Minimum Average

5 (0.3) 25 (1.6)

1 (0.1) 5 (0.3)

REPORTED WELL YIELDS, IN GALLONS PER MINUTE (LITERS PER SECOND)

1 (0.1)

Maximum

100 (6.3)

EXPLANATION

FAULT - Dotted where concealed. Bar and

THRUST FAULT - Dotted where concealed.

Sawteeth on upper plate

ball on downthrown side

----- CONTACT

CHEMICAL ANALYSIS ON MAP AND IN TABLE 2

SPECIFIC CONDUCTANCE, IN MICROMHOS PER

CENTIMETER AT 25°C

SPRING

SPRING

DOMESTIC OR STOCK WELL

CENTIMETER AT 25°C

DOMESTIC OR STOCK WELL

SPECIFIC CONDUCTANCE, IN MICROMHOS PER

INTRODUCTION

This report presents the results of an investigation of ground-water resources in that part of the Yampa River basin between the towns of Craig and Steamboat Springs. The location of the study area is shown on the index map. The investigation was begun in 1975 by the U.S. Geological Survey in cooperation with the Colorado Department of Natural Resources, Division of Water Resources, Office of the State Engineer.

The purpose of the investigation was to describe the aquifers and to evaluate the availability and chemical quality of ground water in the study area. Parts of the area have undergone rapid population growth in recent years which has resulted in an increased demand for additional domestic, industrial, agricultural, and municipal supplies of water. A knowledge of the occurrence of ground water will permit a more efficient allocation of the resource.

The investigation included identification of aquifer units and presentation of hydrologic characteristics of the aquifers. These were accomplished by reviewing published geologic maps, obtaining data from existing wells, and conducting four aquifer tests on selected wells throughout the study area. Seventy-nine water samples were collected from wells and springs and were analyzed to define the chemical quality of water from the aquifers. Geologic information used in preparation of this report is from published reports by Tweto (1975), Bass, Eby, and Campbell (1955), and Buffler (1967). Basic hydrologic data used in the preparation of this report were collected by W. E. Hofstra (written commun., 1975) and by the authors during 1975.

AVAILABILITY OF GROUND WATER

Ground water may be found at varying depths throughout the study area. Aquifers include sand and gravel in the alluvium of the Yampa River and its principal tributaries; sands, semiconsolidated sandstones, and conglomerates of the Browns Park Formation; sandstones of the Fort Union, Wasatch, Williams Fork, and Iles Formations; and fractured and weathered shales in the Lance Formation and the Lewis and Mancos Shales (geologic map and table 1). Except for wells completed in the alluvium of the Yampa River and sandstones of the Williams Fork and Iles Formations in certain parts of the study area, well yields are low, generally less than 25 gal/min (1.6 L/s).

Alluvial aquifers are restricted to the valleys of the Yampa River and its principal tributaries. Aquifers in the Yampa River valley range in thickness from less than 10 ft (3 m) to an estimated 100 ft (30 m), and in the tributary valleys the aquifers are generally less than 20 ft (6 m) thick. The alluvium is thin or absent where streams cross the hard, resistant sandstones of the Williams Fork and Iles Formations. The alluvial aquifers are thick and wide where the streams cross less-resistant rock units, such as the shales in the Lance Formation and the Lewis and Mancos Shales.

Depths of wells completed in the alluvial aquifers range from 8 to 100 ft (2.4 to 30 m) (table 2). The greatest measured depth to water was 10 ft (3 m) and one flowing well was observed.

Well yields are reported to range from 5 gal/min (0.3 L/s) to as much as several hundred gallons per minute. The highest well yields can be developed in the Yampa River alluvium near Steamboat Springs, Hayden, and Craig. Wells that fully penetrate the alluvium, and have been designed and developed properly, can yield as much as 900 gal/min (57 L/s). Withdrawal of water through wells completed in the alluvium can induce surface water in the streams to flow through the streambed and into the alluvium. In this manner, long-term, high-yield wells can be developed in alluvial aquifers.

Some thin terrace deposits occur in the vicinity of Steamboat Springs. These deposits are 100 to 200 ft (30 to 60 m) above the flood-plain deposits of the Yampa River and its tributaries. Because the terraces have a relatively small surface area, are thin, and are relatively permeable, a permanent water table does not exist. During the spring or early summer months, springs may flow at the contact of the terrace material and the underlying impermeable material. These springs dry up as water is discharged from the terrace deposits.

Consolidated and semiconsolidated sedimentary aquifers in the study area include all or parts of the Browns Park, Wasatch, Fort Union, Lance, Williams Fork, and Iles Formations and the Lewis and Mancos Shales. Well yields from these aquifers are more variable and, with few exceptions, they are lower than those from the alluvial aquifers. Because of the low hydraulic conductivity of shales and the fine-grained, partly cemented sandstones, well yields in these aquifers are dependent primarily on porosity and permeability resulting from fracturing.

Well yields from aquifers in the sandstones of the Williams Fork and Iles Formations are generally less than 10 gal/min (0.6 L/s), but in a few instances have been reported to be as much as 100 gal/min (6.3 L/s). Higher yields can be developed in parts of the study area where the sandstones occur at depth, where water in the sandstones is under pressure, and where the sandstones have been fractured extensively. The areas of higher yield occur in the northern part of the outcrop area and in parts of the study area where the sandstones are overlain by the Lewis Shale. Lower yields are obtained where the sandstones are close to the surface, resulting in shallow well depths, and in areas where water in the sandstones is under water-table conditions. The areas of lower yield are in parts of the study area where the sandstones are exposed at the surface. Flowing wells can be obtained in parts of the study area where the sandstones are overlain by impermeable shales and where recharge to the sandstones occurs at a higher altitude than the well sites. These wells can be drilled in most stream valleys in the Mesaverde Group and in parts of the area where the sandstones are overlain by the Lewis Shale. Yields of flowing wells range from less than 1 gal/min (0.06 L/s) to as much as 100 gal/min (6.3 L/s), depending on the extent of fracturing in the sandstone aquifers. The yields of flowing wells decrease rapidly as pressure in the aquifer decreases. Some hydraulic-conductivity values from analysis of aquifer-test data are presented in table 1. Measurements of well depths and water levels of wells visited during the investigation are presented in table 2.

Well yields from aquifers also are low in the Browns Park, Wasatch, Fort Union, and Lance Formations and in the Lewis and Mancos Shales. Well yields from aquifers in the Lance Formation and the Lewis and Mancos Shales seldom exceed 5 gal/min (0.3 L/s). The highest yields are found where the shales have been fractured or weathered extensively. Well yields are generally less than 25 gal/min (1.6 L/s) in aquifers in the Browns Park, Wasatch, and Fort Union Formations. Higher well yields generally are not found in these formations because the sandstone and conglomerate aquifers are semiconsolidated and have not been fractured.

QUALITY OF GROUND WATER

The quality of ground water in the study area is variable and dependent, in part, on rock type (table 2). Most of the waters are calcium and sodium bicarbonate types, because of the abundance of granitic rock fragments rich in calcium and sodium, and the presence of calcium carbonate as a cement in most of the sandstones and conglomerates. Calcium sulfate type waters are found where water in the aquifer has been in contact with gypsum, organic materials, or coals. Sodium bicarbonate and sodium sulfate type waters occur in aquifers where calcium bicarbonate and calcium sulfate type waters are in contact with clays or weathered shales. Calcium ions readily replace sodium ions from the clays and weathered shales.

The quality of water in alluvial aquifers is dependent primarily on the type of material that was eroded and deposited as alluvium. Water quality also can be influenced by the underflow of ground water from adjacent sedimentary aguifers. The types of water in the alluvial aguifers include calcium and sodium bicarbonate, and calcium sulfate. Calcium and sodium bicarbonate type waters are more common and are found where the alluvial aquifer is composed primarily of material eroded from sandstones or granitic rocks. The calcium sulfate type waters occur in parts of the study area where alluvial aquifers are composed of reworked Fort Union Formation material or where ground water from the Fort Union Formation is discharged to the alluvial aguifers. Dissolved-solids concentrations of water in the alluvial aquifers range from 82 to 2,970 mg/L (milligrams per liter), and average 724 mg/L. Arsenic, iron, manganese, nitrate, selenium, sulfate, and dissolved-solids concentrations occur locally in excess of U.S. Public Health Service (1962) recommended standards for drinking water.

Water from the sandstone and conglomerate aquifers of the Browns Park Formation is mostly of the calcium and sodium bicarbonate types. One well in the southeastern part of the study area produced water of the sodium chloride type. This type of water may have originated by water coming into contact with volcanic intrusives. Dissolved-solids concentrations from aquifers in the Browns Park Formation range from 95 to 1,070 mg/L, and average 350 mg/L. Chloride, fluoride, iron, and dissolved-solids concentrations occur locally in excess of U.S. Public Health Service (1962) recommended standards for drinking water.

Water from aquifers in the Fort Union Formation is predominantly of the calcium and sodium bicarbonate types, although calcium sulfate type water also may be found in the formation. The calcium sulfate type water is found where water has been in contact with gypsum or interbedded coals that are common in the formation. Dissolved-solids concentrations of water in the Fort Union Formation range from 440 to 717 mg/L, and average 522 mg/L. Fluoride, iron, manganese, and nitrate concentrations occur locally in excess of U.S. Public Health Service (1962) recommended standards for drinking water.

Calcium and sodium bicarbonate types and calcium sulfate type waters are found in aquifers in the Williams Fork and Iles Formations. Water in contact with interbedded coals or black shales in the two formations can be of the calcium sulfate type. Dissolved-solids concentrations range from 334 to 1,460 mg/L, and average 746 mg/L. Fluoride, iron, manganese, selenium, sulfate, and dissolved-solids concentrations occur locally in excess of U.S. Public Health Service (1962) recommended standards for drink-ing water

predominantly of the calcium and sodium bicarbonate types, although a few samples were of the calcium and sodium sulfate types. The calcium and sodium sulfate type waters originate from the reduction of iron sulfide minerals, such as pyrite, and the reduction of organic materials that are common in black shales. Dissolved-solids concentrations of water in the shale aquifers range from 272 to 4,230 mg/L, and average 1,113 mg/L. Chloride, fluoride, iron, manganese, nitrate, selenium, sulfate, and dissolved-solids concentrations occur locally in excess of U.S. Public Health Service (1962) recommended standards for drinking water.

Water from the Lewis and Mancos Shales is

GROUND-WATER CIRCULATION

Ground water in the study area occurs both under water-table and confined conditions. Water-table aquifers include aquifers in the alluvium, the Browns Park Formation, parts of the Wasatch and Fort Union Formations, the Lewis and Mancos Shales, and areas where the sandstones of the Williams Fork and Iles Formations crop out. Confined aquifers are found in parts of the study area where the sandstones of the Williams Fork and Iles Formations, the Dakota Sandstone, and older Paleozoic formations are overlain by relatively impermeable shales.

Ground-water circulation in water-table aquifers is controlled partly by the degree of hydraulic connection with underlying confined-sandstone aquifers and surface drainages. In the southeastern part of the study area (geologic map), ground water is discharged from the Browns Park Formation to the underlying confined-sandstone aquifers and to the Yampa River and Oak Creek alluvium where the alluvium overlies the Browns Park Formation. Ground water is not discharged directly to streams from the Browns Park Formation.

A regional water table probably does not exist in the fractured shale aquifers of the Lewis and Mancos Shales. Ground-water circulation is shallow and, in most places, extremely poor. Water that enters the aquifers in areas of recharge does not move laterally any appreciable distance before it is discharged at a spring or a seep. Some ground water is discharged from shale to alluvial aquifers but, because of the lack of a regional water table and the shallow circulation, the volume of discharge is relatively small.

In the northwestern part of the study area (geologic map), ground water in the Browns Park, Wasatch, and Fort Union Formations is virtually one ground-water system. Ground water in these aquifers moves downward and to the west. Discharge is by underflow out of the study area. With the exception of Fortification and Elkhead Creeks, no ground water is discharged from these aquifers to streams.

1					Maximum		
System	Series	Geologic unit		Symbol	thickness (feet)	Physical characteristics	Hydrologic characteristics
QUATERNARY	Holocene	Alluvium		Qa	100 (estimated)	Unconsolidated surficial deposits include alluvial, landslide, glacial, and talus deposits. Material ranges in size from clay to large boulders and consists of both angular and well-rounded to subrounded rocks, depending primarily upon type of deposit, rock type, and source material.	Reported well yields are as much as 900 gal/min. Water quality is variable, depending on underlying rock and source of alluvial material. Dissolved-solids concentration ranges from 82 to 2,970 mg/L. Water may contain concentrations of arsenic, iron, manganese, nitrate, selenium, and sulfate in excess of U.S. Public Health Service (1962) standards for drinking water.
TERTIARY	Pliocene		Tertiary volcanics and ntrusives	Tvi	Unknown	Extrusive rocks are primarily olivine basalt with some light-colored tuffs and bouldery volcanics present. The basalts are both massive and vesicular in texture. Intrusive rocks vary from granodiorite to gabbro in composition.	No information available. Not considered an aquifer.
	Miocene	Browns Park Formation		Tbp	2,000	Varying proportions of semiconsolidated siltstone, sandstone, and conglomerate. Volcanic ash present locally. The sandstones are yellowish brown to chalky white, soft, friable, and slightly calcareous. Other beds are more resistant and weather with a characteristic lumpy or jagged surface.	Reported well yields are as much as 25 gal/min. Water is predominantly a calcium bicarbonate type. Dissolved-solids concentration ranges from 95 to 1,070 mg/L. Water may contain concentrations of chloride, fluoride, and iron in excess of U.S. Public Health Service (1962) standards for drinking water.
	Eocene	Wasatch Formation		Tw	5,000	Varicolored shale and sandstone with interbedded conglomerate and coal. The medium- to coarse-grained fluvial arkosic sandstones form resistant horizons giving a "badlands-type" topography.	Reported well yields are as much as 25 gal/min. Quality data from wells outside the study area indicate that the water is predominantly calcium and sodium bicarbonate types. Dissolved-solids concentration ranges from 260 to 372 mg/L.
	Paleocene	Fort Union Formation		Tf	1,500	Interbedded sandstone, shale, and lignitic coal. Sandstones are light brown to gray, fine to medium grained, and locally ferruginous. A basal chert-pebble conglomerate conformably overlies the Lance Formation.	Reported well yields are as much as 25 gal/min. Water is predominantly a calcium bicarbonate type, but a calcium sulfate type water is found when water is in contact with coals. Dissolved-solids concentration ranges from 440 to 717 mg/L. Water may contain concentrations of fluoride, iron, manganese, and nitrate in excess of U.S. Public Health Service (1962) standards for drinking water.
CRETACEOUS		Lance Formation		ΚΊ	1,500	Interbedded gray shale, sandstone, and coal. The sandstones vary from a light-brown, soft, fine-grained sandstone in the eastern part of the area to a white to gray, coarse-grained, ledge-forming sandstone in the western part. Fossil identification in the lower part of the formation indicates a marine environment similar to that of the Lewis Shale as opposed to the overlying fresh-water deposits.	Reported well yields are no greater than 5 gal/min. Only two springs sampled. Water is a calcium bicarbonate type. Dissolved-solids concentrations are 501 and 569 mg/L. Water may contain concentrations of manganese and nitrate in excess of U.S. Public Health Service (1962) standards for drinking water.
	Upper	Lewis Shale		Kls	1,900	Dark-gray to bluish, homogenous, marine shale with several thin interbedded sandstones and calcareous concretions.	Reported well yields are less than 5 gal/min. Water is predominantly a calcium bicarbonate type. Dissolved-solids concentration ranges from 272 to 4,230 mg/L. Water may contain concentrations of iron, manganese, nitrate, selenium, and sulfate in excess of U.S. Public Health Service (1962) standards for drinking water.
	Cretaceous	Mesaverde Group	Williams Fork Formation	Kw	2,100	Sandstone, light-brown to grayish-white, with interbedded gray carbonaceous shale, coal, and clinker beds. The coal beds are of economic importance and more numerous than those of the Iles Formation. The very fine to fine-grained, light-gray to white, massive, crossbedded Twentymile Sandstone Member is a prominent ledge-forming sandstone about 800 to 900 ft above the base of the formation.	in most stream valleys and in areas where sandstones are overlain by Lewis Shale. Water is predominantly calcium and sodium bicarbonate types. Water in contact with coals may be a calcium sulfate type and contain fluoride, iron, manganese, selenium, and sulfate in excess of U.S. Public Health Service (1962) standards for drinking water. Dissolved-solids concentration ranges from 334 to 1,460 mg/L and averages 746 mg/L. Hydraulic-conductivity values for fractured sandstones range from 3.7 to 26 ft/d.
			lles Formation	Κi	1,500	Interbedded light-brown to white, massive, fine-grained, ledge-forming sandstone, brown to black carbonaceous shale, sandy shale, and coal. The Trout Creek Sandstone Member, a 50- to 100-ft thick, light-brown to light-gray, fine-grained, massive sandstone, is located at the top of the formation.	
	Upper and Lower Cretaceous	Mancos Shale		Km	5,300	Light-gray to dark-gray fossiliferous mar- ine shale with interbedded sandstones and limestones. The sandstones are gen- erally thin bedded, fine grained, tan, and fossiliferous, and form resistant ledges in the basal and upper parts of the formation. The overall area occu- pied by the Mancos Shale is character- ized by a rolling hummocky topography.	Reported well yields are less than 5 gal/min. Water is predominantly a calcium bicarbonate type. Dissolved-solids concentration ranges from 338 to 2,590 mg/L. Water may contain concentrations of chloride, fluoride, iron, and manganese in excess of U.S. Public Health Service (1962) standards for drinking water.
CRETACEOUS TO PRECAMBRIAN	Cretaceous to Precambrian	Morri Sunda Chir Chugw Sawa	ota Sandstone ison Formation ance Formation water Formation atch Quartzite granitic rocks	Kp€u	Unknown	Sedimentary rocks in this age category have a wide range of character, but consist primarily of interbedded and varicolored sandstones, shales, limestones, and conglomerates. Igneous and metamorphic rocks also vary considerably, with felsic and biotite gneisses, amphibolites and granitic rocks being predominant.	No information available. Rock units may be aquifers near outcrop areas. Yields are estimated to be less than 10 gal/min.

Recharge to the water-table aquifers occurs primarily during the spring. Runoff in the streams infiltrates through stream bottoms and sides and raises the water level in the aquifers. Water levels in the Yampa River alluvium also are raised by leakage of water through irrigation ditches and laterals. In parts of the study area, ground-water underflow from sedimentary aquifers is another source of recharge to alluvial aquifers in the valleys.

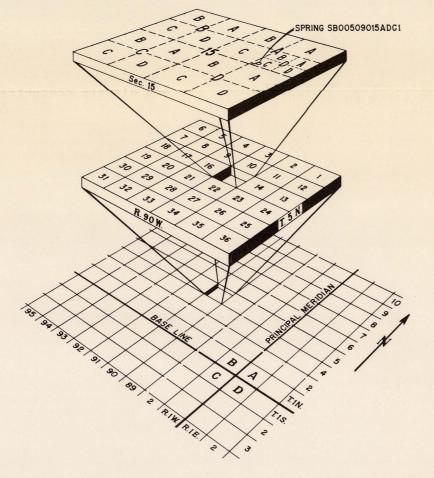
Discharge from the alluvial aquifers principally is to streams and, in the southeastern part of the area, to underlying confined-sand-stone aquifers. Discharge also occurs from the numerous springs in the area. The abundance of springs throughout the study area indicates that in many places water-table aquifers consisting of coarse, relatively permeable material overlie relatively impermeable rocks resulting in springs forming at the contact between the two types of material. Springs also occur where the water-table aquifers are fractured, allowing water to flow to the land surface.

Ground water under confined conditions occurs in the sandstones of the Williams Fork and Iles Formations, the Dakota Sandstone, and older Paleozoic formations. The direction of ground-water flow is controlled partly by the characteristics of the aquifer and partly by the regional geologic structure. In the Yampa River basin, the regional dip of the rock units and the regional ground-water flow is generally to the west and northwest.

The confined aquifers are recharged in parts of the study area where the Yampa River and its tributaries flow over the sandstones. Recharge to the confined aquifers also occurs by leakage from the Browns Park Formation in the southeastern part of the study area. Discharge from the confined aquifers principally occurs to the west and northwest out of the study area. Locally, discharge from the confined aquifers can occur in the eastern and southern parts of the study area. In these parts of the study area, the Lewis Shale and the Williams Fork and lles Formations are faulted extensively, and perennial springs flow in places where the faults extend to the land surface.

SYSTEM OF NUMBERING WELLS AND SPRINGS

The location numbers in the table of groundwater analyses (table 2) indicate the well or spring location on the map. The numbers are hased on the ILS Rureau of Land Management system of land subdivision, and show the location of the well by quadrant, township, range, section, and position within the section. A graphic illustration of this method of well or spring location is shown below. The first letter "S" preceding the location number means that the site is located in the area governed by the sixth principal meridian. The second letter indicates the quadrant in which the well or spring is located. Four quadrants are formed by the intersection of the base line and the principal meridian--A indicates the northeast quadrant, B the northwest, C the southwest, and D the southeast. The first three numbers indicate the township, the next three numbers indicate the range, and the last two numbers indicate the section in which the site is located. The letters following the section number locate the well or spring within the section. The first letter denotes the quarter section, the second the quarter-quarter section, and the third the quarter-quarter-quarter section. The letters are assigned within the section in a counterclockwise direction, beginning with (A) in the northeast quarter. Letters are assigned within each quarter section and within each quarterquarter section in the same manner. Where two or more locations are within the smallest subdivision, consecutive numbers beginning with 1 are added in the order in which the wells or springs were inventoried. For example, SB00509015ADC1 indicates a well or spring in the NE4SE4SW4 sec. 15, T. 5 N., R. 90 W.



T. 8 N.

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Multiply

Bridge Formation in the Woody Creek quad-

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CONVERSION FACTORS

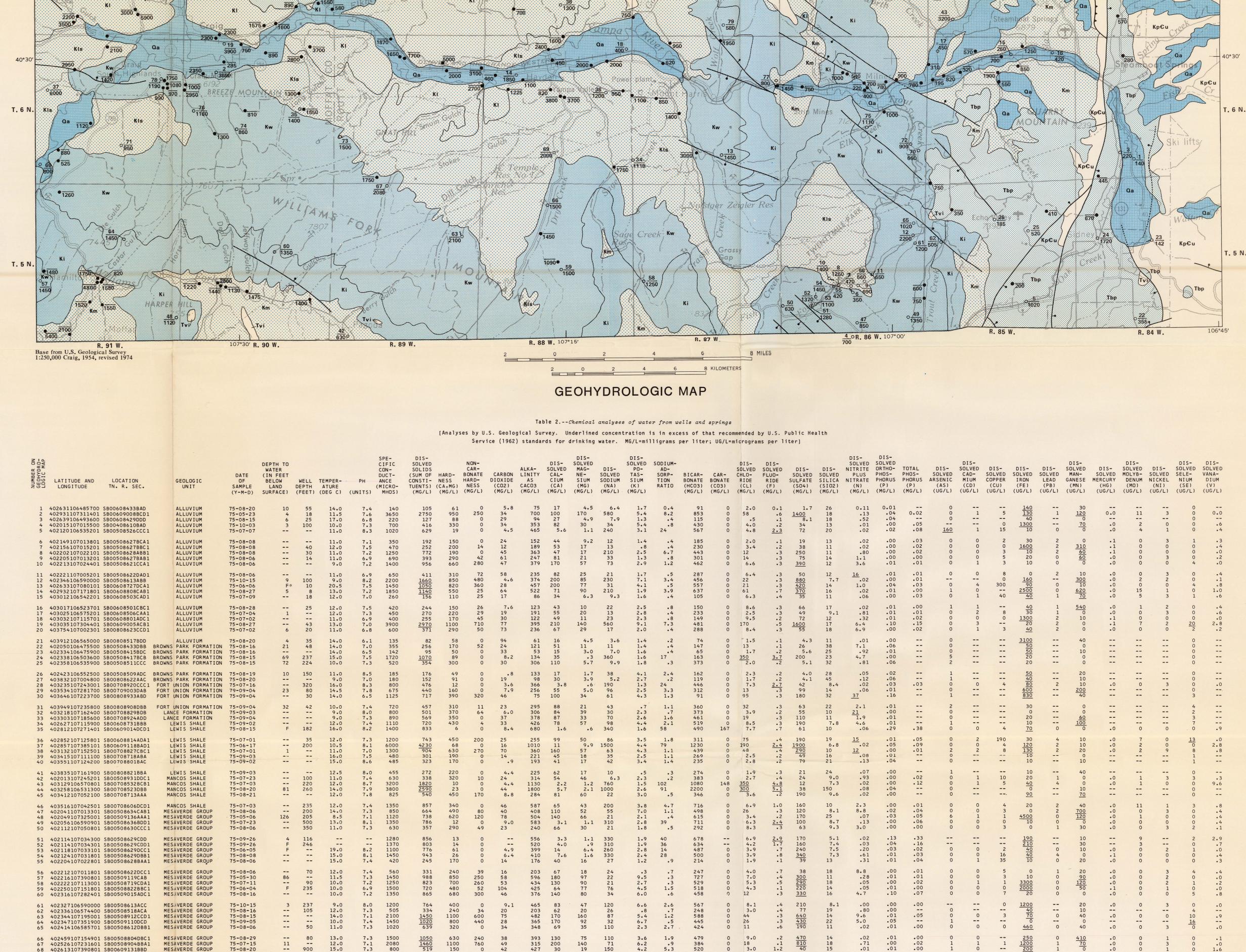
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For those readers who may prefer to use metric units rather than English units, the conversion factors for the terms used in this report are listed below:

feet (ft)
miles
feet per day (ft/d)
gallons per minute

By
metric unit

0.3048 meters (m)
kilometers
feet per day (ft/d)
3048 meters per day (m/d)
3048 meters per second



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71 402659107352801 SB00609127BDD1

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402916107061601 SB00608712DDA

78 402918107333201 SB00609112CCA1

79 403112107075200 SB00708734DBA

*FLOWING WELL.

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