Ground-Water Resources of Sheridan County, Wyoming

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1807

Prepared in cooperation with the Wyoming State Engineer

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By MARLIN E. LOWRY *and* T. RAY CUMMINGS

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GROUND-WATER RESOURCES OF SHERIDAN COUNTY WYOMING

By MARLIN E. LOWRY and T. RAY CUMMINGS

ABSTRACT

Sheridan County is in the north-central part of Wyoming and is an area of about 2,500 square miles. The western part of the county is in the Bighorn Mountains, and the eastern part is in the Powder River structural basin. Principal streams are the Powder and Tongue Rivers, which are part of the Yellowstone River system. The climate is semiarid, and the mean annual precipitation at Sheridan is about 16 inches.

Rocks of Precambrian age are exposed in the central part of the Bighorn Mountains, and successively younger rocks are exposed eastward. Rocks of Tertiary age, which are the most widespread, are exposed throughout a large part of the Powder River structural basin. Deposits of Quaternary age underlie the flood plains and terraces along the larger streams, particularly in the western part of the basin.

Aquifers of pre-Tertiary age are exposed in the western part of the county, but they dip steeply and are deeply buried just a few miles east of their outcrop. Aquifers that might yield large supplies of water include the Bighorn Dolomite, Madison Limestone, Amsden Formation, and Tensleep Sandstone. The Flathead Sandstone, Sundance Formation, Morrison Formation, Cloverly Formation, Newcastle Sandstone, Frontier Formation, Parkman Sandstone, Bearpaw Shale, and Lance Formation may yield small or, under favorable conditions, moderate supplies of water.

Few wells tap aquifers of pre-Tertiary age, and these are restricted to the outcrop area. The meager data available indicate that the water from the Lance Formation, Bearpaw Shale, Parkman Sandstone, Tensleep Sandstone and Amsden Formation, and Flathead Standstone is of suitable quality for domestic or stock purposes, and that water from the Tensleep Sandstone and Amsden Formation and the Flathead Sandstone is of good quality for irrigation. Samples could not be obtained from other aquifers of pre-Tertiary age; so the quality of water in these aquifers could not be determined.

Adequate supplies of ground water for stock or domestic use can be developed throughout much of the report area from the Fort Union and Wasatch Formations of Tertiary age; larger supplies might be obtained from the coarse-grained sandstone facies of the Wasatch Formation near Moncreiffe Ridge. Four aquifer tests were made at wells tapping formations of Tertiary age, and the coefficients of permeability determined ranged from 2.5 to 7.9 gallons per day per square foot. The depths to which wells must be drilled to penetrate an aquifer differ within relatively short distances because of the lenticularity of the aquifers.

Water in aquifers of Tertiary age may occur under water-table, artesian, or a combination of artesian and gas-lift conditions.

Water from the Fort Union is usable for domestic purposes, but the iron and dissolved-solids content impair the quality at some localities. Water from the Fort Union Formation is not recommended for irrigation because of sodium and bicarbonate content. The water is regarded as good to fair for stock use. Water from the Wasatch Formation generally contains dissolved solids in excess of the suggested domestic standards, but this water is usable in the absence of other supplies. The development of irrigation supplies from the Wasatch Formation may be possible in some areas, but the water quality should be carefully checked. Water of good to very poor quality for stock supplies is obtained, depending upon the location. Hydrogen sulfide, commonly present in water of the Fort Union and Wasatch Formations, becomes an objectionable characteristic when the water is used for human consumption.

Deposits of Quaternary age generally yield small to moderate supplies of water to wells. Two pumping tests were conducted, and the coefficients of permeability of the aquifers tested were 380 and 1,100 gallons per day per square foot. Usable supplies of ground water can be developed from the deposits of Quaternary age, principally along the valleys of perennial streams that head in the mountains and from terraces in the western part of the county; the thickest known deposit of alluvium is in the valley of Dutch Creek, which heads in the Powder River structural basin. Water from the alluvium is usable as a stock supply but has objectionable characteristics for domestic and irrigation use.

Recharge to ground-water reservoirs is from precipitation and seepage from streams and irrigation. Recharge conditions are generally better in the western part of the basin, where precipitation is greater and where there are more perennial streams and irrigated lands. Discharge from the ground-water reservoirs is by seepage to streams, evaporation, transpiration, and by wells and springs.

INTRODUCTION

LOCATION AND EXTENT

Sheridan County, Wyo., which is in the north-central part of the State, is an area of approximately 2,500 square miles. It is bounded on the north by Montana, and on the south, east, and west by the Wyoming Counties of Johnson, Campbell, and Big Horn, respectively. The west boundary is also the drainage divide of the Bighorn Mountains.

The area of this project and other areas in the State for which information on ground water is available, or where work is in progress, are shown in figure 1.

PURPOSE AND SCOPE OF THE INVESTIGATION

The purpose of this investigation was to determine the occurrence, quality, and availability of ground water, the character and extent of the water-bearing formations, and the possibilities of developing water supplies for domestic, stock, irrigation, industrial, and municipal uses.

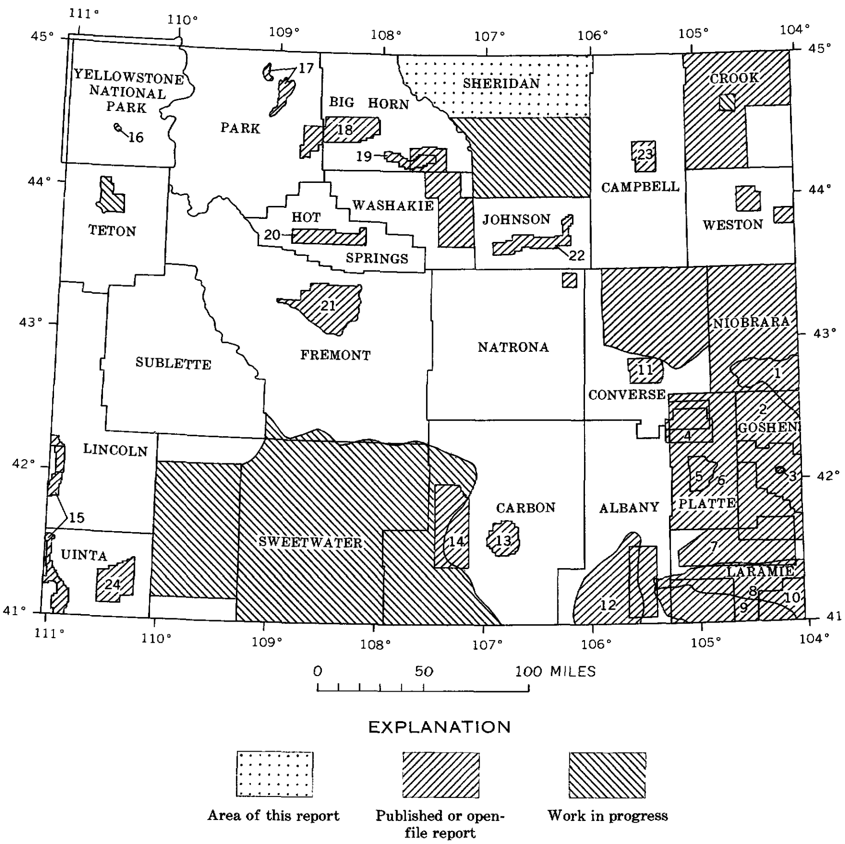

FIGURE 1.—Report area and other areas in which ground-water investigations have been made or where ground-water work is in progress.

The investigation was started in the fall of 1959 as part of the program of the U.S. Geological Survey in cooperation with the office of the Wyoming State Engineer. The ground-water study was under the supervision of E. D. Gordon, district geologist of the Geological Survey for Wyoming. The quality-of-water studies were made under the supervision of T. F. Hanly, district engineer of the Geological Survey for Wyoming.

PREVIOUS INVESTIGATIONS

The geology and ground-water conditions in Sheridan County were first described in a reconnaissance study by Darton (1905). Warner (1946) described ground-water conditions in the vicinity of Ranchester, Wyo., in an open-file report of the Geological Survey. Numerous geologic investigations made in the area proved most useful in the present investigation, and these are cited elsewhere in this report.

Reports for numbered areas have been published by the U.S. Geological Survey as water-supply papers (WSP) or circulars (Cir). (See list below.) Reports for other areas have been released as open-file reports of the U.S. Geological Survey.

Number in fig. 1	U.S. Geol. Survey pub.	Author	Year
1	WSP 1368	Bradley, Edward	1956
2	WSP 1377	Rapp, J. R., and others	1957
	WSP 70	Adams, G. I	1902
3	Cir 238	Visher, F. N., and Babcock, H. M	1953
4	Cir 163	Rapp, J. R., and Babcock, H. M	1953
5	Cir 70	Littleton, R. T	1950
6	WSP 1490	Babcock, H. M., and Morris, D. A	1960
7	Cir 162	Babcock, H. M., and Rapp, J. R	1952
8	WSP 1483	Bjorkland, L. J	1959
	WSP 425-B	Meinzer, O. E	1919
9	WSP 1367	Babcock, H. M., and Bjorkland, L. J	1956
10	WSP 1140	Rapp, J. R., and others	1953
11	Cir 243	Rapp., J. R	1953
12	Cir 80	Littleton, R. T	1950
13	Cir 188	Visher, F. N	1953
14	WSP 1458	Berry, D. W	1960
15	WSP 1539-V	Robinove, C. J., and Berry, D. W	1963
16	WSP 1475-F	Gordon, E. D., and others	1962
17	WSP 1418	Swenson, F. A	1957
18	WSP 1596	Robinove, C. J., and Langford, R. H	1963
19	Cir 96	Swenson, F. A., and Bach, W. K	1951
20	WSP 1519	Berry, D. W., and Littleton, R. T	1961
21	WSP 1375	Morris D. A., and others	1959
22	WSP 1360-E	Kohout, G. A	1957
23	Cir 76	Littleton, R. T	1950
24	WSP 1669-E	Robinove, C. J., and Cummings, T. R	1963

METHODS OF INVESTIGATION

A network of observation wells was established during the spring of 1960, and measurements were made monthly through October 1961. Of the records collected on wells and springs, only 301 were tabulated for use in this report; however, all the data available were used in the conclusions and general statements regarding ground water. Samples of ground water were analyzed in Geological Survey laboratories. Test holes were augered at three sites to determine thickness and physical character of alluvial deposits. Well locations were recorded on aerial photographs and transferred to a base map, adapted from the Sheridan County general highway map which had been prepared by the Wyoming Highway Department.

WELL-NUMBERING SYSTEM

Wells, springs, and test holes are numbered according to the Federal system of land subdivision. Each well number shows the location of the well by township, range, section, and location within the section (fig. 2).

The first numeral of a well number indicates the township; the second, the range; and the third, the section in which the well is located. Lowercase letters following each section number indicate the position of the well in that section. The first letter denotes the quarter section; the second letter, the quarter-quarter section; and the third letter, the quarter-quarter-quarter section (10 acre tract). The subdivisions of a section are lettered a, b, c, and d in a counterclockwise direction, starting in the northeast quarter. If more than one well is listed in a 10-acre tract, consecutive numbers, starting with one, are added to the well numbers.

ACKNOWLEDGMENTS

The writers are indebted to many persons who contributed information and assistance. C. T. Reid and Carl Ritola furnished information on wells they had drilled in the area. Many other residents of Sheridan County supplied information regarding their wells and gave permission for various measurements and tests.

GEOGRAPHY

LANDFORMS AND DRAINAGE

Sheridan County lies within two topographic provinces: the Bighorn Mountains and the Powder River structural basin. In this report the boundary between the provinces is arbitrarily defined as the top of the Tensleep Sandstone of Pennsylvanian age. The Tensleep and older formations, which consist predominantly of resistant sandstone, limestone, and dolomite, constitute the flank of the mountains. Formations younger than the Tensleep, which are composed predominantly of shale and siltstone, have been eroded to a comparatively low surface in the basin.

Altitudes in the Powder River structural basin range from about 4,780 feet at the head of Buffalo Creek to about 3,460 feet where the Tongue River crosses the Montana State line. The highest point in the county is about 11,000 feet.

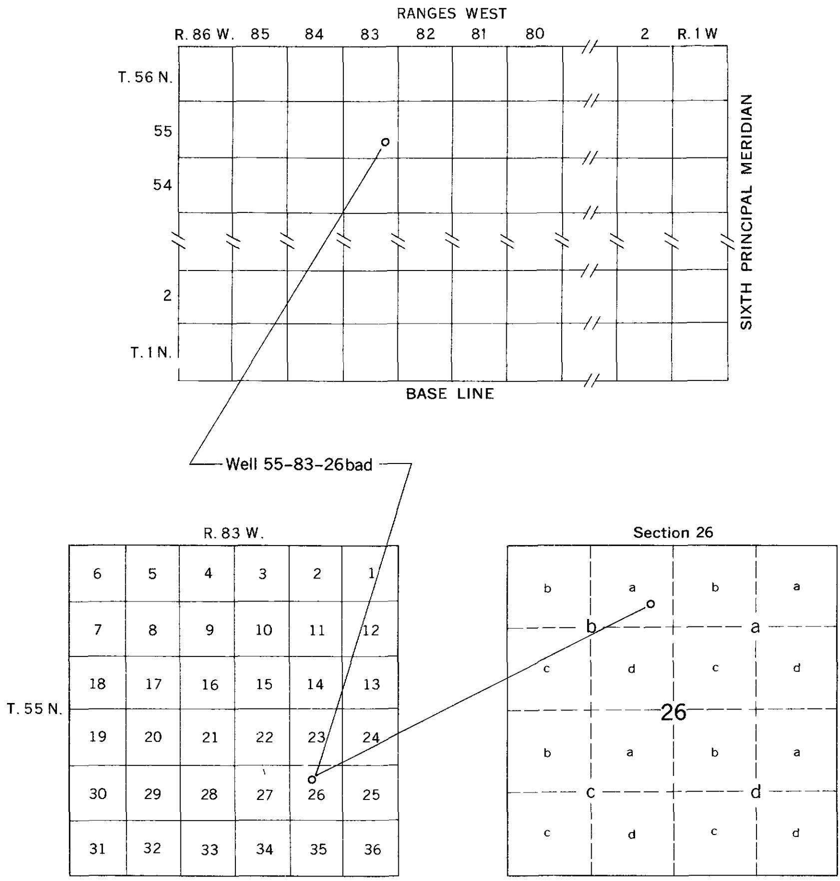

FIGURE 2.—Well-numbering system.

Numerous small streams separated by high ridges and divides dissect the basin. Red clinker (formed by burning coal) and sandstone cap the ridges and divides. Badlands have developed locally.

Land slumps are common in the western part of the basin, where precipitation is greater and irrigation is more common. The large slump shown in figure 3 is due in part to the disturbance of the equilibrium caused by the rechanneling of the creek into the toe of the slope, and in part by the irrigation of land above the slope.

Sheridan County is in the Yellowstone River drainage system and is drained by the Little Bighorn, Powder, and Tongue Rivers. The Little Bighorn River, a perennial stream, drains only about 190 square miles of the northern Bighorn Mountains. Its average flow at the

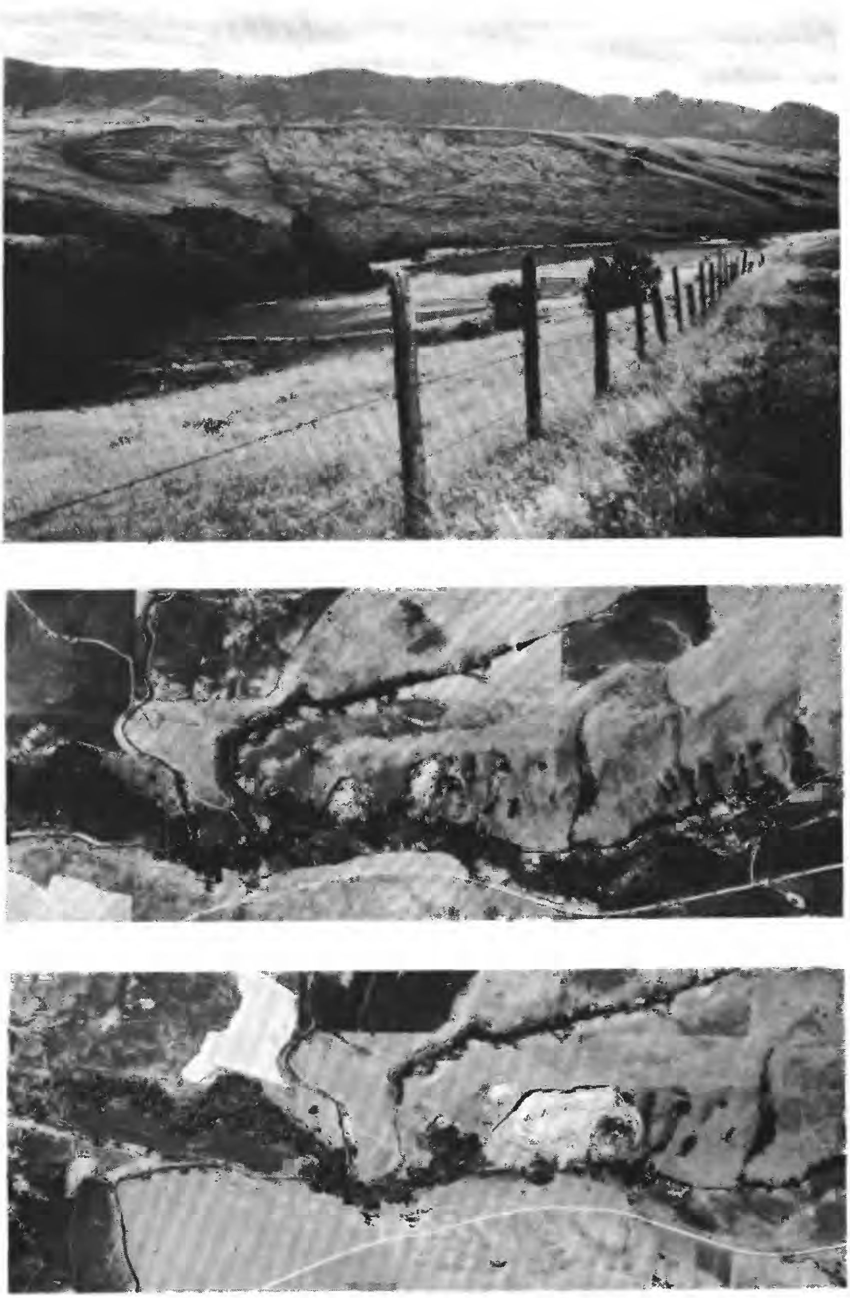

FIGURE 3.—Slump along Jackson Creek in sec. 6, T. 54 N., R. 84 W., and sec. 1, T. 54 N., R. 85 W. Upper, Conditions of land slump in 1961; middle and lower, aerial photographs of same area in 1954 and 1958, respectively. Aerial photographs by U.S. Department of Agriculture.

State line is 140 cfs (cubic feet per second) for 21 years of record (Hendricks, 1961, p. 199).

The Powder River, which flows close to and nearly parallels the east boundary of the county, drains the southern and eastern parts of the county. The average discharge at Arvada for 29 years of record is 257 cfs; a maximum flow of 100,000 cfs occurred September 29, 1923 (Hendricks, 1961, p. 227). At times during most of the years of record, the Powder River has had no flow. Clear Creek, which heads in the Bighorn Mountains and is generally perennial, is the principal tributary of the Powder River in Sheridan County. The flow of the Powder River and its tributaries is affected by reservoirs and diversions for irrigation.

Most of Sheridan County is drained by the Tongue River. This river and its main tributaries head in the Bighorn Mountains and flow eastward to about the longitude of Sheridan and then flow northward out of the county. Average flow of the Tongue River near Dayton for 7 years of record is 10.3 cfs (Hendricks, 1961, p. 207). The average discharge of Goose Creek, the principal tributary to the Tongue River below Dayton, for 19 years of record is 179 cfs (Hendricks, 1961, p. 214).

CLIMATE

Sheridan County is semiarid and has a wide temperature range. The mountains and adjacent areas receive the greatest amounts of precipitation because of frequent orographic storms in the spring and summer. East of the mountains the precipitation decreases in amount from 19 inches at Parkman and 16 inches at Sheridan to less than 14 inches at Clearmont and Arvada. Forty-four percent of the moisture comes during April, May, and June. The driest season is winter, when only 13 percent of the total precipitation occurs. The total amount of precipitation varies considerably from year to year. A minimum of 8.23 inches was recorded at the Sheridan weather station in 1960, and the maximum recorded at that station was 29.79 inches in 1923. Figure 4 shows the annual, normal, and 3-year moving-mean precipitation at Sheridan, Wyo.

SUMMARY OF STRATIGRAPHY

Approximately nine-tenths of Sheridan County is underlain by sedimentary rocks that range in age from Cambrian to Recent. Igneous rocks of Precambrian age are exposed in the Bighorn Mountains (pl. 1).

A summary of the stratigraphic units and their water-bearing characteristics is given in table 1; more detailed information on some of these formations, their water-bearing properties, and the chemical

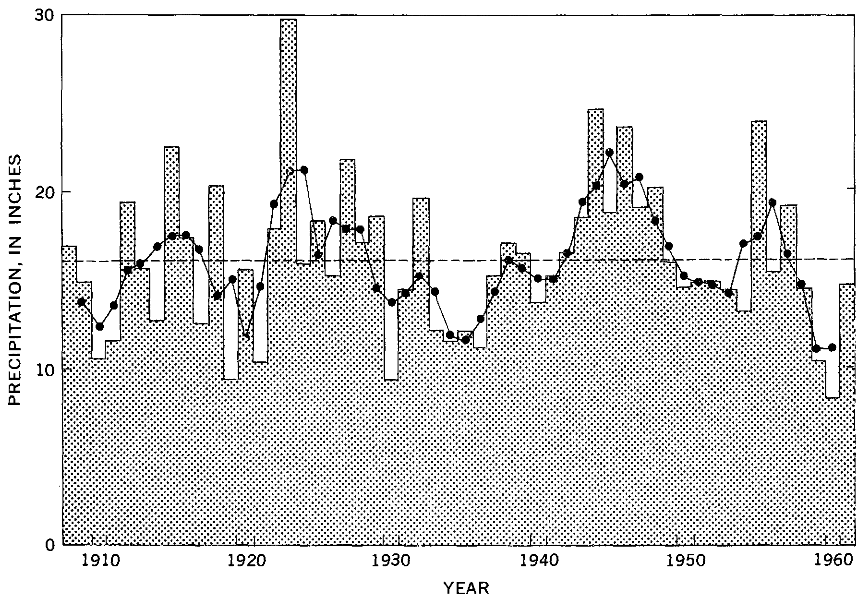

FIGURE 4.—Precipitation at Sheridan, Wyo.: annual (bar graph), normal (dashed line), and 3-year moving mean (points).

characteristics of the water in them is given in the section on geology and water resources. Logs of test holes, seismic shotholes, and selected wells, which are given in tables 6 and 7 at the end of the report, describe the materials penetrated by wells.

GROUND WATER

PRINCIPLES OF OCCURRENCE

Ground water is the water in the zone of saturation. In this zone the water is under hydrostatic pressure, and all the interstices are filled. The principal interstices in which ground water occurs are, in order of their significance, openings between adjacent particles composing sedimentary rocks, joints and other fracture openings, and solution cavities. Rocks that will yield sufficient quantities of water to be regarded as a source of supply are called aquifers. Aquifers are recharged chiefly by precipitation and influent streams, but infiltration of irrigation water is also a major source of recharge in some areas. Discharge from aquifers is through springs, seeps, effluent streams, and wells. Where ground water is near the surface, water may be lost directly to the atmosphere by evaporation and by transpiration from plants whose roots extend into the zone of saturation or into the overlying capillary fringe.

TABLE 1.—*Stratigraphic units and their water-bearing characteristics*

System	Series	Stratigraphic unit	Thickness (feet)	Physical characteristics	Water supply
Quaternary		Alluvium and flood-plain deposits	0–100	Unconsolidated deposits of silt, sand, and gravel.	Yield small to moderate supplies of ground water to wells for domestic, stock, and irrigation use.
		Landslide deposits	50±	Includes loose shale, limestone and dolomite blocks, and conglomerate, depending upon location.	Yield small supplies to springs, mostly in the mountains.
		Terrace and piedmont deposits	0–48	Unconsolidated deposits of silt, sand, and gravel.	Yield mostly small to moderate supplies of ground water to springs and wells for domestic and stock use. Recharge principally from irrigation.
Tertiary	Oligocene	White River Formation	0–30	Sand, volcanic ash, gravel, clay, and boulders.	Water-bearing properties not known.
	Eocene	Wasatch Formation: Moncrief Member	0–1,400 (Wasatch Formation: 1,200±)	Continental deposits of light-gray to yellowish-gray sandstone, dark-colored shale and coal, grading and interfingering westward into conglomeratic members. The Moncrief Member is composed of coarse-grained sandstone and siltstone grading upward into boulder beds. The Kingsbury Conglomerate Member is composed of lenticular conglomerate beds, greenish-gray shale, and sandy shale.	Yield small quantities of water for domestic and stock use. Gas associated with water from many wells. Moderate to large supplies could be obtained from coarse-grained facies of Moncrief and Kingsbury Members near Moncreiffe Ridge.
		Wasatch Formation: Kingsbury Conglomerate Member	0–800		
	Paleocene	Fort Union Formation	2,000±	Continental deposits of light-colored sandstone, dark-colored shale, and coal.	

Cretaceous	Upper Cretaceous	Lance Formation	1,900±	Continental deposits of light-gray to yellowish-gray medium-grained cross-bedded sandstone and dark-gray to green shale.	Yields small supplies of water suitable for domestic and stock use to wells and springs.
		Bearpaw Shale	200–900±	Dark-greenish-gray shale, in parts sandy.	Sandy phase yields small supplies of water to wells in the Parkman vicinity.
		Parkman Sandstone	355	Tan concretionary sandstone, shaly in upper part.	Yields sufficient quantities of water for domestic and stock use. Lodge Grass, Mont., 22 miles north of the project area, obtains its municipal supply from a well which taps this aquifer.
		Cody Shale	3,750	Dark-gray and grayish-black shale with some interbedded fine-grained sandstone. A few thin beds of bentonite. The Shannon Sandstone Member, which is nearly 1,000 ft below the top of the formation ,is about 200 ft thick and consists of light-gray fine grained sandstone and sandy shale.	Not considered a good source of water. Small yields have been developed from the Shannon Sandstone Member in adjacent areas.
		Frontier Formation	515±	Dark-gray shale and light-gray sandstone conglomeratic at the top.	Sandstone will yield sufficient water for domestic and stock supplies.
	Lower Cretaceous	Mowry Shale	525±	Upper part, siliceous shale and siltstone with thin bentonite beds lower part, grayish-black shale with thin beds of bentonite.	Not considered a good source of water.
		Newcastle Sandstone	40±	Light-gray fine-grained sandstone.	Water possibilities not known; would probably yield small quantities.
		Skull Creek Shale	175±	Grayish-black shale with thin beds of brown siltsone.	Relatively impermeable; not considered a good source of water.
		Cloverly Formation	281–308	Interbedded grayish-black shale and brown siltstone, medium- to coarse-grained sandstone 30 ft or more thick at base.	Yields only small supplies to springs in Sheridan County, but yields moderate supplies to wells in adjacent area.

TABLE 1.—*Stratigraphic units and their water-bearing characteristics*—Continued

System	Series	Stratigraphic unit	Thickness (feet)	Physical characteristics	Water supply
Jurassic	Upper Jurassic	Morrison Formation	139–235	Variegated shale and claystone and light-gray fine-grained lenticular sandstone.	Water possibilities not known. Sandstone would probably yield small supplies to wells drilled in the outcrop.
		Sundance Formation	327–452	Green calcareous shale and light-gray calcareous glauconitic sandstone.	
	Middle Jurassic	Gypsum Spring Formation	205	Red claystone and shale, gypsum, and limestone.	Not considered a good source of water.
Triassic		Chugwater Formation	590–644	Red beds of sandstone, siltstone, and shale; ledge-forming limestone 70 ft below the top.	Not considered a good source of water.
Permian		Red shale and gypsum sequence	42–48	Red shale and siltstone; gypsum in the upper part.	
Carboniferous: Pennsylvanian		Tensleep Sandstone	50–250	Light-gray massive to crossbedded sandstone; contains minor amounts of dolomite.	Water is artesian. One well in Sheridan County, which taps the Tensleep Sandstone and the underlying Amsden Formation, flows 60 gpm. Wells to the north, in Montana, have yields as high as 500 gpm.
		Amsden Formation	150–300	Red and purple shale, red sandstone, and dolomite.	
Carboniferous: Mississippian	Upper and Lower Mississippian	Madison Limestone	1,100±	Light-gray limestone, dolomitic limestone, dolomite; sandy at base.	Would probably yield small to large supplies of water to wells from fractures or cavernous zones; yields small to large supplies to springs.
Ordovician	Upper Ordovician	Bighorn Dolomite	400–500	Massive cliff-forming yellowish-gray dolomite; contains thin-bedded dolomite; limestone in the upper part and sandstone at base.	

Cambrian	Upper and Middle Cambrian	Gallatin and Gros Ventre Formations, undifferentiated	645±	Upper part, thin-bedded light-gray glauconitic flat-pebble limestone conglomerate; middle part, green micaceous shale with some interbedded light-gray limestone, flat-pebble conglomerate, and glauconitic sandstone; lower part, brown glauconitic sandstone and interbedded green shale.	Not considered a good source of water in Sheridan County.
	Middle Cambrian	Flathead Sandstone	345±	Light-yellowish-gray sandstone with some interbedded green shale and siltstone; bottom few feet coarse red conglomerate.	Yields small supplies of water from sandstone and conglomerate in the Bighorn Mountains.
Precambrian			?	Mostly red and gray granite.	Yields small supplies of water from fractures, joints, and weathered zones to many springs and one well.

Ground water is under water-table conditions if the water level in an aquifer coincides with the top of the zone of saturation. It is under artesian conditions if the water is confined between relatively impermeable layers and the piezometric surface is above the top of the aquifer. In Sheridan County, water-table conditions exist in the unconsolidated aquifers of Quaternary age, in the shallower aquifers in the Tertiary formations, and in the pre-Tertiary aquifers within and close to the outcrop of the aquifers. Artesian conditions are generally present in the pre-Tertiary and in the deeper Tertiary aquifers. Gas is responsible for some of the lift in many wells in the Tertiary formations, where it is discharged with the water. Meinzer (1923, p. 40) stated: "An area in which the water rises to the surface because of the presence of gas cannot properly be called an area of artesian flow but may be called an *area of gas-lift flow* or may be designated by means of a brief description of the conditions."

WATER-LEVEL FLUCTUATIONS

The water level or piezometric surface in an aquifer is not stationary but fluctuates in response to external influences. If recharge is greater than discharge, the level rises; if discharge is greater, the level declines. Water levels in aquifers near the recharge area respond more quickly to changes in recharge and discharge than do those in aquifers farther away. Wells 58–87–35ca1 and 58–85–24da (fig. 5), which tap alluvium along intermittent streams, show a water-level decline because of below-normal precipitation during the time of the investigation. Well 57–85–19ab is beside a perennial stream, the Tongue River, and the water level fluctuates in response to the changes in stream stage. The gage height of flow in the Tongue River upstream from Dayton is shown in the hydrograph (fig. 5). Wells 53–83–7ad and 57–84–36ab (fig. 6), in consolidated rock, show declines in water levels similar to the declines in the two wells in the alluvium, but the rate of decline is more uniform. Discharge from the alluvial aquifers is principally by evaporation and transpiration, which become greatest during the growing season and negligible during the winter (fig. 5). Ground water is discharged from consolidated aquifers by springs, seepage to alluvium, and wells, and at a more uniform rate than that discharged from the alluvium. Movement of water out of the county as underflow undoubtedly occurs. The small rise of the water levels during the spring of 1961 in wells 53–83–7ad (fig. 6) and 58–85–24da (fig. 5) was a seasonal response to spring rains. Infiltration of water from a stock pond near well 57–84–36ab caused the upward trend in the last part of the hydrograph for that well (fig. 6). The pond was dry when previous measurements were made.

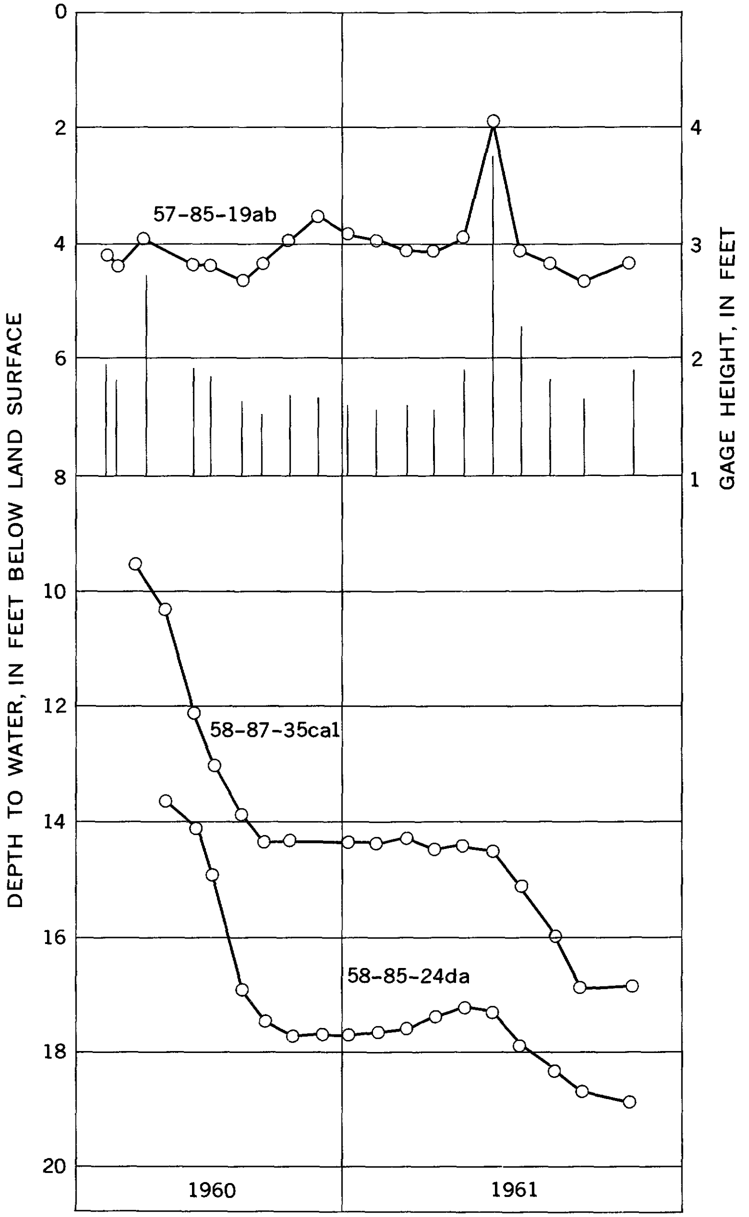

Figure 5.—Hydrographs of three wells that penetrate the alluvium, and gage height of the Tongue River upstream from Dayton, Wyo.

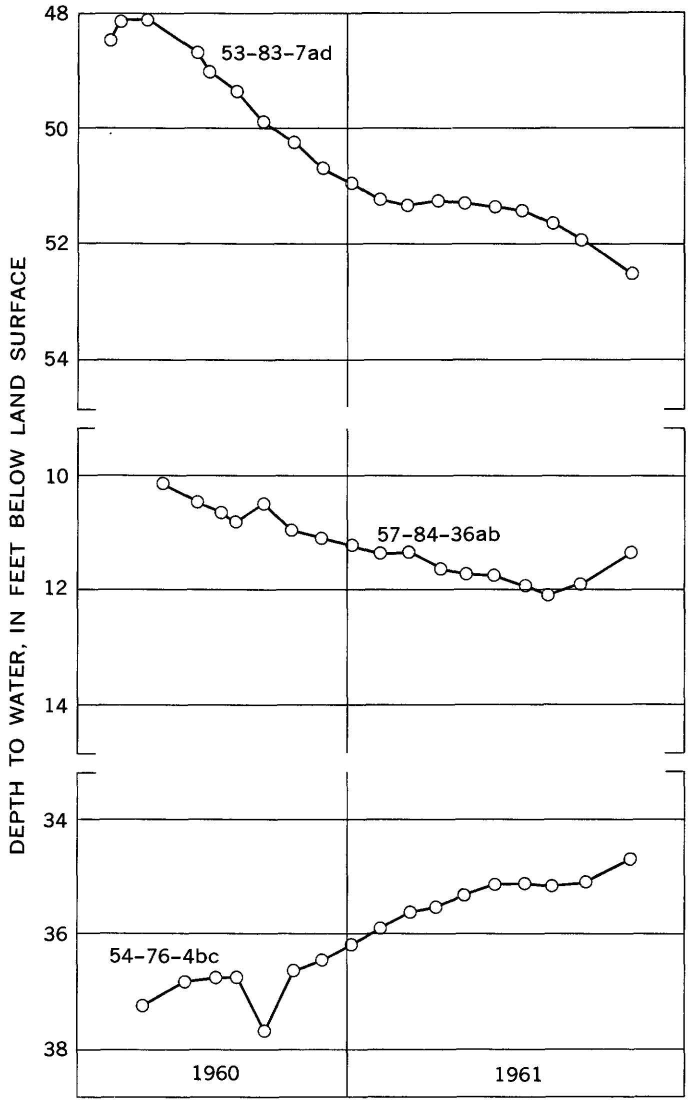

Figure 6.—Hydrographs of three wells that penetrate formations of Tertiary age.

Well 54–76–4bc (fig. 6), which is in the central part of the Powder River Basin, is remote from the recharge area. The aquifer is deep enough that it is not immediately influenced by changes in recharge. The upward trend of the water level in the well during the time of the investigation probably correlates, with a time lag, to an earlier period when precipitation was greater.

Effect of recharge from irrigation on water levels may occur quickly, or there may be a lag of several months. The levels in well 55–84–26cd in the alluvium and well 55–84–35ba in the Wasatch Formation rose almost immediately in response to irrigation which began about May 1, 1961 (fig. 7). The rise in level in well 55–85–34db, in the Fort Union Formation, lags some 2 months behind the start of the irrigation season.

When a well is pumped, or allowed to flow, the water level or piezometric surface near the well is lowered. The configuration of the water table or piezometric surface in the vicinity of a discharging well is that of an inverted cone with the apex at the well. The size of the cone depends upon the rate of discharge, the length of time the well has been discharging, and the hydraulic properties of the aquifer. When discharge ceases, the flow into the depression is rapid at first and then become more gradual, until the gradient toward the well no longer exists.

The water level near a discharging well (fig. 8) fluctuates in response to changes in the rate of pumping. The level in well 54–79–21ab is affected by the pumping of wells 54–79–21bdd and 54–79–21bdb, which are public-supply wells for the town of Clearmont. The fluctuations of level in the observation well correlate with changes in the rate of pumping, as shown by the following data. During the period December 1960–February 1961, well 54–79–21bdd was pumped at about 8 gpm (gallons per minute) for an average of 7.7 hours per day, and the water level in the observation well rose steadily. During March, April, and May, pumping time was increased to an average of 8.8, 11.2, and 13.4 hours per day, respectively, and the upward trend of the water level was reversed. Beginning the first of June, well 54–79–21bdd was pumped almost continuously and, in addition, well 54–79–21bdb was pumped for about 3 hours a day; the result was a rapid decline of the water level.

HYDRAULIC PROPERTIES OF AQUIFERS

The rate at which an aquifer will yield water to wells depends upon the hydraulic properties, principally the coefficients of permeability and storage.

The coefficient of permeability is defined as the rate of flow of water, in gallons per day (gpd), through a cross-sectional area of 1 square foot under a unit hydraulic gradient. The standard coefficient is defined for water at a temperature of 60°F; whereas, the field coefficient requires no correction for temperature, and the units are in the terms of the prevailing water temperature. The coefficient of transmissibility is the product of the coefficient of permeability and the

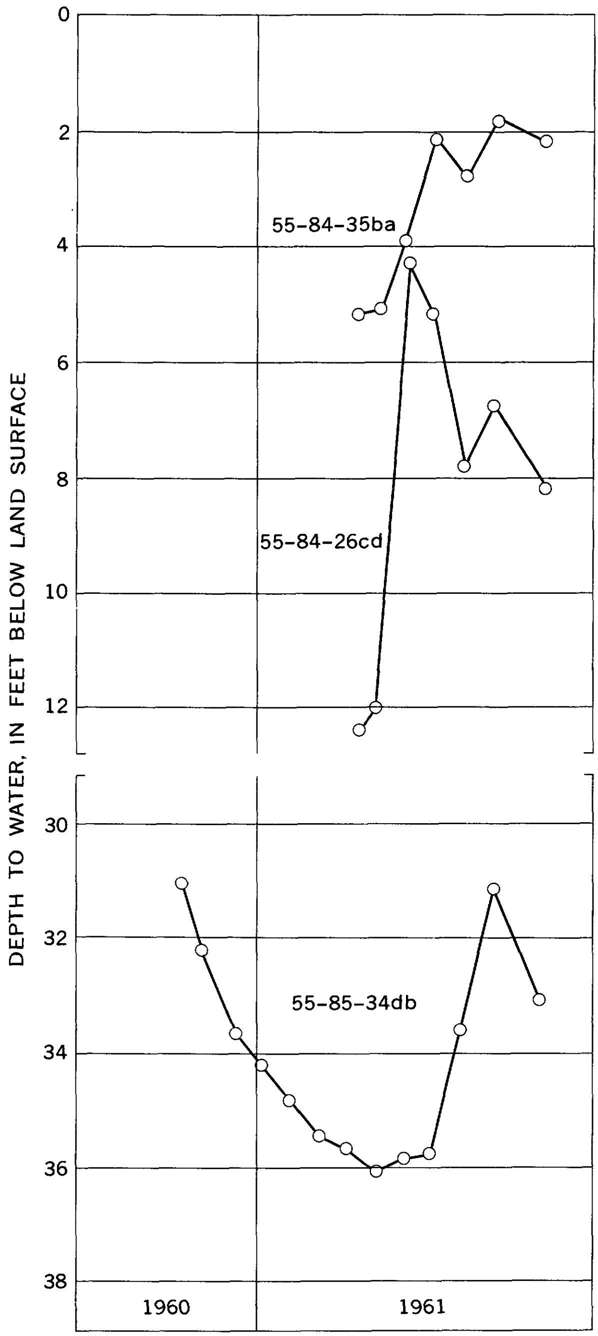

FIGURE 7.—Hydrographs of three wells penetrating aquifers affected by irrigation.

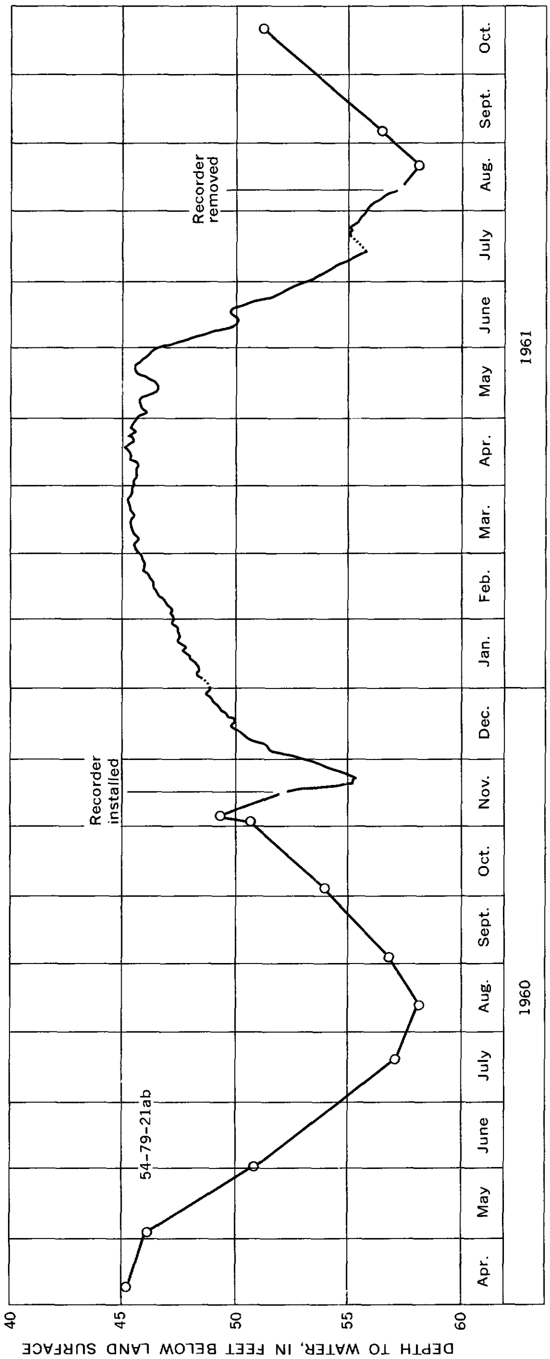

FIGURE 8.—Hydrograph of an observation well near discharging wells.

thickness of the aquifer and is expressed in gallons per day per foot (gpd per ft).

The coefficient of storage of an aquifer is the volume of water which the aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component head normal to that surface. This quantity is approximately equal to the specific yield, which expresses the quantity of water that a given saturated volume of aquifer will yield by gravity drainage under water-table conditions. The ratio of the volume of water to the total volume of water drained is the specific yield. The specific retention is the quantity of water retained against the pull of gravity. Specific retention plus specific yield is equal to porosity.

FIELD TESTS OF AQUIFERS

Aquifer tests were made at six wells—two each of which penetrate the alluvium, the Fort Union Formation, and the Wasatch Formation. The wells were pumped at a constant rate during the tests, and periodic measurements of the water levels were made while the well was being pumped or during the recovery of the water level after the pumping had stopped. The data were analyzed by the "nonequilibrium" methods described by Theis (1935) and Cooper and Jacob (1946).

The results of the pumping tests are given in table 2. Aquifer characteristics computed from the tests of wells drilled into the Fort Union and the Wasatch Formations do not apply to the entire stratigraphic interval, but only to the aquifer in which the well is finished. The test results illustrate the aquifer characteristics that may be expected for wells penetrating either of these two formations.

Aquifers having low coefficients of transmissability and storage, such as those at well 55–84–27bc, are capable of supplying sufficient water for domestic and stock supplies. Continuous pumping for as long as 2 hours, however, sometimes lowers the water level to the lower

TABLE 2.—*Results of pumping tests*

Well	Coefficient of transmissibility (gpd per ft)	Coefficient of storage	Average field coefficient of permeability (gpd per sq ft)	Aquifer	Remarks
54–84–5da	95	3.5×10^{-4}	7.9	Sandstone in the Fort Union.	24-hr test.
54–81–14bc	520	2.4×10^{-2}	6.5	Coal in the Wasatch.	Do.
57–83–14ba	2,200			Sandstone(?) in the Wasatch.	3.5-hr recovery test.
55–84–27bc	10	9×10^{-5}	2.5	Sandstone in the Fort Union.	1.3 hr recovery test.
56–82–34dc	9,700		380	Alluvium	8-hr recovery test.
57–85–19ab	20,300		1,100	do	Average from 10-day 3½-hr tests.

end of the suction pipe, even though the pump has been set as low as possible.

Because of the lenticularity of the aquifers, impermeable boundaries probably exist in most areas where wells are drilled into the Fort Union and Wasatch Formations. An impermeable boundary near a pumped well may cause an increased drawdown in the well. Such boundaries ordinarily would not be an appreciable factor affecting the water levels in domestic and stock wells, because of the normally short duration of pumping and the small discharge from the wells.

The alluvium in some of the larger valleys is probably capable of yielding moderate quantities (50–300 gpm) of water to wells; still, before construction of a large-diameter well, test holes should be drilled and the quality of the water with respect to its intended use should be determined.

SPECIFIC CAPACITY OF WELLS

The specific capacity of a well is the number of gallons per minute that a well will yield for each foot of drawdown. Specific capacity varies with time and with different rates of pumping, except where the different rates cause only small drawdowns in the pumped well. Wells in aquifers having similar characteristics may have different specific capacities because of differences in construction and development of the wells.

A summary of the reported specific capacity of wells tapping the Fort Union Formation and the fine-grained facies of the Wasatch Formation is given in table 3. The duration of pumping was not ordinarily reported, but where reported, it generally ranged from 3 to 8 hours. The data do not show any significant difference between the specific capacity of wells in the Fort Union Formation and of those in the Wasatch Formation. The average specific capacity of 15 wells that tap the coarse-grained facies of the Wasatch is 1.0 gpm per foot of drawdown.

TABLE 3.—*Reported specific capacity of wells in the Fort Union and Wasatch Formations*

Specific capacity (gpm per foot of drawdown)	Fort Union Formation		Wasatch Formation		Fort Union and Wasatch Formations	
	Number of wells	Percent of wells	Number of wells	Percent of wells	Number of wells	Percent of wells
Less than 0.1	22	26	14	37	36	29
Less than 1.0, but more than 0.1	52	61	21	55	73	59
More than 1.0	11	13	3	8	14	12
Average specific capacity	0.42		0.33		0.39	

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Wells in the alluvium have the largest specific capacities reported. The specific capacity of wells drilled in the alluvium ranged from 0.3 to 7.0 gpm per foot of drawdown; for 20 of these wells, it averaged 3 gpm per foot of drawdown.

INTERFERENCE BETWEEN WELLS

When discharging wells are too closely spaced, the cones of depression sometimes overlap, or interfere, and lower pumping levels or decreased artesian flows result. Most of the interference reported in the area has been between flowing wells in eastern and central Sheridan County. Although interference actually occurs between some wells, it is only apparent in many others. The apparent interference may be the result of impermeable boundaries or a decrease in the gas-water ratio where gas is associated with the water, or both. There have been few reports of interference in the areas of greatest ground-water development—south of Sheridan and at Story. In these areas the wells are not heavily pumped, recharge conditions are excellent, and adjacent wells are often completed in different aquifers.

UTILIZATION OF GROUND WATER

The principal use of ground water in Sheridan County is for domestic and stock supplies. Most domestic water supplies in the rural areas are from wells, although a few springs have been developed. The wells generally are of small diameter and are drilled only deep enough to obtain an adequate supply of water of acceptable quality.

In some areas, drilled wells are the only source of water for stock; but in other areas wells supplement surface supplies. Stock wells are similar in construction to domestic wells; but, in localities where flowing wells can be developed, a stock well is commonly drilled to a depth of more than 1,000 feet, rather than being completed as a nonflowing well at a lesser depth. Numerous springs in the mountains also supply much water for stock.

Except for the town of Clearmont, which uses ground water, all the municipal water supplies in Sheridan County are from surface water. The average use of ground water by Clearmont in the winter is about 4,000 gpd. No figures are available for either summer or annual use. Residents in the communities of Big Horn, Arvada, and Story use water from private wells, and some wells are shared by two or more families. The towns of Acme and Monarch, which are not municipalities but are privately owned, obtain water from large-diameter dug wells in the alluvium along the Tongue River.

REPORTING OF CHEMICAL-QUALITY DATA

The concentrations of dissolved chemical constituents are generally expressed in parts per million (ppm) in data on chemical quality of water. A part per million is one unit weight of a constituent in 1 million unit weights of water. Frequently, working with equivalents per million (epm) is more convenient in special problems in water chemistry and the effects of irrigation waters on soils. An equivalent per million is one unit chemical combining weight of a constituent in 1 million unit weights of water. Equivalents per million are calculated by dividing the concentration of the constituent, in parts per million, by its chemical combining weight.

The specific conductance of water is a measure of the ability of water to conduct an electric current and is expressed in micromhos per centimeter at 25°C. Because specific conductance is related to the amount of dissolved material, it can be used for approximating the dissolved-solids content of water. The pH indicates the degree of acidity or alkalinity. A pH progressively higher than 7 denotes increasing alkalinity, and a pH progressively lower than 7 denotes increasing acidity.

Water is commonly referred to as of a certain chemical type. The following examples illustrate how these designations are determined:

1. "Calcium bicarbonate" designates a water in which the calcium amounts to 50 percent or more of the cations and in which the bicarbonate amounts to 50 percent or more of the anions, based on equivalents per million.
2. "Sodium-calcium bicarbonate" designates a water in which the sodium and calcium are first and second, respectively, in order of abundance among the cations, but neither amounts to more than 50 percent of all the cations.
3. "Sodium sulfate bicarbonate" designates a water in which the sulfate and bicarbonate are first and second in order of abundance among the anions, but neither amounts to more than 50 percent of all the anions.

WATER-QUALITY CRITERIA

In the evaluation of the suitability of water for beneficial uses, certain water-quality criteria that are generally accepted as valid should be considered. A discussion of these criteria follows.

DOMESTIC USE

Chemical-quality standards for water to be used for drinking and culinary purposes on interstate-commerce carriers were established by the U.S. Public Health Service (1962). Although these standards established recommended allowable-concentration limits for water to be used on common carriers, many municipal and domestic water supplies exceed these allowable-concentration limits in some respects. The absence of suitable supplies and the high cost of treatment prevents strict adherence to these suggested standards. Some of the limits on chemical constituents in drinking water are as follows:

Constituent	*Maximum recommended concentration (ppm)*
Iron (Fe)	0.3
Manganese (Mn)	.05
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride (F)	[a].8–1.7
Nitrate (NO_3)	45
Dissolved solids	500

[a] Recommended limits for fluoride content are based on the annual average of maximum daily air temperatures. For example, when the average is 50.0°F to 53.7°F the recommended upper limit is 1.7 ppm; when the average is between 79.3°F to 90.5°F, the upper limit is 0.8 ppm

Hardness, a property of water familiar to many people, is caused principally by the presence of calcium and magnesium. Arbitrarily, water has been classified in the following manner with regard to hardness: 60 ppm or less, soft; 61–120 ppm, moderately hard; 121–180 ppm, hard; and 181 ppm or more, very hard.

AGRICULTURAL USE

Although investigations relating the chemical quality of water to its suitability for agricultural use are not numerous, guidelines usually considered reliable have been proposed (Beath and others, 1953; Eaton, 1950; U.S. Salinity Laboratory Staff, 1954). The following statements have been drawn largely from these reports. Many supplies of water that do not fully meet these requirements have been used for many years for agriculture in localities where other water supplies are not available.

Although many chemical constituents or properties of water affect its suitability for irrigation, the two main criteria for determining a suitable supply are the dissolved-solids content and the sodium concentration relative to the calcium and magnesium concentrations. Also, the concentrations of bicarbonate, boron, and selenium are significant under certain conditions.

The significance of water having a high dissolved-solids content (salinity) is that the application of such water to the land tends to upset the salt balance in the soil. The use of saline water in the absence of a favorable salt balance results in the retardation of plant growth, because such water increases the osmotic pressure in the soil solution. As a rule, the higher the salinity of a water, the less suitable the water is for use. Because the salinity of water is closely related to the specific conductance of water, the specific conductance may also be used as a measure of the salinity hazard of water.

When the relative concentration of sodium in irrigation water is greater than that of calcium and magnesium, the sodium tends to replace the calcium and magnesium adsorbed on soil colloids. Soil colloids then tend to disperse and, thus to restrict the movement of air and water through the soil; a soil having poor tilth and low permeability results. As a measure of the suitability of water for irrigation use, the sodium-adsorption-ratio (SAR) is frequently used. It is an indicator of the degree of hazard entailed in the use of water that has a high sodium content.

Investigations of the relation of water quality to the health of stock have not been numerous, and, therefore, rigid criteria for evaluating the usefulness of a stock-water supply are difficult to establish. Stock are capable of good health even when they drink water considered to be unfit for human consumption. Nevertheless, a high dissolved-solids content can cause poor growth, sickness, and even death. Beath and others (1953) suggested the following classification as a guide for evaluating stock water.

Dissolved solids (ppm)	*Classification*
$<1,000$	Good
1,000–3,000	Fair (usable)
3,000–5,000	Poor (usable)
5,000–7,000	Very poor (questionable)
$>7,000$	Not advisable

Harmful effects to stock have been attributed to the selenium, sulfate, and fluoride contents in water supplies. A high iron content may make water unpalatable to stock.

INDUSTRIAL USE

The water-quality requirements of industry depend largely upon the specific use to be made of water. Reports by Moore (1940) and by the California State Water Pollution Control Board (1952) contain information on industrial water-quality standards and may be consulted for criteria applicable to a specific use. Generally, water that has a low dissolved-solids content and low hardness and does not vary greatly in quality or temperature meets the requirements of most industries.

GEOLOGY AND WATER RESOURCES

FORMATIONS OF PRE-TERTIARY AGE

Formations that range from Precambrian to Late Cretaceous in age are exposed in the Bighorn Mountains and in a narrow band along the mountain front, but they are deeply buried throughout most of the project area. The age, thickness, physical characteristics, and water-bearing properties of these rocks and others are summarized in table 1. Only rocks of pre-Tertiary age that are potential sources of large supplies of ground water are described in detail. Other aquifers of pre-Tertiary age will generally yield only small supplies of ground water to wells.

Bighorn Dolomite.—The Bighorn Dolomite of Late Ordovician age is about 500 feet thick near the Montana State line, but it thins southward to less than 400 feet at the Sheridan-Johnson County line (Richards and Nieschmidt, 1961, sheet 1). The formation generally is divided into three units. The basal sandstone, which is about 30 feet thick in Sheridan County, consists of crossbedded friable white sandstone. The middle (cliff-forming) unit is about 280 feet thick. It consists of massive dolomite that weathers to a characteristic rough, pitted surface. The upper unit is about 150 feet thick and consists of thin-bedded dolomite and dolomitic limestone, which generally form slopes above the middle-unit.

Madison Limestone.—The Madison Limestone of Early and Late Mississippian age is exposed as a series of ledges formed by resistant beds. Caverns (fig. 9) and castellated forms are typical, especially in the upper part of the formation. The formation is composed of limestone, dolomitic limestone, and dolomite. It is about 1,100 feet thick in Sheridan County (Darton, 1904, p. 394) but thins to the south in Johnson County.

Amsden Formation.—The Amsden Formation of Pennsylvanian age consists of cherty dolomite, red sandstone, and red and purple shale. The formation was deposited upon the eroded surface of rocks of Mississippian age, and it varies considerably in thickness within short distances. It is about 150 feet thick near the Montana State line and thickens southward to about 250 feet at the Sheridan-Johnson County line. The formation weathers to form the red slopes between the resistant Tensleep and Madison Formations.

Tensleep Sandstone.—The Tensleep Sandstone of Pennsylvanian age forms steep dip slopes along most of the mountain flank. The formation is dominantly a resistant crossbedded sandstone with minor amounts of dolomite. It probably is conformable with the under-

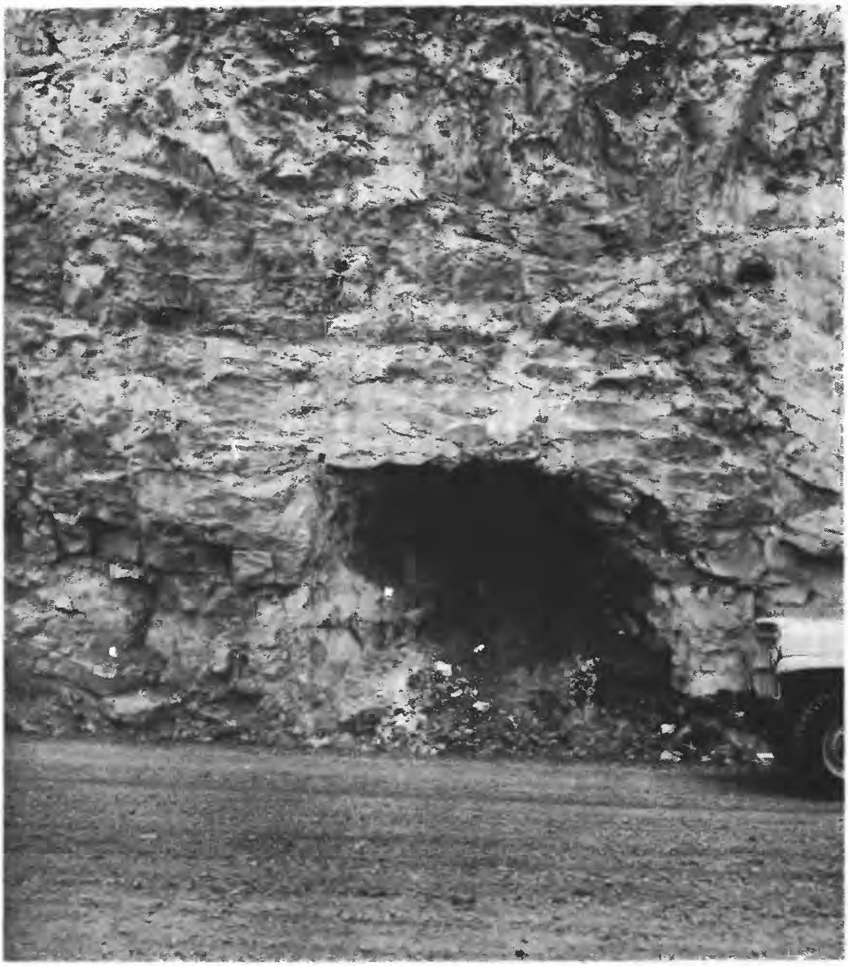

FIGURE 9.—Cavern in the Madison Limestone along U.S. Highway 14 in T. 56 N., R. 87 W.

lying Amsden Formation. The formation thickens from about 50 feet at the State line to about 250 feet at the Sheridan-Johnson County line.

WATER-BEARING PROPERTIES

The aquifers of pre-Tertiary age consist principally of tightly cemented sandstone and carbonate rocks that generally do not have a large primary permeability—that is, permeability due to interstices which were formed contemporaneously with the rock. The Tensleep Sandstone, however, has sufficient primary permeability to yield moderate and possibly large supplies of water to wells. Large yields obtained from the Bighorn Dolomite, Madison Limestone, and Amsden Formation would be principally from zones of secondary permeability—that is, permeability due to fracturing and solution affecting the rocks after deposition. Some wells penetrating these formations to the west of Sheridan County have artesian flows of more than 1,000 gpm. The most productive wells generally are near structural features where fracturing and solution have increased the permeability. Wells penetrating other aquifers of pre-Tertiary age will probably have small yields.

RECHARGE AND DISCHARGE

Recharge to formations of pre-Tertiary age is from precipitation and streamflow. Recharge conditions are favorable throughout the outcrop. Farther east, however, the formations are deeply buried, and recharge is negligible.

Discharge from formations of pre-Tertiary age is through wells, seeps, and springs. All the known discharge points are in the outcrop. Much of the potential recharge of these formations is probably rejected. A description of some of the different types of springs follows to illustrate the recharge-discharge relations, as well as the ground water occurrence.

Contact springs.—Contact springs in Sheridan County may be present where an aquifer is underlain by less permeable beds. Ground water percolates down to the less permeable bed and then moves laterally to the point of discharge. Leaky Mountain Spring (57–90–?), which is an unusually large spring for the region, yields about 1,000 gpm and issues from the Bighorn Dolomite at its contact with the underlying Gallatin Formation of Late Cambrian age.

Landslide springs.—Springs issuing from landslide deposits, such as spring 55–90–16b, are common in the Gallatin and Gros Ventre Formations. The slides are caused, in part, by the contact springs at the base of the overlying Bighorn Dolomite. The relation is apparent at Duncom Mountain, which is on the drainage divide between the Powder River Basin and the Bighorn Basin. Erosion has stripped away the sedimentary rocks down to and including much of the Bighorn Dolomite, and the topography is marked by large solution cavities formed in fractures and in other zones of weakness in the formation. The shale of Cambrian age, which forms the grass-covered slopes below the Bighorn Dolomite, has a hummocky topography that is typical of landslide deposits.

Water percolates downward through the solution cavities in the Bighorn Dolomite to the underlying Cambrian shale and then moves laterally to the point of discharge. The shale is then more susceptible to gravity movement because of the additional weight of the absorbed water and the lubrication of the shale by the water. After the initial movement of the shale and overlying strata, the hummocky topography is capable of retaining snow and runoff, which furnishes additional water to the springs.

Springs from joints, fractures, and tubular openings.—Springs issue from rock openings ranging in size from small fractures or joints to large faults. The spring at Preacher Rock (54–86–32c) flows about 5 gpm from joints in the Precambrian granite, whereas spring 53–84–13bd, which is hydraulically connected with South Piney Creek, flows from sedimentary rocks through openings associated with faults. The flow of the spring ranges from 400 to 1,000 gpm, in direct response to streamflow.

The entire course of Cave Creek is through tubular openings, some of which can be seen in the Tongue River Cave. The creek discharges into the Tongue River below the level of the river. The point of discharge is not visible. A dye study was made to determine whether the source of the water in Cave Creek was the Little Tongue River. Fluorescein dye was mixed with the water of the Little Tongue River in sec 31, T. 56 N., R. 87 W., and the dye was observed later in Cave Creek. The time required for the dye to reach the point of observation was between 37 and 45 hours. The straight-line distance between the two points is about 2.5 miles, and the difference in altitude is about 2,500 feet. The flow of Cave Creek was about 900 gpm at the time of the dye study.

QUALITY OF WATER

Chemical analyses of water from rocks of pre-Tertiary age are given in table 4. Samples of water were obtained from the Flathead Sandstone of Cambrian age, the Amsden Formation and Tensleep Sandstone of Pennsylvanian age, and the Frontier, Parkman, Bearpaw, and Lance Formations, all of Cretaceous age. The quality of water from these formations varies widely: the dissolved-solids content of water ranges from 124 to 1,320 ppm; hardness, from 18 ppm (soft) to 407 ppm (very hard); and iron content, from 0.00 to 1.3 ppm. The quality of water in each formation probably also varies from place to place, as illustrated by analyses of water from the Lance Formation (table 4).

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TABLE 4.—*Chemical analyses of ground*

[Results in parts per million except as

Well	Depth (ft)	Yield (gpm)	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
Flathead												
55-89-1da	66	[2] 20R	Oct. 25, 1960	42	6.8	0.19	0.00	30	7.8	2.0	0.2	128
Amsden Formation and												
57-87-21db	1,596	64	Oct. 25, 1960	50	8.0	0.58	0.00	50	19	0.5	0.6	246
Frontier												
56-86-7dc	148	2R	July 27, 1961	----	10	0.02	0.05	47	14	74	1.0	277
Parkman												
57-86-30ac	115	4R	Oct. 25, 1960	49	13	1.3	0.00	97	40	29	2.0	330
Bearpaw												
58-87-35ca2	129	6R	Oct. 25, 1960	49	38	0.44	0.00	16	2.9	236	0.1	337
Lance												
57-86-34bb	315	.75	Aug. 28, 1961	54	8.4	0.13	0.00	33	18	404	5.3	592
57-87-1bd	195	8R	do	51	9.7	.00	.00	5.6	1.0	150	.8	191
Fort Union												
53-77-10cd	424	1.3	Oct. 26, 1960	67	12	0.47	0.02	22	7.8	620	7.4	1,710
54-76-5ac	710	7	Aug. 29, 1961	64	12	.72	.00	19	3.5	524	6.0	1,430
54-77-5db	1,185	1.64	Aug. 30, 1961	62	13	.08	.02	5.9	2.1	400	5.3	1,040
9cb	743	12R	Oct. 26 1960	59	10	.91	.00	18	3.4	537	4.3	1,450
55-77-28ad	380	6R	Mar. 7, 1962	56	9.0	.21	.00	4.6	.8	219	1.8	553
28dd	500	.75	Mar. 6, 1962	55	9.6	.20	.00	12	2.6	374	4.5	1,000
55-84-16bc	370	.75	Aug. 30, 1961	54	8.6	3.2	.00	62	30	134	8.8	499
27cb	560	1R	June 14, 1962	57	8.7	.19	.00	28	8.3	141	6.5	454
56-78-22ac	165	1	Aug. 30, 1961	59	9.2	.14	.00	7.3	2.9	400	3.5	1,110
56-85-3ad	123	25R	July 27, 1961	50	9.2	.91	.03	43	28	449	7.6	510
57-76-20bd	265	1.47	Oct. 26, 1960	52	9.1	.88	.06	12	2.2	555	4.4	1,480
57-83-3ab	120	3R	Mar. 8, 1962	48	8.2	.19	.00	8.4	2.8	490	4.7	1,320
57-84-19bd	126	15R	Mar. 6, 1962	48	9.8	.10	.00	31	29	810	17	2,370
57-85-19aa	180	5R	do	49	8.2	.14	.00	14	5.2	360	4.2	941
58-82-30aa	480	.71	Oct. 25, 1960	54	11	.31	.00	8.6	3.5	750	6.5	2,010
58-84-29ca	620	5R	Mar. 8, 1962	53	9.4	.15	.00	9.9	17	943	12	1,840
29cd	1,260	.3	do	53	12	.58	.00	3.2	2.7	335	1.8	840

See footnotes at end of table.

water in Sheridan County, Wyo.

indicated. Analyses by U.S. Geol. Survey]

Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids		Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos at 25°C)	pH	Color (units) [1]	Hydrogen Sulfide (H_2S)
						Calculated	Residue on evaporation at 180°C	Calcium, magnesium	Noncarbonate						
Sandstone															
0	3.0	0.0	0.1	2.4	0.04	-------	124	107	2	4	0.1	220	7.2	3	----
Tensleep Sandstone															
0	5.0	0.0	0.2	0.8	0.02	-------	202	204	2	0	0.0	380	7.7	2	----
Formation															
0	104	1.7	0.3	3.2	0.53	-------	390	174	0	48	2.4	638	8.1	0	----
Sandstone															
0	186	1.6	0.4	0.0	0.12	-------	550	407	136	13	0.6	823	7.8	1	----
Shale															
0	233	30	0.2	1.0	0.06	-------	739	52	0	91	14	1,110	7.9	1	----
Formation															
0	493	42	0.3	0.3	0.12	1,300	1,320	155	0	84	14	1,980	8.0	2	----
6.9	157	8.1	.6	.2	.13	-------	450	18	0	95	15	712	8.5	0	----
Formation															
0	1.3	24	0.7	0.1	0.11	1,540	1,560	87	0	93	29	2,420	8.0	3	----
0	.3	16	.7	.0	.07	1,290	1,340	62	0	94	29	1,990	8.0	1	0.0
23	.3	17	.9	.0	.15	------	1,020	23	0	97	36	1,570	8.3	0	.0
0	.4	17	.7	.0	.08	1,300	1,340	59	0	95	30	2,090	8.1	4	.5
10	1.2	14	1.2	------	------	------	530	15	0	96	25	863	8.4	----	.6
0	.8	16	1.6	------	------	------	915	41	0	94	26	1,440	8.1	----	.7
0	136	13	.4	13	.08	------	690	279	0	50	3.5	1,050	7.6	1	.5
0	30	7.0	.6	------	------	------	484	104	0	73	6.0	746	7.9	----	1.3
0	2.3	7.4	2.2	.0	.15	------	1,010	30	0	96	32	1,570	8.2	1	.5
0	708	53	.4	1.0	.16	1,550	1,590	222	0	81	13	2,360	7.7	3	----
0	2.0	21	1.4	.0	.12	1,340	1,340	39	0	96	39	2,080	8.2	3	.5
0	.2	7.6	1.9	------	------	------	1,160	32	0	96	37	1,790	8.1	----	.7
0	55	23	2.1	------	------	------	1,900	196	0	89	25	3,180	7.6	----	2.1
0	.4	57	1.8	------	------	------	888	56	0	93	21	1,460	8.2	----	.7
0	1.3	9.9	2.2	.0	.13	1,780	1,800	36	0	97	54	2,740	8.0	1	.5
0	645	10	1.9	------	------	------	2,380	96	0	95	42	3,620	7.8	----	1.0
16	.0	13	4.0	------	------	------	742	19	0	97	33	1,250	8.3	----	1.3

TABLE 4.—*Chemical analyses of ground*

[Results in parts per million except as

Well	Depth (ft)	Yield (gpm)	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
												Wasatch
53-79-7bc	280	2R	Mar. 7, 1962	43	8.1	0.08	0.00	6.0	2.4	252	2.2	657
53-80-2db	260		do	54	10	.41	.08	317	282	342	9.8	591
18ca2	143		Aug. 30, 1961	62	8.2	.05	.00	4.7	1.8	227	1.8	500
53-82-11cd	143	12R	Mar. 22, 1962	48	8.2	.24	.00	15	4.6	378	3.1	1,060
53-83-7dd	42	30R	Aug. 28, 1961	58	13	.01	.00	34	11	2.3	1.0	156
54-79-21bdd	121	8	Oct. 26, 1960	52	8.8	.26	.00	20	5.1	317	1.9	728
54-80-24bc	120		Mar. 22, 1962	56	30	8.1		457	403	450	26	627
54-81-14bc	110	15R	July 25, 1961	52	11	.00	.00	46	3.2	379	4.2	966
54-82-29ba	60	8R	June 13, 1962	50	21	3.7	.20	136	36	49	7.2	524
54-83-3ba	245	10R	do	55	11	1.2	.00	108	34	567	9.5	665
54-83-7ac	100	10R	Mar. 8, 1962	48	9.1	.03	.00	3.0	.0	155	.9	345
54-84-11ab	160	3R	Oct. 28, 1960	52	14	.24	.00	86	62	22	2.4	528
55-79-30bba1	140	5	Oct. 26, 1960	48	9.0	.93	.16	157	77	822	12	680
30bba2	200	2R	do	56	8.9	.41	.08	8.3	2.3	336	4.6	890
55-81-2bc	Spring		June 14, 1962	53	31	.03	.00	67	10	3.4	2.9	168
55-82-5dc	155	10R	Mar. 7, 1962	48	9.6	.09	.00	13	2.6	405	3.4	1,100
56-81-29bd	378	3R	Oct. 28, 1960	52	10	.12	.00	3.2	.5	243	1.2	484
56-82-35aa	87	16R	June 13, 1962	58	7.1	25	.30	470	519	800	13	801
57-79-25cc	95	6R	Aug. 30, 1961	64	5.7	.00	.03	220	136	1,140	12	574
57-80-31bb	160	3	Aug. 29, 1961	52	11	.12	.00	106	9.6	816	6.2	473
57-81-7cb	510	10R	Mar. 8, 1962	39	9.1	.14	.00	6.0	1.8	350	2.8	918
												Allu-
53-80-18ca1	23	30R	Aug. 30, 1961	55	19	0.27	0.10	201	124	181	13	541
54-84-14bb	65	30R	June 14, 1962	56	12	.08	.00	72	18	12	1.2	324
56-82-34dc	56	108R	July 21, 1961	49	35	4.3	.00	273	136	168	15	613
57-85-19ab	30	25	Aug. 28, 1961	54	12	.00	.32	103	58	100	2.3	441

[1] Platinum—cobalt scale (Hazen, 1892).
[2] R indicates reported yield.

Water from pre-Tertiary rocks is used primarily for domestic and stock purposes. Generally, the water is suitable for domestic use, although the iron content of water from the Tensleep Sandstone and Amsden Formation, the Bearpaw Shale, and the Parkman Sandstone exceeds the recommended limit suggested by the U.S. Public Health Service (1962). Sulfate and dissolved solids in water from well 57–86–34bb, which taps the Lance Formation, also exceed suggested domestic standards, as does the dissolved-solids content of water from the Parkman Sandstone and Bearpaw Shale. Water of suitable quality for irrigation is obtained from the Flathead Sandstone and from the Tensleep Sandstone and Amsden Formation. The Frontier Formation and the Parkman Sandstone yield water that is usable on certain crops under good drainage conditions. Water from the Bear-

water in Sheridan County, Wyo.—Continued

indicated. Analyses by U.S. Geol. Survey]

Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Calculated	Dissolved solids: Residue on evaporation at 180°C	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos at 25°C)	pH	Color (units) [1]	Hydrogen Sulfide (H_2S)
Formation															
8.6	1.8	18	1.4	----	----	----	613	25	0	95	22	1,010	8.4	----	2.4
0	1,990	9.0	.7	----	----	----	3,410	1,960	1,470	27	3.4	3,680	7.3	----	2.9
0	90	12	1.1	8.0	0.08	----	638	19	0	96	23	1,000	7.9	2	.6
0	5.4	2.0	1.0	----	----	----	920	57	0	93	22	1,480	8.0	----	.6
0	1.3	.3	.1	.5	.01	----	160	129	1	4	.1	248	7.9	2	----
0	145	2.8	.9	.1	.11	----	890	71	0	90	16	1,400	8.1	7	1.2
0	3,010	8.0	.8	----	----	----	4,950	2,800	2,280	26	3.7	4,910	7.6	----	.6
0	157	2.8	.4	16	.07	1,090	1,110	128	0	86	15	1,720	8.0	0	1.2
0	157	.6	.4	----	----	----	672	490	60	18	1.0	1,010	7.3	----	.5
0	1,020	6.4	.0	----	----	----	2,090	408	0	75	12	2,910	7.5	----	.6
17	26	1.0	.6	----	----	----	376	8	0	98	25	612	8.7	----	1.0
0	64	2.0	.3	19	.18	----	529	470	37	9	.4	874	7.6	7	----
0	1,930	6.2	.3	38	.28	3,390	3,480	709	151	71	13	4,350	7.6	4	----
0	2.8	11	.8	7.9	.12	----	830	30	0	95	27	1,320	7.7	7	----
0	37	7.0	.6	----	----	----	281	209	72	3.4	.1	432	7.7	----	1.2
0	.6	11	.8	----	----	----	897	43	0	95	27	1,540	8.1	----	1.0
0	118	5.7	1.8	5.6	.12	----	628	10	0	98	33	994	8.2	1	----
0	4,080	45	.7	----	----	----	6,620	3,310	2,650	34	6.0	6,620	7.4	----	4.0
0	3,110	7.4	.2	1.0	.19	4,920	5,080	1,110	639	69	15	5,880	7.8	6	.6
0	1,690	8.5	.4	.8	.11	2,880	2,960	304	0	85	20	3,920	8.1	1	.5
0	3.0	16	1.8	----	----	----	834	22	0	97	32	1,320	8.2	----	.5
vium															
0	883	8.7	0.2	0.0	0.32	1,700	1,860	1,010	566	28	2.5	2,250	7.6	8	0.6
0	8.0	.0	.1	----	----	----	272	253	0	9.3	.3	487	7.6	----	.0
0	1,020	6.1	.5	.1	.22	1,960	2,060	1,240	737	22	2.1	2,440	7.8	7	----
0	329	4.8	.2	1.1	.18	----	844	497	135	30	2.0	1,220	7.7	0	----

paw Shale and the Lance Formation is unsuitable for irrigation because of its high sodium (alkali) hazard. The water from pre-Tertiary rocks generally is good for stock use.

DEVELOPMENT

Bighorn Mountains.—Three water wells are known to have been drilled in the Bighorn Mountains in Sheridan County. Water for stock, summer homes, tourist facilities, and other installations comes mainly from springs or surface water. Aquifers such as the Tensleep Sandstone, Amsden Formation, Madison Limestone, Bighorn Dolomite, and Flathead Sandstone underlie large areas in the mountains (pl. 1), but, because most of the area is remote, additional development of water was not needed at the time of the investigation.

Powder River structural basin.—Water from aquifers of pre-Tertiary age has not been extensively developed in the basin in

Sheridan County. Aquifers that have been tapped by wells are the Amsden Formation and Tensleep Sandstone, Frontier Formation, Parkman Sandstone, Bearpaw Shale, Lance Formation, and possibly the Chugwater Formation. Only two of these formations yield water to more than one well—the Lance (six wells) and the Bearpaw (three wells at Parkman, only one of which is shown on pl. 1). Other potential aquifers yield water only to springs, but artesian supplies could be developed throughout most of the outcrop from the aquifers listed in table 1. Wells drilled some distance from the outcrop of the intended aquifer must necessarily be drilled deeper than those closer to the outcrop because of the steep dip of the formations. Drilling as near the outcrop of the intended aquifer as possible is advisable for this reason; however, a well that is drilled too near the outcrop may not penetrate a maximum saturated thickness.

East of the outcrop area the formations of pre-Tertiary age are deeply buried (fig. 10), and the cost of drilling into them for water wells is great. Ground water possibly may be developed from some "dry" oil-test holes in favorable localities; but the suitability of the water for its intended use should be determined before any such wells are developed.

FORMATIONS OF TERTIARY AGE

Formations of Tertiary age in the report area include the Fort Union Formation of Paleocene age, the Wasatch Formation of Eocene age, and the White River Formation of Oligocene age. The Fort Union and Wasatch Formations, which are widespread, underlie the central and eastern parts of the county. These units consist of continental deposits made up principally of shale, sandstone, coal, and conglomerate. Conglomerate is not known in the Fort Union in Sheridan County; however, it is in the formation near the mountains to the south, in Johnson County. The White River Formation is present only as isolated remnants in the mountains and is not discussed in the following section.

FORT UNION FORMATION

The Fort Union Formation is divided into three members in this area: in ascending order, the Tullock Member, Lebo Shale Member, and Tongue River Member. In this report, however, the formation is regarded as undifferentiated.

The following detailed section, which was adapted from Olive (1957, p. 11–12), illustrates the lithology of the upper part of the Fort Union in eastern Sheridan County.

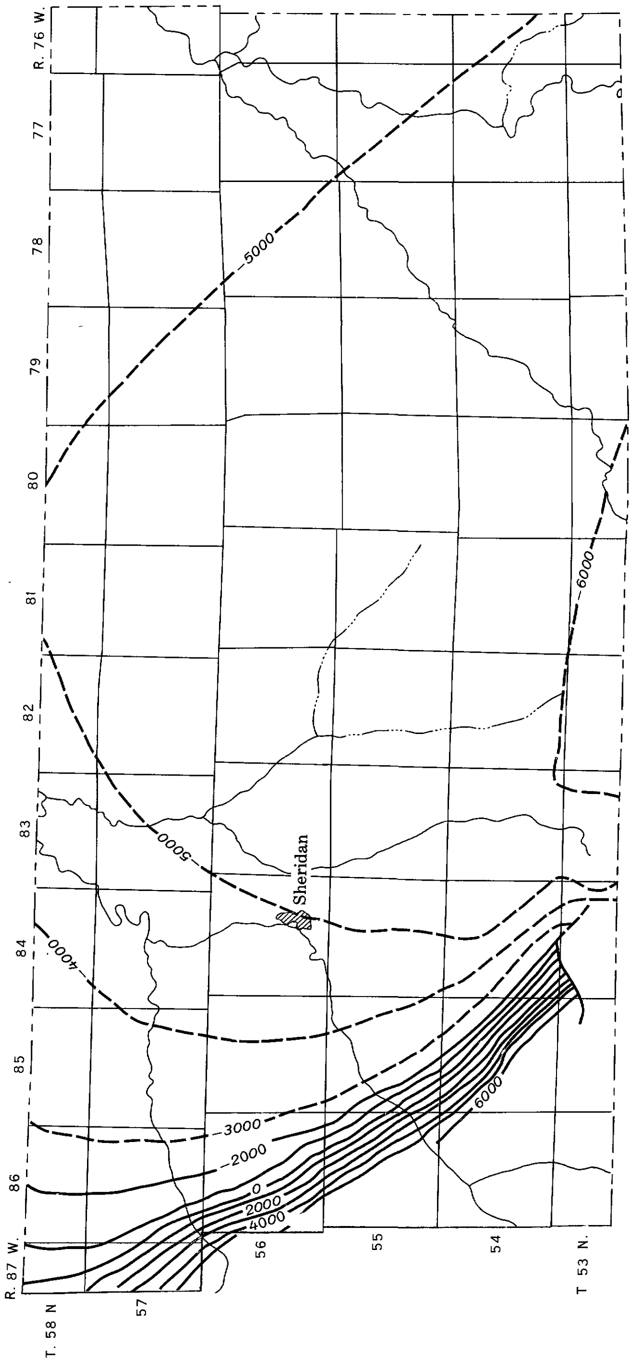

FIGURE 10.—Structure contour map of the top of the Cloverly Formation in Sheridan County, Wyo. Contour lines are approximate. Lines are dashed where several configuration and depth relations are schematic. Contour interval is 1,000 feet; datum is mean sea level. (After Zapp, 1953.)

Section measured in sec. 25, T. 57 N., R. 77 W., Wyo.

[Adapted from Olive, 1957, p. 11–12]

	Feet	Inches
Wasatch Formation:		
Sandstone, medium-grained, friable, yellowish-gray; contains log-shaped concretions 15–20 ft long	96	0
Fort Union Formation:		
Shale, dusky-brown		5
Coal	2	4
Sandstone, medium-grained, mostly friable, yellowish-gray	43	10
Coal	1	8
Shale, dusky-brown and gray; interbedded with fine-grained yellowish-gray sandstone	7	1
Sandstone, friable, yellowish-gray	42	0
Coal with 1-ft shale parting	3	9
Sandstone, fine- to medium-grained, friable, yellowish-gray	24	0
Shale, dusky-brown	3	6
Coal	5	7
Shale, dusky-brown	3	1
Sandstone, medium-grained, friable, yellowish-gray	28	0
Coal with shale partings	4	5
Shale, dusky-brown	4	4
Sandstone, yellowish-gray; interbedded with light-gray shale	28	0
Shale, dusky-Brown	7	3
Coal	7	10
Sandstone and shale, interbedded, gray and yellowish-gray	58	6
Sandstone, fine-grained, friable; contains well-indurated zones	47	9
Shale, dusky-brown and black	6	0
Coal	1	7
Shale, dusky-brown and black	6	6
Sandstone, friable, yellowish-gray; contains indurated sandstone lenses	22	0
Coal with 2-ft shale parting	17	1
Shale, dusky-brown	9	6
Sandstone, fine-grained, friable, yellowish-gray; contains thin layers of dusky-brown shale	42	0
Coal		9
Shale, dusky-brown		2
Sandstone, fine-grained, friable, yellowish-gray; contains ironstone concretions	6	3
Shale, dusky-brown	2	10
Coal	2	9
Shale, dusky-brown		9
Sandstone, fine-grained; contains well indurated zones	40	5
Total measured Fort Union Formation	494	8

The contract between the Fort Union Formation and the underlying Lance Formation is apparently conformable and gradational throughout Sheridan County. In the western part of the county, the Fort Union Formation dips about 4° E. or SE. (Taff, 1909, p.

132) and is probably about 2,000 feet thick. The strata in the Spotted Horse coal field in the eastern part of the county generally dip southwestward at less than 3° (Olive, 1957, p. 21). There, the thickness of the formation is not known; only 900 feet of the upper part of the Fort Union is exposed (Olive, 1957, p. 10).

WASATCH FORMATION

Near the mountains, the Wasatch Formation is divided into two members on the basis of an angular unconformity. The lower member is the Kingsbury Conglomerate Member, and the upper is the Moncrief Member. Both members, which are interpreted as alluvial-fan deposits (Gale and Wegemann, 1910, p. 144; Sharp, 1948, p. 12), grade laterally into the fine-grained facies of the Wasatch Formation and cannot be distinguished a few miles east of the mountains.

The Kingsbury Conglomerate Member is exposed in a small area at the base of Moncreiffe Ridge but is not shown on plate 1. It is about 800 feet thick just south of the report area (Mapel, 1959, p. 64).

The Moncrief Member is as much as 1,400 feet thick (Sharp, 1948, p. 2) and consists of beds of conglomerate, coarse-grained sandstone, and greenish-gray siltstone. Precambrian rocks of the Bighorn Mountains were the source of most of the material in the member, and boulders 5–10 feet in maximum dimension are common in the upper part of the member, which contains relatively coarser material than the lower part.

In the Powder River structural basin, the lithologies of the Wasatch and the Fort Union Formations do not differ greatly. Coal is not as prevalent in the Wasatch, nor is sandstone. (See measured sections by Olive, 1957, p. 11–12, 16–18.) The maximum thickness of the formation in the basin is about 1,200 feet (Taff, 1909, p. 130).

The following section (adapted from Mapel, 1959, p. 67) was measured 3 miles south of the project area, but it illustrates the similarity between the Wasatch and Fort Union Formations.

Partial section of coal-bearing beds of Wasatch Formation in S½ sec. 31, T. 53 N., R. 80 W.

[Adapted from Mapel, 1959, p. 67]

	Feet	Inches
Clinker, red	3	0
Shale and sandstone, interbedded; sandstone very light gray to grayish yellow, fine grained to silty, friable; shale, gray; interval poorly exposed	66	0
Shale, dusky-brown, carbonaceous	3	6
Concealed; probably sandstone and shale	35	0
Sandstone, very light gray, fine-grained, calcareous, crossbedded; interbedded greenish-gray siltstone near base	24	0

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Partial section of coal-bearing beds of Wasatch Formation in S½ sec. 31, T. 53 N., R. 80 W.—Continued

	Feet	*Inches*
Concealed	15	0
Shale, light-olive-yellow	12	0
Coal and interbedded brown shale	13	0
Sandstone and shale, interbedded; sandstone, white, fine-grained, friable; shale, gray	31	0
Coal	2	7
Shale, light-olive-gray; grades upward into dusky brown shale in top 3 ft	18	6
Shale, dusky-brown, carbonaceous		6
Coal	1	3
Shale, dusky-brown, carbonaceous	2	0
Sandstone and shale, interbedded, very light gray, fine-grained, calcareous; shale, olive gray; bed of gray, yellowish-weathering, sandy limestone concretions 8 ft above base	28	0
Shale, dark-gray; contains a few shell fragments near base	12	0
Limestone, light-gray; weathers yellowish brown; composed largely of shells of fresh-water mollusks		4
Coal	1	6
Shale, gray; upper 8 in. is dusky brown	19	0
Shale, dusky-brown, carbonaceous; contains a few ½-in. seams of coal	3	0
Shale, gray, slightly carbonaceous	5	6
Coal	3	1
Concealed	20	0
Sandstone, light-gray, fine-grained; contains a few yellowish-gray limestone concretions	7	0
Concealed	24	0
Shale, dusky-brown, carbonaceous		6
Coal	3	6
Shale, dusky-brown, carbonaceous	1	0
Sandstone, very light gray, fine-grained, friable; contains a few thin partings of gray shale	12	0
Shale, dusky-brown, carbonaceous	2	0
Coal	1	4
Shale, dusky-brown, carbonaceous		6
Shale, olive-gray; sandy near top	14	0
Coal, shaly	2	5
Shale and sandstone, interbedded; shale, olive gray; sandstone, very light gray, fine grained, friable, crossbedded	35	0
Shale, dusky-brown, carbonaceous; contains a few ½-in. seams of coal	3	6
Shale, olive-gray; sandy near base	8	0
Sandstone, very light gray, fine-grained, friable, crossbedded	10	0
Shale, dusky-brown, carbonaceous	2	0
Coal	2	8
Shale, dusky-brown, carbonaceous		6
Sandstone, light-gray to light-yellowish-gray, very fine grained, friable; upper 3–4 ft shaly	12	0

Partial section of coal-bearing beds of Wasatch Formation in $S^1/_2$ sec. 31, T. 53 N., R. 80 W.—Continued

	Feet	Inches
Coal	1	7
Shale, dusky-brown, carbonaceous	1	6
Sandstone, light-yellowish-gray, very fine grained; contains many partings of gray shale	7	0
Shale, olive-gray; 1-in. seam of coal near top	1	6
Sandstone, very light gray, friable	5	0
Coal		9
Shale, dusky-brown, carbonaceous	1	6
Concealed	24	0
Sandstone, gray to white, fine-grained, crossbedded; shaly near top	11	0
Shale, dusky-brown, carbonaceous	3	0
Shale, gray, silty	3	0
Total measured thickness	521	6

The top of the Roland coal is used as the arbitrary boundary between the Fort Union and Wasatch Formations and has been traced throughout much of the basin. Attempts to determine the relation between the Roland coal and the Kingsbury Member at Moncreiffe Ridge have been unsuccessful, and the Wasatch is apparently conformable with the Fort Union throughout most of Sheridan County. Olive (1957, p. 13–14) noted an erosional unconformity in the Spotted Horse coal field in Campbell County, where 670 feet of interbedded sandstone, shale, and coal, including the Roland coal, was replaced by 160 feet of crossbedded sandstone. A conglomeratic mudstone was noted some 150 feet above the Fort Union-Wasatch contact west of Clear Creek in T. 55 N., R. 78 W., and is at about the horizon where Brown (1948, p. 1273) postulated that evidence of an unconformity might be found. A similar conglomerate was noted in the Badger Hills, but the relation to the Roland coal is not known.

WATER-BEARING PROPERTIES

Water levels generally are not deep in the Fort Union and Wasatch Formations. The level in most wells is less than 100 feet, and the maximum measured depth to water was 222 feet in well 57–80–34cc. Wells, even on the drainage divide between the Powder River and the Tongue River, penetrate aquifers at shallower depths than might be expected, because many of the aquifers are lenticular and are recharged locally. In areas of considerable local relief, however, the upper strata may be drained. Flowing wells are common in the valleys of the Powder River, Tongue River, and Little Goose Creek. The location of wells and depth to water are shown on plate 1. Generally, wells drilled in valleys and draws will have higher water levels, with respect to land surface, and may penetrate aquifers at shallower depths.

Depths of wells range considerably because the aquifers are not continuous. The lenticularity of some of the aquifers and the resulting difference in depth of wells are shown in figure 11. The profile is near the western margin of the Wasatch Formation, and the deeper wells are probably completed in the Fort Union. The specific conductance of water from the wells also is shown in figure 11. The difference in conductance that occurs within a short distance indicates that the aquifers are not directly connected. The sandstone aquifers are probably deposits similar to the channel sandstone shown in figure 12.

General correlations are possible on the basis of the known intervals between the coals in localities where several coal beds are penetrated by wells (fig. 13). The aquifers that yield water to wells are usually the only ones noted in the drillers' logs, and although some sands are noted as being dry, probably not all the sand beds above those which contribute water to the wells are dry. Wells commonly are drilled deeper in an attempt to develop them as flowing wells or to reach water of more acceptable quality.

Yields from wells are generally small—less than 10 gpm—but supplies adequate for domestic and stock use can be obtained throughout the area. No water wells are known to penetrate the entire thickness of either the Fort Union or Wasatch Formations, but the yield of wells could be substantially increased if by drilling deeper, a greater number of aquifers were penetrated. The principal aquifers that yield water to wells and springs are sandstone and coal. Large amounts of water accumulate in abandoned coal mines, and this water has been developed from springs (53–82–10aa) at old mine entrances and from wells (53–82–2da) bored into flooded mine workings.

Numerous springs exist in the Powder River structural basin, and springs with flows as small as 0.1 gpm have been developed. Contact springs are the most common, although a few landslide springs occur. In addition to the aquifers previously mentioned, clinker beds—created by the burning of coal seams—commonly yield water to springs that is less mineralized than is the water from other aquifers.

Although the resistant-Moncrief Member of the Wasatch Formation forms an area of high relief and is largely above the water table, the occurrence of water in the Moncrief is similar to the occurrence in alluvial fans. Water-table conditions exist in the recharge area, and artesian conditions occur basinward. Springs near Moncreiffe Ridge issue from sandstone and conglomerate lenses that have been exposed by post-Eocene erosion.

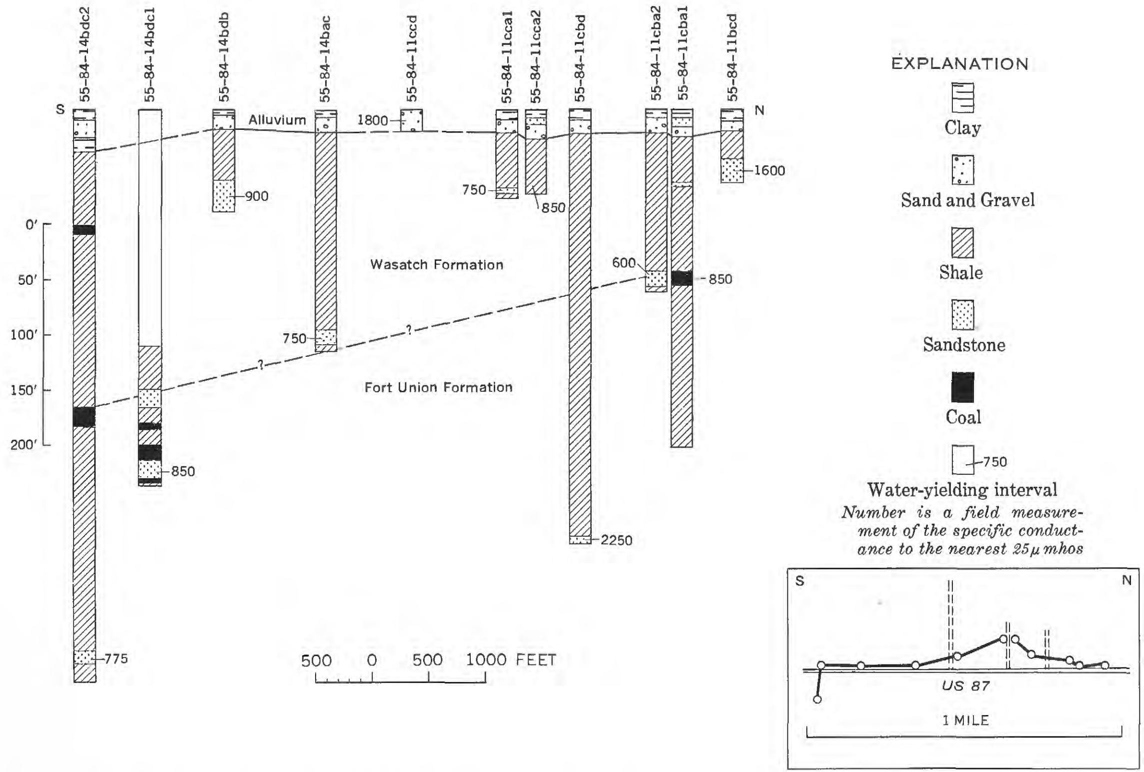

FIGURE 11.—Wells in the valley of Little Goose Creek, 2 miles south of Sheridan, Wyo., in secs. 11 and 14, T. 55 N., R. 84 W., showing difference in depth to aquifers and difference in specific conductance of water.

FIGURE 12.—Channel sandstone in the Fort Union Formation exposed in a roadcut in sec. 34, T. 57 N., R. 84 W.

Drillers' logs show that sandstone and coarser material constitute at least 50 percent of the bedrock penetrated near Moncreiffe Ridge Therefore, moderate to large yields might be obtained from deep wells near Moncreiffe Ridge. These bedrock conditions extend basinward as far as wells 54–83–7ad and 54–83–21cc. The sandstone penetrated by well 54–83–27cd, which is just east of these two wells, was only 30 percent of the bedrock. Although this well may have penetrated a greater saturated thickness of sandstone than did some of the shallower wells to the west, the basinward decrease in permeability has resulted in a specific capacity for the well of less than 0.01 gpm per foot of drawdown.

RECHARGE AND DISCHARGE

Recharge to the aquifers in the eastern and central parts of the county is almost entirely from precipitation. Areas underlain by clinker beds are especially favorable for recharge, because precipitation on these areas percolates rapidly down through the zone where it would evaporate or be transpired.

Recharge in the western part of the project area and along Piney Creek comes principally from irrigation and surface water. Ground water, nonetheless, probably contributes to the flow of Piney Creek in some reaches.

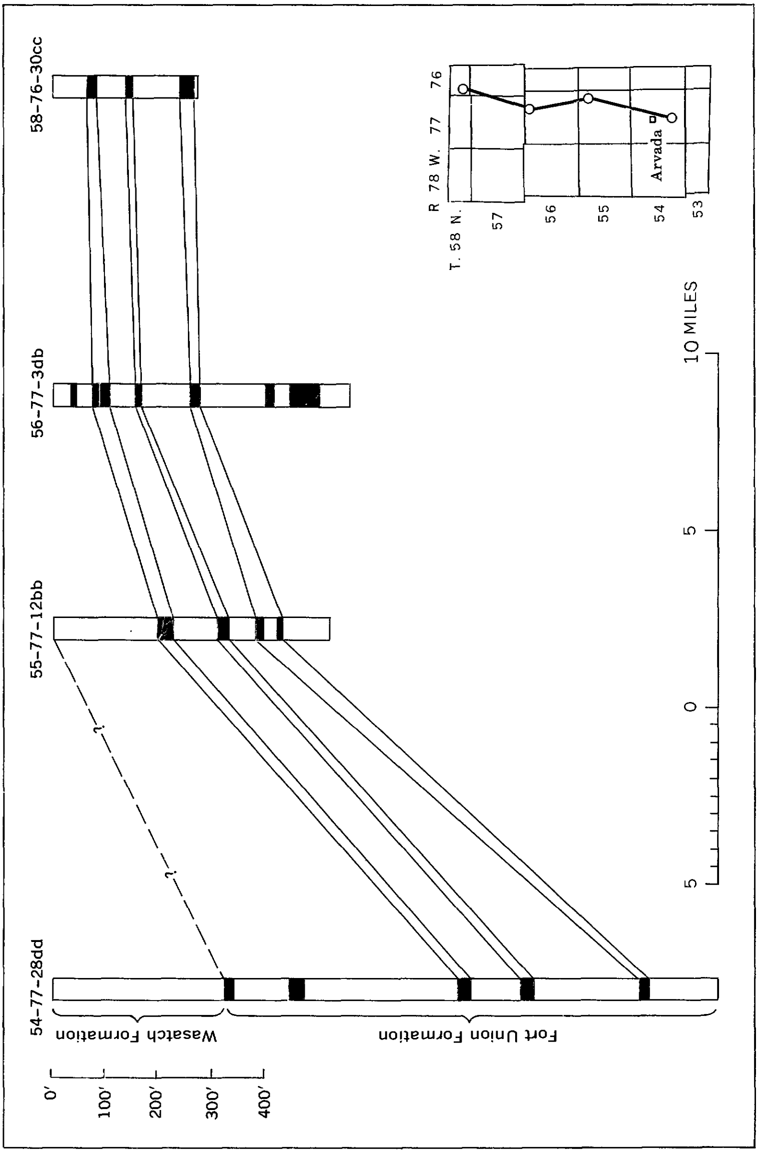

FIGURE 13.—Correlation of coal beds in eastern Sheridan County, Wyo.

QUALITY OF WATER FROM THE FORT UNION FORMATION

Chemical analyses of 17 water samples from the Fort Union Formation are given in table 4. The wells sampled were in, or near, the outcrop of the formation. The water is a sodium bicarbonate type and has a dissolved-solids content that ranges from 484 to 2,380 ppm. The iron content ranges from 0.08 to 3.2 ppm, and the hardness ranges from 15 (soft) to 279 ppm (very hard). The chemical characteristics of water from the Fort Union are presented graphically in figure 14. The quality of water in the Fort Union Formation probably is affected by two chemical reactions as the water moves through the rocks. The reactions are as follows:

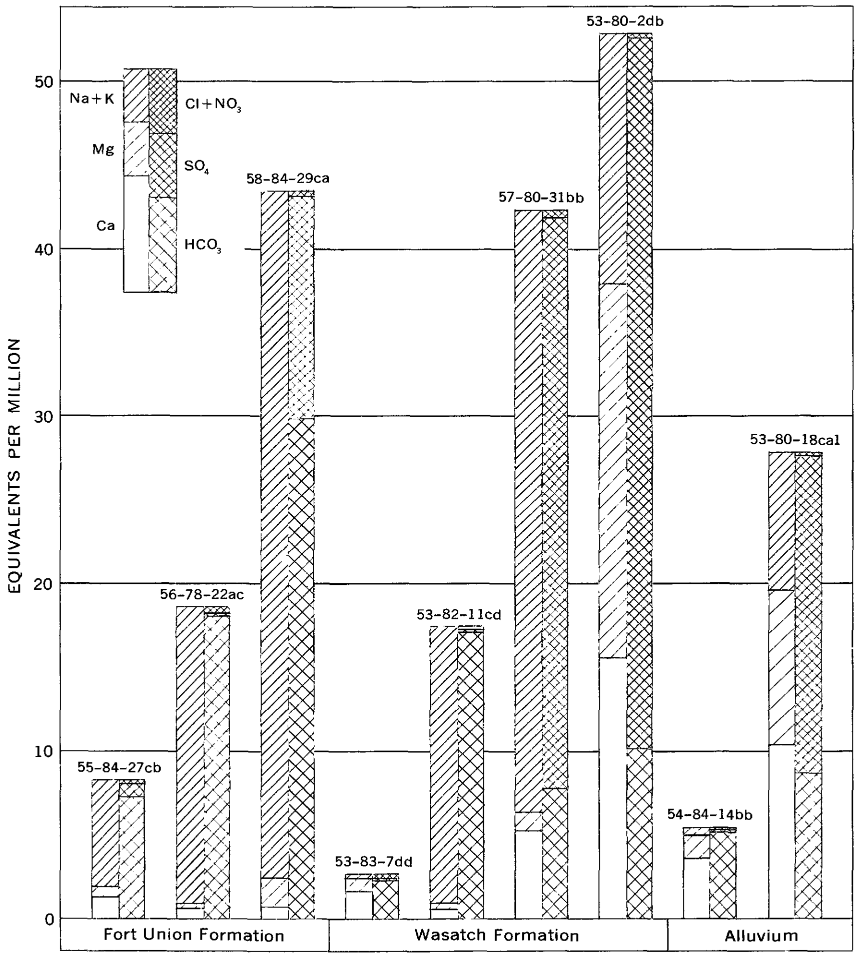

FIGURE 14.—Chemical characteristics of ground water in the Fort Union and Wasatch Formations and in the alluvium, Sheridan County, Wyo.

1. *Cation-exchange softening.*—Many rock materials hold absorbed cations that may be exchanged for cations in solution in water. One such reaction is the exchange of sodium (held by the solid phase) for dissolved calcium. Generalized, it may be written

$$2NaX + Ca^{+2} \rightarrow CaX_2 + 2Na^{+1},$$

where X represents a unit of exchange capacity in the solid-phase material. Riffenburg (1925) cited cation-exchange softening as affecting the quality of water in the Fort Union Formation in Montana; similar conditions occur in Wyoming.

2. *Sulfate reduction.*—In the presence of hydrocarbons and certain bacteria, sulfate may be reduced to form hydrogen sulfide and bicarbonate. The reaction was illustrated by Hem (1959, p. 103) as follows:

$$CaSO_4 + CH_4 \rightarrow CaS + CO_2 + 2H_2O$$
$$CaS + 2CO_2 + 2H_2O \rightarrow H_2S + Ca(HCO_3)_2.$$

The reduction of sulfate in water in the Fort Union Formation is indicated by the presence of relatively high bicarbonate concentrations as compared to the sulfate concentrations, and by hydrogen sulfide and hydrocarbon gases in the water at many locations. Only one water sample had a sulfate concentration higher than the bicarbonate concentration, and that sample was obtained from a shallow well (56–85–3ad).

Although cation-exchange softening is the probable cause of the high percentage of sodium in the water of the Fort Union Formation, sulfate reduction possibly indirectly increases the percentage of sodium. Under favorable conditions the reduction of sulfate will result in the formation of nearly insoluble calcium and magnesium carbonates, which precipitate (Eaton, 1936, p. 515).

Foster (1950) suggested that carbon dioxide which originates in carbonaceous material promotes high sodium bicarbonate concentrations in water. The carbon dioxide, when adsorbed by water, enables the water to dissolve calcium carbonate, and an increase in bicarbonate concentration results. If water that contains calcium carbonate comes in contact with cation-exchange materials, the dissolved calcium may be exchanged for sodium. The exchange not only increases the proportion of sodium in solution, but allows even greater amounts of bicarbonate to be held in solution.

Water from the Fort Union Formation is used principally for domestic and stock purposes. The dissolved-solids content of water from all but one well exceeded the limit recommended by the Public Health Service. The water is usable, however. Iron exceeds the 0.3-ppm suggested maximum in water from some aquifers. Most wells yield soft to moderately hard water. Hydrogen sulfide imparts an unpleasant odor to some of the supplies, but, like carbon dioxide, it is not physiologically harmful in water. At the time of this investigation (1961), water from the Fort Union Formation was not being used for irrigation, and it generally would not be usable as irrigation water except for salt tolerant crops under favorable conditions. Nearly nine-tenths of the samples analyzed had either a high to very high sodium hazard or a high to very high salinity hazard. Water from the Fort Union Formation ranges from good to fair for stock use.

GAS ASSOCIATED WITH WATER IN THE FORT UNION FORMATION

Gas and water are discharged together from some wells that penetrate coal and other carbonaceous material of the Fort Union Formation. Samples of gas were collected at the well head from four flowing wells in accordance with techniques suggested by the Chemical and Geological Laboratories, Casper, Wyo. Analyses were made by that laboratory using a gas chromatograph. These analyses, together with measurements of the quantity of gas discharged, are given in table 5. The gas is mainly methane with lesser qantities of oxygen, nitrogen, carbon dioxide, ethane, propane, isobutane, and higher paraffin hydrocarbons. Hydrogen sulfide is present, although its quantity could not be determined by the chromatographic analysis. The concentration of hydrogen sulfide dissolved in the water at the well head was determined, however. (See table 4.)

Most of the gas probably originates in the coal or other carbonaceous material in the Fort Union Formation. Analyses of gas from coal (Chamberlin, 1909) are similar in many respects to analyses of gas obtained from water wells in Sheridan County. Lewis (1934) stated

TABLE 5.—*Quantity and quality of gas discharged with water from the Fort Union Formation, Sheridan County, Wyo.*

[Analyses by Chemical and Geological Laboratories, Casper, Wyo.]

Well	Date	Gas-water ratio [1] (at 25°C and atmospheric pressure)	Percentage composition (by volume)						
			Oxygen (O_2)	Nitrogen (N_2)	Carbon dioxide (CO_2)	Methane (CH_4)	Ethane (C_2H_6)	Propane (C_3H_8)	Isobutane (C_4H_{10}) and higher paraffin hydrocarbons
54-76-5ac	Aug. 29, 1961	(2)	0.14	8.87	0.31	90.66	0.02	Trace	Trace.
54-77-5db	Aug. 30, 1961	0.5	.63	8.69	.47	90.10	.08	0.03	Trace.
57-76-20bd	do	.3	4.82	23.13	.78	71.18	.07	.02	Trace.
58-82-30aa	Mar. 21, 1962	2.2	1.03	6.14	.94	91.82	.07	--------	

[1] Gas-volume discharge (liters)/water-volume discharge (liters).
[2] Water discharge not measurable.

that carbon dioxide and methane in coal are being formed continuously, primarily by internal molecular adjustments during transitions from rank to rank in the coal series. Ethane and propane have been obtained from coal, but generally as a result of heating. To the authors' knowledge, isobutane has not been cited specifically as a gas formed or contained in coal. Many analyses of gas contained in coal were made several years ago when analytical procedures were less sensitive to small quantities of paraffin hydrocarbons. Isobutane may have been present, therefore, in gas contained in coal, but not detected when the gas was analyzed. Although coal and carbonaceous material of the Fort Union Formation are probably the principal sources of the gases discharged from water wells, the isobutane and the higher paraffin hydrocarbons may be natural gases that have migrated from other rocks. Some of the ethane and propane also may have migrated from natural-gas deposits. Natural gas generally contains a higher percentage of ethane and propane than does the gas obtained from coal.

Moore (1950) stated that the nitrogen in coal comes partly from plant constituents but mainly from air imprisoned in the coal. However, some of the nitrogen discharged with the water from wells in Sheridan County may have been carried downward by percolating ground water. Most of the oxygen from air imprisoned in coal probably combines with carbon and hydrogen during the alteration of vegetal matter from which the coal is formed. Oxygen, nevertheless, has been obtained from coal, and Lewis (1934, p. 33) stated that free oxygen in small quantities is sometimes detected in coal. The oxygen in gas obtained from water wells may have been present in percolating ground water that was once in contact with the atmosphere.

Despite the facts that oxygen and nitrogen have been observed in coal and that both may be present in percolating ground water, the oxygen, and some of the nitrogen in the samples, possibly resulted from air contamination while the samples were being collected. The evacuated tanks used to collect gas samples may have leaked slightly during the interval between evacuation and sample collection. Also, some of the well casings are old and corroded, and air may have entered the casings. Air contamination of the gas from well 57–76–20bd seems probable. If the analysis of gas from well 57–76–20bd is recomputed to air-free conditions, methane content increases to greater than 90 percent, and nitrogen decreases to approximately 7 percent. Thus, recomputed on this basis, the analysis of the gas is similar to analyses of gas from the other wells.

The total volume of gas discharged per unit volume of water discharged—that is, the gas-water ratio—differs from well to well. Well

58–82–30aa has a gas-water ratio of 2.2, whereas wells 54–77–5db and 57–76–20bd have gas-water ratios of 0.5 or less. Although a sample of gas was obtained from well 54–76–5ac, the gas-water ratio could not be measured. Field observations indicated that the gas-water ratio for this well is greater than that of any other in the project area. This well discharges gas and water in alternating surges.

Gas accumulates in fractures in the coal, and it also migrates to adjacent strata. Gas in an aquifer affects the height to which water will rise in a well and may bring the water to the surface (Meinzer, 1942, p. 418). Where the quantity of gas in an aquifer is small, all the gas may be dissolved in the water. A gradual decrease in pressure as the water moves from the aquifer allows the dissolved gas to be liberated. The liberated gas expands, and as it expands the specific gravity of the gas-water mixture is decreased and a lifting action created. Several wells in Sheridan County flow because of this effect that otherwise probably would not. Other wells in Sheridan County undoubtedly flow because of the pressure of free gas in the aquifer.

A 1-liter sample of water was obtained from well 58–82–30aa to determine the quantity and quality of gas in solution at the well head. The sample was allowed to stand unsealed at atmospheric pressure until all visible gas bubbles had disappeared (approximately 1 min.). It then was sealed tightly. The sample yielded 64 milliliters of gas (measured at 25°C) when analyzed. The percentage composition of this gas was as follows:

Gas	*Percentage composition (by volume)*
Oxygen (O_2)	0.42
Nitrogen (N_2)	11.37
Carbon dioxide (CO_2)	37.83
Methane (CH_4)	50.32
Ethane (C_2H_6)	.04
Propane (C_3H_8)	.01
Isobutane (C_4H_{10}) and higher paraffin hydrocarbons	.01

Each type of gas was dissolved in the water in a quantity not exceeding its solubility at atmospheric pressure and at the same water temperature as when the sample was collected. The gases probably remain in the water for some time and gradually escape when the water is in contact with the atmosphere. The escape probably is more rapid when the water is agitated by flowing or by some other action. Literature could not be found that cited harm to human beings or stock as the result of drinking water containing the quantities of hydrocarbon gases likely to be in solution at atmospheric pressure.

QUALITY OF WATER FROM THE WASATCH FORMATION

Chemical analyses of water from the Wasatch Formation are given in table 4. The chemical characteristics of the water are illustrated graphically in figure 14. The dissolved-solids content of the water ranges from 160 to 6,620 ppm; iron content, from 0.00 to 25 ppm; sulfate content, from 0.6 to 4,080 ppm; and hardness, from 8 ppm (soft) to 3,310 ppm (very hard). Hydrogen sulfide, methane, and probably the higher paraffin hydrocarbon gases are in the water of the Wasatch Formation, particularly in areas underlain by coal. No analyses of gas were made, however, because of unsuitable sampling conditions.

Approximately half the wells sampled yield a sodium bicarbonate type water with less than 1,200 ppm dissolved-solids content. The water from these wells is similar to that from the Fort Union Formation and probably has been affected by cation-exchange softening and sulfate reduction. Deposits of both formations are similar, and, therefore, water of similar quality would be expected, particularly from deep wells.

Water from other wells sampled ranges widely in dissolved-solids content. Sodium sulfate, magnesium-sodium sulfate, magnesium-calcium sulfate, and calcium bicarbonate types of water occur. This diversity may be attributed to local differences in recharge conditions, soils, and lithology. A sample of water from clinker beds (spring 55–81–2bc) was of calcium bicarbonate type and had a dissolved-solids content of 281 ppm.

Water from the Wasatch Formation is used principally for domestic and stock purposes. The dissolved-solids content of the water generally exceeds the limit recommended by the Public Health Service, but the water is usable at most locations. Undesirable concentrations of iron, manganese, and sulfate are mainly in water having a dissolved-solids content greater than 2,000 ppm. Water from well 54–79–21bdd, the public supply of the town of Clearmont, has a dissolved-solids content of 890 ppm, is moderately hard, and contains sufficient hydrogen sulfide to impart a noticeable odor. Although wells having sufficient yield may be constructed in the Wasatch Formation, the water is generally unusable for irrigation except on the most salt-tolerant crops under the most favorable conditions. Approximately two-thirds of the analyzed water samples had either a very high salinity hazard or a very high sodium hazard. The water ranges from good to very poor as a stock supply. Wells at most locations, however, yield usable stock water.

DEVELOPMENT OF WATER FROM ROCKS OF TERTIARY AGE

Water supplies for stock and domestic use have been developed throughout the eastern and central parts of the county from the Fort Union and the Wasatch Formations. Wells shown on plate 1 do not indicate their density but were selected as representative of those in the area.

Small yields are available throughout the area underlain by these formations, but moderate to large supplies possibly could be developed from wells in the vicinity of Moncreiffe Ridge.

DEPOSITS OF QUATERNARY AGE

Those deposits of Quaternary age in Sheridan County that contain significant quantities of water are terrace, alluvium, and flood-plain deposits. The water-bearing characteristics of these and other deposits of Quaternary age are given in table 1. Terraces of Tertiary age have been mapped in the area by Mapel (1959, p. 74). In this report, however, the terrace deposits are generalized and are shown on the map as Quaternary age.

TERRACE DEPOSITS

Terrace deposits occur along the major streams throughout the county. They are more prevalent in the western part of the county, and only these terrace deposits are shown on plate 1. Some of these contain significant quantities of water. The deposits, which consist of unconsolidated clay, silt, sand, gravel, and boulders, are as much as 45 feet thick.

FLOOD-PLAIN DEPOSITS

Flood-plain deposits, which are shown on plate 1, comprise flood-plain material, slope wash, and the Recent terrace deposits which were described by Leopold and Miller (1954, p. 6–11). The deposits, composed of unconsolidated clay, silt, sand, gravel, and boulders, are generally coarser in the western part of the county, near the mountains. Locally derived coarse material has been deposited in the valleys of streams that head in the central part of the basin; however, gravel derived from the Bighorn Mountains has been deposited in the eastern part of the county, in the valleys of the Powder River and Clear Creek. The greatest thickness of alluvium penetrated by a well (56–82–19ac) was 91 feet in the valley of Dutch Creek, and seismic shotholes penetrated 100 feet of alluvium in the same valley. (See fig. 16.)

WATER-BEARING PROPERTIES

The quantity of water that the flood-plain and terrace deposits will yield to wells depends on the size and sorting of the material and the saturated thickness of the deposits. Yields from terrace deposits are as large as 25 gpm, and those from the flood-plain deposits are as large as 108 gpm. Larger yields could probably be developed, however.

The saturated thickness of the alluvium in the Powder River valley is not sufficient to yield large supplies of water to wells. The alluvium downstream from the confluence of Powder River and Clear Creek is about 20 feet thick, and the saturated thickness is about 7 feet, as determined by test drilling (fig. 15). The material penetrated was not as coarse as that penetrated in other parts of the valley, but the thickness of the alluvium and the saturated section here is comparable to that in test holes upstream in Johnson County (Whitcomb and McCullough, oral commun., 1961). The thickness of the alluvium is also comparable to that downstream at the proposed site of the Moorehead Dam (Olive, 1957, p. 20).

The alluvium in some of the smaller valleys is thicker than that in the Powder River valley (fig. 16). Sufficient coarse material was not penetrated by test holes in the alluvium of Prairie Dog Creek to furnish moderate supplies of water to wells. Thicker deposits of coarse material are known at other locations in the valley, and moderate supplies of ground water can be developed at places from the alluvium of Prairie Dog Creek as well as from the alluvium in the valleys of the Tongue River and Dutch Creek.

RECHARGE AND DISCHARGE

The alluvium is recharged from precipitation and from irrigation water. Irrigation is a major source of recharge, and its contribution to the ground water in the alluvium is responsible for the existence of adequate supplies in some areas. Water in the terrace deposits west of Sheridan reportedly was inadequate during a year when a below-

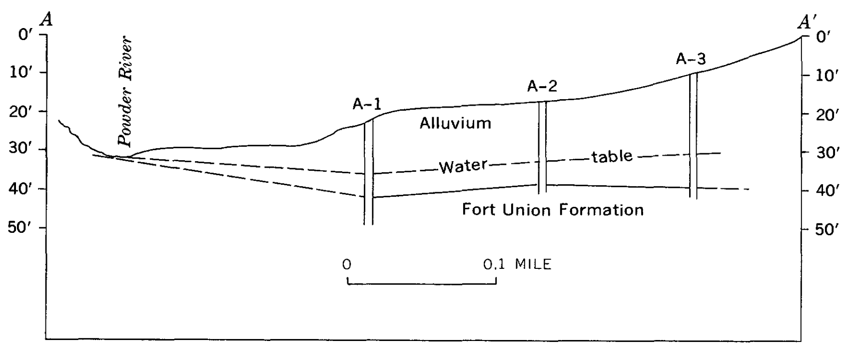

FIGURE 15.—Part of the Powder River valley, view downstream, 1.5 miles downstream from the confluence with Clear Creek.

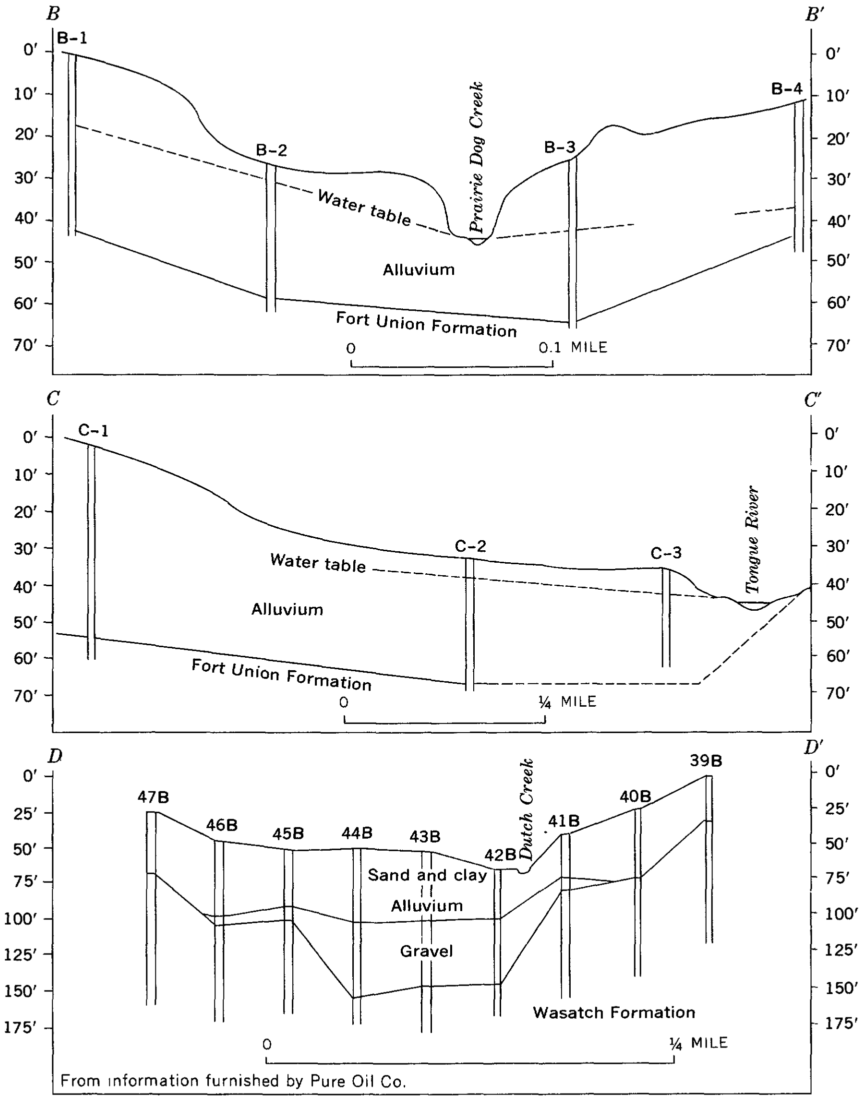

FIGURE 16.—Valleys of Prairie Dog Creek (*B–B′*), Tongue River (*C–C′*), and Dutch Creek (*D–D′*), view downstream.

normal amount of irrigation water was applied in the surrounding area. A rancher near Ranchester reported that the terrace deposits on his ranch did not contain water until a canal was constructed to bring in water for irrigation on the terrace. Water for domestic supply, in 1960, was obtained from a spring at the edge of the terrace deposit near the ranch buildings. Water was applied to the lands upgradient from the spring at least once, late in the irrigation season, to insure an adequate domestic supply for the winter.

Ground water is discharged from the deposits of Quaternary age by evaporation, transpiration, wells, seeps, and springs, and by seepage to streams. The slope of the water table is toward the streams shown in figure 16 (*B–B′*, *C–C′*) because of irrigation on the bordering lands, and, at least in these reaches of the streams, ground water is contributing to streamflow. Because only the land on the west side of Prairie Dog Creek was irrigated, the slope of the water table toward the stream is greater on the west side of the creek than on the east side.

QUALITY OF WATER

Chemical analyses of water from the alluvium are given in table 4. The diverse chemical characteristics of the water are illustrated graphically in figure 14. Iron content ranges from 0.00 to 4.3 ppm, and sulfate content, from 8.0 to 1,020 ppm. The dissolved-solids content ranges from 272 to 2,060 ppm. The water is very hard.

Water from each well sampled has some chemical characteristic that is undesirable in water for a domestic supply. As an irrigation supply, water from the alluvium has a low sodium hazard but a medium to very high salinity hazard. Supplies developed for stock use will probably be good to fair. In general, the alluvium in the mountains and along the mountain flanks yields water of better quality than that in other areas, principally because the quality of surface-water recharge is better.

DEVELOPMENT

Most wells that tap deposits of Quaternary age have been drilled in the western part of the county. The deposits of Quaternary age are more widespread in this area and generally yield water of a better quality than do those in the eastern part of the county. Only one irrigation well was in use at the time of this investigation; however, moderate to large yields can be developed in other areas under favorable conditions.

More extensive test drilling was not possible during the investigation, but several areas warrant exploration. Two such areas are the alluvium near the base of Moncreiffe Ridge and the terrace deposits in the northwestern part of T. 57 N., R. 86 W. Well 54–84–14bb, just north of Moncreiffe Ridge, was still in the alluvium at a total depth of 65 feet. Although the terrace deposits are only 19 feet thick where penetrated by well 57–86–9ab, the terrace in this vicinity is more than 1 mile wide, and the deposits are probably thicker elsewhere.

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BASIC DATA

TABLE 6.—*Records of wells and springs in Sheridan County, Wyo.*

Well or spring: See explanation of well-numbering system in text.
Type of supply: B, bored well; Dr, drilled well; Du, dug well; Sp, spring.
Depth of well: Measured depths are given in feet and tenths below land surface; reported depths are given in feet.
Character of material: C, coal; Cb, cobbles; Cl, clinker; D, dolomite; G, gravel; Gr, granite; Ls, limestone; S, sand; Sh, shale; Ss, sandstone.
Geologic source (symbols listed alphabetically): ₠f, Flathead Sandstone; Kbp, Bearpaw Shale; Kcv, Cloverly Formation; Kf, Frontier Formation; Kl, Lance Formation; Kp, Parkman Sandstone; Ob, Bighorn Dolomite; IPa, Amsden Formation; p₠g, Precambrian granite; IPt, Tensleep Sandstone; IPta, Tensleep Sandstone and Amsden Formation; Qal, alluvium; Ql, landslide deposits; Qt, terrace deposits; Tf, Fort Union Formation; ƦC, Chugwater Formation; Tw, Wasatch Formation)
Method of lift (first letter): C, centrifugal; Cy, cylinder; F, flow; G, gravity; J, jet; N, none; S, submersible turbine; T, turbine. Type of power (second letter): B, butane engine; E, electric motor; G, gasoline engine; H, hand operated; N, none; W, windmill.
Use of water: D, domestic; I, irrigation; In, industrial; N, none; O, observation. P, public supply; S, stock.
Distance to water level: Measured depths are given in feet, tenths, and hundredths; reported depths are given in feet; + not followed by number indicates artesian pressure is not known.
Remarks: Ca, chemical analysis given in table 4; D, discharge, in gallons per minute (E, estimated; M, measured; R, reported); DD, drawdown, in feet while discharging at preceding rate (R, reported); G, analysis of gas given in table 5; K, specific conductance, in micromhos at 25°C, measured with field equipment; L, log of well given in table 7; T, temperature of water, in degrees Fahrenheit.

Well or spring	Owner	Year drilled	Type of supply	Depth of well (feet)	Casing		Principal water-bearing bed		Method of lift	Use of water	Distance to water level above (+) or below land surface (feet)	Date of measurement	Remarks
					Depth (feet)	Diameter (inches)	Character of material	Geologic source					
53-76-4ca	George Claybaugh		Dr	800		4–2		Tf	F	S	+		
77-2bd	Santiago Michelena	1947	Dr	780	780	2	Ss	Tf	F	S	+		
-9db	do	1950	Dr	840	840	2	Ss	Tf	F	S	+		D3R.
-10cd	do	1947	Dr	424	424	2		Tf	F	S	+	10–26–60	Ca, D1.3M.
-11ab	do	1950	Dr	500	500	2	Ss	Tf	F	S	+		D35R.
-13ad	Glen Sorenson	1955	Dr	755	755	2	Ss	Tf	F	S	+		D15R.
78-1cd	Carl Knudson	1958	Dr	1,265	1,105	4–2	Ss	Tw, Tf	Cy, W	S	30	9– -58	D6R, DD30R.
79-7bc	Landeck	1960	Dr	280	239	4	Ss	Tw	?, E	D	70	9– -60	Ca, D2R, DD150R.
-10ac	Ben F. Vannoy	1954	Dr	60	60	6		Tw	Cy, W	S	18	10– -54	D16R, DD12R.
80-2db	J. R. Mitchell	1952	Dr	260		4–2½	Ss	Tw	Cy, E	S	50	8– -52	Ca, T47.
-9ca	John Lusher	1957	Dr	134	134	4–3	Ss	Tw		D			K1,000.
-18ca1	John Fowler	1960	Dr	23	23	6	G	Qal	C, E	D	8.91	5– 2–61	Ca, D30R, DD7R, T47.
-18ca2	do	1960	Dr	143	143	4–3	Ss	Tw	E	D	46	9– -60	Ca.
81-7cc	Walter Hawkey		Dr	80		4		Tw	Cy, W	S	30.76	4–28–61	K1,150.
-8ac	Cline Fowler	1954	Dr	76	71	4	Ss	Tw	N	N	8.81	4–28–61	D30R, DD15R.
-14aa	Fred Kaufmann		Dr	135	135	4–3		Tw	J, E	D	21.97	5– 3–61	K1,000.
-17dd	John P. Kumor	1957	Dr	220	220	4	Ss	Tw	Cy, W	S	28.70	5–15–61	D10R, DD33R.
82-2da	Frank Krezlok		B	93	N		C	Tw	Cy, W	S	82.49	4–28–61	K1,250; water pumped from Krezlok coal mine.

-3cd	do		Sp				Cl	Tw	G	S			D2E, K650, T44.
-4ba	Roy Geer	1954	Dr	120		4	C	Tw	Cy, N	S	28	6- -54	
-10aa			Sp				C	Tw	G	S			D<1R; abandoned mine.
-11cd	Dar. D. Kelley	1954	Dr	143	143	4-3	C	Tw	Cy, E	D	19	11- -54	Ca, D12R, DD71R, L.
83-1bc	S. L. Bobnsack		Du	8.8	8.8	24		Qal	N	N	5.42	4-12-61	K1,200.
-5ba	Sam Blaney	1956	Dr	80	30	4	Ss	Tw	J, E	D	18	5- -56	K450, L.
-7ad	Prather		Dr	115		4		Tw	N	O	48.46	4-18-60	
-7dd	Dan Evers	1959	Dr	42	42	4-3	Ss	Tw	C, E	D, P	6.87	5-15-61	Ca, D30R, DD10R.
-18da	Wagon Box Ranch	1956	Dr	75	75	4-3	Ss	Tw	J, E	D	27	11- -56	D15R, DD28R, K450, L, T48.
84-13bd	Wyoming Game and Fish Commission.		Sp				Ss	Pt	G				D1, 100-400R.
54-76-4bc	Fred Barton	1956	Dr	880		4		Tf	Cy, G	S, O	37.23	5-19-60	
-5ac	Wm. Suranyi		Dr	710	710	4-2		Tf	F	S	+		Ca, D7M, G, T62.
-17ca	C. L. Smith	1959	Dr			4		Tf(?)	Cy, N	S	30.23	6- 6-60	
-19ca	Chas. K. Bulkley	1953	Dr	730		4-2	Ss	Tf	F	N	+		D1E, T58.
-20dd	do	1955	Dr	636	635	4-2	Ss	Tf	F	S	+		D30R.
77-1dd	Wm. Suranyi	1955	Dr	1,070	1,054	4-2	Ss	Tf	F	S	+		D15R, T68.
-3aa	Thomas Lorah		Dr	450		2		Tf	F	S	+		D2E, T56.
-5db	Max Petrich	1955	Dr	1,185	1,185	2	Ss	Tf	F	S	+		Ca, D1.64M, G, T62.
-7cd	Wm. I. Moore	1956	Dr	1,200	1,200	2		Tf	F	S	+		
-9cb	Wm. R. Bell	1960	Dr	743	743	4-2	Ss	Tf	F	S	+		Ca, D12R, T59.
-11ad	Albert Fidler	1958	Dr	980	980	4-2	Ss	Tf	F	S, D	+		D12, T70.
-16da	Chicago, Burlington & Quincy Railroad.	1944	Dr	340	284	12½	Ss	Tf	J, G	D	+		D57R, DD165R.
-22db	Ray Elliott	1955	Dr	740	740	2		Tf	F	S	+		D5E, T60.
-23dc	Monte Smoot	1959	Dr	1,003	963	4-2		Tf	F	S	+		T72.
-25ca	Edward Walsh		Dr	650				Tf	F	S	+		D5E, T62.
-28dd	Wm. I. Moore	1954	Dr	1,220	1,210	2		Tf	F	S	+		D8E, L, T74.
79-3bc	E. D. Worden		Dr	34		4		Tw	Cy, N	N	6.39	6-30-61	
-6bb	H. R. Snider	1955	Dr	200	200	4	Ss	Tw	Cy, G	S	88	11- -55	D6R, DD37R, K3, 500.
-20da	Fay Iroz	1960	Dr	225	225	4	Ss	Tw	Cy, N	N	61.11	5- 3-61	
-21ab	Town of Clearmont	1949	Dr	120	85	8	Ss	Tw	N	O	45.15	4- 6-60	D17R, DD24R, L.
-21bdb	do		Dr	200	200	16		Tw	T, E	P			D50R; high discharge because of storage in well.
-21bdd	do		Dr	121		8		Tw	T, E	P			Ca, D8R.
-29db	Pete Rietveld	1947	Dr	80		6-4	Ss	Tw	F	S	+		D<1E, K1, 300.
-31da	Phillip Muller		Dr	80		4		Tw	Cy, H	D	11.45	5- 4-61	K900.
-34bd	Pete Rietveld	1953	Dr	208	208	4-3	Ss	Tw	Cy, W	S	85	9- -53	D10R, DD85R, K1, 300, T52.
80-18dc	Elizabeth Prusak	1957	Dr	300	300	4	Ss	Tw	Cy, G	S	100	12- -57	D8R, DD180R.
-24bc	H. W. Rasmussen	1958	Dr	120	120	4	Ss	Tw	Cy, E	D	82	8- -60	Ca.
-33cd	John Fowler	1960	Dr	272	272	4	Ss	Tw	Cy, G	S	175	6- -60	D6R, DD55R, K1, 300, T51.
81-10dd	Elizabeth Prusak	1944	Dr	135	126	4½	C	Tw	Cy, E	D			D10R.
-14bc	Ulm School	1960	Dr	110	101	4	C	Tw	Cy, E	D	61.34	6-13-61	Ca, D15R, DD53R, L, T52
-22dc	Ernest Pence	1952	Dr	210	210	4	Ss	Tw	Cy, E	S	57.01	6-12-61	
-23ab	Frank Gorzalka	1959	Dr	92	92	4	C, Ss	Tw	Cy, G	S	33.37	6-13-61	D25R, DD38R.
-30dd	L. W. Butterfield	1953	Dr	240	240	3½		Tw	Cy, E	D			K1, 500.

TABLE 6.—*Records of wells and springs in Sheridan County, Wyo.*—Continued

Well or spring	Owner	Year drilled	Type of supply	Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift	Use of water	Distance to water level above (+) or below land surface (feet)	Date of measurement	Remarks
54-82-2ac	Joe Kobielusz	1957	Dr	45	32	6	G, C	Qal, Tw	Cy, E	S	17.45	5-10-61	D30R, DD14R, K1, 300.
-4cc	Allen Fordyce	1954	Dr	45	34	6	G	Qal	S, E	S	17.85	4-19-61	D30R, DD5R, K1, 250, T50.
-6dc	John Bocek		Sp				Ss	Tw	G	S			D12M, K1, 300, T48.
-29ba	Jim Geer	1956	Dr	60	60	3	Ss	Tw	Cy, E	D	12	10- -56	Ca, D8R, DD38R, T48.
-30db	Roy Geer	1960	Dr	190	175	4	Ss	Tw	?, E	D	72	4- -60	D8R, DD100R, K1, 400.
83-3ba	Allen Fordyce	1952	Dr	245	91	4	Ss	Tw	?, E	D	20	5- -52	Ca, D10R, DD55R, L.
-7ac	W. A. Springer	1926	Dr	100		4½	Ss	Tw	F	D, S	+		Ca, D10R, L, T50.
-10dc	WBR Ranch		Dr	63		4		Tw	S, E	D	13.13	4-12-61	
-14db	Harry Surrena	1954	Dr	190	190	4	Ss	Tw	C, G	S	31.61	4-12-61	D6R, DD95R.
-18bd	Wilhelm Haratyk	1958	Dr	70	70	4-3	Ss	Tw	J, E	D	7		D7R, DD58R, K600, L.
-21cc	John Reich	1957	Dr	110		3		Tw	F	S	+		D3M, K550, T49.
-27cd	Mrs. Oscar Demple	1956	Dr	305	240	4	Ss	Tw	J, E	D	+		D<1R, DD240R, K500, L.
-36ab	Harry Surrena	1954	Dr	232	232	4	Ss	Tw	Cy, G	S	33	12- -54	D8R, DD97R.
84-5da	Big Horn School	1952	Dr	170	170	4-3	Ss	Tf	S,E	D	15.17	6- 7-61	D7R, DD53R.
-5dd	Guy Moore	1956	Dr	93	93	4-3	Ss	Tf	J,E	D	+		D4R, DD80R, K550.
-6da	Francis Logan	1945	Dr	257	257	4-3	Ss	Tf	J,E	D	26.20	10-20-60	K950.
-8ca	Vern W. Needham		Sp				G	Qt	G	D,I			D320R, K700, T50.
-8dd	Mrs. H.-C. Stevens	1955	Dr	73	73	4-3	Ss	Tf	C, E	D	+		D3R, DD60R, K750, T46.
-11ab	Eleanor D. Erdman	1954	Dr	160	160	4	Ss	Tw	Cy, E	S	10.88	10-21-60	Ca, D3R, DD135R, T52.
-14bb	Wyoming Game and Fish Commission.	1957	Dr	65	65	6	G	Qal	J, E	In	26.06	10-14-60	Ca, D30R, DD24R, L.
-18aa	John Riezeika	1950	Dr	48	48	6	G	Qt	J, E	D	27	1950	D25R, DD8R, K510, L.
-20bb	Northerntrust Co.		Dr	700		6		Tf	N	N	14.28	10-14-60	
85-27ca			Sp				Ls	Pa(?)	G				D60M, K425, T42.
86-32c	Forest Service		Sp				Gr	P€g	G				D5E, T39.
55-76-9cd	Jacob Kauck	1951	Dr	170	170	4		Tf(?)	N	N	105.95	5-12-60	
77-1ba	Gibbs Bros.	1952	Dr	720	700	2		Tf	F	S	+		
-6cd	Buffalo Creek	1956	Dr	570		2	Ss	Tf	F	S	+		D1.5M, K1, 500, T59.
-8cd	John E. Dalzell	1955	Dr	275	275	4	C	Tf		S			D3R.
-12bb	Perry J. Waisner	1955	Dr	510	510	2	Ss	Tf	F	S	+		D10R, L.
-15bd	do	1954	Dr	520	520	4-2	Ss	Tf	F	S	+		D9R.
-18cc	Walter Warfield	1955	Dr	90	90	4		Tw(?)	N	N	48.47	8-12-60	
-20ab	John E. Dalzell	1956	Dr	270	270	4		Tw(?)		S			D3R.
-24bc	Chas. K. Bulkley	1959	Dr	560	560	2	Ss	Tf	F	S	+		D3R.
-28ad	Robt. F. Claybaugh.	1960	Dr	380	375	4-2	Ss, C	Tf	F	S	+		Ca, D6R.
-28dd	do	1957	Dr	500	500	4-2	Ss	Tf	F	S	+		Ca, D0.7M.

78-8cd	Phillip Little	1949	Dr	210	193	4	Ss	Tw	Cy, W	S	+		K1, 500.
-15ba	Paul Whitaker		Dr	230		4		Tf	Cy, H	D	28.79	5-11-61	K1, 400, T61.
-19ca	Phillip Little		Dr	210		4-3		Tw	N	N	29.29	8-23-60	
-23db	Wm. I. Moore	1957	Dr	1,045	342	4		Tf, Tw	F	S	+		
-29aa	Joe Trolan	1952	Dr	350	350	4		Tf	J, E	D, I			K1, 800.
-33bd	M. Weinberg		Dr	105		4		Tw	N	N	98.37	8-24-60	
79-16dc	D. H. Roberts	1959	Dr	290	220	4	Ss	Tw	Cy, W	S	46.45	8-26-60	D3R, DD103R, K5, 000.
-21dd	E. D. Worden	1950	Dr	165	165	4	Ss	Tw	Cy, W	S	72.45	8-26-60	K2, 500.
-23bb	James Bumbaca	1957	Dr	385	385	4	Ss	Tw	Cy, G	S	70.0	8-23-60	K1, 900, T50.
-25dd	Jim Mitchell		Dr	133.7		3½		Tw	N	N	+1.0	8-24-60	K1, 050, T58.
-30bba1	Ralph Foster		Dr	140		6		Tw	Cy, G	S			Ca, D5M.
-30bba2	do	1954	Dr	200	188	4-3	Ss	Tw	Cy, W	D	150	11- -54	Ca, D2R, DD40R, L, T56
-35ca	H. Sanders		Dr			4		Tw(?)	N	D	+		K1, 250, T54.
80-6dd	Porter Kennedy		Sp				Ss	Tw	G	S			D10E, K925, T54.
81-2bc	Walt Peters		Sp				Cl	Tw	G	S			Ca, T49.
-19bb	Geo. Scales	1959	Dr	120	120	4-3	Ss	Tw	Cy, E	D	34	6- -61	D8R, DD56R.
82-2cd	Paul Dodd	1959	Dr	61	61	6	G	Qal	N	N	10.05	6-15-61	D72R, DD16R.
-3cb	do		Dr	294	294	4½-3		Tw	Cy, G	S	129.4	6-15-61	K1, 200, T52.
-5ba	Joe Gorzalka	1954	Dr	36	36	6	G	Qal	Cy, G	S	17	9- -54	D30R, DD8R.
-5dc	do	1955	Dr	155	155	4-3	Ss	Tw	Cy, E	D	28	7- -55	Ca, D10R, DD107R.
-15ca	Paul Dodd	1958	Dr	325	325	4	C, Ss	Tw	Cy, G	S	190	12- -58	D5R, DD72R, K1, 600.
-32ad	Stella Hale	1960	Dr	110	110	4	Ss	Tw	Cy, E	S	17.31	4-19-61	D20R, DD21R, K1, 800.
83-1cc	Ivan Kerbel	1955	Dr	51.5	51.5	4	G	Qal	N	N	23.70	5- 5-61	
-3aa	Paul Koltiska		Dr	86		4		Qal(?)	Cy, W	S	39.37	4-18-61	
-8ca	Harvey A. Sieweke	1944	Dr	191	178	4-3	Ss	Tw	Cy, E	D			K1, 000.
-13db	Joe Ligocki, Jr.	1954	Dr	52	52	4½	Ss	Tw	Cy, G	S	30.19	4-19-61	D7R, DD7R.
-20aa	Thomas C. Taylor	1942	Dr	260	233	4	Ss, C	Tw	Cy, E	D	125	1942	D5R, DD20R, K800.
-26bd	John Koltiska		Dr	340	340	4		Tw	Cy, E	D, S	70		K2, 000.
-33bc	Tom Wartensleben	1952	Dr	153	153	4-3	Ss	Tw	Cy, E	D	77	4- -52	D2R, DD63R, K1, 300.
84-2ba	W. E. Edwards	1937	Dr	150	124	5	Ss	Tw	Cy, E	D	+		D<1E.
-8aa			Dr	80.9		4		Tf	N	N	29.80	10-31-60	
-11bcd	Vincent Chalfant	1953	Dr	66	66	4-3	Ss	Tw	J, E	D			D7R, DD50R, K1, 600, L.
-11cba1	Roy Thompson	1956	Dr	301	165	4-3	C	Tf(?)	J, E	D	10	6- -56	D<1R, DD140R, K850, L.
-11cba2	Paul Buyok	1954	Dr	163	163	4-3	Ss	Tw	J, E	D	+		D4R, DD145R, K600, L.
-11cbd	P. C. Bruce	1953	Dr	387		4-2½	Ss	Tf	J, E	D	+		K2, 250, L.
-11cca1	James Sleep	1955	Dr	80	80	4-3	Ss	Tw	J, E	D	13	8- -55	D1R, DD57R, K750, L.
-11cca2	Gus Schaubel	1951	Dr	76	76	4	Sh	Tw	J, E	D	8	12- -51	D4R, DD42R, K850, L.
-11ccd	Ross Sadler	1955	Du	20	20	48	S, G	Qal	J, E	D	2	1955	K1, 800.
-14bac	J. H. Giroux	1954	Dr	213	213	4-3	Ss	Tw	Cy, E	D	0	10- -54	D3R, DD200R, K750, L.
-14bdb	Floyd Pippin	1952	Dr	92	92	4-3	Ss	Tw	J, E	D	10	5- -52	D6R, DD50R, K900, L.
-14bdc1	Chas. Morrell	1953	Dr	336	336	4-3	Ss	Tf(?)	J, E	D	+		D8R, DD150R, K850, L.
-14bdc2	Woodland Park School.	1956	Dr	510	510	4-2½	Ss	Tf	S, E	D	+		D5R, DD150R, K775, L.
-16bc	Harrison Land Co.	1960	Dr	370	370	4	Ss	Tf	F	S	+		Ca, D.75M, L, T50.
-20aa	Lester Fox	1952	Dr	50	39	6	G	Qt	J, E	S	26	3- -52	D25R, DD25R, K1, 200.
-21cc	C. T. Powers	1960	Dr	140	140	4	Ss	Tf	S, E	D	+		D3R, DD120R, T48.
-26cd	Warren Atter	1958	Dr	45	40	4	S, G	Qal	S, E	D, O	12.42	4-11-61	D15R, DD23R.
-27bc	W. F. Schunk	1954	Dr	130	130	4-3	Ss	Tf	Cy, E	D	+		D5R, DD104R.
-27cb	Urbin Donnafield	1959	Dr	560	260	4	Ss	Tf	Cy, E	D	+		Ca, D1R, DD130R.
-29ba	Russel York	1960	Dr	220	219	4	Ss	Tf	F	S	+		D<1E, K3, 500, T47.
-33ad	R. S. Hosford	1957	Dr	140		4½-3	Ss	Tf	Cy, E	D	+		K1, 100.
-35ba	R. I. Diefenderfer, Jr.	1959	Dr	100		4		Tw	N	O	5.20	4-11-61	

TABLE 6.—*Records of wells and springs in Sheridan County, Wyo.*—Continued

Well or spring	Owner	Year drilled	Type of supply	Depth of well (feet)	Casing		Principal water-bearing bed		Method of lift	Use of water	Distance to water level above (+) or below land surface (feet)	Date of measurement	Remarks
					Depth (feet)	Diameter (inches)	Character of material	Geologic source					
55-85-7ab	Becton Stock Farms	1959	Dr	125	125	4	Ss	Kl		D	17	7- -59	D3R, DD93R, L.
-15dd	Demple Bros	1950	Dr	298	298	4-3	Ss	Tf		D	110	1950	D3R, DD110R, K700.
-26ba	do	1952	Dr	75	75	4-3	Ss	Tf		D	19	9- -52	D20R, DD31R, K1, 100.
-34cd	Gene Williams	1957	Dr	32	20	6	G	Qal	J, E	D	3	10- -60	D12R, DD12R, K775.
-34db	Marvin Shell	1958	Dr	172	172	4	Ss	Tf	N	O	31.09	10-13-60	D20R, DD70R, L.
86-35ad	T. C. Colket		Sp				Ss	Kcv	G	S			D<1E, K800, T56.
89-1cc	John E. Hanft	1960	Dr	74	40	5	Ss	Ꞓf	S, E	In	12.99	9-21-60	D15R, DD20R.
-1da	Wyoming State Highway Department.	1958	Dr	66	60	8	Ss	Ꞓf	T, E	D	20	9- -59	Ca, D20R, DD35R, L.
90-16b	Forest Service		Sp				Sh	Qls	G				D50E, K300, T38.
56-76-6cb	Kendrick Cattle Co.	1915	Dr	176		1		Tf	F	S	+		D3M, T52.
-16bb	Chas. Bulkley	1956	Dr	440	440	2	Ss	Tf	F	S	+		D3R.
-19ca	Gibbs Bros	1941	Dr	721		2		Tf	F	S	+		D5E, T62.
-32ad	do	1955	Dr	1,120	1,011	4-2	C	Tf	F	S	+		D2R, T58.
77-3db	Watt Ranch	1955	Dr	550	550	4-2	Ss	Tf	F	S	+		D6R, L.
-4bd	Larry Woods	1955	Dr	235	235	4	Ss	Tf	Cy, W	S	80	12- -55	D6R, DD100R.
-11dd	Wm. W. Ritchie	1957	Dr	746	746	2	Ss	Tf	F	S	+		D<1E.
-24ab	Gibbs Bros	1951	Dr	360		2		Tf	F	D	+		T56.
78-2bd	Buffalo Creek Land	1954	Dr	130	130	4	Ss	Tf	F	S	+	8-12-60	D1.2M, K2, 750, T55.
-7aa	do	1945	Dr	216	216	4½	Ss	Tw	Cy, G	S			
-17ab	do		Dr	109		4		Tw	Cy, W	S	41.75	8-12-60	
-21ca	do		Dr	91		4		Tf	N	N	33.80	8-12-60	
-22ac	do	1954	Dr	165		4-3½	Ss	Tf	F	S	+		Ca, D1M, T58.
-26cd	do	1957	Dr	230	230	4	Ss	Tw	Cy, G	S	55	12- -57	D4R, DD145R.
79-21ad	D. H. Roberts		Sp				Ss	Tw	G	D			D<1, K500.
-21bb	do	1959	Dr	244	244	4	Ss	Tw	Cy, W	S	64.60	9- 1-60	D12R, DD30R.
-24dd	do	1959	Dr	225	225	4	Ss	Tw	Cy, W	S	63.11	9- 1-60	D15R, DD40R, L.
-34db	do	1959	Dr	200	200	4	Ss	Tw	Cy, W	S	35	8- -59	D18R, DD15R, K5, 500.
-36bb	Frank Jacob		Dr	99	99	4-3	Ss	Tw	Cy, W	S	41.59	9- 1-60	D9R, K5, 000.
80-9bd	Florence Schweder		Dr	150	150	4		Tw	CY, E	D	31		K3, 750.
81-5ab	Wallop Ranch		Sp				Ss	Tw	G	S			D.75M, K4,000.
-17cb	James W. Sears	1934	Du	18	18	48			J, E	S	13.47	8-15-60	
-29bd	Mrs. Mike Wagner	1959	Dr	378	334	4	Ss	Tw	Cy, E	D, S	190	10- -59	Ca, D3R, DD140R, L, T52.
82-1cc	F. L. Richardson		Dr	21	21	6		Tw	N	N	7.80	8- 8-60	
-19ac	Chicago, Burlington and Quincy Railroad.	1929	Dr	251	86	6	S, G	Qal	Cy, H	N	41.64	5-13-60	

-23ac	Elma F. Kuhl		Dr	202	60	4	C	Tw	Cy, G	S	27	6- -59	D3R, DD28R, K3, 000, T61.
-29db	Lonabaugh & Powers.	1954	Dr	375	375	4	Ss	Tw	Cy, G	S	160	7- -54	D5R, DD160R.
-34dc	Paul Dodd	1957	Dr	56	55	6	G	Qal	C, B	I	0.70	6-15-61	Ca, D108R, DD17R.
-35aa	Walt Peters	1951	Dr	87	87	6	Ss	Tw	J, E	D	50	8- -51	Ca, D16R, DD20R.
83-3dc	John Symons	1956	Dr	100	100	4	Ss	Tw	E	S	36.03	6-15-61	D15R, DD50R, K1, 050, T53.
-8ac	Elmer Teich	1956	Dr	37	37	4		Qal	C, E	S	3.14	6- -61	D10.5M, DD10.5, K1, 900.
-10db	Wyoming Agriculture Substation.		Dr	80		5		Tw	Cy, E	S	46.81	10-27-60	K2, 000.
-14aa	John Symons	1954	Dr	52	47	6	S, G	Qal	Cy, G	S	17.23	6-15-61	D30R, DD15R.
-18dc	C. L. Scrutchfield	1945	Dr	220	220	6-4	Ss	Tw	F	N	+		D12M, K3, 500.
-19ab	Lee Swartz	1954	Dr	141	141	4	Ss	Tw		D	60	4- -54	D4R, DD60R, K1, 050.
84-4ac	Wrench Ranch		Dr	202		4½		Tf		D			Inadequate supply.
-14ca	J. P. Ardans	1955	Dr	400	400	4	Ss	Tf	Cy, E	S	68.89	5- 5-61	D4R, DD168R, K3, 500, T53.
-20dd	T. W. Patton		Du	8.9	8.9	48	G, Cb	Qt	J, E	D	4.32	4-20-61	K1, 600.
-21ba	Frank Wardle, Jr.	1959	Dr	120	120	6	Ss	Tf	J, E	D	16	5- -59	D20R, DD30R, K1, 600.
-28dd	E. W. Troutt	1954	Dr	123	123	4	Ss	Tf	J, E	D	+		D4R, DD111R.
-34da	F. M. Downing	1961	Dr	550		4	Ss	Tf	S, E	D	0	4- -61	D20R, DD200R, L.
85-3ad	Roy R. Schedlock	1957	Dr	123	123	4	Ss	Tf	Cy, E	S	72.15	4- 7-61	Ca, D25R, DD22R, T50.
-8ab	Geo. L. Roberts		Dr	200	200	4		Tf	N	N	114.18	10-19-60	
-23cb	Geo. Murdock	1952	Dr	100	65	6-4	Ss	Tf	J, E	D	10	8- -52	D4R, DD50R.
-27bb	Ezra Wollen	1945	Dr	90		4		Tf	J, E	D	+		K1,000.
-31bd	Robt. Tate	1942	Dr	116			Ss	Tf	F	D, S	+		D<1E.
86-5cb	Leonard Graham	1959	Dr	30		6		Qal(?)	J, E	D	16.55	9-23-60	
-7dc	do	1952	Dr	148	148	4-3	Ss	Kf	J, E	D	4		Ca, D2R, DD126R, L.
-22aa	Wolf Creek School	1953	Dr	30	21	6	G	Qal	Cy, H	D	11.05	9-27-60	D15R, DD5R, K650.
-22ba	H. W. Wolfe		Dr	200			Ss	Kl	F	D	+		D1.2M, K1,300.
-22cc	Frank Curtiss	1957	Dr	105	20	6	G	Qal	J, E	D	17.17	9-28-60	D3R, DD9R, K550.
88-33cd	Arrow Head Lodge	1961	Dr	23	23	4	Gr	p€g	C, E	P	8	5- -61	D12R, DD1R, K200.
89-36bb	Forest Service		Sp				Ss	€f	G	D, S			D10E, K280.
57-76-20bd	Kendrick Cattle Co.	1920	Dr	265		1¼	Ss	Tf	F	S	+		Ca, D1.47M, G.
-31bb	do	1951	Dr	300	300	3-2	Ss	Tf	F	S	+		D1M.
77-1dc	do		Dr	720		2		Tf	Cy, N	N	105		
-7ca	Coyne C. Tibbets		Sp				Ss	Tf	G	S			
78-12db	Paul McCauley	1948	Dr	500		4		Tf	N	N	102.00	5- 9-60	
-22dd	Jennie Fillmore	1958	Dr	240	240	4	Ss	Tf			67	3- -58	D4R, DD93R.
-31ba	Kendrick Cattle Co.	1959	Dr	130	130	8	Ss	Tw	Cy, G	S	38	2- -59	D15R, DD82R.
79-3db	do	1942	Dr	40		4½		Qal(?)	Cy, W	S			K4,000, T58.
-6cd	do	1950	Dr	34		6	G	Qal	Cy, H	S	9.60	7-27-60	D20R, DD9R.
-12ca	Wm. Dooley	1958	Dr	183	183	4	Ss	Tw		S	18	5- -58	D25R, DD42R.
-14cd	Kendrick Cattle Co.	1953	Dr	50	50	4	Ss	Tw(?)	Cy, H	S	17.94	8-16-60	D12R, DD15R.
-22cb	do	1949	Dr	130		4		Tw	Cy, G	S	66.42	8-16-60	D8R, DD60R.
-25cc	do	1954	Dr	95	95	4	Ss	Tw	Cy, G	S	40	12- -54	Ca, D6R, DD45R, L, T64.
-29ba	do	1951	Dr	117	117	4	Ss	Tw	Cy, W	S	43.69	8-16-60	D18R, DD53R.
-35ba	do	1951	Dr	126	126	4	C, Ss	Tw	Cy, W	S	65	6- -51	D18R, DD35R.
80-23da	do		Dr	174	174	4		Tw	Cy, W	S	28		
-25ad	do	1950	Dr	55	43	6	G	Qal	Cy, G	S	30.85	7-27-60	D28R, DD15R.
-31bb	C. L. Scrutchfield	1959	Dr	160	154	1½	Ss	Tw	F	S	+		Ca, D3M, L, T53.
-34cc	OTO Ranch		Dr			6		Tw(?)	N	N	222.28	9-13-60	

TABLE 6.—*Records of wells and springs in Sheridan County, Wyo.*—Continued

Well or spring	Owner	Year drilled	Type of supply	Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift	Use of water	Distance to water level above (+) or below land surface (feet)	Date of measurement	Remarks
57-81-7cb	Kendrick Cattle Co.	1941	Dr	510	375	4½-3½	Ss, C	Tw	Cy, E	D	80	4- -41	D10R, DD130R, L.
-22aa	Ruth Hutton		Dr	140		4		Tw	Cy, E	S	31.22	8- 5-60	
-26bd	do		Dr	130		4		Tw	N	N	20.31	8- 5-60	
-35ab	do		Dr	160		4		Tw	F	S	+		D0.3M, K3, 000, T53.
82-2cb	NX Bar Ranch	1956	Dr	175	175	4½		Tw	Cy, W	S	85	5- -56	D6R, DD65R.
-18aa	Archie L. Nash	1956	Dr	80	80	6	Ss	Tw	Cy, W	S	21.33	8- 3-60	D25R, DD22R.
-20ad	Emerson Hanson	1954	Dr	120	120	4		Tw	Cy, W	S	35	8- -54	D22R, DD20R.
83-1aa	Archie Nash		Du	11.5		36		Qal	Cy, W	S	6.08	8- 1-60	
-3ab	Joe Pilch	1958	Dr	120	120	4-3	Ss, C	Tf	Cy, H	S	4	6- -58	Ca, D3R, DD106R.
-13ad	Archie Nash		Dr					Tw	Cy, G	S	47.25	8- 3-60	
-14ba	Jesse Gorman		Dr	125		4		Tw	Cy, E	S	71.76	7-26-60	
-21dd	John V. Rose		Dr	119		6-4		Tf	Cy, W	S	63.8	11-14-60	
-34bb	Mansel C. Johnston	1957	Dr	232	232	4		Tw	Cy, W	S	42	12- -57	D7R, DD48R.
84-1ba	W. K. Whitford		Dr	35			S, G	Qal	J, E	D	11.90	7-21-60	
-13cc	Mary Arzy		Dr	137		4		Tf	Cy, H	D	16	6- -60	
-15ca	Gothard Bylund		Du	32		70	S, G	Qal	Cy, E	P	6	4- -61	
-19bd	Geo. W. Boyok	1953	Dr	126	126	6-3	C	Tf	J, E	D	5	1960	Ca, D15R, DD55R, L.
-21bb	Bruno's Nite Club	1949	Dr	58	58	4½-3	C	Tf	Cy, F	D	9.10	4- 6-61	D3R, DD38R, K1, 500.
-36ab	Mary Arzy		Dr	92.1		6		Tf	Cy, H	O	10.15	6-15-60	
85-3da	Padlock Ranch	1952	Dr	40	34	6	G	Qal	Cy, H	S	12.78	9-16-60	D30R, DD14R, K2, 500, T48.
-5cd	Walter Belish		Du	30		36		Qal(?)	Cy, E	S	23.18	9-20-60	K3, 000.
-15cd	Dan Scott	1955	Dr	54	39	6	G	Qal	J, E	D	9	5- -55	D54R, DD11R.
-17da	C. R. Tschirgi	1955	Dr	38	38	6		Qal	N	N	3.03	9-20-60	K3, 500.
-19aa	Avon and Vera Barney.	1954	Dr	180	180	3	Ss	Tf	J, E	D	+		Ca, D5R, DD150R.
-19ab	Town of Ranchester	1959	Dr	30	30	6	S, G	Qal	N	O	4.20	4-19-60	Ca, D25M, L; 4 wells at this location.
-30ba	E. T. Johnston	1941	Dr	488	488	8		Tf	F	D	+		D<1E, K2, 700.
-36dd			Du	25.5	25.5	30		Qal(?)	N	N	19.38	4- 7-61	
86-5cc	Dorthie Wallace		Dr	87		4		Kl	Cy ,E	S	14.30	9-20-61	K1, 050.
-9ab	Padlock Ranch	1951	Dr	36	23	6	G	Qt	J, E	D	6	5- -51	D15R, DD14R, K1, 300, L.
-12cb	Clyde Zimmerman		Dr	370		4		Tf	N	N	+		K1, 500, T50.
-18ba	Geo. Mock		Dr	34.4		6		Qt(?)	Cy, H	N	16.29	9-19-60	K575.
-23ad	M. D. Brown	1960	Dr	65	65	6	G	Qal	S, E	S	30	2- -60	D60R, DD20R.
-30ac	George R. Mock	1952	Dr	115	115	4	Ss	Kp	C, E	D	+		Ca, D4R, L, T50.
-32db	J. K. Willsie		Du	11	11	24	G	Qal	J, E	D	4.78	9-23-60	K550.
-34bb	A. E. Adamson	1950	Dr	315		6	Ss	Kl	J, E	D	+	9-15-60	Ca, D.75M, L, T54.
-36db	Lucien Robinson	1955	Dr	90	90	4-3	Ss	Tf	S, E	D	35	3- -55	D15R, DD35R, K1, 500.

87-1bd	M. E. Hayworth	1948	Dr	195	155	4½	Ss	Kl	C, E	D	36.55	4-20-60	Ca, D8R, DD70R.
-21db	Glenn and Hannah Mock.	1932	Dr	1,596	1,162	12-4	Ss	Pta	F	I, S	+		Ca, D64M, T51.
89-26c	Forest Service		Sp				Sh	Qls	G	S			D8M, T44.
90-?	do		Sp				Ss, D	Ob	G	N			D1,000E, T48.
58-76-30cc	Howard Rideout	1956	Dr	270	270	4	C	Tf	Cy, G	S			L.
77-23ac	do	1959	Dr	250	250	4	S	Tf	Cy, G	S	69	5- -59	D5R, DD10R.
-26ba	do	1954	Dr	40	40	4	G	Qal	Cy, G	S	8	5- -60	D8R.
78-19bc	Kendrick Cattle Co.	1948	Dr	50	36	6	S, G	Qal	Cy, G	S	16	7- -48	
-21da	do		Sp				Ss, C	Tf	G	S			D4M, K1, 900, T50.
79-20bb	do		Dr	90		4½		Tf	Cy, H	N	24.15	7-29-60	
-29aa	do	1948	Dr	60	60	6	Ss	Tf	Cy, W	S	21.10	7-29-60	K3, 200, T58.
-31bd	do	1949	Dr	230	230	4½	Ss	Tf	Cy, H	S	30.5	7-27-60	D15R, DD81R.
-32cc	do	1946	Dr	210		4		Tf(?)	Cy, H	S	19.99	7-27-60	
80-19db	do	1950	Dr	150	150	4	Ss	Tw	Cy, G	S	99.93	7-29-60	D12R, DD23R.
-22bb	do	1949	Dr	178	107	4½		Tf	Cy, H	S	15.34	7-29-60	D10R, DD135R.
-24ad	do		Dr	180		4		Tf	Cy, H	S	34.91	7-29-60	
-32bd	do	1949	Dr	136		4		Tw	Cy, G	S	65.17	7-29-60	
81-20ad	NX Bar Ranch	1955	Dr	296	296	4½	Ss	Tw	Cy, N	S	213	6- -55	D4R, DD67R, L.
-22cb	do		Dr	85		4		Tf	Cy, N	S	42.42	8- 9-60	
-31dc	do	1940	Dr	290	290	6	Ss	Tw	Cy, N	S			D5R.
82-22dd	do	1955	Dr	146	146	4	Ss	Tw	Cy, W	S	55	1- -55	D4R, DD80R.
-29cb	W. S. Perkins	1960	Dr	460	460	4-2½	C	Tf	F	S	+		D5E, T54.
-30aa	Cleo Moreland	1957	Dr	480	480	2	C	Tf	F	S	+		Ca, D0.7M, G, L, T57.
-34ac	NX Bar Ranch		Dr	72		4		Tf(?)	Cy, G	S	24.32	8- 9-60	
83-22cb	Stanley Pilch	1954	Dr	102	102	4	Ss	Tf	Cy, W	S	35.59	4-31-61	D3R.
-23cd	W. S. Perkins	1949	Dr	33	33	6	G	Qal	Cy, E	S	9.17	7-25-60	D30R, DD12R.
-30da	J. H. Zingg		Dr	80		4		Tf	Cy, H	D	7.84	7- 1-60	
84-27dd	E. J. Vail	1932	Dr	120		3		Tf	Cy, H	D	110.45	6-17-60	
-29ca	Vernon States	1960	Dr	620	175	4	C	Tf	S, E	D	43	1960	Ca, D5R.
-29cd	do	1961	Dr	1,260	1,260	2		Tf	F	S	+		Ca, D2R.
85-24da			Dr	38		4		Qal	N	O	13.63	6-17-60	
86-19ac	Mrs. E. F. Barker		Dr	58		3½		Kl	N	N	9.11	9-19-60	
-29ab	John C. Barker	1949	Dr	105		4		Tf	F	N	+		D<1E, K1, 950.
-30bb	Bernice Benidict		Dr	54		4		Kl	J, E	D	24.75	9-19-60	
87-22bc	Gill Cattle Co.	1960	Dr	18		3		Qal(?)	N	N	2.27	9- 7-60	
-35ca1	M. E. Hayworth	1947	Du	33.8		96		Qal(?)	J, E	O, S	9.15	4-18-60	
-35ca2	Chicago, Burlington and Quincy Railroad.	1949	Dr	129	68	6	Ss	Kb	Cy, E	D, S	40.67	7-20-60	Ca, D6R, L.
89-15cc	L. S. Fuller	1950	Dr	60		4		TRc(?)	J, E	D	26-37	10- 5-60	

TABLE 7.—*Logs of test holes, seismic shotholes, and wells*

[Listed in this table are sample logs of test holes, drillers' logs of seismic shotholes, and logs of selected water wells. The drillers' logs were obtained from drillers' records and are essentially unchanged]

SAMPLE LOGS

Material	Thickness (ft)	Depth (ft)
Test hole A-1, section *A-A'*		
Alluvium:		
Silt, brown, and some very fine sand	5	5
Sand, brown, very fine to medium, silt and some coarse sand, and a few granules	5	10
Sand, brown, fine to coarse, silt and very fine sand, and some gravel	5	15
Sand, brown, fine to coarse, and silt and very fine sand	6	21
Fort Union Formation:		
Sand, bluish-gray, very fine	6	27
Test hole A-2, section *A-A'*		
Alluvium:		
Silt, brown	10	10
Silt, brown, and very fine sand	5	15
Silt, brown; some very fine to fine sand	5	20
Fort Union Formation:		
Shale, bluish-gray	2	22
Test hole A-3, section *A-A'*		
Alluvium:		
Silt, brown	15	15
Clay, brown, silty	5	20
Sand, very fine, and silt	4	24
Fort Union Formation:		
Shale, bluish-gray, silty	3	27
Test hole B-1, section *B-B'*		
Alluvium:		
Silt, brown, and some very fine to fine sand	5	5
Test hole B-1, section *B-B'*—Continued		
Alluvium—Continued		
Silt, brown	15	20
Silt, brown and dark-brown, and some very fine to fine sand	26	46
Fort Union Formation:		
Sand, bluish-gray, very fine to fine	1	47
Test hole B-2, section *B-B'*		
Alluvium:		
Silt, brown	5	5
Silt, brown; some very fine to coarse sand	5	10
Sand, brown, very fine to fine, silt, and a few granules	5	15
Sand, very fine to fine, and some medium to coarse sand and silt	5	20
Sand, very fine to medium, and silt	5	25
Shale, gray, and fine to coarse gravel	5	30
No returns, driller's log shows gravel streaks to 35 ft	5	35
Fort Union Formation:		
Shale, bluish-gray	6	41
Test hole B-3, section *B-B'*		
Alluvium:		
Silt, brown	25	25
Silt, brown; some medium to coarse sand and granules	5	30
Silt, brown, and some very fine to medium sand	5	35
Silt, brown, and fine sand to fine gravel	4	39
Fort Union Formation:		
Coal	6	45

TABLE 7.—*Logs of test holes, seismic shotholes, and wells*—Continued

SAMPLE LOGS—Continued

Material	Thickness (ft)	Depth (ft)
Test hole B-4, section *B-B'*		
Alluvium:		
Silt, brown, some sand	10	10
Silt, brown, some clay	20	30
Silt, brown, gray clay and some gravel	5	35
Fort Union Formation:		
Sand, bluish-gray, very fine	5	40
Test hole C-1, section *C-C'*		
Alluvium:		
Clay, dark-brown, silty	5	5
Silt, brown	5	10
Silt, brown; some coarse sand	5	15
Gravel, coarse; some silt	10	25
Test hole C-2, section *C-C'*		
Alluvium:		
Silt, brown, and clay	5	5
Silt, brown, and very fine sand	10	15
Silt, brown, and sand; mostly very fine	5	20
Test hole (C-2, section *C-C'*—Continued		
Alluvium—Continued		
Silt, brown, very fine to medium sand, and coarse gravel	5	25
Gravel, fine to medium, and coarse sand; some silt and fine sand	8	33
Fort Union Formation:		
Shale, bluish-gray, silty	2	35
Test hole C-3, section *C-C'*		
Alluvium:		
Clay, brown, silty, some very fine sand	5	5
Clay, dark-brown, silty	25	30
Clay, dark-brown, and very fine sand; some coarse sand	5	35
Clay, brown, silt, and very fine sand; some coarse sand	10	45
Gravel, brown, fine, coarse sand, and medium sand to silt	7	57
Fort Union Formation:		
Sand, bluish-gray, very fine, silty	7	57

DRILLERS' LOGS

Material	Thickness (ft)	Depth (ft)
Seismic shothole 39-B, section *D-D'*		
Sand	30	30
Shale, blue	80	110
Seismic shothole 40-B, section *D-D'*		
Sand	45	45
Shale, blue	65	110
Seismic shothole 41-B, section *D-D'*		
Clay	30	30
Gravel, red clinker	8	38
Shale, blue	72	110
Seismic shothole 42-B, section *D-D'*		
Sand	35	35
Gravel, red clinker	43	78
Shale, blue	22	100
Seismic shothole 43-B, section *D-D'*		
Sand and clay	45	45
Gravel, red clinker	45	90
Shale, blue	30	120
Seismic shothole 44-B, section *D-D'*		
Clay, yellow and blue	50	50
Gravel, red clinker	50	100
Shale, blue	20	120

TABLE 7.—*Logs of test holes, seismic shotholes, and wells*—Continued

DRILLERS' LOGS—Continued

Material	Thickness (ft)	Depth (ft)
Seismic shothole 45–B, section *D–D'*		
Clay	38	38
Gravel, red clinker	9	47
Shale, blue	73	120
Seismic shothole 46–B, section *D–D'*		
Clay, yellow	50	50
Gravel, red clinker	5	55
Shale, blue and gray	65	120
Seismic shothole 47–B, section *D–D'*		
Sand and clay	40	40
Clay, blue	90	130
Well 53–82–11cd		
Clay	8	8
Gravel	14	22
Shale, blue	4	26
Sand	6	32
Shale, blue	34	66
Sand, hard water	8	74
Shale, blue	41	115
Coal, water-bearing	24	139
Shale, dark	4	143
Well 53–83–5ba		
Sand	10	10
Gravel and cobbles	10	20
Sandstone	55	75
Shale, blue	5	80
Well 53–83–18da		
Gravel and cobbles	20	20
Sandstone	55	75
Well 54–77–28dd		
Clay	30	30
Gravel	10	40
Shale	30	70
Sand	40	110
Shale	60	170
Sand	40	210
Shale	110	320
Coal	10	330

Material	Thickness (ft)	Depth (ft)
Well 54–77–28dd—Continued		
Shale	50	380
Sand	40	420
Shale	20	440
Coal	20	460
Shale	80	540
Sand	40	580
Shale	80	660
Sand	60	720
Shale	20	740
Coal	30	770
Shale	50	820
Sand	20	840
Shale	20	860
Coal	20	880
Shale	80	960
Sand	20	980
Shale	100	1,080
Coal	10	1,090
Shale	70	1,160
Sand	60	1,220
Well 54–79–21ab		
Soil	5	5
Gravel, red clinker	20	25
Sand, blue	7	32
Shale, blue	23	55
Coal	2	57
Shale, blue, with sand streaks	27	84
Sand, water-bearing	16	100
Shale, blue	20	120
Well 54–81–14bc		
Clay	22	22
Shale, blue	19	41
Sand	4	45
Shale, blue and dark	57	102
Coal, water	8	110
Well 54–83–3ba		
Clay	28	28
Sandstone	52	80
Shale, blue	14	94
Sand, water-bearing	3	97
Shale, blue	37	134
Sand, water	6	140
Shale, blue	42	182
Coal, gas	50	232
Shale, blue	13	245

TABLE 7.—*Logs of test holes, seismic shotholes, and wells*—Continued

DRILLERS' LOGS—Continued

Material	Thickness (ft)	Depth (ft)
Well 54-83-7ac		
Clay	3	3
Sand and gravel	12	15
Shale, blue	28	43
Sandstone	8	51
Shale, blue	35	86
Sand, water-bearing	14	100
Well 54-83-18bd		
Gravel	9	9
Sandstone	12	21
Shale, blue	19	40
Sandstone	2	42
Shale, blue	7	49
Sandstone	21	70
Well 54-83-27cd		
Clay	8	8
Gravel	6	14
Clay	5	19
Sandstone	16	35
Shale, blue	37	72
Sandstone	11	83
Shale, blue	52	135
Sandstone	11	146
Shale blue	62	208
Sandstone	7	215
Shale, blue	23	238
Sandstone, water-bearing	7	245
Shale, blue	4	249
Sandstone, water-bearing	56	305
Well 54-84-14bb		
Sand	44	44
Sand and gravel	21	65
Well 54-84-18aa		
Soil	3	3
Gravel	22	25
Clay, brown	10	35
Gravel, water	10	45
Sand	3	48
Well 55-77-12bb		
Soil	8	8

Material	Thickness (ft)	Depth (ft)
Well 55-77-12bb—Continued		
Shale	110	118
Sand	12	130
Shale	65	195
Coal	24	219
Shale	11	230
Sand	33	263
Shale	12	275
Sand	7	282
Shale	23	305
Coal	17	322
Shale	16	338
Sand	22	360
Shale	17	377
Coal	7	384
Shale	31	415
Coal	3	418
Shale	8	426
Sand	82	508
Shale	2	510
Well 55-79-30bba2		
Clay, sandy	17	17
Shale, blue	28	45
Sand, water	3	48
Shale, blue and dark	22	70
Coal	5	75
Shale, blue	20	95
Sand, water	15	110
Shale, blue	38	148
Coal	14	162
Shale, blue and dark	21	189
Sand, soft water	6	195
Shale, blue	5	200
Well 55-84-11bcd		
Clay	10	10
Gravel	10	20
Shale, blue	24	44
Sand, water-bearing	22	66
Well 55-84-11cba1		
Clay	8	8
Clay, sandy	8	16
Gravel	8	24
Shale, blue and dark	41	65
Sand	3	68
Shale, blue and dark	79	147
Coal	8	155
Shale, blue and dark	146	301

TABLE 7.—*Logs of test holes, seismic shotholes, and wells*—Continued

DRILLERS' LOGS—Continued

Material	Thickness (ft)	Depth (ft)
Well 55-84-11cba2		
Clay	8	8
Gravel	14	22
Shale, blue and dark	124	146
Sand	13	159
Shale, blue	4	163
Well 55-84-11cbd		
Clay	10	10
Gravel	13	23
Shale, blue and dark	357	380
Sand	7	387
Well 55-84-11cca1		
Clay, sandy	10	10
Gravel	11	21
Shale, blue and dark	49	70
Sand	4	74
Shale, blue	6	80
Well 55-84-11cca2		
Clay, yellow	8	8
Clay, yellow, sandy	6	14
Gravel	14	28
Shale, blue	48	76
Well 55-84-14bac		
Clay	8	8
Gravel	15	23
Shale, blue and dark	172	195
Sand, water-bearing	13	208
Shale, blue	5	213
Well 55-84-14bdb		
Clay	5	5
Gravel	12	17
Shale, blue	46	63
Sand	29	92
Well 55-84-14bdc1		
Unknown	212	212
Shale, blue	38	250
Well 55-84-14bdc1—Continued		
Sand	15	265
Shale, blue	15	280
Coal	4	284
Shale, dark	16	300
Coal	11	311
Sand	19	330
Coal	3	333
Shale, blue	3	336
Well 55-84-14bdc2		
Soil	11	11
Gravel and sand	15	26
Clay, soft	13	39
Shale, blue	66	105
Coal	5	110
Shale, blue	156	266
Coal	16	282
Shale, blue and brown	200	482
Sandstone	4	486
Sand	?	?
Shale, blue	?	510
Well 55-84-16bc		
Clay and gravel	30	30
Shale, gray	41	71
Sandstone	7	78
Shale, blue	275	353
Sand	4	357
Shale, blue	3	360
Sand, water-bearing	8	368
Shale, blue	2	370
Well 55-85-7ab		
Clay, yellow	29	29
Shale, blue	27	56
Sandstone, hard water	9	65
Shale, blue and dark	36	101
Sand, water-bearing	24	125
Well 55-85-34db		
Soil	2	2
Gravel and cobbles	35	37
Shale, gray	5	42
Coal	6	48
Shale, blue	42	90
Shale, red	25	115
Shale, blue	45	160
Sandstone	12	172

TABLE 7.—*Logs of test holes, seismic shotholes, and wells*—Continued

DRILLERS' LOGS—Continued

Material	Thickness (ft)	Depth (ft)
Well 55–89–1da		
Soil	2	2
Sandy soil	6	8
Sandstone	24	32
Rock (quartzite?)	22	54
Sandstone, water-bearing	4	58
Granite, decomposed	8	66
Well 56–77–3db		
Soil	30	30
Gravel	5	35
Shale	3	38
Coal	5	43
Shale	38	81
Coal	4	85
Shale	5	90
Coal	13	103
Shale	9	112
Sand	4	116
Shale	16	132
Sand	26	158
Coal	9	167
Shale	52	219
Sand	41	260
Coal	12	272
Sand	2	274
Shale	112	386
Sand	8	394
Coal	16	410
Sand	20	430
Shale	10	440
Coal	55	495
Shale	19	514
Sand, water-bearing	21	535
Shale	15	550
Well 56–79–24dd		
Soil	6	6
Sandstone, yellow	34	40
Shale, blue	23	63
Sandstone	8	71
Shale, blue	36	107
Sandstone	33	140
Shale, blue	35	175
Coal	5	180
Shale, blue	20	200
Sand, water-bearing	24	224
Shale, blue	1	225
Well 56–81–29bd		
Clay	6	6
Gravel, composed of clinkers	30	36
Shale, blue	32	68
Coal	1	69
Shale, blue	36	105
Sand, water seep	15	120
Shale, blue	50	170
Sand, water seep	7	177
Shale, blue	43	220
Sandstone	9	229
Shale, blue	103	332
Well 56–84–34da		
Soil	5	5
Sand and gravel	13	18
Shale, gray	22	40
Shale, blue	70	110
Sandstone, water seep	10	120
Shale, blue	115	235
Sandstone, brown, dry	17	252
Shale, blue	36	288
Coal	24	312
Sand, water seep	4	316
Shale, blue	132	448
Coal	9	457
Shale, blue	53	510
Sand, water-bearing	35	545
Shale	5	550
Well 56–86–7dc		
Gravel	29	29
Shale, dark	63	92
Bentonite	3	95
Shale, dark	40	135
Sand, water-bearing	4	139
Shale, dark	9	148
Well 57–79–25cb		
Clay	34	34
Shale, blue	9	43
Sand, water-bearing	11	54
Shale, blue	22	76
Sand, water-bearing	11	87
Shale, blue	8	95

TABLE 7.—*Logs of test holes, seismic shotholes, and wells*—Continued

DRILLERS' LOGS—Continued

Material	Thickness (ft)	Depth (ft)
Well 57-80-31bb		
Soil	15	15
Gravel	30	45
Coal	5	50
Shale, blue	75	125
Sand, water-bearing	10	135
Shale, blue	5	140
Sand, water-bearing	10	150
Shale, blue	10	160
Well 57-81-7cb		
Clay, yellow, and gravel	12	12
Clay, yellow	31	43
Shale, blue	42	85
Sand, water	1	86
Shale, blue	5	91
Sandstone	6	97
Shale, blue	48	145
Sandstone	10	155
Shale, blue	20	175
Sand, hard water	5	180
Shale, blue and dark	38	218
Sand	9	227
Shale, blue	8	235
Sand	5	240
Shale, blue	24	264
Coal, soft water	8	272
Shale	24	296
Sand	6	302
Shale, blue	2	304
Sandstone	3	307
Shale, blue	36	343
Sand, fine	6	349
Clay, light	21	370
Sand, soft water	5	375
Clay, dark	30	405
Sandstone	1	406
Shale, blue	104	510
Well 57-84-19bd		
Clay, yellow	9	9
Clay, sandy	5	14
Gravel	5	19
Shale, blue	17	36
Sandstone	3	39
Well 57-84-19bd—Continued		
Shale, blue	21	60
Coal	3	63
Shale, blue	22	85
Coal	7	92
Shale, blue	13	105
Sandstone	7	112
Shale, blue	8	120
Coal, water-bearing	6	126
Well 57-85-19ab		
Soil	4	4
Sand and gravel	8	12
Shale, blue	2	14
Sand and coarse gravel	10	24
Shale, gray	6	30
Well 57-86-9ab		
Clay, sandy	5	5
Gravel	14	19
Shale, blue	17	36
Well 57-86-30ac		
Soil	5	5
Gravel and sand	25	30
Sandstone, water-bearing	25	55
Shale, blue	2	57
Sandstone	8	65
Limestone	3	68
Shale, brown	37	105
Limestone	2	107
Sand, flow	8	115
Well 57-86-34bb		
Soil, sandy shale and gravel	50	50
Sandstone, gray	20	70
Shale, gray	40	110
Shale, brown, sandy	40	150
Shale, gray	40	190
Shale, brown	50	240
Shale, gray	60	300
Sandstone, gray, water-bearing	14	314
Shale, gray	1	315

TABLE 7.—*Logs of test holes, seismic shotholes, and wells*—Continued

DRILLERS' LOGS—Continued

Material	Thickness (ft)	Depth (ft)
Well 58-76-30cc		
Soil	15	15
Shale	15	30
Gravel	8	38
Shale	27	65
Coal	18	83
Shale	25	108
Coal	2	110
Shale	26	136
Coal	11	147
Shale	86	233
Coal, water-bearing	27	260
Shale	10	270
Well 58-81-20ad		
Clay	35	35
Shale, blue	55	90
Sand	5	95
Shale, blue	10	105
Sand, water seep	7	112
Shale, blue and dark	163	275
Sand, water-bearing	8	283
Shale, blue	7	290
Sand, water-bearing	4	294
Shale, blue	2	296

Material	Thickness (ft)	Depth (ft)
Well 58-82-30aa		
Soil	10	10
Gravel, red clinker	10	20
Shale	40	60
Coal	10	70
Shale	160	230
Coal, gas	10	240
Shale	40	280
Coal	10	290
Shale	90	380
Coal	10	390
Shale	10	400
Sand	40	440
Coal, flow	30	470
Shale	10	480
Well 58-87-35ca2		
Soil	4	4
Shale, gray	31	35
Sandstone, brown	2	37
Shale, gray	23	60
Sand, water-bearing	5	65
Sandstone, gray	35	100
Clay	5	105
Sandstone, gray	10	115
Sand, water-bearing	5	120
Sandstone, gray	8	128
Shale	1	129

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