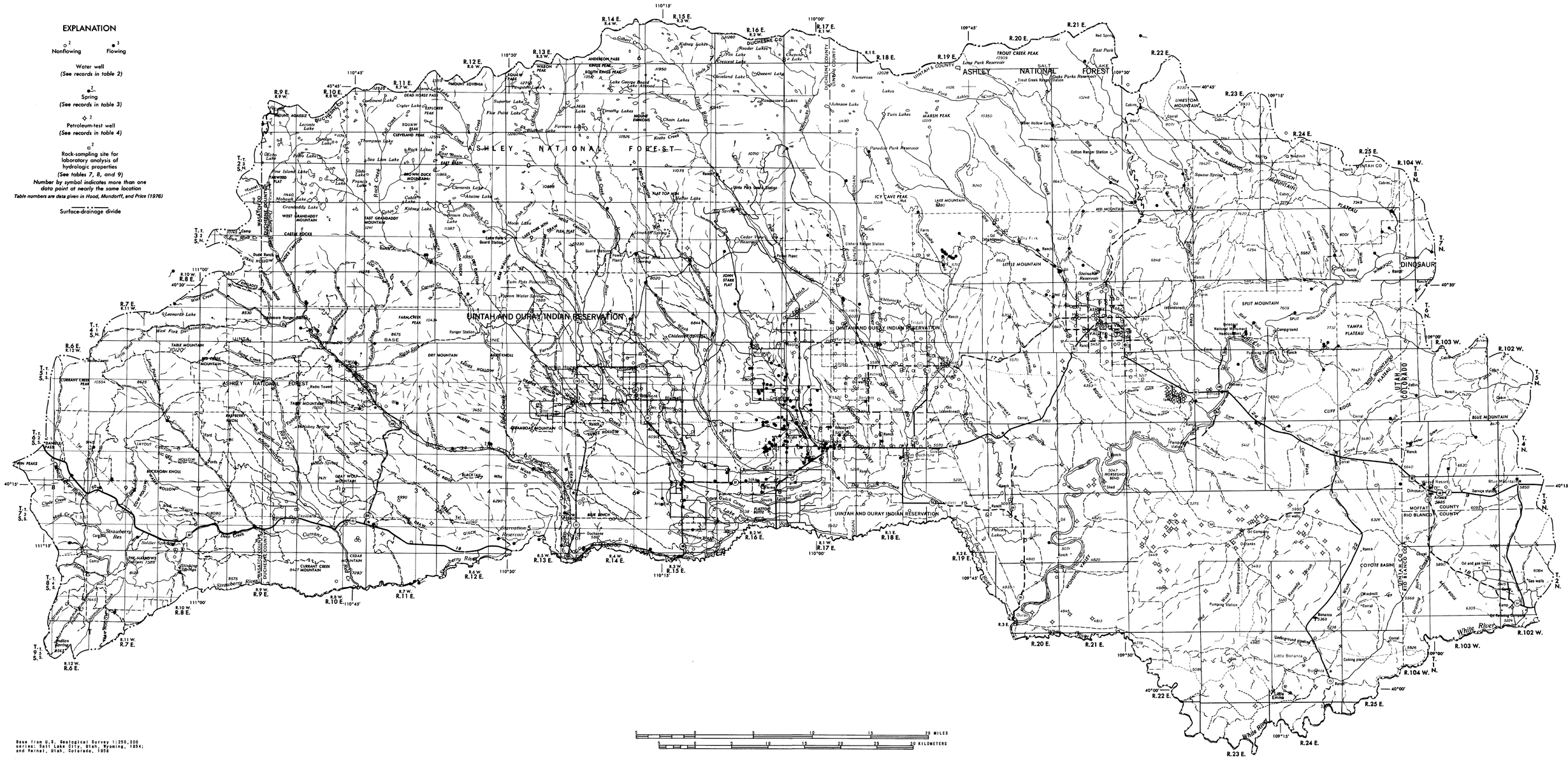


Base from U.S. Geological Survey 1:250,000 series: Salt Lake City, Utah, Wyoming, 1954; and Vernal, Utah, Colorado, 1958

MAP OF THE NORTHERN UINTA BASIN AREA, UTAH AND COLORADO, SHOWING LOCATION OF SOURCES OF GROUND-WATER DATA USED IN ASSESSING THE WATER RESOURCES

Hydrology by J. W. Hood and others, 1974

EXPLANATION

DATA-COLLECTION SITES

△ 364000
Gaging station

See table 12 for summarized record of discharge. Explanation of numbering system is in text. The numbers on this map have been shortened by omitting the "part" number, 09

⊖ 297500
Gaging station and water-quality sampling site

See table 12 for summarized record of discharge, and table 14 for water-quality analysis

◆ 306500
Key gaging station and water-quality sampling site

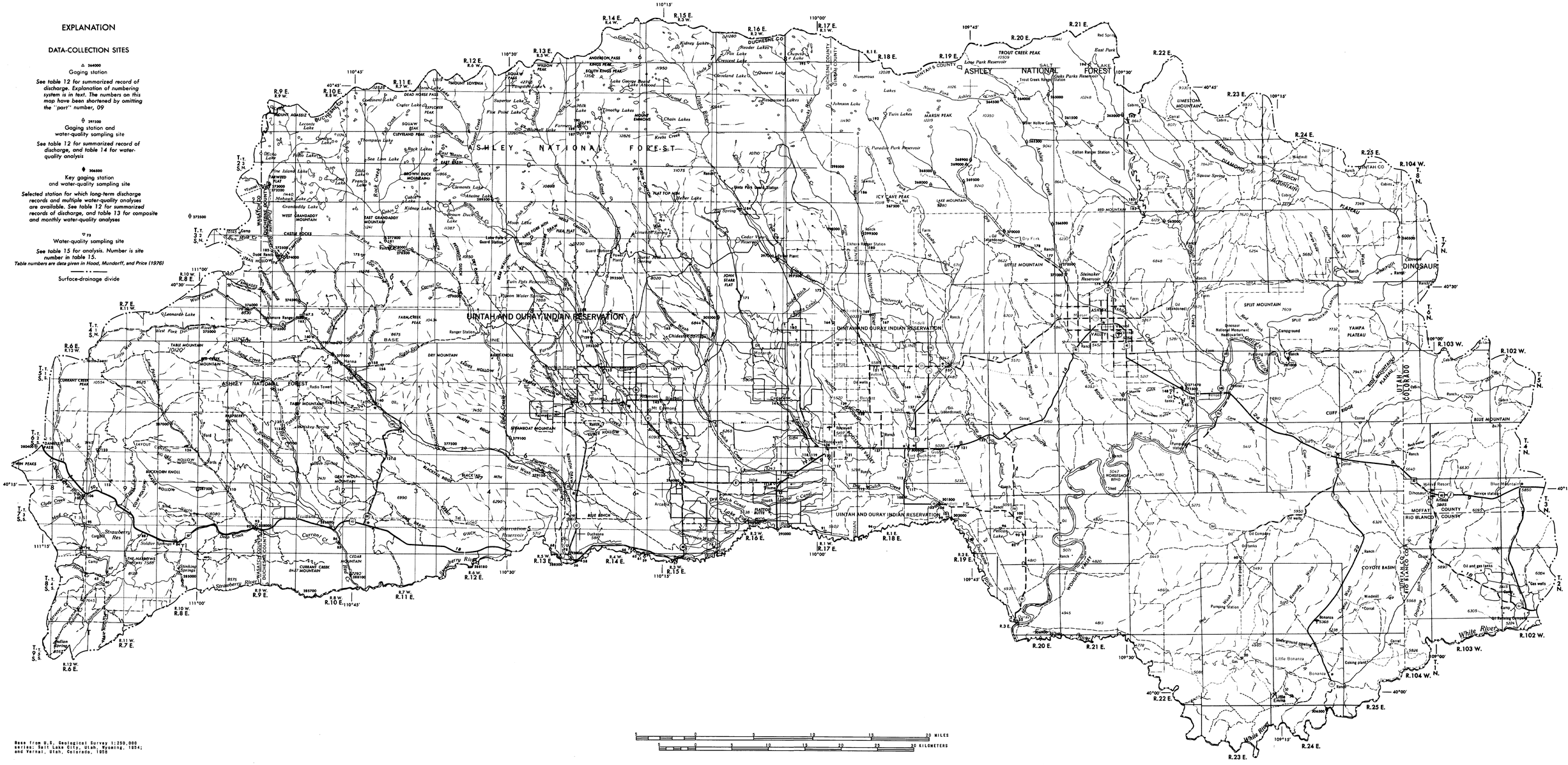
Selected station for which long-term discharge records and multiple water-quality analyses are available. See table 12 for summarized records of discharge, and table 13 for composite and monthly water-quality analyses

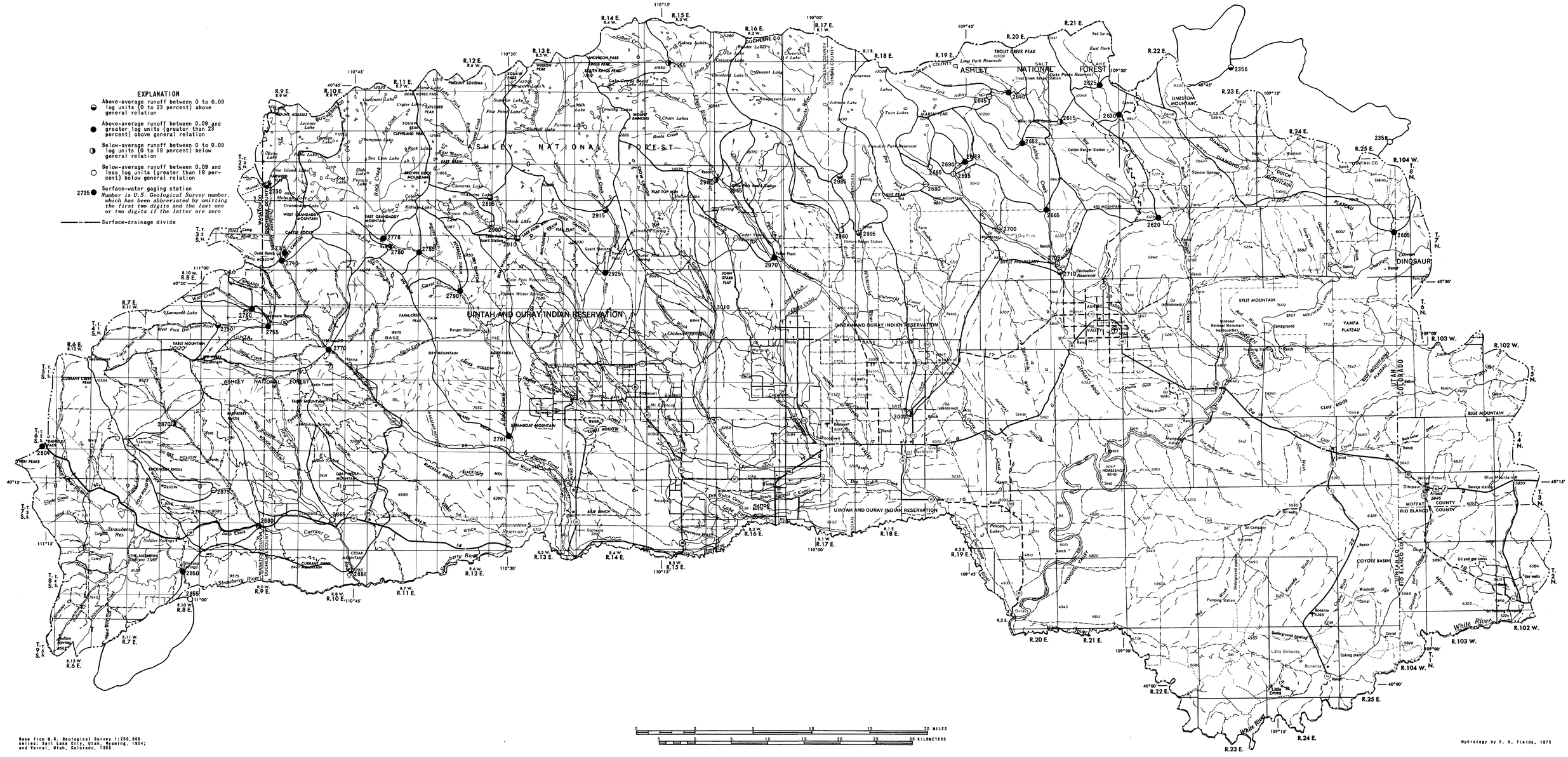
▽ 73
Water-quality sampling site

See table 15 for analysis. Number is site number in table 15.

Table numbers are data given in Hood, Mundorff, and Price (1976)

Surface-drainage divide

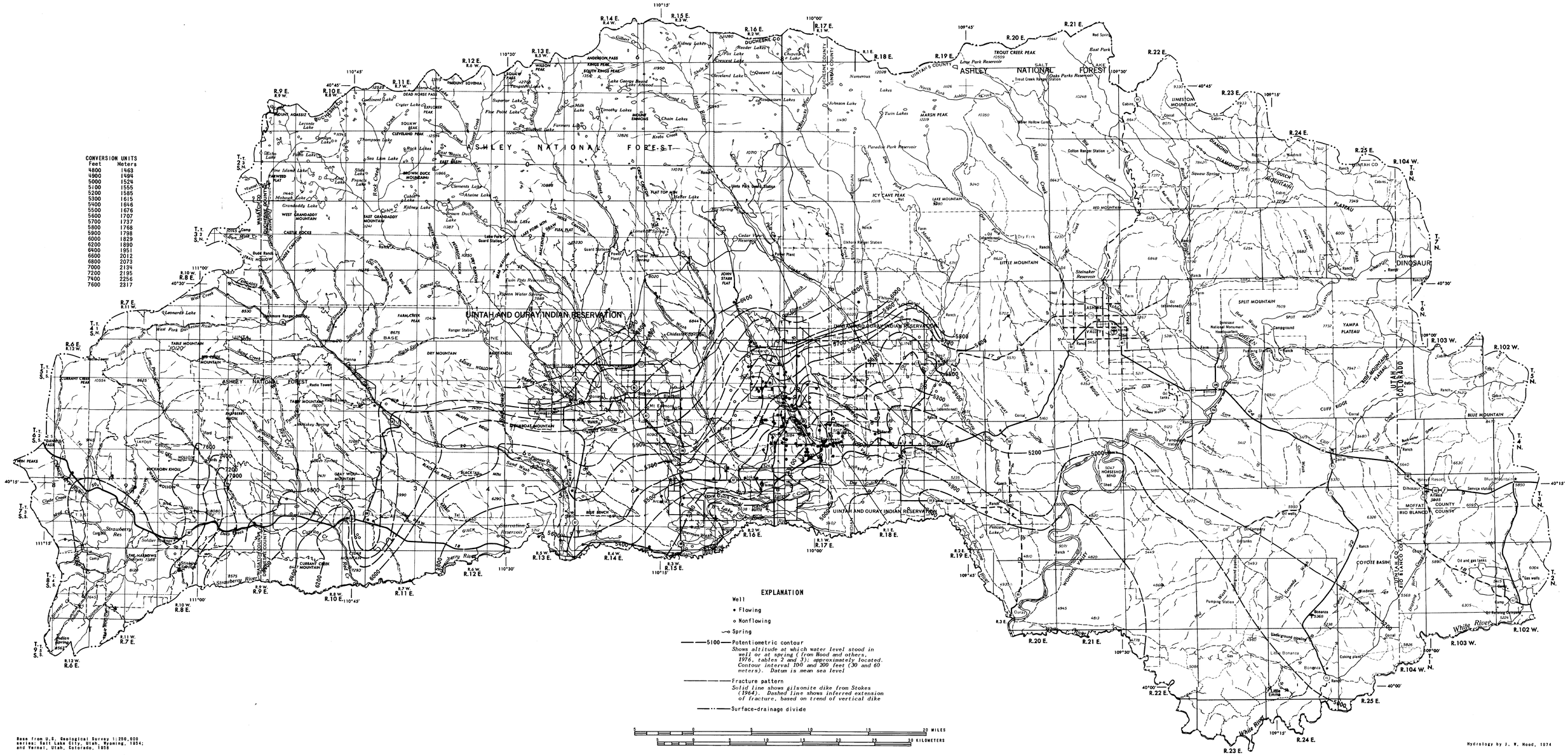

ASHLEY NATIONAL FOREST
UINTAH AND OURAY INDIAN RESERVATION
DINOSAUR
UTAH
COLORADO
MOFFAT COUNTY
RIO BLANCO COUNTY
DUCHESNE CO
UINTAH CO
WASATCH CO
DUCHESNE COUNTY
UINTAH COUNTY
WASATCH COUNTY
White River
Green River
Strawberry River
Duchesne River
Uinta River
Lake Fork River
Yampa River
Little Bonanza
Bonanza
Rangely
Jensen
Vernal
Ashley Valley
Dry Fork
Steinaker Reservoir
Pelican Lake
Red Wash
Ouray
Fort Duchesne
Mt Emmons
Roosevelt
Randlett
Bluebell
Altonah
Tabiona
Hanna
Duchesne
Myton
Arcadia
Dry Gulch Canal
Strawberry Res
Soldier Summit
Indian Spring Area
Leonards Lake
Moffat County
Rio Blanco County
Service station
Water Resort
Blue Mountain
Coyote Basin
Underground mining
Pumping Station
Oil and gas tanks
Oil and gas wells
Oil wells
Oil tanks
Oil Company
Cabins
Ranch
Windmill
Corral
Cabin
Farm
Dinosaur National Monument Headquarters
Campground
Ranger Station
Guard Station
Radio Tower
Pumping station
Cooking plant
Gas
Oil (abandoned)
Oil
Gas wells
Gas tanks
Water Hollow Camp
Colton Ranger Station
Elkhorn Ranger Station
Lake Fork Guard Station
Uinta Park Guard Station
Uinta Pipe Guard Station
Ashley Valley
Vernal
Naples
Maeser
Jensen
Ouray
Fort Duchesne
Roosevelt
Randlett
Bluebell
Altonah
Tabiona
Hanna
Duchesne
Myton
Arcadia
Mt Emmons
Rangely
Dinosaur
Blue Mountain
Bonanza
Little Bonanza
Pelican Lake
Red Wash
Steinaker Reservoir
Dry Fork



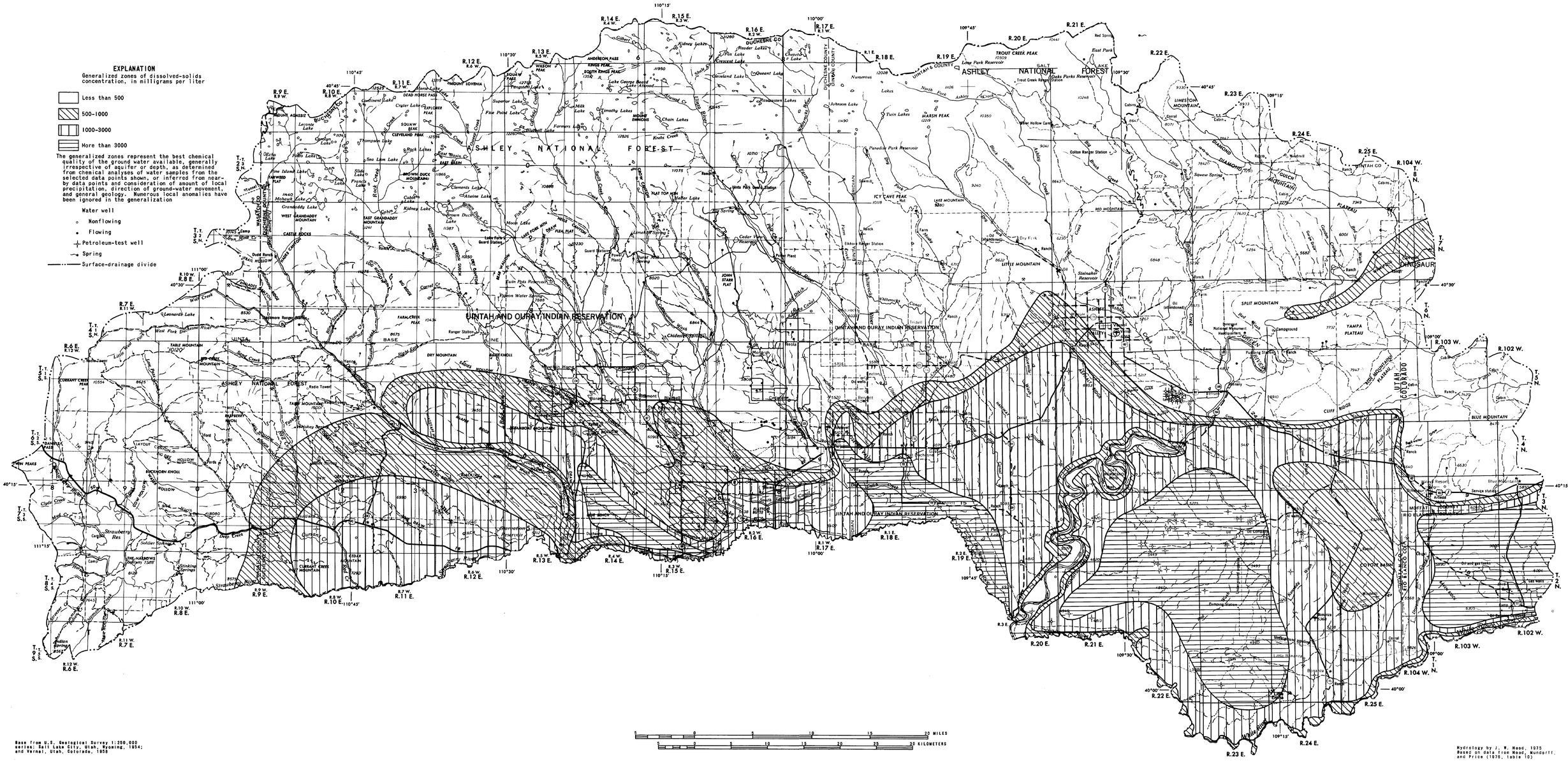
Base from U.S. Geological Survey 1:250,000 series: Salt Lake City, Utah, Wyoming, 1954; and Vernal, Utah, Colorado, 1956

Hydrology by F. K. Fields, 1975

MAP SHOWING GAGING SITES FOR WHICH ABOVE-AVERAGE OR BELOW-AVERAGE SURFACE-WATER YIELDS WERE CALCULATED IN AND NEAR THE NORTHERN UINTA BASIN AREA, UTAH AND COLORADO



MAP SHOWING APPROXIMATE POTENTIOMETRIC-SURFACE CONTOURS FOR PARTS OF THE DUCHESNE RIVER AND UINTA FORMATIONS IN THE NORTHERN UINTA BASIN AREA, UTAH



Base from U.S. Geological Survey 1:250,000 series: Salt Lake City, Utah, Wyoming, 1954; and Vernal, Utah, Colorado, 1956

Hydrology by J. W. Mead, 1975
Based on data from Mead, Mundorff, and Price (1978, table 10)

MAP SHOWING GENERALIZED CHEMICAL QUALITY OF GROUND WATER IN THE NORTHERN UINTA BASIN AREA, UTAH AND COLORADO

STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES

Technical Publication No. 62

WATER RESOURCES OF THE NORTHERN UINTA BASIN AREA, UTAH AND COLORADO, WITH SPECIAL EMPHASIS ON GROUND-WATER SUPPLY

by
J.W. Hood and F. K. Fields
Hydrologists, U.S. Geological Survey

Prepared by
the United States Geological Survey
in cooperation with
the Utah Department of Natural Resources
Division of Water Rights

1978

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U.S. CUSTOMARY-TO-METRIC CONVERSION FACTORS

Most values are given in this report in U.S. customary units followed by metric units. The conversion factors are shown to four significant figures. In the text, however, the metric equivalents are shown only to the number of significant figures consistent with the accuracy of the value in U.S. customary units.

U.S. customary Unit (Multiply)	Abbreviation	(by)	Metric Unit (to obtain)	Abbreviation
Acre		0.4047	Square hectometer	hm^2
Acre-foot	acre-ft	.001233	Cubic hectometer	hm^3
Cubic foot per second	ft^3/s	.02832	Cubic meter per second	m^3/s
Cubic foot per second per square mile	$(ft^3/s)/mi^2$	.01093	Cubic meter per second per square kilometer	$(m^3/s)/km^2$
Foot	ft	.3048	Meter	m
Foot per mile	ft/mi	.1894	Meter per kilometer	m/km
Gallon	gal	3.785	Liter	L
Inch	in.	25.40	Millimeter	mm
Mile	mi	1.609	Kilometer	km
Square mile	mi^2	2.590	Square kilometer	km^2

Chemical concentration and water temperature are given only in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (μg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is about the same as for concentrations in the U.S. customary unit, parts per million.

Chemical concentration in terms of ionic interacting values is given in milliequivalents per liter (meq/L). Meq/L is numerically equal to the U.S. customary unit, equivalents per million.

Water temperature is given in degrees Celsius (^{o}C), which can be converted to degrees Fahrenheit (^{o}F) by the following equation: $^{o}F = 1.8(^{o}C) + 32$.

WATER RESOURCES OF THE NORTHERN UINTA BASIN AREA, UTAH AND COLORADO, WITH SPECIAL EMPAHSIS ON GROUND-WATER SUPPLY

by

J. W. Hood and F. K. Fields
Hydrologists, U.S. Geological Survey

ABSTRACT

The northern Uinta Basin area covers about 5,200 square miles (13,470 square kilometers) in northeastern Utah and northwestern Colorado. Much of the lowlands are arid to semiarid, but the highest parts of the Uinta Mountains have a humid climate. During 1941-70, the average annual precipitation ranged from less than 8 inches (203 millimeters) in the lowest part of the area at the Green River to more than 38 inches (965 millimeters) in the high west-central Uinta Mountains.

In 1974, the estimated population of the area was 28,700 persons. Irrigation accounts for the largest use of water, almost all of which is obtained from streams.

The principal sources of water are precipitation on the area and transbasin inflow through the Green and White Rivers. The average annual volume of precipitation that fell on the northern Uinta Basin area during 1941-70 is estimated to be 4.87 million acre-feet (6,000 cubic hectometers). The average annual transbasin inflow included 3.03 million acre-feet (3,740 cubic hectometers) in the Green River and 521,000 acre-feet (642 cubic hectometers) in the White River.

Of the water from precipitation within the northern Uinta Basin area, approximately 190,000 acre-feet (234 cubic hectometers) was exported, and 440,000 acre-feet (543 cubic hectometers) was added to the flow of the Green River.

The ground-water system is in both unconsolidated and consolidated rocks, of which seven aquifers are considered to be of major importance. The amount of water moving through the consolidated aquifers could not be accurately determined; most of the water in those rocks is discharged back to streams in the mountains. The small remainder circulates to depths of 2,000-8,000 feet (610-2,440 meters) and then moves upward into overlying formations of widely different ages.

Ground-water recharge is estimated to be 500,000 acre-feet (620 cubic hectometers) annually, of which 200,000 acre-feet (250 cubic hectometers) returns to streams in the upland areas. Part of the remaining 300,000 acre-feet (370 cubic hectometers) of recharge enters the system in the mountains and moves through consolidated rocks to the lower parts of the basin. Part of

the recharge occurs in the lowlands. Approximately 160,000 acre-feet (200 cubic hectometers) is consumed by evapotranspiration, 12,000 acre-feet (15 cubic hectometers) is consumed directly by man's activities, and 128,000 acre-feet (158 cubic hectometers) is discharged to the stream system.

Although water levels have fluctuated widely in response to natural and manmade causes, the gross quantity of ground water in storage has changed little. Assuming complete dewatering of the aquifers, the estimated quantity of fresh and slightly saline ground water in storage is 28 million acre-feet (34,000 cubic hectometers). All the water in storage could not be recovered, however, without diminishing the discharge of streams and inducing saline-water migration from other parts of some aquifers.

During periods of high flow, water in all streams in the northern Uinta Basin area is fresh and mainly of the calcium bicarbonate type.

At low flow, however, the lower Duchesne River, Ashley Creek below Ashley Valley, and probably lower Brush Creek contain slightly to moderately saline water, in which sulfate is the dominant anion. In all the headwaters areas, the dissolved-solids concentration is low, but it increases downstream. The degradation of chemical quality is due to irrigation return flow, leaching of saline soils and Tertiary rocks, drainage from waterlogged heavy soils, and inflow of saline ground water.

Ground water in the northern Uinta Basin area ranges in chemical quality from fresh to briny. Fresh to slightly saline ground water can be obtained from at least one aquifer in about two-thirds of the area. The freshest water is from springs in the high mountains. The brines are from petroleum tests in the lower parts of the area and at relatively great depths.

As the ground water moves downdip, it changes in type and increases in dissolved-solids concentration. The most common successive change of water type is from calcium magnesium bicarbonate to sodium bicarbonate to sodium sulfate to sodium chloride. Some saline water in the Green River and Uinta Formations, however, is characterized by high concentrations of sodium carbonate and bicarbonate, which results from solution of sodium carbonate minerals.

Some additional water for future development could be salvaged by conversion of nonbeneficial vegetation to grasses; and some could be salvaged by prevention of canal leakage and by pumping or draining shallow-water areas where nonbeneficial vegetation consumes ground water.

The most productive source of ground water for future needs is glacial outwash and related unconsolidated rocks where they are of sufficient saturated thickness and contain usable water. The Weber Quartzite and the Glen Canyon Sandstone are the next most promising sources because of their yields and thickness.

INTRODUCTION

Purpose and scope

This report presents the results of an investigation of the water resources of the northern Uinta Basin area, Utah and Colordo, which was made

by the U.S. Geological Survey as a part of the continuing cooperative program with the Utah Department of Natural Resources, Division of Water Rights, for study of the State's water resources. Field investigations were made during the period July 1971-June 1974. The principal purpose of the investigation was to define the quantity and quality of ground water available in the study area, which yields water not only for local use but also to the Colorado River system and for transmountain diversion. A subsidiary purpose of the investigation was to provide specific information needed by the Utah State Engineer, including an evaluation of the quantity of water moving through limestone of Mississippian age from the south flank of the Uinta Mountains to the Uinta Basin, and a general assessment of ground- and surface-water relations in Ashley Valley and the upper Duchesne River valley.

This study included the northern part of the Uinta Basin in northeastern Utah and northwestern Colorado and the adjacent southern part of the Uinta Mountains (pls. 1 and 2). The study area lies mainly within latitude 40°00' to 40°45' and longitude 109°00' to 111°15', and it includes approximately 5,200 mi^2 (13,470 km^2). Because of the large size of the area, reconnaissance techniques were used in about 3,800 mi^2 (9,840 km^2), and more detailed methods of study were used for the most highly developed areas, about 1,400 mi^2 (3,630 km^2).

Basic data obtained during the study are given by Hood, Mundorff, and Price (1976). Interpretive information released as part of the study is given by Adams (1974), Fields (1975a, b), Fields and Adams (1975a, b), and Hood (1976, 1977a, b). Results of concurrent studies in the general area are given by Price and Miller (1975), Cruff (1975), Cruff and Hood (1976), and Mundorff (1977).

Acknowledgments

The writers extend thanks to the property owners and to the officials of cities, companies, and governmental agencies who provided basic data and other information used in this report. Among these are the Cities of Duchesne and Roosevelt; the Duchesne River Commissioner; the Utah Division of Environmental Health; the Utah Division of Oil and Gas Conservation; the U.S. Soil Conservation Service; and the U.S. Bureau of Reclamation.

Data-site numbering systems

Well- and spring-numbering systems

The system of numbering wells and springs in Utah is based on the cadastral land-survey system of the U.S. Government. The number, in addition to designating the well or spring, describes its position in the land net. By the land-survey system, the State is divided into four quadrants by the Salt Lake base line and meridian, and these quadrants are designated by the uppercase letters A, B, C, and D, indicating the northeast, northwest, southwest, and southeast quadrants, respectively. Numbers designating the township and range (in that order) follow the quadrant letter, and all three are enclosed in parentheses. The number after the parentheses indicates the section, and is followed by three letters indicating the quarter section, the

quarter-quarter section, and the quarter-quarter-quarter section--generally 10 acres (4 hm^2);[1] the letters a, b, c, and d indicate, respectively, the northeast, northwest, southwest, and southeast quarters of each subdivision. The number after the letters is the serial number of the well or spring within the 10-acre (4-hm^2) tract; the letter S preceding the serial number denotes a spring. If a well or spring cannot be located within a 10-acre (4-hm^2) tract, one or two location letters are used and the serial number is omitted. Thus (D-4-21)2bad-1 designates the first well constructed or visited in the SE¼NE¼NW¼ sec. 2, T. 4 S., R. 21 E., and (A-1-21)33bdd-S1 designates a spring in the SE¼SE¼NW¼ sec. 33, T. 1 N., R. 21 E. The numbering system is illustrated in figure 1.

In the Uinta Basin, part of the southeast quadrant has been subdivided by the Uintah base line and meridian as shown in figure 1. Wells and springs in this land parcel are numbered in the same manner described above, but the numbers are preceded by the letter U. Thus, well U(C-1-2)4add-1 is in the SE¼SE¼NE¼ sec. 4, T. 1 S., R. 2 W., Uintah meridian.

In Colorado also, the well- and spring-numbering system is based on the cadastral land-survey system, and in the Uinta Basin the system is referenced to the base line and the Sixth principal meridian and identified by the prefix letter S. Thus, well S(B-2-103)7bbb-1 is in the NW¼NW¼NW¼ sec. 7, T. 2 N., R. 103 W., Sixth principal meridian (fig. 1). In Colorado records, springs are not identified by the letter S preceding the serial number, but in this report springs are so designated in order to clearly identify the nature of the water source.

Gaging-station numbering system

The Geological Survey uses a nationwide system of numbering gaging stations by referring to the position of the station in a given major river basin. Gaging-station numbers are assigned in a downstream order along the main stems of the major streams, and all stations on a tributary stream that enters above a main-stem station are assigned numbers lower than that main-stem station. A similar order is followed in listing stations on first rank, second rank, and other ranks of tributaries. The numbering system consists of an 8-digit number for each station, for example 09261000. The first two digits (09) represent the "part" number identifying the hydrologic region used by the Geological Survey for reporting surface hydrologic data. The Uinta Basin area is in Part 9, the Colorado River basin. The next six digits represent the position in a downstream order.

HYDROLOGIC SETTING

Physiography

The northern Uinta Basin area lies in two physiographic units. The south flank of the Uinta Mountains is in the Middle Rocky Mountains, and the

---

[1]Although the basic land unit, the section, is theoretically 1 mi^2 (2.6 km^2), many sections are irregular. Such sections are subdivided into 10-acre (4-hm^2) tracts, generally beginning at the southeast corner, and the surplus or shortage is taken up in the tracts along the north and west sides of the section.

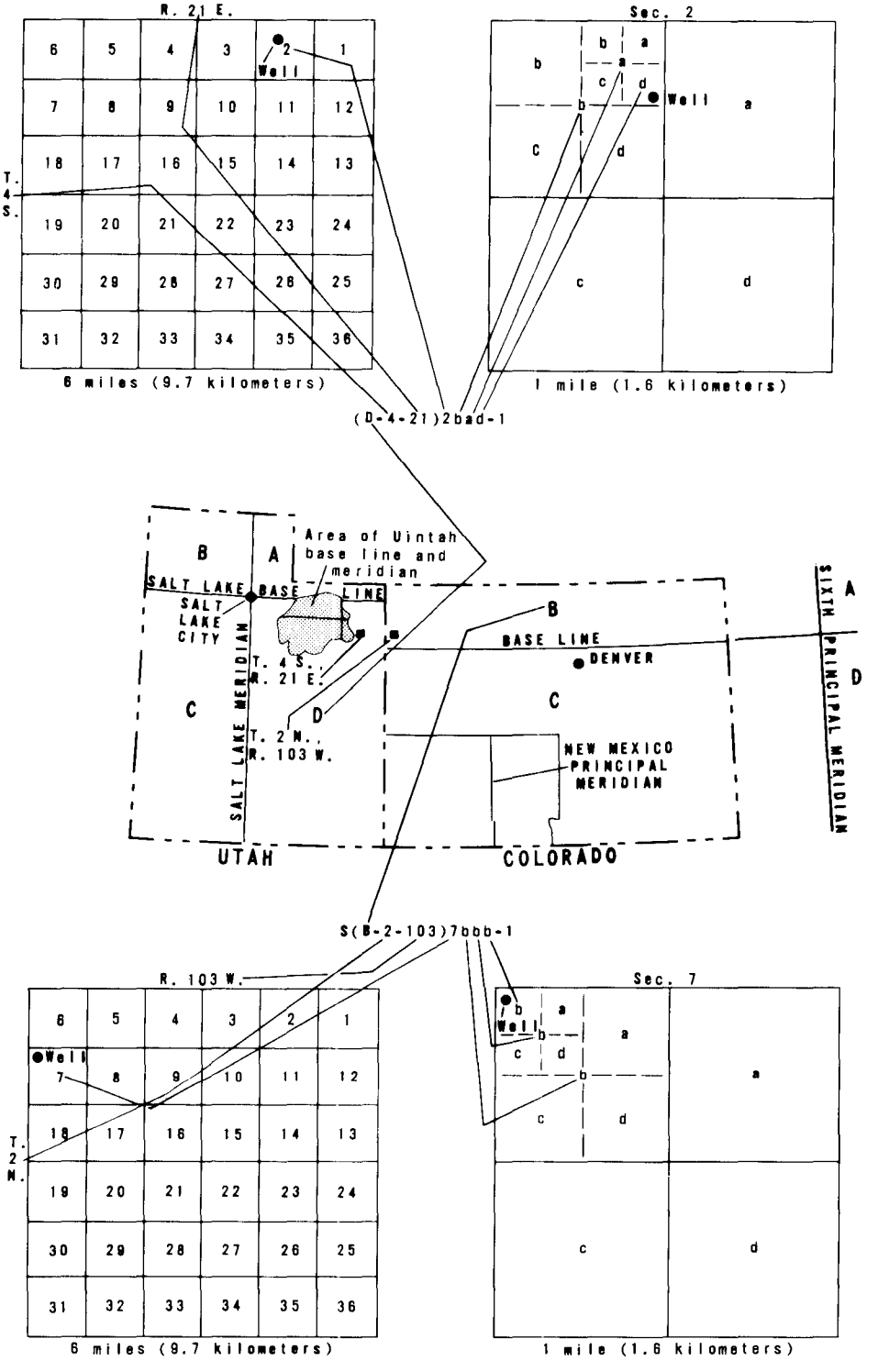


Figure 1.—Well- and spring-numbering systems used in Utah and Colorado.

lower part of the basin is in the Uinta Basin section of the Colorado Plateaus (Fenneman and Johnson, 1946).

Altitudes range from about 4,650 ft (1,417 m) above mean sea level, at the confluence of the Green and White Rivers, to glacially cut peaks in excess of 13,000 ft (3,960 m) above sea level, which extend above the timberline.

The Uinta Basin is the result of erosion of relatively soft rocks, mainly of Tertiary age, which are folded into an east-trending syncline. The lowest part of the basin is displaced onto the south limb of the syncline. Part of the basin consists of strongly dissected badlands, represented by the area east of Roosevelt, and part consists of local plateaus, represented by the area west of Roosevelt, where the general land surface is higher. The several levels (benches) of the plateaus slope gently southeastward. The benches are pediments that are mantled with coarse-grained unconsolidated and semiconsolidated deposits. The cutting of canyons into the plateaus in many places has effectively drained the adjacent rocks of Tertiary age.

The master stream in the Uinta Basin is the Green River, which cuts across the regional geologic structures. In the mountains the river is confined to rock-walled canyons; in the basin the river has cut a flood plain that is from about 0.5 mi (0.8 km) to about 1.5 mi (2.4 km) wide.

Two major tributaries join the Green River in the Uinta Basin. The eastern end of the basin is partly drained by the White River, which rises in northwestern Colorado; and much of the basin west of the Green River is drained by the Duchesne River, which heads within the study area. Drainage from areas other than the basins of the White and Duchesne Rivers is directly to the Green River and includes the drainage of Ashley, Brush, and Jones Hole (Diamond Gulch) Creeks.

The drainage pattern in the Uinta Basin is centripetal and is a complex of antecedent, consequent, and superposed channels. A part of the drainage pattern can be shown or inferred to be the result of control by geologic structure. For the most part, the present drainage lines are the consequence of cutting along eastward-striking beds of shale and southward migration in response to the lowering grade of the Green River.

The entire aspect of the stream system today is one of renewed erosion. Nowhere is there any major evidence of alluviation in excess of erosion, and alluvial fans are conspicuously absent. The stream channels, rather, show evidence of being incised into previously established flood plains and alluvial surfaces, and as a result, probably are progressively draining parts of the unconsolidated aquifers.

Geology

Rocks in the northern Uinta Basin area range in age from Precambrian to Holocene. The exposed section has a composite thickness in the western end of the basin of about 58,000 ft (17,700 m), and in the eastern end of the basin about 53,000 ft (16,200 m). The thickness and hydrologic characteristics of the rock units are summarized by Hood (1976, table 1) and the units are listed in table 1.

Table 1.--List of geologic units that crop out in the northern Uinta Basin area (After Hood, 1976, table 1)

Geologic unit: *a*, considered to be a major hydrologic unit because of large areal extent or thickness, large yields to wells or springs, or function as recharge media; *b*, considered to be an important hydrologic unit, but restricted in potential development because of limitations in thickness, distribution, or chemical quality of water.

	Age	Geologic unit	
		Western part of basin	Eastern part of basin
CENOZOIC	Quaternary	Younger alluvium, gravel surfaces, landslide and talus deposits, and dune sand and other windblown deposits	
		a Glacial deposits, alluvium of Pleistocene age, and terrace deposits	
	Tertiary	*b* Browns Park Formation	
		Extrusive igneous rocks	
		a Duchesne River Formation	
		a Uinta Formation[1]	
		Green River Formation	
		Wasatch Formation	
MESOZOIC	Cretaceous	*a* Currant Creek Formation	
		b Mesaverde Group[2]	
		Mancos Shale (including *b* Frontier Sandstone Member)	
		Dakota Sandstone and Cedar Mountain Formation, undivided	
	Jurassic	Morrison Formation	
		b Curtis Formation	
		b Entrada Sandstone	
		Twin Creek Limestone	Carmel Formation
	Jurassic(?) and Triassic(?)	*a* Glen Canyon Sandstone (Nugget Sandstone of Stokes, 1964)[3]	(Navajo Sandstone of Stokes, 1964)[3]
	Triassic	Chinle Formation (including *b* Gartra Member)	
		Mahogany Formation (Ankareh Formation of Stokes, 1964) Thaynes Formation (or Group) Woodside Formation (Woodside Shale of Stokes, 1964)	Moenkopi Formation
PALEOZOIC	Permian	Park City Formation (or Group)[4]	
	Permian and Pennsylvanian	*a* Weber Quartzite[5] (or Sandstone or Formation)	
	Pennsylvanian	*b* Morgan Formation[6]	
	Pennsylvanian and Mississippian	Manning Canyon(?) Formation (of Stokes, 1964)	
	a Mississippian[7]	Upper Mississippian rocks, undivided Lower Mississippian rocks, undivided	Mississippian rocks, undivided
	b Cambrian	Tintic Quartzite	Lodore Formation
	Precambrian	Red Pine Shale of Uinta Mountain Group	
		Unnamed quartzite unit of Uinta Mountain Group (Mutual Formation of Stokes, 1964)	
		Lower part of the Uinta Mountain Group, undivided	

[1]Aquifer is the uppermost sandy section of the formation, which functions together with the Duchesne River Formation as a common aquifer, mainly in the central part of the area.
[2]Sandstone in the group is the aquifer.
[3]For purposes of aquifer discussion the Nugget and Glen Canyon Sandstones are the same. The name Navajo Sandstone is now obsolete for northeastern Utah.
[4]Identified in some older well records as the Phosphoria Formation. Locally (as in the Ashley Valley oil field), the base of this formation and the underlying Weber Quartzite form a common aquifer.
[5]East of the Uinta River canyon, this formation also is called the Weber Sandstone.
[6]Sandstone in the formation is the aquifer.
[7]Cavernous limestone in these rocks is the principal aquifer.

Seven of the units or their equivalents are considered to be major sources of water, or to have significant effects on the ground-water hydrology of the basin. Eight other units or their equivalents are classed as important aquifers. The remaining units have low permeability, and either inhibit recharge or deter ground-water movement, and some contain evaporites that greatly degrade the chemical quality of the water moving through them.

Geologic events have had profound effects on the movement of water in the hydrologic system in the northern Uinta Basin area. The sequence of intermittent depositional and erosional cycles and related structural events have raised once deeply buried formations to the surface in intake areas and have juxtaposed aquifers of different ages, thus permitting the interformational movement of water. For example, in petroleum test U(B-2-2)20bbc-1, the Green River Formation of Tertiary age lies upon or close to the Park City-Weber aquifer system and receives water from that system. Elsewhere, aquifers are partly sealed off from recharge by younger rocks, as in Lake Fork Canyon, where the basal sandstone of the Duchesne River Formation of Tertiary age lies upon steeply tilted rocks, mainly of Mesozoic age. (See fig. 2.)

Structural features in the study area play an important role, not only in the distribution of the several formations, but also in the enhancement or deterrence of water movement. The intermittent uplift of the Uinta Mountains has resulted in a highland formed from a folded sequence of rocks which dip steeply into the Uinta Basin. The large quantities of snow that accumulate on this highland are the main source of water for the study area.

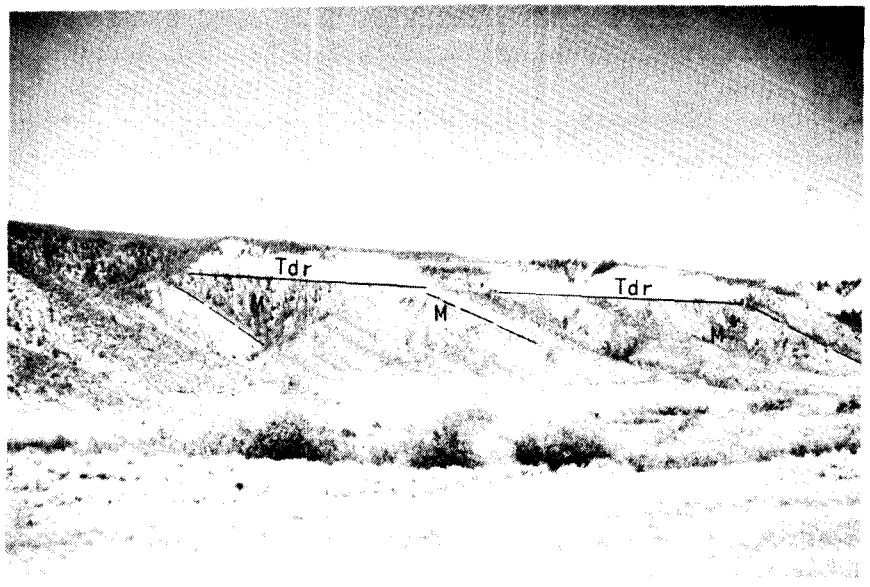


Figure 2.—View east-southeastward across Lake Fork Canyon of steeply tilted, truncated rocks of Mesozoic age (M) overlain by basal sandstone of Duchesne River Formation (Tdr) at approximate location U(C-2-5)35b. Recharge to the older rocks is inhibited by the sandstone, which has low permeability.

The adjacent Uinta Basin is formed from a partly dissected sequence of Tertiary rocks that were deposited in a subsiding trough which parallels the trend of the Uinta Mountains. Intermittent uplift and other structural events not only created the conditions that lead to large-scale erosion of the rocks of early Tertiary age, but also faulted, fractured, and folded them. The means by which both water and hydrocarbons could move or accumulate were thus created. Subsequently, glaciation during Pleistocene time carved the area to approximately its current form and provided the debris from which the major unconsolidated hydrologic units are formed.

Climate

The lowlands of the northern Uinta Basin area are arid to semiarid; at intermediate altitudes the climate is subhumid to humid; and on the highest mountains, it is humid. Precipitation and temperature are closely related to topography and are mainly a function of altitude. Records in support of the following discussion are given by Fields and Adams (1975b), and the means of adjusting observed climatic parameters to the uniform time base of 1941-70 are described by Fields and Adams (1975a).

The average annual precipitation (1941-70) in the northern Uinta Basin area ranged from less than 8 in. (203 mm) in the lowest area, near Ouray, to more than 38 in. (965 mm) in the high west-central part of the Uinta Mountains. Storms from the northwest during October-April account for about 60 percent of the average annual precipitation.

In the high mountains and upland benches, the maximum precipitation is from snowfall in late winter and early spring. In the lowlands, however, the maximum is from thunderstorms during the summer. The average monthly distribution of precipitation for 40 sites within and near the boundaries of the northern Uinta Basin area is shown in figure 3. For the period 1951-60, July was the driest month and August was the wettest.

The northern Uinta Basin area has hot summers and cold winters. Low wintertime temperatures commonly fall below $0^{\circ}F$ ($-18.0^{\circ}C$), and maximum summertime temperatures exceed $90^{\circ}F$ ($32.0^{\circ}C$). The average annual air temperature (1941-70) for the study area (Fields and Adams, 1975a, fig. 6) ranged from about $48^{\circ}F$ ($9.0^{\circ}C$) at the lower altitudes to about $15^{\circ}F$ ($-9.5^{\circ}C$) at the highest altitudes.

Based on the average annual air temperature, potential evapotranspiration at Ouray is about nine times the average annual precipitation. In the highest mountains, the potential evapotranspiration is only about 0.4 times the average annual precipitation. Thus, precipitation at the lower altitudes is mainly ineffective as a source of water to streams or groundwater recharge, and the excess of precipitation that provides water to most of the basin occurs at high altitudes.

Vegetation

The distribution of native vegetation reflects the availability and chemical quality of water in the northern Uinta Basin area. On the flood plains of the White and Green Rivers and near the mouth of the Duchesne River, the plant associations include saltcedar (*Tamarix* sp.) at river level and

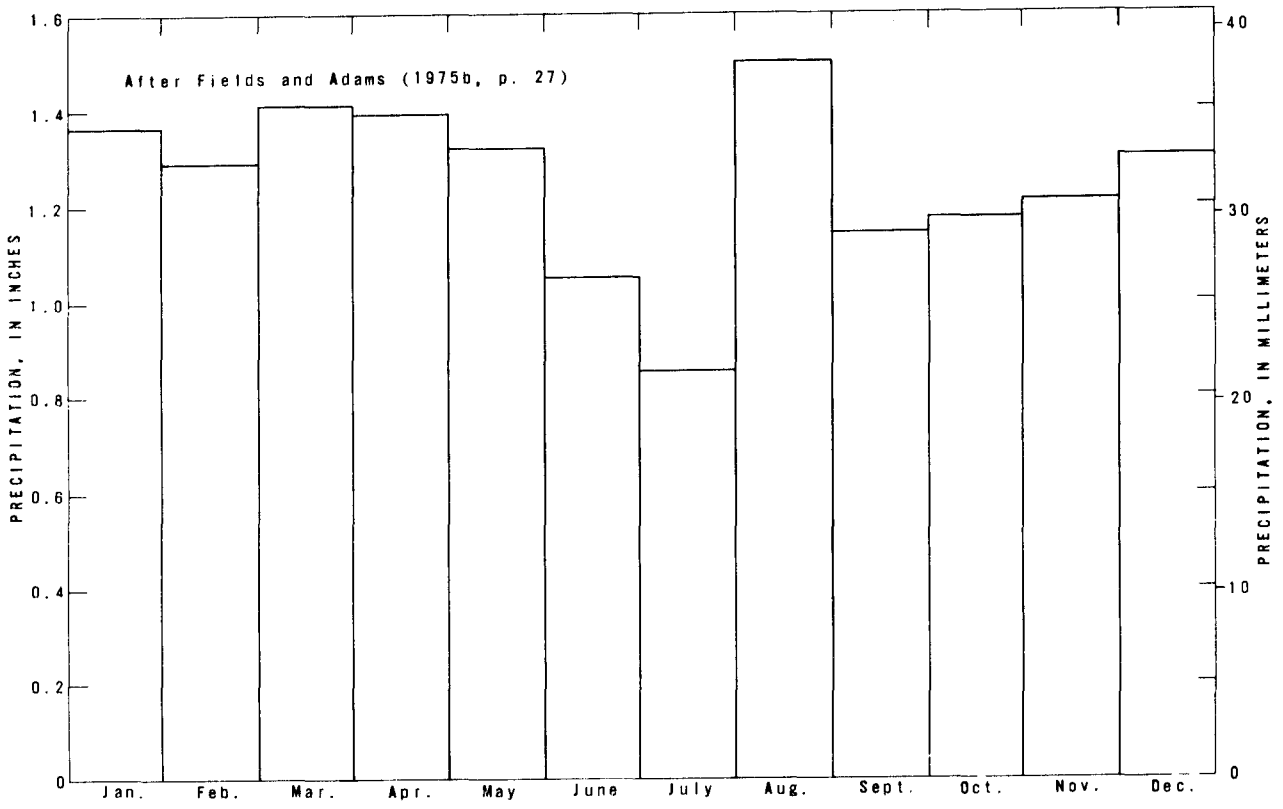


Figure 3.—Average monthly distribution of precipitation determined from 40 sites within and near the boundaries of the northern Uinta Basin area for the period 1951-60.

where the water table is very near the land surface (fig. 4) and greasewood (Sarcobatus vermiculatus) on adjacent slightly higher ground. Both species are phreatophytes and use large amounts of ground water. They can subsist where both soil and water generally are too saline for most other plants. Greasewood, under some conditions, can grow where the depth to water is as much at 60 ft (18 m). Other phreatophytes are saltgrass (Distichlis spicata var. stricta), which is associated with saltcedar and greasewood in shallow-water areas; cottonwood (Populus sp.), of which scattered single plants and small groves are found along most of the waterways and flood plains; narrowleaf cottonwood (Populus angustifolia), which is found in some of the mountain canyons (U.S. Forest Service, 1973, p. 7); and Russian-olive (Elaeagnus angustifolia), which is sparse to locally dense mainly in the lower Duchesne River area and the lower parts of some of its tributaries, and is spreading into grasslands, particularly where the grassland is subirrigated or kept wet by seepage or spring discharge (fig. 5).

Where depths to water are large, or where the surficial material is too coarse grained to allow much capillary rise of ground water, xerophytic stands of shadscale (Atriplex confertifolia) grow where the soil is saline, and sagebrush, mainly big sagebrush (Artemisia tridentata), grows where the soil is less saline or is more permeable.

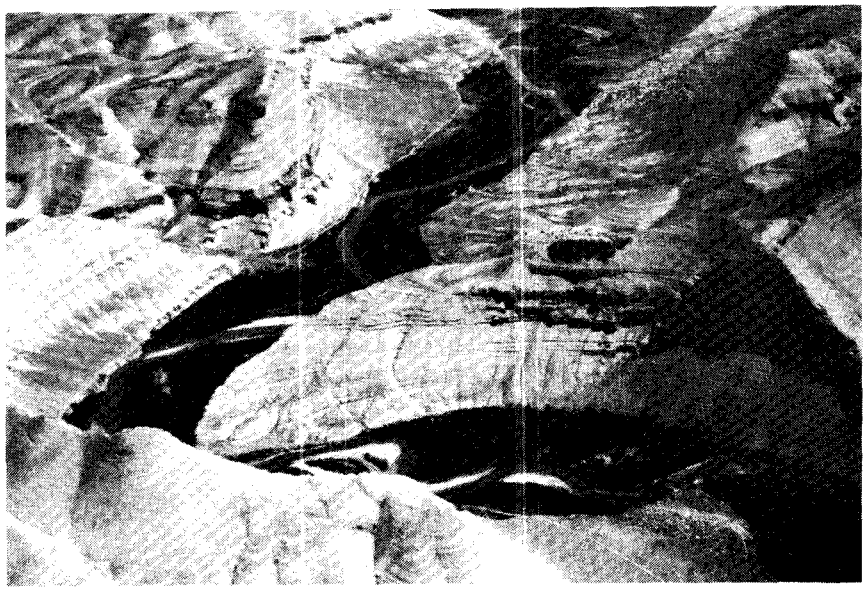


Figure 4.—White River south of Bonanza, Utah. Bare bluffs are cut from the Uinta Formation, and upland surface has only sparse vegetative cover. The flood plain of the river contains locally dense phreatophytic vegetation, mainly saltcedar. (Photograph by D. B. Adams, August 1972.)

At higher altitudes, mainly where the available water is fresher, willow (Salix sp.) is found wherever a perennial supply of water is present, as around springs. Similarly, perennially wet areas in natural meadows and subirrigated fields are marked by wiregrass (rush, Juncus sp.), and locally, sedge (Carex sp.).

Other plants indicative of freshwater availability and of ground-water discharge include rabbitbrush (Chrysothamnus sp.) and chokecherry (Prunus virginiana). Throughout the area, numerous wet tracts contain several species of hydrophytes and peripheral growths of grasses.

In the uplands, plant communities include sagebrush, juniper (Juniperus sp.), and pinyon (Pinus sp.); mountain brush, including Gambel oak (Quercus gambelii) and mountain mahogany (Cercocarpus sp.); aspen (Populus tremuloides); various conifers (fig. 6) including lodgepole pine (Pinus contorta), Douglas fir (Pseudotsuga menziesii), and Englemann spruce (Picea englemannii). Above the timberline, alpine species of generally low habit grow in plant communities that are separated by some extensive areas of bare rock; the plants include willow, grasses, sedges, and alpine forbs. The distribution of the plant communities varies with precipitation, soil type, and exposure (fig. 7). (For example, see U.S. Forest Service, 1973, p. 7.) The principal cultivated plant that affects ground water is alfalfa (Medicago sativa), which in established stands is deep rooted. Despite canal irrigation, alfalfa draws some of its needs from ground water, as do some grasses and trees (not classified as phreatophytes) in shallow-water areas. (See fig. 8 and section on evapotranspiration of ground water.)

Water use

Water in the northern Uinta Basin area is used for three main purposes: irrigation, domestic (including municipal), and industrial (including commercial) use. The first of these is the largest and has the most effect on the quality of the water that leaves the area. The other two uses are relatively small.

Irrigation

Almost all the water used for irrigation in the northern Uinta Basin is obtained from streams. The average annual amount of water diverted from the streams is estimated to be 575,000 acre-ft (709 hm^3); of this amount, an estimated 408,000 acre-ft (503 hm^3) is consumed by evaporation and transpiration. The remainder returns to the stream system by ground-water flow back to the streams and by overland flow from the ends of canals and fields. The estimates are as follows:

Area	Acres	Diversions (acre-ft/yr)	Unit diversion (ft/acre/yr)	Estimated consumption (acre-ft/yr)[1]
Duchesne-Strawberry system, on north side of rivers[2]	27,670	142,130	5.14	66,400
Lake Fork-Uinta River	117,800[3]	322,000[4]	2.7[4]	257,600
Ashley Creek-Dry Fork	29,200[5]	94,600[6]	3.24	71,000
Brush Creek	4,730[5]	13,400[7]	2.8	10,720
Green River	1,000[8]	3,000[9]	3	2,400
Total (rounded)	180,000	575,000		408,000

[1] Assumes that all water in excess of 3 acre-ft per acre returns to stream system and that 80 percent of applications of 3 acre-ft per acre or less is consumed.

[2] Averages are for 15 years of record from reports of water commissioners.

[3] Average of 16 years from reports of water commissioners.

[4] Average of 10 years.

[5] From records of Utah State Engineer for lands associated with water rights.

[6] Assumes 4 ft per acre in Dry Fork area and all Ashley Creek flow diverted.

[7] Assumes all long-term average flow diverted.

[8] Maximum, estimated from maps and field notes.

[9] From assumed rate of 3 acre-ft per year.

Figure 5.—View southward along west side of Indian Bench from spring U(D-1-1)31aaa-S1 (in ditch near back of car). Shows growth of Russian-olive and other brush growing along seepage zone at base of gravel cap of bench east of Montes Creek in zone receiving an average of about 9 inches (229 mm) of precipitation annually. Bottom of valley has dense grass cover; bottom land at far right has cover of Russian-olive.

The quantity of water withdrawn for irrigation from wells is estimated to be 6,000 acre-ft (7.4 hm^3), and the net figure after return flow is 4,800 acre-ft (5.9 hm^3). The total includes 4,530 acre-ft (5.6 hm^3) of water produced with oil in the Ashley Valley oil field in 1974. (See section on industrial use.) Only one large-yield well is known to have been used exclusively for irrigation prior to 1974; a second large-yield well was being installed in the spring of 1974. Most other irrigation with ground water is by water withdrawn from domestic wells.

Irrigation water is applied mainly to lands that support the livestock and dairy industry. According to the 1969 agricultural census (U.S. Dept. Agriculture, 1974, p. 90-107), about 9 percent of the irrigated land in Duchesne and Uintah Counties was used for grains and miscellaneous crops, and 39 percent was used for alfalfa and other hay production. It is inferred that the remaining irrigated land was used for irrigated pastures.

Domestic

Domestic use, as given here, includes the water used for household and culinary purposes in both urban and rural areas, the incidental irrigation of lawns and gardens, and small amounts of water used for stock at residences. The quantity of water used is derived from figures for gross population, which in 1974 is estimated as follows:

	County	Number of people
Utah	Duchesne	11,600
	Uintah	16,000
	Wasatch	100
Colorado	Rio Blanco and Moffat	1,000[1]
Total		28,700

[1]Estimated from 1970 census figures and adjusted to 1974, using growth rate in Uintah County.

A per-capita use of 400 gal (1,500 L) per day (including minor irrigation and stock use) is taken from a weighted average of values reported by Harline and others (1963, tables 4-20 and 4-71) and rounded upward to account for the growing use of home appliances. Thus, an estimated 28,700 people in the northern Uinta Basin area used about 12,900 acre-ft (15.9 hm^3) of water in 1974.

Figure 6.—Sparse to dense coniferous growth and meadowland at Pole Creek Lake, U(B-3-2)12b, altitude 10,151 feet (3,094 m). Vegetation covers thin(?) layer of glacial moraine overlying Precambrian rocks in zone receiving an average of 22-24 inches (559-610 mm) of precipitation annually.

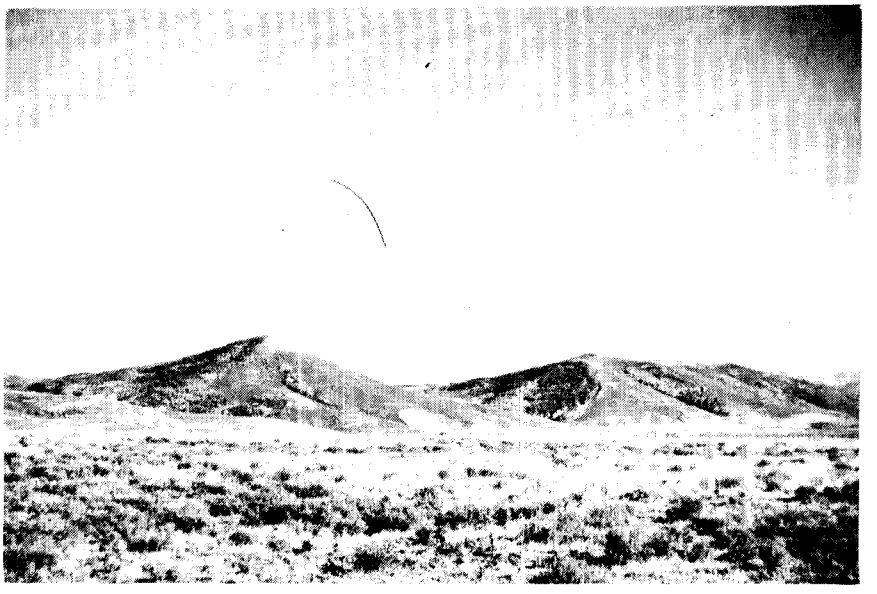


Figure 7.—View southeastward from mouth of Trout Creek Canyon (north of Strawberry Reservoir) of mountain brush growing on hills underlain by Uinta Formation. South-facing slopes are covered with sparse mountain brush. North-facing slopes, protected during part of year from solar radiation, retain more moisture and support a denser growth, mainly of mountain brush and aspen. Alluvial slope in foreground contains mixture of sagebrush, other brush, and grasses in zone receiving about 24 inches (610 mm) of precipitation annually.

An estimated 70 percent of the water used in households is returned to the ground-water system by infiltration from sewage, and the amount of lawn and garden water returned to the system is estimated to be 30 percent of the water applied. It is estimated, therefore, that about 50 percent of the water is returned to the system, and the net consumption for domestic use in 1974 was about 6,500 acre-ft (8.0 hm^3). Almost all this water was withdrawn from wells and springs.

About 3,000 acre-ft (3.7 hm^3) of water is used annually for stock in the northern Uinta Basin area, based on the livestock census and consumptive water use per head allowed by the Utah State Engineer. Of this amount, only an estimated 50 acre-ft (0.06 hm^3) per year is withdrawn from wells specifically drilled for stock use. No separate figure is given in the hydrologic budget for stock use; the small amount of water is absorbed in the much larger figures for irrigation, domestic, and other withdrawals from the system.

Industrial

The industrial (including commercial) use of water in the northern Uinta Basin area in 1974 was about 4,900 acre-ft (6.04 hm^3), as follows:

	Acre-feet	
	Withdrawn	Consumed (estimated)
Miscellaneous industrial[1]	220	
Mining (estimated)	500	
Subtotal	720	200
Production from petroleum wells[2] (Excluding Ashley Valley field; see section on irrigation)	6,963 -4,530	
Subtotal	2,433	
Freshwater production for oil-field repressuring	1,767	
Subtotal	4,210	0[3]
Total (rounded)	4,900	200

[1]Based on data from Harline and others (1963) and adjusted for population growth.

[2]Data on production and repressuring from Utah Division of Oil and Gas Conservation (1974). Total repressuring water reported to be 4,210 acre-ft, including water produced from petroleum wells.

[3]In 1974 all water produced from petroleum wells (except Ashley Valley field) reportedly was reinjected in the producing formation or into shallower formations for disposal.

All the quantities of water cited were withdrawn from wells; they do not include minor amounts of water supplied to businesses in urban areas.

WATER RESOURCES

Summary statement

Water in the northern Uinta Basin area has its source in precipitation on the area and transbasin inflow in the Green and White Rivers. Part of the water that enters the area is consumed by evapotranspiration, a small part is diverted from the basin, and the remainder flows from the area in the Green River.

Most ground water in the basin results from recharge within the basin. The ground water is discharged by evapotranspiration or by seepage into the stream system in the area. Relatively small quantities of ground-water inflow and outflow may occur at both ends of the basin.

Figure 8.—Irrigated meadow in Dry Fork Canyon and trees that line the banks of Dry Fork. Despite irrigation, plants draw on ground-water supply and cause diurnal water-level fluctuations in observation well (D-3-20)25abc-2. (Arrow points to shelter on water-level recorder on well.)

Table 2 summarizes the estimated and calculated values for various components of the hydrologic system in the northern Uinta Basin area.

Precipitation

The average annual volume of precipitation on the northern Uinta Basin area during the period 1941-70 is estimated to be about 4.87 million acre-ft (6,000 hm^3) as shown in table 3.

Surface water

The Green and White Rivers gather most of their flow upstream from the northern Uinta Basin area. The Duchesne River and 10 major tributaries to the Duchesne and Green Rivers, which have their headwaters near the drainage divide in the Uinta Mountains and other highlands, contribute the bulk of streamflow generated within the northern Uinta Basin area. Other perennial streams, which have their headwater areas on the steep foreslope of the highlands, contribute far less water than the larger tributaries. The many ephemeral streams that arise on the lower slopes of the basin are insignificant in terms of the streamflow generated within the basin.

Superimposed on the natural stream system is a network of canals that divert and redistribute the streamflow. Transbasin diversions carry water from the northern Uinta Basin area to the Great Basin via tunnels from the

Table 2.--Summary of quantitative hydrologic estimates

		Long-term average (acre-ft/yr)
Total hydrologic system:		
Inflow		
Precipitation (p. 20)		4,870,000
Green River at State line (p. 19)		3,030,000
White River at State line (p. 19)		521,000
Ground-water inflow (p. 40)		Negligible
Total (rounded)		8,420,000
Outflow		
Green River at Ouray (p. 21)	3,996,000	
Less water derived from southern Uinta Basin (p. 21)	-41,000	
Net		3,955,000
Diversions to southern Uinta Basin (p. 21)		80,000
Diversions to Great Basin (p. 21)		110,000
Ground-water outflow (p. 40)		Negligible
Direct consumption of ground water (rounded; see below)		12,000
Evapotranspiration		
Ground water (p. 43)		160,000
Consumption of irrigation diversions (p. 12)		408,000
Consumption of precipitation and streamflow (rounded)		3,700,000[1]
Total (rounded)		8,420,000
Ground-water system:		
Recharge		
Total from precipitation (p. 20)		500,000
Amount returned to streams in uplands (p. 33)		-200,000
Net total		300,000
Discharge		
Evapotranspiration (p. 43)		160,000
Direct consumption		
Net irrigation use (p. 13)		4,800
Net domestic (p. 15)		6,500
Net industrial use (p. 16)		200

Table 2.--Summary of quantitative hydrologic estimates--Continued

	Long-term average (acre-ft/yr)
Ground-water system--Continued	
Discharge--Continued	
Spring discharge and diffuse seepage to streams (p. 42) (rounded)	128,000[2]
Total (rounded)	300,000
Storage[3] (p. 40)	
Unconsolidated aquifers	2,000,000
Consolidated aquifers	26,000,000
Total	28,000,000

[1]Calculated as difference between total inflow and all other listed items of outflow. Includes evapotranspiration from plants and soils near point of fall of precipitation, excluding amounts calculated for irrigated fields and areas of phreatophytes.

[2]By difference of recharge minus all other listed items of discharge.

[3]Recoverable fresh and slightly saline ground water.

Duchesne River and Strawberry Reservoir. These diversions and supporting reservoirs regulate most streamflow at lower altitudes so that seasonal analysis is meaningless. The flow in some natural channels is entirely depleted of flow from upstream during a part of the year.

In the following discussion, most of the computations, which are summarized in table 2, are based on average annual values for the period 1941-70. (See Fields and Adams, 1975b, table 12.)

Volume of streamflow

The northeastern boundary of the northern Uinta Basin area is immediately below the confluence of the Green and Yampa Rivers; and, therefore, flow into the area is the combined flow of the two rivers. For the period 1941-70, the average annual inflow was 4,190 ft^3/s (119 m^3/s), or about 3.03 million acre-ft (3,740 hm^3). This figure includes a proration of the estimated unit-runoff for ungaged areas. The flow in the Green River across the area boundary is also the flow across the Colorado State line.

The calculated average annual flow across the State line in the White River for the period 1941-70 was 720 ft^3/s (20.4 m^3/s), or about 521,000 acre-ft (642 hm^3). This figure was calculated by adjusting the figure for flow of the White River near Watson, Utah (09306500), using miscellaneous measurements at the Colorado State line and at the mouth of the White River.

Table 3.--Estimated average annual volumes of precipitation and ground-water recharge, 1941-70

Area: From planimeter survey of isohyetal map by Fields and Adams (1975b, fig. 12).
Ground-water recharge: Based on the method of Hood and Waddell (1968, p. 22-23).

Precipitation zone (inches)	Area (acres)	Estimated average precipitation		Ground-water recharge	
		Feet	Acre-feet	Percent of precipitation	Acre-feet
Less than 8	295,800	0.58	171,600	0	0
8-10	507,200	.75	380,400	0	0
10-12	293,000	.92	269,600	1	2,700
12-14	258,000	1.08	278,600	2	5,600
14-16	241,500	1.25	301,900	2	6,000
16-18	241,600	1.41	340,700	5	17,000
18-20	230,800	1.57	362,400	5	18,100
20-22	221,300	1.73	382,800	10	38,300
22-24	165,900	1.89	313,600	10	31,400
24-26	132,100	2.06	272,100	15	40,800
26-30	243,700	2.31	562,900	15	84,400
30-34	266,000	2.64	702,200	20	140,400
34-38	167,300	2.96	495,200	25	123,800
38-less than 42	12,500	3.25	40,600	25	10,200
Totals (rounded)	3,277,000		4,870,000		500,000

Surface flow across the State line in intermittent or ephemeral streams that head within the northern Uinta Basin area is estimated to be a maximum of 2,000 acre-ft (2.5 hm^3) per year, according to channel-geometry measurements (Fields, 1975b).

The calculated average annual outflow from the northern Uinta Basin area during 1941-70 was the discharge of the Green River near Ouray, 3,996,000 acre-ft (4,927 hm^3) (after Fields and Adams, 1975b, table 12), minus the ground- and surface-water inflow to the White, Duchesne, and Strawberry Rivers that is derived from the southern Uinta Basin. That ground-water inflow was an estimated 7,000 acre-ft (9 hm^3) (Price and Miller, 1975, p. 35) and that surface-water inflow was an estimated 34,000 acre-ft (42 hm^3) (based partly on tributary flows given in Price and Miller, 1975, table 6). In addition, diversions to the Great Basin average about 110,000 acre-ft (136 hm^3) per year, and diversions to the southern Uinta Basin amount to about 80,000 acre-ft (99 hm^3) per year. The latter figure results from a recomputation using the data for canal diversions (Price and Miller, 1975, p. 27), in order to show the approximate existing conditions at the beginning of the study period covered by this report. (See also the section on water use, p. 12).

Streamflow characteristics

More than half of the volume of annual streamflow is in May and June of the average year (fig. 9), when nearly all the flow is runoff from snowmelt. June, the second driest month (fig. 3), has the greatest streamflow. Only about 20 percent of the annual streamflow occurs during the period October-April, when most of the snowpack accumulates in the mountains. The influence of upland precipitation on tributary streamflow is clearly indicated when average annual runoff at gaging stations (Fields and Adams, 1975b, table 12) is converted to unit runoff (fig. 10).

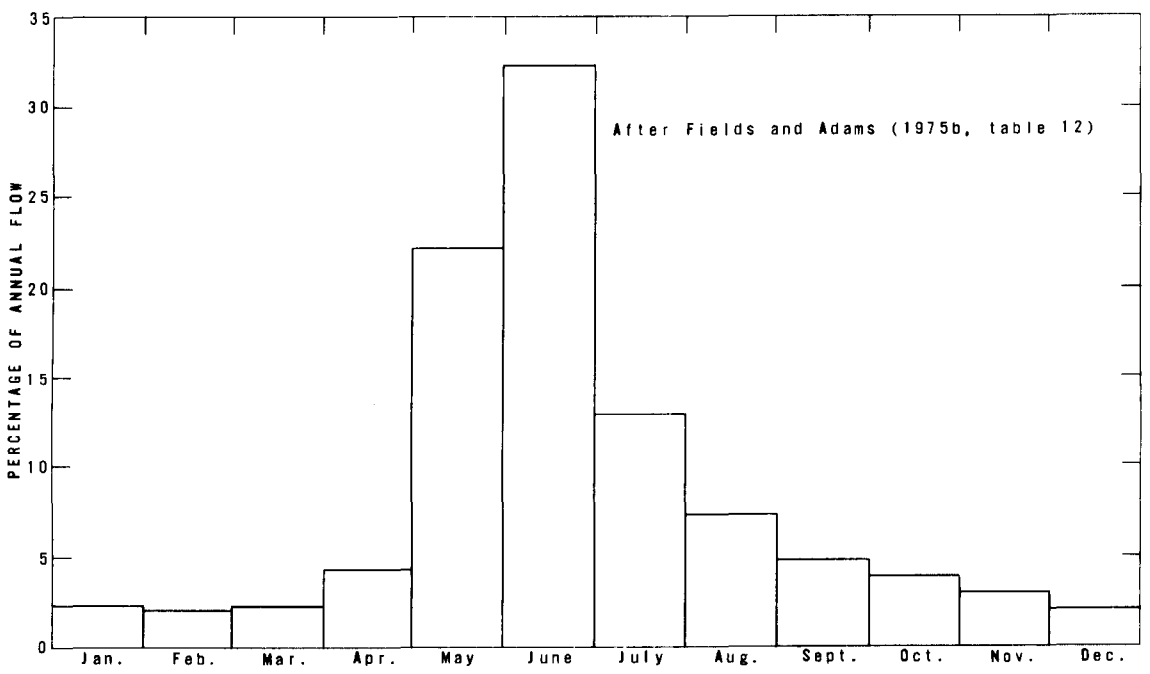
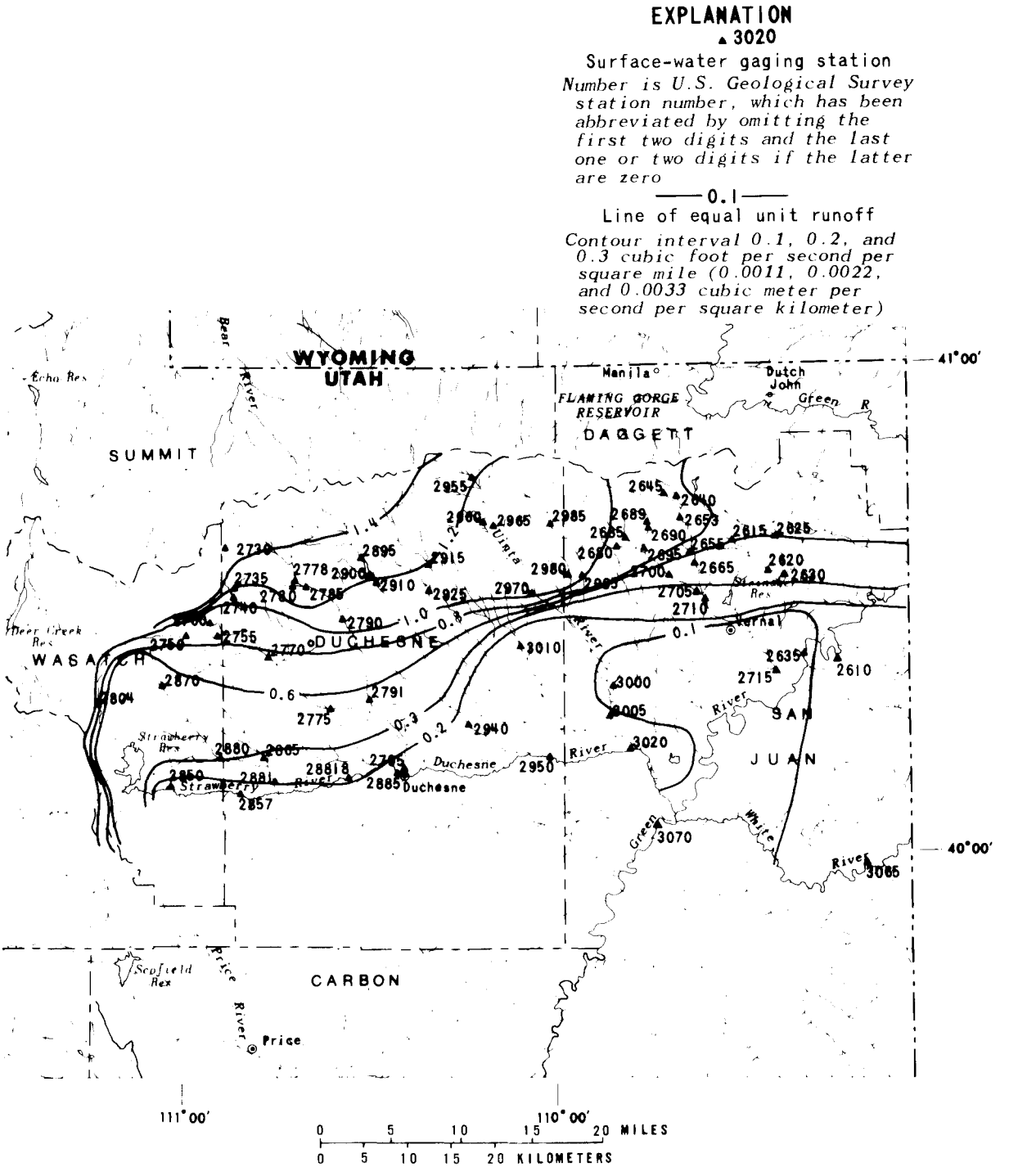


Figure 9.—Average monthly streamflow determined from 26 sites within and near the boundaries of the northern Uinta Basin area.



Base from U.S. Geological Survey
State base map, 1:500,000

Figure 10.—Approximate lines of equal unit runoff.

Variability of streamflow

The variability of streamflow is affected by basin size, precipitation, vegetation, air temperature, geology, and other factors. This variability is best expressed through flow-duration characteristics of a stream, which express the percentage of time that a particular mean daily discharge will be exceeded.

The flow-duration characteristics of natural, unregulated streams in the northern Uinta Basin area were studied by graphical and statistical comparisons. Three curves shown in figure 11 are representative of natural, unregulated streams in the area. The curve in figure 11A is typical of streams in areas of high precipitation where the stream basin contains soils and geologic strata that can absorb large amounts of water during the snowmelt season. The water seeps into the ground, moves downgradient in the subsurface, and reappears as streamflow. The streamflow is sustained by the ground-water discharge, thus accounting for the small differences in discharges in the 50 to 90 percentile range.

The curve in figure 11B is typical for areas of little precipitation that are underlain by relatively impermeable formations. The curve has a sharp slope and closely approaches a straight line, which would indicate a normal distribution.

The curve in figure 11C represents areas of high precipitation in which underlying aquifers are so permeable that they either drain quickly or divert water to an adjacent basin. The slope of the curve for probabilities of greater than 60 percent is greater than the curve in figure 11A but less than that of figure 11B.

A statistical analysis of flow-duration characteristics of the streams in the northern Uinta Basin area indicates that these characteristics can be estimated on the basis of mean annual discharge. The latter can be determined from interpolated or extrapolated discharges or by equations that have been developed by multiple-regression techniques (Whitaker, 1971; Fields, 1975a) or with channel geometry (Fields, 1975b). Table 4 lists the constants used to estimate the discharges that will be exceeded between 10 and 90 percent of the time. The constants are used in the equation form:

$$D = C(0)\ Q^{C(1)}$$

where,

D is the mean daily discharge, in cubic feet per second, that will be exceeded a certain percentage of the time,

C(0) is a constant,

Q is the mean annual discharge, in cubic feet per second, and

C(1) is a constant.

The largest standard error of estimate for a sampling of flow-duration characteristics from 31 gaging sites in and near the northern Uinta Basin area

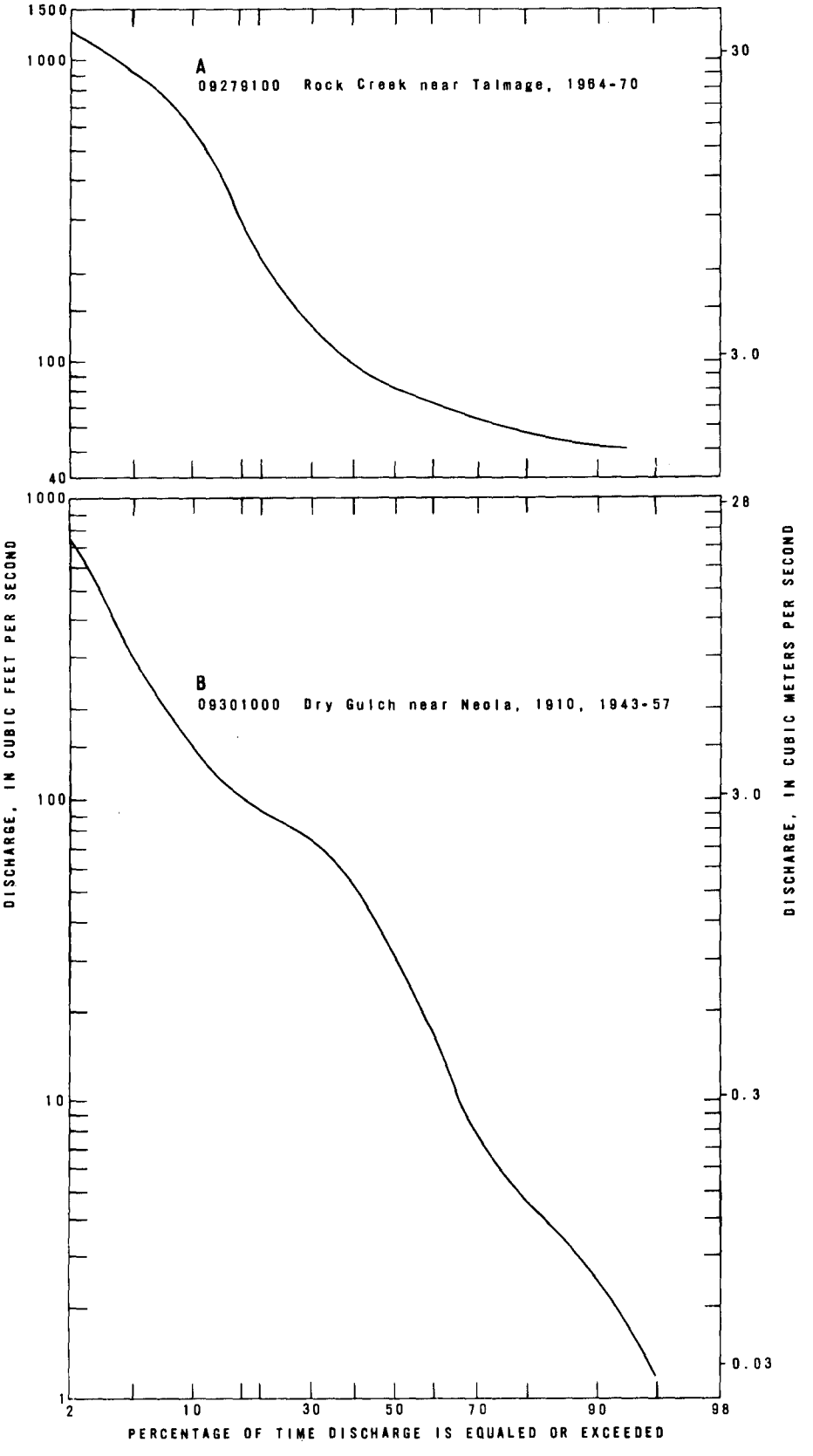


Figure 11.—Flow-duration curves for three selected gaging sites.

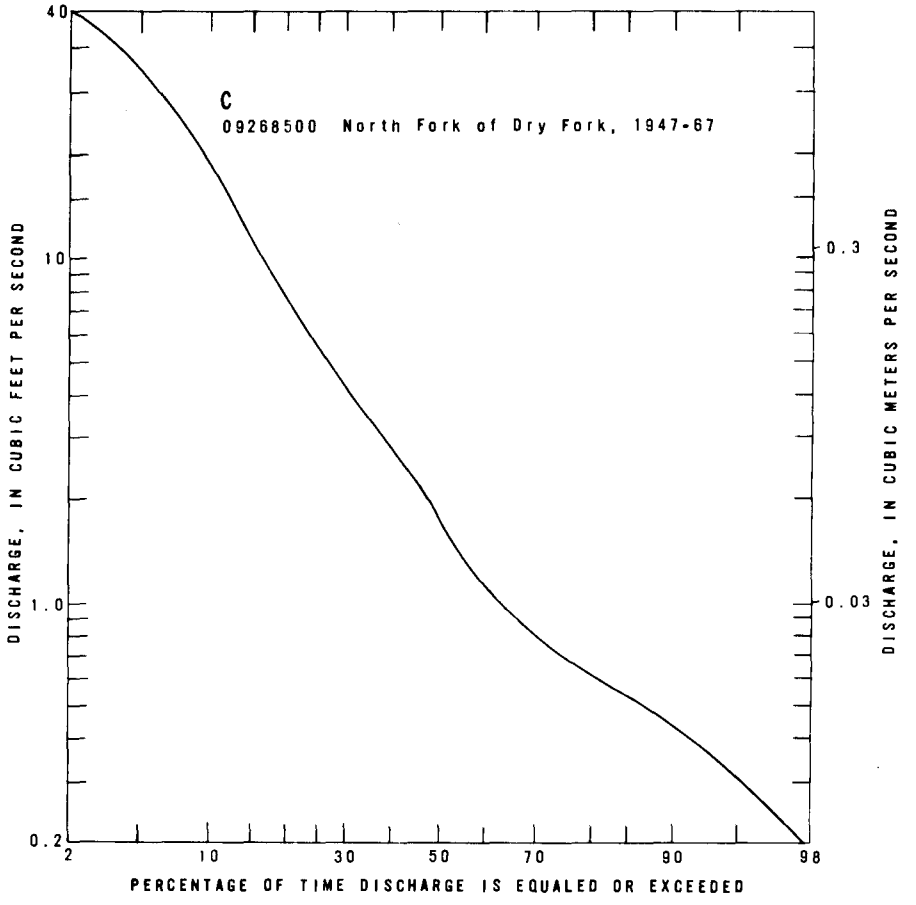


Figure 11.—Continued.

was 9 percent. The mean annual discharge was approximately the same discharge that was exceeded 30 percent of the time, and the median streamflow was about 0.4 of the mean annual discharge.

Table 4.--Constants to estimate the discharge, in cubic feet per second, that will be exceeded for various percentages of time

Percentage of time the discharge will be exceeded	C(0)	C(1)	Standard error of estimate (percent)
10	3.15	0.95	2
30	.99	.93	4
50	.44	.97	8
70[1]	.48	.89	8
90[1]	.29	.94	9

[1]Subtract 1 from calculated value for correct answer.

To illustrate the differences that can be expected in the flow-duration curves for two areas with dissimilar precipitation characteristics, the discharges for selected duration intervals for 15 sites are expressed as a percentage of the median daily discharge in table 5. The site locations are shown in figure 10. In the area of high precipitation (more than 30 in. [762 mm] annually), the mean daily discharge that is exceeded 95 percent of the

Table 5.--A comparison of flow-duration characteristics of streams in areas of high- and low-precipitation in and near the northern Uinta Basin area

Site number: U.S. Geological Survey gaging-station number, which has been abbreviated by omitting the first two digits and the last one or two digits if the latter are zero.

Site number (see fig. 10)	The mean daily discharge, expressed as a percent of the median daily discharge, that is exceeded for selected percentages of time: Percentage of time			
	70	80	90	95
		High precipitation		
2778	62	55	48	46
2780	72	62	54	50
2785	69	60	54	50
2790	81	69	62	57
2895	70	63	58	56
2955	73	65	53	43
2985	66	57	48	44
2960	65	58	51	48
Average	70	61	54	49
		Low precipitation		
2705	54	36	17	9
2889	71	50	9	3
3010	25	15	8	4
3080[1]	51	25	6	2
3085[1]	55	35	18	9
3090[1]	64	38	14	8
Average	53	33	12	6

[1] Station in nearby southern Uinta Basin. See Hood, Mundorff, and Price (1976, pl. 2B).

time is 49 percent of the median daily discharge. In the area of low precipitation (less than 30 in. [762 mm] annually), the mean daily discharge that is exceeded 95 percent of the time is only 6 percent of the median daily discharge.

Effects of reservoir operation.--Reservoirs on streams flowing from or through the northern Uinta Basin area affect the seasonal flow by regulating

floods and increasing the supply of water available for use by man. The reservoirs, however, also result in an increase in the loss of water from the system by evapotranspiration.

The Green River is regulated mainly by Flaming Gorge Reservoir, which is about 10 mi (16 km) north of the area. Its main tributary, the Yampa River, has a little regulation far above the confluence with the Green River. When Flaming Gorge Dam was closed in November 1962, the annual variation in flow of the river at Jensen was suppressed. Low flows were larger than before regulation and the flood peaks were suppressed. The peaks shown in figure 12 after 1963 are mainly due to flows issuing from the Yampa River.

The largest reservoir in the northern Uinta Basin area is Strawberry Reservoir, with a capacity of 270,000 acre-ft (333 hm^3) (1974). In 1974, it was used entirely for the accumulation of water for transbasin diversion. Other large reservoirs include Starvation Reservoir near Duchesne, Moon Lake on Lake Fork Creek, and Steinaker Reservoir north of Vernal. The latter is an off-channel storage facility that modifies the flow of Ashley Creek. Figure 12 shows that prior to operation of the reservoir, Ashley Creek often was dry at the gaging station. As a result of extending the period of irrigation, ground-water discharge to the creek maintains flow past the gage throughout the year. (See Hood, 1976b.)

Several small reservoirs at high altitudes in the Uinta Mountains were constructed to provide irrigation water after the peak flow from snowmelt had passed. Among the highest of these is Chepeta Lake in the Whiterocks River drainage basin, with a capacity of 2,530 acre-ft (3.1 hm^3), at an operating-level altitude of 10,560 ft (3,219 m).

In addition to the intended effects of flood regulation and water-supply enhancement, the operation of reservoirs increases the loss of water from the stream system by evaporation and transpiration. Most obvious is the evaporation from the large surface area of the reservoir itself. In addition, the larger continuous flow has increased the surface area and the time during which there is water in the streams and related canals and thus has increased direct evaporation from the streams and canals.

Less obvious is the increase of evapotranspiration from the flood plains due to interaction of ground-water levels with the stream-surface levels. When the streams rise, ground water is backed up, and water levels are high; when the streams recede, the ground-water levels fall. Thus with increased base flow due to the reservoirs, ground-water levels are maintained closer to the land surface than formerly, and transpiration from phreatophytes growing on the flood plain is increased.

Variability of drainage-basin yields.--Mean annual streamflow in the northern Uinta Basin area was analyzed to determine sites with above-average and below-average yields when the drainage area and precipitation are considered. These excesses and deficiencies are part of the basis for evaluating ground-water recharge and discharge in the following sections of this report.

The yields of streams were compared by two methods. First, a general relation was defined through multiple-regression techniques. This relation is dependent upon drainage area, precipitation, and mean basin elevation to

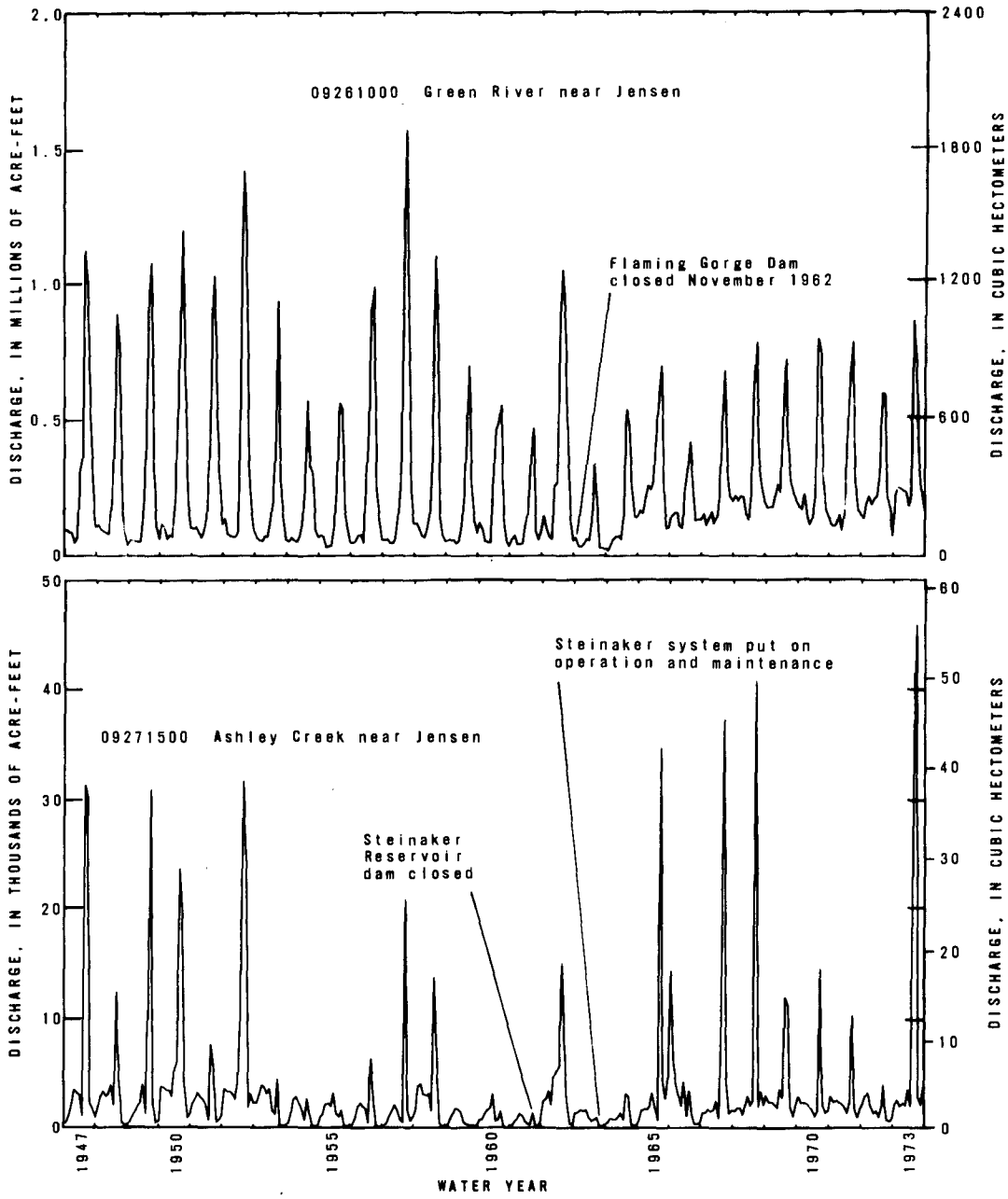


Figure 12.—Monthly streamflow in the Green River near Jensen and in Ashley Creek near Jensen.

estimate the yield. The second method simply compares unit runoff and the ratio of input to output to determine those streams that are above or below average in runoff.

A multiple-regression analysis of the average annual flow was made for 53 gaged streams (pl. 3) with drainage areas of less than 250 mi^2 (648 km^2). The mean annual streamflow was estimated by the following equation:

$$Qa = 0.00000758\ (DA)^{0.87}(P)^{1.45}(E)^{3.13}$$

where,

Qa is the 1941-70 average annual discharge, in cubic feet per second, plus a constant of 1.00,

DA is the drainage area, in square miles,

P is the 1941-70 average annual precipitation, in inches,

E is the mean basin elevation, in thousands of feet above mean sea level, and

0.00000758, 0.87, 1.45, and 3.13 are equation constants.

This equation has a standard error of estimate of 78 percent and a multiple-correlation coefficient of 0.74.

The departures from this general equation or residuals are measured in log units. The departure of each site, according to four groupings of log units is shown on plate 3. Use of the estimating equation indicates that the Strawberry River, Currant and Red Creeks, and Dry Fork of Ashley Creek are below average in annual runoff (19 percent, or more, below average), and the Duchesne River and Rock and Ashley Creeks have above-average runoff (23 percent, or more, above average).

The yields of streams were also compared by graphical technique. The inflow or input to each basin can be calculated from the average annual precipitation and the drainage area. The gaging sites shown in figure 10 have an average annual yield of 0.60 $(ft^3/s)/mi^2$ [0.0066 $(m^3/s)/km^2$], which is about 19 percent of the average annual inflow (precipitation). The yield rates of the above-average runoff and below-average runoff streamflow-gaging sites are given in table 6 and compared graphically in figure 13. Only about 15 percent of the annual inflow (precipitation) appears as streamflow in the "below-average runoff" basins and about 46 percent is gaged as streamflow in the "above-average runoff" basins.

An increase in gaging-station number indicates a farther-downstream position of the gage in a basin, and precipitation decreases in a downstream direction. Therefore, table 6 confirms the multiple-regression equation as well as demonstrating the general change in unit runoff with downstream location. This decrease in unit runoff may be magnified by irrigation diversions or reduced by return flows; however, no attempt has been made to adjust discharge for these effects.

Table 6.--A comparison of above-average and below-average runoff at streamflow-gaging sites

Station number	Input (ft^3/s)	Output (ft^3/s)	Drainage area (mi^2)	Yield $(ft^3/s)/mi^2$
Above-average-runoff sites				
Duchesne River basin:				
09273000	103	55.6	39.0	1.43
09273500	16.6	8.18	7.50	1.09
09274000	179	77.8	78.0	1.00
09275000	112	37.9	47.0	.81
09275500	140	47.4	61.0	.78
09276000	17.8	6.65	9.00	.74
09277000	495	193	230	.84
Rock Creek basin:				
09277800	237	132	98.0	1.35
09278500	287	157	120	1.31
09279000	342	174	149	1.17
Ashley Creek basin:				
09265300	117	60.9	58.0	1.05
09266500	211	96.0	101	.95
Average	188	87.2	83.1	1.05
Below-average-runoff sites				
Dry Fork of Ashley Creek:				
09268000	112	35.5	48.0	0.74
09268500	28.4	5.76	12.0	.48
09269500	43.2	7.51	18.0	.42
09270000	231	31.8	102	.31
09270500	250	27.3	118	.23
09271000	509	21.6	241	.09
Strawberry River basin:				
09285000	392	29.3	212	0.14
09285500	85.6	4.51	44.0	.10
09285700	587	59.8	360	.17
09288150	76.2	11.3	300	.04

Table 6.--A comparison of above-average and below-average runoff at streamflow-gaging sites--Continued

Station number	Input (ft^3/s)	Output (ft^3/s)	Drainage area (mi^2)	Yield $(ft^3/s)/mi^2$
	Below-average-runoff sites - Continued			
Currant Creek basin:				
09287000	121	27.0	48.0	0.56
09288000	281	46.7	142	.33
Red Creek basin:				
09286500	137	6.79	89	0.08
Average	220	32.0	133	.24

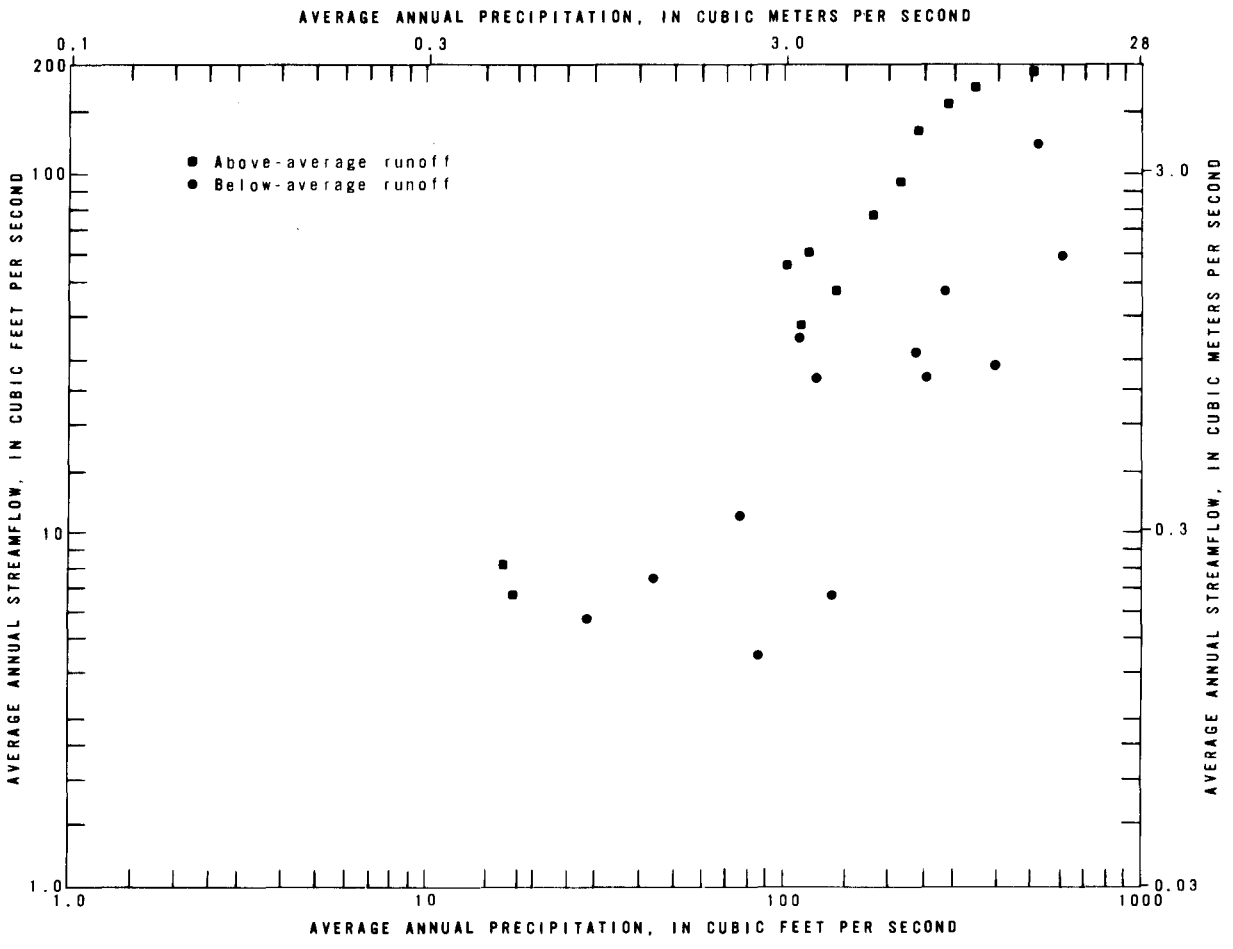


Figure 13.—A comparison of the inflow and outflow for above-average and below-average runoff in and near the northern Uinta Basin area.

Ground water

Recharge

Ground-water recharge in the northern Uinta Basin area is principally from precipitation that falls within the area. Relatively small quantities of recharge are induced from the Green and White Rivers, mainly by natural evapotranspiration, but also partly by withdrawals from wells in the flood plains. Along the northeastern and northwestern boundaries, southward-dipping strata may carry a small amount of inflow to the area.

The gross volume of recharge to the northern Uinta Basin area is estimated to be 500,000 acre-ft (617 hm^3). (See table 2.) This figure is based on the method of Hood and Waddell (1968, p. 22-23), which assumes that a fixed percentage of the average annual precipitation becomes ground-water recharge, taking into account such factors as volume, time, and area of distribution of precipitation, geology, and physiography. The volume estimated includes not only direct recharge from precipitation, but recharge from streamflow and water diverted from streams for irrigation.

Most recharge occurs during winter and the snowmelt season of spring. Some recharge occurs along stream valleys during summer, particularly where stream regulation maintains substantial flow. Little recharge results from summer thunderstorms, particularly in the lowlands, because the duration of the storms is short.

Recharge from a stream is illustrated in figure 14, which shows that an increase in the discharge of the Whiterocks River is closely followed by an increase in the discharge of Uriah Heap Springs, near U(D-1-1)4b and U(D-1-1)5. Although part of the increase in spring flow is due to seepage from canals and irrigated fields, most of the increase is believed to be due to the loss of water from the channel of the Whiterocks River downstream from the mouth of Whiterocks Canyon.

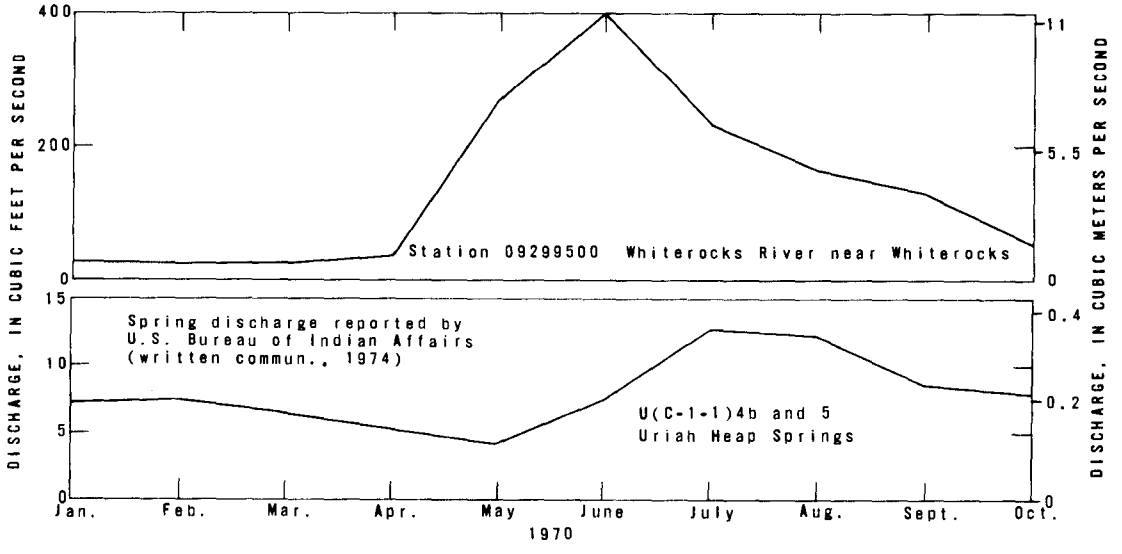


Figure 14.—Discharge of Whiterocks River near Whiterocks and Uriah Heap Springs.

Most of the ground-water recharge enters the system in the mountains, and the water then moves to the Uinta Basin mainly in the consolidated rocks. The remaining ground-water recharge occurs in the basin, principally on the alluvial surfaces, whence the water moves downgradient and to nearby streams.

Part of the ground-water recharge returns to the streams in the upland areas. This amount was estimated as follows: the total discharge of all major upland springs (Hood and others, 1976, table 3) was estimated to be 150,000 acre-ft (185 hm^3). The mountains and uplands contain several hundred other smaller springs, and the discharge of these together with diffuse seepage to the mountain streams is estimated to be at least a third as much as the aggregate of the major springs. The total return to the streamflow, therefore, is about 200,000 acre-ft (247 hm^3); and the residual recharge thus available to the areas of actual or potential use in the lowlands amounts to about 300,000 acre-ft (370 hm^3).

Some ground water moves from the mountains to the Uinta Basin through glacial and other deposits of Quaternary age which underlie the floors of the streams where they issue from the mountains. These deposits have small saturated cross-sectional areas; their hydraulic conductivities are in the range mainly of 20 to 80 ft/d (6 to 24 m/d) (Hood, 1976, p. 23); and the hydraulic gradients approximate the land surface. Computations and estimates by Maxwell, Bridges, Barker, and Moore (1971, p. 24), Thomas and Wilson (1952, p. 1), and Hood (1977b) show that underflow through the sections is relatively small--in the range of 0.5 to 2 ft^3/s (0.014 to 0.057 m^3/s). These data and other estimates based on valley widths and gradients indicate that the underflow from seven major stream valleys, from Ashley Creek westward to the upper Duchesne River, amounts to about 14 ft^3/s (0.4 m^3/s), or about 10,000 acre-ft (12.3 hm^3) per year.

The underflow in numerous minor stream valleys may amount to an additional 10,000 acre-ft (12.3 hm^3) per year, giving a total estimated underflow of 20,000 acre-ft (25 hm^3) per year. This is only 7 percent of the net ground-water recharge (table 2).

Ground-water recharge occurs also from canals. Cruff and Hood (1975, p. 28-29) found that the Rocky Point Canal system near Duchesne lost a net 6 percent of the 60 ft^3/s (1.7 m^3/s) diverted from the Duchesne River; and the Grey Mountain-Pleasant Valley Canal system immediately south of the Duchesne River, east of Duchesne, lost a net of about 8 percent of the 320 ft^3/s (9.1 m^3/s) diverted. Leakage from these two canals occurs in a geologic setting that tends to minimize canal loss. Areawide, canal loss probably is at least 10 percent.

Deep percolation losses from irrigated lands add to natural ground-water recharge. These losses are inextricably obscured by the water returned from canal wastage and from the fields as overland runoff. For this reason, the losses are not counted as recharge, but are lumped for budgetary purposes with irrigation return flow.

Occurrence

Aquifers in the northern Uinta Basin area are unconfined, perched, or confined; and these conditions may grade into each other in a complex way. In most parts of the area, the unconsolidated rocks of Quaternary age contain

unconfined ground water. Locally, however, as in parts of Ashley Valley (Hood, 1977a), zones of low permeability--clay and "hard-pan"--below the water table create confined or leaky confined conditions. On some of the benches and other upland areas, as near Lapoint, Neola, and north of Bluebell and Altamont, water in local stream channels and terrace deposits are perched.

Water in the consolidated formations is unconfined in most of the outcrop (recharge) areas; but deep within each formation, or where the formation is overlain by another of lower permeability, confined conditions exist. It is estimated that confined conditions occur in about 90 percent of the area underlain by sedimentary rocks. In part of the area, the confined conditions cause wells to flow. The greatest hydrostatic pressure measured was at well U(C-2-2)12acd-1, which discharges from the Duchesne River Formation, where the measured pressure was 119 ft (36.3 m) above land-surface datum in March 1974. The occurrence of flowing wells is a function of altitude and hydraulic conductivity of the water-bearing formation; therefore, hydrostatic pressures vary widely, and most flowing wells are in the lower parts of the area.

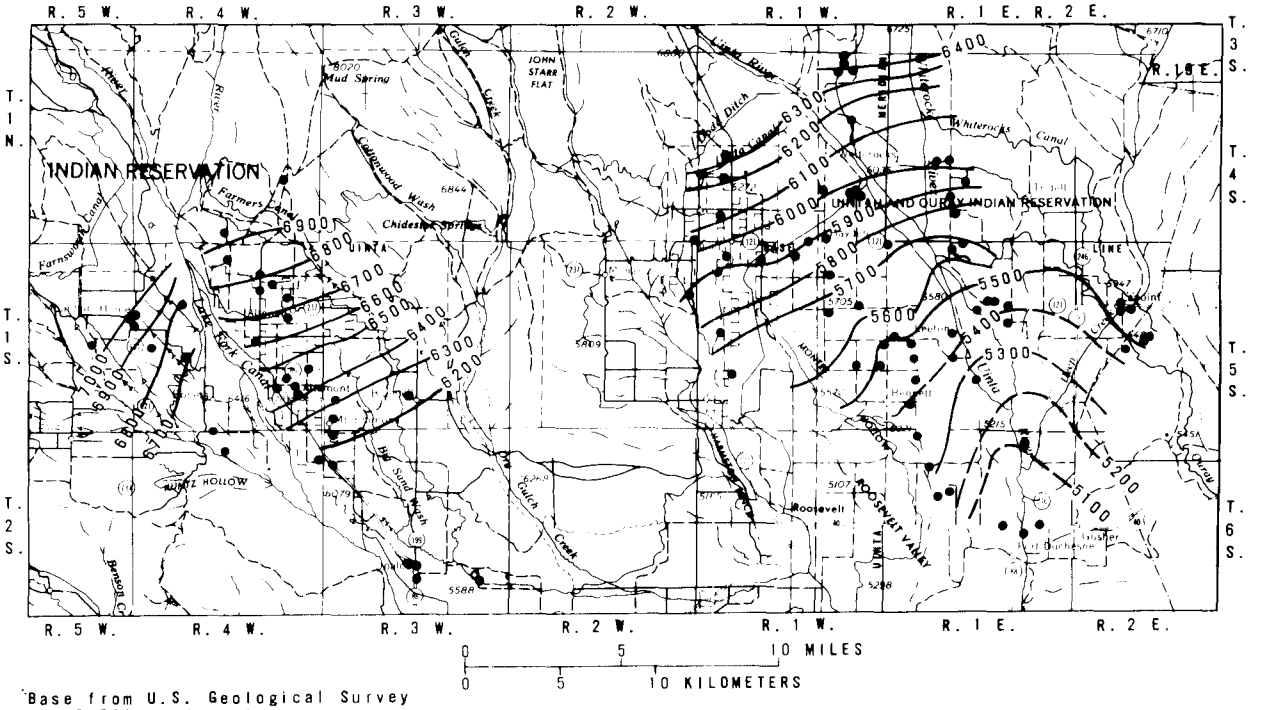
Movement

Ground water in the northern Uinta Basin area generally moves toward surface streams. Locally, the ground water may move directly to streams that are deeply incised, but the general direction of movement is toward the main channels of the Strawberry, Duchesne, Green, and White Rivers. A basin-wide map of the potentiometric surface was not prepared, owing to the wide variation in structural and stratigraphic controls on movement of ground water and to the lack of data in some areas. Potentiometric maps were prepared for several parts of the area. Two maps are included in this report and discussed below; Hood (1977a, pl. 1C) shows water-level contours in unconsolidated deposits in Ashley Valley; and Hood (1977b, pl. 2) shows water-level contours in unconsolidated deposits in the upper Duchesne River valley.

Water moving through shallow, unconsolidated deposits of Quaternary age moves toward stream channels or down the slope of the top of the consolidated rocks on which the deposits rest. This is demonstrated in figure 15, which shows water-table contours for water in areas of glacial outwash near Altamont, Neola, and Lapoint.

Ground water moving through the Duchesne River Formation and the upper part of the Uinta Formation also moves generally toward the streams, but locally the direction of movement varies from the areal pattern. Plate 4 shows contours on the potentiometric surface in the two aquifers.

Near Roosevelt, the contours curve around the area of confluence of Dry Gulch, the Uinta River, and the Duchesne River, thus indicating the ultimate discharge area for some of the water in the two formations. The paths of the contours show some consistent changes in direction, however, that are not due to decline of head alone. Although some flowing wells near Roosevelt have discharged water, and thus lowered the potentiometric surface for more than half a century, the head loss is estimated to be no more than about 100 ft (30 m). Thus the slope shown on plate 4 is approximately the natural slope. The bending contours must be due to geologic causes, and any decline in artesian head tends to amplify anomalies due to these causes.



Base from U.S. Geological Survey
1:250,000 quadrangles

EXPLANATION

Well

Spring

6200 — — — —

Water-level contour

Shows altitude of water table, as reported or measured in wells and at springs (from Hood and others, 1976, tables 2 and 3). Dashed where approximately located. Contour interval 100 feet (30 meters). Datum is mean sea level

Figure 15.—Water-table contours of ground water in glacial outwash and related coarse-grained deposits near Altamont, Neola, and Lapoint.

The Duchesne River and Uinta Formations are relatively fine grained, thus only a few hundred acre-feet per year of water, at most, would move through these formations if the rocks were not fractured. For example, potential upward flow can be estimated for the area of these formations in which upward flow could take place--about 1,800 mi^2 (4,660 km^2). The rate of flow is limited by the beds of lowest permeability; and the lowest measured vertical hydraulic conductivity of a rock specimen from the formations is about 0.000005 ft/d (0.0000015 m/d), or 0.0018 ft (0.00055 m) per year (Hood, 1976, table 3). The vertical pressure drop across a section of the aquifer where known, as at well U(C-2-2)12acd-1, is 0.17 ft/ft (0.17 m/m). The resultant value is a vertical flow of only 350 acre-ft (0.43 hm^3) per year. Similar computations using the flow through a section of the formations 4,000 ft (1,220 m) thick and the length of the outcrop yield a discharge of about 50 acre-ft (0.06 hm^3) per year. Thus, the undisturbed rock would not transmit a large quantity of water. It follows, therefore, that fracturing must play a major role in both regional and local ground-water movement.

The most obvious areal indications of fracturing in the Duchesne River and Uinta Formations are the gilsonite dikes near Roosevelt (Stokes, 1964). The dikes are essentially vertical, and thus, the fractures can be extrapolated as a straight line. The extrapolated fractures shown on plate 4 not only trend through or adjacent to potentiometric-contour anomalies, but also trend through points of abnormally high transmissivity, as at well U(C-2-2)29ccc-1 (Hood, 1976, table 6); anomalies in the chemical quality of ground water, as at well U(C-2-1)14ccc-1 and spring U(C-1-1)31ddd-S1; and possible indications of subsurface gilsonite, such as the "lava" (highly improbable in this geologic setting) logged by the driller of well U(C-2-1)14dcc-1 (Hood and others, 1976, table 6).

Where the fractures are not filled with impermeable material, upward leakage of saline waters that are characteristic of the deeper section of Tertiary rocks is possible. Where gilsonite is present, it presumably acts as a barrier to ground-water movement.

The movement of freshwater through the lower Duchesne River Formation is important because the formation supplies a large area with domestic and stock water. The direction of movement for water in the formation northwest of Roosevelt is southeastward, partly along the strike of the formation and partly updip. Were it not for the fracturing, this direction would be puzzling, because the area is south of the synclinal axis of the Uinta Basin. The water could not have passed beneath the basin's axis and remained as fresh at it is, nor could all the water have come from the local outcrop of the basal sandstone to the south and southwest. It follows, therefore, that the water enters the formation north of Bluebell and Altamont and moves through the relatively permeable beds and fractures toward the discharge area south and east of Roosevelt. Because of the fracture system and the artesian pressures of 50 to 120 ft (15 to 37 m) above land surface, there must be a component of upward leakage in the area, which moves freshwater through the system and flushes saline water from the deeper beds.

The movement of ground water in consolidated rocks that underlie the upper part of the Uinta Formation cannot be precisely defined with respect to either direction or quantity. Thus, this study only partly meets the subsidiary purpose of evaluating the quantities of ground water moving through limestone of Mississippian age and related aquifers. At best, this study

shows that (1) most of the water that recharges the bedrock in the Uinta Mountains is discharged to streams in or at the edges of the mountains (see page 33), (2) a relatively small part of the fresh or slightly saline water moves downward to depths of about 2,000 to 8,000 ft (610 to 2,440 m) along the edges of the mountains, and (3) the ground water at those depths is under high artesian pressure, and it leaks upward via fractures and fault planes and through formations of widely different ages. A part of the water is thought to be dissipated through overlying fine-grained rocks by diffuse leakage.

Examples of the evidence for depth of circulation of fresh to slightly saline water are given in table 7 (abstracted from Hood and others, 1976, tables 2-4 and 10).

Data in table 7 indicate that as the water moves downward, it acquires an increasing dissolved-mineral load. Little or no ground water moves through the deeply buried rocks, which contain brines.

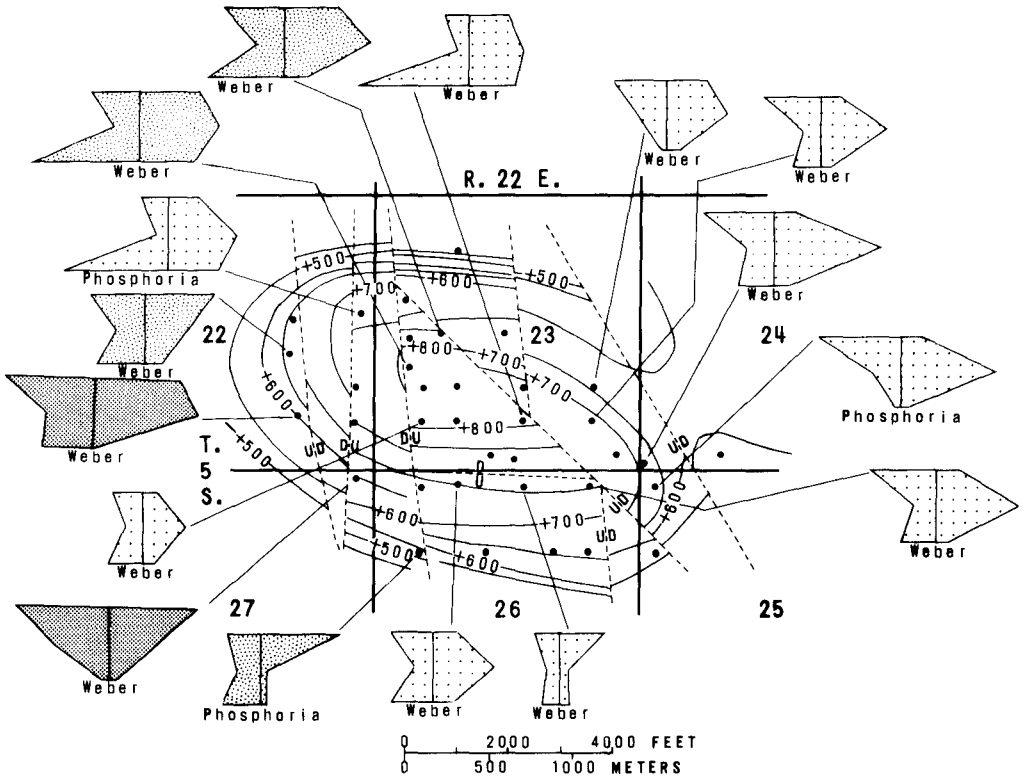
A specific example of deep ground-water movement is the area of the Ashley Valley oil field (fig. 16) where fresh to slightly saline water has been obtained from the Entrada and Park City Formations and the Weber Quartzite. Since 1949, the field has produced fresh to slightly saline water with oil from the Weber Quartzite and the overlying Park City Formation at depths averaging about 4,200 ft (1,280 m). (See Goode and Feltis, 1962.) Withdrawals caused a large decline in artesian pressure. In 1949, the potentiometric surface was about 600 ft (183 m) above the land surface; but by 1973 most of the wells in the field were being pumped.

As shown in figure 16, the freshest water comes from the north and west sides of the field, thus indicating that the source of the water is most probably to the northwestward, from the Dry Fork area. As noted by Goode and Feltis (1962, p. 12) the water may be coming not only from the oil-bearing strata but also from the underlying limestone of Mississippian age.

Table 7.--Summary of chemical quality of water from selected wells and springs in consolidated rocks of pre-Tertiary age

Formation	Well or spring number	Depth of well or of zone sampled (ft)	Dissolved solids (mg/L)	Water type or dominant ion(s)
Entrada Sandstone	(D-4-23)26cab-2	168	353	Calcium magnesium bicarbonate
	(D-5-22)23dcc-1	2,069	1,170	Sodium bicarbonate
Glen Canyon Sandstone	(D-4-21)7bcb-1	882	586	Calcium sulfate
	16ccc-1	5,852	1,870	Sulfate[1]
	(D-9-20)22ccb-1	17,350	Brine[1]	Sodium chloride
Park City Formation[2]	(D-5-22)22add-1	4,293	2,140	Sodium sulfate chloride
	U(B-2-3)22dcc-1	4,555	493[3]	Sodium sulfate bicarbonate
Weber Quartzite	(D-3-21)28dba-1	2,552	353	Calcium magnesium bicarbonate sulfate
	(D-4-21)16ccc-1	7,867	714	Sulfate bicarbonate[1]
	(D-5-22)22dba-1	4,306	692	Calcium sodium bicarbonate
	(D-7-24)21dda-1 (Red Wash field)	18,060	Brine[1]	Sodium chloride
	S(B-2-102)32bcb-1 (Rangely field)	7,500	31,200	Do.
	S(B-3-101)3acd-1[4]	3,161	2,500	Sodium bicarbonate sulfate
	S(B-3-102)5adb-1	750	373	Magnesium calcium bicarbonate
Mississippian rocks	(D-2-21)24cbb-S1[5]	Spring	98	Calcium bicarbonate
	(D-4-24)16cdd-S1	do	942	Sodium calcium chloride sulfate
	(D-9-20)22ccb-1	20,000	Brine[1]	Sodium chloride
	S(B-7-103)20cad-S1	Spring	938	Do.

[1]From partial analysis.
[2]Formation has low permeability, but cavernous limestone in base is in direct contact with underlying Weber Quartzite.
[3]Calculated as sum of determined constituents.
[4]Petroleum test 5.8 mi (9.3 km) east of boundary of northern Uinta Basin area.
[5]Brush Creek Spring discharges from Weber Quartzite, but water has been shown to discharge directly from underlying Mississippian rocks through fractures (Maxwell and others, 1971, p. 40).



EXPLANATION

• Oil well or test well

U, D — Inferred fault
U, *upthrown side;* D, *downthrown side*

—+500— Contour in top of Weber Quartzite
Contour interval 50 feet (15 meters)
Datum is mean sea level

Hydrology by J. W. Hood, 1975. Geologic data after Johnson (1964, fig. 1). Water-quality diagrams based on data in Hood, Mundorff, and Price (1976, table 10)

CHEMICAL QUALITY OF WATER

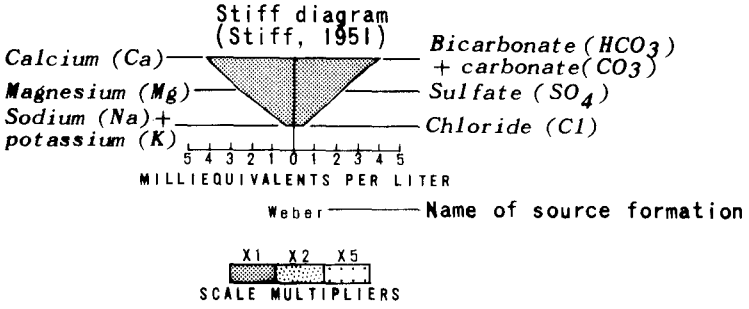


Figure 16.—Map of the Ashley Valley oil field showing location of wells, structural information, and Stiff diagrams of chemical analyses of the water produced with the oil.

The quantity of water moving through the Weber Quartzite near the Ashley Valley oil field is relatively small. Natural potentiometric gradients in the aquifer, based on a few reported pressures, old records, and inferences from petroleum tests, are in the range of 10 to 15 ft/mi (1.9 to 2.8 m/km) from the east and 30 to 40 ft/mi (5.7 to 7.6 m/km) from the north; the average may be as much as 20 ft/mi (3.8 m/km). The transmissivity of the quartzite in the oil field, based on a few permeabilities reported by oil companies, is estimated to be 300 ft^2/d (28 m^2/d). This is similar to the lowest value cited by Hood (1976, table 2) and is consonant with the concept that permeability decreases with depth of burial. If these estimates are extrapolated to the entire approximately 120 mi (193 km) along the north margin of the Uinta Basin, the indicated flow rate is about 4,000 acre-ft (5 hm^3) per year, or less than 1 percent of the total estimated ground-water recharge (table 2). The rate of ground-water movement in the other aquifers near the northern margin of the Uinta Basin is estimated to be even less.

Water that enters the consolidated rocks in the mountains and then moves downdip is believed to discharge upward through the overlying beds near the edges of the mountains, rather than moving deep into the basin or across the basin. Circulation is in part upward along fractures and into overlying formations, such as was noted for the Ashley Valley oil field.

It is believed also that a part of the water moves by diffuse leakage upward through fine-grained rocks over a broad area. In petroleum test U(B-2-2)20bbc-1, at a depth of 4,412 ft (1,345 m), the fine-grained Green River Formation lies directly upon the Weber Quartzite, a known source of freshwater. The Green River Formation does not crop out updip, and there is no surface indication that the formation is fractured. A water sample from the Green River Formation at a depth of 4,115 ft (1,254 m), only 300 ft (90 m) above the Weber Quartzite, contained 348 mg/L of dissolved solids, thus indicating leakage from the deeper formation.

Petroleum test U(A-1-1)6aca-1 yielded a water sample from the Wasatch Formation at a depth of 4,957 ft (1,511 m) containing 1,460 mg/L of dissolved solids. A sample from a zone about 300 ft (90 m) shallower contained about three times more dissolved solids, suggesting that the fresher water moved into the formation laterally or from below. The Wasatch does not crop out updip and is covered with rocks of low permeability. Thus, the source of the water must be the older consolidated rocks that underlie the formation. In both cases, the relatively low dissolved-solids concentration shows that the water is moving in formations that elsewhere in the area contain moderately saline to briny water at equivalent depths.

Ground-water movement across the State line in the northern Uinta Basin area was considered on the basis of separate rock units. The lowest points of outcrop of rocks of Mississippian age are along the Green River in Dinosaur National Monument. Thus springs in this area could well be discharge points for water that has moved considerable distances through these rocks. Spring (D-4-24)16cdd-S1 in Split Mountain Canyon in Utah discharges water of the sodium calcium chloride sulfate type with dissolved solids of 942 mg/L (table 7). Upstream in Whirlpool Canyon in Colorado, spring S(B-7-103)20cad-S1 also discharges water from rocks of Mississippian age. This water is of the sodium chloride type with dissolved solids of 938 mg/L. Updip to the northwest in Utah, water in the rocks of Mississippian age in Big Brush Creek Spring,

(D-2-21)24cbb-S1, is of the calcium bicarbonate type with dissolved solids of 119 mg/L. Thus the water discharging from spring (D-4-24)16cdd-S1 is believed to represent a mixture of waters moving from the east and north through the Mississippian rocks. It can be inferred, therefore, that some water in rocks of Mississippian age in the northern Uinta Basin area in Utah has moved west from across the Colorado State line. Spring (D-4-24)16cdd-S1 discharges an estimated 10 ft^3/s (0.28 m^3/s), but only part of this is believed to be moving from the east across the State line.

To the northeast of Split Mountain, Jones Hole Creek heads at large springs in the SE¼NW¼ sec. 1, T. 3 S., R. 25 E., which discharge from the Morgan Formation. The Morgan dips southwestward from highlands along the State line. The springs are less than 0.5 mi (0.8 km) from a major fault that trends south-southwestward across the State line and into the area. The Weber Quartzite underlies much of the Yampa and Blue Mountain Plateaus that straddle the State line. Both the Weber and the underlying Morgan are extensively cut by west-trending faults and the formations dip toward Utah. (See Hood, 1976, pl. 1.)

It is unlikely that significant quantities of water move across the State line in rocks younger than the Park City Formation because of their structure or their relatively low permeabilities. The bulk of the water moving across the State line, therefore, is in the rocks of Mississippian age, the Weber Quartzite, and the Park City Formation. This quantity consists of part of the discharge of spring (D-3-25)1bda-S1 at Jones Hole Creek and spring (D-4-24)16cdd-S1 in Split Mountain Canyon and possibly scattered amounts of discharge elsewhere. The total may be as much as 40,000 acre-ft (49 hm^3) per year. Of this amount, perhaps 25 percent--10,000 acre-ft (12 hm^3) per year--may flow from Colorado into Utah.

In Colorado, 10-18 mi (16-29 km) east of the State line, wells obtain water from the Weber Quartzite approximately on strike with the Weber in the Ashley Valley oil field. Chemical analyses of three water samples from the wells in Colorado show progressive changes from a magnesium calcium bicarbonate type to a sodium bicarbonate sulfate type as dissolved solids increase; the changes indicate probable local movement downdip toward the south rather than westward along the strike. Thus, it is believed that little water moves into Utah from Colorado in the Weber along the margin of the Uinta Basin.

The quantity of water moving across the boundary of the northern Uinta Basin area other than at the State line is estimated to be small and insignificant in terms of the total ground-water system.

Generally, small inflows are balanced by small outflows. The estimated 10,000 acre-ft (12 hm^3) per year that flows across the Colorado State line is 2 percent of the total estimated ground-water recharge (table 2). Almost all the 10,000 acre-ft (12 hm^3) per year is included in the quantity of ground-water discharge that returns to the stream system in the mountain areas.

Storage

The estimated minimum quantity of ground water in transient storage in the northern Uinta Basin area is 28 million acre-ft (34,000 hm^3) (table 8).

That quantity includes only fresh and slightly saline water that is considered in 1975 to be useful with little or no treatment. The total quantity of ground water in storage, including all saline water, may be five times or more greater than that shown in table 8. The quantity of water in storage is essentially unaffected by the small withdrawals from wells.

The quantity of ground water in storage was calculated by assuming complete dewatering of the aquifers. It would not be practical to accomplish this, however, because dewatering of the rocks would diminish the discharges of streams in the area, large-scale dewatering in such formations as the Weber Quartzite would cause migration of saline water from adjacent parts of the aquifer, and pumping lifts to accomplish complete dewatering would be too costly (1975 conditions) to be economically feasible.

Table 8.--Estimated quantity of fresh and slightly saline ground water in transient storage

Aquifer	Minimum area (acres)	Average thickness[1] (ft)	Volume of saturated formation (million acre-ft)	Water available from storage[2] (acre-ft/100 acre-ft of saturated formation)	Storage (million acre-ft)
Glacial outwash and related coarse-grained rocks	400,000	50	20	10	2.0
Duchesne River Formation	640,000	1,000	640	1.0	6.4
Uppermost part of the Uinta Formation	760,000	200	152	1	1.5
Currant Creek Formation	230,000	2,000	460	.5	2.3
Glen Canyon Sandstone	690,000	900	621	1	6.2
Weber Quartzite	880,000	1,300	1,140	.75	8.6
Subtotal					27.0
Estimated storage in other aquifers					1.0
Total (rounded)					28.0

[1]Based on data from Hood (1976, table 1).
[2]From Hood (1976, p. 23-36).

Fluctuations of water levels

Water levels have been measured by the Geological Survey in observation wells in the northern Uinta Basin area since 1935 in order to determine changes in ground-water conditions. Records of water-level measurements are given in Hood, Mundorff, and Price (1976, table 5).

Under natural conditions, water levels respond to changes in rates of recharge and discharge. In wet periods, water levels rise, showing that the net ground-water storage has increased; and in dry periods, water levels decline, showing that the discharge from the aquifer has exceeded the recharge, and the storage has decreased. In shallow or highly permeable aquifers the changes are rapid and may occur in a matter of months or even days. If the aquifer has low permeability or the observation well is remote from the recharge area, response to changes in rate of recharge may occur over a period of years.

In areas where man has changed the hydrologic regimen, the natural aquifer response to recharge may be enchanced, decreased, or masked by response to the changes. In shallow, permeable aquifers, such as those in Ashley Valley and near Altamont, water levels respond rapidly to changes in rates of water application to fields, canal loss, or stream stage.

Figure 17 shows hydrographs of selected observation wells, with brief explanations of the causes of water-level fluctuations, and plots of cumulative departure from average annual precipitation at several climatological sites for comparison with the hydrographs. Additional explanations for water-level fluctuations are given in figures 18 and 19, which show the water-level record of three wells specifically observed for this study and a detail from one of those records.

Discharge

Ground water is discharged from aquifers in the northern Uinta Basin area largely by natural means. Total average annual ground-water discharge is 300,000 acre-ft (370 hm^3), of which about 12,000 acre-ft (15 hm^3) is discharged by wells, 160,000 acre-ft (200 hm^3) is discharged by evapotranspiration, and the remainder is discharged by springs and diffuse seepage.

The discharge from wells for irrigation and domestic and industrial use is discussed in the section on water use.

An estimated 160,000 acre-ft (200 hm^3) of ground water is discharged annually in the northern Uinta Basin area by evapotranspiration. This figure is based on (1) the depths to water as determined from wells or estimated for parts of the area, (2) observations of vegetation type and density, and (3) rates of use estimated from conditions in the individual locale, considering the rate of precipitation, the availability of streamflow or irrigation water, and the plant community. The estimates are shown in table 9.

Phreatophytes may use ground water even where plants are irrigated or where the depth to water is relatively large--10 to 60 ft (3 to 18 m). Figure 20 shows the diurnal variation of water levels in well (D-3-20)25abc-2 when the depth to water was between 6 and 7 ft (1.8 and 2.1 m), at a time when irrigation was not in progress, and the stage of nearby Dry Fork was relatively constant. The well is in a meadow that contains mixed species of grasses that are grown for hay. The diurnal fluctuations of water level, with the water level declining from morning to evening, show that the grasses were drawing on the ground-water supply.

A widely cultivated hay crop in the basin is alfalfa. Established fields of this plant are deep rooted (Robinson, 1958, p. 60), and use ground water even where most of the water requirement is supplied by surface irrigation. Greasewood is also deep rooted (Robinson, 1958, p. 66-68). Both of these plants can withdraw ground water where the depth to water is as great as 60 ft (18 m).

The discharge of ground water in the lowlands by springs and diffuse seepage into stream channels was calculated to be 128,000 acre-ft (158 hm^3) per year in the northern Uinta Basin area. Some large springs or spring areas discharge several cubic feet per second into streams and pipelines in the lowlands, but the bulk of spring discharge is from numerous small springs and

Table 9.--Estimated discharge of ground water by evapotranspiration

Vegetation and depth to water: All areas include swampy tracts, mainly in spring or seepage areas and old meander scars, which contain very dense stands of phreatophytes and hydrophytes.

Area	Acres	Rate of use (ft/yr)	Annual discharge (acre-ft/yr)	Vegetation and depth to water
Uplands and tributary bottom land				
Miscellaneous area including parts of Uinta River-Whiterocks River bottom lands	120,470	0.2	24,000	Greasewood, willow, Russian-olive, rabbitbrush, mixed brush (locally very dense), and irrigated and subirrigated pasture. Depth to water 0-15 ft. Locally shallow only during summer.
Rock Creek-Lake Fork-Dry Rock and miscellaneous smaller channels	18,470	.5	9,200	Native grasses, willow, greasewood, chokecherry, cottonwood. Locally dense, but generally sparse to light. Depth to water 0-15 ft.
Dry Gulch	7,500	1.0	7,500	Sparse to dense greasewood in lower reach, willow, native grasses, irrigated pasture, mixed species of trees locally; local areas of saline bare ground. Depth to water ranges from above land surface to 15 ft below land surface.
Cottonwood Creek	8,560	1.0	8,600	Sparse to dense greasewood, native grasses, irrigated pasture, willow, cottonwood, some bare ground near lower end. Depth to shallow water generally unknown; bedrock crops out in many parts and contains confined ground water as shallow as 70 ft. Lower part of this area and part of Dry Gulch are lined with numerous seeps and springs where vegetation is locally dense.
Brush Creek	1,580	1.5	2,400	Willow, local clumps of mixed trees, Russian-olive, native grasses, irrigated pasture. Depth to water estimated 0-15 ft.
Strawberry River-Currant Creek-Deep Creek bottom lands	5,400	1.0	5,400	Native grasses, irrigated pasture, willow, chokecherry, local clumps of mixed trees, rabbitbrush locally; vegetation locally very dense. Depth to water 0-15 ft.
Lower Uinta River bottom land	5,570	1.5	8,400	Mixed brush, locally very dense, cottonwood and other trees, Russian-olive, irrigated pasture, and native grasses. Depth to water 0-10 ft.
Green River bottom land	23,540	1.5	35,300	Native grasses and hydrophytes, some irrigated pasture and cropland, greasewood as local fringe, clumps of cottonwood and other trees and a few scattered very large trees, fringes of willow in upper part of reach, fringes and locally dense clumps of saltcedar in lower part of reach. Depth to water mainly 0-10 ft, locally 20 ft. Subject to occasional inundation during periods of high water; some bodies of open water and swampy tracts in cutoff meanders.
Duchesne River bottom land (north of river)	24,450	1.5	36,700	Sparse to dense greasewood in some undeveloped land, willow, Russian-olive, single to clumps of cottonwood and other trees, native grasses, irrigated pasture and cropland, some saltcedar in lower reach. Lowermost part of reach subject to occasional inundation. Depth to water 0-25 ft. Some parts have shallow water only during irrigation season.
White River bottom land (north of river)	6,500	3.5	22,800	Locally very dense mixed brush, including saltcedar, native grasses, some irrigated land and single or clumps of cottonwood near lower end of reach, some bare ground in edges of recent meanders. Depth to water 0-15 ft. Lowermost part of reach subject to occasional inundation.
Totals (rounded)	222,000		160,000	

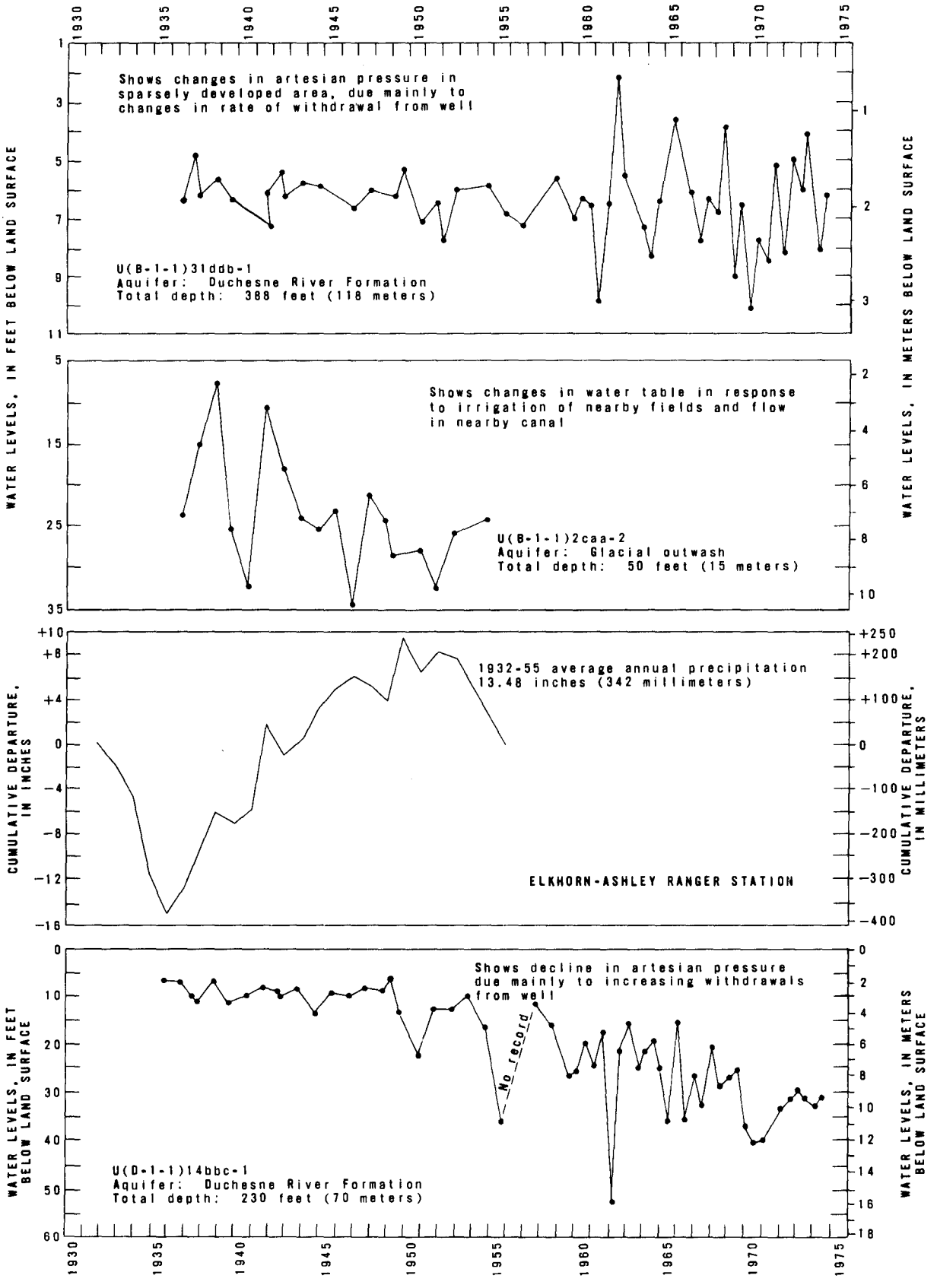
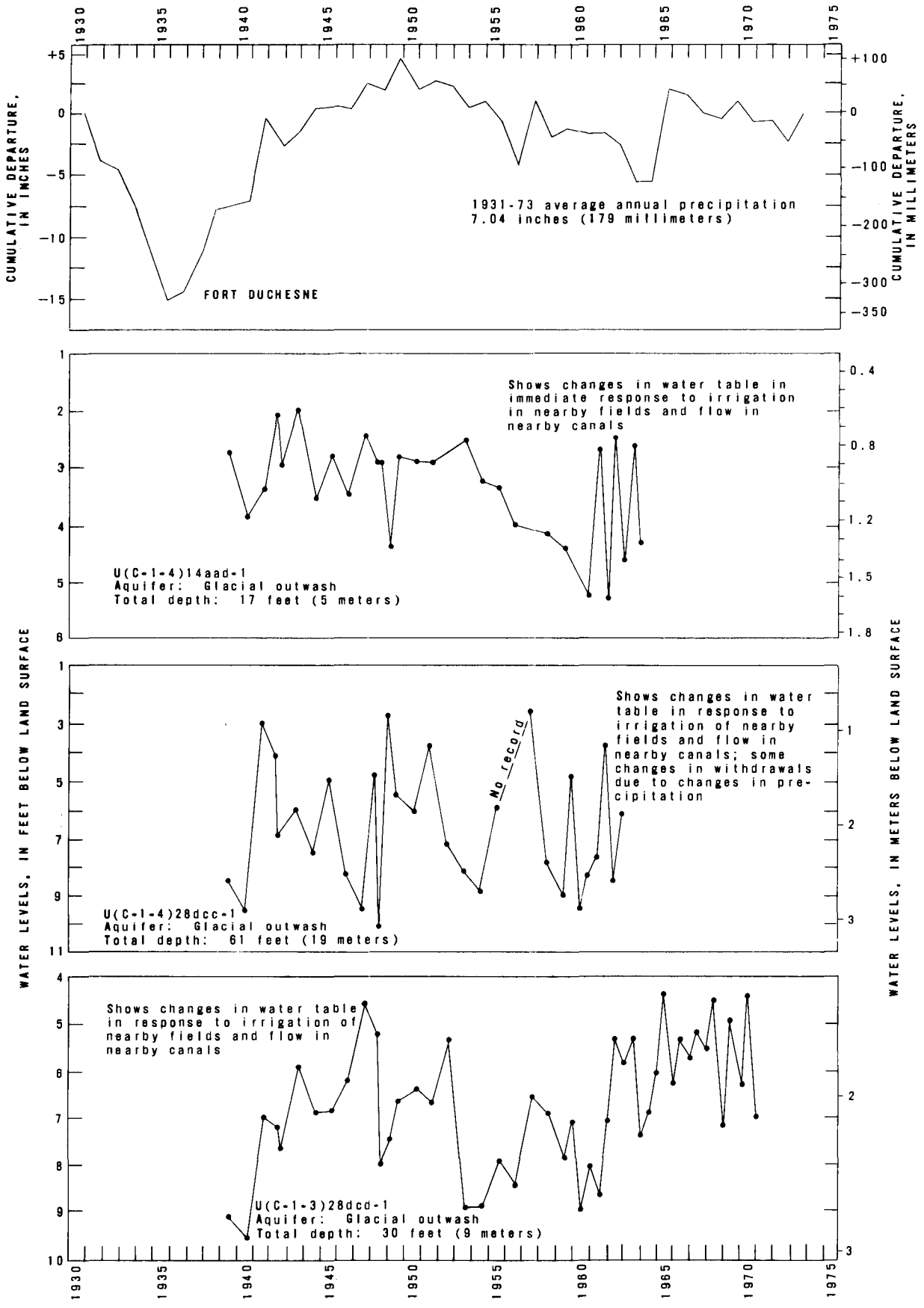


Figure 17.—Water levels in selected observation wells and cumulative departure from average annual precipitation at selected climatological stations near the wells.



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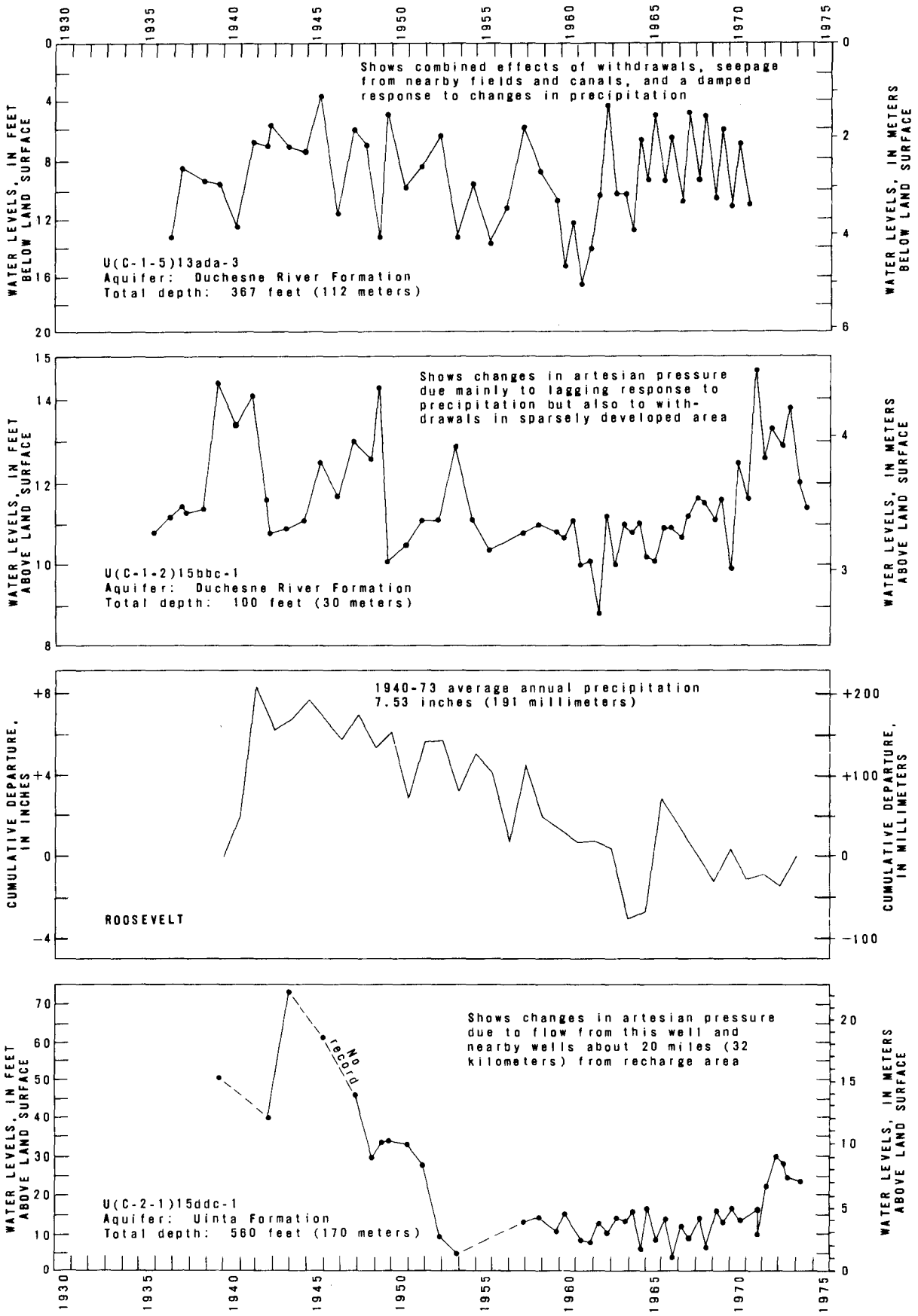

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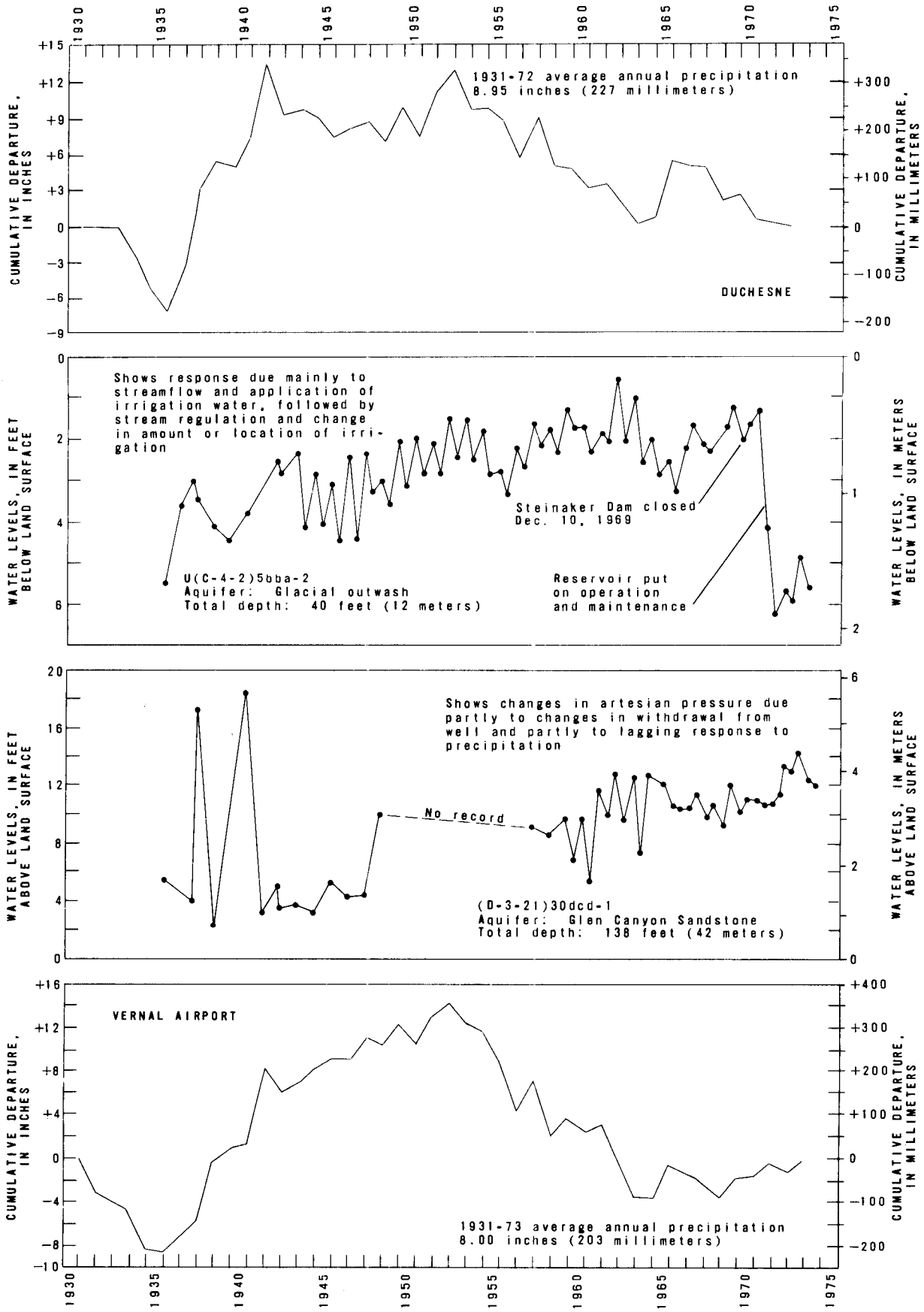

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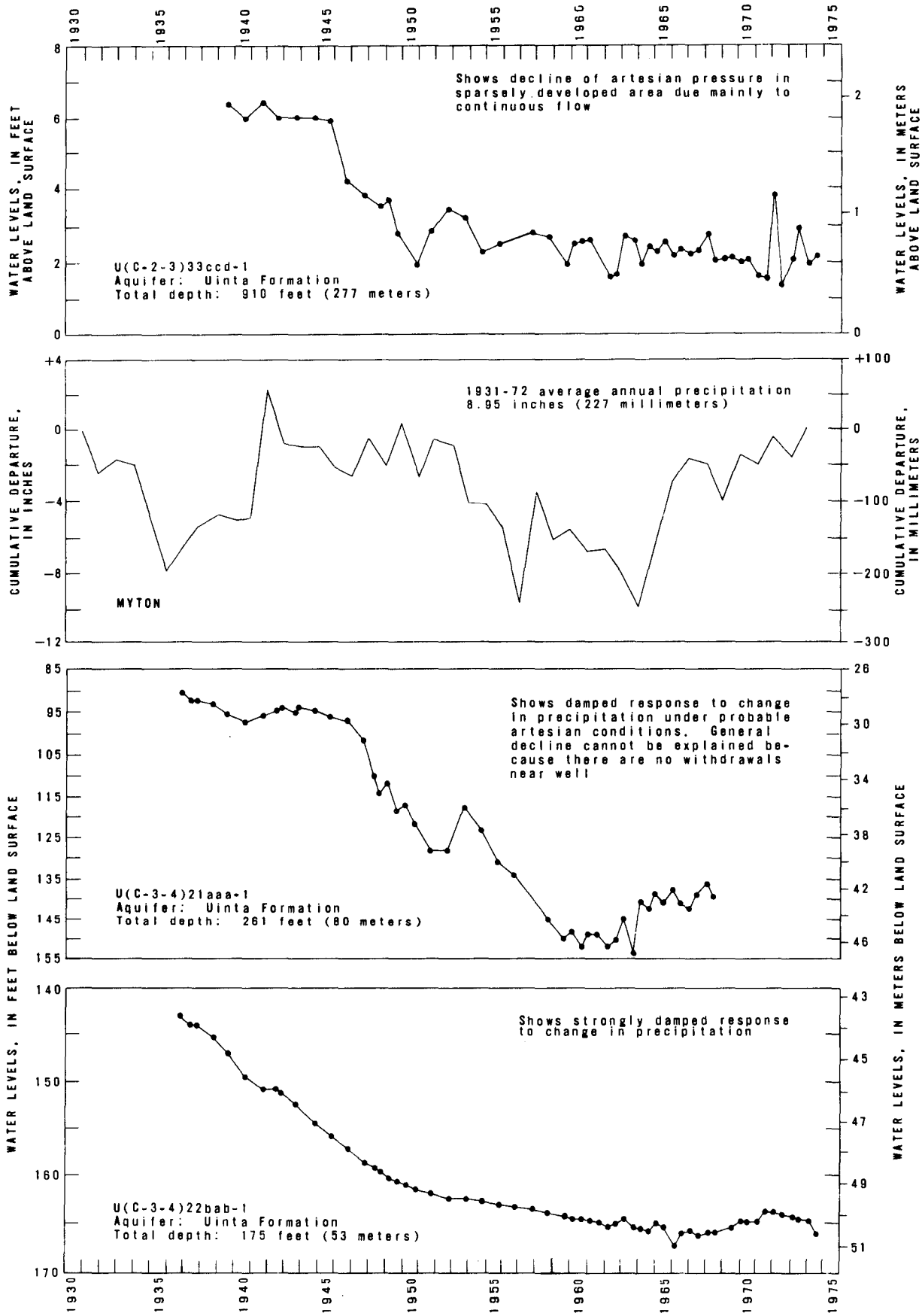

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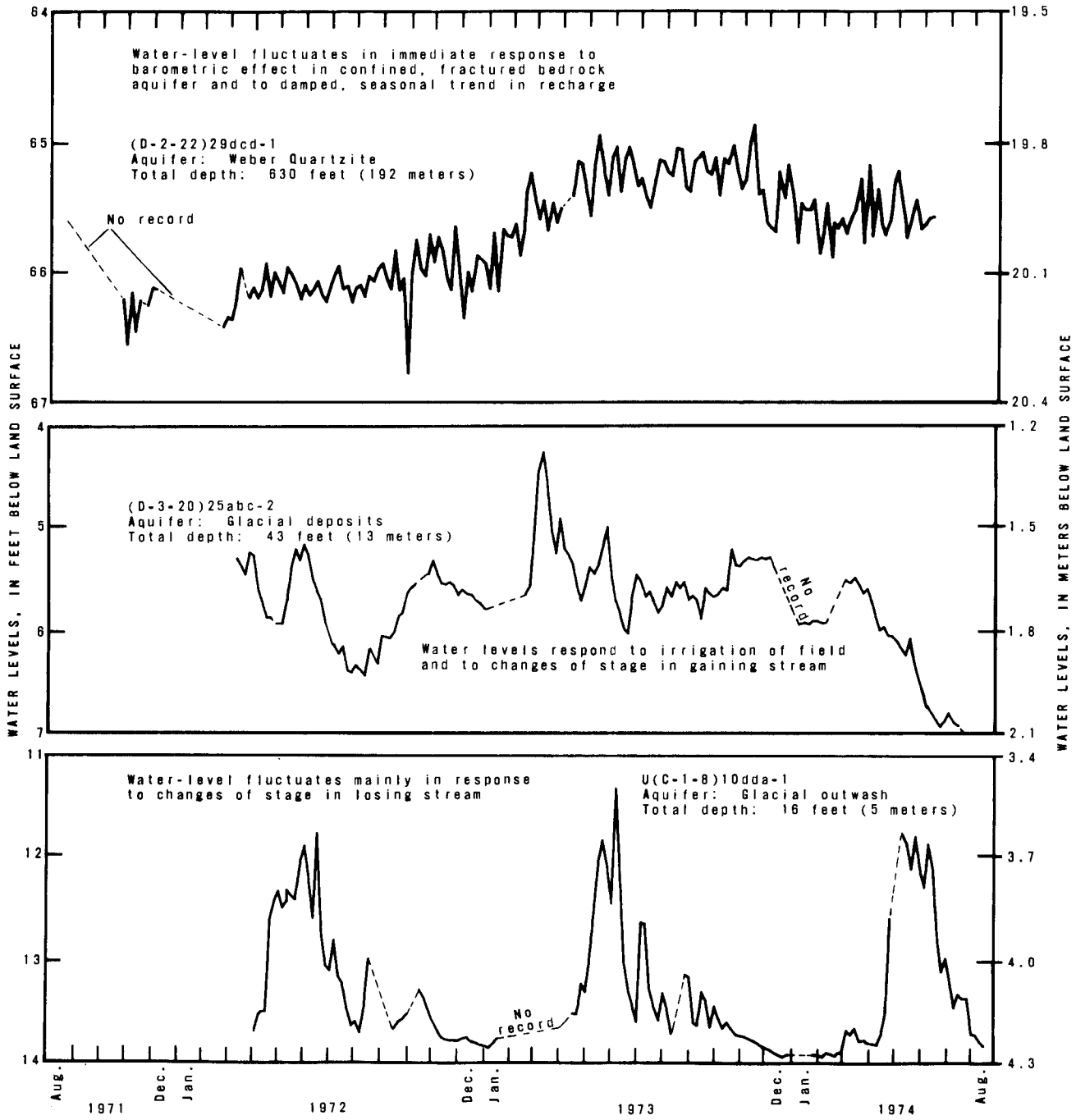

Figure 18.—Water levels in three wells showing water-level response under three different conditions of occurrence.

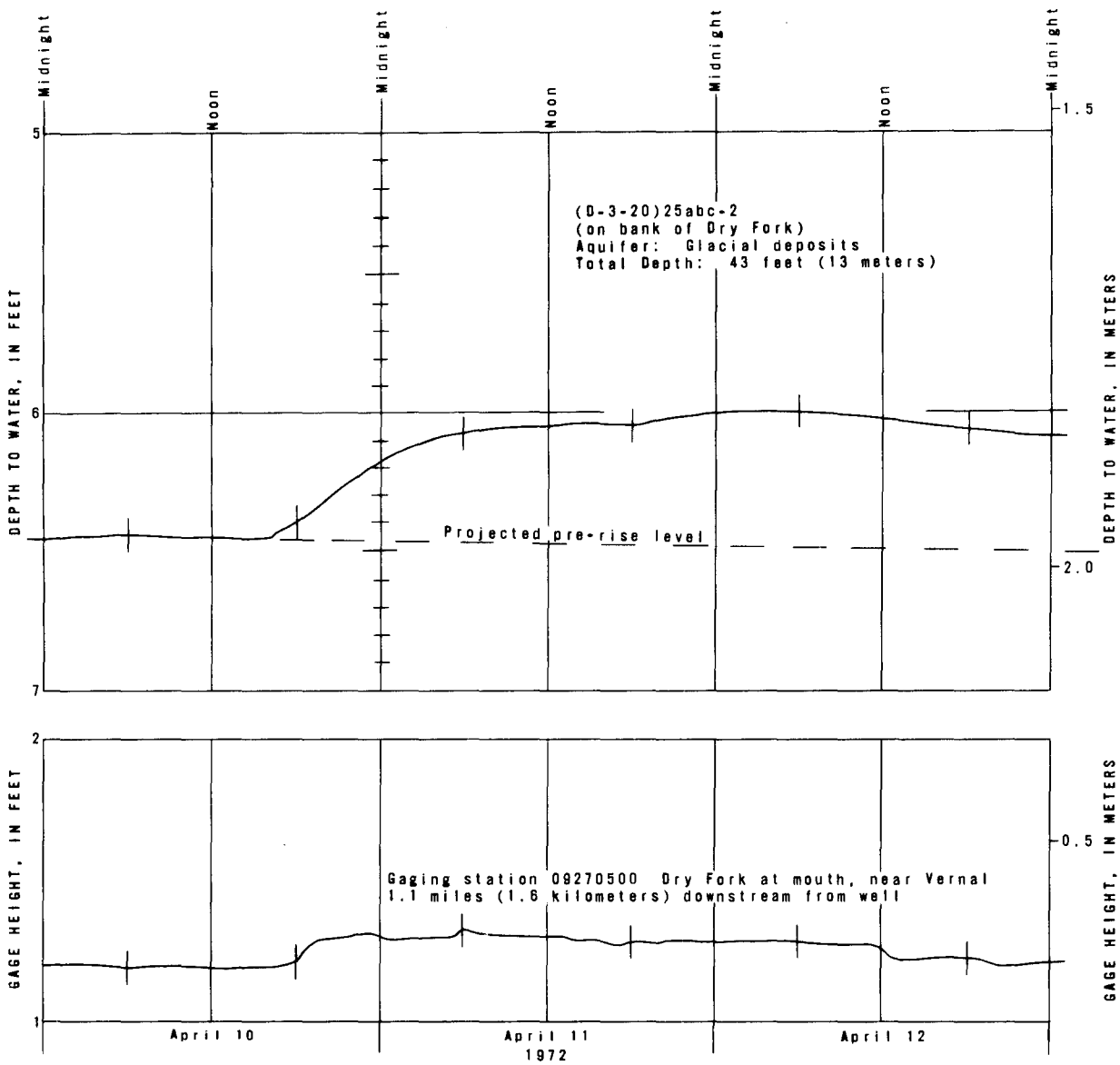

Figure 19.—Water levels in well (D-3-20)25abc-2 and in Dry Fork showing aquifer response to beginning of spring freshet, April 10-12, 1972.

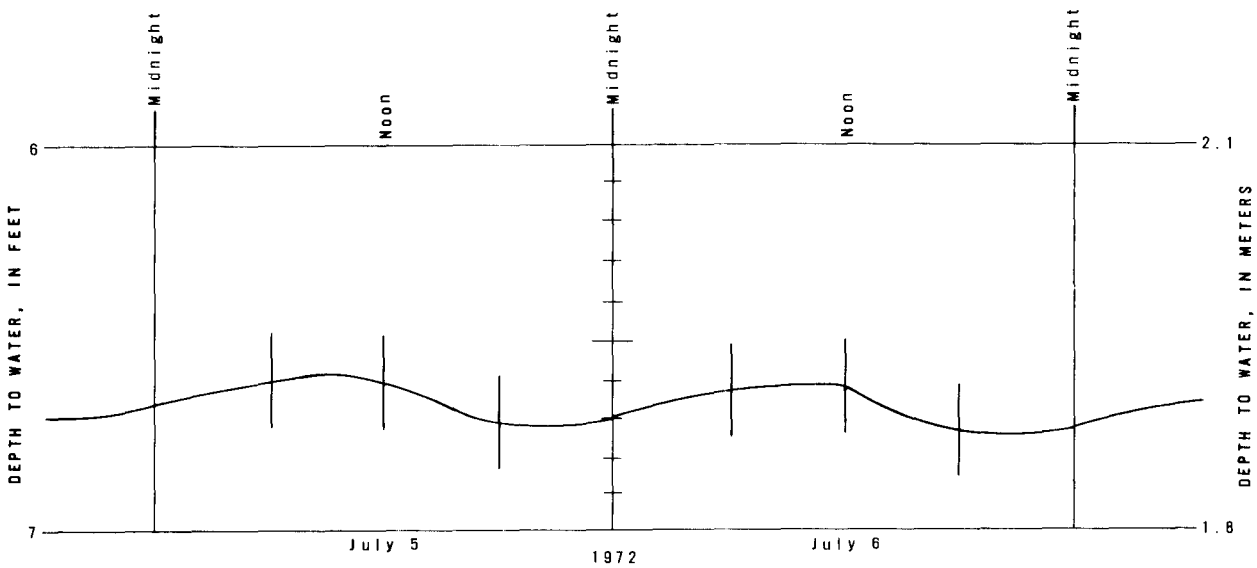

Figure 20.—Water level in well (D-3-20)25abc-2 showing effect of evapotranspiration.

swampy seepage tracts. This type of discharge and diffuse seepage into stream channels is inextricably merged with the constantly changing streamflow and irrigation return flow. Consequently, the water discharged by springs and diffuse seepage was calculated as the difference between recharge (300,000 acre-ft [370 hm^3] per year) and the total of discharge by evapotranspiration and consumptive use of water withdrawn from wells (172,000 acre-ft [212 hm^3] per year).

The feasibility of discharging as much as 128,000 acre-ft (158 hm^3) per year into stream channels in the northern Uinta Basin area without visible evidence of the discharge was checked as follows: Ground-water discharge to the upper Duchesne River (Hood, 1977b, p. 25) averages 39 ft^3/s (1.1 m^3/s) in 34 mi (54.7 km) or about 1 ft^3/s (0.03 m^3/s) per mile (1.6 km). At this rate, the discharge by springs and diffuse seepage would require 178 mi (286 km) of stream channel to receive the water. The total length of channels in the area is ample. Moreover, the low rate of discharge per mile would be difficult to detect in the flow regimen extant; and it probably could be evaluated only if all natural surface flow, diversionary activity, and return flow of irrigation water were stopped for at least several months.

Chemical quality of water

The water types and the amounts of dissolved solids in water in the northern Uinta Basin area vary greatly both areally and with depth. The dissolved-solids concentrations of most streams increase in a downstream direction, and seasonal variations are found at most sampling points; the local interchange of water between streams and aquifers contributes to the variations. The dissolved-solids concentrations of the ground water change markedly from one aquifer to another. The water in the area ranges from fresh to briny, according to the following classification (Hem, 1970, p. 219):

Class	Dissolved solids (milligrams per liter)
Fresh	0-1,000
Slightly saline	1,000-3,000
Moderately saline	3,000-10,000
Very saline	10,000-35,000
Briny	More than 35,000

The two principal sources of water in the northern Uinta Basin area are precipitation and transbasin inflow in the Green and White Rivers. Precipitation yields water of the calcium bicarbonate type, and in upland areas it probably contains 5 mg/L or less of dissolved solids. Snow that accumulates during the winter provides the largest amount of water for both streamflow and ground-water recharge. During residence in the snowpack, the water probably gains additional dissolved solids from both airborne and local organic sources. The following table shows analyses from a sample of snow, a stream, and a spring, all in the Uinta Mountains in areas that are underlain by rocks of Precambrian age. The similarity of the three analyses suggests that water in highland streams and springs, in areas underlain by crystalline rocks, will be similar in chemical quality to snow.

[Dissolved constituents in milligrams per liter]

	Snow[1] Jan. 1, 1959	Stream[2] June 20, 1973	Spring[3] July 27, 1973
Calcium (Ca)	2.8	2.3	3.5
Magnesium (Mg)	.5	.6	.6
Sodium (Na)	1.2	1.0	.6
Potassium (K)	1.0	.4	.0
Bicarbonate (HCO_3)	7	8	11
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	2.4	3.4	4.8
Chloride (Cl)	1.3	1.0	1.2
Nitrite (NO_2) plus nitrate (NO_3) as nitrogen (N)	1.3[4]	-	.25
Boron (B)	.0	-	.01
Dissolved solids	18	16	22
Specific conductance (μmho/cm at 25°C)	36	19	22
Hardness, as $CaCO_3$	9.0	8	10
pH	6.2	6.5	6.5

[1]Analysis from Feth, Rogers, and Roberson (1964, p. J14-J15); sample from Julius Park at location U(A-3-1)15cc by U.S. Soil Conservation Service; altitude approximately 10,000 ft.

[2]Sample from gaging station 09289500, Lake Fork River above Moon Lake; altitude 8,180 ft. (See Hood and others, 1976, table 14.)

[3]Sample from spring U(B-3-2)19cbd-S1; altitude 7,780 ft. (See Hood and others, 1976, table 10.)

[4]Converted from 0.01 mg/L of nitrite and 5.6 mg/L of nitrate.

Surface water

The major streams in the northern Uinta Basin area yield water that ranges in dissolved-solids concentration from less than 20 mg/L in the uplands to about 3,000 mg/L near the mouth of the Duchesne River. During high flows, all the stream water is fresh and is of the calcium bicarbonate type. Minor tributaries and drains that return irrigation flow on some occasions have yielded water with higher dissolved-solids concentrations. Degradation of the chemical quality of streamflow is due to (1) irrigation return flow, (2) evapotranspiration, and (3) inflow of saline ground water.

Transbasin inflow.--The chemical quality of the water that enters the study area in the Green River is judged from samples taken at Green River near Jensen (gaging station 09261000). The volume of flow is so large at this station that the small amount of water originating in the study area above the station should have little effect on the average annual concentration of dissolved solids.

The closure of Flaming Gorge Dam in 1962 had a measurable effect on the chemical quality of the Green River downstream. (See Madison and Waddell, 1973, p. C9-C12; Bolke and Waddell, 1975.) Since the closure of the dam, the inflow to the northern Uinta Basin in the Green River has become more uniform in chemical quality. The flow past the station at Green River near Jensen, except during periods of high flow from the Yampa River, has been almost uniformly a mixed water of the calcium sodium sulfate bicarbonate type, with a discharge-weighted average annual concentration of dissolved solids of about 300 mg/L.

The chemical quality of inflow to the study area in the White River is judged from samples taken at White River near Watson (gaging station 09306500). The discharge-weighted average annual concentration of dissolved solids is about 500 mg/L. A small amount of saline water, mainly from the southern Uinta Basin, enters the river between the gaging station and the upstream boundary of the study area, but the volume of flow in the main stem generally is large enough that such inflow has little effect on the chemical quality of water in the river. Daily specific conductances have ranged from 295 micromhos per centimeter at 25°C (June 1971) to a maximum of 4,450 µmho/cm (August 1955). The water ranges from a calcium bicarbonate type during high flow to a sodium bicarbonate sulfate type during low flow.

Tributary flow.--With regard to water originating within the northern Uinta Basin area, the principal tributary to the Green River is the Duchesne River, which drains about 60 percent of the area. A reconnaissance study of the chemical quality of the surface water in the Duchesne River basin was made by Mundorff (1977), who used information from 157 data sites in the basin. The following remarks are largely taken from his report.

Surface water in the Uinta Mountains and the area around Strawberry Reservoir is mainly a dilute water of the calcium bicarbonate type. The specific conductance is less than 500 µmho/cm, and in many of the Uinta Mountain streams the specific conductance during the high flow from snowmelt is less than 50 µmho/cm (Hood and others, 1976, tables 14 and 15). The chemical quality degrades downstream, but the water remains fresh until it flows across rocks of Tertiary age or is diverted for irrigation. In and near the mountains, the inflow of the ground water does not appreciably degrade the quality.

In the lower reaches of the Duchesne River, the dissolved-solids concentration rises and the water changes to a sodium sulfate type due to (1) return flow from irrigation, (2) leaching of saline soils and underlying rocks of Tertiary age which contain soluble salts, (3) drainage from waterlogged heavy soils, and (4) discharge of saline ground water in the lower parts of the drainage basin. The downstream increase in dissolved-solids concentration of the stream water has been intensified by the transbasin diversion of freshwater from the headwater areas of the Duchesne and Strawberry Rivers.

Data obtained at Duchesne River near Randlett (gaging station 09303000) is regarded as representative of the outflow of the Duchesne River basin. There, the daily specific conductance has ranged from 291 µmho/cm in May 1951 to 4,490 µmho/cm in August 1960. The discharge-weighted annual average concentration of dissolved solids is about 700 mg/L.

Inflow to the Green River, other than from the White and Duchesne River basins, is from the small, mainly ephemeral streams in the area east of the Green River, from the Diamond Mountain area, and from Brush and Ashley Creeks. None of the small streams add significantly to the dissolved-solids load of water in the river. Discharge from the Diamond Mountain area mainly is from springs which discharge freshwater of the calcium magnesium bicarbonate type. Brush Creek in its upper reaches also contains freshwater. In its lower reaches, Brush Creek flows across rocks of Mesozoic age and is diverted for irrigation. The chemical quality of water at the mouth of Brush Creek has not been determined, but it probably has degraded to a type and concentration similar to that in Ashley Creek near Jensen.

Ashley Creek above the mouth of Ashley Creek canyon yields freshwater of the calcium bicarbonate type, which during the spring freshet is very dilute. (See gaging station 09271000 in Hood and others, 1976, table 14.) In Ashley Valley, the stream is almost completely diverted and part of the water is impounded. The return flow from irrigation is a slightly saline water of the calcium magnesium sulfate type. (See gaging station 09271500, Ashley Creek near Jensen, in Hood and others, 1976, table 14.)

Outflow.--The chemical quality of water flowing out of the northern Uinta Basin area in the Green River is judged from the records for the Green River near Ouray (gaging station 09307000). During 1958-66, the discharge-weighted average annual concentration of dissolved solids was 460 mg/L, the minimum daily specific conductance was 268 µmho/cm, and the maximum daily value was 2,030 µmho/cm. For the period 1962-66, the average increase in dissolved-solids concentration at this station over that of the Green River near Jensen was 84 mg/L. The increase in dissolved solids is caused mainly by addition of water from the Duchesne River.

Ground water

Chemical analyses show that ground water in the northern Uinta Basin area ranges from fresh to briny (Hood and others, 1976, table 10). The lowest concentration of dissolved solids was 19 mg/L at spring U(B-4-9)34b-S, which discharges from the Mutual Formation of Stokes (1964) of Precambrian age in the Mirror Lake area. As the ground water moves downgradient, it generally becomes more saline. Deep within the strata underlying the Uinta Basin, the slowly moving or stagnant water is a brine. The highest dissolved-solids

concentration recorded was 112,000 mg/L in water from the Weber Quartzite at a depth of 18,200 ft (5,548 m). (See also general comments on chemical quality of water in Hood, 1976, table 1.)

The freshest ground water in the area is obtained from rocks of Precambrian age in the Uinta Mountains. These rocks have low solubility, and they are recharged directly from precipitation and local streamflow. The dissolved-solids concentration of water in the Precambrian rocks always is less than 100 mg/L, even where the water apparently has circulated some distance along fractures or fault zones. The water is of the calcium bicarbonate type, although it is slightly acidic, with pH from 6.4 to 6.5. Part of the acidity may be residual from that of the precipitation, but a part probably is due to the leaching of coniferous forest litter and the resultant acid soils that are present in much of the mountains.

Water in the sedimentary rocks in the area contains from 2 to 10 times the dissolved-solids concentration of that in the Precambrian rocks while still in or close to the area of outcrop. This water is primarily of the calcium magnesium bicarbonate type, but as it moves downdip, the dissolved-solids concentration increases and in most formations the water type changes.

The most common change of water type is from calcium magnesium bicarbonate to sodium bicarbonate to sodium sulfate to sodium chloride. The transition to sodium as the dominant cation occurs in some of the fine-grained sandstones such as the Entrada Sandstone, the Frontier Sandstone Member of the Mancos Shale, and the Duchesne River Formation. Sulfate becomes the dominant anion in water in parts of the Glen Canyon Sandstone, and water of the calcium sulfate type characterizes gypsum-bearing formations such as the Morrison and Moenkopi Formations and also the Park City Formation.

Water in the Green River and Uinta Formations in places is of the carbonate bicarbonate type. Concentrations range from slightly saline to briny in samples from petroleum-test wells east of the Green River and near Duchesne. Most of the carbonate content is believed to originate in the Green River Formation. Milton (1957, p. 137) describes the occurrence of nahcolite (sodium bicarbonate) 3 ft (0.9 m) or more in thickness and the occurrence of trona (hydrated sodium carbonate-sodium bicarbonate). Deposits of these minerals are the most probable sources of briny water such as found in the Green River Formation in petroleum-test well U(C-4-4)17bcd-1, south of the Duchesne River near Duchesne. This well and spring U(C-4-7)15dab-S1 both lie on the trend of a fault zone. The spring yields warm (14.0°C) moderately saline water that is almost identical by percentage of composition of dissolved constituents to that of the water from the petroleum-test well. This indicates that water is moving from the Green River Formation upward along the fault zone through the Uinta Formation, where it mixes with more dilute water before discharging from the spring.

The Uinta Formation elsewhere is also the source of water with a high bicarbonate and carbonate content. It is not known if such water results from solution of deposits in the Uinta Formation or from movement upward from the underlying Green River Formation. In either case, the two formations are the sources of much of the saline water in the northern Uinta Basin area.

Water in rocks of Quaternary age ranges from fresh to very saline and has a wide variation in water type. This reflects the variations in sources

of recharge and the varying effects of solution of minerals from the debris of older rocks that is mixed in the unconsolidated deposits. For example, the coarse-grained permeable glacial outwash at well U(B-1-1)27ada-1 yields a calcium bicarbonate water that contains 109 mg/L of dissolved solids. The source of recharge water is the Uinta River and canals that divert water from the river. Spring U(B-1-1)14add-S1 also discharges from coarse-grained permeable glacial outwash, but the spring water is a calcium magnesium bicarbonate type that contains 270 mg/L of dissolved solids. The greater concentration of dissolved solids and the different water type indicate that part of the recharge to the glacial outwash near the latter spring probably comes from the underlying Duchesne River Formation or older rocks.

Near Roosevelt, well U(C-2-1)27dbb-1 was dug in shallow alluvium derived from the adjacent Duchesne River Formation. Ground water near the well must be recharged from surface sources because water in the underlying consolidated rocks is more highly mineralized. The sodium bicarbonate water from the well contains 399 mg/L of dissolved solids; and the water type results from recharge that moves through the relatively fine-grained deposits derived from the Duchesne River Formation. By contrast, glacial outwash at well (D-5-23)32adb-1 yields a calcium sodium sulfate water that contains 2,320 mg/L of dissolved solids. The glacial outwash underlies the Green River flood plain and overlies the Mancos Shale. The river water, which is assumed to be the major source of recharge to the well, has an average dissolved-solids concentration of 300 mg/L. The high mineral content of the well water is inferred to result from degradation of the river water as it moves through erosional debris from the Mancos Shale and mixes with ground water that moves from other consolidated aquifers to the unconsolidated deposits upstream from the sampling point.

Plate 5 shows a generalized distribution of dissolved-solids concentration in the freshest water available to the various parts of the northern Uinta Basin area irrespective of depth.[1] The map shows that fresh to slightly saline ground water can be obtained from at least one aquifer in about two-thirds of the area. For any given zone of concentration, water with a higher concentration may be found locally at a different depth or in a different formation. As examples, much of the area east of the Green River contains water with concentrations of less than 3,000 mg/L, but water of greater salinity is found in deeper rocks; near Neola, the shallowest water may contain less than 500 mg/L, but deeper rocks of Tertiary age yield very saline water; and southeast of Vernal, shallow rocks yield saline water, but rocks at depths of 2,000-5,000 ft (600-1,500 m) yield fresh to slightly saline water.

Relation to use

Domestic and stock.--In recommending water-quality standards for drinking water, the U.S. Public Health Service (1962, p. 7) stated:

"The following chemical substances should not be present in a water supply in excess of the listed concentrations * * * where other more suitable supplies are or can be made available."

[1]The zones of dissolved solids shown on plate 5 do not precisely match those shown by Price and Miller (1975, pl. 3) for the southern part of the basin. The differences are due to differing geohydrologic conditions in the two areas and the availability of more data for interpretation in the northern part.

Substance	Recommended limit (milligrams per liter)
Chloride (Cl)	250
Fluoride (F)	1.3[1]
Iron (Fe)	.3
Nitrate (NO_3)	45 (10 mg/L expressed as N)
Sulfate (SO_4)	250
Dissolved solids	500

[1]Based on the average maximum daily air temperature of 60.7°F (15.9°C) at Duchesne, Utah (1968-72), which is about average between the warmer low parts and the cooler high parts of the populated areas.

Most streams in the northern Uinta Basin area have a chemical quality that meets the above criteria for drinking water (Hood and others, 1976, table 12-15) except in the lower reaches of some tributary streams during low flow, where the limits for dissolved solids, sulfate, and chloride are exceeded. Other constituents are not generally present in excessive amounts, except that occasionally they exceed the recommended limits in Ashley Creek below Ashley Valley and in part of the Duchesne River basin. (See Mundorff, 1977.)

Of approximately 1,000 chemical analyses of ground water listed in Hood, Mundorff, and Price (1976, table 10), most show that the water in samples from wells and springs in the mountains and the upper reaches of the area meet the recommended limits for drinking water. Many of the water samples from the consolidated rocks, however, especially near the river lowlands, exceed the limits for chloride, sulfate, or dissolved solids.

Six of 367 samples of fresh or slightly saline water contained more than 47 mg/L of nitrate (NO_3); the highest concentration was 318 mg/L (72 mg/L of NO_2 + NO_3, as N) at well U(C-2-7)11cbd-1, which taps the Duchesne River Formation. Of the six samples, two each were obtained from glacial outwash and from the Duchesne River and Uinta Formations.

Of the 271 samples of fresh or slightly saline water analyzed for fluoride, 32 samples contained fluoride in excess of 1.3 mg/L; the highest concentration was 12 mg/L at well U(C-3-5)25dca-1, which taps the Uinta Formation. Of the 32 samples, 10 were from the Uinta Formation, 13 from the Duchesne River Formation, 3 from the Weber Quartzite, 2 from glacial outwash, 2 from alluvium, and 2 from the Frontier Sandstone Member of the Mancos Shale.

In most areas, iron does not exceed 0.3 mg/L; for nearly every formation tested, however, one or more sources showed concentrations in excess of the recommended limit. The maximum in fresh to slightly saline water was 5.6 mg/L in well (D-5-23)32abd-1, which taps glacial outwash where the formation overlies the Mancos Shale beneath the Green River flood plain.

The State of Montana (McKee and Wolf, 1963, p. 113) rates water for livestock on the basis of dissolved solids as follows:

Rating	Dissolved solids (milligrams per liter)
Good	Less than 2,500
Fair	2,500-3,500
Poor	3,500-4,500
Unfit	More than 4,500

According to this classification, most surface water and water from wells and springs in the northern Uinta Basin area is rated "good" for livestock. Exceptions are water rated as "unfit" from most of the deep petroleum-test wells, a few springs, such as U(C-4-7)15dab-S1, and a few water wells finished mainly in the Uinta Formation in the lower Duchesne River bottom lands. In the latter area, streams at low flow and many of the ground-water sources would be rated as "fair to poor."

Irrigation.--Important characteristics that help to determine the chemical suitability of water for irrigation in arid and semiarid areas are the specific conductance (electrical conductivity) and sodium-adsorption ratio (SAR) of the water. Specific conductance is an index of dissolved-solids concentration of the water, and SAR is an index of the ratio of sodium to other cations in the water according to the following equation:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

where the concentrations of the ions are expressed in milliequivalents per liter.

The U.S. Salinity Laboratory Staff (1954, p. 79-81) has devised a method of classifying irrigation water by plotting SAR against specific conductance. The classification is based on average conditions with respect to soil texture, infiltration rate, drainage, amount of water applied, climate, and salt tolerance of crops.

According to this classification, water from the Green, White, and Duchesne Rivers (Hood and others, 1976, table 13) generally has a low sodium hazard and a medium to high salinity hazard for irrigation under average conditions. Water from most tributary streams in the mountains is low in both hazards, but where irrigation return flow and the discharge of saline ground water occurs, water in the tributaries at low flow may seasonally have a medium sodium hazard and a very high salinity hazard (as in Ashley Creek below Ashley Valley at gaging station 09271500) (Hood and others, 1976, table 14). (See also Mundorff, 1977.)

Water from glacial deposits and other unconsolidated rocks of Quaternary age range in suitability for irrigation from low salinity-low sodium hazards to very high in both hazards, depending on the source of recharge to the rocks and the nature of both the rocks and the formations they overlie. Thus, spring (D-3-20)5ccc-S1 yields water low in both hazards because it issues from boulders or quartzite (little or no soluble minerals) which overlie fractures in the Weber Quartzite, a source of freshwater in the area of the spring. Wells U(C-2-1)27dbb-1 and U(C-3-3)31cdc-1 yield water with high to very high sodium hazard and medium to very high salinity hazard. The wells are in

unconsolidated deposits that contain erosional debris from the Duchesne River and Uinta Formations, respectively, and they probably also receive saline-water discharge directly from the formations themselves.

Water from the Duchesne River Formation ranges from a low sodium-low salinity hazard type, as at spring U(B-2-1)15dcb-S1, to a very high salinity hazard type, as at well U(C-1-1)36cdc-1. Because of the conversion from a water in which calcium is dominant to a water in which sodium is dominant as the water moves through the formation, some water with a medium salinity hazard can have a very high sodium hazard, as at well U(C-1-2)24ccc-1D. Much the same can be said of water from the Uinta Formation, except that the water is generally less suitable for irrigation. Most of the samples from the Uinta Formation, such as from spring U(C-3-12)35acb-S1, with medium salinity-low sodium hazard are from outcrop areas, which are high in the mountains near Strawberry Reservoir. Downgradient in the basin--where the formation is more fine grained, receives less recharge, and may receive saline water from underlying rocks--much of the formation water has high to very high salinity and sodium hazards, as at well U(C-3-3)10cab-2.

Water from other formations has from low to very high hazards. Some water, such as that from well (D-4-24)32ccd-1 in the Morrison Formation has a very high sodium hazard and a medium salinity hazard. Almost all water in the Green River and Wasatch Formations in the northern Uinta Basin area is too saline for irrigation.

The concentration of boron also determines the suitability of water for irrigation. Wilcox (1958, p. 5) has classified plants as sensitive, semi-tolerant, and tolerant, according to their ability to withstand the toxic effects of various concentrations of boron. Water with boron in concentrations of less than 0.3 mg/L is considered suitable for irrigation of the most boron-sensitive crops such as corn and legumes, whereas water with concentrations of boron in excess of 4.0 mg/L may be unsuitable for the most boron-tolerant plants, such as alfalfa.

Boron is not a problem in most of the surface waters of the northern Uinta Basin area. Occasionally during low flow, Ashley Creek below Ashley Valley and some of the small streams in the eastern part of the area contain water with boron concentrations in excess of 0.3 mg/L. Mundorff (1977, p. 20-24) points out that the lower Duchesne River, mainly during low flow, receives tributary water that has excessive boron concentrations. Generally such inflow does not appreciably raise the boron concentration in the main stem.

Of the 215 samples of fresh and slightly saline ground water analyzed for boron (Hood and others, 1976, table 10), only 40 contained boron in concentrations greater than 0.3 mg/L. The maximum concentration was 7.5 mg/L in a sample from well U(C-3-5)25dca-1, which taps the Uinta Formation. Of the 40 samples, 20 were from the Uinta Formation, 8 from the Duchesne River Formation, and 7 from deposits of Quaternary age associated with the two consolidated formations. The other five samples include two from the Weber Quartzite, one from the Entrada Sandstone, and two from the Frontier Sandstone Member of the Mancos Shale.

Availability of water for future development

Additional water for future development in the northern Uinta Basin area could be obtained from streams, aquifers, or by increased efficiency in the use of existing supplies.

The availability of surface-water supplies for development depends upon provisions of the Colorado River and the Upper Colorado River Compacts and on the extent to which existing projects, such as the Central Utah Project, are implemented. (See Austin and Skogerboe, 1970, p. 175-176.) In any event, the development of additional surface-water supplies, under the present regimen, cannot exceed 400,000 acre-ft (493 hm^3) without depleting the locally generated surface-water discharge from the area. Implicit in such full depletion is an accompanying strong degradation of chemical quality of water in the lowermost parts of the area.

The most easily developed and most productive source of ground water for future needs is the glacial outwash and related coarse-grained unconsolidated deposits that underlie the flood plains of the Green, White, and Duchesne Rivers, the terraces and outwash plains (as near Neola), and the Ashley Valley area. Although in most stream valleys the saturated thickness is about 30 ft (9 m), the deposits are very permeable and should yield 1-3 ft^3/s (0.03-0.08 m^3/s) to wells. Locally the outwash is about 200 ft (60 m) thick and produces 3 ft^3/s (0.08 m^3/s). (See Hood, 1976, p. 33-34.)

Five major consolidated aquifers--the Duchesne River, Uinta, and Currant Creek Formations, the Glen Canyon (Nugget) Sandstone, and the Weber Quartzite --all are relatively undeveloped, and withdrawals from them have not depleted storage. The Weber and the Glen Canyon are the most promising for large yields of fresh to slightly saline water. The formations all have intergranular permeability, but their yields to wells are greatest where they are fractured. Potential yields from fractured areas of the formations range from less than 1 to as high as 4 ft^3/s (0.03 to 0.1 m^3/s). The same is true of other consolidated formations; but their potential yields to wells are lower or the formations are of smaller areal extent or thickness.

Fresh and slightly saline water in storage in the northern Uinta Basin area is calculated to be 28 million acre-ft (34,000 hm^3), based on complete dewatering. Complete dewatering, however, is not practical because it would diminish the discharge of streams and induce migration of saline water into aquifers that presently yield freshwater to wells.

Increased efficiency in the use of water could make part of the presently used supply available for additional use. Part of the water presently available and diverted could be salvaged by prevention of canal leakage, much of which enters shallow formations and is then lost by evapotranspiration. In addition, a small part of the estimated 160,000 acre-ft (200 hm^3) consumed by evapotranspiration of ground water can be salvaged mainly along stream flood plains by drainage or pumping wells. An associated benefit of such salvage would be a long-term improvement in the chemical quality of water by prevention of the accumulation of salts in waterlogged areas. Additional quantities of water could also be salvaged by the conversion of nonbeneficial vegetation to grasses or other vegetation with a lower rate of water consumption.

Effect of ground-water withdrawal on streamflow

Large withdrawals from the unconsolidated rocks in most areas would be in effect a diversion from streams, either by inducing infiltration from streams, or by diverting water that is moving to the streams. The degree of effect would be variable, depending on the extent of pumping and the position of the wells with respect to the streams. Wells finished in flood plains and pumped continuously ultimately will withdraw nearly all their water from the streams.

Withdrawal of water from wells in the consolidated rocks also will diminish streamflow, but the time required to affect streamflow varies widely. In those areas where streams are partly sustained by artesian springflow, such as in Dry Fork, withdrawals from the aquifer would immediately affect streamflow. Where the formations are deeply buried, as along much of the south flank of the Uinta Mountains, or where the formations are under water-table conditions at the outcrop, as in parts of the Glen Canyon Sandstone, significant effects on streamflow would not be expected for a decade or more of continuous pumping. Intermittent pumping would take even longer to affect streamflow.

NEED FOR ADDITIONAL STUDIES

1. A more detailed stream-gaging, well-monitoring, and sampling program, if established, would provide the detail that the existing basic-data networks cannot yield. This is necessary in order to be able to adequately assess the possible impacts of additional impoundments, diversion, or withdrawal of water, such as would accompany the Central Utah Project, a reservoir to provide water for oil-shale development, or the construction of new municipal, industrial, or irrigation wells. Specific goals of the expanded networks would be to identify changes in the quantity and quality of streamflow, changes in ground-water levels and quality, and changes in the quantity and quality of ground-water discharge to streams.

2. The quantities of water moving at great depths in limestone of Mississippian age and related consolidated aquifers that overlie the limestone could not be determined because of lack of data for the deeper parts of the aquifers. Information from deep petroleum-test wells, however, may provide the necessary data. Such information accumulated rapidly during the study, but evaluation of all these data was beyond the scope of the study. When petroleum exploration stabilizes, analysis of these data would provide a quantitative evaluation of deep interformational movement of ground water.

3. In the "Greater Altamont" oil-field area (Ritzma, 1974), the production of saline water with petroleum increased in 1974, and wells were being authorized for disposal of the water into the Uinta Formation and possibly the Duchesne River Formation. Increases in the already high artesian pressures in these formations could lead to an increase in the discharge of saline water through fractures into surface streams or to adjacent freshwater aquifers. A detailed study of the conditions in the area of disposal wells would provide timely information regarding future hydrologic conditions.

CONCLUSIONS

The northern Uinta Basin area has two principal sources of water--transbasin inflow in the Green and White Rivers and precipitation on the area. Assuming, for purposes of computations that water in the rivers flows through without diversion, about 8 percent of the water from precipitation adds to the Green River outflow from the area, about 4 percent is diverted from the area, and the remainder is discharged by evapotranspiration in the area.

Most of the surface water in the northern Uinta Basin area is contributed by the Duchesne River and 10 major tributaries to the Green and Duchesne Rivers, which have their headwaters near mountain drainage divides. Most of the flow is derived from melting of winter snow accumulations. The bulk of the surface-water supply is fresh.

The estimated gross average annual recharge to the ground-water system is 500,000 acre-ft (620 hm^3). Of this amount, 200,000 acre-ft (250 hm^3) returns to streams in upland areas. Most of the recharge is in the uplands, and the water then moves to the lowlands mainly in consolidated aquifers. The remainder of the net 300,000 acre-ft (370 hm^3) of recharge occurs in the lowlands.

Fresh and slightly saline ground water in transient storage in the northern Uinta Basin area amounts to an estimated 28 million acre-ft (34,000 hm^3), the bulk of which is stored in six of the seven major aquifers in the area. Despite local water-level declines, withdrawals of ground water have changed the amount in storage little.

Ground-water circulation in the northern Uinta Basin area is largely internal. Small inflows and outflows may cross the basin boundary and probably balance one another. Within the area, ground water moves through intergranular spaces, through fractures, and through cavernous zones in the rocks.

Some groups of small mountain drainage basins in the northwestern and northeastern parts of the area have yields that are 23 percent or more greater than drainage area, average precipitation, and mean basin elevation would indicate. Some adjacent small basins yield about 20 percent less than the above-mentioned variables would indicate. These phenomena indicate, in part, that the limestone of Mississippian age and related aquifers take in recharge and transmit the water to lower altitudes, where it is discharged to the streams undiminished in transit by evapotranspiration. The phenomena also indicate that water moves from one small drainage basin to another.

Water not discharged from the older consolidated rocks in the mountains circulates to depths of 2,000-8,000 ft (610-2,440 m) near the north margin of the Uinta Basin and then leaks upward into overlying formations. The quantity of leakage cannot be calculated with available data (1974), but it is concluded that the amount may be only 1 or 2 percent of the total average annual recharge.

Water in the Duchesne River Formation and the upper part of the Uinta Formation, which underlie much of the central part of the northern Uinta Basin

area, moves generally toward stream channels. These formations have low permeability, however, and fracturing plays an important role in the transmission of water through them. The ultimate discharge point for a part of the water in the two formations is near the confluence of the Duchesne River with Dry Gulch and the Uinta River.

Ground-water discharge is largely by natural means. Evapotranspiration consumes an estimated 53 percent of the net recharge, and discharge through springs and diffuse seepage to streams accounts for an estimated 43 percent.

The chemical quality of ground water ranges from fresh to briny. Fresh to slightly saline ground water can be obtained from at least one aquifer in about two-thirds of the northern Uinta Basin area.

The most productive sources of water for future needs is ground water in glacial outwash and related deposits. The Weber Quartzite and the Glen Canyon Sandstone are the next most promising sources. Although pumping these and less productive aquifers will affect the discharge of streams in varying degree, the aquifers are alternative sources of water, especially in times of drought.

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