Ground-Water Conditions and Geologic Reconnaissance of the Upper Sevier River Basin, Utah

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1836

Prepared in cooperation with the Utah State Engineer

Ground-Water Conditions and Geologic Reconnaissance of the Upper Sevier River Basin, Utah

By C. H. CARPENTER, G. B. ROBINSON, Jr., *and* L. J. BJORKLUND

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1836

Prepared in cooperation with the Utah State Engineer

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1967

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

Library of Congress catalog-card No. GS 67-168

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

TABLES

GROUND-WATER CONDITIONS AND GEOLOGIC RECONNAISSANCE IN THE UPPER SEVIER RIVER BASIN, UTAH

By C. H. Carpenter, G. B. Robinson, Jr., and L. J. Bjorklund

ABSTRACT

The upper Sevier River basin is in south-central Utah and includes an area of about 2,400 square miles of high plateaus and valleys. It comprises the entire Sevier River drainage basin above Kingston, including the East Fork Sevier River and its tributaries. The basin was investigated to determine general ground-water conditions, the interrelation of ground water and surface water, the effects of increasing the pumping of ground water, and the amount of ground water in storage.

The basin includes four main valleys—Panguitch Valley, Circle Valley, East Fork Valley, and Grass Valley—which are drained by the Sevier River, the East Fork Sevier River, and Otter Creek. The plateaus surrounding the valleys consist of sedimentary and igneous rocks that range in age from Triassic to Quaternary. The valley fill, which is predominantly alluvial gravel, sand, silt, and clay, has a maximum thickness of more than 800 feet.

The four main valleys constitute separate ground-water basins. East Fork Valley basin is divided into Emery Valley, Johns Valley, and Antimony subbasins, and Grass Valley basin is divided into Koosharem and Angle subbasins. Ground water occurs under both artesian and water-table conditions in all the basins and subbasins except Johns Valley, Emery Valley, and Angle subbasins, where water is only under water-table conditions. The water is under artesian pressure in beds of gravel and sand confined by overlying beds of silt and clay in the downstream parts of Panguitch Valley basin, Circle Valley basin, and Antimony subbasin, and in most of Koosharem subbasin. Along the sides and upstream ends of these basins, water is usually under water-table conditions.

About 1 million acre-feet of ground water that is readily available to wells is stored in the gravel and sand of the upper 200 feet of saturated valley fill. About 570,000 acre-feet is stored in Panguitch Valley basin, about 210,000 in Circle Valley basin, about 6,000 in Emery Valley subbasin, about 90,000 in Johns Valley subbasin, about 36,000 in Antimony subbasin, about 90,000 in Koosharem subbasin, and about 60,000 in Angle subbasin. Additional water, although it is not readily available to wells, is stored in beds of silt and clay. Some ground water also is available in the bedrock underlying and surrounding the basins, although the bedrock formations generally are poor aquifers.

The principal source of recharge to the valley fill in the upper Sevier River basin is infiltration from streams, canals, and irrigated fields. Some ground water also moves into the valley fill from the bedrock surrounding the basins.

The basin contains about 300 wells, most of which are less than 4 inches in diameter, are less than 250 feet deep, and are used for domestic purposes and stock watering. More than half the wells are flowing wells in Koosharem subbasin.

Approximately 82,000 acre-feet of ground water was discharged in 1962 from the valley fill. Springs discharged about 33,000 acre-feet, wells about 3,000, and drains about 3,000; and evapotranspiration from phreatophyte areas about 43,000 acre-feet. Springs in bedrock discharged an additional 75,000 acre-feet. Most of the water discharged by springs, wells, and drains was used for irrigation.

The ground water in the basin generally is of good chemical quality. The water is excellent for irrigation and stock but is not as desirable for most domestic and industrial uses because of its hardness. The dissolved-solids content of the ground water generally increases slightly from the upstream end of the individual ground-water basins to the downstream end owing mostly to repeated use of the water for irrigation.

Surface water and ground water in the upper Sevier River basin are interconnected, and the base flows of streams are affected by changes in ground-water levels. Increased pumping of ground water would result in (1) an increase in the recharge to the aquifers from surface-water sources or (2) a decrease in the discharge from streams, springs, flowing wells, and areas of phreatophytes or (3) a combination of these.

About 43,000 acre-feet of ground water is now discharged annually by evapotranspiration from phreatophyte areas, and perhaps one-third of this loss, or about 14,000 acre-feet, could be salvaged by eliminating wet areas and phreatophytes. The areas where water could be salvaged are at the downstream ends of Panguitch Valley basin, Circle Valley basin, and Antimony subbasin. Most of the 14,000 acre-feet of water could be pumped from large-diameter wells or developed by properly designed drains without greatly affecting streamflow and with only moderate effect on spring discharge. If the wells were properly located, the pumping would lower water levels and dry up wet areas where phreatophytes grow. Conjunctive use of ground water and surface water would facilitate the more efficient use of all water resources in the basin.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

The U.S. Geological Survey, in cooperation with the Utah State Engineer, investigated ground-water and geologic conditions in the upper Sevier River basin to determine the following: the availability of water in the unconsolidated valley fill and the consolidated rocks in the basin, the amount of water in storage in the valley fill, the relation of ground water and surface water, and the effect of pumping additional quantities of ground water. The invesigation was part of a cooperative program of ground-water investigation in the entire Sevier River basin, which began with a study of ground-water conditions in the central Sevier Valley in 1956 (Young and Carpenter, 1965).

The investigation in the upper Sevier River basin included determination of the relation of geology to ground water; source, occurrence, recharge, and discharge of ground water; present ground-water development; fluctuations of water levels; chemical quality of ground and surface waters; relation between ground water and surface water; inflow-outflow analyses of several subbasins; the amount of ground water stored in the valley fill; and conclusions about potential development and its effect on hydrologic conditions in the area.

LOCATION AND EXTENT OF THE AREA

The upper Sevier River basin occupies about 2,400 square miles in south-central Utah, and it includes parts of Garfield, Iron, Kane, Piute, and Sevier Counties (fig. 1). It comprises the Sevier River drainage basin above Kingston, including the Sevier River, the East Fork Sevier River, and their tributaries. The geologic reconnaissance covered the entire drainage basin, but the detailed hydrologic study was concentrated in the valleys in an area of about 300 square miles.

PREVIOUS WORK

Previous hydrologic studies in the upper Sevier River basin by the U.S. Geological Survey resulted in reports on the surface-water resources of the Sevier Lake basin (Woolley, 1947), the ground-water resources of the Bryce Canyon National Park area (Marine, 1963), and the hydrology and hydrogeology of Navajo Lake (Wilson and Thomas, 1964). The Geological Survey has collected streamflow records in the basin since 1911 and has measured ground-water levels in the basin since 1935. These data have been published annually or at intervals of 5 years in U.S. Geological Survey Water-Supply Papers. The Sevier River water commissioners have measured and compiled records of diversions for irrigation for most years since 1917.

Investigations of the geology and geography of parts of the upper Sevier River basin and adjacent areas have been made by Averitt (1962), Callaghan (1938, 1939), Callaghan and Parker (1961, 1962a, b), Gregory (1944, 1945, 1949, 1950a, b, 1951), Gregory and Moore (1931), and Willard and Callaghan (1962).

Honorable LeRoy H. Cox (1936), judge of the Fifth Judicial District of the State of Utah, compiled water rights in the upper Sevier Rever basin in a court decree adjudicating the Sevier River system.

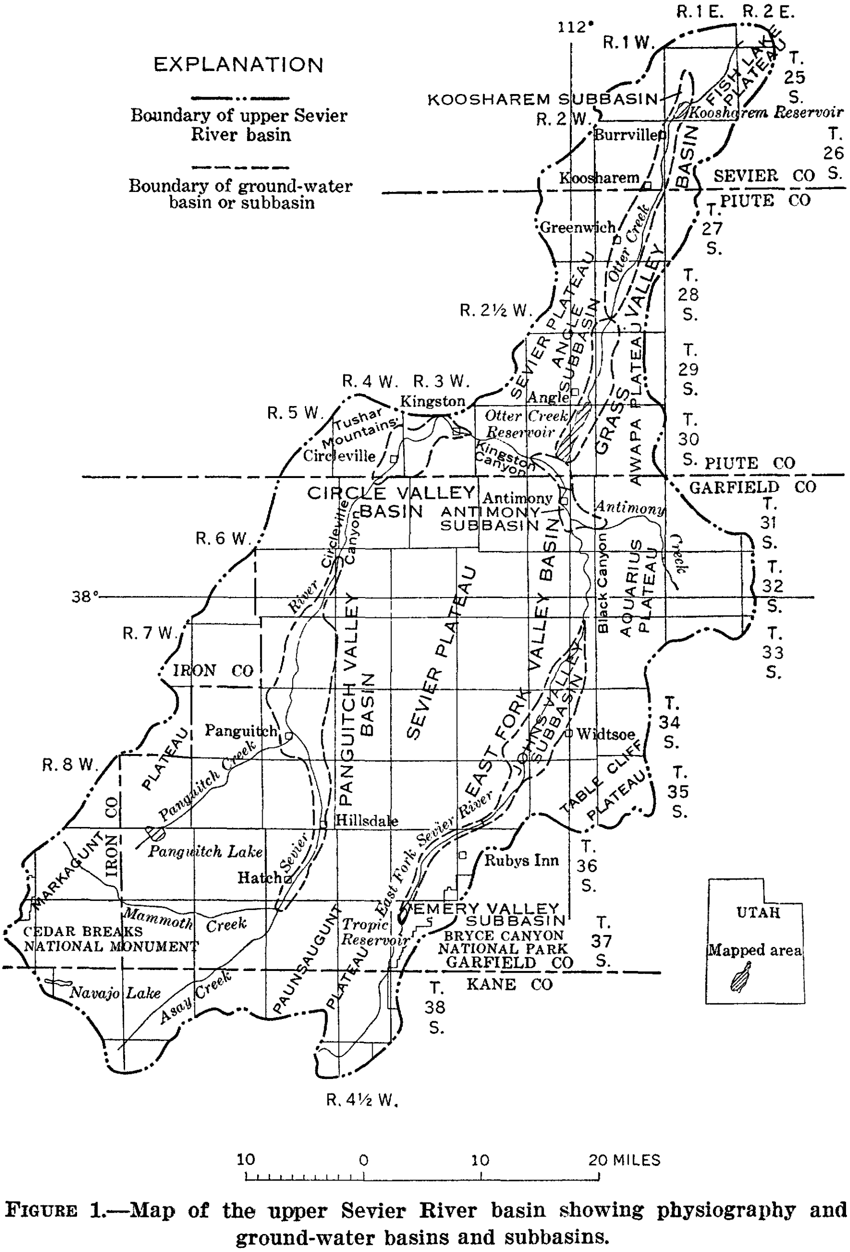

FIGURE 1.—Map of the upper Sevier River basin showing physiography and ground-water basins and subbasins.

PERSONNEL AND METHODS OF INVESTIGATION

R. A. Young, project chief, and C. H. Carpenter began the investigation in July 1961. Mr. Young was transferred in December 1961, and L. J. Bjorklund was assigned as project chief. Mr. Bjorklund was assigned to another investigation in the Sevier River basin in September 1962, and Mr. Carpenter was designated project chief. G. B. Robinson, Jr., was assigned to the project in February 1963. R. D. Feltis supervised the test-drilling program during the summer of 1962, assisted by G. B. Robinson, Jr., and they prepared a report on the test drilling (Feltis and Robinson, 1963.)

Many types of basic data were collected and analyzed during the investigation. Much of the data, including well and spring records, water-level measurements, well logs, and chemical analyses, are included in a separate report (Carpenter, Robinson, and Bjorklund, 1964).

More than 300 wells and 50 springs were recorded; periodic water-level measurements were made in 55 observation wells and water-level recording gages were maintained on 4 wells. Estimates of ground-water discharge from wells, springs, and drains were made using periodic discharge measurements at selected locations and single measurements at other locations. Aquifer tests were made using selected wells to determine well performance and the hydraulic properties of the aquifers. Chemical analyses were made for 10 samples collected from surface-water sources and 35 samples collected from ground-water sources.

Many drillers' logs were studied to provide information about the thickness and composition of the valley fill, and in addition 21 test holes were drilled during 1962. The test-drilling program was financed by the U.S. Geological Survey in cooperation with Garfield, Piute, Sevier, Sanpete, and Millard Counties, many of the irrigation companies in those counties, and the Utah State Engineer. The test holes were drilled by the rotary method, and composite samples were obtained for 10-foot intervals. The samples were examined microscopically to determine their mineral and fossil content, and electric and gamma-ray logs of several of the holes were made to help indicate the character and thickness of the material penetrated. Seven of the test holes were cased and used as observation wells.

A geologic map was compiled mainly from field reconnaissance and photogeologic data and partly from data from available reports.

Stream-gaging stations were installed at Panguitch Creek near Panguitch, East Fork Sevier River near Antimony, and Otter Creek near Antimony. Streamflow data from these and other stations and records of diversions for irrigation were studied and compared with ground-water levels and precipitation data to determine the relation between ground water and streamflow.

The amount of ground water consumed by evapotranspiration was estimated from data on consumptive use by phreatophytes in other areas in Utah and in other Western States. These data were applied to areas of phreatophyte growth in the upper Sevier River basin. Evaporation was estimated from areas of surface reservoirs and rates of evaporation measured at Piute Reservoir in the central Sevier Valley (Young and Carpenter, 1965).

Inflow-outflow studies were made for all basins and subbasins, using all available data for ground water, surface water, evapotranspiration, geology, and climatology. These studies accounted for all water entering and leaving each area.

ACKNOWLEDGMENTS

Officials of Garfield, Piute, Sevier, Sanpete, and Millard Counties and of some irrigation companies assisted in financing and organizing the test-drilling program.

Information on streamflow was furnished by the Sevier River water commissioner, K. B. Christensen. Personnel of the Soil Conservation Service, U.S. Department of Agriculture, helped map and classify phreatophytes and provided information on irrigation. Personnel of the National Park Service helped with the collection of water-level data in the Bryce Canyon National Park area. Many individuals contributed information about their wells and permitted the measurement of water levels in the wells.

WELL AND SPRING NUMBERING SYSTEM

The well and spring numbers used in this report indicate the location by land subdivision according to a numbering system that was devised cooperatively by the Utah State Engineer and the Geological Survey about 1935. The system is illustrated in figure 2. The complete number 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 well within the 10-acre tract (designated by a number). If a spring is indicated, the final number is omitted. 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 Bureau of Land Management, and the letters a, b, c, and d designate respectively the

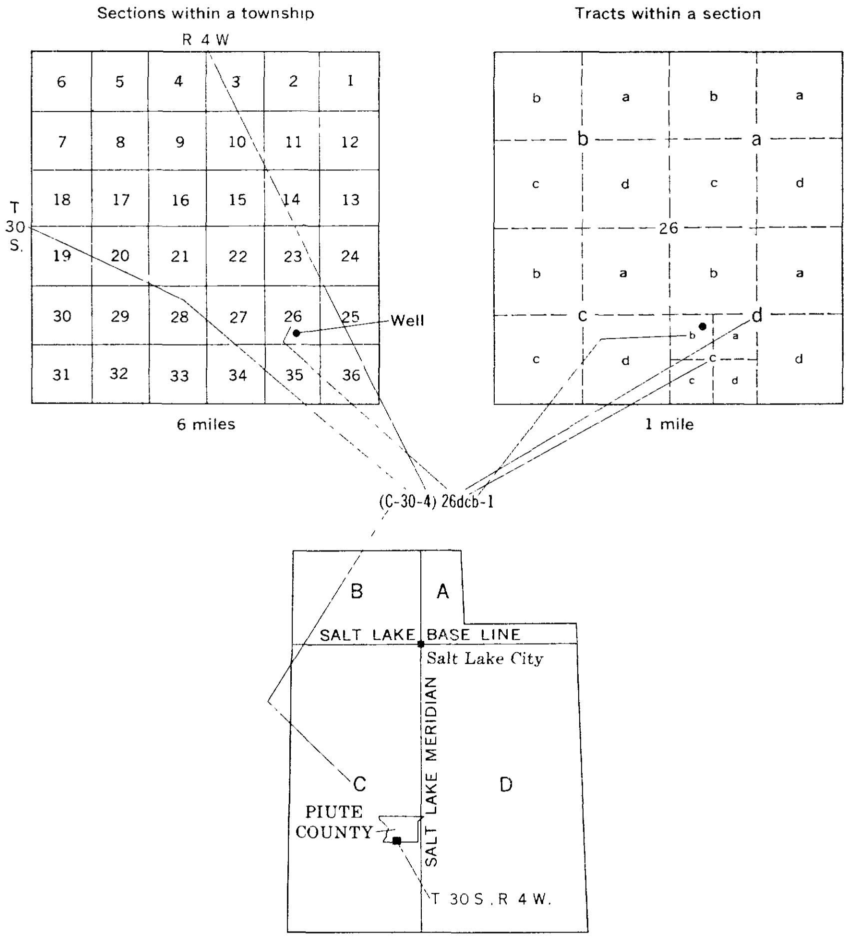

FIGURE 2.—Well and spring numbering system used in Utah.

northeast, northwest, southwest, and southeast quarters of the section, of the quarter section, and of the quarter-quarter section. Thus, the number (C–30–4)26dcb–1 designates well 1 in the NW¼SW¼SE¼ sec. 26, T. 30 S., R. 4 W., the letter C showing that the township is south of the Salt Lake Base Line and the range is west of the Salt Lake Meridian.

GEOGRAPHY

PHYSIOGRAPHY

The upper Sevier River basin is in the High Plateaus of Utah section of the Colorado Plateaus physiographic province (Fenneman, 1931, p. 295). The basin comprises four main valleys—Panguitch Valley, Circle Valley, East Fork Valley, and Grass Valley—which are surrounded by high plateaus and mountains (fig. 1). Panguitch Valley and Circle Valley combined locally are called South Fork Valley.

Panguitch Valley is approximately 40 miles long and is as much as 8 miles wide in the area north of Panguitch. The altitude of the valley ranges from about 6,300 feet at the north end to about 7,500 feet at the south end. The valley is bordered on the west by the Markagunt Plateau, which reaches an altitude of more than 11,000 feet above mean sea level, and on the east by the Paunsaugunt and Sevier Plateaus, which reach altitudes of more than 9,000 and 11,000 feet, respectively.

Circle Valley is about 8 miles long and is more than 6 miles wide at Circleville. The altitude of the valley floor ranges from about 6,000 feet at the north end to about 6,200 feet at the south end. The valley is bordered on the west by the Tushar Mountains, which reach an altitude of more than 11,000 feet, and on the east by the Sevier Plateau.

East Fork Valley is approximately 75 miles long and is more than 5 miles wide near Widtsoe. The altitude of the valley floor ranges from more than 6,300 feet at the head of Kingston Canyon to more than 8,000 feet south of Tropic Reservoir. The valley is bordered on the west by the Paunsaugunt and Sevier Plateaus, and on the east by the Table Cliff and Aquarius Plateaus, which reach altitudes exceeding 10,000 and 11,000 feet, respectively.

Grass Valley is approximately 40 miles long and ranges in width from half a mile in the area south of Greenwich to about 4 miles at Greenwich. The altitude of the valley floor ranges from about 6,400 feet at Otter Creek Reservoir to about 7,200 feet north of Koosharem Reservoir. The valley is bordered on the west by the Sevier Plateau and on the east by the Awapa and Fish Lake Plateaus, which reach altitudes exceeding 9,000 and 11,000 feet, respectively.

Each of the valleys consists of three parts: (1) a valley floor, the flood plain of the main stream in the valley, (2) a valley basin, those areas that are underlain by unconsolidated deposits, and (3) the valley sides—areas that are underlain by bedrock. These features are shown on the geologic cross sections (pl. 1), and a more detailed description of the structure of the basins is given in the section on geology (p. 11).

The discussion of ground-water conditions in this report is by valley basins. These basins are Panguitch Valley basin, Circle Valley basin, East Fork Valley basin, and Grass Valley basin. East Fork Valley and Grass Valley basins are further divided into subbasins. East Fork Valley basin includes Emery Valley subbasin, Johns Valley subbasin, and Antimony subbasin; and Grass Valley basin includes Koosharem subbasin and Angle subbasin (fig. 1).

CLIMATE

The climate in the upper Sevier River basin ranges from semiarid in the valleys to humid on the plateaus. The climatological data recorded at Panguitch are regarded as typical of the valleys in the region.

Large daily ranges in temperature are usual in the valleys. The temperature rarely exceeds 90°F in the summer and is usually between 40° and 50°F during summer evenings. Winters are usually cold in the valleys, and temperatures below 0°F are common. The average annual temperature at Panguitch is 43°F. The frost-free, or growing, season ranges from 2 to 3½ months in the valleys, and below freezing temperatures have been recorded in every month of the year. The lowest temperature recorded at Panguitch was −38°F in January 1937, and the highest was 96°F in June 1951. The average frost-free period at Panguitch is from June 18 to September 9.

The principal precipitation in the valleys is during July, August, and September when warm moist air moves into the area from the Gulf of Mexico. The annual precipitation in the valleys ranges from about 7 to 10 inches; November and June usually are the driest months and July and August the wettest. The area is influenced also by storms, however, from both the northern and southern Pacific coasts between September and May. Most of the precipitation from these storms falls on the surrounding high plateaus in the form of snow. This precipitation has an annual range from about 20 to 40 inches, and the snow accumulates in places to depths of more than 10 feet and often has a water content of as much as 40 inches.

Annual precipitation at Panguitch ranged from a minimum of 5.44 inches in 1942 to a maximum of 18.02 inches in 1910 and averaged 9.12 inches for 30 years of record (1931–60). The trend in precipitation between 1930 and 1963 is illustrated by a graph of the cumulative departure from the mean annual precipitation at Panguitch (fig. 3). The wettest years are shown by the most steeply rising parts of the graph and the driest years by the steepest descents. The late 1930's and late 1940's were wetter than average, and the climate has been relatively dry since 1950 except during 1952, 1957, and 1961.

Winds in the area usually are light to moderate in all seasons. The only strong winds usually are associated with thunderstorms and squalls.

Evaporation in the valleys greatly exceeds annual precipitation. Mean annual evaporation at Piute Reservoir, 8 miles north of Kingston, is 55.2 inches (U.S. Weather Bureau, written commun., 1958) and is considered to be representative of potential evaporation in the valleys in the upper Sevier River basin.

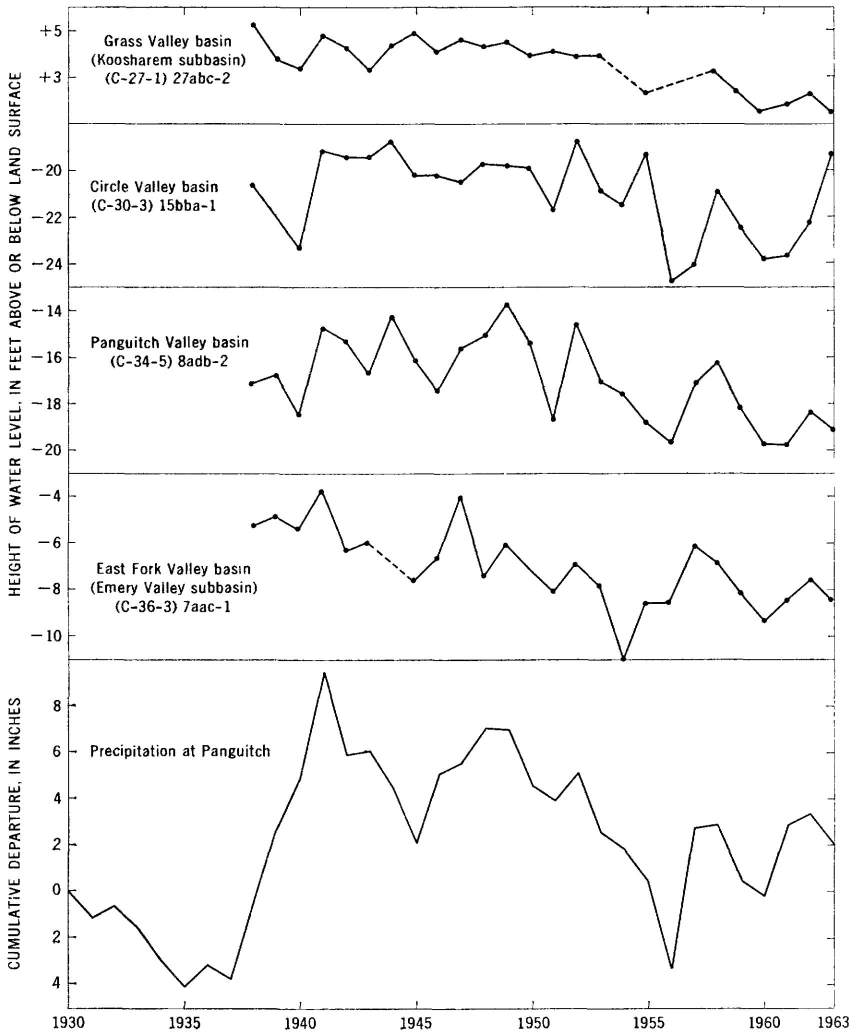

FIGURE 3.—Hydrographs of selected wells for the period 1938–63 and cumulative departure from the 1931–60 normal annual precipitation at Panguitch.

VEGETATION

Native vegetation in the upper Sevier River basin ranges in type from desert to alpine. Saltgrass (*Distichlis stricta*), rabbitbrush (*Chrysothamnus nauseosus*), greasewood (*Sarcobatus vermiculatus*), willows (*Salix* sp.), and sagebrush (*Artemisia tridentata*) grow in the uncultivated lands of the valleys. The vegetation on the alluvial fans and lower hills up to an altitude of about 7,000 feet is mainly sagebrush, juniper (*Juniperus* sp.), scrub oak (*Quercus* sp.), mountain-mahogany (*Cercocarpus* sp.), and pinyon pine (*Pinus edulis*).

Above an altitude of about 7,000 feet, aspen (*Populus tremuloides aurea*), ponderosa or yellow pine (*Pinus ponderosa*), spruce (*Picea* sp.), and Douglas-fir (*Pseudotsuga taxifolia*) predominate. These genera are most dense on the plateaus and mountain slopes having a northern exposure. Along all stream channels in the valleys, willows and cottonwoods (*Populus* sp.) are the principal vegetation.

POPULATION, AGRICULTURE, AND INDUSTRY

The total population in the upper Sevier River basin is about 3,000. Panguitch, the largest community, has a population of about 1,400. Most of the local residents are engaged in agriculture and related activities and live in towns near their farms. The principal crops are alfalfa, native hay, small grains, and potatoes. Sheep and cattle raising is an important part of the agricultural economy. Next to agriculture, lumbering and tourists are the most important sources of income.

A large part of the area is administered by the U.S. Forest Service (Dixie and Fish Lake National Forests), the Bureau of Land Management, and the National Park Service (Bryce Canyon National Park and Cedar Breaks National Monument).

GEOLOGY

The geologic map of the upper Sevier River basin was compiled partly from maps in previous geologic reports and partly from photogeologic and geologic field studies conducted during this investigation. The previous maps are primarily the work of Gregory (1949, 1950a, 1951) and Marine (1963). (See pl. 1.)

During this investigation the geology of approximately 1,500 square miles of the basin was mapped. This mapping was done in a single field season and, hence, is considered a reconnaissance. The valley and mountain areas containing sedimentary bedrock were studied in greatest detail; these areas were mapped on aerial photographs, primarily in the field, but some were not checked in the field. Areas containing only volcanic rocks were mapped by photogeologic methods, with but slight field checking.

The geology obtained from maps in previous reports was adopted with only a few changes: the valley fill was subdivided into several formations, some outcrops were modified to conform with those shown on aerial photographs, outcrops were modified along map boundaries to conform with mapping done during this study, and faults and small outcrops were added in places to show slightly greater detail. These changes are primarily in the valley areas, in the area around and north of Panguitch Lake, and in the northern Paunsaugunt Plateau.

240-729—67——2

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING CHARACTERISTICS

The geologic formations exposed in the upper Sevier River basin include rocks of Triassic, Jurassic, Cretaceous, Tertiary, and Quaternary age. Rocks older than Late Cretaceous age, however, although widely exposed in surrounding areas, are limited to an exposure of less than 11 square miles near the head of Antimony Creek; elsewhere in the basin they are deeply buried. Rocks of Late Cretaceous age are exposed principally on the Paunsaugunt Plateau, and rocks of Tertiary age are exposed almost everywhere in the area except where covered with valley fill. Unconsolidated deposits of Quaternary age fill the valley basins, and form the reservoir for most of the ground water in the project area.

The areal distribution and structure of the various formations are shown on the geologic map (pl. 1). The structure and some of the prominent physiographic elements in the area are shown on the geologic sections (pl. 1). The age, thickness, lithology, surface expression, and water-bearing characteristics of the formations are summarized in table 1 and described in detail in the pages that follow.

MESOZOIC FORMATIONS

The oldest rocks exposed in the upper Sevier River basin are in the upthrown block of the Paunsaugunt fault on the northwest edge of the Aquarius Plateau in Antimony Creek canyon and Dry Wash (pl. 1). The outcrops include six formations and one additional formation member of Late Triassic and Jurassic age and two formations of Late Cretaceous age (Gregory, 1944, p. 582–589). These formations, individually listed in table 1, have only small areal exposure and elsewhere in the basin lie at great depth; hence, they are not important as sources of ground water. They are shown on the geologic map (pl. 1) as sedimentary rocks.

CRETACEOUS SYSTEM

UPPER CRETACEOUS SERIES

CRETACEOUS FORMATIONS

General description

Upper Cretaceous formations include the Straight Cliffs and Wahweap Sandstones and the Kaiparowits Formation. The Straight Cliffs and Wahweap Sandstones are lithologically and hydrologically similar; are exposed along the sides of the Paunsaugunt Plateau, along the east side of Emery Valley subbasin and bordering the southeast part of Johns Valley subbasin (pl. 1); and are probably continuous

TABLE 1.—*Generalized geologic section in the upper Sevier River basin*

System	Series	Stratigraphic unit		Thickness (feet)	Description of rocks	Surface expression and areal exposure	Water-bearing characteristics
Quaternary	Pleistocene and Recent	Alluvium	Flood-plain deposits	0–340	Interbedded well-sorted and well-stratified sand and gravel in channel deposits; bedded fine sand, silt, and clay in over-bank deposits.	Forms present flood plains of Sevier River, East Fork Sevier River, and Otter Creek.	Principal aquifer in upper Sevier River basin; yields small to large quantities of water to wells and springs, mainly from clean sand and gravel.
			Young alluvium and old alluvium	0–800+	Interbedded, lensed, and interfingered deposits of cobbles, pebbles, sand, silt, and clay; poorly to moderately well sorted and stratified. Old alluvium is not distinguishable from the young alluvium in the subsurface and may be equivalent to the Sevier River Formation.	Coalescing and single alluvial fans, fill in major valleys and along mountain stream courses; old alluvium, exposed only in Panguitch Valley, forms bluffs and terracelike forms which are remnant from dissection of old alluvial fans.	
		Landslide deposits		0–300+	Nonsorted, nonbedded heterogeneous masses of slide material derived from steep slopes along the Awapa Plateau.	Hummocky "slump" masses on valley sides; very small areal exposures; limited to Grass Valley.	Low permeability; not known to yield water to wells or springs in the basin.
		Igneous rubble		0–100+	Poorly sorted and poorly stratified deposits of boulders, cobbles, pebbles, sand, and silt composed almost entirely of angular to subangular volcanic-rock fragments; may be as old as, or older than, the Sevier River Formation.	Hummocky and rubbly masses which overlie stream divides and slopes of parts of the Markagunt and Sevier Plateaus.	Low permeability; not known to yield water to wells or large springs in the basin.
		Unconformity					
		Basalt		0–1,500	Olivine and hornblende basalt, finely to coarsely crystalline to porphyritic; some dense, some vesicular and scoriaceous.	Flows, sheets, streams, cones, and ash fields exposed mainly on eastern Markagunt Plateau.	Not known to yield water to wells or large springs in the area. Forms important catchment areas for the recharge of underlying formations. Locally fills mountain valleys, retards surface flow and induces recharge.
		Unconformity					

TABLE 1.—*Generalized geologic section in the upper Sevier River basin*—Continued

System	Series	Stratigraphic unit	Thickness (feet)	Description of rocks	Surface expression and areal exposure	Water-bearing characteristics
Tertiary or Quaternary	Upper Pliocene or lower Pleistocene	Sevier River Formation	0–450+	Poorly sorted and poorly bedded deposits of unconsolidated to partly consolidated cobbles, pebbles, sand, silt, and clay; typical alluvial-fan deposits; contains some lacustrine deposits of white- to cream-colored clay and marl and argillaceous limestone, which all contain gastropods and pelecypods.	Large isolated to semiconnected bluffs, fans, and terracelike forms which are remnant from dissection of old alluvial fans; exposed mainly in southern half of Panguitch Valley.	Generally has low permeability and is a poor aquifer, although it yields small to moderate quantities of water to a few wells and springs from permeable zones of sand and gravel.
		Unconformity				
Tertiary	Miocene(?) and Pliocene(?)	Intrusive rocks	?	Light- to medium-gray quartz monzonite and quartz monzonite porphyry; finely to coarsely crystalline.	Steep-sided hills, cliffs, rubbly to smooth slopes, and highly jointed ridges; exposed only at northern end of Panguitch Valley.	Extremely low permeability; acts as a ground-water barrier; not known to yield water to wells or springs.
		Volcanic rocks	0–4,000+	Latite and quartz latite flows, tuffs, latitic and basaltic breccias. Includes parts of the Bullion Canyon Volcanics and the Roger Park Basaltic Breccia.	Caps most of the plateaus and foothills; forms jagged cliffs, ledges, and rubbly slopes; forms Fish Lake, Awapa, northern Aquarius, northern and central part of the Sevier Plateau, and the southern Tushar Mountains.	Generally low permeability, although it contains some fractures and joints which yield small to large quantities of water to a few wells and many springs.
		Unconformity				
	Eocene and Miocene(?)	Brian Head Formation: Upper unit	0–600?	Roughly bedded but generally poorly sorted deposits of dark-gray water-laid agglomerate and conglomerate; contains interbedded medium-gray to black medium- to coarse-grained sandstone; moderately well consolidated and cemented; also includes several intraformational volcanic flows.	Forms foothills in Panguitch Valley and gentle slopes beneath volcanic rocks in Black Canyon and near Antimony.	Low to high permeability; yields small quantities of water to a few wells, but supplies large quantities to springs in Black Canyon and near Antimony.
		Brian Head Formation		Well-stratified white, gray, green, tan, and black siliceous limestone, impure marl, cal-	Forms caps, cliffs, and steep slopes on parts of all the major plateaus in the area	Low to moderate permeability; yields small quantities of

		Lower unit	0–1,000	careous silt, shale, argillaceous and tuffaceous sandstone, conglomerate, and water-laid pyroclastic material.	except Fish Lake and Awapa Plateaus; also forms rounded hills along sides of valleys; often weathers into badland topography.	water to wells and springs, mainly from permeable sandstone beds.
		Wasatch Formation	0–1,100	Thick-bedded pink to red fresh-water limestone; contains irregularly interbedded pink to yellow shale, siltstone, sandstone, and conglomerate.	Forms caps, cliffs, ridges, spires, columns of pinnacles on all plateaus except Fish Lake and Awapa Plateaus; also forms foothills along sides of Panguitch and East Fork Valleys.	Sandstone and conglomerate beds within the formation have low to moderate permeability and yield small to moderate quantities of water to wells and springs. Limestone beds, where containing solution channels, have high permeability and yield large quantities of water to springs.
		——— Unconformity ———				
Cretaceous	Upper Cretaceous	Kaiparowits Formation	0–700	Thin- to thick-bedded dark-gray, gray-green, yellow, and tan arkosic sandstone; medium to coarse grained and weakly cemented by calcium carbonate and iron oxide.	Dark-colored slopes, interrupted by shelflike benches; exposed only around edges of Paunsaugunt Plateau.	Low permeability; yields small quantities of water to wells and springs.
		——— Unconformity ———				
		Wahweap and Straight Cliffs Sandstones	0–1,600+	Massive to thin-bedded tan to buff-brown sandstone containing interbedded shale and shaly sandstone; sandstone is fine to coarse grained and cemented by calcium carbonate and iron oxide.	Prominent steep-sided valleys and cliffs and steplike cliffs; crops out around edges of Paunsaugunt Plateau and on sides of Emery and Johns Valley subbasins.	Low to moderate permeability; yields small to large quantities of water to wells and springs; generally yields more water than overlying Kaiparowits Formation.
Triassic, Jurassic; and Cretaceous	Upper Triassic; Lower, Middle, and Upper Jurassic; and Upper Cretaceous.	Sedimentary rocks	-----?-----	Includes eight formations and one additional formation member exposed in an area of less than 11 square miles in Antimony Creek canyon: parts of the Tropic Formation, Dakota(?) Sandstone, Winsor(?) Formation, Curtis(?) Formation, Entrada Sandstone, Carmel Formation, Navajo Sandstone, Chinle(?) Formation, and Shinarump Member of Chinle Formation.	Succession of prominent cliffs, ledges, and slopes within Antimony Creek canyon.	Not known to yield water to wells or springs in the basin.

in the subsurface throughout most of the area. The Kaiparowits Formation is exposed around the east, south, and west sides of the Paunsaugunt Plateau, but thins rapidly in a northerly direction, extending only about to the middle of the upper Sevier River basin. The combined thickness of these formations ranges from about 500 to 2,300+ feet (Gregory, 1951, p. 23; Marine, 1963, p. 456–457).

The following lithologic description was derived largely from Gregory and Moore (1931), Gregory (1951), and Marine (1963). The combined Straight Cliffs and Wahweap Sandstones consist mostly of massive to thin-bedded sandstone which intergrades and intertongues unsystematically with material that ranges from shale to shaly sandstone. The predominant sandstone of the unit is tan to yellow tan and buff brown, fine to coarse grained, cemented mainly by calcite and some iron oxide, and is mostly massive bedded, beds thicker than 10 feet predominating. The shale and shaly sandstone is tan to gray, mostly argillaceous, carbonaceous, or calcareous, and thin bedded. In addition, irregular beds and lenses of conglomerate occur in the two formations. Coal is also present in the Straight Cliffs Sandstone, as described in Feltis and Robinson (1963, p. 24–26), Carpenter, Robinson, and Bjorklund (1964, p. 23–24), and Marine (1963, p. 457, pl. 26).

The Straight Cliffs Sandstone forms prominent steep-sided valleys and cliffs; the Wahweap Sandstone forms a group of steplike cliffs which are distinguishable from the cliffs of the Straight Cliffs Sandstone in some places but in other places combine with them to form a single slope interrupted by ledges.

The Kaiparowits Formation consists of dark-gray, gray-green, yellow, and tan arkosic sandstone which is medium to coarse grained and weakly cemented by calcium carbonate. The sandstone is highly variable, both horizontally and vertically, in bedding, texture, and composition. Beds range in thickness from several inches to less than 5 feet. The unit forms predominantly dark-gray receding slopes interrupted by shelflike benches.

Water-bearing characteristics

The best water-bearing zones in the Upper Cretaceous formations are in the Straight Cliffs and Wahweap Sandstones. These zones contain the more permeable sandstone beds and also fractures in the sandstone beds. The Upper Cretaceous formations on the north end of the Paunsaugunt Plateau yield small quantities of water, generally less than 10 gpm (gallons per minute), to wells that range from about 130 to 310 feet in depth. Well (C–37–4)11ddd–1 in Bryce Canyon National Park, however, is 2,000 feet deep and yields about 200 gpm from the Straight Cliffs and Wahweap Sandstones (Marine, 1963, p.

480). The depth to the Cretaceous formations in most of the upper Sevier River basin is too great for economical well construction.

Many small springs and seeps around the Paunsaugunt Plateau yield water from the Upper Cretaceous formations. Only a few of these springs, however, discharge into the upper Sevier River basin. Marine (1963, table 6, p. 464–465) listed 15 springs in the Bryce Canyon area which discharge from the Upper Cretaceous formations southeastward into the Paria River drainage. Recharge to the formations, however, is from the upper Sevier River basin. Of these 15 springs, 12 discharge from about 2 to 185 gpm from the Straight Cliffs and Wahweap Sandstones and 3 springs discharge unmeasured amounts from the Kaiparowits Formation. Several springs on the plateau, usually yielding 10 gpm or less, issue from the Kaiparowits Formation south of Tropic Reservoir, but the source of the water is probably from the basal conglomerate of the overlying Wasatch Formation (Marine, 1963, p. 462).

TERTIARY SYSTEM

EOCENE AND MIOCENE(?) SERIES

WASATCH AND BRIAN HEAD FORMATIONS

General description

The Wasatch and Brian Head Formations are well exposed throughout much of southern Utah. Although both formations are distinct in appearance, a gradational zone between them makes separation difficult; hence, they have been mapped as an undifferentiated unit in previous reports (Gregory, 1949, 1950a).

The Wasatch Formation is one of the most widely exposed formations in the upper Sevier River basin. It forms prominent pink cliffs on the Markagunt, Paunsaugunt, and Table Cliff Plateaus and on the south ends of the Sevier and Aquarius Plateaus; in Bryce Canyon National Park it forms cliffs, spires, and columns. The formation thins rapidly to the north, ranging in thickness from 400 to 1,100 feet on the Paunsaugunt and Table Cliff Plateaus to practically zero north of Johns Valley subbasin (Gregory, 1944, p. 590–591; 1951, p. 44; Marine, 1963, p. 456). It consists of thick-bedded pink to red fresh-water limestone which contains irregularly interbedded pink to yellow shaly limestone, shale, siltstone, sandstone, and conglomerate. At many localities the lowest part of the formation is a red massive calcareous basal conglomerate which is lenticular and discontinuous.

Gregory (1945, p. 108) described the Brian Head Formation as containing a lower unit of evenly stratified fine-grained material and an upper unit of coarse agglomerate. The lower unit generally is exposed in the same areas as is the Wasatch Formation, except that the lower unit generally has been "stripped" from the Paunsaugunt Plateau. In addition, the lower unit is well exposed on the northern end of the Markagunt Plateau, northwest of Panguitch, where erosion has not yet exposed much of the underlying Wasatch Formation. The thickness of the lower unit in the area reportedly ranges from 0 to nearly 1,000 feet (Gregory, 1944, p. 601; 1945, p. 111; 1949, p. 987–989; 1951, p. 50). It is composed of well-stratified siliceous limestone, impure marl, calcareous silt, shale, calcareous and clayey sandstone, tuffaceous sandstone and conglomerate, and water-laid pyroclastic material of various types. The material is shades of white, gray, green, tan, and black. There is some evidence that the deposits included in the unit in the northern Markagunt Plateau are not part of the Brian Head Formation. Determining the exact age of these deposits was beyond the scope of this investigation, however, and they were mapped as part of the Wasatch and Brian Head Formations.

A notable feature of the lower unit is an increase, from south to north, of the amount of volcanic debris and of grain size. In general, the unit forms cliffs, ledges, and steep slopes, or a cap on parts of the major plateaus. It also forms rounded hills along valley edges and often weathers into badlands.

The upper unit of the Brian Head Formation is exposed on the west side and the lower end of Panguitch Valley and near Antimony on both sides of East Fork Sevier River between the head of Black Canyon and the head of Kingston Canyon (pl. 1) (Gregory, 1944, p. 595). Much of the unit as described in these areas, however, may later prove to be part of the Bullion Canyon volcanic sequence. Part of the rocks mapped as Sevier River Formation on the eastern margin of the Markagunt Plateau between Panguitch and Hatch (pl. 1) may be part of the upper unit of the Brian Head Formation. The upper unit of the Brian Head thickens to the north, reaching an estimated maximum of about 600 feet.

The upper unit has indefinite upper and lower boundaries and is sometimes difficult to distinguish from the volcanic rocks with which it intergrades. It was described by Gregory (1945, p. 108; 1949, p. 983) as "dark-gray, remarkably coarse agglomerate." The conglomerate in Black Canyon was further described by Gregory (1944, p. 595) as being "roughly bedded, but very poorly sorted," and including "* * * rare lenses of thin-bedded, medium-grained sandstone * * *." Except for the outcrops in Black Canyon, much of the dark-gray agglomerate assigned by Gregory to the upper unit at several places (Gregory, 1944, p. 594; 1945, p. 108; 1949, p. 983) probably is part of the Tertiary volcanic rock series. Most of these outcrops lack notable stratification and are probably pyroclastic debris belonging to the

Roger Park Basaltic Breccia. In this report the upper unit of the Brian Head Formation is considered to include primarily only stratified and apparently water-laid tuffaceous conglomerate and sandstone deposits of volcanic origin. The upper unit is believed to crop out north of Kingston Canyon but it is interbedded with volcanic rocks of Tertiary age; therefore, it is not differentiated on the geologic map (pl. 1). The upper unit is expressed topographically as rounded hills formed of a succession of conglomerate ledges and receding sandstone slopes.

Water-bearing characteristics

The Wasatch and Brian Head Formations both contain water-bearing zones that consist mainly of fractures and joints in otherwise impervious strata or are in porous strata within the sandstone and conglomerate beds. In addition, the Wasatch Formation transmits large quantities of water in solution channels in limestone beds, and the upper unit of the Brian Head Formation in Black Canyon transmits large quantities of water from fractures and joints and at the contact between the conglomerate and intraformational volcanic flows.

The Wasatch and Brian Head Formations yield small quantities of water to wells, chiefly in East Fork Valley basin. These wells usually produce less than 30 gpm, mainly from the Wasatch Formation, and are generally less than 150 feet deep. Wells penetrating the upper unit of the Brian Head Formation near Antimony produce from about 4 to 25 gpm.

These formations also are the sources of many springs. Springs in the Wasatch Formation in the eastern Markagunt Plateau normally discharge from 25 to 4,500 gpm from solution channels in limestone; Mammoth Spring, (C–36–7)31dac, has discharged as much as 121,000 gpm (Wilson and Thomas, 1964, fig. 13). The Wasatch Formation elsewhere in the area generally yields less than 100 gpm to springs.

The lower unit of the Brian Head Formation yields small quantities of water (generally less than 25 gpm) to a few springs and seeps. The upper unit yields water to a few springs in Black Canyon and near Antimony. Five of the springs in Black Canyon issue at the contact of fractured intraformational volcanic rocks and underlying relatively impermeable conglomerate and sandstone. These springs discharge from 50 to more than 1,600 gpm. Large quantities of water also issue from contact zones between volcanic rocks and relatively impermeable conglomerate in the upper unit at the head of Antimony Creek. These springs are largely responsible for the consistent base flow of the creek, about 15 cfs (cubic feet per second).

MIOCENE(?) AND PLIOCENE(?) SERIES

VOLCANIC ROCKS

General description

Volcanic rocks of Miocene(?) and Pliocene(?) age compose the bulk of the Fish Lake, Awapa, Aquarius, and Sevier Plateaus, the southern Tushar Mountains, and the highlands of the northern Markagunt Plateau between Panguitch and Circleville Canyon (pl. 1). These rocks include two separate formations—the Bullion Canyon Volcanics of Miocene(?) age, exposed mainly north of Circleville and Kingston Canyons, and the Roger Park Basaltic Breccia of Pliocene(?) age, exposed in the remainder of the area. The Bullion Canyon Volcanics overlies and interfingers with the upper unit of the Brian Head Formation north of Kingston Canyon and is possibly conformable to it. In fact, much of the upper Brian Head unit described in Black Canyon and near Antimony may later prove to be part of the Bullion Canyon volcanic sequence. Elsewhere the Bullion Canyon Volcanics and the Roger Park Basaltic Breccia are probably unconformable on the underlying rocks. The combined volcanic rocks in the northern part of the upper Sevier River basin are more than 4,000 feet thick (Willard and Callaghan, 1962) and are estimated to range in thickness from 0 to a few hundred feet in the southern part of the basin.

According to Willard and Callaghan (1962), the Bullion Canyon Volcanics "consists of a thick series of latitic breccias, tuffs, and thin flows at the base, a succession of latite and quartz latite flows within thin intervening beds of volcanic breccia, and more calcic flows and breccias at the top." The Roger Park Basaltic Breccia is described (Callaghan and Parker, 1962b) as "a breccia composed of fragments and matrix of basaltic andesite."

Topographically, the volcanic rocks form caps, jagged cliffs, ledges, and rubbly slopes on most of the major plateaus and mountains and underlie foothills on the valley sides.

Water-bearing characteristics

Water-bearing zones consist of fractures and joints which occur irregularly; therefore, ground-water conditions in the volcanic rocks in any single locality are unpredictable. In most places these rocks impede the movement of ground water. Only one well, (C–27–1) 20dca–1, is known to produce water from the volcanic rocks; this well reportedly yields 20 gpm.

The volcanic rocks yield water to many springs, the largest being Burr Springs, (C–25–1)26bc (pl. 2), which produced about 1,440 gpm in July 1962. Other springs issuing from volcanic rocks of Tertiary age yield from less than 1 to more than 500 gpm.

INTRUSIVE ROCKS

General description

Intrusive rocks of Tertiary age are exposed at the north end of Panguitch Valley basin near the head of Circleville Canyon (pl. 1). Because they appear to have intruded the upper unit of the Brian Head(?) Formation of Miocene(?) age and are overlain by the Roger Park Basaltic Breccia of Pliocene(?) age, the intrusive rocks probably are of Miocene(?) age.

The intrusive rocks consist of quartz monzonite and quartz monzonite porphyry, are light to medium gray, and are finely to coarsely crystalline. They form steep-sided, rubbly to smooth slopes, cliffs, and highly jointed ridges.

Water-bearing characteristics

The intrusive rocks are compact and homogeneous and are not brecciated; therefore, they are poor aquifers. In fact, they form a barrier to ground-water movement at the lower end of Panguitch Valley basin and are largely responsible for the marshy conditions there.

TERTIARY OR QUATERNARY SYSTEMS

UPPER PLIOCENE OR LOWER PLEISTOCENE DEPOSITS

SEVIER RIVER FORMATION

General description

The Sevier River Formation of late Pliocene or early Pleistocene age is exposed in the upper Sevier River basin only as relatively small, isolated to semiconnected deposits in the south end and on both sides of Panguitch Valley basin (pl. 1). It is a valley-fill deposit, consisting primarily of old alluvial fans, and, therefore, it is similar in most respects to, and is usually difficult to distinguish from, deposits of Recent alluvium. (The phrase "valley fill," as used in this report, includes all alluvium, lake(?) or marsh(?) deposits, landslide deposits, and the Sevier River Formation.) The Sevier River Formation can be differentiated in outcrops, however, by (1) topographic form, (2) excessive, deficient, or reversed dip of bedding planes (Willard and Callaghan, 1962), (3) a generally poorer degree of sorting and stratification, (4) a generally greater degree of consolidation, (5) faulting within the formation (Callaghan and Parker, 1962b), and (6) the presence of lacustrine deposits similar to those in the type area of the formation near Sevier, Utah (Callaghan, 1938, p. 101, and Callaghan and Parker, 1962a).

The Sevier River Formation is believed to underlie much of the surficial Quaternary and Recent alluvium in the southern part of Panguitch Valley basin (pl. 1, section *D–D′*). Gregory (1949, p. 987 and pl. 1) mapped exposures of the formation on the west side of Panguitch Valley between Panguitch and Hatch, but much of this may be the upper unit of the Brian Head Formation. No attempt was made in this study to alter Gregory's (1949) mapping of the Sevier River Formation.

The Sevier River Formation is greatly eroded and mostly buried by younger sediments; therefore, the thickness of the formation cannot be determined from outcrops. Study of outcrops, drillers' logs, and logs of test holes in Panguitch Valley basin, however, indicates a thickness ranging from 0 to more than 450 feet. The formation generally is poorly sorted and poorly stratified valley fill which consists of unconsolidated to partly consolidated cobbles, pebbles, sand, silt, and clay deposited as alluvial fans. It also contains lacustrine deposits of sand, silt, clay, and argillaceous limestone beds which contain fossil gastropods, pelecypods, and microfossils(?).

Topographically, the Sevier River Formation forms high rounded hills, isolated to semiconnected bluffs, fans, and terracelike forms, and long "trainlike" deposits which were dissected from old alluvial fans by recent streams.

Water-bearing characteristics

The lack of sorting and stratification and the abundance of silt in the Sevier River Formation generally results in low permeability. The best water-bearing zones are lenses of well-sorted sand and gravel that contain little silt. These permeable zones yield small to moderate amounts of water to domestic and stock wells. Reported yields from wells generally range between 12 and 50 gpm.

The formation yields water to springs and seeps in an area about 2½ miles west of Red Canyon, the largest of which, Myers Springs, (C–35–5)25ab, flows about 450 gpm. Yields of other springs range from less than 1 to about 50 gpm.

QUATERNARY SYSTEM

PLEISTOCENE AND RECENT SERIES

BASALT

General description

Basalt flows of Quaternary age cover large areas of the Markagunt Plateau and occur as small isolated flows long the east side of Panguitch Valley and on the northern Paunsaugunt Plateau near the entrance to Red Canyon (pl. 1). The estimated thickness of the basalt on the Markagunt Plateau ranges from 0 to 1,500 feet (Gregory, 1950a, p. 26). The flows on the Paunsaugunt Plateau are estimated to be less than 100 feet thick.

The basalt flows of the Markagunt Plateau include finely crystalline to coarsely crystalline and porphyritic olivine or hornblende basalt (Gregory, 1949, p. 993). The basalt is black, dense, often vesicular and scoriaceous; in many places it displays well-marked flow structures. The basalt forms sheets, streams, cones, and ash fields.

Water-bearing characteristics

The basalt flows of the Markagunt Plateau were described as being "* * * permeable enough that they can absorb the water of maximum cloudburst storms or maximum snowmelt without runoff * * *," but "* * * sufficiently impermeable to form effective barriers to water movement along the pre-basalt valleys * * * where the drainage is now achieved by channels in the limestone [Wasatch] beneath the basalt" (Wilson and Thomas, 1964, p. 19). The basalt is not known to yield water to wells or large springs on the Markagunt Plateau, but it does yield water to many seeps and small springs.

The basalt flows of the Markagunt Plateau have "dammed" the flow of many surface streams, and thereby forced them to seek new drainages. Many of these streams have bypassed the damming effect by dissolving solution channels in the underlying Wasatch Formation. These solution channels yield large quantities of water to springs that assist in sustaining the base flow of the Sevier River above Hatch (Wilson and Thomas, 1964, p. 24–25).

IGNEOUS RUBBLE

General description

Gregory (1949, p. 981, 991) briefly noted patches of unusual layers of igneous gravel on the northeast edge of the Markagunt Plateau. He mapped this material in two areas (1949, pl. 1) as "Quaternary igneous gravel." Similar deposits on the north end of the Paunsaugunt Plateau and on the south end of the Sevier Plateau (pl. 1) were mapped during this study. These deposits and one of the deposits mapped by Gregory are shown on the geologic map as "Quaternary igneous rubble" because most of the material is angular. The second deposit mapped by Gregory as igneous gravel near the north boundary of his map is believed to be part of the Tertiary volcanic rocks. The deposits mapped during this study cover the slopes, cap most of the ridges, and form long extended deposits in the vicinity of Casto Bluff. This material is not considered to be part of the valley fill.

The age of the igneous rubble is unknown, but the rubble probably was deposited during an earlier cycle of erosion and deposition similar to that described by Willard and Callaghan (1962). It thus may be as old as or older than the Sevier River Formation, which is of late Pliocene or early Pleistocene age. However, inasmuch as there is little evidence that the rubble is of Pliocene age, the formation is here assumed to be of Quaternary age, although parts or all of it may be older.

The thickness of the igneous rubble ranges from 0 to more than 100 feet and averages about 25–50 feet. The outcrops of the formation are quite uniform and consist of poorly sorted and poorly stratified boulders, cobbles, pebbles, sand, and silt. The larger fragments are generally angular to subangular. The rubble is composed almost entirely of volcanic-rock fragments similar to the Roger Park Basaltic Breccia. In many areas the rubble is about 5 percent box-shaped to oblate boulders and cobbles of white and maroon banded quartzite. This quartzite is foreign to the upper Sevier River basin, and its source is unknown.

The Quaternary igneous rubble forms hummocky and rubbly masses which cap interstream divides and slopes of the drainages of the Sevier and Paunsaugunt Plateaus.

Water-bearing characteristics

The Quaternary igneous rubble probably is not a good water-bearing formation because it contains abundant silt and lacks sorting. It is not known to yield water to wells or large springs in the area.

LANDSLIDE DEPOSITS

Two small landslides are shown on the geologic map (pl. 1). One slide is several miles east of Otter Creek Reservoir and the other is about 3 miles southeast of Greenwich. The slides have a combined area of less than 3 square miles and are composed of a hetergeneous nonsorted mass of material that has moved downslope from the face of the Awapa Plateau. The maximum thickness of these deposits probably is more than 300 feet. The landslides are not important water-bearing units because of their small areal extent and poor sorting.

ALLUVIUM

The alluvium in the upper Sevier River basin was subdivided into three mappable units—old alluvium, young alluvium, and flood-plain deposits. The old alluvium, which is exposed only in Panguitch Valley basin, generally is distinguishable from the young alluvium only on the basis of topographic expression. It consists of old dissected alluvial-fan remnants which are topographically higher than present young alluvial fans. All alluvium elsewhere in the basin other than flood-plain deposits is shown on the geologic map as young alluvium, even though much of this alluvium may be equivalent to the old alluvium. "Flood-plain deposits," as used in this report, refers to sediments deposited in the present flood plains of the Sevier River, the East Fork Sevier River, and Otter Creek. The old alluvium is similar to the young alluvium in water-bearing properties. The flood-plain deposits constitute the best aquifers in the alluvium, but they are lenticular and discontinuous and interfinger with the other alluvial deposits in the subsurface. Therefore, although the three units are shown separately on the geologic map, they are discussed as a single hydrologic unit in this report.

Old and young alluvium

The old alluvium (pl. 1) is exposed only in Panguitch Valley basin as isolated bluffs and terrace-like forms or outliers 75–100 feet high, on the valley sides as large semidissected fans whose aprons are being stripped away by the Sevier River, and within side canyons as small remnant hanging terraces. Its topographic form is similar to that of the Sevier River Formation, which is also exposed in the valley, and the old alluvium may be equivalent in age to the Sevier River Formation. Much of the material underlying the outcrops of young alluvium in all the major valley basins probably is equivalent in age to the old alluvium.

The young alluvium includes alluvial-fan sediments in the valley basins and alluvium in mountainous tributary valleys. Lake(?) or marsh(?) deposits, not exposed in the upper Sevier River basins, but penetrated by test holes and wells in Koosharem subbasin, are assigned to the young alluvium in this report, even though they are technically not of alluvial origin.

Both the old and young alluvium generally consist of interbedded, lenticular, and interfingering deposits of cobbles, pebbles, sand, silt, and clay. The pebbles and sand range in size from very fine to very coarse and contain small to large amounts of silt and clay. Sorting and stratification range from poor to moderately good. The most permeable water-bearing zones in the old and young alluvium are the gravel and sand beds which have been deposited in stream channels in alluvial fans.

The lake(?) or marsh(?) deposits identified only in the subsurface of Koosharem subbasin interfinger with and underlie the alluvial-fan sediments of the subbasin. They consist of regularly interbedded light- or blue-gray carbonaceous silt and clay and sand and pebbles. Some of the silt and clay beds contain fossil gastropod and pelecypod shells. The lake(?) or marsh(?) deposits were penetrated in test holes (C-27-1)2caa-2, (C-27-1)15cba-1, and (C-27-1)27bac-1 (Feltis and Robinson, 1963, p. 27–31).

The thickness of the combined old and young alluvium ranges from 0 to more than 800 feet in the upper Sevier River basin.

Flood-plain deposits

Flood-plain deposits, as shown on plate 1, consist of channel and overbank deposits within the present flood plains of the Sevier River, the East Fork Sevier River, and Otter Creek. Outcrops of the unit are differentiated from the old and young alluvium only by location, and all deposits exposed within the present flood plains of the three streams are classified as flood-plain deposits. Channel deposits generally are well-sorted and well-stratified sand and gravel which contain little silt, whereas overbank deposits generally are sand, silt, and clay. Although ancient flood-plain deposits extend in the subsurface beyond the present flood plains of the three streams, their full extent is not known everywhere in the upper Sevier River basin.

The maximum known thickness of the ancient and present flood-plain deposits is about 200 feet in Panguitch Valley basin, about 340 feet in Circle Valley basin, about 185 feet in East Fork Valley basin, and about 200 feet in Grass Valley basin (Feltis and Robinson, 1963).

Water-bearing characteristics

The alluvium is the principal aquifer in the upper Sevier River basin, and it yields small to large quantities of water to wells and springs. The main water-bearing beds are sand and gravel. The extent and thickness of the alluvium is described in the section "Valley basins" (p. 28), and water-bearing characteristics of the alluvium in each valley basin are discussed in detail in the section "Ground-water conditions in the basin" (p. 64).

STRUCTURE

The major structural features of the upper Sevier River basin include: (1) a prevailing northeasterly dip of both surface and deep-seated strata in the major plateaus (Gregory, 1951, p. 73), (2) two great faults of large displacement, the Sevier and Paunsaugunt faults (pl. 1), which are the chief cause of continuous and nearly straight depressions in the area, and (3) three prominent north-south strips formed of several plateaus and separated by depressions or basins which parallel the strips (Fenneman, 1931, p. 295).

REGIONAL DIP AND FOLDS

Most formations in the plateaus in the upper Sevier River basin have a regional dip of 2°–5° N., NE., and E. (Gregory, 1949, p. 995; 1950a, p. 105; 1951, p. 73–74). This regional dip is remarkably uniform, and dips that exceed 5° or dips in southerly or westerly directions generally are due to local faults (see pl. 1). According to Gregory (1951, p. 73), the regional dip played a major role in the physiographic development of the upper Sevier River basin, not only as a control to surface drainage, but to areal exposure of formations as well. The regional dip also commonly controls the movement of ground water in bedrock aquifers. For example, water moves down the dip through a permeable basalt that overlies an impermeable conglomerate in the upper unit of the Brian Head Formation and discharges through springs at the base of the basalt along the west wall of Black Canyon.

Prominent or large-scale folding is nonexistent in the upper Sevier River basin. Small local folds are merely small flexures in the regional dip and usually occupy less than 1 square mile. They are of little significance in the structure of the area. A typical small fold is the Johns Valley anticline, 5 miles south of Widtsoe (pl. 1).

FAULTS

The Sevier and Paunsaugunt faults delineate the major valleys and plateaus in southern and central Utah. These two north- to northeast-trending master faults are parallel and about 15–25 miles apart.

The Sevier fault is a normal fault, the downdropped block being on the west, and it forms the boundary between the Sevier and Paunsaugunt Plateaus and the Panguitch and Circle Valley basins (pl. 1). The fault can be traced from northern Arizona to the upper end of Sanpete Valley in central Utah (Fenneman, 1931, p. 295; Gregory, 1951, p. 74–76). The throw along the Sevier fault within the upper Sevier River basin ranges from 500 to about 2,000 feet and varies greatly within short distances (Gregory, 1951, p. 76). The fault generally is marked by a prominent scarp or fault-line scarp, the upthrown side forming the scarp.

The Paunsaugunt fault is also a normal fault, the downdropped block being on the west. It can be traced from near the southern boundary of Utah, through the upper Sevier River basin to near the Fish Lake Plateau. It forms the boundary along the eastern edge of the Paunsaugunt Plateau and, farther north, the boundary between the Table Cliff, Aquarius, Awapa, and Fish Lake Plateaus and the East Fork Valley and Grass Valley basins (pl. 1). The throw of the fault is mostly between 600 and 2,000 feet (Gregory, 1951, p. 77), but it exceeds 3,500 feet along the Aquarius Plateau (Gregory, 1944, p. 604). Like the Sevier fault, its displacement varies greatly within short distances. The Paunsaugunt fault generally is not as well expressed in the topography as the Sevier fault. The Paunsaugunt fault generally lies in the foothills at a distance from the plateaus; it is often covered by alluvium and in places displays topographic inversion, the downthrown block forming the plateau.

Many other faults, shorter and having smaller displacements than the Sevier and Paunsaugunt faults, occur in the highlands and foot-

240-729—67——3

hills of the upper Sevier River basin. Many of these faults parallel the two major fractures and lie in close proximity to them (pl. 1). Apparently the two master faults controlled the formation and orientation of the smaller faults.

VALLEY BASINS

Faulting, erosion, and deposition by streams have shaped the several ground-water basins in the upper Sevier River basin. The valley fill in these basins has been derived from the consolidated and unconsolidated formations in the uplands that surround the valleys. In Circle and Grass Valley basins all the sediments are derived from volcanic rocks; in Panguitch and East Fork Valley basins, the sediments are derived from both volcanic and sedimentary rocks. The word "alluvium," as used in the following discussion, includes old alluvium, young alluvium, and flood-plain deposits. A description of the physiographic elements of the valley basins is given in the section "Physiography" (p. 7).

PANGUITCH VALLEY BASIN

Panguitch Valley basin is the segment of the upper Sevier River basin between the mouth of Mammoth Creek and the head of Circleville Canyon (pl. 1). It includes an area of about 76,000 acres. The basin is bounded on the south by sedimentary rocks which constrict the valley, on the west by sedimentary and volcanic strata which descend from the eastern and northeastern Markagunt Plateau and continue beneath the valley fill (pl. 1, sections *A–A′* and *B–B′*), on the east by the Paunsaugunt and Sevier Plateaus and the Sevier fault, and on the north by sedimentary and igneous rocks. The Sevier fault is more responsible for the presence of Panguitch Valley basin than any other structural element. A maximum known thickness of 833 feet of valley fill, all of which is alluvium, was penetrated by test hole (C–33–5)13bdd–1 (Feltis and Robinson, 1963, p. 16) in the northeastern part of the valley.

Panguitch Valley basin is separated from Circle Valley basin downstream by a constriction of volcanic rock between the Sevier Plateau and the southern Tushar Mountains. The Sevier River flows through this constriction in a steep-sided gorge about 5½ miles long and about 100–300 feet wide called Circleville Canyon (pl. 1, geologic map and section *D–D′*).

CIRCLE VALLEY BASIN

Circle Valley basin includes about 14,000 acres, and it occupies the area between the mouth of Circleville Canyon and the bedrock constriction west of Kingston (pl. 1). The basin was formed by en echelon faulting in the surrounding volcanic rocks. It is bounded on the west by the southern Tushar Mountains and on the east by the

Sevier Plateau. A constriction formed by volcanic rock at the northeast corner of the basin separates Circle Valley basin from the central Sevier Valley downstream (Young and Carpenter, 1965). A maximum known thickness of 680 feet of valley fill, all of which is alluvium, was penetrated by test hole (C–30–3)32bbb–1 near the center of the basin.

EAST FORK VALLEY BASIN

East Fork Valley basin is the basin between Tropic Reservoir and the upper end of Kingston Canyon (pl. 1). The basin is subdivided into three subbasins by two bedrock constrictions, one formed by Flake Mountain and the other by the rock at the lower end of Johns Valley subbasin (see pl. 1, section *E–E′*).

EMERY VALLEY SUBBASIN

Emery Valley subbasin, between Tropic Reservoir and Flake Mountain, includes an area of about 12,000 acres. Part of the subbasin is bounded on both sides by faults (pl. 1), along which the subbasin was uplifted; a horst was thus formed, which has since been eroded to form the present valley. The subbasin is bounded at its southern end and on its eastern and western sides by sedimentary bedrock and at its northern end by volcanic and sedimentary rocks. A maximum known thickness of 66 feet of valley fill, all of which is alluvium, was penetrated by well (C–36–4)2dca–1 in the south-central part of the subbasin.

JOHNS VALLEY SUBBASIN

Johns Valley subbasin, between Flake Mountain and the head of Black Canyon, includes an area of about 30,000 acres (pl. 1). It is bounded at its southern end by the volcanic-rock constriction formed by Flake Mountain, on its western side by sedimentary and volcanic rocks of the Sevier Plateau, on its eastern side by sedimentary and volcanic rocks at the Table Cliff and Aquarius Plateaus, and at its northern end by bedrock at the head of Black Canyon. The Paunsaugunt fault separates the valley from the Table Cliff and Aquarius Plateaus along much of the eastern valley margin and is the main structural element forming the subbasin. Several other faults are in the subbasin, one along the western side and one assumed at depth beneath the valley floor. A maximum known thickness of 360 feet of valley fill, all of which is alluvium, was penetrated by test hole (C–33–2)33ddd–1 in the central part of the subbasin.

Johns Valley subbasin is separated from Antimony subbasin downstream by a bedrock constriction between the Aquarius and Sevier Plateaus. The East Fork Sevier River flows through the constriction in Black Canyon, a steep-sided gorge about 8 miles long, 100–400 feet wide, incised in sedimentary and volcanic bedrock (pl. 1, geologic map and section *E–E′*).

ANTIMONY SUBBASIN

Antimony subbasin includes an area of about 6,000 acres between the mouth of Black Canyon and the head of Kingston Canyon (pl. 1., geologic map and section *E–E′*). It is a small valley bounded at its southern end by the bedrock at Black Canyon, on its western side by volcanic and sedimentary rocks of the Sevier Plateau, on its eastern side by eastward-dipping sedimentary and volcanic rocks of the Aquarius Plateau, and at its northern end by junction with the Grass Valley basin and the bedrock at the head of Kingston Canyon (pl. 1). This subbasin, like Johns Valley subbasin, is due largely to the Paunsaugunt fault, which occurs several miles east of the valley and separates it from the Aquarius Plateau (pl. 1). A maximum known thickness of 201 feet of valley fill, all of which is alluvium, was penetrated by test hole (C–31–2)3cbc–1 in the central part of the subbasin.

Downstream from Antimony subbasin, the East Fork Sevier River flows through the Sevier Plateau in Kingston Canyon, a narrow, steep-sided gorge, approximately 9 miles long, 100 feet to half a mile wide, incised in sedimentary (?) and volcanic rock.

GRASS VALLEY BASIN

Grass Valley basin is between the low topographic divide 7 miles north of Koosharem Reservoir and the Otter Creek Reservoir dam near the head of Kingston Canyon (pl. 1). The low topographic divide at the north end of the basin separates the Otter Creek drainage from the central Sevier Valley to the west and north. Grass Valley basin is divided into two subbasins by a bedrock constriction about 5½ miles south of Greenwich (pl. 1, section *F–F′*).

KOOSHAREM SUBBASIN

Koosharem subbasin includes an area of about 30,000 acres between the low topographic divide north of Koosharem Reservoir and the bedrock constriction south of Greenwich (pl. 1). It is bounded by the volcanic rocks of the Sevier Plateau on the west and the volcanic rocks of the Awapa and Fish Lake Plateaus on the east (pl. 1). The subbasin is a graben valley between the Paunsaugunt fault on the east and an unnamed fault on the west. A maximum known thickness of 770 feet of valley fill, most of which is alluvium, was penetrated by test hole (C–27–1)27bac–1 near the central part of the subbasin.

ANGLE SUBBASIN

Angle subbasin includes an area of about 20,000 acres between the bedrock constriction south of Greenwich and Otter Creek Reservoir dam, which is near the junction with Antimony subbasin and the head of Kingston Canyon (pl. 1). It also is a graben valley, bounded on the east by the Awapa Plateau and the Paunsaugunt fault, and on the west by the Sevier Plateau and an unnamed fault. Several large outcrops of volcanic rock within the subbasin define smaller basins which contain valley fill (pl. 1, section *F–F′*). A maximum known thickness of 490 feet of valley fill, all of which is alluvium, was penetrated by test hole (C–29–2)26dac–1 near Angle.

WATER RESOURCES

HISTORY OF WATER-RESOURCES DEVELOPMENT

Irrigation began in the upper Sevier River basin in the early 1850's when the first white settlers constructed diversion dams on some of the larger streams. Surface-water development reached its maximum in about 1920 (Woolley, 1947, p. 155).

Development of ground water in the basin began at about the same time as surface-water development but was limited mainly to the use of springs for public supply and irrigation. The first wells were constructed in about 1880, and the number has steadily increased to about 300. Most of the wells are used for domestic and stock supply, but periods of drought have increased interest in the possibilities of using additional water from wells for irrigation.

Controversies over water rights on the Sevier River system have occurred continually since the 1880's, mostly during drought periods. These controversies have resulted in many court decrees, including the Cox Decree of 1936 (Cox, 1936), which is used by the Utah State Engineer to distribute the water of the Sevier River system to the water users.

In the Cox decree, water rights pertaining to ground water are mostly for springs, but rights for a few drains and wells are also listed. The decree made little mention of wells in the upper Sevier River basin because it was assumed that unappropriated ground water was not available for additional appropriation. This assumption has persisted and has been an important factor in deterring large-scale development of ground water. The rights in the decree concerning wells specify only use for irrigation. Water rights for many domestic, stock, public-supply, and industrial wells and some irrigation wells that are not listed in the decree are in the files of the State Engineer.

SURFACE WATER

The source of all streams in the upper Sevier River basin is precipitation within the basin. Most of the surface flow that leaves the basin is in the Sevier River and its largest tributary, the East Fork Sevier River. These streams merge about 1½ miles north of the basin near Kingston. Some water also leaves the basin in irrigation canals near Kingston and by a transmountain diversion from a point on the East Fork Sevier River below Tropic Reservoir eastward to Paria Valley in the Colorado River basin.

Surface water is stored in several reservoirs in the basin and is diverted from the river and its main tributaries by many canals. The Sevier River, its tributaries, reservoirs, and canals are discussed in the following pages.

THE SEVIER RIVER AND ITS TRIBUTARIES

The Sevier River above Kingston (locally called the South Fork Sevier River) drains about 1,110 square miles. The chief water-yielding areas are high in the Markagunt Plateau near Cedar Breaks National Monument and Navajo Lake (pl. 2), and the main stem of the river is formed by the merging of Asay and Mammoth Creeks south of Hatch. As the river flows northward through Panguitch Valley and Circle Valley basins, it receives water from many tributaries and from ground-water discharge, part of which was originally water diverted for irrigation upstream.

The monthly flow of the Sevier River at three stream-gaging stations for the period 1945–62 is shown in figure 4, and the locations of the gaging stations are shown on plate 2. The Sevier River at Hatch had an average annual flow of 94,800 acre-feet for 40 years of record (1911–28, 1939–62); the Sevier River near Circleville, 111,500 acre-feet for 22 years of record (1914–22, 1923–24, 1949–62); and the Sevier River near Kingston, 94,120 acre-feet for 48 years of record (1914–62).

Both gains and losses have been recorded in the flow of the Sevier River between Hatch and Circleville and between Circleville and Kingston (fig. 4). The gains occur mainly during the nonirrigation season when little water is diverted from the main stream or its tributaries. The losses occur mainly during the growing season when much water is diverted for irrigation. The gains and losses in streamflow are discussed in greater detail on pages 40–42.

Near Kingston, the Sevier River merges with the East Fork Sevier River, its largest tributary, which drains both East Fork and Grass Valleys. The East Fork Sevier River originates high on the south end of the Paunsaugunt Plateau. Otter Creek, whose source is high on the Fish Lake Plateau, is the chief tributary of the East Fork Sevier River, and it drains Grass Valley. Data for the principal perennial tributaries of the Sevier River, the East Fork Sevier River, and Otter Creek are listed in table 2. Some of these tributaries are perennial only in their upper reaches, and flow reaches the main stream only during periods of high runoff.

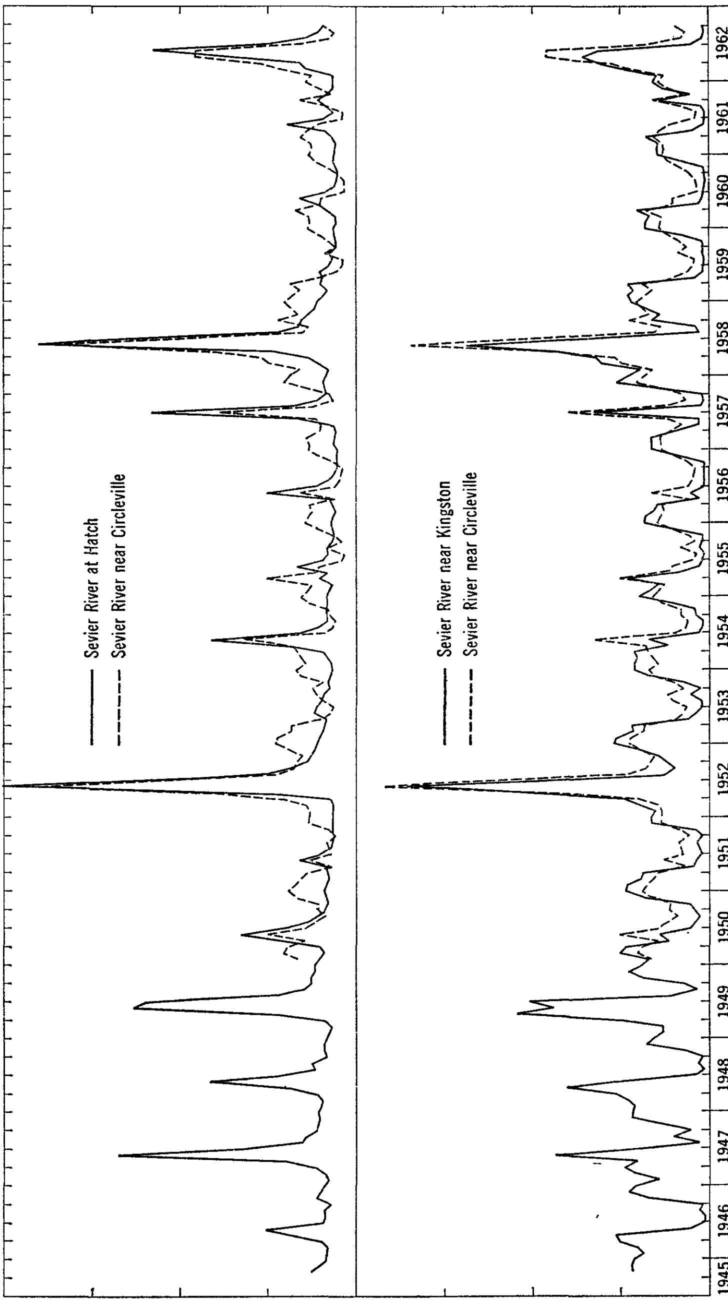

FIGURE 4.—Hydrographs of Sevier River flow at Hatch, near Circleville, and near Kingston.

TABLE 2.—*Data for the principal perennial tributaries of the Sevier River, East Fork Sevier River, and Otter Creek*

Tributary (in downstream order)	Stream length (miles)	Approximate drainage area (square miles)	Average annual flow (acre-feet per water year)	Period of record	Estimated average base flow (cfs)	Area irrigated by stream (acres)	Stream diversions and regulation
Panguitch Valley basin							
Sevier River (main stem) (South Fork):							
Asay Creek	18	131	23, 600	1954–59	26	--------	Several small diversions. Storage in Navajo Lake.
Mammoth Creek	22	134	58, 800	1916–18	14	--------	One canal and one diversion to Panguitch Creek.
Panguitch Creek	23	131	20, 000	1917–18, 1961–63.	4	4, 400	Two diversions. Storage in Panguitch Lake.
Threemile Creek	9	35	2, 300	Estimated	2	100	One diversion.
Sandy Creek	8	29	1, 500	do	. 5	120	One diversion. One small reservoir.
Sanford Creek	12	45	5, 000	do	2	220	Several diversions.
Bear Creek	15	56	3, 600	do	2	370	Several diversions and small reservoirs.
Circle Valley basin							
Loss Creek	11	45	4, 500	Estimated	1	52	One diversion. One small reservoir.
East Fork Sevier River	75	1, 260	59, 800	1913–63	10	--------	Many diversions and several reservoirs.

East Fork Valley basin

East Fork Sevier River:							
Hunt Creek	16	53	7,700	Estimated	1	200	One diversion.
Pine (Clay)[1] Creek	14	33	4,100	do	2	2,975	One diversion. Storage in Pine Lake Reservoir.
South Creek	8	14	1,600	do	.5	309	One diversion.
Sweetwater Creek	9	15	1,700	do	1	280	Do.
Horse Creek	9	13	1,900	do	2	200	One diversion. One small reservoir.
Birch Creek	6	7	1,100	do	.5	200	Do.
Ranch Creek	4	7	800	do	.5	200	Several diversions. One small reservoir.
Cottonwood (Needle Rock)[1] Creek.	13	30	3,700	do	<.5	658	Several diversions.
Deer (Mitchell)[1] Creek	14	26	4,900	do	4		No diversions or regulation.
North Creek	10	19	3,000	do	2		Do.
Center (Crystal)[1] Creek	6	15	2,300	do	1		Several diversions. One small reservoir.
Forest (Willow Spring)[1] Creek.	12	18	2,800	do	1	12	One diversion.
Poison Creek	6	10	800	do	1	92	Several diversions.
Antimony Creek	19	112	16,070	1946–48, 1957–63.	15	1,278	Do.
Pole Canyon (Hoodle)[1] Creek.	10	24	3,400	Estimated	2	56	One diversion.
Otter Creek	43	330	12,600	1915–20, 1961–63.	15		Many diversions and several reservoirs.

TABLE 2.—*Data for the principal perennial tributaries of the Sevier River, East Fork Sevier River, and Otter Creek*—Cont.

Tributary (in downstream order)	Stream length (miles)	Approximate drainage area (square miles)	Average annual flow (acre-feet per water year)	Period of record	Estimated average base flow (cfs)	Area irrigated by stream (acres)	Stream diversions and regulation
Grass Valley basin							
Otter Creek:							
Booby Hole Creek	3	11	1, 400	Estimated	1	790	One diversion. One reservoir. Small diversion from adjacent drainage into creek.
Daniels Canyon Creek	9	28	6, 400	do	7	1, 580	Several diversions.
Preater Creek	6	9	2, 300	do	1	170	One diversion.
Burr Creek	8	31	6, 400	do	4	655	Several diversions.
Koosharem Creek	11	22	2, 800	do	. 5	75	One diversion.
Greenwich Creek	10	29	3, 100	do	1	--------	Several diversions.
Box (Beaver) [1] Creek	12	41	6, 100	do	4	950	Several diversions. Two reservoirs.
Pole Canyon Creek	8	13	100	do	. 5	110	One diversion.

[1] Local name

Intermittent and ephemeral tributaries of the Sevier River, the East Fork Sevier River, and Otter Creek drain areas that range from a few to more than 50 square miles. The quantity of water yielded by these tributaries is dependent largely upon precipitation, drainage area, topography, vegetative cover, and geology. The annual yield of an intermittent or ephemeral tributary is in general small compared to a perennial tributary, and it may range from a few to as much as several thousand acre-feet following a cloudburst.

RESERVOIRS

The total storage capacity of reservoirs in the upper Sevier River basin is about 90,000 acre-feet. The principal reservoirs are listed in table 3 and are shown in figure 6.

Besides the reservoirs listed in table 3, many small reservoirs and natural lakes (less than 20 acres in area) are scattered throughout the plateaus surrounding the valleys. They are particularly numerous on the Aquarius Plateau and on the southwestern part of the Markagunt Plateau.

CANALS AND DITCHES

The principal canals and ditches that divert water for irrigation in the upper Sevier River basin from the Sevier River and its tributaries are shown in figure 6 and are listed in table 4. More than 30 irrigation companies maintain about 140 miles of canals and ditches. Individual canals vary in length from approximately 1 to 9 miles and discharge from about 250 to 35,000 acre-feet per year. Most of the canals and ditches are constructed of natural earth materials, but some of the canals are lined with concrete in places to prevent water losses.

TABLE 3.—*Data for the principal surface-water reservoirs in the upper Sevier River basin*

[Data largely from Woolley (1947)]

Reservoir	Location	Major drainage basin	Source of supply	Storage capacity (acre-feet)
Navajo Lake	T. 38 S., Rs. 8 and 9 W.	Sevier River (main stem).	Midway and Long Valley Creeks and Deer Hollow.	10,700
Panguitch Lake	Tps. 35 and 36 S., R. 7 W.	do	Castle, Blue Spring, Deer, Bunker, Clear, and Ipson Creeks.	18,580
Tropic	Secs. 5 and 8, T. 37 S., R. 4 W.	East Fork Sevier River.	East Fork Sevier River.	1,600
Pine Lake	Secs. 24 and 25, T. 35 S., R. 2 W.	do	Pine Creek	1,808
Booby Hole	Sec. 33, T. 24 S., R. 1 E.	Otter Creek	Booby Hole Creek	450
Koosharem	T. 25 S., R. 1 E	do	Daniels Canyon Creek.	3,858
Upper Box Creek	Sec. 10, T. 27 S., R. 2 W.	do	Box Creek	
Lower Box Creek	Sec. 11, T. 27 S., R. 2 W.	do	do	339
Otter Creek	Tps. 29 and 30 S., R. 2 W.	do	Otter Creek and East Fork Sevier River.	52,590
Total				89,925

TABLE 4.—*Principal canals and ditches that divert water for irrigation from the Sevier River and its tributaries*

Canal or ditch (in downstream order)	Source of water	Location of diversion point	Approximate canal length (miles)	Estimated average annual discharge (acre-feet per water-year)	Remarks
Panguitch Valley basin					
John Yardley Ditches	Asay Creek	SE¼ sec. 32, T. 37 S., R. 6 W	1	1,050	Flow measured by Sevier River water commissioner.
West Hatch (Hatch Bench)[1] Canal	Mammoth Creek	NE¼ sec. 3, T. 37 S., R. 6 W	5	3,800	Do.
East Hatch Ditch	Sevier River	SE¼ sec. 32, T. 36 S., R. 5 W	2	740	Do.
Upper Wilson Ditch	do	SE¼ sec. 10, T. 36 S., R. 5 W	1	340	Do.
Hillsdale Ditch	do	NW¼ sec. 2, T. 36 S., R. 5 W	2	1,000	Do.
Showalter Ditch	do	NW¼ sec. 2, T. 36 S., R. 5 W	3	900	Do.
Long and East Bench Canals	do	NW¼ sec. 11, T. 35 S., R. 5 W	9	14,140	Do.
Riggs Ditch	do	NW¼ sec. 11, T. 35 S., R. 5 W	2	250	Do.
Orton Ditch	do	SW¼ sec. 2, T. 35 S., R. 5 W	1	900	Do.
East Panguitch Canal	do	NE¼ sec. 34, T. 34 S., R. 5 W	5	7,750	Do.
West Panguitch Main Canal	Panguitch Creek	NW¼ sec. 32, T. 34 S., R. 5 W	8	20,000	Estimated.
Barton-LeFevre-Tebbs Canal	Sevier River	NW¼ sec. 9, T. 34 S., R. 5 W	4	4,190	Flow measured by Sevier River water commissioner.
McEwan Canal	do	NW¼ sec. 9, T. 34 S., R. 5 W	7	5,590	Do.
Bear Creek Canal	do	SW¼ sec. 10, T. 33 S., R. 5 W	5	2,330	Do.
Marshall Ditch	do	SW¼ sec. 35, T. 32 S., R. 5 W	2	650	Do.
Marshall Slough Ditch	Marshall Slough	SE¼ sec. 26, T. 32 S., R. 5 W	2	1,080	Do.
Whittaker Ditches	Sevier River	SW¼ sec. 18, T. 32 S., R. 4 W	2	800	Do.

Circle Valley basin					
Cannon Ditch	Sevier River	NW¼ sec. 9, T. 31 S., R. 4 W	2	510	Flow measured by Sevier River water commissioner.
Parker Ditch	do	SE¼ sec. 4, T. 31 S., R. 4 W	1	330	Do.
Loss Creek (Fox)[1] Canal	do	SW¼ sec. 3, T. 31 S., R. 4 W	6	3,630	Do.
Circleville West Canal	do	SW¼ sec. 3, T. 31 S., R. 4 W	6	8,970	Do.
Old Kingston Canal	do	SE¼ sec. 34, T. 30 S., R. 4 W	6	8,900	Do.
Dalton-Thompson Canal	do	SW¼ sec. 25, T. 30 S., R. 4 W	2	4,320	Do.
Junction (Mitchell Slough)[1] Canal	Mitchell Slough	NW¼ sec. 18, T. 30 S., R. 3 W	5	4,380	Do.
Junction Middle Ditch	Sevier River and Mitchell Slough	NW¼ sec. 16, T. 30 S., R. 3 W	2	1,890	Do.
Zabriskie Ditch	East Fork Sevier River	NE¼ sec. 14, T. 30 S., R. 3 W	2	900	Estimated.
Allen Ditch	do	NE¼ sec. 14, T. 30 S., R. 3 W	2	950	Flow measured by Sevier River water commissioner.
Kingston Main Canal	do	NE¼ sec. 15, T. 30 S., R. 3 W	2	5,300	Do.
East Fork Valley basin					
Tropic and East Fork Canal	East Fork Sevier River	NE¼ sec. 28, T. 36 S., R. 4 W	9	2,610	Flow measured by Sevier River water commissioner. Transmountain diversion.
Steed Canal	do	SE¼ sec. 36, T. 34 S., R. 3 W	8	1,200	Estimated.
Wiley Ditch	do	SW¼ sec. 35, T. 31 S., R. 2 W	2	700	Do.
Antimony-East Fork Canal	do	SE¼ sec. 27, T. 31 S., R. 2 W	6	4,000	Do.
Antimony Bench Canal	Antimony Creek	NE¼ sec. 20, T. 31 S., R. 1 W	3	9,800	Do.
Otter Creek Feeder Canal	East Fork Sevier River	NE¼ sec. 16, T. 31 S., R. 2 W	4	35,000	Do.
Grass Valley basin					
Koosharem Canal	Otter Creek	SW¼ sec. 6, T. 26 S., R. 1 E	8	10,000	Estimated.
Meridian Ditch	do	SW¼ sec. 7, T. 26 S., R. 1 E	3	1,000	Do.
Jolley Ditches	do	SW¼ sec. 19, T. 29 S., R. 1 W	3	5,000	Do.

[1] Local name.

GAINS AND LOSSES IN STREAMFLOW

The Sevier River and its principal tributaries gain or lose water in many places in the upper Sevier River basin. Gains are largely from tributaries, drains, springs, and seeps; and losses are by diversion into canals and ditches, by evapotranspiration, and by seepage into stream beds and banks.

The gains and losses to the Sevier River between Hatch and Kingston for the water years 1956–62, as indicated by measurements of streamflow and diversions, are summarized in table 5.

Panguitch Creek is the only measured tributary between the gaging stations at Hatch and Kingston, and except for a period between 1915 and 1920 it has been measured only since 1961. The net unmeasured inflow from tributaries, however, is included in the measured flow of the river near Circleville and near Kingston. The quantities of water diverted by the 20 canals and ditches between Hatch and Kingston are shown in table 5. Although this water is lost from the stream at the point of diversion, part of it seeps to the ground-water reservoirs from the canals and ditches and from irrigated fields, and eventually some water leaves the ground-water reservoirs to return to the river downstream. Much of the water diverted in canals and ditches is consumed by evapotranspiration. Use of water by this means is discussed in the section "Evapotranspiration" (p. 52), so the amounts lost in this way are not listed in table 5.

Table 5 indicates that the Sevier River consistently gains water in both Panguitch and Circle Valley basins. In Panguitch Valley basin this gain is principally from the various tributaries to the river, return flow of irrigation water, and ground water from springs and seeps. The amount supplied by tributaries varies considerably from year to year, depending on the amount of precipitation. The amount of return flow of irrigation water also varies from year to year, depending on the amount of water diverted for irrigation, but the discharge from springs and seeps is more consistent from year to year. The average annual gain to the river for the 1956–62 period in Panguitch Valley basin is about 47,000 acre-feet. The authors' study of the Sevier River water commissioners reports indicate that about 15 percent of the gain is ground-water discharge and that most of the water diverted by the Bear Creek Canal, Marshall Ditch, and Whittaker Ditches is ground-water discharge.

The gain in flow of the river in Circle Valley basin also comes principally from tributaries, return flow of irrigation water, and springs and seeps, but inflow from tributaries is smaller than it is in Panguitch Valley basin. The 1956–62 average gain in Circle Valley basin is about 21,000 acre-feet, of which about 30 percent is from ground-water

TABLE 5.—*Inflow, outflow, and gains of the Sevier River between Hatch and Kingston, in acre-feet, for the water years 1956–62*

[Canal diversion-point localities shown in table 4 and pl. 2; data from U.S. Geological Survey water-supply papers or Sevier River water commissioners' annual reports]

	1956	1957	1958	1959	1960	1961	1962
Panguitch Valley basin							
Inflow:							
Sevier River at Hatch	42,030	62,430	117,260	45,760	37,780	41,970	85,580
Panguitch Creek	--------	--------	--------	--------	--------	--------	18,120
Total inflow	42,030	62,430	117,260	45,760	37,780	41,970	103,700
Diversions:							
Upper Wilson Ditch	270	210	0	0	240	650	530
Hillsdale Ditch	1,520	1,510	850	960	610	590	920
Showalter and Riggs Ditches	1,250	1,230	930	820	970	1,040	930
Long and East Bench Canal	15,680	17,270	16,970	11,550	11,960	11,395	15,213
Orton Ditch	1,050	1,170	960	670	810	720	970
East Panguitch Canal	7,890	9,340	8,530	6,610	6,970	7,154	9,225
Barton-LeFevre-Tebbs Ditch	4,320	4,260	4,580	4,390	5,010	2,563	5,015
McEwan Canal	5,280	6,450	6,050	5,880	4,810	5,078	6,060
Bear Creek Canal	2,530	2,530	2,120	1,990	2,620	2,190	2,330
Marshall Ditch and Slough	2,180	1,590	1,410	1,270	1,530	1,380	1,750
Whittaker Ditches	880	760	940	960	760	520	490
Sevier River near Circleville	45,280	61,740	140,500	59,890	46,340	53,140	91,480
Total outflow	88,130	108,060	183,840	94,990	82,630	86,420	134,913
Gain	46,100	45,630	66,580	49,230	44,850	44,450	31,213
Circle Valley basin							
Inflow: Sevier River near Circleville	45,280	61,740	140,500	59,890	46,340	53,140	91,480
Diversions:							
Cannon Ditch	730	640	550	350	440	370	410
Parker Ditch	120	400	460	310	330	330	370
Loss Creek Canal	2,770	5,080	5,630	3,080	3,060	2,174	3,684
Circleville West Canal	7,070	10,530	11,850	6,910	8,240	9,500	11,681
Old Kingston Canal	6,330	10,090	12,990	8,080	6,860	9,077	11,934
Dalton-Thompson Canal	3,470	5,180	6,600	3,420	3,260	4,000	5,726
Junction Canal	4,300	4,300	4,050	4,220	4,430	5,000	4,050
Junction Middle Ditch	2,150	2,060	1,540	1,750	1,810	2,030	1,910
Sevier River uear Kingston	37,080	45,970	127,000	53,500	36,810	39,250	72,120
Total outflow	64,020	84,250	170,670	81,620	65,240	71,731	111,885
Gain	18,740	22,510	30,170	21,730	18,900	18,591	20,405

discharge. Nearly all the water diverted by the Junction Canal and Junction Middle Ditch is from return flow or ground-water discharge.

The East Fork Sevier River usually is dry between the Tropic and East Fork Canal diversion and a point south of Black Canyon in sec. 15, T. 33 S., R. 2 W., but there is enough inflow from tributaries in this reach to supply the Steed Canal and several smaller ditches.

The East Fork Sevier River gains about 20 cfs, or 15,000 acre-feet, in 10 miles, from the area south of Black Canyon to Antimony Creek. About 29 percent of this gain is from tributaries and about 71 percent is from springs. The entire flow of the East Fork Sevier River downstream from Antimony Creek generally is diverted into the Otter Creek Reservoir Feeder Canal. Between this diversion and Otter Creek, at the head of Kingston Canyon, the East Fork Sevier River gains about

5–10 cfs, or 3,000–7,000 acre-feet. About half of this gain is the combined flow of Pole Canyon plus seepage from Otter Creek Reservoir, and half is discharge from drains and seeps.

Otter Creek consistently gains about 13 cfs, or 10,000 acre-feet, between Koosharem Reservoir and a point about 16 miles downstream, in sec. 19, T. 28 S., R. 1 W., although the Koosharem Canal, Meridian Ditch, and several other ditches divert water from the Creek. Almost the entire gain is from seeps and springs. Enough water enters Otter Creek during the irrigation season, when diversions are at a maximum, to supply the Jolley Ditches near Angle.

GROUND WATER

SOURCE, OCCURRENCE, AND MOVEMENT

The source of all water in the upper Sevier River basin is precipitation within the basin. Water that reaches the land surface as precipitation either (1) evaporates, (2) transpired by plants, (3) becomes streamflow, or (4) seeps into the ground and either (1) is retained by soil moisture or (2) percolates downward to the zone of saturation and becomes part of the ground-water body. The source of ground water is discussed in greater detail in the next section on "Recharge."

The principles of the occurence of ground water have been discussed in detail by Meinzer (1923a, p. 2–102; 1923b). Only a few essential statements will be made here.

Water in an aquifer may be under either confined (artesian) or unconfined (water-table) conditions. Water is confined where a saturated permeable bed, such as gravel, is overlain by less permeable confining beds, such as clay or silt. Because it is confined, the water in the permeable bed is under hydrostatic pressure. A well that penetrates such a bed and flows at the ground surface is a flowing artesian well; a well that penetrates such a bed and does not flow is a nonflowing artesian well. The imaginary surface that everywhere coincides with the static level of the water in an artesian aquifer is called the piezometric surface.

If water is unconfined, that "surface" within the zone of saturation at which the pressure is everywhere atmospheric, is called the water table. If the water level in an artesian acquifer declines below the overlying confining bed, the aquifer will then be under water-table conditions. Where water-table conditions grade into artesian conditions within an aquifer, a common occurrence in the upper Sevier River basin, the water table and the piezometric surface are continuous or, in other words, are parts of the same surface.

Most of the available ground water in the upper Sevier River basin is contained in the sand and gravel deposits in the several ground-water basins, and it occurs under both artesian and water-table conditions.

Ground water is not stationary; it moves through an aquifer in the direction of greatest hydraulic slope. The rate of movement is slow, usually ranging from less than an inch to a few feet per day, but the quantity of water moving may be relatively large if the cross section of the aquifer is large.

RECHARGE

The principal source of recharge to the valley fill in the upper Sevier River basin is infiltration from the Sevier River and its tributaries, irrigation canals and ditches, and irrigated fields. Such recharge occurs only where the ground water is unconfined.

The Sevier River and its tributaries recharge the valley fill where the streams flow across deposits of gravel and sand that are above the water table. Such areas of recharge are generally where streams enter the several ground-water basins. Thus for the major streams, the area of recharge is the upper end of the basin; but for small streams it is where they emerge from canyons onto alluvial fans bordering the valleys.

Canals and ditches recharge the ground-water reservoir where they cross permeable material, such as gravel, sand, and friable soil, along the margins of the various valleys. Water infiltrates from irrigated fields mainly in the upper ends and along the sides of the ground-water basins where the soils generally are coarse grained.

Another source of recharge to the valley fill is from consolidated aquifers in the mountains around the valleys. The aquifers in the mountains in turn are recharged from precipitation and runoff.

Water-level contours may indicate areas of recharge, as ground water moves at right angles to the contours from areas of recharge toward points of discharge. Plate 2 indicates that the main recharge areas in Panguitch Valley basin are along the sides and at the upper end of the basin; recharge areas are in similar places in the other basins (pl. 2).

AQUIFER CHARACTERISTICS

The amount of ground water that can be withdrawn from an aquifer and the effects of withdrawal depend upon the hydraulic characteristics of the aquifer as well as its extent and saturated thickness. The principal hydraulic properties of an aquifer are its ability to store water, expressed by a "coefficient of storage," and its ability to transmit water, expressed by a "coefficient of transmissibility."

The coefficients of storage and transmissibility help determine, among other things, the magnitude, rate, and extent of the lowering of the water level in an aquifer caused by a discharging well. The

240-729—67——4

coefficient of storage of an aquifer is defined as the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. The coefficient of transmissibility is the rate of flow of water, at the prevailing water temperature, in gallons per day, through a vertical strip of the aquifer 1 foot wide extending the full saturated height of the aquifer under a hydraulic gradient of 100 percent. Methods used to determine the hydraulic characteristics of aquifers are described by Wenzel (1942), Ferris and others (1962), Jacob and Lohman (1952) and Theis, Brown and Meyer (1963).

The known range in coefficients of storage and transmissibility for each of the main ground-water basins in the upper Sevier River basin is shown in table 6. The coefficient of storage of artesian acquifers in the basin ranges from about 0.0001 to 0.001 and that of water-table aquifers from about 0.05 to 0.15. Circle Valley basin contains the aquifers having the highest known coefficient of transmissibility, 80,000 gpd per ft (gallons per day per foot), whereas the acquifers in Johns and Emery Valley subbasins have a maximum known coefficient of transmissibility of only 800 gpd per ft.

TABLE 6.—*Range in measured and estimated coefficients of storage and transmissibility in the upper Sevier River basin*

Basin or subbasin	Coefficient of storage	Coefficient of transmissibility (gpd per ft)
Panguitch Valley	[1] 0. 10 –0. 15	500–15, 000
Circle Valley	. 001– . 15	100–80, 000
East Fork Valley:		
Johns and Emery Valleys	. 05 – . 10	100–800
Antimony	. 001– . 15	1, 000–20, 000
Grass Valley (Koosharem and Angle subbasins)	. 0001– . 10	100–5, 000

[1] No determinations or estimates were made of the coefficient of storage for the artesian area in Panguitch Valley basin.

A wide range of values for the coefficients of storage and transmissibility, such as that shown in table 6, is common in alluvial aquifers where various degrees of sorting have taken place. If more complete data were available, however, they would probably show a range in coefficient of storage from 0.0001 to 0.15 in all the basins.

ESTIMATE OF RECOVERABLE GROUND WATER IN STORAGE

The recoverable ground water in storage in the principal ground-water reservoirs in the upper Sevier River basin was estimated from the areal extent, the saturated thickness, and the average coefficient of storage of the water-bearing sediments. The areal extent and thickness of the aquifers were determined by test drilling and a study of drillers' logs. The average values of coefficient of storage assigned to the sand and gravel comprising the principal aquifers of the area were estimated to range from 0.05 to 0.15. The storage estimate was made only for the upper 200 feet of saturated valley fill because sediments at greater depths probably cannot be economically dewatered under present conditions. The estimated amount of recoverable ground water in the sand and gravel of the upper 200 feet of saturated valley fill in the various ground-water basins is about 1 million acre-feet (table 7).

The 1 million acre-feet does not represent all the recoverable ground water stored in the upper 200 feet of saturated valley fill; the rest is in silt and clay which do not yield water readily to wells. The silt and clay, however, could ultimately yield some water to the sand and gravel aquifers if and when the latter are depleted by pumping.

TABLE 7.—*Estimated amount of recoverable ground water in storage in the sand and gravel of the upper 200 feet of saturated valley fill in the upper Sevier River basin*

Basin or subbasin	Average thickness of saturated sand and gravel (feet)	Assigned average coefficient of storage	Approximate area of aquifer (acres)	Estimated storage (acre-feet)
Panguitch Valley	50	0. 15	76, 000	570, 000
Circle Valley	100	. 15	14, 000	210, 000
East Fork Valley:				
Emery Valley [1]	10	. 05	12, 000	6, 000
Johns Valley	30	. 10	30, 000	90, 000
Antimony [1]	40	. 15	6, 000	36, 000
Grass Valley:				
Koosharem	30	. 10	30, 000	90, 000
Angle	30	. 10	20, 000	60, 000
Total				1, 062, 000

[1] Upper 100 feet of valley fill.

FLUCTUATIONS OF WATER LEVEL

Ground-water levels fluctuate primarily in response to the net withdrawals of water from or additions to the ground-water reservoir. The fluctuations may range in duration from minutes to years, and they are here classified as short term, annual, and long term.

SHORT-TERM FLUCTUATIONS

Short-term fluctuations of water levels can be caused by changes in streamflow, evapotranspiration, discharge from wells, and other factors. Some of the short-term changes observed in wells in the upper Sevier River basin are discussed below.

Changes in flow in nearby waterways cause changes in water levels in wells (C–32–5)26aca–1 and (C–34–5)20dbd–1 near Panguitch. Both wells tap unconfined water and were equipped with automatic water-level recording gages. Well (C-32-5)26aca-1 is about 70 feet from an irrigation canal, and well (C-34-5)20dbd-1 is about 100 feet from a small irrigation ditch and about 0.2 mile from Panguitch Creek. Records show that changes in flow in the waterways are followed in 1-5 days by changes in water level in the wells.

Daily fluctuations of water level are caused by evapotranspiration in areas where the water table is near the land surface. In such areas the water levels decline during the day and rise during the night. These fluctuations are relatively small and probably occur to some degree in all the area in the basin that is covered by phreatophytes (pl. 2).

Short-term fluctuations of water levels also are caused by discharge from wells. When a well discharges, the water table or piezometric surface of the aquifer penetrated by the well is depressed and assumes the approximate form of an inverted cone with the well at the apex. The extent and depth of this cone, called the cone of depression, depends on the hydraulic properties of the aquifer and the rate and duration of discharge. The cone of depression develops much faster under artesian conditions, where it is caused largely by the release of hydrostatic pressure, than it does under water-table conditions, where it is caused by gravity drainage of water from storage. When the spreading cone of depression reaches a nearby well, it causes a decline of water level in that well.

Records of a continuous water-level recording gage on well (C-36-4)34bda-3 show a decline in water level caused by pumping wells (C-36-4)34bda-1 and (C-36-4)34bda-2. Well (C-36-4)34bda-1 is 250 feet east and well (C-36-4)34bda-2 is 350 feet northwest of the well having the recording gage. The three wells tap the valley fill under water-table conditions at about the same depth. When well (C-36-4)34bda-1 was pumped for 48 hours on May 17-18, 1957, at a rate of about 25 gpm, the water level declined 0.21 foot in the gaged well; when the pump was turned off, the water level in the gaged well recovered 0.15 foot in 29 hours.

ANNUAL FLUCTUATIONS

Water levels fluctuate annually in most wells in the upper Sevier River basin. An annual rise of the water table is caused mostly by seepage of water from streams and by diversions of water from streams for irrigation. Annual fluctuations in artesian head generally are small, but they show some similarity to water-table fluctuations. The fluctuations in selected wells in each ground-water basin are shown on plate 3.

The pattern of annual fluctuation of water levels in wells that tap water-table aquifers is similar in all the ground-water basins in the upper Sevier River basin. Water levels usually begin to rise in March or April in response to recharge resulting from spring runoff and early irrigation. The levels continue to rise throughout the irrigation season, and they usually are highest in July, August, or September, near the end of the irrigation season. Water levels usually decline between the end of the irrigation season and the following spring; but in some areas irrigation in the fall causes a slight rise in water levels.

Annual fluctuations in artesian head are caused by discharge of flowing wells which are opened at the beginning of the irrigation season and closed at the end. This fluctuation is observed mainly in Koosharem subbasin. This condition exists especially where there is a high concentration of wells, such as in secs. 23 and 24, T. 26 S., R. 1 W., and secs. 1 and 2, T. 27 S., R. 1 W. (see pl. 2).

LONG-TERM FLUCTUATIONS

Long-term fluctuations of water levels in the several upper Sevier River ground-water basins were generally similar during the period 1938–63 (fig. 3). Water levels in all basins were highest during the late 1930's and through the 1940's but declined during the 1950's, although water levels generally rose in 1952, 1958, and 1962, which were years of above-normal recharge. The correlation between water-level changes and precipitation and streamflow is shown in figures 3 and 4. Ground-water levels usually rise during periods of high precipitation and streamflow, whereas they decline during dry periods. Precipitation and streamflow were below normal from 1950 through 1956 (except for 1952), and ground-water levels generally declined during the same period.

DEVELOPMENT AND DISCHARGE

Although more than 300 wells have been constructed in the upper Sevier River basin, springs supply most of the ground water used in the basin. The wells supply water mostly for domestic use and stock, but the springs furnish the public supply for most of the communities and also much of the irrigation supply. Drains also supply some water for irrigation.

In 1962 the discharge of ground water, in acre-feet, in the upper Sevier River basin by wells, springs, and drains is summarized as follows:

Source	Use, in acre feet				
	Public supply	Irrigation	Industry	Domestic and stock	Total (rounded)
Wells	100	1,800	3	1,100	3,000
Springs	1,800	106,400	0		108,000
Drains	0	3,000	0	0	3,000
Total	1,900	111,200	3	1,100	114,000

In addition to discharge from wells, springs, and drains, ground water is discharged by evapotranspiration and, in some basins, by subsurface outflow. Most of the discharge is directly from the valley fill, but several springs along the valley margins discharge from the bedrock of the surrounding highlands.

WELLS

More than 300 wells have been constructed in the upper Sevier River basin by digging, jetting, and cable-tool and rotary drilling. A description of these well-construction methods is given by Todd (1959, p. 115–148). The locations of selected wells are shown on plate 2 and details of construction and other features are given by Carpenter, Robinson, and Bjorklund (1964). Many domestic and stock wells were dug by hand before the other methods were introduced into the area. These dug wells, many of which are still in use, range from 14 to 120 inches in diameter and are from 6 to 100 feet deep. They generally are lined with rock or concrete. Most of the wells less than 4 inches in diameter were jetted, whereas most wells 4 to 16 inches in diameter were drilled by the cable-tool method. A few wells have been drilled by the rotary method.

Most of the drilled and jetted wells in the valley fill are less than 250 feet deep and are drilled just deep enough to produce a moderate amount of water. Generally only a small part of the aquifer is penetrated, especially in areas of artesian flow. Most of the well casings are unperforated and obtain water through the open bottom, but a few casings have been perforated at water-bearing zones. Wells designed to discharge large amounts of water usually are equipped with perforated casing and are developed by surging and pumping in order to remove silt and fine sand around the well.

The small-diameter domestic and stock wells are pumped mostly by gasoline or electrically driven centrifugal or piston pumps. Jet and small submersible turbine pumps supply water to many rural homes. Most of the irrigation and public-supply wells are equipped with turbine pumps driven by electric motors. Water flows freely from many domestic, irrigation, and stock wells in areas where the ground water is under artesian pressure.

"Specific capacity" is a term used to indicate the efficiency of a well. It is calculated by dividing the discharge of a well by the water-level drawdown, after the well has been discharging at a constant rate for at least several hours; it is expressed in gallons per minute per foot (gpm per ft) of drawdown. The specific capacity of a given well varies slightly depending on the rate of discharge and the length of time pumped. Table 8 shows that observed specific capacities of wells in the upper Sevier River basin range from 0.01 to 53 gpm per ft.

TABLE 8.—*Range and average of specific capacities of wells in the upper Sevier River basin*

Basin or subbasin	Wells for which data are available	Range in specific capacity (gpm per ft)	Average specific capacity (gpm per ft)
Panguitch Valley	16	0. 6–10	3. 8
Circle Valley	9	. 4–53	9. 0
East Fork Valley:			
Johns Valley-Emery Valley	11	. 01–7. 5	2. 4
Antimony	8	. 8–15	4. 2
Grass Valley	113	. 02–33	2. 0

The wide range in specific capacities of wells in the basin is mainly due to differences in methods of well construction, differences in the permeability of the water-bearing zones, or a combination of both. For example, well (C–30–4)25bcc–1, which has a specific capacity of 53 gpm per ft, is an irrigation well constructed to produce a large yield. The well is 133 feet deep, penetrates 65 feet of saturated sand and gravel, and has a 12-inch casing, of which 89 feet is perforated. In contrast, well (C–30-3)30baa–1, which has a specific capacity of about 4 gpm per ft, was constructed to produce only a small amount of water for stock. The well is 193 feet deep, penetrates 26 feet of saturated gravel, and has a 5-inch unperforated casing which receives water only through its open end.

The average annual discharge from wells in the upper Sevier River basin is about 3,000 acre-feet. Approximately 1,800 acre-feet is used for irrigation, 1,100 acre-feet for domestic use and stock, 100 acre-feet for public supply, and 3 acre-feet for industry. Of the 1,800 acre-feet used for irrigation, about 1,300 acre-feet is from flowing wells and about 500 is from pumped wells. The amounts discharged by wells in the four main basins, classified by use and type of well, are listed in table 9. The discharge by wells in Grass Valley basin is about 80 percent of the total discharge by wells in all four basins. The quantities in table 9 were estimated for 1962 from information on the type and period of use of wells, periodic measurements of discharge of selected wells, discharge measurements made during the well inventory, and yields reported by owners and drillers.

The discharge of flowing wells is greatest when artesian head is high, usually during years of high precipitation and high streamflow, when recharge also is high. Discharge of pumped wells is usually greatest when precipitation and streamflow are low, and wells are used to supplement streamflow and spring discharge.

TABLE 9.—*Use of water, number of wells, and estimated discharge from wells in 1962 in four basins of the upper Sevier River system*

Basin	Domestic and stock		Industry		Irrigation		Public supply		Wells not used	Total	
	Wells	Discharge (acre-feet)	Wells	Discharge (acre-feet)	Wells	Discharge (acre-feet)	Wells	Discharge (acre-feet)		Wells	Discharge (acre-feet)
All wells											
Panguitch Valley	39	5	0	0	0	0	1	44	33	73	49
Circle Valley	15	10	1	3	1	500	1	27	9	27	540
East Fork Valley	21	5	0	0	0	0	6	37	24	51	42
Grass Valley	133	1, 135	0	0	35	1, 320	0	0	7	175	2, 455
Total	208	1, 155	1	3	36	1, 820	8	108	73	326	3, 086
Flowing wells											
Panguitch Valley	0	0	0	0	0	0	0	0	1	1	0
Circle Valley	3	9	0	0	0	0	0	0	0	3	9
East Fork Valley	0	0	0	0	0	0	0	0	0	0	0
Grass Valley	108	1, 132	0	0	35	1, 320	0	0	0	143	2, 452
Total	111	1, 141	0	0	35	1, 320	0	0	1	147	2, 461
Pumped wells											
Panguitch Valley	39	5	0	0	0	0	1	44	32	72	49
Circle Valley	12	1	1	3	1	500	1	27	9	24	531
East Fork Valley	21	5	0	0	0	0	6	37	24	51	42
Grass Valley	25	3	0	0	0	0	0	0	7	32	3
Total	97	14	1	3	1	500	8	108	72	179	625

SPRINGS

Most of the ground water used beneficially in the upper Sevier River basin comes from springs. Springs furnish the public supplies for Panguitch, Circleville, Kingston, Antimony, Burrville, and Koosharem; most of these springs discharge from bedrock in the mountains and plateaus adjacent to the valleys. Development for public supply ordinarily consists of one or more collecting chambers at the spring site, a gravity conveyance system from the spring to the town, and a distribution system.

Many springs in the valleys and in the surrounding mountains and plateaus are important sources of water for irrigation. For example, springs discharging from bedrock in the Mammoth and Asay Creek drainages ordinarily contribute more than half the annual flow of the Sevier River at Hatch (Wilson and Thomas, 1964, p. 3). The location of some of the principal springs in the upper Sevier River basin is shown on plate 2, and the discharge from these springs is given in table 10.

TABLE 10.—*Estimated discharge and use of water in 1962, in acre-feet, from major springs in the upper Sevier River basin*

Basin	Total discharge	Use		
		Irrigation and stock		Public supply [1]
Panguitch Valley	85,780	85,000	(75 percent from bedrock, springs largely in surrounding plateaus; 25 percent from alluvium).	780
Circle Valley	6,195	6,000	(all from alluvium)	195
East Fork Valley	11,880	11,500	(50 percent from bedrock; 50 percent from alluvium).	380
Grass Valley	4,390	3,900	(90 percent from bedrock; 10 percent from alluvium).	490
Totals (rounded)	108,000	106,400		1,800

[1] All from bedrock.

About 98 percent of the spring discharge listed in table 10 is used for irrigation and stock and the remainder is used for public supply. Approximately 30 percent of the water discharged by these springs is from the valley fill and 70 percent is from bedrock. Many other bedrock springs are in remote parts of the mountains and plateaus surrounding the valleys, and the water discharged from them in accounted for in the flow of the perennial streams.

DRAINS

Control of water levels by artificial drainage in areas underlain by artesian aquifers has been attempted in Circle Valley basin and Antimony subbasin. The two drainage systems yield about 3,000 acre-feet of water annually, and they have become more important as a source of supply for irrigation downstream than as a means of controlling water levels. The drains are open channels, deep enough to penetrate to the water table in the saturated clay and silt near the surface but not deep enough to tap directly the underlying artesian aquifers. Water is forced through the confining silt and clay overlying the aquifer and it eventually moves into the drains. The drains also collect some water that has been applied for irrigation of areas adjacent to the wet bottom lands. Several canals have been constructed in Panguitch and Circle Valley basins and in Koosharem subbasin to collect water from slough and spring areas and deliver it to irrigated land. Although these canals in a sense are drains, they have not lowered water levels significantly, and their intended result was not drainage but recovery of water for irrigation.

Drains and canals in artesian areas such as the downstream parts of Panguitch Valley and Circle Valley basins and most of Antimony and Koosharem subbasins have not lowered water levels greatly because they are not deep enough to tap the more permeable water-bearing beds in the valley fill. The sand and gravel deposits in artesian areas generally are overlain by at least 5–20 feet of relatively impermeable silt and clay which will yield water to drains slowly but not in sufficient quantity to lower water levels significantly. Water levels could be lowered significantly by penetrating the underlying permeable deposits of gravel and sand with wells, deeper drains, a more efficient type of drain, or flowing wells in the bottom of drains.

Discharge of ground water by drains in the upper Sevier River basin is estimated to be about 3,000 acre-feet per year (table 11), and almost all the water is used for irrigation. The discharge from drains usually fluctuates in direct proportion to the amount of water distributed for irrigation.

EVAPOTRANSPIRATION

Evapotranspiration includes water discharged to the atmosphere by transpiration of vegetation or by direct evaporation. Water can evaporate directly from open-water surfaces, from the water table when it is at or near the land surface, from the soil, and from any exposed surface on which precipitation falls. About 12,000 acre-feet of surface water is evaporated annually from eight reservoirs in the upper Sevier River basin. In addition, about 43,000 acre-feet of water is discharged annually by evapotranspiration from about 23,000 acres of wet land in the basin. Most of this 43,000 acre-feet of water is derived from the ground-water reservoir, but some seeps in from adjacent irrigated areas.

TABLE 11.—*Estimated average annual discharge of drains in the upper Sevier River basin*

Basin	Length of drains (miles)	Average annual discharge (acre-feet)
Panguitch Valley	0	0
Circle Valley	5	2, 000
East Fork Valley, Antimony subbasin	4	1, 000
Grass Valley	0	0
Total	9	3, 000

EVAPORATION FROM SURFACE-WATER RESERVOIRS

The average annual evaporation from surface-water reservoirs in the upper Sevier River basin is more than five times the long-term average annual precipitation. Evaporation data have been collected for 45 years (1964) at Piute Dam, which is 8 miles north of Kingston and about 6,000 feet above sea level; a standard U.S. Weather Bureau land pan was used. Since 1918 the average annual evaporation from May through November has been about 55 inches (U.S. Weather Bureau, written commun., 1958).

The annual evaporation from the eight largest surface-water reservoirs in the upper Sevier River basin is estimated to be about 12,000 acre-feet; it is summarized below:

Reservoir	Annual evaporation [1] (acre-feet)	Reservoir	Annual evaporation [1] (acre-feet)
Navajo Lake	1, 200	Booby Hole	70
Panguitch Lake	3, 500	Koosharem	500
Tropic	500	Lower Box Creek	90
Pine Lake	200	Otter Creek	6, 000
		Total (rounded)	12, 000

[1] Based on an evaporation rate of 55 inches per year at Piute Dam; adjustments made for differences in altitude on the assumption that evaporation varies directly with altitude.

DIRECT EVAPORATION OF GROUND WATER

The amount of ground water discharged directly by evaporation depends upon many factors, including depth to the water table, soil type, and various climatological factors. Where the water table intersects the land surface, evaporation takes place directly from the ground-water body. Where the water table is only a few feet below the land surface and the soils are fine grained, the capillary fringe above the water table may reach the land surface; water then evaporates from the damp soil and is replaced from the ground-water reservoir by capillary action. (According to Meinzer (1923b, p. 26), "The capillary fringe * * * contains capillary interstices some or all of which are filled with water that is continuous with the water in the zone of saturation * * *."

The amount of ground water that is discharged directly by evaporation in the upper Sevier River basin is not known.

TRANSPIRATION

Transpiration is the discharge of water to the atmosphere by plants. If the water table or capillary fringe is within reach of the roots of plants, ground water will be discharged by transpiration. The rate of transpiration depends upon many conditions, including climate, plant type, size and density, depth to water, and the quality of the water. Transpiration of water by plants that have some recognized benefit to mankind is a consumptive use; transpiration of water by plants that do not benefit man is a consumptive waste (Thomas, 1951, p. 217).

Phreatophytes are plants that depend for their water supply on ground water that lies within reach of their roots (Robinson, 1958, p. 1.) The principal phreatophytes in the upper Sevier River basin are saltgrass, willow, cottonwood, greasewood, and rabbitbrush.

Areas that contain small bodies of surface water fed by springs and areas where the water table is close to the land surface generally support extensive growths of phreatophytes. Studies and experiments in the western conterminous United States, made under wide varieties of climate, plant-growth density, depth to water, quality of ground water, and soil type, indicate that fully developed cottonwoods use from 5 to more than 7 acre-feet of water per acre per year and that saltgrass, willow, greasewood, and rabbitbrush use approximately 2 to 3 acre-feet per year (Robinson, 1958, p. 49–75).

Phreatophytes in the upper Sevier River basin probably consume water at 50–75 percent of the rates given by Robinson, because much of the data on which Robinson's figures are based were collected in areas having higher average temperatures and longer growing seasons. The gross rate of evapotranspiration for the valleys in the upper Sevier River basin is estimated to be 20–30 inches per acre per year. Values in this range were used in table 12 in estimating the average annual evapotranspiration from the principal areas of phreatophyte growth in wet areas in the basin. (See pl. 2.)

SUBSURFACE OUTFLOW

Some ground water leaves the upper Sevier River basin or moves between the individual ground-water basins in the area by subsurface outflow through both the valley fill and bedrock. The amount

TABLE 12.—*Average annual evapotranspiration of water from phreatophytes in wet areas in the ground-water basins of the upper Sevier River basin*

Basin or subbasin	Area (acres)	Gross rate of evapotranspiration (in. per year)	Estimated average annual evapotranspiration (acre-feet)
Panguitch Valley	8, 500	20	14, 000
Circle Valley	3, 200	30	8, 000
East Fork Valley:			
Emery Valley	3, 000	20	5, 000
Johns Valley	700	20	1, 200
Antimony	2, 100	30	5, 200
Grass Valley:			
Koosharem	5, 600	20	9, 300
Angle	300	30	800
Total	23, 400	----------	43, 500

leaving each ground-water basin through valley fill generally is small because subsurface bedrock barriers at the downstream end of each of the basins make the cross-sectional area of valley fill small. Circle Valley basin and Angle subbasin are the only areas from which there is any significant amount of subsurface outflow. Gravel and sand beds at the downstream end of Circle Valley basin transmit about 1,000–2,000 acre-feet of water per year to the central Sevier Valley downstream. About 1,000 acre-feet per year moves from Angle subbasin to Antimony subbasin at the Otter Creek Reservoir damsite.

Ground water leaves the upper Sevier River basin by subsurface outflow through solution channels in limestone of the Wasatch Formation near Navajo Lake. This water discharges southward from Cascade Spring in the NE¼SE¼SE¼ sec. 17, T. 38 S., R. 8 W., in the Virgin River basin at a rate of about 1,000–2,000 acre-feet annually (Wilson and Thomas, 1964). Some ground water also seeps through bedrock eastward into the Paria River drainage from the Paunsaugunt Plateau (Marine, 1963, p. 461–463). A determination of the total amount seeping out of the upper Sevier River basin through bedrock is beyond the scope of this investigation, but recent studies by Goode (1964) and the U.S. Soil Conservation Service (written commun., 1963) indicate that the amount from the Markagunt Plateau alone may be several thousand acre-feet annually.

RELATION BETWEEN GROUND WATER AND STREAMFLOW

The base flow of the Sevier River, the East Fork Sevier River, and Otter Creek in most parts of their channels is affected by discharge to or recharge from the ground-water reservoir. The streams lose water where the water table or piezometric surface is lower than the stream surface, especially where the stream beds overlie permeable materials such as gravel or coarse sand. Conversely, the streams gain water where ground-water levels are above the stream levels. The water that enters the ground from the streams moves through the aquifers at velocities of only a few feet per day or less. The quantity of water moving through the aquifers, however, probably is relatively large because the aquifers generally have a high average permeability, a large cross-section area, and a hydraulic gradient of several feet per mile.

At several places in the upper Sevier River basin, subsurface barriers of bedrock impede the downstream movement of ground water, force the water toward the surface, and thus cause the ground-water reservoirs to overflow. These barriers are at the downstream ends of Panguitch Valley and Circle Valley basins, Johns Valley and Antimony subbasins of East Fork Valley basin, and Koosharem and Angle subbasins of Grass Valley basin. Upstream from these barriers, ground water is discharged mainly by evapotranspiration, by springs, and by seeps that return much of the water to the stream. For example, the base flow of the Sevier River in Circleville Canyon can be correlated directly with water levels in the valley fill at the downstream end of Panguitch Valley basin. This direct relation is illustrated in figure 5, which shows that high water levels in the valley fill correspond to a high base flow in the Sevier River and low water levels correspond to a low base flow.

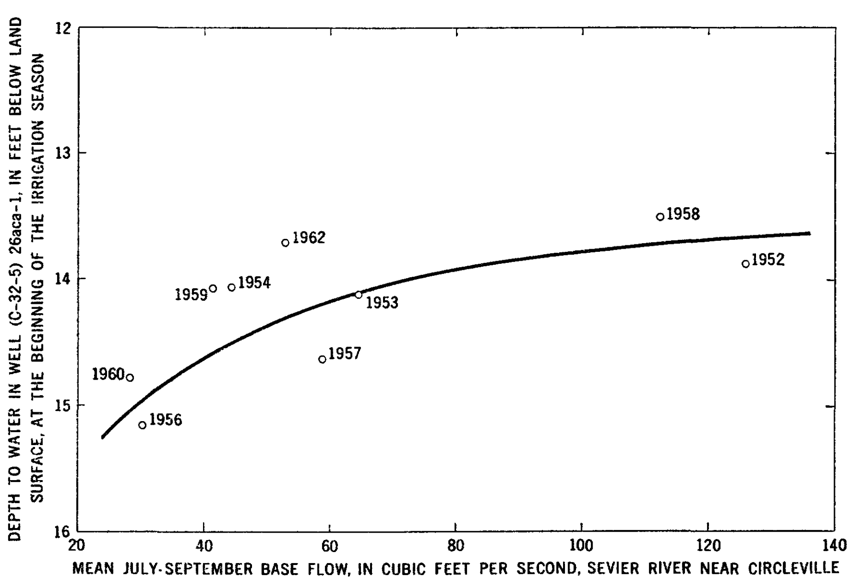

FIGURE 5.—Graph showing the relation between the water level in well (C-32-5)26aca-1 and the base flow of the Sevier River near Circleville (in Circleville Canyon).

Withdrawals of ground water by wells and drains may lower water levels and consequently reduce the base flow of streams. If enough water is withdrawn, the natural discharge of ground water to a stream may decrease significantly or stop. The surface-water and ground-water systems in the upper Sevier River basin are in approximate equilibrium, and the removal of large amounts of ground water could eventually (1) increase recharge to the aquifers from surface streams and thereby decrease streamflow, (2) decrease ground-water discharge to streams and from springs, flowing wells, and evapotranspiration, or (3) have combined effects of (1) and (2).

INFLOW-OUTFLOW ANALYSES OF THE GROUND-WATER BASINS

In any basin, the quantity of water entering by surface-water inflow, ground-water inflow, and precipitation is equal to the quantity of water leaving the basin by surface-water outflow, ground-water outflow, and evapotranspiration, plus or minus the quantity gained or lost in surface- and ground-water storage and changes in soil moisture. All these quantities can be related by means of an inflow-outflow analysis, a type of hydrologic budget.

Inflow-outflow analyses were made for each of the ground-water basins in the upper Sevier River basin for the 1961 and 1962 water years. The major difficulties in making the analyses were the complexity of the distribution system for irrigation water, insufficient precipitation data, and lack of data (1) for several important surface-water sites, (2) for inflow from perennial, intermittent, and ephemeral streams, and (3) for ground water entering each basin by inflow from bedrock. Because of these difficulties, some estimates and assumptions were necessary, and the data listed in tables 13–19 should not be considered as absolute.

Surface-water inflow and outflow were based upon measurements, where available, and upon estimates. Estimates of surface-water inflow were based largely upon size, altitude, and geology of the drainage area and upon precipitation on the drainage area. Some of the ungaged inflow from intermittent and ephemeral streams is included in the item "Inflow from other sources."

Ground-water inflow and outflow at the upper and lower ends of the basins were estimated on the basis of the thickness of, permeability of, and hydraulic gradient in the valley fill. Sufficient information was not available to make a separate estimate of the amount of ground water moving into the basins directly from bedrock. An indirect estimate of this amount, however, is included in the item "Inflow from other sources."

Precipitation was estimated from records of the U.S. Weather Bureau. Precipitation data at a station within a basin were used when available, but an average of data from surrounding stations was used when local data were not available.

The evapotranspiration from cultivated areas was estimated using a method described by Criddle, Harris, and Willardson (1962). The croplands were classified according to crop type (including alfalfa, small grains, corn, potatoes, pasture, wild hay) or as idle land. The acreage of each crop type varied from year to year depending upon the water supply and other factors. Gross water-use requirements for each type were multiplied by the acreage of each type to determine the annual amount of water consumed.

The method of estimating evapotranspiration from noncultivated wet areas is described in the section on "Evapotranspiration." No data are available for evaporation from waterlogged land; therefore, the estimates are based on transpiration from phreatophytes in all wet areas, including ponds and sloughs.

Evapotranspiration from noncultivated brushland was assumed to equal all the precipitation on these lands. Much of the area that comprises the ground-water basins in the upper Sevier River basin is not cultivated. It is covered with native brush and other vegetation that depend for their water supply entirely on soil moisture derived directly from precipitation. Little, if any, of the precipitation recharges the ground-water reservoir.

The method of estimating evaporation from Otter Creek and Koosharem Reservoirs is described in the section on "Evaporation from surface-water reservoirs." The other reservoirs in the upper Sevier River basin are outside the ground-water basins. The rates of evaporation from Otter Creek and Koosharem Reservoirs are assumed to be similar for both the 1961 and 1962 water years. However, the large difference in storage in Otter Creek Reservoir during the period of high evaporation (May–September) caused a significant change in the total evaporation from 1961 to 1962.

The changes in storage in Otter Creek Reservoir were measured. Records of changes in storage in Koosharem Reservoir are not available, but about the same amount of water is in the reservoir at the beginning and end of every water year; therefore, there is little significant change in storage.

The changes in ground-water storage were determined as the product of three factors: (1) the area where ground water is under water-table conditions, (2) the annual change in the level of the water table, and (3) the average storage coefficient of the water-table aquifer. Changes in storage in artesian aquifers were not included in the analyses because they were considered to be neglible owing to the extremely small storage coefficient of artesian aquifers and small changes in head. Changes in soil moisture were not considered in the analyses because it was assumed that there was little net change on an annual basis.

The inflow from other sources is inflow not otherwise accounted for in the analyses. It includes surface flow from some perennial, intermittent, and ephemeral streams and inflow of ground water from the following sources: seepage from streams into the valley fill near the plateau and mountain fronts and seepage from bedrock in the mountains and plateaus directly to the valley fill of the ground-water basins.

The inflow from the other sources is the unknown quantity in the analyses, and it was approximated by taking the difference between all other items of estimated inflow and outflow, plus or minus changes in storage. This difference, of course, also includes all errors involved in making the estimates or assumptions.

PANGUITCH VALLEY BASIN

The inflow-outflow analyses of Panguitch Valley basin for the 1961 and 1962 water years are given in table 13 (next page). Precipitation generally was above normal during the 1961 water year throughout the upper Sevier River basin. Subsequently, streamflow generally was high during the 1962 water year. The inflow during these years was 167,000 and 175,000 acre-feet, respectively. Of this amount, about one-third to one-half left the basin in the Sevier River, whereas the remainder was consumed in the basin or else went into temporary ground-water storage.

During the 1961 and 1962 water years, an average of about 25 percent of the water consumed in the basin was used in cultivated areas, about 16 percent was used in noncultivated wet areas, and about 59 percent in noncultivated brushland. The measured streams supplied an average of about 40 percent of the total inflow, precipitation on the basin supplied about 43 percent, and inflow from other sources provided about 17 percent.

CIRCLE VALLEY BASIN

The inflow-outflow analyses of Circle Valley basin for the 1961 and 1962 water years are given in table 14. The inflow during these years was 75,000 and 108,000 acre-feet. Of this amount, about 66 percent left the basin in the Sevier River and in two canals, about 2 percent left the basin as underflow, about 30 percent was consumed in the basin, and about 2 percent went into temporary ground-water storage.

During the 1961 and 1962 water years, an average of about 54 percent of the water consumed in the basin was used in cultivated areas, about 31 percent was used in wet noncultivated areas, and about 15 percent in noncultivated brushland. The Sevier River supplied about 77 percent of the total inflow to the basin, precipitation on the basin

240-729—67——5

contributed about 13 percent, and inflow from other sources supplied about 10 percent.

TABLE 13.—*Inflow and outflow of water and change in storage, Panguitch Valley basin, in thousands of acre-feet*

	Water years 1961	1962
Surface-water inflow at upper end (Sevier River plus West Hatch Canal and East Hatch Ditch)	46	90
Ground-water inflow at upper end	Negligible	
Precipitation on ground-water basin (76,000 acres)	95	51
Inflow from other sources (includes Panguitch Creek)	26	34
Total water entering the basin	167	175
Surface-water outflow (Sevier River)	53	91
Ground-water outflow	Negligible	
Evapotranspiration from—		
Cultivated areas (10,500 acres)	22	22
Noncultivated wet areas (8,500 acres)	14	14
Noncultivated brushland (57,000 acres)	71	38
Total water leaving the basin	160	165
Change in ground-water storage	+7	+10
Total water entering the basin	167	175

TABLE 14.—*Inflow and outflow of water and change in storage, Circle Valley basin, in thousands of acre-feet*

	Water years 1961	1962
Surface-water inflow at upper end (Sevier River)	53	91
Ground-water inflow at upper end	Negligible	
Precipitation on ground-water basin (14,000 acres)	13	9
Inflow from other sources	9	8
Total water entering the basin	75	108
Surface-water outflow (Sevier River plus Junction and Junction Middle Canals)	46	78
Ground-water outflow	1	2
Evapotranspiration from—		
Cultivated areas (4,800 acres)	14	14
Noncultivated wet areas (3,200 acres)	8	8
Noncultivated brushland (6,000 acres)	5	3
Total water leaving the basin	74	105
Change in ground-water storage	+1	+3
Total water entering the basin	75	108

EAST FORK VALLEY BASIN

EMERY VALLEY SUBBASIN

The inflow-outflow analyses of Emery Valley subbasin for the 1961 and 1962 water years are given in table 15. The inflow during each of these years was about 26,000 acre-feet. Of this amount, about 27 percent left the subbasin in the East Fork Sevier River, about 12 percent left the subbasin and the Sevier River drainage basin by transmountain diversion in the Tropic and East Fork Canal, and about 61 percent was consumed in the subbasin or went into temporary ground-water storage.

During the 1961 and 1962 water years, an average of about 33 percent of the water consumed in the subbasin was used in noncultivated wet areas and about 67 percent was used in noncultivated brushland. The East Fork Sevier River supplied about 19 percent of the total inflow to the subbasin, precipitation on the subbasin contributed about 54 percent, and inflow from other sources supplied about 27 percent.

TABLE 15.—*Inflow and outflow of water and change in storage, Emery Valley subbasin, in thousands of acre-feet*

	Water years 1961	1962
Surface-water inflow at upper end (East Fork Sevier River)	4	6
Ground-water inflow at upper end	Negligible	
Precipitation on ground-water subbasin (12,000 acres)	17	11
Inflow from other sources	5	9
Total water entering the subbasin	26	26
Surface-water outflow:		
East Fork Sevier River	5	9
Tropic and East Fork Canal	2	4
Ground-water outflow	Negligible	
Evapotranspiration from—		
Noncultivated wet areas (3,000 acres)	5	5
Noncultivated brushlands (9,000 acres)	13	8
Total water leaving the subbasin	25	26
Change in ground-water storage	+1	0
Total water entering the subbasin	26	26

JOHNS VALLEY SUBBASIN

The inflow-outflow analyses of Johns Valley subbasin for the 1961 and 1962 water years are given in table 16. The inflow during these years was 67,000 and 47,000 acre-feet. Of this amount, about 35 percent left the subbasin in the East Fork Sevier River, about 61 percent was consumed in the subbasin, and about 4 percent went into temporary ground-water storage.

During the 1961 and 1962 water years, an average of about 13 percent of the water consumed in the subbasin was used in cultivated areas, about 3 percent was consumed in noncultivated wet areas, and about 84 percent was consumed in noncultivated brushland. The East Fork Sevier River supplied about 13 percent of the total inflow, precipitation on the subbasin contributed about 55 percent, and inflow from other sources supplied about 32 percent.

TABLE 16.—*Inflow and outflow of water and change in storage, Johns Valley subbasin, in thousands of acre-feet*

	Water years 1961	1962
Surface-water inflow at upper end (East Fork Sevier River)	5	9
Ground-water inflow at upper end	Negligible	
Precipitation on ground-water subbasin (30,000 acres)	41	23
Inflow from other sources	21	15
Total water entering the subbasin	67	47
Surface-water inflow (East Fork Sevier River)	21	19
Ground-water outflow	Negligible	
Evapotranspiration from—		
Cultivated areas (2,500 acres)	5	4
Noncultivated wet areas (700 acres)	1	1
Noncultivated brushland (26,800 acres)	38	21
Total water leaving the subbasin	65	45
Change in ground-water storage	+2	+2
Total water entering the subbasin	67	47

ANTIMONY SUBBASIN

The inflow-outflow analyses of Antimony subbasin for the 1961 and 1962 water years are given in table 17. The inflow during each of these years was about 60,000 acre-feet. Of this amount, about 83 percent left the subbasin in the East Fork Sevier River and the Otter Creek Reservoir Feeder Canal for use downstream, and about 17 percent was consumed in the subbasin or went into temporary ground-water storage.

During the 1961 and 1962 water years, an average of about 38 percent of the water consumed in the subbasin was used in cultivated areas, about 48 percent was used in noncultivated wet areas, and about 14 percent in noncultivated brushland. The East Fork Sevier River supplied about 55 percent of the total inflow and Antimony Creek about 30 percent; precipitation on the subbasin contributed about 8 percent, inflow from other sources supplied about 5 percent, and underflow from Angle subbasin contributed about 2 percent.

GRASS VALLEY BASIN

KOOSHAREM SUBBASIN

The inflow-outflow analyses of Koosharem subbasin for the 1961 and 1962 water years are given in table 18. The analyses indicate that 61,000 acre-feet of water entered the subbasin during each of these years. Of this amount, about 30 percent left the subbasin as surface flow in Otter Creek for use downstream, about 65 percent was consumed in the subbasin, and about 5 percent went into temporary ground-water storage.

TABLE 17.—*Inflow and outflow of water and change in storage, Antimony subbasin, in thousands of acre-feet*

	Water years 1961	1962
Surface-water inflow at upper end (East Fork Sevier River)	29	38
Inflow from Antimony Creek	19	17
Ground-water inflow:		
At upper end	Negligible	
From Angle subbasin	1	1
Precipitation on ground-water subbasin (6,000 acres)	6	4
Inflow from other sources	4	2
Total water entering the subbasin	59	62
Surface-water outflow (East Fork Sevier River and Otter Creek Reservoir Feeder Canal)	47	52
Ground-water outflow	Negligible	
Evapotranspiration from—		
Cultivated areas (2,000 acres)	4	4
Noncultivated wet areas (2,100 acres)	5	5
Noncultivated brushland (1,900 acres)	2	1
Total water leaving the subbasin	58	62
Change in ground-water storage	+1	0
Total water entering the subbasin	59	62

TABLE 18.—*Inflow and outflow of water and change in storage, Koosharem subbasin, in thousands of acre-feet*

	Water years 1961	1962
Surface-water inflow (from tributaries)	19	31
Precipitation on ground-water subbasin (30,000 acres)	33	18
Inflow from other sources	9	12
Total water entering the subbasin	61	61
Surface-water outflow (Otter Creek)	15	22
Ground-water outflow	Negligible	
Evapotranspiration from—		
Cultivated areas (6,000 acres)	14	14
Noncultivated wet areas (5,600 acres)	9	9
Noncultivated brushland (18,400 acres)	20	11
Evaporation from Koosharem Reservoir	1	1
Total water leaving the subbasin	59	57
Change in ground-water storage	+2	+4
Total water entering the subbasin	61	61

During the 1961 and 1962 water years, an average of about 36 percent of the water consumed in the subbasin was used in cultivated areas, about 24 percent was used in noncultivated wet areas, about 38 percent in noncultivated brushland, and about 2 percent was evaporated from Koosharem Reservoir. The surface flow of tributaries supplied about 41 percent of the total inflow, precipitation on the subbasin contributed about 42 percent, and inflow from other sources supplied about 17 percent.

240–729—67——6

ANGLE SUBBASIN

The inflow-outflow analyses of Angle subbasin for the 1961 and 1962 water years are given in table 19. The inflow during these years was 61,000 and 69,000 acre-feet of water. Of this amount, about 53 percent left the subbasin as surface flow through Otter Creek Reservoir for use downstream, about 2 percent left the subbasin as underflow, about 36 percent was consumed in the subbasin, about 7 percent went into temporary surface-water storage, and about 2 percent went into temporary ground-water storage.

During the 1961 and 1962 water years, about 4 percent of the water consumed in the subbasin was used in cultivated areas, about 4 percent in noncultivated wet areas, about 65 percent in noncultivated brushland, and about 27 percent evaporated from Otter Creek Reservoir. Otter Creek and Otter Creek Reservoir Feeder Canal supplied about 68 percent of the total inflow, precipitation on the subbasin contributed about 23 percent and inflow from other sources contributed about 9 percent.

TABLE 19.—*Inflow and outflow of water and change in storage, Angle subbasin, in thousands of acre-feet*

	Water years 1961	1962
Surface-water inflow at upper end (Otter Creek and Otter Creek Reservoir Feeder Canal)	40	48
Precipitation on ground-water subbasin (20,000 acres)	18	12
Inflow from other sources	3	9
Total water entering the subbasin	61	69
Surface-water outflow (Otter Creek Reservoir outlet)	31	39
Ground-water outflow	1	1
Evapotranspiration from—		
Cultivated areas (540 acres)	1	1
Noncultivated wet areas (300 acres)	1	1
Noncultivated brushland (19,160 acres)	18	12
Evaporation from Otter Creek Reservoir	4	8
Total water leaving the subbasin	56	62
Change in surface-water storage	+4	+5
Change in ground-water storage	+1	+2
Total water entering the subbasin	61	69

GROUND-WATER CONDITIONS IN THE BASINS

PANGUITCH VALLEY BASIN

Availability and storage of ground water

Ground water is readily available to wells in Panguitch Valley basin, mainly in the valley fill from Hatch to the head of Circleville Canyon. The valley fill in the northern part of Panguitch Valley basin ranges in thickness from 0 to more than 800 feet (Feltis and Robinson, 1963, p. 7–17). Test hole (C–33–5)13bdd–1, in the northeastern part of the valley, penetrated 833 feet of valley fill, all of which is alluvium, without reaching bedrock. The thickest zone of valley fill, 400–600 feet thick, extends north-south through the central and eastern parts of the valley. From this zone the valley fill probably thins to the north, west, and south toward the basin boundaries (pl. 1, sections *B–B′* and *D–D′*). Generally it is coarsest on the eastern side of the valley in proximity to the Sevier fault and the plateau, but the most permeable deposits are along the Sevier River channel. About 25–50 percent of the valley fill in the northern part of the basin is permeable sand and gravel.

The valley fill in the southern part of Panguitch Valley basin between Panguitch and Hatch is much thinner and less permeable than that in the northern part of the basin. On the basis of data from the few wells that have been drilled in this area, the valley fill was estimated to range in thickness from 0 to 200 feet.

Ground water is under artesian conditions in the valley fill in a small area at the lower end of the basin (see pl. 2). It is impounded there by a constriction in the bedrock which forms a barrier to further subsurface movement toward the north. The ground water is confined in permeable gravel by 5–20 feet of overlying silty clay of low permeability, and the piezometric surface in wells in the gravel ranges from 0 to 3 feet above the land surface and averages about 2 feet above the land surface. At the lower end of the basin the artesian area is marked by marshes and meadowlands.

Ground water generally is under water-table conditions in the southern four-fifths of Panguitch Valley basin. The observed water table ranges from less than 1 foot below the land surface in well (C–33–5)9adb–1 to more than 89 feet in well (C–34–5)2cbc–1.

An estimated 570,000 acre-feet of ground water is stored in the sand and gravel in the upper 200 feet of saturated valley fill in the basin (table 7), mostly under water-table conditions. The sand and gravel deposits are separated by saturated silt and clay which are not permeable enough to yield water readily to wells.

The Sevier River Formation on both the east and west sides of the south-central part of the basin contains ground water, some of which is perched above the water levels shown in plate 2.

No production wells have been constructed in the bedrock that surrounds and underlies the valley. Therefore, although the rocks are known to contain ground water, it is not known if they will yield water readily to wells.

Existing use

Most of the ground water used in Panguitch Valley basin is discharged by springs which issue from either the valley fill or from bedrock. The largest springs that discharge from valley fill are in the Marshall and Veater Sloughs (sec. 35, T. 32 S., R. 5 W.). These springs have a combined discharge of about 1,800 gpm. Many smaller springs discharge from less than 1 to about 450 gpm from permeable zones in the alluvial fans and in the Sevier River Formation along the sides of the basin. Many of these springs are along the edge of the bluffs on the east side of the Sevier River betwen Hatch and Casto Canyon and along the edge of the alluvial fans on the west side of the river between Threemile Creek and Bear Creek.

The bedrock springs are mostly in mountainous areas, generally remote from the valley floor. Information on the major bedrock springs is summarized below:

Name	Location	Discharge (cfs)	Date of measurement	Use of water
Blue Spring	(C-36-7)18acb	10	Aug. 1962	Irrigation and stock.
Mammoth Spring	31dac	2–270	Apr.–June 1957.	Do.
Upper Asay Spring.	(C-37-6)32dac	8	Oct. 1962	Do.
Lower Asay Spring.	33bc	22–333	1954	Do.
Duck Creek Spring.	(C-38-8)12cd	9.4–25	1954	Do.
Indian Hollow (or Panguitch) Springs.	(C-34-6)18c	1	Dec. 1961	Public supply, Panguitch.

These springs usually have a combined flow of about 90 cfs and supply about 65,000 acre-feet of water annually to the Sevier River system. All except Indian Hollow Springs discharge from solution channels in the limestone of the Wasatch Formation, although the water from many of them emerges from broken basalt overlying the limestone. Indian Hollow Springs issue from volcanic rocks of Tertiary age.

Most of the wells in Panguitch Valley basin were constructed for domestic and stock use, but one well is used for public supply at Hatch. All the wells obtain water from the alluvial deposits or the Sevier River Formation, and yields from individual wells range from about 1 to 75 gpm. Wells produce less than 50 acre-feet of water annually in Panguitch Valley basin, and all the water is pumped.

There are approximately 70 wells in the basin. About 30 are dug wells, and they range from 24 to 54 inches in diameter and from 8 to 76 feet in depth. About 40 are drilled wells, and they range from 3 to 10 inches in diameter and from 33 to 458 feet in depth; most of them, however, are less than 200 feet deep. Most of the ground water pumped in Panguitch Valley basin is from well (C-36-5)29dcd-1, which yields about 40 acre-feet annually for public supply at Hatch.

Potential development

About 7,000 acre-feet of additional ground water could be withdrawn annually in Panguitch Valley basin without greatly affecting the flow in the Sevier River if the water can be salvaged from existing uses. About 14,000 acre-feet of water (table 12) is discharged annually by evapotranspiration from 8,500 acres of marshes and wet meadowland which support growths of saltgrass and other phreatophytes. Probably about half of the 14,000 acre-feet could be salvaged by means of new drains or wells which would lower water levels in the gravel and sand deposits in the lower end of the basin and thereby decrease losses by evapotranspiration. The lowering of water levels, however, would undoubtedly decrease the flow of water from the Marshall Slough. The wells and drains used to lower water levels must be constructed within the wet areas if they are to lower water levels within these areas.

In addition to salvaging water, reduction of evapotranspiration would improve the productivity of some of the land by decreasing the precipitation of salts at the land surface. Furthermore, if the land were drained, crops requiring much less water than do phreatophytes could then be grown. Lining of canals and mechanical eradication of phreatophytes are other methods of salvaging water.

CIRCLE VALLEY BASIN

Availability and storage of ground water

The valley fill is the main source of ground water in Circle Valley basin. The fill ranges in thickness from a thin edge near the valley margins to more than 600 feet near the center of the valley, where test holes have been drilled without penetrating bedrock (Feltis and Robinson, 1963, p. 18–21; Young, 1960, p. 2, 6–7). The valley fill consists of the flood-plain and alluvial-fan deposits, about 50–60 percent of which are well sorted and highly permeable. The fill in Circle Valley basin has the highest proportion of permeable material of any of the valley fill in the upper Sevier River basin. The most permeable deposits are along the Sevier River channel. Ground water in the valley fill is under artesian conditions at the lower end of the basin and under water-table conditions at the upper end of the basin (pl. 2).

In the artesian area, the subsurface movement of water is impeded by a ground-water barrier of volcanic bedrock, and the water is confined in permeable sand and gravel under a layer of silty clay of low permeability which is 5–25 feet thick. The piezometric surface in the artesian area ranges from about 5 feet above the land surface in well (C–30–3)19daa–1 to about 11 feet below the land surface in well (C–30–3)19dcc–1. At the lower end of the basin the artesian area contains springs and wet meadowlands. The artesian aquifers are recharged at the upper end and along the margins of the valley where the ground water is unconfined (pl. 2). The observed depth to the water table ranges from about 7 feet below the land surface in well (C–30–4)14abd–1 to about 68 feet in well (C–30–4)34ddc–2.

An estimated 210,000 acre-feet of ground water is stored in the sand and gravel of the upper 200 feet of saturated valley fill in Circle Valley basin (table 7). The beds of sand and gravel are separated by saturated silt and clay of low permeability.

The bedrock formations that surround and underlie Circle Valley basin contain some ground water, but these formations generally are poor aquifers. Only one well, (C–30–3)16bbb–1, is known to penetrate bedrock in Circle Valley basin, and it yields about 50 gpm of water from sedimentary or volcanic rocks of Tertiary age.

Existing use

Most of the ground water used in Circle Valley basin is obtained from springs which discharge from the valley fill. The largest of the springs are in the Mitchell Slough in secs. 17 and 18, T. 30 S., R. 3 W., and in sec. 13, T. 30 S., R. 4 W.; they have a combined discharge of about 3,670 gpm, and the water is used for irrigation and stock.

Several bedrock springs, which are in the mountains and plateaus surrounding Circle Valley basin, discharge less than 200 gpm each. Part of the public supply of Circleville is obtained from Circleville Spring, (C–30–4)16ab, which yielded 60 gpm in December 1962 from volcanic rocks of Tertiary age.

Other than from springs, ground water used in Circle Valley basin is obtained from only a few wells and drains which produce minor quantities of water. Pumped wells produce only about 540 acre-feet of water annually, and all except three wells are used for domestic or stock purposes. Well (C–30–4)26dcb–1 is pumped to supplement the Circleville public supply (Circleville Spring) during the summer, and it produces 10–50 acre-feet of water annually; well (C–30–4)25aad–1 produces about 3 acre-feet of water annually for a potato processing plant; and well (C–30–4)25bcc–1, which is pumped for irrigation, yields most of the ground water pumped in the basin. The pumpage supplements a supply from the Sevier River, and it varies from year to year depending on the surface-water supply. The pumpage has varied from 0 in 1958 to 825 acre-feet in 1959, and it averaged about 500 acre-feet annually during the period 1957–62.

All the wells in the basin except one (C–30–3)16bbb–1, tap valley fill, and individual well yields range from about 1 to 1,475 gpm. Dug wells range from 12 to 38 inches in diameter and from 12 to 30 feet in depth, and 18 drilled wells range from 1½ to 12 inches in diameter and from 10 to 407 feet in depth. Most of the drilled wells are less than 200 feet deep. Three of the drilled artesian wells (C-30-3)19daa-1, (C-30-3)29bad-1, and (C-30-4)14dac-1, flow, yield about 1-2 gpm of water each, and supply water for stock.

A few open drains have been excavated in the artesian area at the north end of Circle Valley basin. These drains, which are 2-3 feet deep and total about 5 miles in length, do not lower the water level appreciably because they are constructed in silty clay of low permeability, are not properly designed, and are inadequately maintained. They yield about 2,000 acre-feet of water to the Sevier River during most years.

Potential development

Wells that would yield several hundred gallons per minute could be constructed in the valley fill throughout Circle Valley basin, but wells drilled near the center of the valley would have the best yields. About 4,000 acre-feet of additional ground water could be withdrawn annually in Circle Valley basin without greatly affecting the flow in the Sevier River if the water can be salvaged from existing uses. Most of the water could be developed by lowering the water level in about 3,000 acres of wet phreatophyte-infested bottom land that comprises most of the artesian area. About 8,000 acre-feet of water is discharged by evapotranspiration annually in this wet area. Much of the area is wet because artesian ground water leaks to the land surface through the silty-clay surface layer. Probably about half of the 8,000 acre-feet of loss could be salvaged by means of carefully spaced and designed wells and drains which would lower artesian heads in the sand and gravel deposits underlying the silty-clay layer. Furthermore, if the artesian head causing the upward leakage could be reduced, it would help alleviate waterlogging, but probably would result in a reduction of flow from the Mitchell Slough. This loss, however, would be compensated by water pumped from wells or obtained from more efficient drains. Lining of canals and mechanical eradication of phreatophytes would salvage additional water.

EAST FORK VALLEY BASIN

EMERY VALLEY SUBBASIN

Availability and storage of ground water

Ground water is under water-table conditions in the valley fill throughout Emery Valley subbasin. Bedrock is near the land surface in most of the subbasin, and playalike deposits at the downstream end indicate that ground water is impounded there. The valley fill is all alluvium and ranges from 0 to less than 100 feet in thickness (pl. 1, section *E-E'*), and about 10 percent is permeable sand and gravel.

The most permeable deposits are along the East Fork Sevier River channel. The observed depth to water ranges from about 4 feet below the land surface in well (C–36–4)34bda–2 to about 46 feet in well (C–36–3)6dba–1. About 6,000 acre-feet of ground water is stored in the upper 100 feet of saturated valley fill in the subbasin, and the principal water-bearing zones are beds of sand and gravel.

The bedrock underlying and surrounding the subbasin contains ground water, but the water-yielding characteristics of the bedrock and the quantity of water in storage are not well known. The available data, however, suggests that the bedrock formations are poor aquifers. Depth to water in the bedrock adjacent to the subbasin ranges from about 1 foot below the land surface in well (C–36–3) 18acc–1 to about 652 feet in well (C–37–4)11ddd–1.

Existing use

Most of the ground water used in Emery Valley subbasin is obtained from the more than 20 wells that have been constructed in or adjacent to the subbasin. Nine of the wells in the subbasin obtain water from the valley fill, and the remainder obtain water from sedimentary formations of Tertiary or Cretaceous age. Wells in the valley fill generally yield less than 10 gpm, but one well, (C–36–4)34bda–1, is reported to yield 180 gpm. Discharge of wells penetrating bedrock ranges from less than 10 to 200 gpm. Most of the wells in or adjacent to the subbasin are drilled, range from 30 to 2,000 feet in depth, and range from 5 to 16 inches in diameter. Only two wells have been dug in Emery Valley subbasin; although several others adjacent to the subbasin were originally dug, they were later deepened by drilling.

Six wells are pumped for public supply and have a combined annual yield of more than 30 acre-feet; the other wells are pumped for domestic and stock use or are unused. Wells (C–36–3)7bbc–1 and (C–36–3)7bbd–1 penetrate the sedimentary formations of Cretaceous age underlying Emery Valley subbasin and supply water to the Federal Aviation Agency housing area near Bryce Canyon. Four wells supply water to Bryce Canyon National Park. Wells (C–36–4) 34bda–1 and (C–36–4)34bda–2 obtain water from the valley fill; well (C–36–4)36acc–1, adjacent to the subbasin, penetrates limestone of the Wasatch Formation; and well (C–37–4)11ddd–1, also adjacent to the subbasin, penetrates sedimentary formations of Tertiary and Cretaceous age.

Some ground water is obtained from springs in and adjacent to the subbasin. Bryce Canyon National Park obtains water from a seep area in the valley fill of East Creek, NW¼ sec. 34, T. 36 S., R. 4 W. The discharge of the seep ranges from 1 to 40 gpm, and the water is used for public supply. Other small springs and seeps in the valley fill are used for stock watering and usually discharge less than 20 gpm.

Many small springs mark the contact between the Wasatch and Kaiparowits Formations near Tropic Reservoir. The individual springs generally yield less than 10 gpm, and the water is used for stock.

Potential development

It is doubtful that wells capable of yielding more than 200 gpm could be pumped in Emery Valley subbasin for irrigation without affecting streamflow. The most permeable aquifers are the flood-plain deposits of the East Fork Sevier River, but pumping wells close to the stream would cause losses in streamflow.

JOHNS VALLEY SUBBASIN

Availability and storage of ground water

Ground water is under water-table conditions in the valley fill throughout Johns Valley subbasin. The fill is composed entirely of alluvium and ranges in thickness from a thin edge on the valley sides to more than 350 feet in the center and east-central side of the valley (pl. 1, section C–C′). About 15 percent of the valley fill in the subbasin is composed of permeable sand and gravel. The most permeable deposits are near the East Fork Sevier River channel. The wet meadows at the lower end of the subbasin are evidence that ground water is impounded there by a bedrock barrier (pl. 1, section E–E′). The observed depth to water in the valley fill ranges from about 10 feet below the land surface in test hole (C–33–2)22aab–1 to about 150 feet in test hole (C–34–2)29ccd–1.

About 90,000 acre-feet of ground water is stored in sand and gravel beds in the upper 200 feet of saturated valley fill. The sand and gravel beds are the most permeable water-bearing deposits.

The sedimentary rocks of Tertiary and Cretaceous age underlying and surrounding the subbasin contain small quantities of water. The water-yielding characteristics of the bedrock and the quantity of water in storage are not known, but the available data suggest that, in general, the bedrock formations are poor aquifers. The observed depth to water in the bedrock ranges from about 30 feet in well (C–35–2)22dbb–1, which is adjacent to the subbasin, to about 206 feet in well (C–34–2)22dab–1.

Existing use

Most of the ground water used in Johns Valley subbasin is obtained from springs which discharge from either the valley fill or bedrock. A considerable amount of ground water seeps from the valley fill into the East Fork Sevier River south of Black Canyon in secs. 11, 14, 15, and 22, T. 33 S., R. 2 W. In this area, the stream gains about 6,000 acre-feet annually or 8 cfs in a channel length of about 2½ miles.

Large amounts of water are discharged from bedrock by springs in the plateaus adjacent to the subbasin. The largest springs discharge from the Wasatch and Brian Head Formations of Tertiary age. The largest of these, Deer Creek Spring, (C–32–2)23adb, discharges about 1,640 gpm from fractures and joints in volcanic rock within the formations. Tom Best Spring, (C–34–3)27ddc, discharges about 500 gpm from fractures and solution channels in the limestone of the same formations. Many other springs in Black Canyon discharge from the same formations along contacts between volcanic flows and an underlying conglomerate. Individual yields of these springs range from 50 to 450 gpm.

Little ground water is withdrawn from wells in the subbasin. The seven wells in the subbasin range in depth from 34 to 339 feet; one taps bedrock and six tap the valley fill. None of the wells were used in 1963.

Potential development

Information for yields of wells in Johns Valley subbasin is not available, but wells that probably would each yield several hundred gallons per minute could be drilled into the flood-plain deposits of the valley fill along the East Fork Sevier River. Wells penetrating alluvial fans and bedrock probably would yield lesser amounts. It is doubtful that wells yielding more than about 500 gym each could be developed in the subbasin to furnish irrigation supplies without affecting streamflow. Inasmuch as the most permeable aquifer in the subbasin is the flood-plain deposits of the East Fork Sevier River, pumping from wells in the lower part of the subbasin in secs. 11 and 14, T. 33 S., R. 2. W., probably would lower the water table and diminish the flow of the river.

ANTIMONY SUBBASIN

Availability and storage of ground water

Ground water is under both artesian and water-table conditions in the valley fill in Antimony subbasin. The valley fill, which is composed entirely of alluvium, generally is 50–75 feet thick in most parts of the subbasin, although in the valley bottom it is more than 200 feet thick (pl. 1, section *E–E′*). About 40 percent of the valley fill in Antimony subbasin is permeable gravel and sand. The fill in this subbasin has the highest proportion of permeable material of any in the East Fork Valley basin. The most permeable deposits are along the channel of the East Fork Sevier River.

The water is under artesian conditions in the lower part of the subbasin (pl. 2) where subsurface movement is impeded by a barrier formed by bedrock near the head of Kingston Canyon in sec. 29, T. 30 S., R. 2 W. The water is in beds of permeable sand and gravel, and it is confined by 5–10 feet of overlying silty clay of low permeability. The piezometric surface is near the land surface throughout the artesian area, which is marked by marshes, wet meadowland, and seepage areas. The artesian aquifers are recharged in the upper part and along the margins of the valley where ground water in unconfined (pl. 2).

Bedrock is near the surface in most parts of the valley, and the observed depth to water in the valley fill in the water-table area ranges from about 11 feet below the land surface in well (C–31–2) 23cca–1 to about 14 feet in well (C–32–2)2dda–1.

Ground water also occurs in the bedrock of Tertiary age underlying the valley fill and adjacent to the subbasin, and the observed depth to water in the bedrock underlying the subbasin ranges from about 26 feet in well (C–31–2)23ccd–1 to about 155 feet in well (C–31–2)24dac–1.

About 36,000 acre-feet of ground water is stored in the sand and gravel of the upper 100 feet of saturated valley fill in Antimony subbasin. Additional ground water is stored in the bedrock underlying and adjacent to the subbasin, but the water-yielding characteristics of the bedrock and the quantity in storage are not known.

Existing use

Most of the ground water used in Antimony subbasin issues from springs in the valley fill in the subbasin or from bedrock in the surrounding plateaus and adjacent to the valley floor. As much as 5 cfs, or 3,600 acre-feet, of ground water seeps from the valley fill in the artesian area in the north end of the subbasin into the East Fork Sevier River.

Bedrock springs on the Sevier Plateau outside the subbasin yield water for public supply to Antimony and Kingston. Antimony Spring, (C–31–2)19bb, discharges about 220 gpm from volcanic rocks of Tertiary age. Kingston is supplied by a spring in Kingston Canyon, (C–30–3)24aab, which yields about 15 gpm from volcanic rocks of Tertiary age.

Ground water has been little developed by wells in Antimony subbasin. Of 15 wells in the subbasin, 14 are pumped for domestic and stock use and 1 is unused. The wells obtain water from the valley fill and from permeable zones in volcanic rocks or conglomerate of the Wasatch and Brian Head Formations. Yields of individual wells penetrating the valley fill average about 20 gpm and yields of wells penetrating bedrock range from about 4 to 25 gpm. Drilled wells generally range from 4 to 6 inches in diameter and from 40 to 180 feet in depth.

A few open drains, which discharge about 1,000 acre-feet of water annually, have been excavated in the silt and clay overlying the artesian aquifer. The drains, which are 1–3 feet deep and total about 4 miles in length, are ineffective in lowering the water level because they are not deep enough to penetrate the underlying permeable beds of sand and gravel, are improperly designed, and are inadequately maintained.

Potential development

Possibly 3,000 acre-feet of additional ground water could be withdrawn from wells and drains annually in Antimony subbasin without greatly affecting streamflow if water can be salvaged from existing uses. Construction of pumped wells and drains designed to penetrate confined aquifers would reduce artesian head and help drain the wet bottom land. The wells and drains could result in salvage of about 3,000 acre-feet of water annually, which is approximately half of the annual loss of 5,200 acre-feet by evapotranspiration from about 2,100 acres of wet bottom land. Furthermore, crops requiring less water than phreatophytes could be grown on the drained land.

GRASS VALLEY BASIN

KOOSHAREM SUBBASIN

Availability and storage of ground water

Ground water is under both artesian and water-table conditions in the valley fill in Koosharem subbasin. The valley fill, most of which is alluvium, is more than 500 feet thick in the center of the valley south of Koosharem and more than 770 feet thick in midvalley about 1 mile northeast of Greenwich (pl. 1, section *F–F′*; see also Feltis and Robinson, 1963, p. 27–31). About 15 percent of the alluvium in the subbasin is permeable sand and gravel. The most permeable deposits are confined layers of sand and gravel in the lake(?) or marsh(?) deposits near the channel of Otter Creek between the vicinity of Burrville and Greenwich.

Ground water is under artesian conditions throughout most of the valley fill (pl. 2), and the observed piezometric surface ranges from about 15 feet below the land surface in well (D–25–1)8ccd–1 to more than 31 feet above the land surface in well (C–26–1)23dab–1. The water is confined under layers of silt and clay in the more permeable beds of sand and gravel that slope from the sides of the valley toward the center. The marsh and meadowland and the discharge of ground water to Otter Creek at the lower end of the valley indicate that ground water is impounded there by a bedrock constriction.

The artesian aquifers are recharged through permeable alluvial-fan deposits along the valley sides where the ground water is unconfined (pl. 2). The observed depth to water in the water-table areas ranges from about 8 feet below the land surface in well (C-27-1) 21baa-1 to about 120 feet in well (C-27-1)29dba-1.

About 90,000 acre-feet of ground water is stored in the sand and gravel of the upper 200 feet of saturated valley fill in Koosharem subbasin. Small amounts of ground water are also in the volcanic rocks of Tertiary age underlying and adjacent to Koosharem subbasin, but the quantity in storage and the water-yielding potentialities of the rocks are not known.

Existing use

Springs issuing from bedrock or the valley fill yield most of the ground water used in Koosharem subbasin. The bedrock springs on the surroundings plateaus and adjacent to the valley floor discharge from volcanic rocks of Tertiary age. Two of the largest are Burr Springs, (C-25-1)26bc, which yield about 1,440 gpm, and Red Cedar Grove Springs, secs. 13, 14, and 23, T. 26 S., R. 1 W., which yield about 540 gpm. Many small springs and seeps issue in the valley fill, and they have a combined yield of several hundred gallons per minute. Many of the springs and seeps are at the toes of alluvial fans on the valley sides, and others are adjacent to Otter Creek.

Most of the water from springs in Koosharem subbasin is used for irrigation and stock; however, part of the discharge of Burr Springs is used for public supply in Burrville, and the discharge from Brown Spring, (D-26-1)30ab, is used for public supply at Koosharem. Both springs discharge from volcanic rocks of Tertiary age.

More ground water is withdrawn from wells in Koosharem subbasin than in any of the other ground-water basins or subbasins in the upper Sevier River basin. Wells produce more than 2,400 acre-feet of water annually in this subbasin, mostly from flowing artesian wells. Of the approximately 164 wells that have been constructed in the subbasin, all but 1 obtain water from the valley fill and 143 are flowing artesian wells, 8 of the wells are dug, 13 are drilled, and 143 are jetted. The dug wells range from 10 to 100 feet in depth and from 20 to 120 inches in diameter, the drilled wells from 79 to 519 feet in depth and from 4 to 10 inches in diameter, and the jetted wells from 11 to 278 feet in depth and from 1 to 3 inches in diameter. Yields of individual wells penetrating the valley fill range from about 0.1 to more than 140 gpm; the well that penetrates bedrock, (C-27-1)20dca-1, yields about 20 gpm. Most of the wells are used for domestic and stock purposes, but about 35 are used solely for irrigating pastures. Individually owned wells are used for domestic water supply in Greenwich, which has no public-supply system.

The 35 irrigation wells are flowing wells which discharge about 1,300 acre-feet of water annually. These wells are mostly 200–250 feet deep, are 2 inches in diameter, and obtain water through the open end of unperforated casing. Generally only 20–30 feet of casing was installed in these flowing wells, and the rest of the hole commonly has collapsed and restricted the flow. Many of these wells were constructed before 1890, and the casings have almost rusted away. Many local wet spots, 10–50 feet in diameter, mark places where flowing wells once existed but have been virtually obliterated.

Drains have not been dug in Koosharem subbasin to develop ground water. However, some ditches in the Red Cedar Grove Springs area, sec. 23, T. 26 S., R. 1 W., convey water from the springs for irrigation downstream.

Potential development

More than 9,000 acre-feet of water per year is discharged by evapotranspiration from about 5,600 acres of wet bottom land in Koosharem subbasin. It is doubtful, however, that much of this water could be salvaged by additional withdrawal of ground water from the artesian areas without greatly affecting present water use. Lowering artesian heads would affect most of the flowing wells and the flow of artesian springs into Otter Creek. Otter Creek gains water in Koosharem subbasin largely by upward leakage from artesian aquifers, and wells of large discharge would reduce artesian head and in turn reduce the discharge of ground water to the stream. However, constructing drains, lining canals, and eradicating phreatophytes could salvage some water in the subbasin.

ANGLE SUBBASIN

Availability and storage of ground water

The valley fill is the main source of ground water in the Angle subbasin. The thickness of the valley fill, which is mostly alluvium, ranges from a thin edge near the valley margins and near bedrock outcrops within the valley to 490 feet near Angle, as indicated by the log of test hole (C–29–2)26dac–1 (Feltis and Robinson, 1963, p. 31). About 15 percent of the valley fill is permeable sand and gravel. The most permeable deposits are near the channel of Otter Creek.

Ground water is mostly under water-table conditions in the valley fill throughout the subbasin, but it may be under artesian conditions near the north end of Otter Creek Reservoir. The observed depth to water in the valley fill in Angle subbasin averages about 20 feet below the land surface. Wells do not penetrate the bedrock underlying or adjacent to Angle subbasin, but knowledge of springs in the bedrock suggests that small quantities of water are available in bedrock.

About 60,000 acre-feet of ground water is stored in the sand and gravel of the upper 200 feet of saturated valley fill in Angle subbasin. The principal water-bearing zones in the valley fill are deposits of sand and gravel.

Existing use

Springs in bedrock or the valley fill provide most of the ground water used in Angle subbasin. The bedrock springs discharge from volcanic rocks of Tertiary age in the surrounding plateaus or adjacent to the valley floor. The water from the largest springs, Pole Canyon Spring, (C-29-2)15cdb, which discharges about 270 gpm, and Pete's Spring No. 1, (C-30-1)5b, which discharges about 225 gpm, is used for irrigation and stock. A small amount of ground water seeps from the valley fill bordering Otter Creek just above Otter Creek Reservoir and is used for irrigation and stock.

Of the total of seven wells in Angle subbasin, two are dug and five are drilled, all are used for domestic and stock purposes, and all penetrate the valley fill. Individual wells yield from about 5 to 10 gpm, although wells constructed by modern methods could yield as much as 100 gpm. The drilled wells range from 66 to 197 feet in depth and from 2 to 6 inches in diameter.

Potential development

Lowering water levels in Angle subbasin by means of additional wells and drains could salvage some water lost by evapotranspiration near the upstream end of Otter Creek Reservoir. However, inasmuch as the most permeable deposits are near Otter Creek, it is doubtful that wells yielding more than about 500 gpm could be pumped without greatly affecting the flow of the creek.

EFFECTS OF PUMPING ADDITIONAL GROUND WATER IN THE UPPER SEVIER RIVER BASIN

Pumping additional water from wells in any of the ground-water basins in the upper Sevier River basin would eventually lower the water level and reduce artesian heads in that basin. The amount of water-level decline would be approximately proportional to the net amount of water pumped. If water is pumped from wells penetrating artesian aquifers, the water-level decline would spread rapidly over a relatively large area and would eventually affect adjoining water-table areas. If the water is pumped from wells penetrating water-table aquifers, the water-level decline would spread slowly and be limited largely to an area in the vicinity of the pumped wells. If pumping from the water-table aquifers is continued long enough, the water-level declines would eventually extend to the artesian areas and reduce artesian head.

Important benefits could result from reducing artesian pressures. Pressure reduction would reduce or stop the seepage of ground water to the land surface, mainly at the lower ends of the basins. Eventually many sloughs and waterlogged areas would dry up except some wet areas that may be sustained by shallow movement of water from adjacent irrigated lands. Much of the water now being discharged by evapotranspiration in these areas might be salvaged and used beneficially. In addition, the waterlogged land, now impregnated with salts that are deposited when the ground water evaporates, could eventually be reclaimed if irrigation water were applied at intervals to leach the salts from these soils. If the overall use of water were more efficient, more water would be available to satisfy local and downstream demands.

Streamflow would decrease if water levels were lowered appreciably in the valley fill. In water-table areas adjacent to streams, lowering water levels would increase the hydraulic gradient from the stream bed to the reservoir, and seepage from the stream bed would thus be increased. In artesian areas the hydraulic gradient is from the ground-water reservoir to the streams. Although the streams are separated from the aquifers by layers of relatively impermeable silty clay, small amounts of water seep through the clay and discharge into the streams.

The construction of additional wells in the upper Sevier River basin should be carefully planned. The first production wells should be spaced several miles apart, and water levels should be measured periodically in a network of observation wells to determine the amount and extent of the change resulting from pumping. In artesian areas. the discharge of springs and flowing wells in the vicinity of production wells should be measured periodically to observe changes. In the water-table areas, where water levels are near the altitude of the streams, production wells should be at least half a mile from streams so that the cone of depression does not reach the streams. To be most effective, ground-water development should be coordinated with improvement of surface-water diversion, more effective drainage, improved distribution systems, and phreatophyte control. The most efficient use of water in the basin would require that the ground-water reservoir be managed in a way similar to the management of surface-water reservoirs.

About 14,000 acre-feet of water per year, in addition to the amount now pumped, eventually could be developed from the ground-water reservoirs in the upper Sevier River basin. The 14,000 acre-feet would be salvaged from water now discharged by evapotranspiration from wet areas that support phreatophytes.

QUALITY OF WATER

The chemical quality of the ground water in the upper Sevier River basin is good for most uses. The following sections describe the mineral constituents found in the water and the quality of the water in relation to use.

DISSOLVED MINERALS

The major chemical constituents in the water of the upper Sevier River basin are silica, calcium, magnesium, sodium, potassium, chloride, sulfate, and nitrate. The chemical constituents commonly present in smaller amounts are iron, fluoride, manganese, and boron. Other properties and characteristics that help determine water quality are temperature, specific conductance, pH, and hardness. Chemical analyses of water from selected wells and springs in the basin and from a few sites along the Sevier River and its tributaries are included in a compilation of basic data by Carpenter, Robinson, and Bjorklund (1964).

QUALITY IN RELATION TO USE

IRRIGATION

The characteristics of water that appear to be most important in determining the suitability of water for irrigation are "(1) total concentration of soluble salts; (2) relative proportion of sodium to other cations; (3) concentrations of boron or other elements that may be toxic; and (4) under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium" (U.S. Salinity Lab. Staff, 1954, p. 69).

1. The total concentration of soluble salts, or salinity, may be expressed in units of dissovled-solids concentration or of specific conductance. Chemical analyses were made of samples of ground water from 24 wells and 23 springs in the upper Sevier River basin. The dissolved solids range from 86 to 778 ppm (parts per million) and average 245 ppm for 46 samples, and the specific conductance ranges from 85 to 690 micromhos per centimeter and averages 339 micromhos per centimeter for 40 samples. Thus, the ground water has a salinity hazard that ranges from low to medium for irrigation, according to the classification of the U.S. Salinity Laboratory Staff (1954, p. 79–81).

   The relation of dissolved solids and specific conductance for surface water in the upper Sevier River basin at certain times of the year is quite similar to that of ground water. (See fig. 6.)

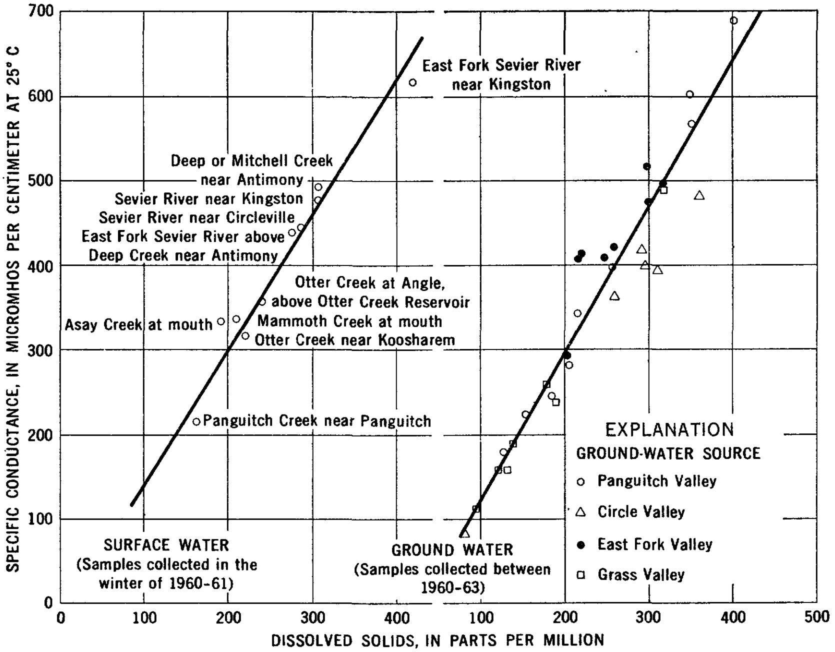

Figure 6.—Graphs showing the relation between the dissolved solids and specific conductance of selected surface- and ground-water samples.

Chemical analyses of 10 samples of surface water collected during the winter of 1960–61 indicate that the dissolved solids ranged from 163 to 420 ppm and averaged 262 ppm and the specific conductance ranged from 216 to 618 micromhos per centimeter and averaged 404 micromhos per centimeter. The surface-water samples were collected during a period of low flow when most of the streamflow was derived from ground water. During periods when much of the streamflow is derived from snowmelt or rainfall, however, the dissolved-solids content generally is less.

2. The proportion of sodium to other cations, and the probable extent to which a soil may adsorb sodium from water (and thereby become less permeable) is expressed in terms of the sodium-adsorption ratio (SAR). The SAR of the ground water in the upper Sevier River basin ranges from 0.1 to 1.9 and averages about 0.6. Thus the ground water in the basin has a low sodium hazard for irrigation, according to the classification of the U.S. Salinity Laboratory Staff (1954, p. 79–81).
3. A small quantity of boron is essential to the normal growth of all plants, but excessive concentrations are toxic. Toxicity varies

according to the tolerance of individual species (U.S. Salinity Lab. Staff, 1954, tables 9, 14). In general, water containing less than 0.33 ppm of boron is not harmful to any plant, whereas water containing more than 3.75 ppm may be toxic to all crops. The amount of boron in 28 ground-water samples collected in the upper Sevier River basin ranged from 0.02 to 0.14 ppm and averaged 0.05. These small concentrations are not harmful to plants.

4. The relation between the bicarbonate concentration and the concentration of calcium plus magnesium is expressed as residual sodium carbonate (RSC). The U.S. Salinity Laboratory (1954, p. 81) states that "* * * waters with more than 2.5 meq per l (millequivalents per liter) 'residual sodium carbonate' are not suitable for irrigation purposes." None of the ground-water samples collected in the upper Sevier River basin had a RSC that exceeded 2.5 meq per l.

Ground water in the valley fill in Panguitch, Circle, and Grass Valleys deteriorates in quality slightly from the upper to the lower end of each valley (pl. 3). Although few data are available for the quality of water in the valley fill of East Fork Valley, the fact that the quality of the surface water deteriorates downstream indicates that this deterioration also probably occurs in the ground water. The deterioration in quality in all the valleys in a downstream direction is due largely to use and reuse of water for irrigation.

DOMESTIC AND PUBLIC SUPPLY

The U.S. Public Health Service (1962) has recommended the following maximum concentrations for some of the more common constituents in water used for domestic and public supply:

Substance	*Parts per million*
Chloride	250
Fluoride	([1])
Iron	.3
Manganese	.05
Nitrate	45
Sulfate	250
Dissolved solids	500

[1] The recommended maximum fluoride concentration is variable, depending on air temperature. For temperatures similar to that at Panguitch, the maximum recommended fluoride concentration is 1.3 ppm. (See U.S. Public Health Service, 1962, p. 8.)

The concentrations of chemical constituents observed in samples of ground water from the upper Sevier River basin commonly are less than the maximums recommended by the Public Health Service. The recommended concentrations were exceeded in a few of the ground-water samples as follows: the concentration of fluoride in three samples, iron in eight samples, manganese in one sample, and dissolved solids in two samples. The recommended fluoride concentration was exceeded in samples collected from spring (C–30–3)24aab (3.2 ppm), well (C–30–3)16bbb–1 (3.1 ppm), and well (C–30–4)26dcb–1 (2.9 ppm). Igneous rocks often yield water with a high fluoride concentration, and spring (C–30–3)24aab and well (C–30–3)16bbb–1 tap volcanic rocks of Tertiary age and sedimentary or volcanic rocks of Tertiary age, respectively. Well (C–30–4)26dcb–1 obtains water from valley fill which is derived from volcanic rocks.

The recommended iron concentration was exceeded in samples collected from wells (C–35–5)24ccb–1 (5.0 ppm) and (C–30–3)16bbb–1 (0.32 ppm) and from springs (C–30–2½)17d (0.82 ppm) and (C–31–2)19bb (0.8 ppm); it was also exceeded in two samples from well (C–30–4)26dcb–1 (2.6 and 1.6 ppm) and well (C–36–3)6dba–1 (1.6 and 0.99 ppm). The source of the iron is believed to be igneous- or carbonate-type rocks that supply water directly to six of the eight springs and wells. Wells (C–30–4)26dcb–1 and (C–36–3)6dba–1 tap valley fill that is derived largely from igneous- and carbonate-type rocks, respectively. Some of the iron, however, may possibly be derived from the well casing or pipe-conduit systems.

The recommended manganese content was exceeded in a sample from well (C–30–3)16bbb–1 (0.16 ppm). The well obtains water from volcanic or sedimentary rocks of Tertiary age which are probably rich in manganese.

The recommended dissolved-solids content was exceeded in samples from two wells. The high concentration in the water from well (C–36–3)7aac–1 (778 ppm) may be caused by return flow from irrigation. The high concentration in the water from well (C–35–5)24ccb–1 (613 ppm) may be due to the fact that the sample was collected during deepening of the well and could have been contaminated with drilling fluid.

The hardness of water is important in domestic and public supply because soap consumption for washing and laundering increases as the hardness increases and hardness causes part of the incrustation (boiler scale) found in pipes, coils, and boilers. The U.S. Geological Survey uses the following classification for hardness of water: less than 60 ppm, soft; 61–120 ppm, moderately hard; 121–180 ppm, hard; and more than 180 ppm, very hard. Water having a hardness of more than 200 ppm needs to be softened for most purposes.

Of the ground-water samples from 24 wells and 23 springs for which hardness was determined, 3 contained less than 60 ppm of hardness, 16 contained 60–120, 9 contained 121–180, and 19 contained more than

180. The hardness of the water in the 47 samples ranged from 35 to 506 ppm and averaged 170 ppm. The hardness is generally highest in water obtained from the valley fill and lowest in water obtained from volcanic rocks of Tertiary age. The three samples which contained less than 60 ppm of hardness are all from springs in volcanic rocks of Tertiary age: springs (C-33-6)5ccb (57 ppm), (C-30-4)16ab (35 ppm), and (D-26-1)30ab (47 ppm). Most of the samples containing more than 60 ppm of hardness are from the valley fill, but some are from consolidated sedimentary rocks. Plate 3 shows graphically the values of hardness for a few selected samples collected from the valley fill or bedrock.

LIVESTOCK

Although animals are more able to tolerate water having a high dissolved-solids content than man, prolonged periods of drinking highly mineralized water may cause physiological disturbances such as wasting, gastrointestinal disorders, disease, and even death. Other effects include reduced lactation and rate of reproduction. The State of Montana (W. F. Storey, oral commun., 1961) rates water containing less than 2,500 ppm of dissolved solids as good for livestock use, from 2,500 to 3,500 ppm as fair, from 3,500 to 4,500 ppm as poor, and more than 4,500 ppm as unfit. On the basis of this classification, the water sampled in the upper Sevier River basin is good for livestock.

INDUSTRY

The chemical characteristics of water that are most important in determining the suitability of the water for industrial use vary according to the particular use involved and the product manufactured. Two characteristics that are significant to practically all industries, however, are hardness (discussed in the section on "Domestic and public supply") and silica content. Silica forms a hard, adherent scale in boilers; Moore (1940, p. 263) has suggested the following allowable concentration of silica in water for boilers operating at various pressures: for a pressure less than 150 psi (pounds per square inch), 40 ppm; 150-250 psi, 20 ppm; 250-400 psi, 5 ppm; and more than 400 psi, 1 ppm.

Of the ground-water samples collected from 23 wells and 23 springs in the upper Sevier River basin that were analyzed for silica, 17 contained more than 40 ppm of silica, 34 contained more than 20 ppm, and all but 1 contained more than 5 ppm. The average silica content of the ground-water samples was 32 ppm. The sample with less than 5 ppm silica was from well (C-37-4)11ddd-1 (1.7 ppm) which derives water from limestone of the Wasatch Formation. In the upper Sevier River basin, igneous rocks generally yield water having the greatest content of dissolved silica and limestone yields water that contains the least silica.

Temperature is an important characteristic of water used for cooling. Low temperatures, of course, are preferred, and water having a relatively constant temperature is considered desirable. The temperature of water from wells in the upper Sevier River basin commonly ranges from 50° to 59°F. The average temperature of water from 231 wells is 53°F, the range being from 41° to 61°F; the average temperature of water from 47 springs is 51° F, the range being from 40° to 68°F. By comparison, the temperature of surface water in the basin varies with the season and the stream and ranges from freezing to tepid. The temperature of the water from a spring in sec. 17, T. 33 S., R. 5 W., is 90° F; however, this water issues from considerable depth along a fault, and its temperature is not representative of ground-water temperatures in the basin.

SUMMARY

The upper Sevier River basin contains four ground-water basins which were formed by geologic processes including faulting and stream action. They are Panguitch Valley basin, Circle Valley basin, East Fork Valley basin, and Grass Valley basin. East Fork Valley basin is divided into Emery Valley, Johns Valley, and Antimony subbasins. Grass Valley basin is divided into Koosharem and Angle subbasins.

Ground water occurs under both artesian and water-table conditions in the valley fill in Panguitch and Circle Valley basins and in Antimony and Koosharem subbasins. It is under water-table conditions in the valley fill in Johns Valley, Emery Valley, and Angle subbasins. In Panguitch and Circle Valley basins and Antimony subbasins, the artesian conditions are at the downstream ends, and the water-table conditions are at the upstream ends. Ground water is under artesian conditions throughout most of Koosharem subbasin but is under water-table conditions in places along the sides. Depths to water in wells in the valley fill range from practically 0 to about 150 feet below the land surface. Many wells flow in the artesian areas, and artesian heads reach a maximum of about 30 feet above the land surface.

The valley fill in the basins and subbasins consists of gravel, sand, silt, and clay. An average of about 25 percent of the valley fill is permeable sand and gravel which yields water readily to wells and springs. The approximate percentages of sand and gravel in the valley fill are: 25–50 percent in Panguitch Valley basin, 50–60 percent in Circle Valley basin, 10 percent in Emery Valley subbasin, 15 percent in Johns Valley subbasin, 40 percent in Antimony subbasin, 15 percent in Koosharem subbasin, and 15 percent in Angle subbasin.

About 1 million acre-feet of ground water that is recoverable by wells is stored in the upper 200 feet of saturated valley fill in the various basins and subbasins. The amounts of water in the sand and gravel deposits are (in acre-feet): Panguitch Valley basin, 570,000; Circle Valley basin, 210,000; Emery Valley subbasin, 6,000; Johns Valley subbasin, 90,000; Antimony subbasin, 36,000; Koosharem subbasin, 90,000; and Angle subbasin, 60,000. The silt and clay deposits in each basin and subbasin contain large quantities of water, but little of this water is readily available to wells. Some of the water in the silt and clay, however, is indirectly available to wells because it would move into the permeable gravel and sand deposits if water were removed from those deposits.

The bedrock surrounding and underlying the various basins and subbasins also contains ground water, but the quantity is not known. In places the bedrock will yield significant amounts of water to wells, but in most of the basin the bedrock has low permeability.

The ground-water reservoirs are recharged mostly by the Sevier River and its tributaries at the upper ends and sides of the ground-water basins and by seepage from irrigation systems and irrigated lands in water-table areas. Inflow from bedrock aquifers surrounding the valleys also recharges the reservoir. The ultimate source of all recharge is precipation within the upper Sevier River basin.

Water is discharged from the ground-water reservoir by flowing and pumped wells, springs, drains, evapotranspiration, and subsurface outflow. The discharge in 1962 from the valley fill by wells was about 3,000 acre-feet, by drains about 3,000 acre-feet, by springs about 33,000 acre-feet (springs in bedrock discharged an additional 75,000 acre-feet), and by evapotranspiration from areas of phreatophytes about 43,000 acre-feet. A slight decline in ground-water levels in the valley fill during the 1938–63 period indicates that the total discharge of ground water slightly exceeded the recharge.

The surface- and ground-water systems in the upper Sevier River basin are interrelated, and increasing the ground-water discharge will, in general, decrease the surface-water discharge. The most efficient use of water in the basin, however, requires that the ground-water reservoir be managed in a way similar to the management of surface-water reservoirs.

About 43,000 acre-feet of the ground water discharged in the upper Sevier River basin is consumed by phreatophytes in wet areas in the valleys; part of this water might be salvaged without significantly decreasing surface-water discharge and ground-water discharge from existing wells, springs, and drains. If new large wells and drains were carefully designed and spaced, they could lower water levels enough to dry up wet areas; thus about 14,000 acre-feet of water could be salvaged, and little decrease would result in the flow of existing wells, springs, and streams in most basins.

Of the 14,000 acre-feet of water to be salvaged from existing uses, about 7,000 acre-feet could be supplied by wells and drains in Panguitch Valley basin, about 4,000 acre-feet could be supplied by wells and drains in Circle Valley basin, and about 3,000 acre-feet could be supplied by wells and drains in Antimony subbasin. Additional withdrawal of ground water, however, in (1) Johns Valley or Emery Valley subbasins, would ultimately decrease the flow of East Fork Sevier River and in (2) Koosharem or Angle subbasins would decrease the yield of flowing wells and the flow of Otter Creek.

The ground water in the upper Sevier River basin generally is suitable in chemical quality for irrigation, domestic and public supply, livestock, and industry. The dissolved-mineral content of the ground water within individual basins generally increases downstream, owing mostly to repeated use of the water for irrigation.

SELECTED REFERENCES

Averitt, Paul, 1962, Geology and coal resources of the Cedar Mountain quadrangle, Iron County, Utah: U.S. Geol. Survey Prof. Paper 389, 72 p., 3 pls.

Barrett, W. C., and Milligan, C. H., 1953, Consumptive water use and requirements of the Colorado River area of Utah: Utah State Agr. Coll., Agr. Expt. Sta. Spec. Rept. 8, 28 p., Logan, Utah.

Callaghan, Eugene, 1938, Preliminary report on the alunite deposits of the Marysvale region, Utah: U.S. Geol. Survey Bull. 886–D, 134 p., 1 pl.

——— 1939, Volcanic sequence in the Marysvale region in southwest-central Utah: Am. Geophys. Union Trans., pt. 3, p. 438–452.

Callaghan Eugene, and Parker, R. L., 1961, Geology of the Monroe quadrangle, Utah: U.S. Geol. Survey Geol. Quad. Map 155.

——— 1962a, Geology of the Sevier quarangle, Utah: U.S. Geol. Survey Quad. Map 156.

——— 1962b, Geology of the Delano Peak quadrangle, Utah: U.S. Geol. Survey Geol. Quad. Map 153.

Carpenter, C. H., and Young, R. A., 1963, Ground-water data, central Sevier Valley, parts of Sanpete, Sevier, and Piute Counties, Utah: U.S. Geol. Survey open-file rept. [duplicated as Utah Basic-Data Rept. 3], 34 p., 1 pl.

Carpenter, C. H., Robinson, G. B., Jr., and Bjorklund, L. J., 1964, Selected hydrologic data, upper Sevier River basin, Utah: U.S. Geol. Survey open-file rept. [duplicated as Utah Basic-Data Rept. 8], 29 p., 1 pl.

Connor, J. G., Mitchell, C. G., and others, 1958, A compilation of chemical quality data for ground and surface waters in Utah: Utah State Engineer Tech. Pub. 10, 276 p.

Cox, LeRoy H., 1936, Decree adjudicating the Sevier River system: Fillmore, Utah, The Progress Printing Co., 232 p.

Criddle, W. D., Harris, Karl, and Willardson, L. S., 1962, Consumptive use and water requirements for Utah: Utah State Engineer Tech. Pub. 8 (revised), 47 p.

David, G. H., Green, F. H., Olmstead, F. H., and Brown, D. W., 1959, Ground-water conditions and storage capacity in the San Joaquin Valley, California: U.S. Geol. Survey Water-Supply Paper 1469, 287 p., 29 pls.

Feltis, R. D., and Robinson, G. B., Jr., 1963, Test drilling in the upper Sevier River drainage basin, Utah, 1962: U.S. Geol. Survey open-file rept., 32 p.

Fenneman, N. M., 1931, Physiography of western United States: New York, McGraw-Hill Book Co., 534 p.

Ferris, J. G., Knowles, D. B., Brown, R. H., and Stallman, R. W., 1962, Theory of acquifer tests: U.S. Geol. Survey Water-Supply Paper 1536–E, 174 p.

Goode, H. D., 1964, Reconnaissance of water resources of a part of western Kane County, Utah: Utah Geol. and Mineralog. Survey Water-Resources Bull. 5, 63 p., 3 pls.

Gregory, H. E., 1944, Geologic observations in the upper Sevier River valley, Utah: Am. Jour. Sci., v. 242, no. 11, p. 577–606.

——— 1945, Post-Wasatch Tertiary formations in southwestern Utah: Jour. Geology, v. 53, no. 2, p. 105–115.

——— 1949, Geology of the eastern Markagunt Plateau, Utah: Geol. Soc. America Bull., v. 60, p. 970–997.

——— 1950a, Geology of eastern Iron County, Utah: Utah Geol. and Mineralog. Survey Bull 37, 153 p., 53 pls.

——— 1950b, Geology and geography of the Zion Park region, Utah and Arizona: U.S. Geol. Survey Prof. Paper 220, 200 p., 5 pls.

——— 1951, The geology and geography of the Paunsaugunt region, Utah: U.S. Geol. Survey Prof. Paper 226, 116 p., 5 pls.

Gregory, H. E., and Moore, R. C., 1931, The Kaiparowits region, a geographic and geologic reconnaissance of parts of Utah and Arizona: U.S. Geol. Survey Prof. Paper 164, 161 p., 31 pls.

Hem, J. D., 1959, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 1473, 269 p., 2 pls.

Jacob, C. E., and Lohman, S. W., 1952, Nonsteady flow to a well of constant drawdown in an extensive aquifer: Am. Geophys. Union Trans., v. 33, no. 4, p. 559–569.

Linsley, R. K., Jr., Kohler, M. A., and Paulhus, J. L. H., 1949, Applied hydrology: New York, McGraw-Hill Book Co., 689 p.

McGuinness, C. L., 1963, The role of ground water in the national water situation: U.S. Geol. Survey Water-Supply Paper 1800, 1121 p., 4 pls.

Marine, I. W., 1963, Ground-water resources of the Bryce Canyon National Park area, Utah: U.S. Geol. Survey Water-Supply Paper 1475–M, 45 p., 3 pls.

Meinzer, O. E., 1923a, The occurrence of ground water in the United States, with a discussion of principles: U.S. Geol. Survey Water-Supply Paper 489, 321 p., 31 pls., 110 figs.

——— 1923b, Outline of ground-water hydrology, with definitions: U.S. Geol. Survey Water-Supply Paper 494, 71 p.

Moore, E. E., 1940, Progress report of the committee on quality tolerances of water for industrial uses: New England Water Works Assoc. Jour., v. 54, p. 263.

Robinson, T. W., 1958, Phreatophytes: U.S. Geol. Survey Water-Supply Paper 1423, 84 p.

Searcy, J. K., 1959, Flow-duration curves: U.S. Geol. Survey Water-Supply Paper 1542–A, 33 p.

Theis, C. V., Brown, R. H., and Meyer, R. R, 1963, Estimating the transmissibility of aquifers from the specific capacity of wells, *in* Bentall, Ray, ed., Methods of determining permeability, transmissibility, and drawdown: U.S. Geol. Survey Water-Supply Paper 1536–I, p. 331–340.

Thomas, H. E., 1951, The conservation of ground water: New York, McGraw-Hill Book Co., 327 p.

Todd, D. K., 1959, Ground-water hydrology: New York, John Wiley & Sons, Inc., 336 p.

Trewartha, G. T., 1954, An introduction to climate: New York, McGraw-Hill Book Co., 402 p.

U.S. Public Health Service, 1962, Drinking water standards, 1962: U.S. Public Health Service Pub. 956, 61 p.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Dept. Agr. Handbk. 60, 160 p.

Wenzel, L. K., 1942, Methods for determining permeability of water-bearing materials, with special reference to discharging-well methods: U.S. Geol. Survey Water-Supply Paper 887, 192 p., 6 pls.

Willard, M. E., and Callaghan, Eugene, 1962, Geology of the Marysvale quadrangle: U.S. Geol. Survey Geol. Quad. Map 154.

Wilson, M. T., and Thomas, H. E, 1964, Hydrology and hydrogeology of Navajo Lake, Kane County, Utah: U.S. Geol. Survey Prof. Paper 417–C, 26 p., 3 pls.

Woolley, R. R., 1947, Utilization of surface-water resources of Sevier Lake basin, Utah: U.S. Geol. Survey Water-Supply Paper 920, 393 p., 33 pls.

Young, R. A., 1960, Ground-water areas and well logs, central Sevier Valley, Utah: U.S. Geol. Survey open-file rept., 21 p.

Young, R. A., and Carpenter, C. H., 1965, Ground-water conditions and storage in the central Sevier Valley, Utah: U.S. Geol. Survey Water-Supply Paper 1787.

INDEX

[Italic page numbers indicate major references]