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GEOLOGICAL SURVEY CIRCULAR 163

RECONNAISSANCE OF THE GEOLOGY AND GROUND-WATER RESOURCES OF THE GLENDO-WENDOVER AREA PLATTE COUNTY WYOMING

WITH A SECTION ON THE CHEMICAL QUALITY OF THE WATER

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary

GEOLOGICAL SURVEY
W. E. Wrather, Director

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By J. R. Rapp and H. M. Babcock

WITH A SECTION ON THE CHEMICAL QUALITY OF THE WATER

By W. H. Durum

Prepared as part of a program of the Department of the Interior
for development of the Missouri River Basin

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ABSTRACT

The area described in this report is in the northwestern part of Platte County, Wyo., in the extreme western part of the High Plains section of the Great Plains physiographic province. A reconnaissance of the geology and ground-water resources was made along the North Platte River and its tributaries--Horseshoe, Bear, and Cottonwood Creeks--to determine the possibilities of developing ground-water supplies for irrigation.

The areas of rocks exposed in the Glendo-Wendover area are shown on a geologic map included in the report. The rock formations range in age from pre-Cambrian to Recent. The only pre-Tertiary rocks known to yield water to wells and springs in the area are the "Converse sand," a porous sandstone bed of the Hartville formation, and the Cloverly formation, which consists mainly of sandstone. Tertiary rocks in the area include the Brule and Arikaree formations. The Brule formation, a sandy siltstone, yields small amounts of water through fractures and fissures to wells; and the Arikaree sandstone, which consists mainly of fine-grained sandstone, yields water through beds of sandstone and conglomerate to wells and springs. The Quaternary alluvium is the principal water-bearing formation in the area. It consists of coarse sand and gravel containing beds and lenses of silt and clay, and readily yields water to wells.

Unconfined ground water is contained in the alluvial fill of the stream valleys in sufficient quantities for irrigation supplies. Wells yielding 500 to 1,000 gpm probably could be developed from the alluvium of the North Platte River valley and of the lower ends of the valleys of the Cottonwood, Bear, and Horseshoe Creeks where the thickness of the alluvium is greatest.

Ground water under artesian pressure is contained in the "Converse sand" of the Hartville formation. It is estimated that yields of 100 gpm or more could be obtained from wells in this sand. The lateral extent of the sand and the depth at which it could be encountered throughout the area are not known; it is very likely, however, that it underlies most of the area.

Ground water from several geologic sources in the Glendo-Wendover area is generally moderately mineralized, though hard. The range in dissolved solids was from 222 to 1,460 ppm, and most samples had less than 400 ppm. Concentrations of iron, chloride, fluoride, and boron normally are low except where the supply has been affected by surface drainage. Differences in the chemical character of water from shallow aquifers are attributed to local deposits of the more soluble minerals. Water from shallow wells in the valleys is similar both in concentration and in chemical character to the water in adjacent streams. The ground water from the various geologic sources contains a low percentage of sodium and is generally of satisfactory quality for irrigation.

INTRODUCTION

Purpose and scope of the investigation

This investigation is one of several being made by the United States Geological Survey as a part of the studies undertaken by the Department of the Interior for the control, conservation, development, and use of the water resources of the Missouri River basin. The purpose of this study is to determine the possibility of developing ground-water supplies for irrigation in the valleys of the North Platte River and its tributaries--Horseshoe, Bear, and Cottonwood Creeks--and to determine the possibility of obtaining water under artesian pressure in the Glendo area.

The investigation was begun in October 1948. This report covers the progress of the work from the beginning of the investigation through December 1949. The work was under the general supervision of A. N. Sayre, chief, Ground Water Branch, Geological Survey, and G. H. Taylor, regional engineer in charge of ground-water investigations in the Missouri River drainage basin, and under the immediate supervision of S. W. Lohman, district geologist for Colorado and Wyoming. The quality-of-water studies were under the general supervision of S. K. Love, chief, Quality of Water Branch, Geological Survey, and under the immediate supervision of P. C. Benedict, district engineer in charge of quality-of-water studies, Missouri River drainage basin. The water analyses were made by M. B. Florin, W. M. Barr, and R. P. Orth, chemists in the Quality of Water laboratory, Geological Survey, Lincoln, Nebr.

Location and extent of the area

The Glendo-Wendover area is situated mainly in Platte County, but extends 2 miles westward into Albany County, in southeastern Wyoming (pl. 1 and fig. 1). The area lies within Tps. 27, 28, and 29 N., Rs. 67 through 71 W., and covers about 400 square miles.

The area is transected by the Chicago, Burlington, and Quincy Railroad which serves the towns of Wendover, Cassa, and Glendo; and the Colorado and Southern Railway which serves the town of Wendover. U. S. No. 87, which runs north, is the only paved road in the area; along the creeks, however, there are several county roads which are graveled and are maintained throughout the year.

Previous investigations

Several earlier studies cover parts or all of the Glendo-Wendover area. Smith (1903) studied and mapped the geology of the Hartville quadrangle, which covers the extreme eastern part of the Glendo-Wendover area. In 1934 the Geological Survey of Wyoming prepared a map (unpublished) of the geology in the immediate vicinity of the Cottonwood Creek tunnel, situated in the southwest corner of the area. In 1946 Pennington[1] described the geology of the Horse Draw area, which is situated in the western part of the Glendo-Wendover area. Love, Denson, and Botinelly (1949) described the geology of the northeastern part of the area covered by this investigation. Their report proved most helpful in understanding the stratigraphy of the area and was used freely in the preparation of this report.

Methods of investigation

The geologic and hydrologic field data were recorded on aerial photographs. The map of the area (see pl. 1) was compiled from these photographs. The geologic mapping and hydrologic studies were confined mostly to the main valleys where irrigation from wells is deemed most practicable.

Wells and springs shown on the map were located within the sections by use of an odometer and by inspection of the aerial photographs, and their locations are believed to be accurate within one-tenth of a mile.

A field test was made to determine the hydrologic properties of the "Converse sand" of the Hartville formation at one locality.

Records were obtained of 62 wells and springs in the area. Very little information was obtainable regarding the character of the water-bearing material penetrated or the yield and drawdown of the wells. Nineteen samples of water for chemical analysis were collected from representative wells and springs and from creeks. Twenty-one of the

[1] Pennington, J. J., 1946, Geology of the Horse Draw area. (Manuscript report in files of the Geological Survey of Wyoming.)

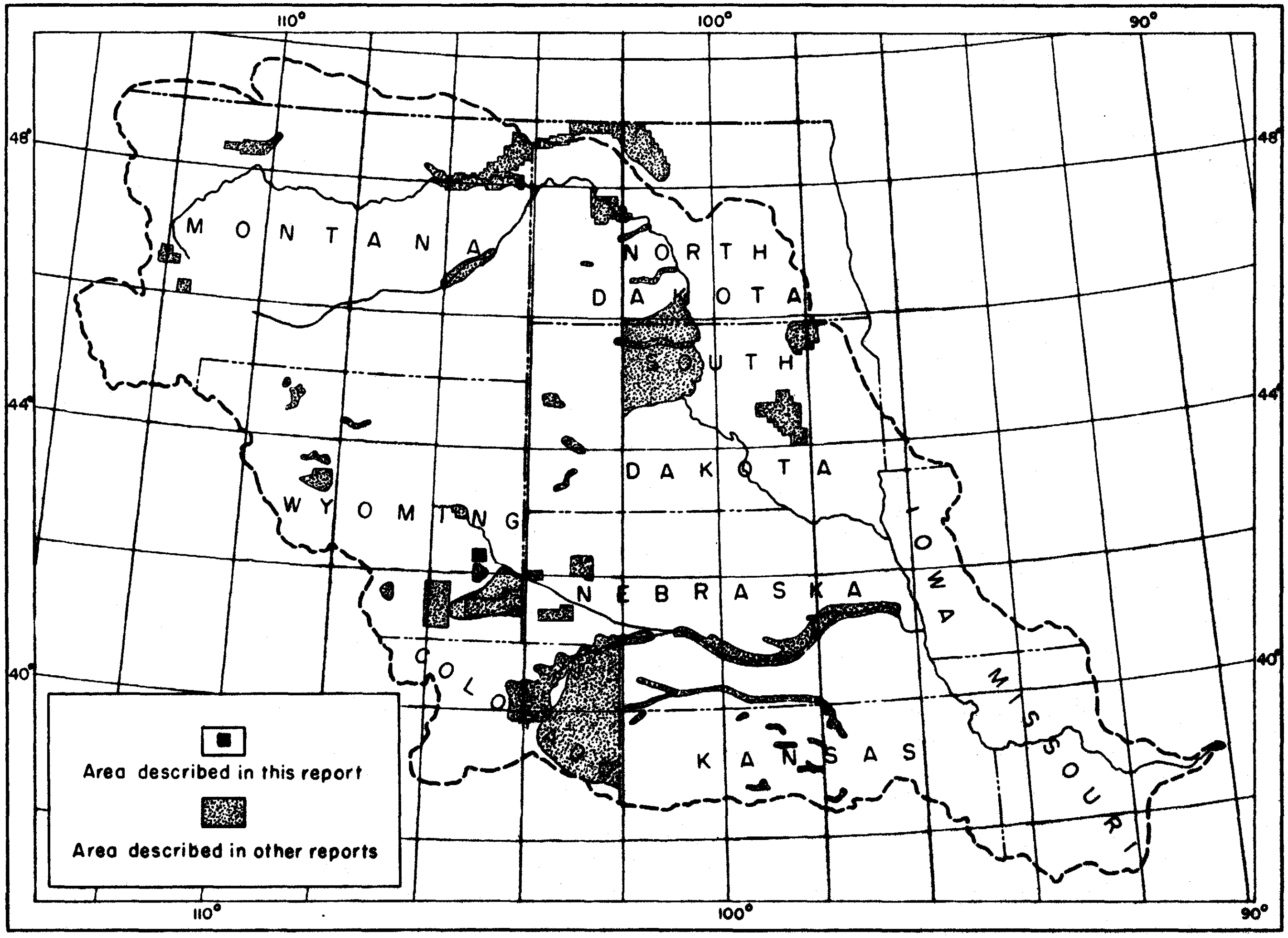

Figure 1.--Map of the Missouri River drainage basin showing areas in which ground-water studies have been made under Missouri Basin development program.

wells were measured with a steel tape to determine their depth and the depth to water below some fixed measuring point, generally the top of the pipe clamp or the bottom of the pump base. Reported data are listed for those wells that could not be measured.

In July 1949 seven representative wells were selected for monthly observations of water level in order to obtain information concerning the seasonal fluctuations of the water table.

indicates the township, the second the range, and the third the section in which the well is located. The lower-case letters following the section number locate the well within the section. The first letter denotes the quarter section, the second the quarter-quarter section, and the third the quarter-quarter-quarter section (10-acre tract). The subdivisions of the section are lettered a, b, c, and d in a counterclockwise direction beginning in the northeast quarter. When more than one well is situated in a 10-acre tract

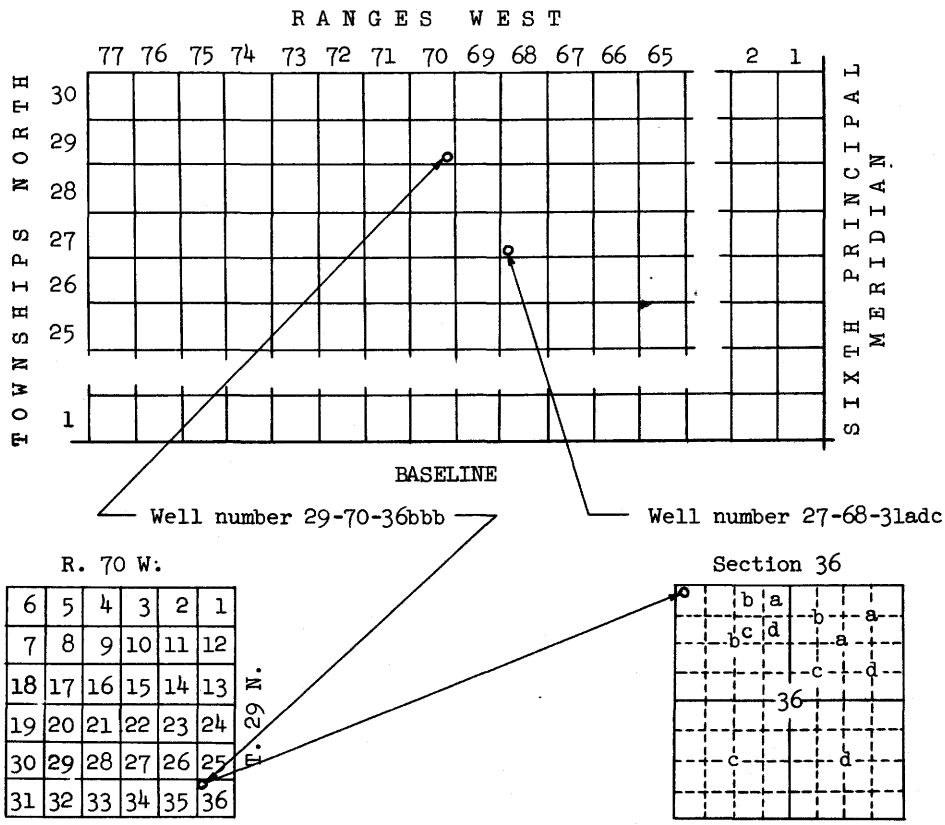

Figure 2.--Sketch showing well-numbering system.

consecutive numbers beginning with 1 are added to the well number.

Well-numbering system

In this report, wells and springs are numbered according to their location within the General Land Office system of land subdivision. The Glendo-Wendover area is in the northwest quadrant of the sixth principal meridian and baseline system. The well number shows the location of the well by township, range, section, and position within the section. A graphical illustration of this well-numbering system is shown by figure 2. The first numeral of a well number

Acknowledgments

Residents of the area were very cooperative in supplying information about and permitting the measurement of their wells. Thanks are extended to Mr. D. L. Blackstone, Jr., for contributing information and material that were helpful in compiling this report.

GEOGRAPHY

Topography and drainage

The area described in this report is in the extreme western part of the High Plains section of the Great Plains physiographic province and lies along the east front of the Laramie Range. The highest point, which is in the extreme western edge of the area, is about 6,000 feet above sea level, and the lowest point, where Cottonwood Creek enters the North Platte River, is about 4,400 feet above sea level. The relief of the area, therefore, is about 1,600 feet.

The westernmost part of the area has a rugged, mountainous topography. East of the mountains the topography consists of gently rolling uplands that slope gradually to the southeast. Deep erosion of these uplands by the main streams has produced narrow valleys.

The Glendo area is drained by the North Platte River and its main tributaries--Cottonwood, Bear, and Horseshoe Creeks. Cottonwood and Horseshoe Creeks rise on the eastern slope of Laramie Peak and flow eastward to their confluence with the North Platte River. Horseshoe Creek enters the area at an altitude of about 5,200 feet and joins the North Platte River at an altitude of about 4,500 feet. It has an average gradient of about 41 feet to the mile. Bear Creek originates in the upland area east of the Laramie Range.

Climate

The climate of the area is much like that of other parts of the High Plains section. The area is characterized by low precipitation, high evaporation, and a wide range in temperature. The weather is variable from year to year, but usually the summers are dry and mild and the winters very cold.

Climatological data are not available for the Glendo-Wendover area. According to a 61-year record of the United States Weather Bureau, the normal annual precipitation is 13.70 inches at Wheatland, which is about 30 miles south and the nearest comparable area. Weather information was recorded in the Wheatland area as early as 1889; precipitation records, however, have been kept continuously only since 1931. The annual precipitation during the period of record is shown graphically by figure 3. The greatest annual precipitation recorded was 22.58 inches in 1912, and the least was 5.92 inches in 1893. The maximum precipitation occurs during the spring and early summer and the minimum occurs during the winter, when it usually takes the form of light dry snow. The mean annual temperature at Wheatland is 48.8°F. The highest recorded temperature

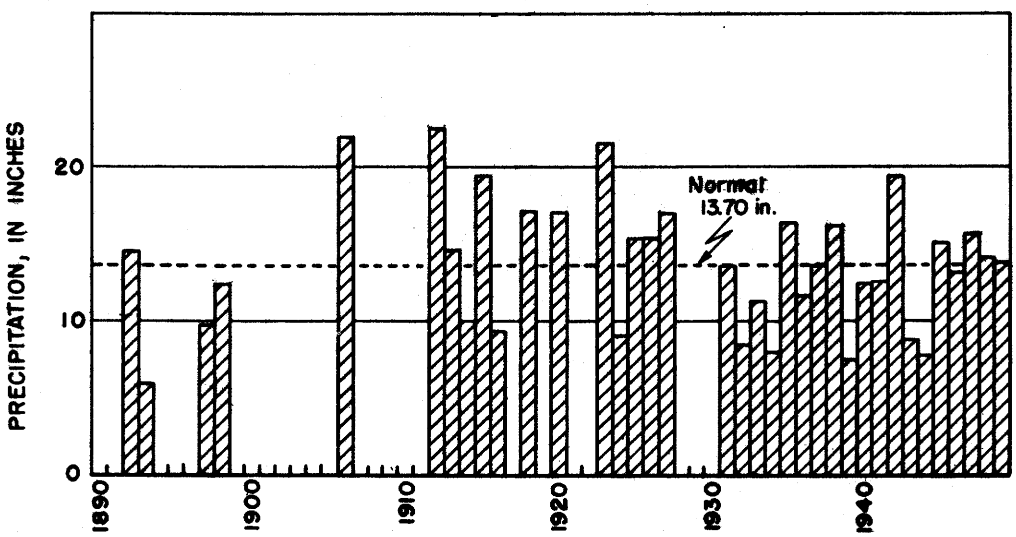

Figure 3.--Graph showing annual precipitation at Wheatland, Wyo. (From records of the U. S. Weather Bureau)

Table 1.--Generalized section of the geologic formations in the Glendo-Wendover area, Wyoming
[Adapted from Love, Denson, and Botinelly (1949)]

System	Series	Subdivision	Thickness (feet)	Physical characteristics	Water supply
Quaternary.	Recent.	Slope wash.	0-10±	Clay, silt, sand, and gravel...............................	Lies mainly above water table, hence generally does not yield water to wells but serves as an infiltration area for precipitation.
		Alluvium.	0-62±	Sand, coarse, and gravel; contains thin beds of silt and clay.	Supplies water to stock, domestic, and irrigation wells.
	Pleistocene.	Terrace deposits.	0-20±	Sand and gravel; contains thin beds of silt and clay and a few boulders.	Generally lies above the water table; serves as an infiltration area for recharge from precipitation.
Tertiary.	Miocene.	Arikaree sandstone.	0-400	Sand, massive to poorly bedded, tuffaceous, fine-grained; and siltstone; contains beds of cemented sandstone and conglomerate.	Yields limited amounts of water to wells and springs from beds of sandstone and conglomerate.
	Oligocene.	Brule formation.	320±	Siltstone, bentonitic, sandy, somewhat argillaceous, with beds and lenses of sandstone and some moderately hard conglomerate; contains many fractures and fissures.	Yields water to domestic and stock wells from fractures and fissures.
Cretaceous.	Lower Cretaceous.	Mowry shale.	40-90	Shale, dark-gray, siliceous, slabby, weathering silver gray; contains fish scales and thin yellow beds of bentonite.	Ground-water possibilities not known.
		Thermopolis shale.	50-100	Sandstone, thick to thin-bedded, medium-grained, clean, gray; known as the Muddy sandstone member.	Do.
			90-150	Shale, black, soft, fissile, flaky; contains thin layers of bentonite and partings of ironstone.	Do.
		Cloverly formation.	120-260	Chiefly sandstone; contains thin unit of shale at the middle. The sandstone is clean to shaly and ferruginous.	Yields water to springs.
Jurassic		Morrison formation.	150-220	Claystone, dull, variegated; fine-grained fresh-water limestone; and lenticular sandstone. The claystone is dull green, pink, and purple.	Ground-water possibilities not known.
		"Upper Sundance."	50-100	Shale, highly glauconitic, green; shaly sandstone; and gray slightly glauconitic basal sandstone.	Not a producing aquifer in the area, but may contain water.
		"Lower Sundance."	125-300	Sandstone, fine-grained, limy, red; contains persistent purple, green, and gray shaly zones and olive-drab silty zones.	Do.
		Basal sandstone of Jurassic sequence.	30-75	Sandstone, light-gray, fine- to coarse-grained, massive to cross-bedded; contains abundant large rounded frosted grains.	Do.
Triassic.		Chugwater formation.	275-500	Mainly siltstone, red; contains small amounts of red shale and fine-grained red silty sandstone and a few thin seams of gypsum or anhydrite.	Ground-water possibilities not known.
Permian(?).		"Gypsum and red-shale sequence."	220-270	Shale, red; gypsum, or anhydrite; soft silty shale; gray dolomite; gray to pink coarsely crystalline crinkled limestone; and layers of pink and gray chert.	Do.
		Minnekahta limestone.	20-40	Limestone, yellow to pink, slabby, silty; and purple to bluish slabby thin-bedded limestone.	Do.
		Opeche shale.	25-75	Shale, bright red, silty; yellow to red shaly sandstone; some white gypsum; some geodes; and thin lenses of purple, red, and gray chert.	Yields little or no water.

Carboniferous.	Pennsylvanian.	Hartville formation.	250±	Sandstone, limestone, shale, dolomite and breccia. At the top is 50 to 90 feet of soft white to yellow fine- to medium-grained sandstone which probably correlates with the "Converse sand." Below this unit is a cherty dolomitic red sandstone, thin beds of dolomite, and breccia composed of angular blocks of sandstone and dolomite.	Yields water under artesian conditions from the "Converse sand." Other sandstones and porous limestones may contain water.
	? Mississippian.		730±	Limestone, shale, sandstone, dolomite, siltstone, quartzite, and chert. The thickness of the formation ranges considerably because of the very irregular erosion surface at the top of the Guernsey formation.	Sandstone and porous limestone may contain water under artesian pressure.
	Mississippian. ?	Guernsey formation.	115-215	Limestone, hard, gray, moderately cherty, coarsely crystalline, coarsely bedded; the lower part is oolitic, porous, and highly dolomitic.	Ground-water possibilities not known.
Devonian(?).			35±	Dolomite, thin-bedded, slabby, very fine-grained, hard, brittle, silty, purple to gray; interbedded with hard, fissile dolomitic purple shale and siltstone. From 1 to 4 feet of pink arkose occurs at the base.	Do.
Pre-Cambrian.		Igneous and metamorphic rocks.		Metamorphic rocks composed of gneiss, schist, and phyllite intruded by coarse-grained granite, which was in turn cut by pegmatite veins and dikes of crystalline quartz and basic rock.	Do.

was 109°F and the lowest was -36°F. The length of the growing season has ranged from 104 to 150 days for the period of record.

Agriculture

Most of the area is used for stock raising and dry farming; there are, however, a few isolated patches of irrigated land along the stream valleys. Wheat and hay are the main crops raised in the area. In some places small vegetable gardens are grown along the stream valleys.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Pre-Tertiary

Pre-Tertiary rocks ranging in age from pre-Cambrian to Early Cretaceous are exposed in the area. The age, thickness, physical characteristics, and water supply of these formations are summarized in table 1.

The Hartville and Cloverly formations are the only pre-Tertiary rocks known to produce water in the area. Other pre-Tertiary formations in the area may contain water, but sufficient data are not available to ascertain their water-bearing possibilities; therefore, the Hartville and Cloverly formations are the only ones that are discussed further in this report.

Hartville formation

The Hartville formation consists of beds of sandstone, limestone, shale, dolomite, and breccia. The only known producing aquifer in this formation is a sandstone which lies at the top of the formation and is of Carboniferous and Permian(?) age. Love, Denson, and Botinelly (1949, sheet 2) call this the "Converse sand" and state that it is probably the correlative of the Converse oil sand of the Lance Creek area. Several other beds of porous sandstone and limestone in the formation also may contain water; the limestone strata are cavernous and readily receive water where they are exposed. (See fig. 4.)

The "Converse sand" of the Hartville formation is a soft white sandstone that generally weathers light yellow to gray. The material consists of fine- to medium-grained, subangular to rounded quartz sand. Locally the sand contains thin strata of limy sandstone. Some cross bedding is observed.

The "Converse sand" crops out on the west margin of the area, along Horseshoe Creek, and in the northern part of the area. It is shown on the geologic map as part of the Hartville formation as no attempt was made to map it separately.

The "Converse sand" is about 100 feet thick where it is exposed on Horseshoe Creek and about 50 feet thick where it is exposed west

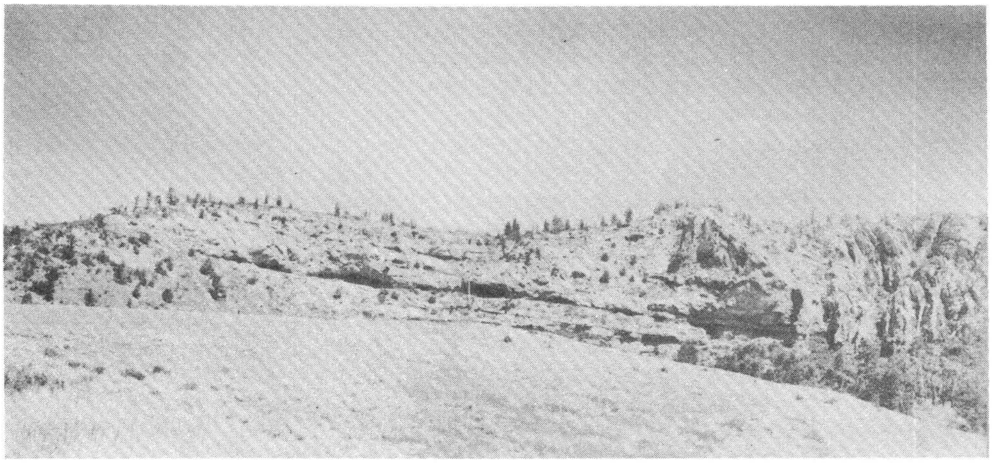

Figure 4.--Outcrop of the Hartville formation in the vicinity of the Cottonwood Creek tunnel. Note the caverns in the sandstone and porous limestone. Construction of the tunnel revealed a subterranean cavern 4 to 15 feet high, about 7 feet wide, and of unknown length.

of the town of Glendo. The log of well 29-68-20bac indicates the total thickness of the "sand" to be 120 feet and that a bed of limestone 1 foot thick occurs 9 feet below the top of the "sand."

The "Converse sand" yields water to three flowing wells in the area. It is possible the well that supplies the town of Glendo also obtains water from this "sand."

Cloverly formation

The Cloverly formation of Early Cretaceous age, which ranges in thickness from 120 to 260 feet, crops out in several places in the Glendo area. It forms conspicuous escarpments south of Horseshoe Creek and along the North Platte River southeast of the town of Glendo. The formation consists of three divisions: a lower sandstone unit, a thin middle shale unit, and an upper sandstone unit.

The lower unit is 50 to 75 feet thick and consists of clean, sparkly medium-grained resistant noncalcareous sandstone. It is gray and weathers buff to tan. The middle unit, which ranges in thickness from a featheredge to 50 feet, consists of a plastic waxy shale that is interbedded with thin layers of sandstone and siltstone. It is generally gray but in a few places is black or pale pink. In some areas where this shale unit is missing, the entire formation consists of sandstone. The upper unit, which ranges in thickness from 70 to 135 feet, is a shaly ferruginous thinly bedded sandstone. It contains abundant worm trails, especially near the top.

The Cloverly formation lies unconformably on the Morrison formation but is conformable with the overlying Thermopolis formation. There is a sharp break in lithology at both the upper and lower contacts of the Cloverly formation.

The Cloverly formation, probably the lower sandstone unit, supplies water to a group of springs, locally called Twin Springs (29-69-35cbb). No attempt has been made to develop ground water from this formation in the Glendo-Wendover area; it is likely, however, that adequate water could be developed from the sandstones in this formation for stock and domestic use, and possibly for irrigation.

Tertiary

The Tertiary strata in the Glendo-Wendover area include the Brule formation of the White River group and the Arikaree sandstone. These formations cover more than half the area studied. The Chadron formation, which is the basal stratigraphic unit of the White River group, does not crop out in the area; its presence in the area therefore is questionable. Classification of the Brule formation of Oligocene age and the Arikaree sandstone of Miocene age in the area is made on the basis of lithology and stratigraphic position. Vertebrate fossil remains were collected by Love (1949, sheet 2) from both Oligocene and Miocene sediments.

Brule formation

In the Glendo-Wendover area the Brule formation of Oligocene age is a moderately hard bentonitic sandy siltstone, which is compact and brittle. Mechanical analyses were not made of the material in this area, but megascopically it compares favorably with that in the Scotts Bluff area, Nebraska, as described by Wenzel, Cady, and Waite (1946, pp. 66-70). Fresh exposures reveal the material to be pinkish or flesh-colored; it is almost white, however, on weathered surfaces. It has indistinct but regular bedding planes and typically weathers into cubical blocks and slabs. Extensive erosion of outcrops of the Brule has produced badlands in some places.

Light-colored resistant zones cemented by calcium carbonate have produced a layered effect in parts of the Brule formation. The zones are not persistent but grade laterally into massive beds of the Brule. Bare surfaces of the formation reveal many fractures and fissures some of which are filled with clay and sand or with crystalline or amorphous calcium carbonate. Many fractures are present in upper weathered zones, and some fractures and fissures occur throughout most of the formation. Where the fractures and fissures are open, the permeability of the formation is increased.

The Brule formation is exposed mainly in the northern part of the area; southward it extends beneath younger sediments. In the western part of the area the Brule abuts against outcrops of older rocks. The formation has a regional dip of about 2° to the southeast.

Only a few wells in the area produce water from the Brule formation, and most of them are on the uplands. The wells supply only small amounts of water for stock and domestic use.

Arikaree sandstone

The Arikaree sandstone of Miocene age consists mainly of loosely to moderately cemented fine sand, interbedded with lenses of sandstone and gravel, and of layers or concretions of very hard, tough fine-grained brownish to dark-gray sandstone. Pebbles and cobbles ranging from one-fourth inch to as large as 5 inches in diameter are scattered throughout the sand. The individual concretions are quite numerous in places; they reach a maximum of 7 inches in diameter and $10\frac{1}{2}$ feet in length. Darton (1903 pp. 23-29) referred to these cylindrical masses as pipy concretions. These "pipes" generally lie in a northeast direction. In other places the concretions are solidly cemented into a mass that is as hard and tough as the concretions themselves. These coalesced relatively flat masses attain thicknesses as much as 2 or 3 feet and grade laterally into sandstone that is poorly consolidated. Wenzel, Cady, and Waite (1946, pp. 72-75) attributed the origin of these concretions to the deposition of calcium carbonate by ground water percolating through unconsolidated sediments. A few beds of white volcanic ash are found in the upper part of the formation. A cemented basal conglomerate, about 30 feet thick, lies unconformably on the Brule formation and forms the escarpment along U. S. No. 87, 2 miles west of Cassa. (See fig. 5.)

The Arikaree sandstone is exposed in the southern part of the area and, as a continuous body, extends northward to about the southern limits of Horseshoe Creek valley. North of the valley a few small isolated patches of this formation occur on the upland areas. The Arikaree sandstone ranges in thickness from a knife edge in the northern part of the area to a maximum of 400 feet in the southern part.

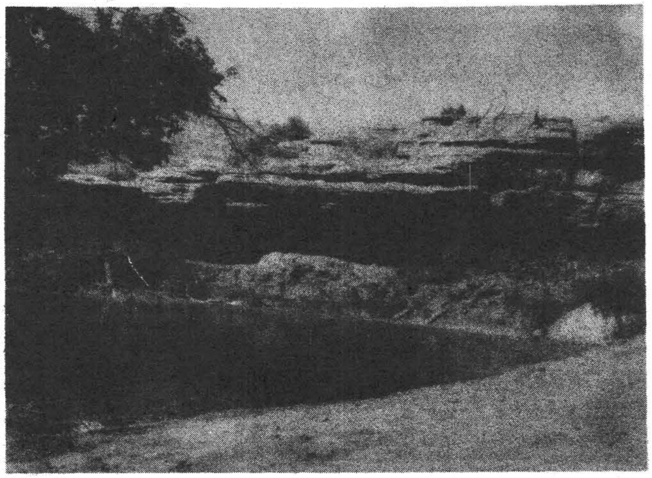

Figure 5.--Outcrop of basal conglomerate of Arikaree sandstone on Bear Creek in sec. 15, T. 28 N., R. 68 W. The bed thickens to the left. The weathered material below the shadows is the Brule formation.

Pervious beds of sandstone and gravel in the Arikaree sandstone yield water to a few stock wells in the highlands and also supply several small springs.

Quaternary

Terrace deposits

Terrace deposits of Pleistocene and Recent age capping the highest ridges south and east of Glendo are thought to have been deposited by the ancestral North Platte River before the down cutting of the present deep canyons. Three lower terraces were observed along Horseshoe Creek but were not mapped separately on the geologic map.

These water-laid terrace deposits consist of unsorted and unconsolidated mixtures of sand, gravel, cobbles, and boulders. The material was derived mainly from crystalline rocks, but fragments of sandstone, limestone, and shale are included in some of the deposits. These terraces are discontinuous in the eastern part of the area, but in the western part they become more continuous as they approach the Laramie Range, from which the materials were derived. The terrace deposits range in thickness from a knife edge to 20 feet or more.

Most of the terrace deposits in the Glendo-Wendover area lie above the zone of saturation and hence contain no ground water. The terraces constitute a good recharge area because the deposits absorb considerable precipitation which then percolates into the underlying sediments.

Alluvium

Alluvium of Recent age in the Glendo-Wendover area consists of stream-laid deposits of coarse sand and gravel, which contain beds and lenses of silt and clay. Large boulders reportedly have not been encountered in the channel fill by well drillers. In the Glendo-Wendover area this alluvial fill is concentrated mainly in the valleys of the North Platte River and of Horseshoe, Bear, and Cottonwood Creeks; it attains its greatest thickness in several parts of the North Platte River valley. Little or no alluvium is present along several deep, narrow canyons of the North Platte River; one well, however, in the North Platte River valley near Cassa (see pl. 1) penetrated 62 feet of alluvium. Although this is the greatest thickness recorded, it is believed that in some parts of the valley the alluvium is even thicker. The alluvial fill along Horseshoe Creek is thin in the upper reaches of the valley but becomes progressively thicker, attaining a thickness of 32 feet south of Glendo and reaching a maximum thickness at the junction of the creek with the North Platte River. Little is known about the thickness of alluvium in the valleys of Cottonwood and Bear Creeks, but it is probably comparable to that of Horseshoe Creek valley.

The alluvium is the main source of ground water in the Glendo-Wendover area and supplies most of the water for domestic and stock use and for irrigation wells. The largest supplies are obtainable where the alluvium is thickest in the North Platte River valley and in the lower parts of the creek valleys.

Slope wash

The slope wash of Recent age is made up of thin patches of unsorted and unconsolidated water-laid debris consisting of clay, silt, sand, and gravel. It lies on surfaces of older formations that slope away from escarpments along the drainage courses, and it is generally removed by erosion before it can accumulate to any great thickness.

In general the slope wash is above the water table and is not an important source of ground water. It serves, however, as an infiltration area for precipitation.

GROUND-WATER RESOURCES

Principles of occurrence

The fundamental principles of the occurrence and movement of ground water are set forth in an authoritative and detailed report by Meinzer (1923). Only a brief discussion of the subject will be given here, and the reader is referred to Meinzer's report for a more detailed discussion.

The rocks that make up the outer crust of the earth generally are not solid but contain numerous openings, called voids or interstices, which may contain gas or liquid. The number, size, shape, and arrangement of these voids depend upon the character of the rock. They range in size from microscopic openings to huge caverns and generally are interconnected so that gases or liquids may pass from one to another.

The porosity of a rock is the percentage of the volume of the rock that is occupied by the interstices; it determines only the amount of water the rock can hold, not the amount it may yield to wells. Some rocks, such as clay and silt, may have a high porosity but will yield very little water to wells. The porous rocks below the water table are generally saturated and will yield water to wells if the rocks are sufficiently permeable.

The rate of movement of ground water is determined by the quantity, size, shape, and degree of interconnection of the interstices and also by the hydraulic gradient. The capacity of a rock to transmit water under hydraulic head (pressure) is its permeability. The coefficient of permeability may be expressed as the rate of flow of water, in gallons a day, through a cross-sectional area of 1 square foot, under a hydraulic gradient of unity, and at a temperature of 60°F. The coefficient of transmissibility may be defined as the number of gallons a day transmitted through each strip 1 foot wide and extending the saturated thickness of the aquifer, under a unit gradient. Ordinarily transmissibility is computed under prevailing temperature conditions. The coefficient of transmissibility therefore is the product of the coefficient of permeability and the saturated thickness, in feet, of the aquifer.

The amount of water released from storage in an aquifer is dependent upon the coefficient of storage. The coefficient of storage is defined as the amount of water, in cubic feet, discharged from each vertical column of the aquifer with a base 1 foot square, as the water level or artesian head declines 1 foot. In artesian aquifers the coefficient of storage is dependent only upon the compressibility of the aquifer and the expansion of the water, and its magnitude is only a few percent or a fraction of one percent of that of unconfined aquifers. Hence, the cone of depression developed around a well in an artesian aquifer grows many times as fast as it does in an unconfined aquifer. The coefficient of storage of an unconfined aquifer commonly is called the specific yield.

Hydrologic properties of the principal water-bearing formations

General conditions

In the Glendo-Wendover area water is obtained from the "Converse sand" of the Hartville formation, a medium-grained soft porous sandstone; the coarse sand and gravel of the alluvium in the stream valleys; the Cloverly formation, a fine-grained sandstone that yields water to springs; the Brule formation, a sandy siltstone that yields water from fractures to wells; and the Arikaree sandstone, a fine-grained sandstone containing a few lenses of gravel, which yields small amounts of water to wells.

The first two formations mentioned above are the only ones permeable and extensive enough to be considered as possible sources of water for irrigation. Only these two formations therefore, will be considered further in this report.

"Converse sand" of the Hartville formation

Field tests

The coefficients of transmissibility and storage of the "Converse sand" of the Hartville formation, were determined at one locality by tests made on well 29-68-20abd, a flowing artesian well about 2 miles south of the town of Glendo. The well is 4 inches in diameter and 442 feet deep.

The coefficients of transmissibility and storage were determined by the flow method and by the nonequilibrium method. At the completion of each of these tests the coefficient of transmissibility was determined by the recovery method also. The average value of the coefficient of transmissibility obtained by the three tests was 10,300 gallons a day per foot. The value of the coefficient of storage obtained by the flow method was 3.06×10^{-7}, and the value obtained by the nonequilibrium method was 2.02×10^{-4}. The value of the storage coefficient obtained by the flow method was considered unreliable because there was some doubt as to the diameter of the hole through the aquifer and hence of the effective radius of the well; therefore, the value obtained by the nonequilibrium method was used in the computation of the theoretical drawdown. The flow method was developed by Jacob and Lohman (in press), and both the nonequilibrium method and the recovery method were developed by Theis (1935, pp. 519-524).

Flow method.--The flow method permits the determination of the coefficients of transmissibility and storage by measuring the changes in rate of discharge of a flowing well from an aquifer that is extensive, is homogeneous, and is uniformly thick. The formulae used in computing the values of transmissibility and storage are based on the assumption that the drawdown remains essentially constant during the test. The values of storage coefficient are accurate only to the extent that the effective radii are accurate. Accurate records of the depth and diameter of wells are not always available. Moreover, even if the values reported are correct, any caving of the walls of the uncased effective parts of the wells would make the true value of effective radius larger than reported. As the effective radius appears as r_w^2 in the denominator of the equation, it follows that when using values of r_w that are too large the resultant values of storage coefficient are too small, and vice versa.

For the test on well 29-68-20abd, the static artesian head was measured with an ink-well mercury gage (devised by Lohman)[2] after the well had been shut in for several days. The valve was opened, which allowed the well to discharge freely, and the discharge was measured, with the use of a calibrated container and a stop watch, at various times throughout the 3-hour duration of the test. The discharge was measured at gradually increasing intervals of time, ranging from 1 minute at the beginning to 30 minutes at the end of the test. The artesian head in the well was measured at intervals during the test and at the end of the test before the well was capped. These data were used to compute the coefficients of storage and transmissibility by the flow method. Measurements of the recovery of the artesian head by means of the ink-well mercury gage were made at recorded times for about 3 hours after the well was shut off. These data were used to compute the coefficient of transmissibility by the recovery method.

The effective radius of the well (r_w), in feet; the shut-in artesian head minus the flowing artesian head (s_w), in feet; the discharge measurements made during the test (Q), in gallons a minute; and the time that the discharge measurements were made after the well began flowing (t), in minutes, were used to compute the coefficient of transmissibility (T) and the coefficient of storage (S) by the formulae

$$T = \frac{229\ Q}{s_w\ [G\ (\alpha)]}$$

2 Lohman, S. W., 1947, Ink-well mercury gage for measuring artesian head: U. S. Geol. Survey Water Resources Branch, Proc. West-Central Branch Conference, April 9-12, Lincoln, Nebr., pp. 110-115 (mimeographed).

and

$$S = \frac{9.28 \times 10^{-5}\ Tt}{r_w^2\ \alpha}.$$

These equations also can be written

$$G\ (\alpha) = \left[\frac{229}{s_w\ T}\right] Q$$

$$\alpha = \left[\frac{9.28 \times 10^{-5}\ T}{r_w^2\ S}\right] t$$

The bracketed parts of the above equations are constant values for a given pumping test. Therefore, it is seen that G (α) is related to α as Q is related to t. By plotting values of the discharge (Q) against values of time (t) on logarithmic tracing paper (see fig. 6), using the same scale as that used to construct a type curve which was obtained by plotting G (α) against α, a curve of the observed data is developed that is similar to the type curve. Values of α and G (α) used in plotting the type curve were obtained from a table (Jacob and Lohman, in press). The graph of the observed data is superimposed on the type curve. By alining the coordinate axes of the two curves, a position for which most of the plotted points fall on the type curve is found by trial. An arbitrary match point then is chosen on the well curve for which values of Q and t are obtained, and from the corresponding point on the type curve the values of α and G (α) are obtained. Using data obtained in this manner, the values of T and S were computed as follows:

$$T = \frac{229 \times 118}{31.74 \times 0.0927} = 9{,}200 \text{ gallons a day per foot}$$

$$S = \frac{9.28 \times 10^{-5} \times 9{,}200 \times 10}{(0.167)^2 \times 1 \times 10^9} = 3 \times 10^{-7}$$

Nonequilibrium method.--After completion of the flow test, the artesian head in well 29-68-20abd was allowed to recover until it had reached approximately its original static position. The static artesian head was then determined for this well and also for well 29-68-20abb, situated 1,073 feet northwest from the test well. The valve was opened on the test well, and the well was allowed to discharge at a relatively constant rate of 78 gpm for 24 hours. The changes in artesian head were observed in the second well, 1,073 feet from the test well, during the 24-hour period of the test. The data obtained from

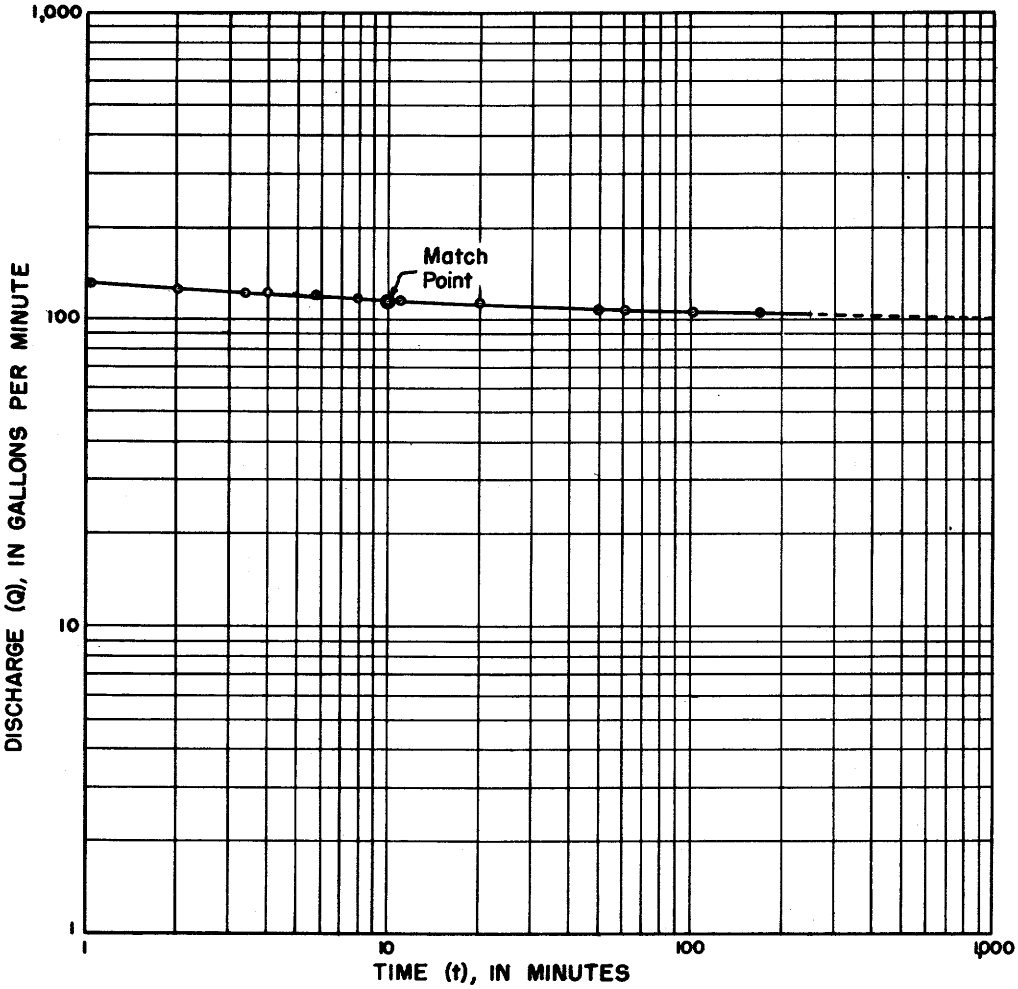

Figure 6.--Logarithmic graph of the discharge-time relationship for well 29-68-20abd.

this test were used to compute the coefficients of storage and transmissibility by the nonequilibrium method. At the end of this test, the valve was shut off and the rate of recovery of the artesian head in the test well was measured. These data were used to compute the value of transmissibility by the recovery method.

The nonequilibrium formula is based on the assumption that Darcy's law is analogous to the law of the flow of heat by conduction. It is assumed, also, that the water-bearing formation is homogeneous and isotropic, the formation has an infinite areal extent, the coefficient of transmissibility is constant at all places and all times, the water taken from storage is discharged instantaneously with decline in head, and that the discharge well has an infinitesimal diameter. The following formula is the equation for the drawdown of the water level in the vicinity of a discharging well:

$$s = \frac{114.6\,Q}{T} \int_{\frac{1.87\,r^2S}{Tt}}^{\infty} \frac{e^{-u}}{u}\,du$$

in which $u = \frac{1.87\,r^2S}{Tt}$;

s = drawdown, in feet, at any point in the vicinity of a well discharging at a uniform rate;
Q = discharge, in gallons a minute;
T = coefficient of transmissibility, in gallons a day per foot;

r = distance, in feet, from discharging well to point of observation;
S = coefficient of storage as a decimal fraction;
t = time, in days, well has been discharging.

The exponential integral of the above equation may be replaced by the term W(u) and the equation may be rewritten as follows:

$$s = \frac{114.6\ Q}{T} W(u)$$

transmissibility can be determined.

A graphical method of superimposition was used in solving the above equations. These equations can be written:

$$s = \left[\frac{114.6\ Q}{T}\right] W(u); \text{ and } \frac{r^2}{t} = \left[\frac{T}{1.87\ S}\right] u$$

The bracketed parts of the above equations are constant in value for a given flow or pumping test. In these equations, s is related to $\frac{r^2}{t}$ as W(u) is related to u. By

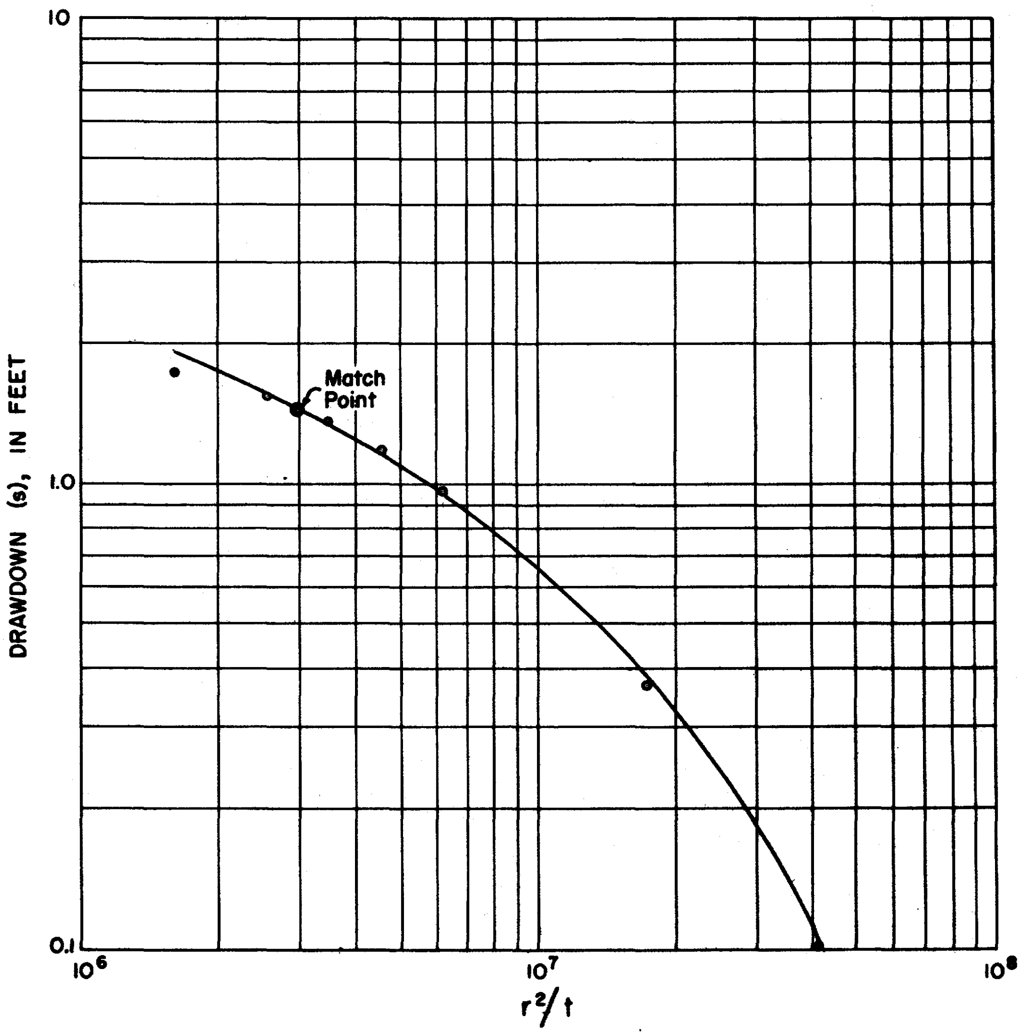

Figure 7.--Logarithmic graph of the drawdown of water level in well 29-68-20abb, 1,073 feet from the flowing well.

The values of W(u) for corresponding values of u between 9.9 and 10^{-15} are given by Wenzel (1942, pp. 88-89). It is seen from the above equations that, if the rate of drawdown at a given distance from the well under test is known, the coefficients of storage and plotting values of the drawdown (s) against values of $\frac{r^2}{t}$ on logarithmic tracing paper (see fig. 7), on the same scale as a type curve obtained by plotting W(u) against u, a curve of the observed data is developed that is similar to the type curve. The curve of the observed data, s against $\frac{r^2}{t}$, is superimposed on the type curve. An arbitrary match point then is chosen on the well curve for which values of s and $\frac{r^2}{t}$ are obtained, and from the corresponding point on the type curve the values of W(u) and u are obtained. Using the data from this test the values of T and S were computed to be 11,200 gallons a day per foot and 2.02 x 10^{-4}, respectively.

$$T = \frac{114.6 \times 78 \times 1.82}{1.45} = 11{,}200 \text{ gallons a day per foot}$$

$$S = \frac{0.10 \times 11{,}200}{1.87 \times 2.97 \times 10^6} = 2 \times 10^{-4}$$

Recovery method.--From his nonequilibrium formula, expressing the relation between the drawdown and the rate and duration of discharge of a well, Theis developed the following recovery formula:

$$T = \frac{264\ Q}{s} \log_{10} t/t'$$

in which

T = coefficient of transmissibility, in gallons a day per foot;
Q = discharge, in gallons a minute;
t = time since discharge began;
t'= time since discharge stopped;
s = residual drawdown of the well, in feet, at time t'.

Values of residual drawdown (s) to linear scale are plotted against corresponding values of the ratio of the time since discharge began and the time since discharge stopped (t/t') to logarithmic scale (fig. 8). A straight line is then drawn through these points. The value Δs for one log cycle of t/t' (for which the value of $\log_{10}$ t/t' is unity) is determined and T is computed from the simplified formula

$$T = \frac{264\ Q}{\Delta s}$$

in which Q is the weighted average discharge, in gallons a minute, during the period of flow for the flow test, and the relatively constant rate of discharge for the nonequilibrium test. The value of T computed by the recovery method was 11,900 gallons a day per foot, following the flow test; and 9,000 gallons a day per foot, following the nonequilibrium test.

Interference between wells

When an artesian well is pumped or allowed to flow, the cone of depression of the piezometric surface expands as discharge continues. In areas where wells are closely spaced, the decline of artesian head (piezometric surface) is greatly increased by interference between wells. The theoretical shape and extent of the cones of depression around a well (29-68-20abd) in the "Converse sand" of the Hartville formation that has been allowed to flow at the rate of 100 gpm for various periods of time is shown in figure 9. The curves have not been corrected for any boundaries that might affect their shape. The curves were computed by the nonequilibrium formula using the data obtained from the flow tests. As the drawdown is directly proportional to the rate of discharge, the theoretical drawdown for various rates of discharge also can be determined from the curves. The curves show that the theoretical drawdown decreases as the distance from the flowing well increases. For example, the theoretical drawdown, after flowing for 1 year at a rate of 100 gpm, would be 8 feet at a distance of 2,000 feet from the flowing well, and it would be 6.5 feet at a distance of 4,000 feet.

Specific capacity

The specific capacity of a well is defined as the number of gallons a minute that a well will yield for each foot of drawdown. A comparison of the specific capacity of wells is useful in estimating the relative efficiency of wells and the relative transmissibility of formations.

The specific capacities of the two wells tested were 3.1 gpm per foot of drawdown for well 29-68-20abd after flowing 30 minutes, and 4.8 gpm per foot of drawdown for well 29-68-20abb after flowing 30 minutes. The specific capacity for well 29-68-20abd was 2.6 gpm per foot of drawdown after the well had been flowing for 24 hours.

Alluvium

No tests were made to determine the water-bearing properties of the alluvium. Available logs and pumping data of wells drilled into this material indicate that it is very

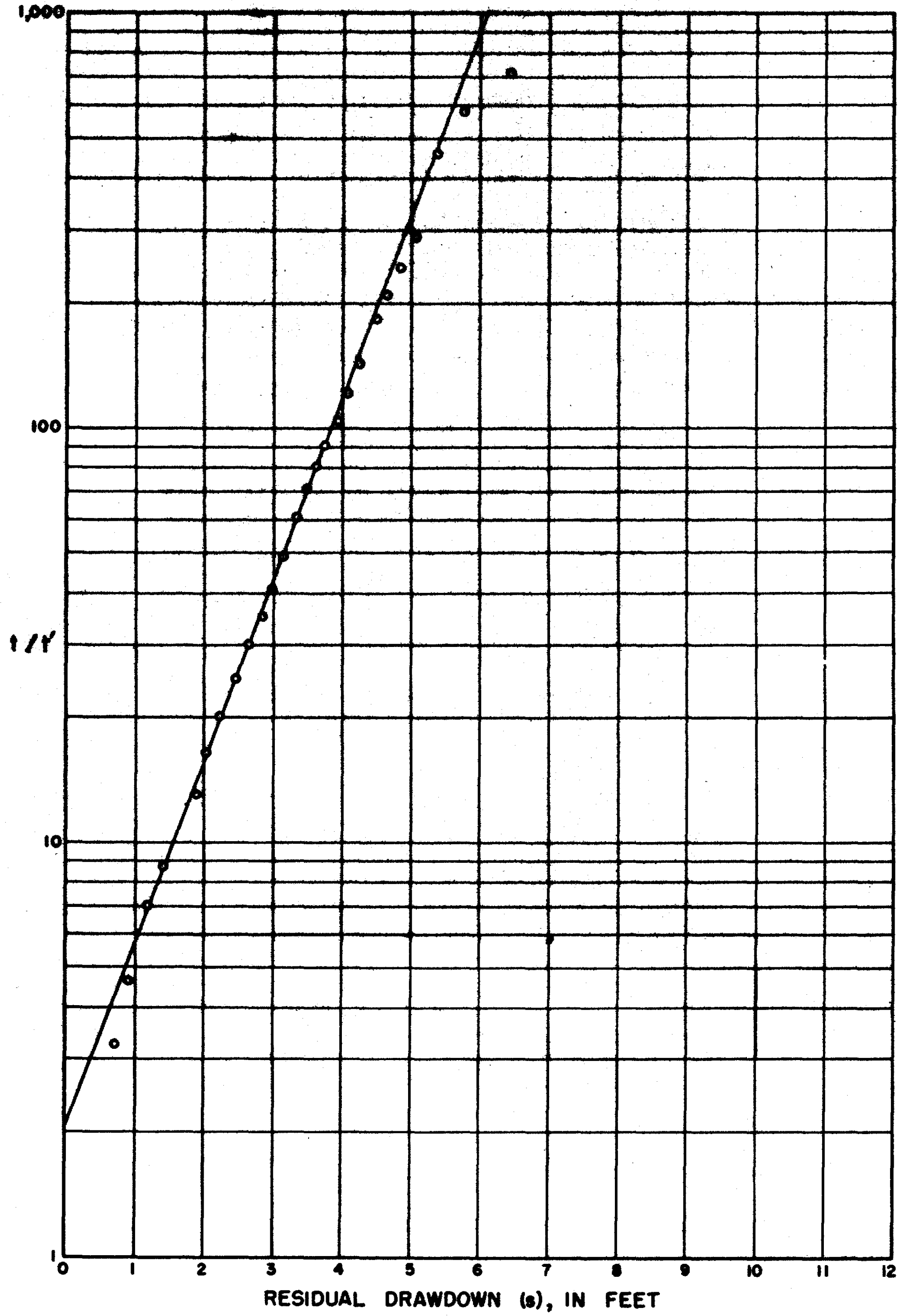

Figure 8.--Graph of the recovery of the water level in well 29-68-20abd after flowing 24 hours at a rate of 78 gpm.

permeable and that it would readily yield water to wells in places where a sufficient thickness of saturated material is available. Well 28-67-18bcc, in the alluvial fill of the North Platte River valley, has a reported discharge of 400 gpm. A battery of three wells in the valley of Cottonwood Creek in the SW$\frac{1}{4}$ sec. 20, T. 27 N., R. 68 W., is reported to have a combined yield of 1,500 gpm. Most of the wells in the alluvium yield only small quantities of water because they penetrate only the top few feet of the aquifer. These shallow wells are used only for domestic purposes and stock use and consequently do not develop the maximum amount of water possible.

valleys of Cottonwood, Bear, and Horseshoe Creeks, and of the North Platte River is within 10 to 20 feet of the land surface in most places. The depth to water in the upland interstream areas is controlled largely by the configuration of the land surface. The water table in these areas generally is encountered at greater depths than in the alluvial fill, and in some places it is more than 100 feet below the land surface. Depths to water level in wells are given in column 13 of table 6.

Ground water in a confined aquifer under artesian pressure will rise in tightly cased wells above the top of the aquifer to a level

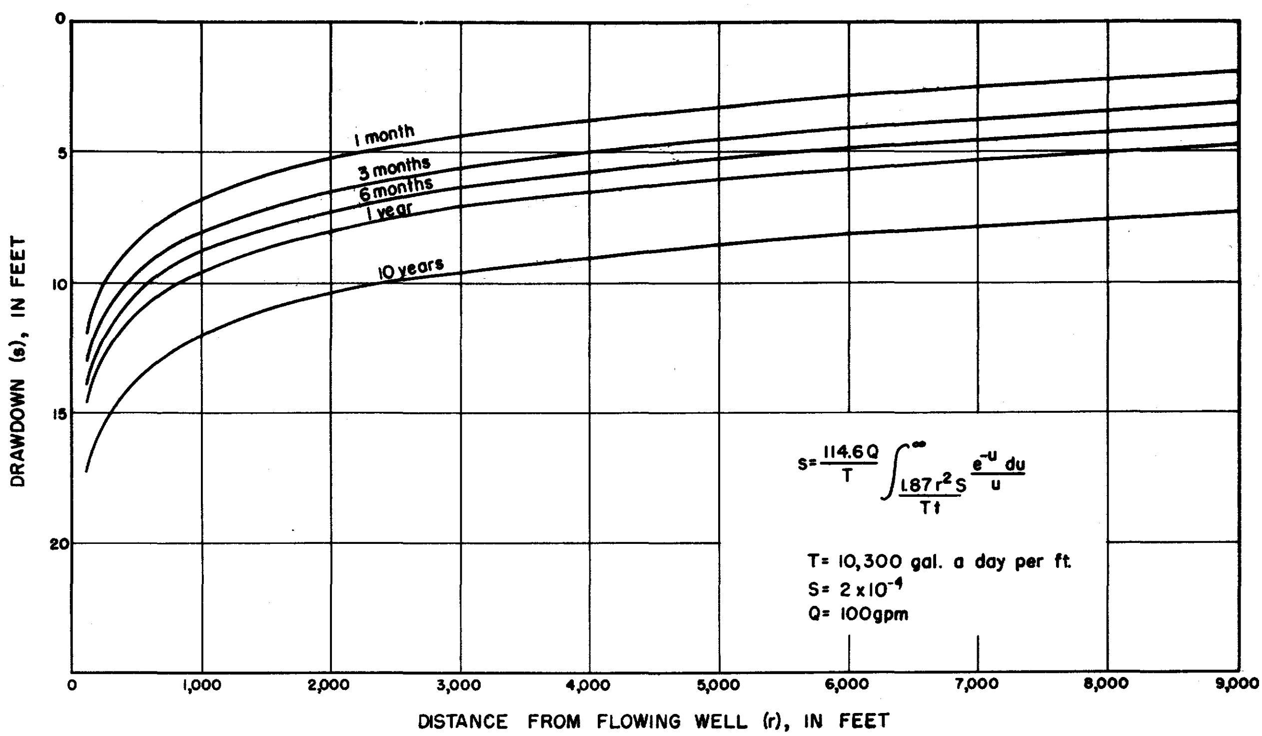

Figure 9.--Theoretical drawdown of well 29-68-20abd in "Converse sand" of the Hartville formation computed by the nonequilibrium formula.

Depth to ground water

The upper surface of the zone of saturation in permeable soil or rocks has been defined as the water table. The water table is not a static level surface but generally is a sloping surface that has many irregularities. These irregularities are caused by differences in the thickness and transmissibility of the water-bearing material and by differences in recharge to, and discharge from, the ground-water reservoir at different places. The water table in the alluvial fill of the

referred to as the piezometric surface. Water under artesian pressure in the "Converse sand" of the Hartville formation was encountered by three wells situated about 2 miles south of the town of Glendo. The measured shut-in head in well 29-68-20abd was 41 feet above the land surface, or about 446 feet above the top of the formation; in well 29-68-20abb, it was 33 feet above land surface. It is probable that artesian water occurs in the "Converse sand"throughout most of the area; sufficient data were not available, however, to determine the extent of this artesian aquifer or the shape and slope of the piezometric surface.

Fluctuations of water levels

Measurements were begun in November 1948 in seven wells selected for regular observation of the fluctuations of ground-water levels in the area; these are listed in table 2. From the data available it appears that there has been no significant change in water levels in the area in recent years; the measurements do indicate, however, a seasonal rise and decline. Measurements covering a period of several years would be needed to evaluate more fully the significance of the water-level fluctuations.

If extensive development of ground water for irrigation is undertaken in the future, considerable change in the water levels can be anticipated. In the alluvial fill water levels will decline in the vicinity of the wells that are pumped during the irrigation season, but they can be expected to recover during the nonirrigation season as the result of recharge from stream flow and from the surrounding upland areas. Also, the removal of water from the alluvial fill will cause a decrease in the flow of the streams and, during periods of heavy withdrawal, may cause them to cease flowing.

Withdrawal of water from additional wells in the "Converse sand" of the Hartville formation will cause a reduction of artesian head in the area. The theoretical drawdown curves (see fig. 9) indicate that the cone of depression in an artesian aquifer extends out a great distance from a producing well. It is important, therefore, that additional wells drilled in the "Converse sand" be placed as far apart as practicable.

Table 2.--Water levels in observation wells, in feet below land surface

Date	Water level	Date	Water level
27-68-20dcb1			
Nov. 2, 1948	15.72	Nov. 16, 1949	12.66
July 25, 1949	8.50	Dec. 9	13.19
Sept.13	12.19	Jan. 24, 1950	13.90
Oct. 27	14.51	Mar. 28	13.64

Table 2.--Water levels in observation wells, in feet below land surface--Continued

Date	Water level	Date	Water level
27-68-30acc			
Nov. 3, 1948	10.24	Nov. 16, 1949	9.78
July 26, 1949	7.15	Dec. 9	9.92
Sept.13	8.73	Jan. 24, 1950	9.08
Oct. 27	9.49	Mar. 28	10.17
28-68-2dcd			
Aug. 24, 1949	29.93	Dec. 9, 1949	33.94
Sept.16	29.75		
28-68-27abb			
July 30, 1949	29.62	Nov. 16, 1949	24.89
Sept.16	31.18	Dec. 9	28.39
Oct. 27	25.05	Mar. 30, 1950	30.02
28-68-27abc			
Aug. 30, 1949	5.62	Dec. 9, 1949	3.26
Sept.16	a 8.76	Jan. 24, 1950	3.27
Oct. 27	3.57	Mar. 28	3.17
Nov. 16	3.05		
29-68-21bbb2			
Nov. 4, 1948	35.16	Nov. 16, 1949	33.15
Aug. 23, 1949	31.17	Dec. 9	30.90
Sept.15	28.52	Jan. 24, 1950	32.45
Oct. 27	33.15	Mar. 28	31.47
29-68-21dad			
Nov. 5, 1948	8.23	Nov. 16, 1949	9.28
Aug. 23, 1949	9.53	Dec. 9	9.11
Sept.15	9.29	Jan. 24, 1950	9.84
Oct. 27	5.94	Mar. 28	11.89

a Well pumping.

Movement of ground water

Ground water moves from areas of high altitude or head to those of low altitude or head in the direction of the hydraulic gradient, and, if all other factors remain constant, the rate of movement is proportional to the gradient. In the Glendo-Wendover area the general direction of movement of unconfined ground water is from the upland areas of recharge to the stream valleys where the ground water flows into the alluvial fill, or is discharged through springs and seeps, or is lost by evaporation and transpiration. A schematic cross section of the valley of

Cottonwood Creek showing the inferred relationship between the water table and the surface topography is shown in figure 10. The ground water that moves into the alluvial fill of the stream valleys continues on downstream as underflow or is forced to the surface and is added to the flow of the streams. Horseshoe, Bear, and Cottonwood Creeks are effluent or gaining streams throughout most of their courses.

Recharge to the "Converse sand" of the Hartville formation occurs principally to the west and north, where many small streams, some of which are perennial, flow across the outcrops of the "Converse sand." Recharge of this type is demonstrated by the water loss from Cottonwood Creek where the creek flows over an outcrop of the Hartville formation. It was reported by L. C. Bishop, in a personal communication (1949), that a surface flow of 25 cfs was required at the upper end of a 1.3-mile stretch of the stream to assure a flow of water at the lower end. During periods of flow of less than 25 cfs, all the water was lost in the 1.3-mile stretch of the stream. A 960-foot tunnel was constructed in sec. 14, T. 27 N., R. 70 W. to bypass the area of maximum loss, thus making a larger flow of surface water available for use downstream.

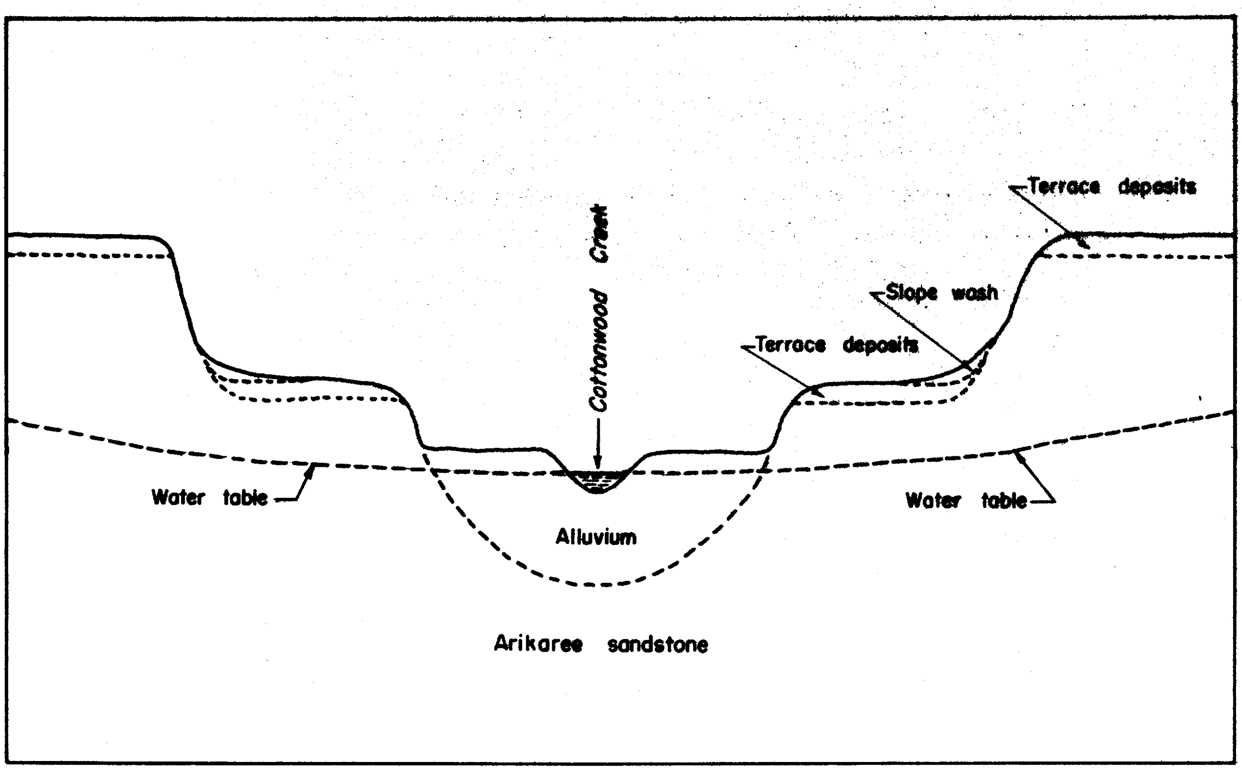

Figure 10.--Schematic cross section of Cottonwood Creek valley showing the inferred relation between the water table and the surface topography.

Ground-water recharge

Recharge to the unconfined ground-water reservoir is derived from precipitation, either in the stream valleys or on the adjacent upland areas. Part of the precipitation in the area is removed as runoff, some is used by plants, a small part percolates to the water table, and the remainder is lost by evaporation. Water that percolates downward to the zone of saturation in the upland areas moves laterally toward the stream channels, where it emerges as surface flow, moves down valley in the alluvial fill, or is lost by evaporation or transpiration.

Ground-water discharge

Water is discharged from the alluvial fill by evaporation and transpiration, through wells, and as surface flow in the stream channels; no attempt has been made to determine the amounts of water discharged in the Glendo-Wendover area by these various processes.

The amount of ground water discharged by evaporation and transpiration varies with the season; the rates of both are greatest during the growing season when the temperatures are highest. The amount of water discharged by these processes is probably large, as the water table is near the surface, and a large part of the valleys is covered by a luxuriant growth of cottonwood and willow.

Five wells drilled in the valley fill supply ground water for irrigation of a few small farms and gardens. The total amount of water pumped annually for irrigation probably does not exceed a few hundred acre-feet.

Ground water is discharged from the "Converse sand" of the Hartville formation through three flowing wells whose combined flow is about 400 gpm. These wells are allowed to flow only a small part of the time, and it is estimated that the total annual discharge of the wells is only about 100 acre-feet. Additional ground water probably is discharged by underground leakage into the Platte River.

Possibilities of developing additional irrigation supplies from wells

The amount of water that can be withdrawn from a ground-water reservoir without causing excessive permanent lowering of the water table depends upon the capacity of the reservoir and the recharge to it. When water from a ground-water reservoir is continuously pumped faster than it is being recharged, the water levels in the wells will decline and the supply eventually will be depleted. Water in excess of the rate of recharge can be pumped from a ground-water reservoir for short periods of time without permanently depleting the reservoir if there is sufficient recharge during the nonpumping period to replace the water removed. Under artesian conditions the amount of water that can be withdrawn generally is dependent upon the ability of the aquifer to transmit water; therefore, it is important to space artesian wells as far apart as practicable in order to allow each well to draw from a maximum cross-sectional area of the aquifer.

The best localities for successful irrigation wells are in the alluvial fill of parts of the North Platte River valley and at the lower ends of Cottonwood, Bear, and Horseshoe Creek valleys, where the thickness of the alluvium is the greatest. Wells that yield 500 to 1,000 gpm probably could be developed in some places where there is a substantial saturated thickness of alluvium. Test drilling probably would be profitable to determine the most favorable areas and to obtain information that would be useful in determining the best type of well construction. Pumping tests should also be made in order to determine the yield, the proper spacing of wells, and the safe yield of the aquifer.

Irrigation wells of smaller yield probably could be developed from the "Converse sand" of the Hartville formation in parts of the area; these wells could be used to irrigate some of the small plots of land along the stream valleys. Considerable test drilling would be necessary to determine the lateral extent and the depth of the formation, although it is likely that the "Converse sand" underlies a large part of the area. Additional wells that yield 100 gpm, or more, probably could be developed in this "sand." Water in the formation is confined under artesian pressure; hence it would rise appreciably above the point at which it is encountered, and in some parts of the area it would flow at the land surface. In areas where the water is not under sufficient pressure to flow at the surface, water could be obtained by pumping.

Rocks that underlie the area at greater depth also may contain water under artesian pressure, but considerable deep test drilling would be necessary to prove the existence of these aquifers.

CHEMICAL CHARACTER OF THE GROUND WATER

Introduction

A study of the chemical character of the ground water in the Glendo-Wendover area was made to determine its suitability for domestic and proposed irrigation uses. This report is based on the chemical analyses of samples from 13 representative wells and 2 springs and on the analyses of 4 samples from streams that traverse the area. The samples were collected in the fall of 1949 by J. R. Rapp. Most of the ground-water samples were from wells adjacent to water courses. (See fig. 11.) Four of the wells that were sampled supply water for irrigation, and the remainder are used for domestic and stock purposes or are observation wells. Because most of the wells have been in use for several years, the analyses are considered to reflect expressed in parts per million in table 3 and in equivalents per million in table 4. In both tables the analyses are grouped as follows: analyses of spring water; water from wells drawing from the slope wash, the alluvium, the Brule formation, and the "Converse sand" of the Hartville formation; and surface water. The analyses of representative waters from the several sources are shown graphically in figure 12.

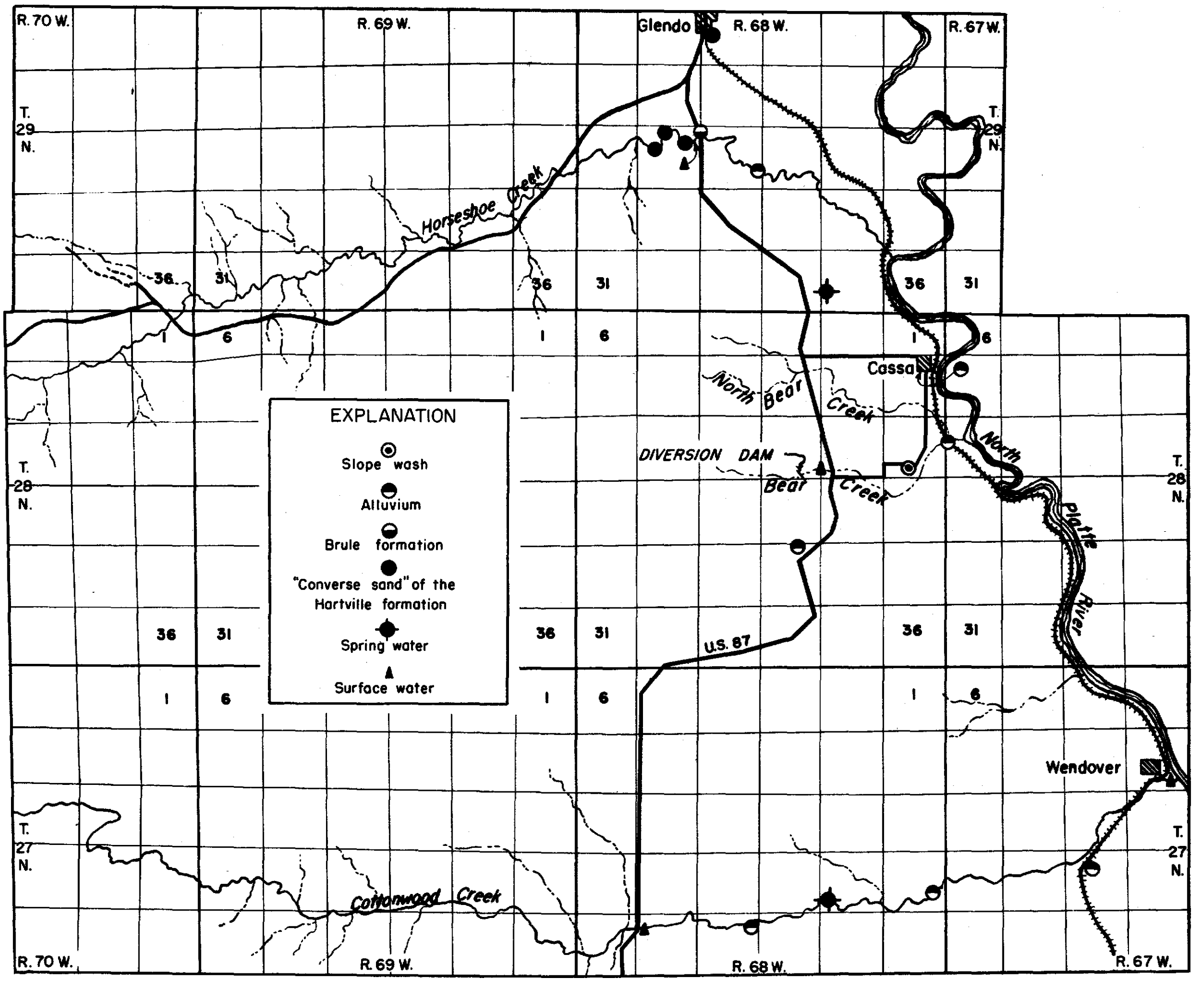

Figure 11.--Map of Glendo-Wendover area, Wyoming, showing location of ground and surface waters sampled for chemical analysis.

conditions that are characteristic of the ground-water sources sampled. The quality of the water, however, may be significantly altered periodically by such factors as the draft on the well, the quality and quantity of recharge to the aquifer, and the mixing of waters from one or more water-bearing zones.

Results of analyses of water samples collected in the Glendo-Wendover area are

Springs

Samples were obtained from two springs in the Glendo area. Spring 27-68-23ccc is believed to originate in the alluvium and spring 29-68-35cbb, from the Cloverly formation. Both waters show a moderately low mineralization, with 334 and 296 ppm dissolved solids, respectively. The sample from the spring originating in the deeper Cloverly

Table 3.--Chemical analyses, in parts per million, and related physical measurements of ground and surface waters

Location of sample	Date of collection (1949)	Depth of well (feet)	Temperature (°F)	pH	Specific conductance (micromhos at 25°C)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$ Total	Hardness as $CaCO_3$ Noncarbonate	Percent sodium
Springs																					
27-68-23ccc	9-25	...	54	7.5	571	27	0.24	73	12	27	3.2	336	8.0	4.0	0.2	2.0	....	334	232	0	20
29-68-35cbb	9-13	...	53	7.7	515	19	.12	49	7.5	40	8.0	296	4.0	3.6	.2	1.7	0.35	296	154	0	35
Slope wash																					
28-68-13dcb	7-20	23	53	8.6	434	19	0.08	67	8.7	19	6.0	a/ 277	9.2	4.0	0.4	1.8	0.20	284	203	0	16
Alluvium																					
27-67-21bda	9-14	19	56	7.5	511	47	0.42	63	4.5	24	8.8	232	22	7.6	0.2	10	0.40	332	176	0	22
27-68-24dab	9-15	16	56	7.5	558	31	.20	61	7.7	45	3.2	316	12	5.0	.2	.8	.40	342	184	0	34
27-68-28aac	9-15	34	50	7.6	486	27	.20	68	7.5	20	3.2	274	20	5.0	.2	1.9	.40	292	201	0	18
28-67-18bcc	1-24	64	52	7.5	449	39	.05	70	6.7	15	7.2	276	9.6	3.0	.2	4.7	.20	302	202	0	13
28-68-12adc	9-15	28	53	7.6	2,010	19	2.8	259	49	84	5.6	286	252	27	.2	622	.10	1,460	848	613	18
28-68-27abc	9-13	12	57	7.6	515	44	.44	72	3.0	31	2.4	302	2.4	4.8	.2	.8	.40	330	192	0	26
29-68-21dad	9-14	58	52	7.5	939	38	1.2	153	17	34	2.4	252	296	3.0	.4	1.2	.10	692	452	245	14
Brule formation																					
29-68-21bbb2	9-14	94	52	7.6	901	29	0.26	113	12	52	8.0	208	236	24	0.2	5.9	0.35	646	332	161	25
"Converse sand" of the Hartville formation																					
29-68-9bcd	....	793	..	7.8	439	28	0.12	43	20	21	5.6	234	33	4.0	1.2	1.1	0.20	248	190	0	19
29-68-20abb	9-21	410	54	8.0	414	18	.12	46	11	21	3.2	244	1.6	2.6	.2	1.6	.35	222	161	0	22
29-68-20abd	7-20	442	54	7.8	408	21	.08	45	15	18	4.8	240	19	4.0	.4	.7	.13	234	174	0	18
29-68-20bac	9-22	b/ 460	54	7.8	416	15	.20	45	13	18	3.2	240	3.2	2.6	.2	1.5	.30	226	166	0	19
Surface waters																					
27-67-10dbc c/	9-25	...	..	7.9	569	39	d/ 0.04	67	12	39	4.0	324	34	5.0	0.4	1.6	0.20	364	217	0	28
27-68-29bbc c/	9-25	...	..	7.9	434	31	d/ .04	56	14	14	5.6	288	4.0	1.4	.4	2.0	.10	280	197	0	13
28-68-14cbb e/	9-25	...	..	8.2	427	37	d/ .04	57	10	17	6.4	f/ 270	2.4	1.0	.4	.8	.10	266	183	0	16
29-68-20ada g/	9-25	...	..	7.7	875	38	d/ .04	141	16	29	13	214	296	3.0	.8	.7	.10	650	418	243	13

a/ Includes equivalent of 20 ppm carbonate (CO_3).
b/ Drilled to 1,296 feet but plugged back to 460 feet.
c/ Cottonwood Creek.
d/ Dissolved iron.
e/ Bear Creek.
f/ Includes equivalent of 14 ppm carbonate (CO_3).
g/ Horseshoe Creek.

Table 4.--Chemical analyses, in equivalents per million, of ground and surface waters

Location of sample	Calcium (Ca)	Magnesium (Mg)	Sodium plus potassium (Na+K)	Sulfate (SO_4)	Chloride plus nitrate ($Cl+NO_3$)	Bicarbonate (HCO_3)
			Springs			
27-68-23ccc	3.62	0.99	1.24	0.17	0.15	5.53
29-68-35cbb	2.47	.62	1.96	.08	.14	4.83
			Slope wash			
28-68-13dcb	3.29	0.71	0.96	0.19	0.16	4.61
			Alluvium			
27-67-21bda	3.09	0.37	1.25	0.46	0.38	3.87
27-68-24dab	3.01	.62	2.02	.25	.16	5.24
27-68-28aac	3.44	.63	.96	.42	.18	4.43
28-67-18bcc	3.50	.55	.83	.20	.17	4.51
28-68-12adc	12.92	4.03	3.79	5.25	10.80	4.69
28-68-27abc	3.56	.25	1.39	.05	.16	4.99
29-68-21dad	7.58	1.39	1.53	6.21	.13	4.16
			Brule formation			
29-68-21bbb2	5.65	0.99	2.47	4.91	0.79	3.41
			"Converse sand" of the Hartville formation			
29-68-9bcd	2.10	1.64	1.04	0.71	0.19	3.88
29-68-20abb	2.28	.91	.98	.03	.11	4.03
29-68-20abd	2.28	1.24	.91	.40	.14	3.89
29-68-20bac	2.23	1.06	.85	.07	.10	3.97
			Surface waters			
27-67-10dbc	3.37	0.99	1.81	0.71	0.19	5.27
27-68-29bbc	2.85	1.18	.76	.08	.09	4.62
28-68-14cbb	2.83	.82	.90	.05	.06	4.44
29-68-20ada	6.99	1.31	1.58	6.21	.14	3.53

formation is considerably softer, with a hardness of 154 ppm; it also has 35 percent sodium, the highest sodium ratio found in the ground waters studied. All the hardness is of the carbonate or temporary type, a characteristic of all except three of the ground waters sampled in the Glendo-Wendover area. It is significant (see table 3) that a somewhat proportionate increase in hardness, as $CaCO_3$, occurs with increase in dissolved solids concentration; this indicates similarity in the chemical character of the waters from the various geologic sources. Concentrations of iron, fluoride, nitrate, and boron are low.

Slope wash

Although the slope wash is not an important aquifer in this area, one sample of water from this source was obtained for chemical analysis from well 28-68-13dcb, 23 feet deep. The analysis showed the sample to contain 284 ppm dissolved solids (mostly calcium bicarbonate) and to have a hardness of 203 ppm. The percentage of sodium was 16.

Alluvium

Seven samples were obtained from wells drawing water from the alluvium. Although generally similar in chemical character to water in the "Converse sand" of the Hartville formation and to other ground waters in the area, the waters in the alluvium have a wider range in concentration of dissolved solids. The dissolved solids ranged from 292 to 1,460 ppm; five of the seven samples, however, contained less than 350 ppm dissolved solids. Total hardness ranged from 176 to 848 ppm, and the percentage of sodium was low, ranging from 14 to 34. With one exception, concentrations of chloride, fluoride, boron, and nitrate were low. The extremely high nitrate of 622 ppm in the sample of water from well 28-68-12adc (28 feet deep) was probably due to surface seepage, inasmuch as all other samples had 10 ppm nitrate, or less. High nitrate in water, particularly when present with an appreciable quantity of chloride, are usually indicative of previous contamination by sewage or barnyard drainage. The chloride content (27 ppm) of the sample from well 28-62-12adc is not high, but it exceeds that found in the other samples. Increased calcium, magnesium, sodium, and sulfate content is further evidence of surface inflow. The sample was reported to contain roots, and this evidence, together with a high-iron content of 2.82 ppm, may indicate deterioration of the well casing. Because the sample is not representative of other water from the formation, the analysis is not considered in the illustrations.

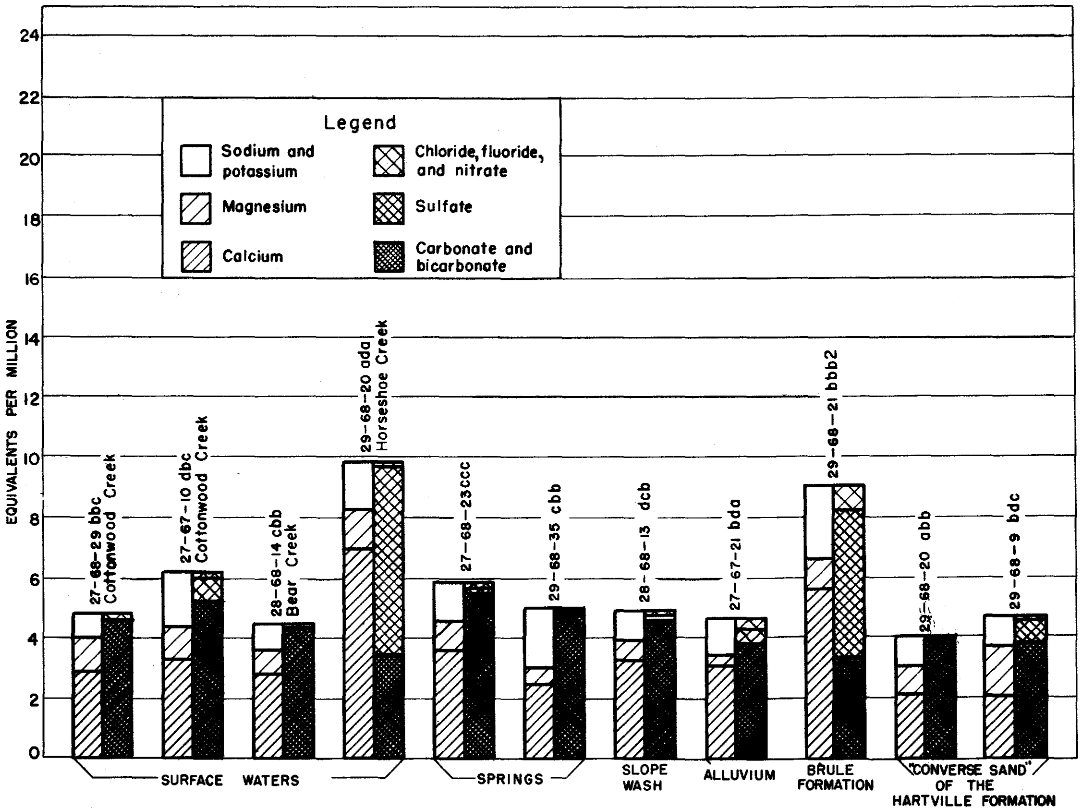

Figure 12.--Principal mineral constituents of representative ground and surface waters, Glendo-Wendover area, Wyoming.

Brule formation

The water in the Brule formation is represented by a single sample from well 29-68-21bbb2, adjacent to Horseshoe Creek. This sample of water, obtained from a depth of 94 feet, had a comparatively high concentration of 646 ppm dissolved solids and a hardness of 332 ppm. The percentage of sodium of 25 is low, and concentrations of fluoride, nitrate, and boron were not appreciably different from those present in other samples of ground water from the area.

"Converse sand" of the Hartville formation

Four samples were obtained from wells tapping the "Converse sand" of the Hartville formation, an important source of ground water in the area. The analyses show a relatively low mineral content, with dissolved solids ranging from 222 to 248 ppm.

The samples from the Hartville formation showed a marked uniformity in both chemical character and concentration. The temporary (carbonate) hardness ranged from 161 to 190 ppm. The percent of sodium ranged from 18 to 22. However, concentrations of sulfate (33 ppm) and fluoride (1.2 ppm) in the deep well 29-68-9bcd were somewhat higher than in the other samples from the "Converse sand." Boron concentrations were less than 0.4 ppm.

Relation of chemical quality of the ground and surface water

There is a marked similarity in the chemical character of the base flow of streams sampled in the area to that of shallow aquifers sampled adjacent to the streams. This would be expected inasmuch as the water, prior to reaching the stream, percolates through one or more of the stratigraphic units. This relationship between ground water and base flow of streams is also consistent with the areal geology. At periods of high stream flow, the chemical composition of the waters in the stream is altered by surface runoff and at such times the relationship between ground water and surface water may not be apparent.

Four surface-water samples were collected in the area, and the analyses, in parts per million, are shown in table 3. The dissolved solids ranged from 266 ppm in Bear Creek to 650 ppm in Horseshoe Creek. The analysis of a single sample from Horseshoe Creek showed a high sulfate concentration of 296 ppm; this is identical to that found in a sample from a nearby well (29-68-21dad) which taps the alluvium. The source of this sulfate is probably the "gypsum and red shale sequence" below the Chugwater formation, which crops out in the upper course of the stream (T. 29 N., R. 69 W.).

A downstream increase in mineral content occurs in Cottonwood Creek within a distance of about 10 miles, with the percentage of sodium increasing twofold from 13 to 28 and sulfate increasing from 4 to 34 ppm. The analysis of the sample taken downstream, which showed 280 ppm of dissolved solids and a hardness of 197, compares closely with the analyses of waters from three wells in the alluvium adjacent to the stream. These analyses show dissolved solids concentrations of 332, 342, and 292 ppm and hardness values of 176, 184, and 201 ppm, respectively.

The single sample from Bear Creek had the lowest mineralization of the four surface samples, 266 ppm dissolved solids, 183 ppm hardness, and 16 percent sodium. These results are similar to those obtained in samples from the slope wash (well 28-68-13dcb) and alluvium (well 28-67-18bcc) adjacent to the stream.

Relation of quality of water to use

Water from 7 of the 15 wells and springs sampled is used for domestic purposes. The water from these wells, together with the other samples of ground water, can be evaluated for domestic use on the basis of the United States Public Health Service (1946, pp. 371-384) recommendations for public supplies, which include the following maximum limits (abridged) of chemical substances in natural or treated waters:

Constituent	Maximum parts per million
Iron and manganese together........	0.3
Magnesium.........	125
Sulfate...........	250
Fluoride..........	1.5
Chloride..........	250
Dissolved solids..	500 (1,000 permitted)

Of the 15 samples of water, 13 meet these requirements, but 2 samples, which are from wells being used for domestic purposes, have higher concentrations of sulfate and iron. The excessive amount of iron may cause stains on plumbing fixtures and laundered fabrics, and it may discolor the water.

Among the various methods of classifying water for irrigation is one devised by Wilcox (1948, pp. 5-6) that provides a quality rating on the basis of electrical conductivity (an approximate measure of the total ions in solution) expressed in micromhos at 25°C and percent sodium (ratio of reactant value of sodium to total cations).

The specific conductance of 14 of the samples analyzed is plotted against its corresponding value of percent sodium on the empirical diagram constructed by Wilcox. (See fig. 13.) In this diagram the lower margin is a scale of conductivity which is subdivided into four classes on the basis of increase in concentration and corresponding decrease in quality. The left margin is a scale of percent sodium from 0 to 100. The upper limit in any class, other than "unsuitable," is defined by the percentage of sodium in the analysis, and as the total concentration increases, the sodium limit for any class becomes lower. Thus, a water analysis having a percentage of sodium of 70 and a specific conductance of 500 micromhos rates class 1, "excellent to good," whereas an analysis having a percentage of sodium of 70 and a specific conductance of 750 micromhos rates only class 3, "permissible to doubtful." The plotted points for the analyses of water sampled in the Glendo-Wendover area fall largely into class 1, "excellent to good;" the samples of water from the "Converse sand" of the Hartville formation fall consistently into this class. The concentration of boron is also considered in the evaluation of water for irrigation; the waters analyzed in this study are low in boron, the greatest concentration (0.4 ppm) falling well below the maximum recommended limit.

Examination of the analyses expressed in equivalents per million (see table 4) reveals the bicarbonate-total anion ratio to be very high; in most analyses the bicarbonate ion exceeds the sum of the calcium and magnesium ions. This indicates that these waters when applied to the lands and concentrated as a result of evapotranspiration are likely to contain higher proportions of sodium carbonate and the pH of the water will increase. A high sodium ratio and high pH are detrimental to the soil structure. Although the total mineralization of the water is low, this alkaline characteristic of the water makes advisable the periodic testing of soil and water after irrigation is begun in order to determine when remedial action may be needed.

CONCLUSIONS

Unconfined ground water is contained in the alluvial fill of the stream valleys in sufficient quantities for irrigation. Wells that yield 500 to 1,000 gpm probably could be developed from the alluvium of the North Platte River valley and of the lower ends of Cottonwood, Bear, and Horseshoe Creek valleys, where the saturated thickness of the alluvium is greatest.

Further detailed investigation of the shallow ground-water conditions should be made preliminary to the construction of irrigation wells, inasmuch as the present reconnaissance investigation was not designed to give the detailed data required for the proper location and construction of wells. The selection of sites for irrigation wells should be preceded by adequate test drilling to determine the most favorable areas for development of ground-water supplies. Pumping tests should also be made in order to determine the yield and the proper spacing of wells and to assist in determining the safe yield of the aquifer. The pumping-test data should be supplemented by laboratory determination of the hydrologic properties of the alluvium. If extensive development of ground water for irrigation is undertaken in the future, a considerable decline in the water levels can be anticipated; consequently, periodic measurements of the water levels in observation wells should be continued in order to observe the changes in water levels and, thus, to warn against the possibility of overdevelopment. The removal of water from the alluvial fill will cause a decrease in the flow of the streams and, during periods of heavy withdrawal, may cause them to cease flowing in places.

Yields of 100 gpm or more could be obtained from wells in the "Converse sand" of the Hartville formation. Water in this formation is confined under artesian pressure; hence it would rise above the point at which it is encountered and, in some parts of the area, would flow at the surface. Considerable test drilling would be necessary to determine the lateral extent and depth of the formation, but it is apparent that the "Converse sand" underlies a large part of the area.

Rocks that underlie the area at greater depth also may contain water under artesian pressure, but considerable deep test drilling would be necessary to prove the existence of these aquifers.

Ground waters in the Glendo-Wendover area generally are of moderate mineralization; most of the samples analyzed showed less than

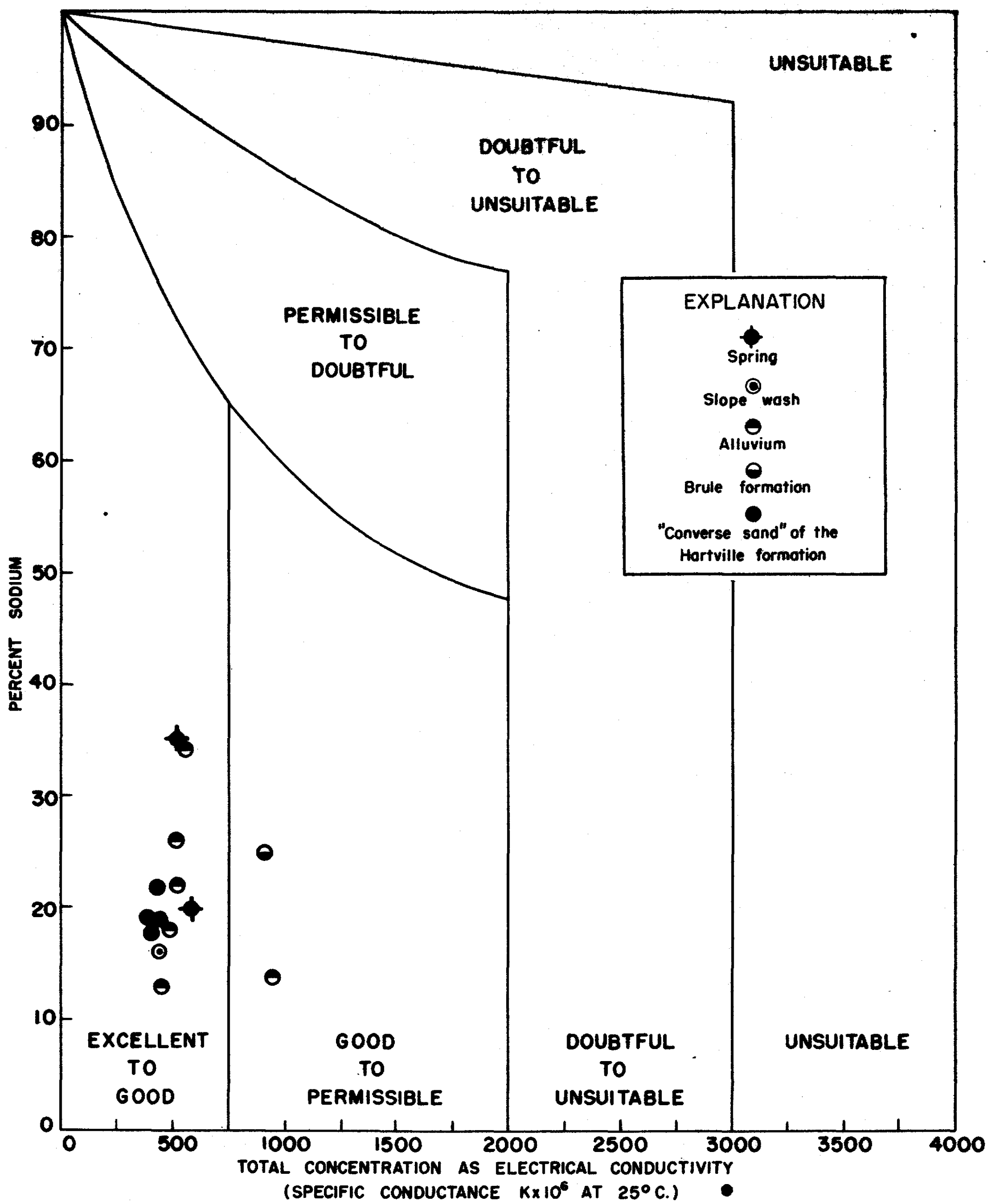

Figure 13.--Classification of waters in the Glendo area for irrigation use (after Wilcox).

400 ppm dissolved solids. The waters from all the geologic sources are hard and reflect the presence of calcium carbonate in the water-bearing formations. The percentage of sodium is low, generally not exceeding 30. Samples from shallow aquifers adjacent to Horseshoe Creek contain appreciable quantities of sulfate, apparently brought in from the "gypsum and red shale sequence" and the Chugwater formation, which crops out in the western part of the area.

Waters from the "Converse sand" of the Hartville formation are of good quality and contain less dissolved solids than waters from the alluvium. Most of the waters sampled are satisfactory for general domestic use, and, because of low percentage of sodium and moderately low content of dissolved solids, they are satisfactory for irrigation.

WELL RECORDS

Logs of wells

Logs of wells were obtained from well drillers and from the well owners. These logs are presented in table 5. Because it was impossible to verify the logs by examination of the drilling samples, they are presented with the driller's terminology unchanged. It is believed, however, that the logs are reasonably accurate and that they give a fairly good description of the materials penetrated.

Table 5.--Drillers' logs of wells in the Glendo-Wendover area, Wyoming

	Thickness (feet)	Depth (feet)
27-69-25abbl		
Soil and clay.............	20	20
Rock, cement.............	40	60
Rock, hard................	2	62
Gravel (water)...........	11	73
28-67-18bcc		
Soil.....................	22	22
Sand and gravel..........	40	62
Chalk rock...............	2	64
28-68-12aac		
Soil and sand............	24	24
Gravel (water)...........	16	40
Sand, fine...............	2	42

Table 5.--Drillers' logs of wells in the Glendo-Wendover area, Wyoming--Continued

	Thickness (feet)	Depth (feet)
29-68-9bcd		
Clay, bentonitic, brown; and coarse sand..........	80	80
Clay, brown and gray......	110	190
Clay, brown; and sand.....	40	230
Clay, sandy, brown and gray....................	160	390
Clay, sandy, white, brown, and gray................	15	405
Clay, sandy, white and brown....................	25	430
Clay, bentonitic, vari-colored.................	90	520
Clay, brown and gray; some gypsum and sand..........	10	530
Clay, orange; some sand...	15	545
Clay, chalky white, orange; some fine sand...........	15	560
Clay, brown, orange; some fine sand................	15	575
Sand, fine, red; shale, orange; and anhydrite....	40	615
Shale, red; and anhydrite.	15	630
Lime, purple; some fine sand....................	20	650
Sand, red, yellow; some shale, red, gray; and an-hydrite..................	25	675
Anhydrite, white..........	8	683
Sand, white (contains water)..................	7	690
Anhydrite, white..........	35	725
Lime, pink; and white an-hydrite.................	5	730
Anhydrite, white..........	63	793
29-68-20abb		
White River group, pink...	225	225
"Red beds"................	25	250
"Ledge," hard, red[1/]......	6	256
Shale, red................	24	280
"Ledge," red..............	2	282
Sand, red.................	28	310
Sand, yellow..............	4	314
Shale, red................	42	356
Limestone, hard...........	2	358
Sandstone, ledgy, white...	40	398
Sandstone, soft, white (contains water under artesian pressure).......	10	408
"Ledge," hard............	2	410

1/ "Ledge" in drillers' logs refers to an unusually hard stratum.

Table 5.--Drillers' logs of wells in the Glendo-Wendover area, Wyoming--Continued

	Thickness (feet)	Depth (feet)
29-68-20abd		
Gravel and sand............	37	37
White River group..........	97	134
Lime shell.................	4	138
Shale, red.................	18	156
Lime shell.................	3	159
Shale, red.................	7	166
Lime shell.................	2	168
Shale, red.................	12	180
Lime shell, hard...........	4	184
Clay.......................	7	191
Shale, red.................	18	209
Shell, hard................	6	215
Sandstone, hard, red (water)...................	35	250
Shale, tan.................	15	265
Shale, red.................	25	290
"Ledge," hard, red.........	5	295
Shale, red.................	9	304
"Ledge," hard, red.........	2	306
Shale, red.................	52	358
Sand, red..................	8	366
Shale, ledgy, red..........	37	403
Limestone..................	2	405
Sandstone, white (water)...	9	414
Sandstone, yellow..........	28	442
29-68-20bac		
Soil and gravel (water)....	36	36
Shale, gray................	68	104
Limestone shells1/.........	61	165
Shale, sandy, gray and pink	45	210
Chugwater formation, pink..	130	340
Sand, white (water under artesian pressure)........	9	349
Limestone caprock, very hard; contains shells.....	1	350
Sand, light-brown..........	110	460
"Red bed," sandy, pink and red; with lime shells.....	180	640
Sand, white (water and gas)	3	643
"Red bed," pink; with lime shells....................	264	907
"Red bed," light-pink......	136	1,043
Limestone shells, sandy; contains some water.......	13	1,056
"Red bed," very sticky; red and pink..................	74	1,130
"Red bed," sandy, red; with lime shells..............	166	1,296
29-68-21bbb2		
Soil.......................	20	20
Sand.......................	25	45
Shale......................	49	94

1/ "Shells" in drillers' logs refers to thin lime-cemented strata.

Well inventory

Records were obtained of 62 wells and springs in the area. The locations of these wells are shown on plate 1. Available pertinent data on all wells shown on the map are given in table 6. In many cases it was not possible to obtain measurements of the depth of the well or of the depth to water in a well, and the data for such a well are based on the memory of the owner or driller.

Table 6.--Records of wells and springs in the Glendo-Wendover area, Wyoming

Well number: See text for description of well-numbering system.
Type of supply: Dn, driven well; Dr, drilled well; Du, dug well; Sp, spring.
Depth of well: Measured depths are given in feet and tenths below measuring point; reported depths are given in feet below land-surface datum.
Type of casing: C, concrete, brick, or tile pipe; N, none; P, iron or steel pipe; W, wood.
Character of material: Cl, clay; G, gravel; S, sand; Sl, siltstone; Ss, sandstone.
Geologic source: Ch, Hartville formation ("Converse sand"); Kc, Cloverly formation; Po, Opeche formation; Qa, Quaternary alluvium; Qs, Quaternary slope wash; Ta, Arikaree sandstone; Tb, Brule formation.
Method of lift (first letter): C, cylinder; Cf, centrifugal; F, natural flow; J, jet; N, none; T, turbine.
Type of power (second letter): E, electric motor; G, gasoline engine; H, hand operated; W, windmill.
Use of water: D, domestic; I, irrigation; In, industrial; N, none; O, observation; P, public supply; S, stock.
Measuring point: Bpb, bottom of pump base; Ls, land surface; Tbc, top of board cover; Tc, top of casing; Tcu, top of curb.
Depth to water: Measured depths to water level are given in feet, tenths, and hundredths; reported depths are given in feet.
Remarks: Ca, sample collected for chemical analysis; D, discharge in gallons a minute; E, estimated; M, measured; R, reported; DD, drawdown in feet while discharging at the preceding rate; L, log of well given in table 8; T, temperature in degrees Fahrenheit.

Well number	Property owner or tenant	Type of supply	Depth of well (feet)	Diameter of well (inches)	Type of casing	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift	Use of water	Measuring point: Description	Measuring point: Distance above (+) or below (-) land surface (feet)	Distance to water level above (+) or below (-) measuring point (feet)	Date of measurement	Remarks
27-67-10dba1	C. B. & Q. RR. Co.	Dr	42	6	P	S,G	Qa	C,H	In	Ls	....	-22	10-20-49	
10dba2	E. E. Ragan.......	Dr	60	6	P	S,G	Qa	C,E	D	Ls	....	-40	10-20-48	
10dba3	.....do...........	Du,Dn	8	...	N	S,G	Qa	C,W	N	Tcu	0	-5.91	11-12-48	
10dbd	C. B. & Q. RR. Co.	Du	.....	120	C	S,G	Qa	C,E	In	Ls	....	-11	1945	D300R
21bbb	F. T. Stanfield...	Du,Dn	15	36	W	S,G	Qa	C,W	D,S	Bpb	0	-7.82	11- 4-48	
21bda	W. A. Herman......	Du	19	36	C	S,G	Qa	C,W	S	Tcu	+.5	-7.35	9-11-49	T56, Ca
27-68-20cdc1	S. Willadsen......	Dr	18	10	P	S,G	Qa	Cf,G	I	...	....	.....	....	D1,500R
20cdc2	.....do...........	Dr	20	10	P	S,G	Qa	Cf,G	I	...	....	.....	....	Do.
20cdc3	.....do...........	Dr	22	10	P	S,G	Qa	Cf,G	I	...	....	.....	....	Do.
20dcb1	.....do...........	Dr	.....	6	P	S,G	Qa	N	O	Tcu	+2.5	-18.22	11- 2-48	

Table 6.--Records of wells and springs in the Glendo-Wendover area, Wyoming--Continued

Well number	Property owner or tenant	Type of supply	Depth of well (feet)	Diameter of well (inches)	Type of casing	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift	Use of water	Measuring point: Description	Measuring point: Distance above (+) or below (-) land surface (feet)	Distance to water level above (+) or below (-) measuring point (feet)	Date of measurement	Remarks
27-68-20dcb2	S. Willadsen......	Dr	60	6	P	S	Ta	C,W	D	Ls	....	-20	10-19-48	
23ccc	Bob Russell.......	Sp	.....	...	...	S	Ta(?)	F	S	...	....	.....	....	T53.5, D250E, Ca
24ccc	.....do..........	Du	7	72	C	S,G	Qa	N	N	Tcu	+0.8	-6.01	11- 2-48	
24dab	W. A. Herman......	Du	16	72	C	S,G	Qa	J,E	D,S	Tbc	+.3	-13.38	10-19-48	T56, Ca
28aac	Claude Adams......	Du	34	36	P	S,G	Qa	J,E	D	Bpb	0	-30.60	11- 4-48	T50, Ca
28abc	.....do..........	Du	14	72	C	S,G	Qa	T,G	I	Tcu	+2.8	-11.30	11- 4-48	
30acb	M. L. Coleman.....	Dr	21	6	...	S,G	Qa	J,E	D	Ls	.....	-14	11- 3-48	D6E
30acc	.....do..........	Dr	22	4	P	S,G	Qa	C,G	O	Tc	+2.75	-12.99	11- 3-48	
31adc	Arthur Seaton.....	Dr	74	6	P	Ss	Ta	C,E	D	Ls	....	-8	8-30-49	
27-69-25abb1	F. L. Fletcher....	Dr	73	4	P	G	Ta	C,W	S	Ls	....	-54	10- 3-47	L
25abb2	.....do..........	Dr	67	6	P	G	Ta	C,W	D	Ls	....	-40	10-20-48	
27-70-16cab	Mr. Hegiemaster...	Du	14	...	C	S,G	Qa	C,E	D	Tc	+.3	-10.47	10-21-48	
28-67-6cca1	Ivan Hooley.......	Dr	56	6	P	Ss	Tb	J,E	D	Ls	....	-19	8-23-49	
6cca2	.....do..........	Dr	40	6	P	Ss	Tb	J,E	D,S	Ls	....	-19	8-23-49	
18bcc	Harry Twiford.....	Dr	64	12	P	S,G	Qa	T,E	I	Ls	....	-20	7-20-49	T52, D400E, Ca, L
20bbb	George Robb.......	Dn	24	2	P	S,G	Qa	C,W	D,S	Ls	....	-20	8-23-49	T54.5
28-68-1cdc	Ivan Hooley.......	Dr	56	6	P	S,G	Qa	C,W	S	Ls	....	-19	8-23-49	T51
2dcd	.....do..........	Du	35	84	N	S,G	Qa	N	O	Tbc	0	-29.93	8-24-49	
10bbb	Jim P. Hughes.....	Dr	48	6	P	Cl,Sl	Tb	C,E	D	Ls	....	-38	8-31-49	
12aac	C. B. & Q. RR. Co.	Dr	42	12	P	S,G	Qa	T,E	In	Ls	....	-20	10-28-42	D100R, L
12adc	I. J. Hammer......	Dr	28	6	P	S,G	Qa	C,H	D	Ls	....	-12	7-28-49	T53, Ca
13dad	T. VanBuskirk.....	Dr	36	4	P	S,G	Qa	C,W	D,S	Ls	....	-34	7-28-49	T53
13dcb	B. A. Caster......	Dn	23	6	P	S,G	Qs	C,W	D	Ls	....	-15	11-31-48	T54, Ca
15bbb	J. P. Hughes......	Dr	217	6	P	G	Tb	C,W	S	Ls	....	-182	8-31-49	
16cdb	Harry Twiford.....	Du,Dr	20	6	P	S	Qs	C,W	D	Ls	....	-19	11- 3-48	

24bcb	Jack Jones........	Dr	65	6	P	G	Qs	C,E	D,S	Ls	....	-40	7-28-49	T57
27abb	D. W. Brown.......	Dr	58	6	P	Ss	Tb	N	O	Tc	+.8	-30.42	7-30-49	T53.5
27abc	.....do...........	Du	12	48	W	G	Qa	C,G	D,O	Tcu	0	-5.62	8-30-49	T57, D50R, DD5, Ca
28-70-1dca	Clayton Russell...	Dr	140	6	P	Cl,Sl	Tb	C,W	D,S	...	....	.....	....	T54
2adb	Hans Christiansen.	Dr	54	6	P	S,G	Qa	C,H	D,S	Tc	+.2	-23.09	8-24-49	
11bba	Mr. Jacobson......	Dr	16	6	P	S,G	Qa	N	N	Tc	+.3	-8.87	8-25-49	
29-68-9bcd	Town of Glendo....	Dr	793	...	P	Ss	Ch(?)	....	P	...	....	.....	....	Ca, L
20abb	A. M. Downey......	Dr	410	6	P	Ss	Ch	F	I	Tc	+.83	+32.46	9-21-49	T54, D160M, DD33, Ca, L
20abd	.....do...........	Dr	442	4	P	Ss	Ch	F	I,D	Tc	+.70	+40.40	9-21-49	T54, D75M, DD29, Ca, L
20bac	W. E. Hughes......	Dr	a/1,296	4	P	Ss	Ch	F	I,D	Ls	....	.....	....	T54.5, D150E, Ca, L
21bbl	Clark Coleman.....	Dn	14	25	...	G	Qa	C,H	D	Ls	....	-7	10-22-48	
21bb2	.....do...........	Dr	94	...	...	Ss	Tb(?)	C,H	S,O	Tbc	+1.0	-36.16	11- 4-48	T52, Ca, L
21bcc	J. R. Landcaster..	Dr	48	4	P	S,G	Qa	J,E	D	Ls	....	-28	10-22-48	
21dad	Hauf brothers.....	Dr	58	6	P	S,G	Qa	C,H	D,O	Tc	+.1	-8.33	11- 5-48	T51.5, Ca
22cdc	T. R. Nida........	Dr	40	6	P	S,G	Qa	C,E	D,S	Ls	....	-15	11- 5-48	
26adc	Mr. Thompson......	Dr	65	...	P	S,G	Qa	J,E	D,S	Ls	....	-12	10-22-48	
27cca	Don Summers.......	Dr	75	6	P	Ss	Tb	J,E	D	Ls	....	-57	10-22-48	
35cbb	Ivan Hooley.......	Sp	.....	...	...	Ss	Kc	F	S	...	....	.....	....	T53, D33M, Ca
29-69-24aab	L. R. Patterson...	Dr	300	...	...	Ss	Po(?)	C,W	D,S	...	....	.....	....	
27dca1	Mrs. E. Conlogue..	Dr	700	6	P	S,G	Qa(?)	N	N	Ls	....	-20	10-22-48	
27dca2	.....do...........	Dr	60	...	...	S,G	Qa	J,E	D	Ls	....	-20	10-22-48	
28dcc	J. A. Moran.......	Dr	72	4	P	S,G	Qa	J,E	D	Ls	....	-22	11- 3-48	
31dbd	W. L. Schmidt.....	Dr	16	...	...	S,G	Qa	C,E	S	Tbc	-.2	-10.15	11- 4-48	
32bac1	Don Gordan........	Dr	135	4	P	S,G	Qa	C,E	D	Ls	....	-18	11- 4-48	
32bac2	.....do...........	Dr	32	8	P	S,G	Qa	C,H	D	Ls	....	-20	11- 4-48	
34bca	Stella Martindale.	Dr	.....	6	P	S,G	Qa	C,W	D,S	...	....	.....	....	
29-70-36bbb	C. B. Harmon......	Dr	48	...	...	Cl,Sl	Tb	C,H	D	Bpb	+2.95	-33.97	8-24-49	T53.5

a/ Well plugged back to 460 feet.

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