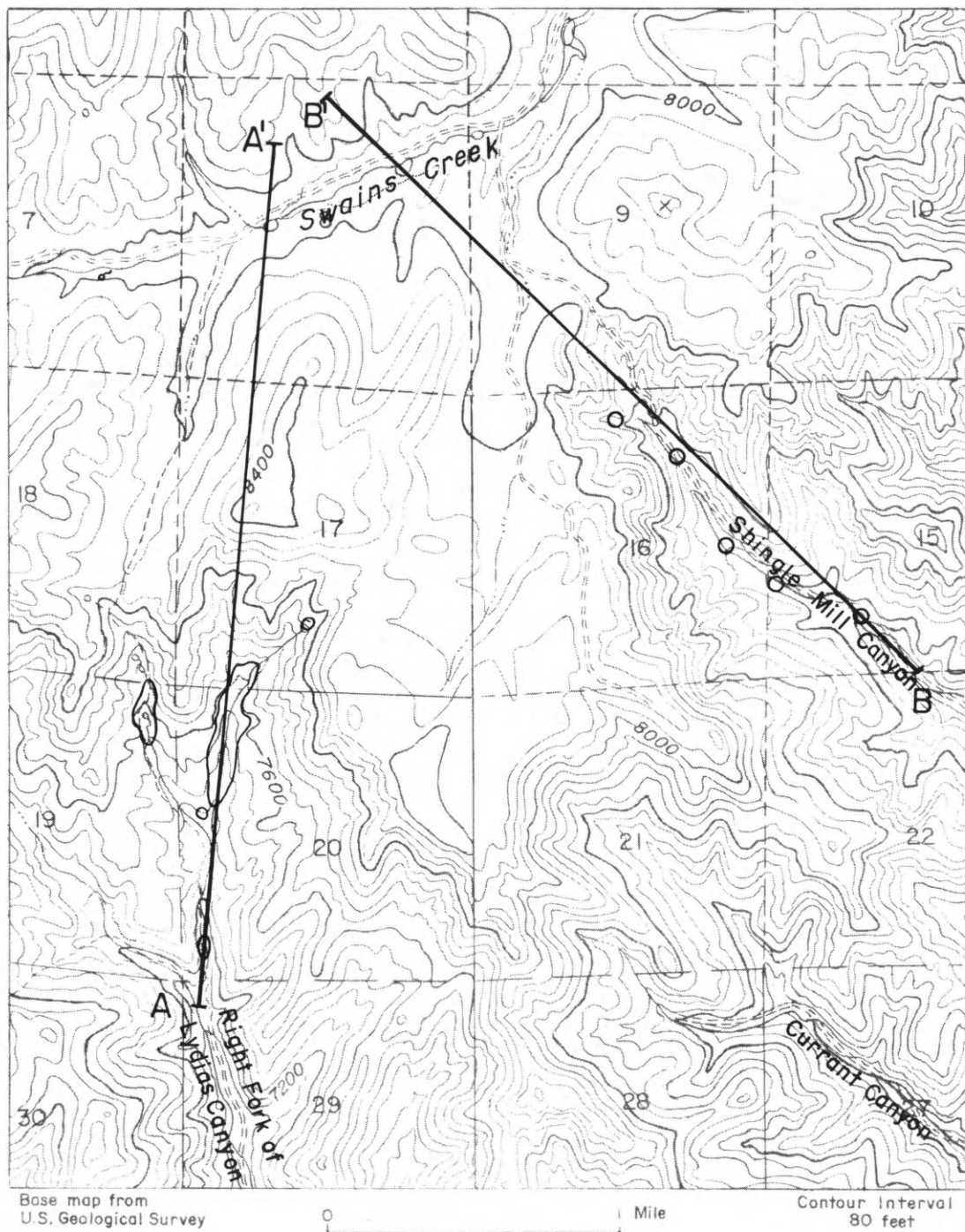


Figure 10.—Map of upper portions of Right Fork of Lydias Canyon and of Shingle Mill Canyon showing principal springs and lines of profiles on figure 11.

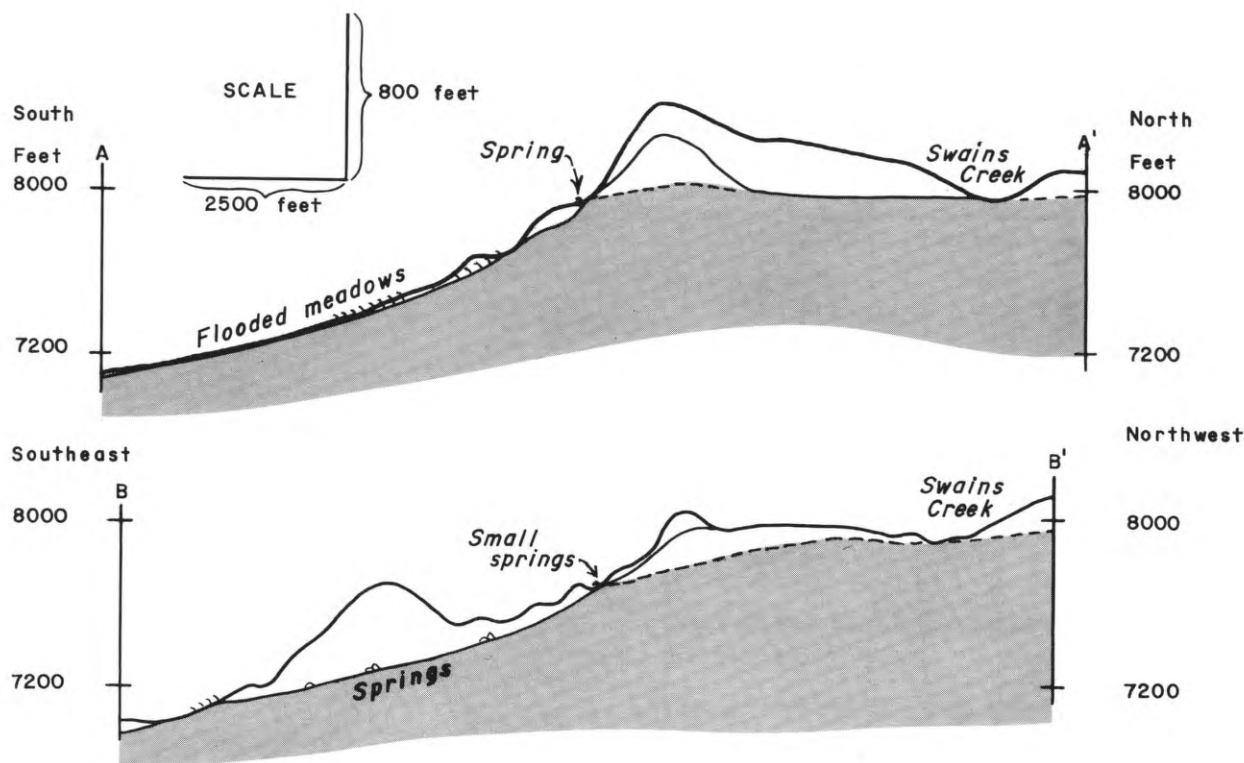


Figure 11.—Profiles: A-A' along Right fork of Lydias Canyon and B-B' along Shingle Mill Canyon. Upper solid lines are topographic surfaces along lines of profiles on figure 10; lower solid lines are surface channels projected to lines of profiles; dashed lines indicate presumed position of the water table.

Wells

Western Kane County probably has fewer than 25 water wells; records of 17 wells in western Kane County plus the records of 2 in Utah and 9 in Arizona in the vicinity of Glen Canyon Dam are included in table 4. Chemical analyses of water from some of these wells are included in tables 6 and 7, and drillers' logs of some are in table 5. The wells in the vicinity of Glen Canyon Dam are discussed in Appendix 2; the others will be discussed briefly here.

The 15 recorded producing wells in western Kane County yield 15 to 1000 gpm and were completed in alluvium or in the Navajo Sandstone at depths of 60 to 600 feet; the two deep wells drilled to 1400 and 1600 feet by Nevada Power Co. also penetrated the Navajo Sandstone, and, although they yielded some water, were not considered sufficiently productive to complete. Two wells in the Navajo Sandstone (Kanab City and Clay Flats, table 7) yielded water containing 220 ppm total solids or less, but samples from wells in the alluvium of the East Fork and Johnson Wash (tables 6 and 7) contained 750 to more than 1800 ppm total solids.

Chemical quality of spring and well water

Composition of natural waters

All natural waters dissolve mineral matter as they percolate through the ground as ground water or flow over the surface of the ground as surface water. The kinds and amounts of minerals dissolved by surface or ground water depend on the kinds and solubility of the minerals in the adjacent rocks and soils, and on the length of time the water is in contact with soluble mineral matter.

Some of the most common elements or ions dissolved in natural water are: 1) calcium and magnesium carbonates dissolved principally from limestone and dolomite and expressed in the analyses as calcium, magnesium, and carbonate (or bicarbonate); (2) sodium and potassium sulfates and chlorides, derived from sodium chloride and sodium, potassium, or calcium sulfate, and expressed as sodium plus potassium, and sulfate and chloride; (3) silica derived from silica-bearing rocks such as sandstone or igneous rocks; (4) iron derived from iron-bearing minerals; and (5) nitrate, derived chiefly from the oxidation of organic matter or from fertilizers. Other less abundant constituents of natural water are fluoride, boron, and metallic elements such as lead, zinc, copper, and uranium.

Table 4.—Records of selected wells in Kane County, Utah, and Coconino County, Arizona

Use of water: Dom, domestic; PS, public supply; Irr, irrigation; Ind, industry
Other data available: C, chemical analysis (Table 6 or 7); L, drillers log (Table 5); P, pumpage (Table 5)

Well number or location	Owner or user and owner's number	Year drilled	Depth of well (ft reported)	Diameter of well (inches)	Reported yield in gallons/minute	Use of water	Water Levels		Other data available	Water- bearing formation	Remarks
							Altitude of land surface datum : + = approximate	In feet below land surface			
Kanab Creek Drainage											
(C-39-5)18bcd	Nevada Power Co. #1	1961-63	1600				6600 ±		C, L	Navajo Ss	Static water level at 86 ft when hole was 703 ft deep.
(C-39-5)30bdc	Nevada Power Co. #2	1962	1400	16			6600 ±		C, L	Navajo Ss	
(C-42-6)19bdc	Kanab City #1	1952	271	16		PS	5500 ±	2	L	Navajo Ss	
(C-42-6)19bcd 1/	Kanab City #2	1957	250	16 & 12		PS	5500 ±	12	L	Navajo Ss	1/State Engineer record gives number as (C-42-6) 19bdc-1. Perforated 155 to 199 ft.
East Fork of Virgin River Drainage											
(C-40-7)34cda	Harry Laver	1962	90	8		Dom	5550 ±	59	C, L	Alluvium	Perforated 75-85 ft.
(C-41-7)7baa 2/	Mt. Carmel Pipe-line Company	1961	60	14	200	PS	5300 ±	7	C, L	Alluvium	2/State Eng. record shows number as (C-41-7)8cdd.
(C-41-7)19ccd-1	Eugene & Bill Rife	1954	350	8	15		5200 ±	235	L		
(C-41-7)30bba	J. W. Morrison	1958	271	6			5175 ±		L	Alluvium	
(C-42-7)19bdd	U.S. Gov't BLM	1956	600	8		Stock	5640 ±		C, L	Navajo Ss	
Johnson Wash Drainage											
(C-40-4-1/2)32bab-1	J. G. Robinson	1947	110	8	450	Irr	6100 ±		L	Alluvium	
(C-42-5)1bab-1	W. D. Fitzgerald	1948	225	6 1/2	250		5600 ±	95		Navajo Ss	Reported in red sandstone to total depth.
(C-42-5)11bb	U.S. Gov't BLM	1935	160	8 1/4	15	Stock	5550 ±	120	C, L	Alluvium	
(C-42-5)23bbb		1960	185	5 1/4	35	Stock	5450 ±	33	L	Navajo Ss	
(C-42-5)26ccb	J. Alvin Judd	1960	285	10 3/4	1000	Irr	5375 ±	21	L	Navajo Ss	Drawdown 90 ft after 5 hrs pumping.
(C-42-5)35bcc	J. Alvin Judd	1959	225	10	45		5360 ±	18	L	Navajo Ss	
(C-43-5)25dbc-1	L. F. Little	1957	120	10		Stock	5120 ±	35	L	Alluvium	Perforated 75-105 ft.
(C-43-5)25dbc-2	L. F. Little	1960	125	16	200		5120 ±		L	Alluvium	Perforated 84-115 ft.
Wahweap Creek Drainage, Utah and Arizona											
(C-44-4)7aab	3/M-C & S Corp. #9	1960	800	20 & 16	1335	Ind	3723	407	C	Navajo Ss	3/Merritt-Chapman & Scott Corp. Perf. 408-600 ft.
(D-44-4)8bbd	M-C & S Corp. #10	1960	770		1320	Ind	3734	407	C, L	Navajo Ss	Perforated 418-610.
T42N, R8E, sec 35	M-C & S Corp. #5	1958	625	18 & 14	1062	Ind	3742	423	C	Navajo Ss	Perforated 475-550.
T42N, R8E, sec 35	M-C & S Corp. #6	1958	675	20 & 16	970	Ind	3736	412	C	Navajo Ss	Perforated 440-464 & 494-590.
T42N, R8E, sec 35	M-C & S Corp. #7	1958	640	20 & 16	910	Ind	3735	402	C	Navajo Ss	Perforated 416-620.
T42N, R8E, sec 36	M-C & S Corp. #8	1959	655*	20 & 16	1200	Ind	3735	422	C, L	Navajo Ss	Perf. 500-620; 620-655 open. *Log shows depth about 725.
T42N, R8E, sec 36	4/N P S #1	1961	703	12	260	PS	3748	444	L, P	Navajo Ss	4/National Park Service; Perforated 503-703.
T42N, R8E, sec 14	M-C & S Corp. #3	1957	1500	10 3/4 to 11 ft	110	PS	4121	880	C	Navajo Ss	Open hole below 11 ft.
T42N, R8E, sec 14	M-C & S Corp. #4	1958	1200	18 & 14	190	PS	4112	870	C, L	Navajo Ss	Perf. 880-1010; open below 1030.
T42N, R8E, sec 23	M-C & S Corp. #1	1957	910	10 3/4 & 7	35	Cool-ing	3907	680	C	Navajo Ss	Perf. 755-910.
T42N, R8E, sec 23	M-C & S Corp. #2	1957	1285	18 to 6 ft	65	Cool-ing	3981	880	C	Navajo Ss	Open hole below 6 ft.

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* indicates perforations
** indicates open hole
Altitudes are of land surface at well in feet above sea level
+ indicates approximate

Perforated 75 to 85 ft

(C-41-7)17baa. Kane County, north edge of Mt. Carmel.
Mt. Carmel Pipeline Co., owner. Altitude, 5300 $\pm$; depth,
60 ft; diameter, 14 inches.

		<u>Depth</u>
Clay, gravel	0	- 30
*Clay, gravel	30	- 52
Clay	52	- 60

(C-41-7)19ccd-1. Kane County, near Mt. Carmel Jct.
Eugene and Bill Rife, owners. Drilled in 1954 by Ben
Gardner. Altitude, 5200 +; depth, 355 ft; diameter, 8 inches.

	<u>Depth</u>
Top soil	1 - 10
Small gravel with sandy clay	10 - 170
Rotten yellow sand rock	170 - 185
Red sand rock	185 - 195
Sand rock	195 - 235
*Red sand, loose	235 - 336
*Sand rock	336 - 355

(C-41-7)30bba. Kane County, near Mt. Carmel Jct. J. W. Morrison, owner. Drilled in 1958 by P. C. Bradshaw, Hurricane, Utah. Altitude 5200 $\pm$; depth, 271 ft; diameter, 6 inches.

		<u>Depth</u>
Sandy clay	0	- 23
Sandy clay with rocky and clay	23	- 43
Gravel	43	- 92
Sandy clay	92	- 110
Gravel	110	- 160
Sandstone ledge	160	- 271

(C-42-7)19bda. Kane County, near Clay Flat. U. S. Govt., owner. Drilled in 1956 by P. C. Bradshaw, Hurricane, Utah. Altitude, 5640 +; depth, 600 ft; diameter, 8 inches.

	<u>Depth</u>	
Sand	0	- 28
Sand and rocks	28	- 550
Water in sand rock	550	- 600

Johnson Wash Drainage

(C-40-4-1/2)32bab-1. Kane County, on Skutum-pah Terrace. J. G. Robinson, owner. Drilled in 1947. Altitude, 6100±; depth, 110(?) ft; diameter, 8 inches.

	Depth
Silt	0 - 10
Clay	10 - 28
Heavy gravel	28 - 52
Black shale	52 - 63
Sand and gravel	63 - 100

(C-42-5)11bb. Kane County, Johnson Wash. U.S. Govt., owner. Drilled in 1935. Altitude, 5550 ±; depth, 160 ft; diameter, 8-1/4 and 6-1/4 inches.

	Depth
Clay	0 - 40
Quicksand	40 - 50
Quicksand and gravel	50 - 62
Sandy clay	62 - 100
Quicksand	100 - 130
Gravel, much water	130 - 137
Sand and gravel	137 - 150
Gravel, quicksand	150 - 160

(C-42-5)23bbb. Kane County, Johnson Wash. Drilled in 1960. Altitude, 5450 ±; depth, 185 ft; diameter, 5-1/4 inches.

	Depth
Unknown	0 - 101
Navajo Sandstone	101 - 185

(C-42-5)26ccb. Kane County, Johnson Wash. J. Alvin Judd, owner. Drilled in 1960. Altitude, 5375 ±; depth, 285 ft; diameter, 10-3/4 inches.

	Depth
Navajo Sandstone	0 - 285

(C-42-5)35bcc. Kane County, Johnson Wash. J. Alvin Judd, owner. Drilled in 1959. Altitude, 5360±; depth, 225 ft; diameter, 10 inches.

	Depth
Blowsand, red	0 - 7
Blue mud and clay, water at 18 ft	7 - 32
*Very clean quicksand, all water-bearing	32 - 87
Clay and sand	87 - 109
**Yellow sandstone, very much fractured (water)	109 - 150
**Loose sand strata	150 - 154
**Yellow sandstone, all fractured, water-bearing	154 - 198
**Yellow sandstone, layers red clay	198 - 221
**Water-washed white sand strata (water-bearing)	221 - 226

(Probably Lamb Point Tongue member of Navajo Sandstone from 109 to bottom.)

(C-43-5)25dbc-1. Kane County, mouth of Johnson Wash. L. F. Little, owner. Drilled in 1957 by P. C. Bradshaw, Hurricane, Utah. Altitude, 5120±; depth, 120 ft; diameter, 10 inches.

	Depth
Sandy clay	0 - 5
Sand	5 - 40
Sandy clay	40 - 60
Sand	60 - 65
Gravel	65 - 75
*Gravel	75 - 105
Clay	105 - 120

(C-43-5)25dbc-2. Kane County, mouth of Johnson Wash. L. F. Little, owner. Drilled in 1960 by P. C. Bradshaw, Hurricane, Utah. Altitude, 5120±; depth, 125 ft; diameter, 16 inches.

	Depth
Sand	0 - 60
Sand, gravel	60 - 75
Clay, sand	75 - 84
*Gravel	84 - 115
Blue clay	115 - 125

Wahweap Creek Drainage

(D-44-4)8bbd. Kane County, about 1/10 mile north of Arizona State line. Merritt-Chapman & Scott Corp. Well #10. Drilled in 1960. Altitude, 3734; depth, 770 ft; diameter 16 inches.

	Depth
Overburden	0 - 10
Caliche	10 - 61
Sandstone, soft red	61 - 160
Sandstone, hard brown	160 - 200
Sandstone, soft brown	200 - 235
Clay and sandstone	235 - 300
Sandstone, some gravel	300 - 320
Clay	320 - 347
Fine sand	347 - 380
Fine sand, some clay	380 - 418
*Fine sand, some clay	418 - 450
*Coarse and fine sand	450 - 545
*Sandstone, soft	545 - 555
*Sand, water bearing	555 - 565
*Sand, water bearing	565 - 580
*Sand fine, water bearing	580 - 595
*Sand fine, water bearing	595 - 610
Fine sand	610 - 685
Sand, fine, coarse	685 - 700
Sand, fine	700 - 730
Sandstone, soft	730 - 770

(Probably all Navajo Sandstone)

Wahweap Creek Drainage

T. 42N., R. 8E., sec. 36. Coconino County, Arizona. Merritt-Chapman & Scott Corp. Well #8. Drilled in 1959. Altitude, 3735; depth, 655 ft (of casing?); diameter 20 and 16 inches.

	Depth
Top soil	0 - 7
Caliche	7 - 20
Soft sandstone	20 - 350
Hard sandstone	350 - 455
Water-bearing sand	455 - 500
*Water-bearing sand	500 - 505
*Water-bearing sand, fine	505 - 615
*Water-bearing sand, very fine	615 - 620
Water-bearing sand, very fine	620 - 655
**Water-bearing sand, very fine	655 - 695
**Sandstone	695 - 725

(Probably all Navajo Sandstone)

T. 42N., R. 8E., sec. 36. Coconino County, Arizona. National Park Service Well #1. Drilled in 1961 by Perry Bros. Altitude, 3748; depth, 703 ft; diameter, 12 inches. This well pumped about 58,250,000 gallons (metered) between Oct. 17, 1961 and June 24, 1963.

	Depth
Red sandy shale	0 - 20
Red sandstone	20 - 60
Red shale	60 - 65
Red sandstone	65 - 200
Red sandy shale	200 - 207
Red sandstone	207 - 220
Light red sandstone	220 - 350
Red sandstone	350 - 370
Light red sandstone	370 - 410
Brown sandstone	410 - 420
Light red sandstone	420 - 450
Light brown sandstone	450 - 500
Light red sandstone	500 - 503
*Light red sandstone	503 - 580
*Brown sandstone	580 - 630
*Light red sandstone	630 - 703

(Probably all Navajo Sandstone)

T. 42N., R. 8E., sec. 14. Coconino County, Arizona. Merritt-Chapman & Scott Corp. Well #4. Altitude, 4112; depth, 1200 ft; diameter, 18 and 14 inches.

	Depth
Top soil, sandy	0 - 8
Caliche with layers of hard white sandstone	8 - 30
Changing from hard light grey to softer brown ledges of sandstone	30 - 365
Uniform light brown sandstone, solid	365 - 815
Broken brown sandstone (first water at 885 with 15' artesian head)	
*Perf. 850 to 1010	815 - 1030
Hard brown sandstone, solid	1030 - 1200

(Probably all Navajo Sandstone)

**Table 6.—Chemical analyses of water from 27 selected springs and 2 wells
in western Kane County, Utah.**

All analyses by State Chemist, Department of Agriculture, State of Utah

Name, owner, or other identifying designation	Spring or well coordinate number	Date collected All 1963	Temperature (°F)	Parts per million											Field sample number	Probable source formation (see table 1 for meaning of symbols)	Yield (gpm) E = Est. M = Meas.
				Silica (SiO ₂)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na + K)	Alkalinity (as CaCO ₃)	Sulfate (SO ₄)	Chloride (Cl)	Nitrate (NO ₃)	Total dissolved solids (Evap. at 105°C)	Total hardness (as CaCO ₃)			
SPRINGS																	
Upper Kanab																	
Headwaters spring upper Kanab	(C-38-5)23cd	July 3	45	0.8	0.04	58	30	0.3	255	10	6	None	277	271	Alton 1	Kk	250
Headwaters south alcove Rush Hollow	(C-39-5)3da-1	Aug. 29	45	1.6	0.09	85	40	20	335	74	8	None	462	376	Alton 8	Kk	50M
Main spring Water Canyon	(C-39-5)15ac	July 6	44	7.8	None	68	33	15	310	19	9	None	332	304	Alton 2	Kk	28M
Stock spring Swapp Canyon	(C-39-5)22caa	Aug. 21	58	1.4	None	60	29	6.5	260	11	10	None	292	269	Alton 6	Kw(?)	1M
Domestic spring Sorensen Ranch	(C-39-5)29bac	Aug. 21	56	1.3	None	70	50	15	340	61	9	None	449	379	Alton 5	Kt	1/2E
Preston Swapp, owner	(C-40-5)5bcd	Aug. 21	50	3.1	0.04	70	37	23	325	34	14	None	420	328	Alton 4	Kt	3M
Lower Kanab																	
Spring south of "Big Lake" west side Kanab Creek	(C-42-6)17dac and 17ddb	Aug. 26	57	6.7	None	32	15	14	140	18	9	2.0	182	139	Alton 7	Jrn	25E
East Fork Virgin River																	
Main spring Alton town supply	(C-38-6)25ccc-1	July 9	47	11.6	None	62	27	12	290	2.2	9	1.5	307	266	Alton 3	Kk(?)	4-5M
Spring on Major property	(C-39-6)17dbd	Aug. 14	50	2.8	None	56	34	6.5	275	5.3	10	None	287	278	Order 17	Tw	100- 150E
Spring at campground on US 89	(C-39-7)36acb	July 20	57	5.6	0.06	30	12	8.1	125	6.1	8	None	145	124	Order 7	Kw	0.8M
Headwaters Stout Creek	(C-39-6)7bcb	July 27	54	1.2	None	46	34	7.4	250	4.7	8	None	283	256	Order 10	Kk	160M
Old Wagon meadow, Shingle Mill	(C-39-7)15cca	Aug. 28	48	5.8	None	44	40	39	375	20	10	None	416	274	Order 19	Kk	200- 300E
Spring in Currant Canyon	(C-39-7)26cdc	July 26	52	3.9	None	65	34	11	285	30	8	None	347	301	Order 9	Kk	10E
Hidden Lake (Temp. 69°-74°)	(C-40-7)11dbb	July 16	72	6.0	None	57	19	22	290	None	10	None	324	221	Order 2	Kw	250M
Chokecherry Spring	(C-39-8)25dca	July 29	45	5.3	None	74	36	14	320	32	10	None	379	334	Order 11	Kw	3/4E
Aspen Springs (Temp. 50°-57°)	(C-39-7)30bcc	July 29	52	8.0	None	97	67	9.7	400	135	14	None	650	538	Order 12	Kw	15- 20E
Dr. Thomas' west spring	(C-40-7)10dad	July 17	56	2.3	0.1	55	24	19	180	54	8	None	295	235	Order 3	Kw	3-1/2M
Big Spring, mouth Lydias Canyon	(C-40-7)10dda	July 17	57	7.6	0.08	35	13	9.7	140	6.7	10	None	180	140	Order 4	Kw	400- 500E
Seep near head of Dry Wash	(C-40-6)7dab	July 22	57	11.5	None	86	39	22	270	132	10	None	527	373	Order 8	Kt(?)	2-3E
At head of Spring Hollow	(C-40-7)25adb	July 31	58	12.1	None	119	59	21	285	258	15	1.5	809	540	Order 13	Jc	5E
Orderville town supply, main spring	(C-40-7)27cdd	July 18	54	7.2	0.04	80	40	29	290	116	12	None	511	363	Order 5	Fault	60M
Part of proposed new town supply	(C-40-7)34bad	July 19	60	40	.02	350	231	46	585	1245	28	None	2708	1819	Order 6	Fault	1/2M
Orderville town supply, south spring	(C-40-7)34bdc	July 16	58	9.9	None	81	40	33	280	144	8	1.0	521	367	Order 1	Fault	12- 13M
Spring in Calf Pasture Hollow	(C-40-7)28adc	Aug. 12	52	6.0	None	117	57	27	370	196	9	None	690	527	Order 15	Kw	2-3E
Spring in Calf Pasture Hollow	(C-40-7)34bcb	Aug. 13	58	5.3	None	78	51	28	290	158	10	None	566	406	Order 16	Kw	1-2E
At head of Red Hollow	(C-41-7)11bad	July 31	58	20	None	143	61	66	250	458	19	8.4	1017	610	Order 14	Jc	2E
Sevier River																	
Bear Spring along Strawberry Creek	(C-38-7)30dcb	July 20	43	4.3	None	68	21	9.4	260	6.5	10	None	272	256	Sevier 1	Tw	28M
WELLS																	
Mt. Carmel municipal well	(C-41-7)17baa	Aug. 27	51	80	None	247	84	146	560	669	16	8.0	1825	962	Order 18	Qal	
Well at mouth of Johnson Wash	(C-43-5)25dbc	July 30	57	7.7	None	106	101	123	390	441	70	None	1227	678	Johnson 1	Qal	200E

**Table 7.—Chemical analyses of water from selected wells in Kane County, Utah,
and Coconino County, Arizona.**

(Analyses supplied by Nevada Power Co., and by Merritt-Chapman and Scott Corp.)

			Parts per million																				
Well number	Owner or other identification	Date Sampled	Silica (SiO ₂)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium plus Potassium (Na+K)	Alkalinity as Calcium Carbonate	Sulfate (SO ₄)	Chloride (Cl)	Nitrate (NO ₃)	Total dissolved solids	Total hardness as Calcium Carbonate	Calcium hardness (as CaCO ₃)	Magnesium hardness (as CaCO ₃)	Phenolphthalein alkalinity (as CaCO ₃)	Methyl orange alkalinity (as CaCO ₃)	Chloride as NaCl	Sulfate as Na ₂ SO ₄	Ortho phosphate (as PO ₄)	pH	Remarks	
WELLS SAMPLED AND WATER ANALYZED BY NEVADA POWER CO.																							
(C-39-5)30bdc	Nevada Power Co.#2	May 62	8.3	Trace								2392	520	425	95	0	292	52		2.5	7.5	Sampled 850 ft.	
(C-30-5)30bdc	Nevada Power Co.#2	May 62	7.0										2352	540	430	110	0	292	48		0	7.5	Sampled 1100 ft.
(C-39-5)18bcd	Nevada Power Co.#1	9/ 8/62	26					360					3100	1250	980	270	0		140	3500	0	7.8	
(C-39-5)18bcd	Nevada Power Co.#1	12/20/62	17					456					900	300	170	130	0		48	500		8.0	Sampled at 1100 ft after 40 balls.
(C-40-7)34cda (C-41-7)17baa	Kanab City Well	July 62	18	Trace								200	140	66	74	0	132	10	17		7.9	Well not further ident.	
	North Orderville	July 62											750	600	280	320	0	400	18				
	Mt. Carmel	July 62	25					560					1330	1200	770	430	0	0	40	1240		7.0	Sampled at Mt. Carmel Motel.
(C-42-7) 19bdd-1	Clay Flats BLM	July 62	18									220	164	100	64	0	164	20	10		8.1		
(C-42-5)11bb	Johnson Canyon BLM	July 62	19									790	570	360	210	0	210	24	660		7.9		

MERRITT-CHAPMAN AND SCOTT CORP. WELLS IN UTAH AND ARIZONA

		<u>1/</u>					<u>2/</u>	<u>3/</u>														
Well # 1				.05	39	18	20		70	7	5.0	232	176			6	11					
Well # 2				0.15	36	18	18		60	7	5.5	216	166			0	11					
Well # 3		12/ 5/57	6	0.1	120	26	148	307	300	116			408	300	108	0	252				7.3	
Well # 4		1/28/58							260													
Well # 5		1/22/58	7	0.3	108	42	165	415	240	148		1029	442	270	172	0	340				7.3	
Well # 6		4/ 7/58	8	0.0	106	48	143	410	160	190		917	460	264	196	0	336				7.5	
Well # 7		4/ 3/59	7	0.05	99	38	206	475	220	164		951	406	248	158	0	390				7.2	
Well # 8		8/11/58	8	0.15	156	55	375	405	800	188		1814	616	390	226	0	332				7.2	
Well # 8		3/11/61	17	0	158	45	339	410	685	188		1684	580	396	184	0	336				7.5	
Well # 9		3/ 2/61	17	0	116	39	149	476	180	138		876	450	290	160	0	390				7.1	
Well #10		3/ 2/61	17	0	116	41	143	476	180	138		822	460	290	170	0	388				7.3	

1/ Date of test

2/ Alkalies as sodium

3/ Bicarbonate (HCO₃)

Fluorides, 0.15;
Manganese 0.05
Fluorides, 0.09;
Manganese 0.05 } Drinking Water Supply

Cooling Supply

Two convenient methods of comparing waters are by means of total hardness and total dissolved solids. Hardness is the quality of water that is usually recognized because hard water requires a greater quantity of soap to produce lather and because it forms scale inside pots and boilers. Water that contains 60 ppm (parts per million) or less is considered soft; 61 to 120 ppm is moderately hard; 121 to 200 hard; and over 200 very hard (Connor and others, 1958, p. 23). Total dissolved solids are usually determined by evaporating the measured sample to dryness; the samples recorded on table 6 were evaporated to dryness at 105° C. Water that contains more than 500 ppm total solids is generally considered to be unsuitable for public or domestic supply, but many irrigation waters that contain 1000 to 1500 ppm are satisfactory for such use, and some animals not only tolerate but relish water that contains more than 5,000 ppm total solids. Water considered suitable by Nevada Power Co. for its generating plant should contain less than 900 ppm dissolved solids.

Waters of Kanab Creek drainage

All waters sampled in both upper and lower Kanab Creek areas were hard to very hard, but contained less than 500 ppm total solids (table 6). None of these waters contained excessive quantities of silica, sulfate, chloride, or iron, but the excessive hardness of all but the sample from the Navajo Sandstone in the lower Kanab drainage suggests that this water should be treated before being used for domestic, public, and most industrial uses.

The water from the Navajo Sandstone in lower Kanab is comparable to the water sampled from the Kanab well in Three Lakes Canyon by Nevada Power Co. (table 7).

The two samples from the Tropic Shale (Alton 4 and 5) are harder than any other surface samples from this drainage, and both contain more than 400 ppm total solids. The evident similarity of the two samples in all constituents except sulfate supports the idea that they have a common source.

The other four samples (Alton 1, 2, 6, and 8) probably all came from Cretaceous sandstone; their range in total solids, 277 to 462, and in other constituents can probably be attributed to the differences in the kinds of rocks through which the waters percolated before appearing as springs and to the length of time the percolation lasted. Samples Alton 1 (from headwaters, upper Kanab) and Alton 8 (from Rush Hollow) both probably percolated through the limestone of the Paunsaugunt Plateau, but Alton 1 with 277 ppm, came from an artesian spring whose water may have moved through a rather large conduit in a short time, whereas Alton 8 with 462 ppm came from a spring at the contact between sandstone and shale and probably was in closer contact with the containing rocks and for a longer period of time.

The high total dissolved solids in the samples collected by Nevada Power Co. from their wells 1 and 2 near Alton (table 7) indicate that three of the four samples came from formations containing large quantities of sulfate, presumably the Curtis or Winsor Formations which contain gypsum, and that the fourth sample, although also containing appreciable sulfate, came from a source of

better water, presumably the upper part of the Navajo Sandstone. Water equal in quality to this last sample probably would be usable by Nevada Power Co. standards (J. H. Zornes, written communication, Sept. 3, 1963), but such water is not nearly so good as water from lower in the Navajo, as indicated by the water from the Kanab City well (table 7) and from the spring near lower Kanab Creek (sample Alton 7, table 6).

Waters of East Fork and tributaries

The 20 samples collected from 19 springs and 1 well in the drainage of the East Fork have a range in dissolved solids of 145 to 2708 ppm and a range in hardness of 124 to 1819 ppm (table 6). The median values of these 20 samples (10 had less, 10 had more) were 450 ppm for total dissolved solids and 350 ppm for hardness.

The best water in the East Fork drainage comes from springs in the Cretaceous sandstones and from a spring in the Wasatch Formation. Nine (Alton 3, Orderville 2, 3, 4, 7, 9, 10, 11, and 19) of the 15 samples collected from springs issuing from the Cretaceous sandstones have less than 425 ppm total dissolved solids, although seven of these are very hard and two, Orderville 4 and 7, are hard. These nine samples probably come from the Kaiparowits or Wahweap Sandstones and are low in all constituents except for calcium and magnesium carbonate; two of the samples, Orderville 4 from the Big Spring in Lydias Canyon and Orderville 7 from the campground on US 89, which respectively contain 180 and 145 ppm total solids, are of water that is as good or better than the water from the Navajo Sandstone (Kanab and Clay Flats wells, table 7; Alton 7, table 6). The only sample from Wasatch Formation (Orderville 17, table 6) contains 287 ppm total solids and has a hardness of 278 ppm. Five (Orderville 1, 5, 12, 15, and 16) of the other six samples, probably from the Wahweap or Straight Cliffs Sandstones, contain between 511 and 690 ppm total solids, and one (Orderville 6), possibly due to surface contamination, contains more than 2700 ppm total solids. In addition to being very hard, the five samples contain 116 to 196 ppm sulfates, appreciably more than do the nine samples from the Kaiparowits and Wahweap.

One sample (Orderville 8) was collected from a spring probably in the Tropic Shale in Dry Wash. It contained 527 ppm total solids, was very hard, and had 132 ppm sulfate.

Two samples (Orderville 13 and 14) of poor quality water were collected from the Carmel Formation in Spring Hollow and Red Hollow. These samples contained 809 and 1017 ppm total solids and sulfates of 258 and 458 ppm. These waters are probably satisfactory for their present use for stock watering.

The only sample (Orderville 18) I collected from a well in this drainage represents some of the poorest water of the area, yet it is water used for municipal supplies in Mt. Carmel. As indicated in Appendix 1 and table 6, this sample contained 1825 ppm total solids and 669 ppm sulfates, both quantities appreciably higher than the maximums recommended by the U.S. Public Health Service.

One other sample from a well in this drainage (North Orderville, table 7) was collected by Nevada Power Co. This water, probably from alluvium, contained 750 ppm total solids and is harder than most spring water in the vicinity. With adequate treatment it would probably be satisfactory for domestic use.

Other waters

One sample (Sevier 1) was collected from Bear Spring on Strawberry Creek in the headwaters of the Sevier River. This water contained 272 ppm total solids and had a hardness of 256 ppm. It was issuing from Tertiary rock, probably limestone of the Brian Head Formation, and is comparable in quality to water from the Wasatch, Kaiparowits, and Wahweap formations.

Samples from wells in Johnson Wash (Johnson 1, table 6; Johnson Canyon BLM, table 7) contained 1227 and 790 ppm total solids and both were high in sulfate. Probably these waters are satisfactory for their present use, irrigation and stock watering.

Included in table 7 are analyses of water from 10 Merritt-Chapman and Scott Corp. wells in the Navajo Sandstone near Glen Canyon. These analyses show a range in total dissolved solids of 216 to 1814 ppm, and it therefore seems evident that different horizons in the Navajo may yield water of appreciably different quality. These wells are so far from the area of interest of this report that detailed interpretations could not prove useful to development of water in the Navajo in western Kane County so no further interpretations are attempted.

Salvage of water through reduction of evaporation and reduction of water-wasting plants

The total amount of water available for all use is limited by the amount available from precipitation, and, of the total amount available, man generally uses only a small part because he has not yet exerted full control over the total supply. In areas where water is abundant the lack of control is not critical, but in areas where water is scarce the lack of control can cause unnecessary hardships.

Full control of precipitation would entail capture and use of all water that falls, and, except in very small areas, total capture is essentially impossible. But if man were to capture and put to beneficial use only the runoff part of precipitation, he would be taking a giant step toward reasonably complete control. In many areas all or most of the runoff is captured, but much of the captured water evaporates from open reservoirs and much more is used by useless water-wasting plants. Thus control of the water supply not only entails capture of the water, but also the prevention of non-beneficial waste after the water is captured; in many areas it is necessary to prevent non-beneficial waste before as well as after capture so that more water is made available for capture.

An accepted practice to make more water available for beneficial use is to salvage wasting water by reducing or eliminating evaporation from surfaces of swamps and open water and by reducing or eliminating water-wasting plants. In some areas every drop of water commands a premium price, and it may therefore be worthwhile to prevent all

wastage, while in areas of great abundance of water, salvage of waste water could cost more than the water might be worth. Most areas have water supplies that are within the range of adequacy; the supplies are not over abundant but they are not especially scarce. And in most such areas some water is wasted. This wastage may be natural and occur in swampland, in flooded meadows, in lush but unnecessary vegetation, or it may be the result of man's efforts, such as applying too much water to irrigated crops, permitting useless plants to grow near ditches, or losing water through unlined or poorly constructed ditches.

I feel that we are not oversimplifying the problem of water wastage if we say that water would not be wasted if it were valuable enough to save. If any wasted water can be put to a use that will offset the cost of preventing waste, then at some time the effort will be expended to stop the waste. If the man who gets some small benefit from a flooded meadow has no better use for the water, it is likely that he will make no attempt to decrease wastage; but if that same owner can make better use of the water by irrigating crops or by diverting the water for any use that will give a greater benefit than the flooded meadow, it is likely that he will at some time decide to take advantage of the better use.

The problem of deciding whether or not to eliminate wastage, then, is one for the water users. Therefore, I do not intend to suggest that water users should start immediately to destroy useless water-wasting plants or to dry up flooded meadows, but instead I intend to suggest that if the water users want to make available more water for any use, one way to obtain that water would be by salvage of water that is now being consumed by relatively non-beneficial uses.

This salvage could be accomplished by 1) developing springs that are feeding flooded meadows, and then diverting the developed water to higher-order beneficial uses, 2) lining ditches and removing non-beneficial vegetation that is now supported by ditch water, and 3) reducing or eliminating non-beneficial, water-wasting plants along natural water courses.

Fair-sized springs that feed flooded meadows are at the headwaters of upper Kanab Creek and in several of its tributaries and are in Stout, Shingle Mill, and Lydias Canyons. These springs probably could be developed inexpensively by drains or short tunnels and perhaps more expensively but more thoroughly by wells, but a greater cost would be involved in transporting the water to the point of use; the high altitude of these areas precludes the nearby use of the water for agriculture so the water would have to be moved several miles if it were to be used elsewhere for agriculture or for industry.

In the East Fork drainage no ditches above the Glendale diversions are lined and not all below those diversions are lined, thus seepage from the ditches supports thick growths of willows and other water-wasting plants. These plants serve no useful purpose and could well be eliminated at the time of lining irrigation ditches. No records of loss from the present ditches are available, but lining of ditches would assure that essentially all water that passes the diversion headgates would reach the farmers' distribution systems. In Escalante Valley a program

of land leveling and ditch lining is reported by Utah State University to have increased efficiency of water use sufficiently to make the farmers' investments in the program worth while (Gardner and Wagstaff, 1963, p. 41 ff). In Kane County, the benefits would have to be measured in terms of the extra water available for beneficial use.

Some of the natural water courses, such as lower Kanab Creek and Johnson Wash, are becoming infested with saltcedar (Tamarix pentandra), a non-beneficial plant that consumes great quantities of water and spreads rapidly. All watercourses have larger or smaller growths of willows (Salix fluviatilis) lining their banks or covering their flood plains.

Both saltcedar and willows consume large quantities of water but they also provide some slight flood protection because they hold the soil together. If both willows and saltcedars were to be eliminated, it would be necessary to replace them with other vegetation or to treat the natural water courses as ditches and provide lining. Obviously, either alternative is costly and would not be attempted until water is worth much more than it is now. But if the saltcedars advance and multiply here as they have in many other areas, they will consume an ever larger amount of the available water supply. Thus, unless control measures are taken, non-beneficial vegetation will continue to consume more and more water, and will soon, if it is not already, be using water for which there is an urgent beneficial need.

Previously proposed surface reservoirs

A larger percentage of a fluctuating supply of surface water may be made available for use by constructing dams that will store water during times of excess supply. Hence, any program for developing the full use of runoff from spring snowmelt and from flash floods must include surface reservoirs if these can be constructed cheaply enough so that the benefits derived are obtained at a moderate cost. The engineering and evaluation of dam sites and surface reservoirs were far beyond the scope of this study, but early in the study I was advised that two possible dam sites had been talked about by residents of Kane County and that it might therefore be worth while to look at the proposed sites—one on Kanab Creek at the Elbow and the other in Dry Wash, a tributary to East Fork about half a mile north of Glendale.

I found records of extensive correspondence on the Elbow dam site in the office of the Soil Conservation Service in Kanab, and pertinent abstracts from that correspondence are given below. But I could find nothing on the Dry Wash site so the notes on that subject are my own.

Elbow Dam Site

The interest in constructing a dam at the Elbow (fig. 7) probably goes back about 30 years, and as long ago as 1944, the Reclamation Service (now U.S. Bureau of Reclamation) stated in a memorandum dated May 25, 1944:

"In view of the limited water supply (2000 to 3000 acre-feet yield at most, measured at Kanab diversion dam), the limited potential capacity of the reservoir site, and the relatively high average silt discharge it is obvious that development at the site for irrigation and/or flood control purposes would be impracticable."

A 1949 report on an extensive watershed survey by Soil Conservation Service includes this statement about the proposed Elbow reservoir, "Little or no flood protection can be expected because of small initial capacity and need for keeping the reservoir as full as possible for irrigation."

These two statements by federal agencies suggest that the benefits to be derived from the construction at the Elbow of a dam with reservoir capacity of 7,000 to 13,000 acre-feet could not justify its cost. They were not made lightly but were the result of considerable investigation by those agencies and by others. In brief, the Elbow dam site was surveyed by Julian Low in November 1935, and estimates of capacity and cost have been made on the basis of this or other surveys; at least two estimates of silt accumulation have been made, one by the Reclamation Service and one by Soil Conservation Service; and estimates of the water available to fill a reservoir have been made from a few measurements of stream flow and from the estimated rainfall on the drainage basin. The estimates of water available range from 5,500 to 12,000 acre-feet a year, and the life of the reservoir, based on speed of silting, is estimated at 17 to 23 years.

Dry Wash Dam Site

Summary

My cursory examination of the proposed dam site on Dry Wash half a mile north of Glendale (fig. 8) indicates that there are two rather important drawbacks to the site, but these drawbacks do not prevent me from suggesting that the site be studied further by a competent dam-site engineer or geologist. As I see them, the present drawbacks are 1) the proposed reservoir lies just west of the main Sevier fault and is cut by at least two faults that might promote seepage from the reservoir (fig. 3) and 2) the comparative narrowness and steep gradient of Dry Wash would require a high and probably expensive dam to store any appreciable quantity of water.

Dry Wash is a tributary to the East Fork of the Virgin River and has no perennial flow at its mouth. Water stored in Dry Wash would have to come from the East Fork of the Virgin or from the few floods and spring runoff in Dry Wash; both Dry Wash sources likely would contribute only a few hundred acre-feet each year. The few stream measurements made on the East Fork during the summer of 1963 suggest that the yield of the stream should be ample to fill a reservoir up to 10,000 acre-feet, but before the site is given serious consideration further periodic measurements should be made of the East Fork about 2 miles above Glendale, of Hidden Lake, and of Lydias Canyon near its mouth.

General geology and the problem of faults

The Dry Wash reservoir area is west of the Sevier fault and is cut by normal faults that have tilted some of the rocks and have formed breccia zones of high probable permeability. The south wall and bottom of Dry Wash are underlain by the Tropic Shale, and the north wall is composed of the Tropic at its base and of the Straight Cliffs Sandstone higher on the wall. The two principal faults are about one quarter and one half mile east of the mouth of Dry Wash, and their trends are about N30W and N-S, respectively (fig. 3). Both faults are downthrown on the west. The displacement on the eastern fault is of the order of several hundred feet, but whereas the displacement on the western fault is only a few tens of feet, the brecciation in the fault zone and the westward tilting of the block between the west and east faults probably have increased the permeability of rocks on the north wall, especially near the canyon mouth. If a dam were placed between the two faults, probably much of the area of potential leakage would then be outside the reservoir, yet the reservoir capacity probably would be reduced less than 20 percent.

The problem of narrowness and steep gradient

The topographic quadrangle at a scale of 1:62,500 (U.S.G.S. Orderville Quadrangle) with a contour interval of 80 feet is not a good map for evaluating and estimating the capacity of a reservoir, but must be used until a future survey produces a more detailed map. This map indicates that the gradient at the bottom of Dry Wash is about 150 feet per mile for the first 1-1/2 miles inside the mouth and increases to 300 feet or more per mile farther upstream and in the tributaries. This gradient indicates a dam 150 feet high would be required to back up water for one mile up the canyon. If a dam of that height were built one-third of a mile inside the canyon mouth, it could retain water up to about the 6000-foot contour. A reservoir filled to the 6000-foot contour would cover an area of about 250 acres and might have a capacity of 8,000 to 10,000 acre-feet. By contrast, a dam about 75 feet high at the Elbow could impound more than 9,000 acre-feet.

The small surface area of a reservoir in Dry Wash would result in smaller losses due to evaporation but the cost of building a high dam would probably be prohibitive.

Recommendations for Dry Wash

I feel that my impressions of the Dry Wash dam site should not be used to condemn or recommend it, and, therefore, if the site is to be given further consideration, I suggest 1) that records of stream flow be collected as mentioned above and that a reconnaissance study be made by a competent dam-site geologist or engineer and 2) that further detailed studies be made if the reconnaissance study results in a favorable report. Detailed studies would include:

Topographic and geologic mapping of the dam site and adjacent area

Test drilling to determine depth of surficial materials and strength of bedrock

Availability of water

Availability of building materials

Kind, size, and cost of dam.

These studies would be costly but all are necessary if the economic feasibility of the proposed dam is to be determined.

Future development of water for industry in western Kane County

The water resources of western Kane County might be developed for industry by 1) removing water that is now in storage in deep sandstone aquifers, such as the two members of the Navajo Sandstone, 2) developing springs that rise from the Tropic Shale in Sink Valley and from the Cretaceous sandstone in upper Kanab Creek, 3) developing and diverting springs in the Upper Cretaceous sandstones and in the Wasatch Formation in Long Valley or in tributaries of Long Valley, 4) developing springs or drilling wells along the fault in Three Lakes Canyon, or 5) building dams to store flood- and spring-runoff water. Of these choices the one that appears to have the greatest potential in the vicinity of the coal deposits east of the Sevier fault in Townships 39 and 40 South is the Navajo Sandstone. In the same vicinity, the spring area in Sink Valley and the spring areas in upper Kanab Creek, although probably of much lower potential than the Navajo, undoubtedly would yield water to shallower wells and might therefore prove to be more useful and more economical even though less productive. West of the Sevier fault the springs in the Upper Cretaceous sandstones and in the Wasatch Formation could probably supply more than 10 cfs to shallow wells or tunnels, but these springs are some distance from the coal deposits and it would probably be necessary to guarantee maintenance of existing rights before development could proceed. Farther south, Three Lakes Canyon might be considered to have potential, but appreciable development probably would reduce the size of the lakes in the canyon or cause them to dry up completely. I have not felt qualified to make a thorough evaluation of the possibilities of surface storage, but prior evaluations by personnel of the U.S. Bureau of Reclamation and Soil Conservation Service suggest that the site that has been given most consideration, the site at the Elbow, would not provide economical storage. These five possible sources of water are considered further below.

1 Navajo Sandstone

Probably the greatest potential source of water is the Navajo Sandstone. Within the Navajo, the two most favorable water bearers are: the base of the massive upper member, probably about 1,200 to 1,500 feet below the top of the Navajo in Johnson Wash, and the base of the Lamb Point Tongue, which is probably about 400 to 500 feet thick and which is separated from the upper member in the vicinity of Johnson Wash by about 100 feet of the Tenney Canyon Tongue of the Kayenta (fig. 3). According to Wilson (1958, p. 113) the "Tenney Canyon tongue pinches out into Navajo

sandstone to the east of Johnson Canyon" and it probably thins northward as well. If so, the two members of the Navajo in the vicinity of Alton may form a single unit 1,600 to 2,000 feet thick. Near Alton the Nevada Power Co. wells penetrated the top of the Navajo at 1,200 feet in sec. 30, T. 39 S., R. 5 W., and at 1430 feet in sec. 18, T. 39 S., R. 5 W. (table 5).

The Navajo underlies about 300 square miles east of the Sevier fault in T. 40 to 42 S., R. 4-1/2 to 7 W., and in T. 39 S., R. 5 and 6 W. in the vicinity of Alton (fig. 3). In this area the greatest depths to the base of the Lamb Point Tongue are in the vicinity of Alton where the base is probably a little more than 3,000 feet deep, and the shallowest depths are in the vicinity of Johnson Wash where the Lamb Point Tongue crops out and forms the surface over large areas. If the bottom 200 feet of either the massive upper member or the Lamb Point Tongue is saturated and if the porosity of the rock is a conservative 15 percent, then the Navajo in this area contains more than 18,000 acre-feet of water per square mile or about 5,000,000 acre-feet in the 300-square-mile area.

No deep-well information is available to support the above estimates of saturation because the cost of drilling wells to depths of 2500 to 3000 feet so far has deterred adequate exploration that will prove or disprove the estimates. Therefore, it is necessary to depend for some support for the estimates on information from shallow wells, from springs, and from deep wells drilled in the Navajo near Glen Canyon Dam, some 75 miles from our area of interest.

Near Kanab, where the Navajo is at the surface, wells that serve the city of Kanab are reported to yield 400 to 600 gpm, probably from the Lamb Point Tongue member; in the same general area along Kanab Creek and Three Lakes Canyon, springs at the base of the massive upper member also yield moderate amounts. Although the Navajo was not tested adequately by the Nevada Power Co. wells which were drilled near Alton but failed to reach the base of the massive upper member, the Navajo did yield about 250 gpm. In Johnson Wash, the presence of springs in the outcrops of the Lamb Point Tongue suggests that this unit is completely saturated at depth down dip from the spring areas; and the reported yield of 1000 gpm with about 90 feet of drawdown from the Judd well, (C-42-5)26ccb, indicates that the Navajo can produce good yields. And in the Glen Canyon area, six Merritt-Chapman and Scott Corp. wells in the Navajo are reported to have yielded an aggregate of about 5000 gpm for the 2-1/2 years that their production was needed.

Possible yields of wells in the Navajo

The possible yields of wells that might completely penetrate the Navajo can be estimated only within broad limits, but if the zone of saturation is as much as 200 feet thick, which is the probably conservative estimate given above, and if the rock is jointed or fractured so that water can move through it at a greater rate than it could between the grains of unfractured rock, the wells might be expected to yield within the range of the maximum yields of the Judd well in Johnson Wash or of the Merritt-Chapman and Scott Corp. wells near Glen Canyon, say 1000 to 1500 gpm. If the Navajo at the point of test

is saturated through a lesser thickness or if the rock is unjointed and less permeable than in the vicinities of the present wells, the yields might be 400 to 500 gpm. Whatever the ultimate yields turn out to be, it will be necessary first to complete some wells before a final and more reliable estimate can be made.

Effect of possible artesian conditions in the Navajo

If some of the more-permeable zones within the Navajo are saturated and are topped by less-permeable zones, water in that part of the Navajo may be expected to be under artesian pressure. This pressure would be controlled largely by the altitude of the outcrop area of the saturated zones, but, because all outcrops of the Navajo are at lower elevations than outcrops of the coal-bearing beds, the pressure would not be sufficient to yield flowing water to wells in the vicinity of the coal beds. At best, the pressure might lift the water several hundred feet above the top of the water-bearing stratum, but the water might still be 2000 feet below the surface. For example, if the Lamb Point Tongue is saturated, artesian pressure could raise the water about as high as its outcrop in Johnson Wash, say 5,100 to 5,200 feet. But a well started at about 6,800 feet in Sink Valley would have to lift the water 1,600 to 1,700 feet plus the drawdown at the well.

Interference or effects on current users of water from Navajo

Within the area of interest, the present withdrawals of water from the Navajo are in the drainages of lower Kanab Creek and Johnson Wash. If water were withdrawn from the Navajo in the upper Kanab Creek drainage, or in the vicinity of the upper tributaries of Johnson Wash, say 10 miles or more north of Johnson, this water would come from storage within the Navajo, and it would take a long time, probably decades, before the effects of pumping would extend out beyond a radius of 10 miles. Meanwhile, if the water withdrawn by present users is carefully measured, it not only will be possible to detect any effects of pumping the proposed deep wells, but there will be some basis for determining just compensation for any interference, if it ever occurs.

2a Tropic Shale in Sink Valley

The present aggregate yield of the springs and seeps in Sink Valley, including that used by local vegetation, is probably little more than 1 cfs, but the water rising in the springs may represent the overflow from a more extensive aquifer than is evident at the surface, and it is possible, therefore, that development might yield appreciably more than the potential 3 or 4 cfs that might be estimated from the springs themselves. The rather tenuous support for this speculation is the spring in the Tropic Shale, (C-40-5)5bcd, about one mile south of most of the springs in Sink Valley. The analyses of the water from this spring and of the water from the Sorensen spring, (C-39-5)29bac, (table 6) are sufficiently similar in all constituents to be of waters from the same source.

If this area could yield 8 to 10 cfs to wells less than 500 feet deep, this water would be available close to the coal deposits. Rights of present users in the area would

have to be satisfied if the area were developed, but there is no perennial base-flow yield to downstream users from this area so there is no need to plan on providing an out-flow from the area. However, withdrawal at the maximum potential rate of 10 cfs probably would result in the removal each year of more water than is returned to the aquifer by natural recharge. If this were to occur, water levels would lower at a rate dependent on the capacity and areal extent of the aquifer and on the amount by which withdrawal exceeded recharge. If the aquifer extends over several square miles and if the annual recharge is more than half the withdrawal, the lowering of the water table might be at a rate that would be low enough to justify development. Reliable approximations of the effects of pumping on the aquifers can be determined only by actual pumping; estimates of the recharge to the aquifer might be made after logs of test wells are examined to determine the thickness and stratigraphic position of the water-bearing beds.

2b Cretaceous sandstone in upper Kanab Creek drainage

The Cretaceous sandstones of the upper Kanab drainage yield appreciable quantities, probably in excess of 5 cfs, in Water, Cougar, Cabin, and Rush Hollows. Development of these areas possibly could increase the yield to 10 cfs which would provide 3 to 5 cfs for use by irrigation around Alton and make the rest available for other uses. But the sources of water are spread so far apart that a long and intricate system of pipelines would be required to bring the water to the coal deposits. In addition, development would have to be gradual to determine the effect on meadow land that now produces forage. Likely these springs would not be so economical a source of supply as the springs in Sink Valley.

3 Cretaceous sandstone and Wasatch Formation in East Fork drainage

Probably a very good source for water for industry, but probably too distant to be a good source for water for developing the coal near Alton, are the many springs in the headwaters of the East Fork and its tributaries. Development of the springs could make available perhaps 10 cfs above the amount now being used. Most of the springs that rise in the valley of Long Valley Creek and in Stout Canyon supply base flow to streams whose water is appropriated, so plans to satisfy existing downstream rights would have to be included in any plans for development of these springs; but other springs, especially in the Right Fork of Lydias Canyon and in Shingle Mill Canyon, yield water that is nearly all consumed by flooded meadows or nearby downstream vegetation and thus they supply little water farther downstream.

Among the springs whose water is now appropriated but which might be developed further are the headwaters and several other large springs along Long Valley Creek, a large spring area about 1-1/2 miles up Stout Canyon, and Big Spring near the mouth of Lydias Canyon. Development by wells of the springs listed below and other similar springs might double or triple their present yields and make that much more water available for beneficial use:

	<u>Estimated yield</u>	<u>Potential by development</u>
Headwaters, Long Valley, (C-39-6)9cca	1 cfs	2-3 cfs
Long Valley, (C-39-6)17dbd	100-150 gpm (0.2-0.3 cfs)	1 cfs
Stout Canyon, above Dairy Canyon	nearly 2 cfs	4-6 cfs
Stout Canyon, near Shingle Mill (C-39-7)26add	200-300 gpm (0.4-0.6 cfs)	1-2 cfs
Big Spring, Lydias Canyon, (C-40-7)10dda	1 cfs	2-3 cfs

In Shingle Mill Canyon and in the Right Fork of Lydias Canyon are springs that feed flooded meadows. At present we have no measurements of the yields of these springs, but springs that can maintain ankle-deep water on grassy slopes with a gradient of 500 to 600 feet to the mile must be yielding appreciable water, water that is available for development. Some of these areas, such as the springs (table 3) that I have listed in the several branches of Right Fork, yield appreciable downstream flow, 375 gpm for those springs, but they also yield other water that is consumed by local vegetation and evaporation.

In order to estimate the yield of these areas I have measured the areas of flooded meadows on aerial photographs, have applied a consumptive-use factor of 3 acre-feet per acre equivalent to a flow of almost 2 gpm, or more than .004 cfs, to the flooded areas, and have added the consumptive-use figure to the apparent downstream yield. The consumptive-use factor gives an approximation of the amount of water that may be salvaged, but the total yield is a better base for estimating total potential of the aquifer supplying the water for the spring. Evaluation of these factors suggests that the potential yield of the areas listed below, if they were developed by wells, could be 4 to 5 cfs.

	<u>Acres of flooded meadows</u>	<u>Consumptive use (cfs)</u>	<u>Meas. or est. down-stream yield</u>	<u>Potential development</u>
Shingle Mill (four spring areas)	40	.16	.5(E)1/	1-1/2 - 2 cfs
Right Fork Lydias (seven spring areas)	70	.28	.85(M)1/	2-3 cfs 2/

1/The downstream flows of Shingle Mill and Right Fork diminish rapidly below the lowest spring areas.

2/Although seven spring areas contribute to the yields recorded, by far the greatest amount of water is contributed by springs (C-39-7)17c and 20b, 18dd and 19aa, 19ba, and 19bb; development of these four areas probably would yield close to the 2 to 3 cfs indicated for all seven springs.

Other springs that must be mentioned but probably would not be considered for development are the LeVanger Lakes, McDonald Lake, and Hidden Lake. Development of these areas by wells would reduce the size of these lakes or cause them to dry up completely, and therefore development will probably not be considered so long as these lakes prove useful as they are.

In all the areas discussed above there is no doubt about the presence of water; there are doubts about the exact amount available, the best way to develop it, the effect of development on downstream users, and the cost of developing and transporting the water to where it can be used.

The amounts of water that can be developed cannot be reliably measured until development proceeds, but better estimates of present yield, which could give better approximations of potential yield, could be made by studying the evaporation and transpiration that are now using up much of the yield and by making periodic measurements of yield below the flooded areas.

A full discussion of the ways to develop these springs is beyond this paper, but an engineering and geological study to determine whether drains, tunnels, or wells would best develop the water could be made as soon as it is determined that the potential supply would be worth the cost of development.

From the amount developed it will be necessary to divert enough water downstream to satisfy present users. Periodic measurements of the present yields of Right Fork, Stout Canyon Creek, and Long Valley Creek would begin to establish basic data that can be used in the future to define rights.

4 Additional Wells in Three Lakes Canyon

The presence in this canyon of the wells that supply Kanab and of three lakes evidently supported by springs suggests that further development by wells could produce appreciably more water than is now being supplied to the lakes. But unless such development were carefully controlled it undoubtedly would be at the expense of one or more of the lakes, which would disappear if the water table were lower appreciably. Development of this area, then, hinges on the value of the lakes as they are, against the value of the water that might be obtained, say 3 to 5 cfs, if one or more of the lakes were drained by this further development.

5 Surface Reservoirs

Surface reservoirs, specifically the one at the Elbow or the one in Dry Wash (both discussed earlier in this report), cannot be completely discarded as a way of developing water for industrial use, but their potential would appear to place them in a position after the Navajo Sandstone and the Cretaceous sandstones, and probably even after the Tropic Formation. If the earlier surveys of the Elbow are correct and if my own short cursory examination of the Dry Wash area has led me to the correct interpretation of its potential, I feel that development of any of the ground-water sources would result in a more dependable supply for year-round use than would development of either surface reservoir.

Recommendations for future work

Collection of basic data

As was pointed out in the introduction, the interpretations given here are little more than guesses because they are based almost exclusively on data collected during the summer of 1963. In water investigations, single records of flow or yield provide only a shaky foundation for interpretation; long-term repeated records are required if an interpretation is to be better than a guess. Therefore there is urgent need to establish a system of record collection to provide information so that the next study of the water resources of the area will be based on solid facts and not on educated guesses.

The data that should be collected in the future include:

Continued measurement of diversions on the East Fork (as now done by the River Commissioner) supplemented by periodic measurements (say once a week April 1 to Nov 1) of 1) Long Valley Creek and Stout Creek at their confluence (staff gages were installed on these streams by the Dept. of Agriculture in 1963 but there is no program for periodic measurements); 2) Lydias Canyon Creek at its mouth and perhaps at Right Fork; and 3) Muddy Creek at its mouth.

Continuous measurement of streamflow on the East Fork by means of an automatic gaging station about one mile below Mt. Carmel Junction just below Foote's diversion. (This station would record the yield of the East Fork in excess of the diversions above this point.)

Periodic measurement of diversions from upper Kanab Creek. This could be accomplished during the irrigation season by weekly measurements of a Parshall flume to be installed at the head of the diversion.

Year-round weekly observations of flow at the flood gage at the Elbow. The presumed long periods of no flow would actually become a matter of record, rather than of conjecture.

Periodic measurement of diversions from lower Kanab Creek. This could be done during the irrigation season by weekly measurements of a Parshall flume to be installed at the diversion dam.

Periodic measurement of flow of Kanab Creek below diversions. This could be accomplished by year-round weekly measurements of a staff gage to be installed at the overflow of the diversion dam.

Periodic measurement of flow of Johnson Wash at Johnson or at bridge where US 89 crosses the creek. Year-round weekly measurements would record downstream yield of this area.

Periodic measurement of flow of some of the larger springs. Of especial interest would be Hidden Lake, Big Spring in Lydias Canyon, headwaters spring in Long Valley Creek, headwaters spring in upper Kanab Creek, headwaters springs in lower Kanab Creek. Each of these would provide interesting information if measured weekly or monthly for a year or two. Easiest to measure would be

Hidden Lake where a Parshall flume could be installed at the overflow. On this spring a continuous record for several months or even a full year might provide interesting information not only about constancy of yield but also about fluctuations due to evaporation and transpiration.

Measurement of water levels in wells. Although there are as yet few wells in the whole of western Kane County, it is suggested that three or four wells be selected and measured annually or seasonally so that they can become the nucleus of an observation-well net that will be needed if more wells are developed.

The data recommended for collection would be of use and interest principally to the local water users to permit them to manage their water resources more carefully, and therefore the measurements of diversions of the tributaries of the East Fork and of spring flow should become the responsibility of the irrigation companies and the river commissioner of the East Fork of the Virgin River. But the establishment of gaging stations on the East Fork and on Kanab and Johnson Creeks has been recommended as part of the State Water Plan (Bagley, 1963, p. 37 and 38), and these new stations should be added to those already operated by the U.S. Geological Survey in cooperation with the State Engineer. The need for these and other stations recommended to be established as part of the State Water Plan is discussed rather thoroughly in that report and will not be repeated here (Bagley, 1963, p. 34-39). Measurements of water levels in observation wells also should be fitted into the cooperative program of the U.S. Geological Survey and the State Engineer.

Further interpretive studies

Interpretive studies that would include quantitative information for a water budget for western Kane County cannot be completed until most of the program proposed above has been in operation for several years, but meanwhile other studies in this area could include 1) further inventory of springs, especially in the Navajo Sandstone; 2) a closer determination of the geologic environment of some of the springs--for example, Hidden Lake and the Big Spring in Lydias Canyon may be on faults, but only more detailed study can prove the actual control; and 3) further sampling of water for chemical analyses. For example, a new study could include sampling of water from upper and lower reaches of the East Fork to determine effect of irrigation on water quality. Sampling the headwaters spring on Long Valley Creek, Stout Creek at confluence with Long Valley Creek, and East Fork at diversion dam above Orderville should give some indication of effect of return flow from irrigation yet not be complicated by the gypsum in the rocks near Mt. Carmel.

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APPENDIXES

I. Municipal Supplies

Alton Town Supply

The water system for the town of Alton consists principally of three springs, (fig. 7) a collection box, a two-mile-long pipeline, a storage cistern, and the necessary mains and pipes for distributing the water to the twenty-odd families that live in Alton. The water system is owned by the Alton Farmers Association, and the users of the water own shares in the association.

The three springs--main, east, and west springs--are about two miles due north of Alton on the south-facing slope of a canyon that drains into the East Fork of the Virgin River (fig. 7). On July 9, 1963 these springs were yielding a measured 4-5 gpm (gallons per minute) for main, and an estimated 1/2 gpm for west and less than a gallon for east. The temperature of the water at main was 47°.

The development at main spring consists of a tunnel 2-1/2 to 3 feet wide and 4-1/2 to 5 feet high dug about 45 feet into the hillside on a bearing about N35E. The portal of the tunnel is protected by a 30-inch diameter culvert, 16 feet long. About half the culvert is exposed on the hill slope, and its entrance is covered by a sliding metal door. The walls and back of the tunnel are of cross-bedded, medium- to coarse-grained, arkosic, poorly-cemented sandstone with interbeds of well-rounded pebbles to two inches in diameter, and with a few clayey layers. The rock of the tunnel is nearly saturated, but the largest flow of water comes from an opening 3 to 4 inches across at the far end of the tunnel. The bedding of the rock dips about 4° into the hillside. Water is collected by a screened pipe at the bottom of the tunnel.

The east spring also has a culvert set into the hillside but it is shorter--only 21 feet long--and the tunnel beyond the culvert appears shorter but was not measured. The collection system here is not so efficient as at main spring because a flow about equal to the near gallon captured escapes around the culvert and feeds grasses down-slope. West spring has a drain system and feeds two pipes; one leads into the collection box in the Alton system and the other feeds a stock trough in the center of the valley.

The concrete storage cistern about one-half mile north of Alton is connected to the springs by a pipeline about 1-1/2 miles long. This pipeline is buried one to two feet deep over most of its length but was exposed where parts recently had been replaced. This line crosses two major ridges between the springs and the cistern. Hand leveling indicates the following pertinent heights above the cistern:

First ridge north of cistern	220 ft
Low point in next valley	135 ft
Second ridge north of cistern	345 ft
Trough in next valley	215 ft
Main spring culvert	380 ft
(Collection box for main, east, and west springs about 10 ft below main spring culvert)	

Source

The source of the water for all three springs is probably the overlying plateau whose area is about one-half square mile, but water from that source could be supplemented by other water reaching the area through faults. The spring area is in part bracketed by faults of the Sevier Fault zone but whether or not these faults contribute water is unknown. More likely the faults in part outline the overlying plateau area (figs. 3 and 7) and help to retain the local precipitation within the area thus feeding not only the springs that supply Alton but also other springs on the north side of the plateau.

The water from the Alton springs is of good quality although very hard, as is most of the water of the region (table 6), but it is of insufficient quantity to supply the needs of the present population and would be wholly inadequate to supply any others who might move into the area. There is a need, therefore, to supplement the present supply or to replace the present system with a new system. The present supply might be supplemented by preventing wastage of seepage around east and west springs, which might yield 1 to 3 gpm additional water, or by prospecting for another spring or seep areas in the vicinity. Two areas in the vicinity would be worthy of investigation: 1) a stand of Ponderosa pines above the main spring may indicate an additional spring there, and 2) an area about 1/3 mile north of the Alton springs where aspen on the north side of the plateau may be drawing their supplies from a near-surface source of ground water.

If these possible sources do not prove adequate or feasible, the most likely source of water for replacing the present supply would be one of the tributaries of upper Kanab Creek or the springs in the main canyon of Kanab Creek. The closest tributary, and probably the best source for appreciably increasing the present supply, is Rush Hollow. Several springs on the east (or southeast) side of main canyon might yield enough without development by wells to double the present supply, and further search in main canyon probably would find other small springs. Development of these springs by tunneling into the Straight Cliffs Sandstone or by drilling shallow wells through the sandstone to the top of the Tropic Shale should produce 25 to 50 gpm, several times the present supply.

Orderville town supply

In the summer of 1963 Orderville was supplied by water from its main spring and middle spring. These springs were yielding 60 gpm (measured) of 54° water and 5 gpm (estimated) respectively. A third spring, south spring, had been developed, and its cistern was connected to the water system, but its yield was not getting into the system, presumably because the pressure from the main spring was preventing the opening of the check valve on south spring. On July 16, south spring was yielding 12-13 gpm (measured) of 58° water. This water was going into an irrigation ditch.

The system is gravity fed, and each successively distant spring is at a higher elevation than the previous one. Precise surveying instruments were not available but the following measurements made by hand level from the irrigation ditch on the west side of Long Valley show that the system has a gradient in relation to the ditch as follows:

Ditch to base of main storage tank	15 ft
Ditch to base of cistern at south spring	15 ft
(measured 27 ft to top of cistern which is reported as 12 feet high)	
Ditch to outlet pipe on cistern at middle spring	60 ft
Ditch to main spring	145 ft
Ditch to proposed spring site between main spring and middle spring	130 ft

(all measurements made from a point on ditch below point measured)

This system, with its nominal yield of 75 gpm and a storage tank whose reported capacity is 150,000 gallons, is probably more than adequate to fill the ordinary needs of 437 persons served by the system (Harline and others, 1963b, p. 100), but is not adequate to meet unusual demands in summertime. If the yield of the springs is consistent, and measurements on other springs suggest a consistency within 10 or 15 percent, this system can supply about 250 gallons per day per person, which although it is appreciably greater than the average per capita use in Orderville of 159 gallons (Harline and others, 1963b, p. 100), is probably much less than the demand in summertime. The inability of the system to meet peak summertime demands can be remedied only by adding an additional source of water to the system. Additional storage facilities, short of a tank having a capacity of 4 or 5 million gallons, can be ruled out because only a higher daily yield could meet a sustained high demand for a period of a month or more.

Additional supplies appear to be available in a spring area on the west side of Long Valley between main and middle springs, but a chemical analysis of this water shows it to be of poor quality, and it is therefore suggested that additional samples be collected and analyzed before this area is considered for development. This area includes several springs and seeps that might yield 20 to 30 gpm if developed by trenching and laying perforated drain pipe. If additional analyses show some or all of this water to be satisfactory it would prove a good supplement to the present supply.

The caution against the future development of this area is based on an analysis of a sample of water from the north end of this spring area which shows that this water is of very poor quality, containing more than 2700 ppm total solids of which almost 1250 ppm are sulfate (table 6). This sample was collected from a test hole that yielded less than 1 quart per minute and it may not be representative of the whole area. Additional sampling and analyses would show which if any part of the water can be used for municipal purposes.

Source of water for Orderville springs

The water from main spring and the water from south spring are so similar chemically (table 6) that it is reasonable to suppose that both come from a common source, the eastward dipping Cretaceous rocks to the west and northwest of the springs, by way of a fault (see figure 5). The eastward dip of these rocks is a local structure whose complete extent has not been delineated but whose eastern border is a north-trending fault along which the Orderville springs rise. This fault is a branch of the Sevier fault zone whose trend follows Long Valley. Probably the middle spring and the spring that has been proposed for development are also on this fault but there is no chemical analysis of the water of middle spring and the analysis of the water from the proposed spring suggests that it is completely unlike the water in main and south Orderville springs.

The recharge area for these springs is only a few hundred acres, but the storage capacity of the overlying rocks should be sufficient to maintain yields at about the present rate because there is little likelihood of up-structure development of water to deplete the reservoir.

Mt. Carmel Town Supply

Mt. Carmel gets its water supply from a well, (C-41-7) 17baa, in the flood plain of the East Fork of the Virgin River. This well is 60 feet deep, and its casing is perforated between 30 and 52 feet. The log of the well shows clay and gravel from the surface to 52 feet and clay to the bottom at 60 feet. The well evidently yields an adequate but unmeasured amount to satisfy the needs of the 33 connections on the system, but the quality of the water is very poor for municipal use. Given below are abstracts of three analyses made at different times by different agencies. These analyses suggest that there is an appreciable variation in the water, but the most favorable of these analyses shows that the water is poor.

Date of collection	3/31/61	July 62	8/27/63
Analysis by	State Dept	Nevada	State
	<u>Health</u>	<u>Power Co</u>	<u>Chemist</u>
	PPM 2/	PPM	PPM
Total dissolved solids	1454	1330	1825
Hardness as CaCO ₃	1022	1200	962
Calcium	269		247
Magnesium	85		84
Sodium plus potassium	69		146
Sulfate	623	1240 1/	669
Silica	13	25	80
Chloride	13	20	16
Total alkalinity	511	560	560
Nitrate	3.8		8

1/ as sodium sulfate

2/ reported as milligrams per liter

This water is of appreciably poorer quality than the water from most springs of the region; its especially high sulfate content could be the result of percolation of the water through beds containing gypsum. Surface outcrops of gypsum are to the south downstream from the well, but the regional northeastward dip of the beds may bring gypsum-bearing strata to the vicinity of the well at depth. Another possible but rather doubtful cause of the poor quality could be that the water is return flow from upstream irrigation. However, the low temperature of 51°F and the low nitrate content both indicate that the water comes from a deep rather than shallow source, and therefore the water probably is not return flow.

II. Wells in the vicinity of Glen Canyon Dam

Merritt-Chapman and Scott Corp. wells in Southern Utah and Northern Arizona

Between July 1957 and February 1961 Merritt-Chapman and Scott completed ten deep wells (fig. 12), all in the Navajo Sandstone. Wells 1 and 2 were 910 and 1285 feet deep and yielded 35 and 65 gpm, respectively. Both wells yielded hard water with TDS (total dissolved solids) of 232 and 216 ppm, respectively. Water from these wells is used for drinking and cooking.

Wells 3 and 4 were drilled to 1500 and 1200 feet and yielded 110 and 190 gpm, respectively. Incomplete analyses show that these waters contain 300 and 260 ppm

sulfates, and thus they probably contain 3 or 4 times the TDS of 1 and 2. Water from these wells was used for cooling.

Wells 5 to 10 inclusive were drilled along Wahweap Creek on an irregular line about 1-1/2 miles long, from a couple of hundred yards to half a mile southwest of and sub-parallel to the creek. These six wells are reported to have pumped 5,000 gpm from the summer of 1960 (Well 10 went into service February 1961) to April 1963.

Five of these wells yielded water containing 822 to 1029 ppm TDS and the sixth, Well 8, yielded water that contained 1814 ppm in August 1958 and 1684 ppm in March 1961.

(More complete records of these wells, logs, and chemical analyses of their water are in tables 4, 5, and 7, respectively.)

Static water levels in wells 5 to 10 are about 50 to 150 feet below the channel of Wahweap Creek but they show no correspondence to the gradient of the channel (fig. 12). Well 9 is farthest upstream and its water level is at 3315 feet, probably 150 feet below the nearest part of the channel of Wahweap Creek. Well 8 is farthest downstream, and its water level at 3313 feet is about 50 feet below the creek channel. Wells in between these two have water levels of 3319 to 3333 feet. Presumably these wells should receive some recharge from Wahweap Creek, but the water levels in these wells themselves suggest movement of water both northwestward and southeastward from Well 7, whose water level at 3333 feet is higher than the level in any other well. Such movement would be both upstream and downstream with respect to Wahweap Creek, and the water levels of these wells, therefore, may be reflecting general movement of ground water from higher areas in the west or southwest and from the creek itself to a common sink in the vicinity of Wahweap Creek.

Water levels in Wells 1, 3, and 4 are 40 to 70 feet above either Wahweap Creek or the Colorado River (fig. 12). They are, however, nearly 100 feet lower than the water levels in Wells 5 to 10, all of which are 200 to 800 feet shallower than Wells 1, 3, and 4. The chemical analyses of the water in Wells 1 and 2 suggest that these wells tap a different aquifer from that tapped by all other wells, and hence water levels in these two wells might be expected to be different from water levels in the rest.

The water level in Well 2 does not fit into the pattern of water levels in Wells 1, 3, and 4; it is more than 125 feet below the closest other level. If the original water level in Well 2 was correct, this level remains an anomaly.

These water levels that existed in Wells 1 and 3 to 10 prior to extensive pumping suggest that the natural movement of ground water is from this area toward the Colorado River, rather than from the river to the ground-water reservoir. Whether or not pumping has changed the direction of movement is not known because there are no records of change in water levels.

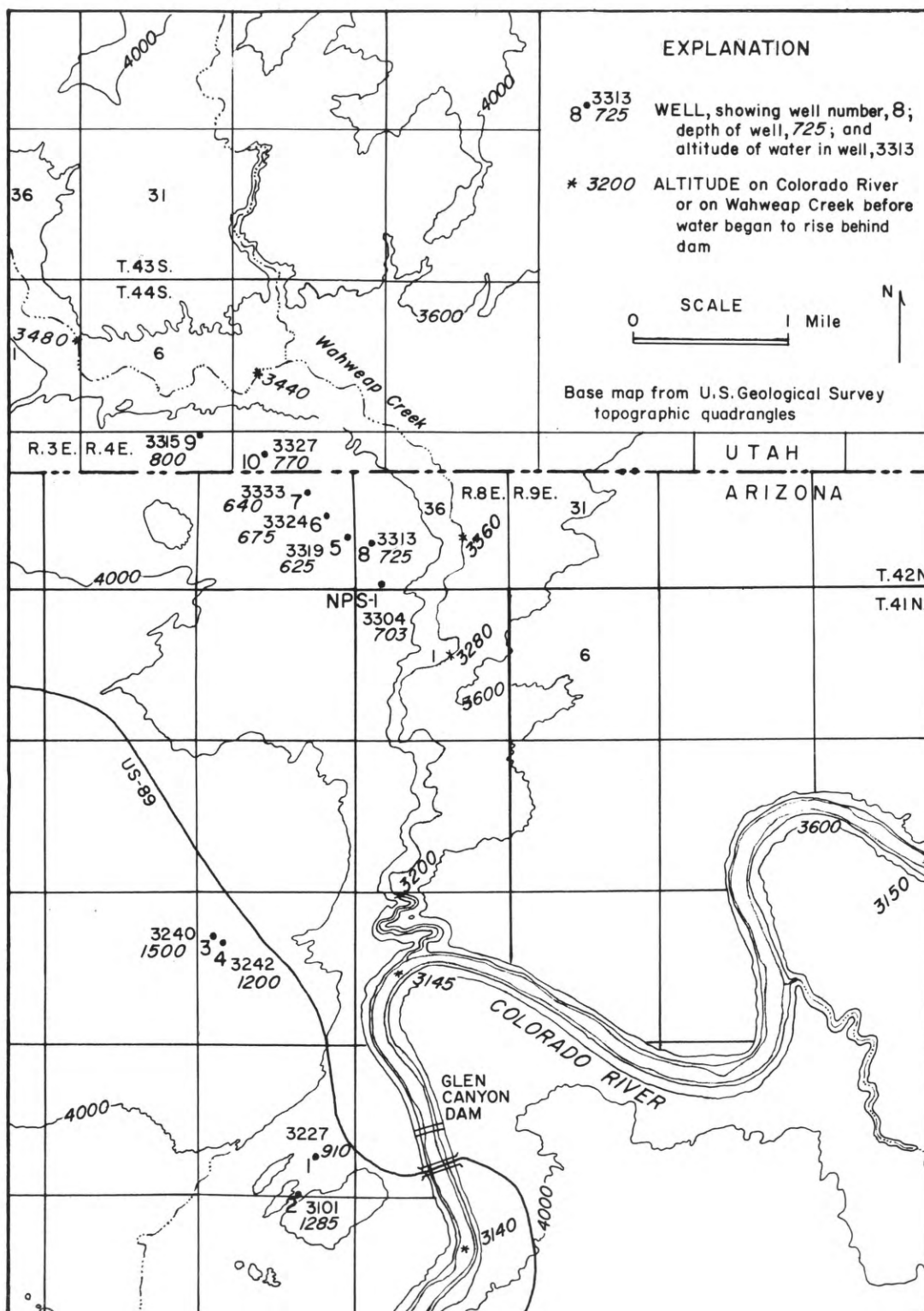


Figure 12.—Map of vicinity of Glen Canyon Dam showing principal wells, well depths, and water levels in those wells.

Glen Canyon Recreation Area well

The National Park Service Well No. 1 in sec. 36, T. 42 N., R. 8 E., in Coconino County, Arizona, was drilled to a depth of 703 feet, probably all in Navajo Sandstone. Static water level after drilling in the well was at about 3304 feet above sea level. This water level fits into the pattern established by the Merritt-Chapman and Scott Corp. wells (section above and fig. 12). The National Park Service reported that the well pumped about 58,250,000 gallons between October 17, 1961 and June 24, 1963.

During drilling of this well, the first water was reached at 450 feet, and by the time drilling was completed the water had risen 6 feet to the static level of 444 feet below the surface.

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