GEOLOGICAL SURVEY CIRCULAR 76

October 1950

GROUND-WATER CONDITIONS IN THE VICINITY OF GILLETTE, WYOMING

BY

ROBERT T. LITTLETON

WITH A SECTION ON THE QUALITY OF GROUND WATERS

BY

HERBERT A. SWENSON

Prepared in cooperation with
the City of Gillette and the
Wyoming State Engineer

UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary
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WASHINGTON, D. C.

Free on application to the Director, Geological Survey, Washington 25, D. C.

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INTRODUCTION

Purpose and Scope of the Investigation

The City of Gillette lies in northeastern Wyoming in about the center of the Powder River structural basin. It is the county seat of Campbell County and has an estimated population of about 3,150. The Gillette area is underlain by a thick succession of sand, sandstone, clay coal, and carbonaceous shale of Tertiary age. There are no perennial streams in the immediate vicinity of the city, hence water for municipal and industrial use is obtained from wells.

In October 1948 W. T. Fulkerson, Mayor of Gillette, requested the assistance of H. D. Thomas, Wyoming State Geologist, in an investigation of the ground-water conditions in the vicinity of Gillette, the principal objective of which was to locate a municipal ground-water supply of better quality and greater quantity. This request was referred to the Ground Water Branch of the United States Geological Survey, which cooperates with the Wyoming State Engineer in studying the occurrence, availability, and chemical quality of ground water in Wyoming. The ensuing investigation was made by the Geological Survey in cooperation with the City of Gillette and the Wyoming State Engineer.

The writer was in the area from May 19 to June 15, 1949, and again on August 7 and 8. An inventory was made of 52 wells and 4 springs. Six test holes aggregating 1,788 feet were drilled for the city by geophysical companies operating in the Powder River Basin. Water samples for complete analysis were obtained from 11 wells and 2 springs and were analyzed by chemists of the Quality of Water Branch, United States Geological Survey at Lincoln, Nebr., under the supervision of Paul C. Benedict, regional engineer. A map was prepared showing the locations of wells, springs, and test holes. Two cross sections showing geologic conditions in the upper part of the Fort Union and lower part of the Wasatch formation were prepared from data obtained from test holes and well logs.

The investigation was under the general supervision of A. N. Sayre, Chief of the Ground Water Branch of the Geological Survey, and under the direct supervision of S. W. Lohman, district geologist for Colorado and Wyoming. Mr. Lohman helped in planning the investigation and critically reviewed this report. Miss Natalie Willesen aided in preparing the manuscript. The final typing for duplimat reproduction was done at Lincoln, Nebr., by Crystal J. Rollf of the Missouri Basin ground-water staff.

Acknowledgments

The writer wishes to express his appreciation for the help and splendid cooperation received from city officials, residents in and around Gillette, officials of oil companies and geophysical companies, and officials of the Chicago, Burlington and Quincy Railroad and the Wyodak Manufacturing Co.

Farmers and ranchers in the vicinity of Gillette generously supplied information about their wells. The Shell Oil Corp. released to the writer the logs, locations, and altitudes of 280 shot holes drilled in the vicinity of Gillette, and gave permission for the United Geophysical Co. to drill a test hole. The Texas Co. gave permission through their local geologist, Louis Roos, for the Geotechnical Corp. and the Young Exploration Co. to drill two test holes and released to the writer the geologic and hydrologic details of deep oil tests drilled 12 miles north of Gillette. The Gulf Oil Corp. provided a rig and personnel to drill a test hole. By permission of the Amerada Petroleum Corp., the Dayton Geophysical Co. drilled a test hole. The Carter Oil Co. supplied the writer the logs of two core holes drilled near Gillette and made available aerial photographs for use in this investigation.

GEOGRAPHY

Topography and Drainage

The area surrounding Gillette is a hilly-to-rugged upland interrupted by wide rolling valleys and dotted with conspicuous buttes capped by red shale and clinker (Thom, 1927, pp. 50-64, pls. 11-13). There are several enclosed depressions that are occupied intermittently by lakes. The origin of these depressions seems to be related to slumping caused by the burning of coal beds and to wind erosion.

Gillette lies at an altitude of about 4,550 feet, at about the divide between the Powder River to the west, the Little Powder River to the north, and the Belle Fourche River to the east.

Streams in the vicinity of Gillette, such as Donkey Creek, Little Rawhide Creek, and Rock Pile Drain, are ephemeral and flow only in response to precipitation. Little Powder River, which heads in the northeastern part of the area covered by this investigation, is a small perennial stream below the point at the northeast edge of the area where it intercepts the flow of springs. These springs issue from clinker beds or zones of slump associated with the burning of coal beds.

Climate

The climate in the Gillette area is semiarid but the precipitation is sufficient in most years to support dry farming and grazing. The average annual precipitation during the 35-year period of record has been 14.94 inches. The area has warm, dry summers and cool, blustery winters. The precipitation consists principally of spring snows and rains. Early in summer thundershowers are common and the frequent hailstorms cause considerable damage to grain crops.

A soil mantle has developed over most of the area and is fairly thick in the valleys. This condition allows much of the water from rain and snow to seep to underground storage.

Economy

Gillette serves a large stock-raising and dry farming area that includes the whole of Campbell County and a large part of the Powder River Basin. The city has had continued and steady growth since it was established as a camp at the railhead of the Chicago, Burlington and Quincy Railroad, when construction was delayed during the winter of 1891-92.

The city is served by the railroad and by United States Highway 14-16 and Wyoming State Highway 59. It has much tourist trade during the summer months, as it is the only stopping point of any consequence between the Black Hills to the east and the Big Horn Mountains to the west.

In recent years the city has become the center of a greatly expanded program of petroleum exploration in the Powder River Basin. This has caused a sharp rise in population and has created a demand for additional water. City officials and civic-minded residents were quick to recognize that the continued growth and development of Gillette are dependent primarily upon the availability of additional water of better quality.

GEOLOGY

Summary of Geologic History

The geologic history of the area covered by this report is an integral part of the geologic history of the Powder River Basin. As the history of the entire basin is long and involved and poorly known, only the history pertaining to the deposition of the Fort Union and Wasatch formations of Tertiary age is discussed here.

The Fort Union and Wasatch formations are of fresh-water origin, having been deposited in inland lakes and marshes and on extensive flood plains. During most of Fort Union time the area was characterized by large, shallow inland lakes and marshes in which were deposited mud, sand, and carbonaceous material that were later compacted into shale, sandstone, and coal. The marshes at first developed locally, but at the close of Fort Union time they covered most of the area. A luxuriant growth of vegetation in this extensive marsh contributed the vast amount of carbonaceous material from which developed the Roland coal.

In early Wasatch time sluggish meandering streams deposited irregular bodies of fine-grained sand and clay. Throughout Wasatch time deposition by streams alternated locally with the development of marshes forming thin beds and lenses of coal, notable among which is the Felix coal.

The drainage pattern of the main streams in early Wasatch time had an important bearing on the present occurrence of ground water in the vicinity of Gillette, as their former courses are now marked by channel sandstones. From the meager evidence at hand in the vicinity of Gillette, the long, narrow sandstone bodies of the Wasatch formation seem to trend generally northward.

Summary of Stratigraphy

Pre-Tertiary Sedimentary Rocks

A succession of stratified rocks ranging in age from Cambrian to Upper Cretaceous unconformably underlies the thick covering of younger, Tertiary rocks. The pre-Tertiary rocks crop out in a wide belt against the Black Hills uplift to the east, dip westward into the Powder River Basin, and are deeply buried in the vicinity of Gillette. This succession of pre-Tertiary stratified rocks underlying the area probably exceeds 10,000 feet in thickness. The Texas Co's deep oil test was drilled into the Pahasapa limestone of Mississippian age, having penetrated 8,045 feet of pre-Tertiary rocks.

The pre-Tertiary rocks consist largely of coarse- and fine-grained sandstone, thick beds of shale, and massive and porous beds of limestone, but sufficient information is not available to compose an adequate stratigraphic section. Table 1, based on data obtained from deep oil tests, however, gives the stratigraphic sequence and the probable average depths and thicknesses of formations that would be encountered by deep drilling.

Table 1.--Stratigraphic section at Gillette, Wyo.

Formation	Thickness (feet)	Depth (feet)
Tertiary:		
Wasatch formation	335	335
Fort Union formation	1,955	2,290
Pre-Tertiary:		
Lance formation	1,000	3,290
Fox Hills sandstone	460	3,750
Pierre shale and Niobrara formation	2,845	6,595
Frontier formation	775	7,370
Graneros shale and its lateral equivalents, the Skull Creek shale, Newcastle sandstone, Mowry shale, and Belle Fourche shale	445	7,815
Inyan Kara group: Lakota sandstone, Fuson shale, and Fall River sandstone	250	8,065
Morrison formation	95	8,160
Sundance formation	165	8,325
Spearfish formation	800	9,125
Minnekahta limestone	15	9,140
Opeche shale ("red beds")	55	9,195
Minnelusa sandstone	770	9,965
Pahasapa limestone	?	?

Tertiary Sedimentary Rocks

Fort Union formation.--In the vicinity of Gillette the Fort Union formation consists of gray clay, gray silty clay, thin beds of fine-grained gray sandstone, and beds of subbituminous coal and carbonaceous shale. The sandstone beds range in thickness from 10 to 65 feet. The coal beds vary in size and shape and range in thickness from a few feet to 88 feet. The formation crops out at Minturn, 6 miles east of Gillette, where it is capped extensively by red clinker produced by burning of the Roland coal.

According to Dobbin (1927, pp. 1-50, pls. 1-10), the formation is made up of the Tongue River member above and the basal Lebo shale member. The upper contact of the Fort Union is placed at the top of the Roland coal. The contact between the finer materials of the Fort Union and the coarser sediments of the underlying Lance formation can be inferred from electric logs of deep oil tests obtained by the Texas Co. Dobbin assigned a maximum thickness of 800 feet to the Fort Union formation at the eastern margin of the Powder River Basin. Deep drilling by the Texas Co. and by the City of Gillette suggests a thickness of about 1,950 feet in the vicinity of Gillette. It is reasonable to assume that the formation should thicken toward the center of the vast early Tertiary geosyncline.

Wasatch formation.--The Wasatch formation consists of lenticular bodies of fine-grained sand, sandstone, clay, and silty clay interbedded with beds and lenses of subbituminous coal and carbonaceous shale. The sandstone beds are gray and yellowish brown and are poorly to tightly cemented. The yellowish-brown sandstones contain abundant limonite as concretions and irregular streaks and locally as cementing material. Beds of red shale and clinker crop out along the coal horizons in many places. The stratigraphic units that make up this formation lack continuity, particularly the sandstones, which thin and thicken markedly eastward. The history of deposition of the Wasatch, however, suggests that the channel sandstones may persist for several miles along their length.

The Wasatch formation crops out at the surface in the vicinity of

Gillette. Previous investigators (Thom, 1927, pp. 50-64, pls. 11-13) have placed the contact between the Wasatch and Fort Union in the vicinity of the Wyodak coal mine, about 5½ miles east of Gillette.

At the Powder River drainage divide 6 miles west of Gillette the thickness of the Wasatch formation is estimated to be about 800 feet. Dobbin (1927, pp. 1-50, pls. 1-10) postulates an over-all thickness of 1,000 feet for the formation in this part of the Powder River Basin. In the vicinity of Gillette erosion has removed all but about 335 feet of the Wasatch.

Quaternary Deposits

Alluvium of Quaternary age deposited in the valleys of the main streams consists predominantly of sand, silt, and clay but contains also a few lenses of fine gravel consisting of pebbles of hard fine-grained sandstone and of fragments of red shale and clinker. The thickness of the alluvium in the valleys ranges from a few feet to about 35 feet.

Structure

According to Dobbin (1927, pp. 1-50, pls. 1-10) the Tertiary rocks in the eastern part of the Powder River Basin dip gently southwestward. The writer obtained information on the Roland coal suggesting a westerly dip of about 1½ degrees. However, the exact directions of strike and dip cannot be ascertained owing to the lack of uniformity of thickness of the Roland coal.

The structure of the Tertiary formations conforms only in a general way to that of the underlying rocks. Post-Tertiary disturbances that may have occurred in the Powder River Basin are, in the opinion of the writer, reflected in the Tertiary strata as variations in the direction and amount of predominantly gentle dips.

GROUND WATER

Water in Quaternary Alluvium

Ground water occurs in the alluvium along the main streams, but owing to the limited thickness and fine-grained texture of the alluvium only limited supplies are available. Only three of the wells inventoried yield water from the alluvium. The water generally is highly mineralized and contains an excessive amount of iron, making it hardly suitable even for stock use. A few dug wells in the alluvium were reported to yield water of good quality, but these reports could not be verified. The writer obtained information suggesting the presence of small, isolated lenses of clean sand that are recharged directly from precipitation and hence contain water of better quality.

Water in Tertiary Rocks

Wasatch formation

Ground water in the Wasatch formation occurs principally in irregularly bedded, lenticular sandstone and in jointed coal, and generally is under artesian pressure. In the immediate vicinity of Gillette artesian water generally is found in the lenticular sandstones between the Felix coal above and the base of the formation (top of the Roland coal) below (see pl. 2), but the artesian pressures range widely within short distances. Reportedly dry sandstone was penetrated at a depth of 228 feet in well 8, which suggests that some of the sandstone lenses are completely surrounded by impervious clay and shale and contain no water.

Unconfined ground water occurs in the lenticular sandstones in places where they crop out at the surface or beneath saturated alluvium.

Most of the wells in the Wasatch formation obtain water from fine-grained sandstone at depths ranging from a few tens of feet to 380 feet, and yield from 10 to 50 gallons a minute. The depth to water level in the shallower wells averages about 30 feet but in the deeper wells it ranges from 75 to 150 feet.

Because of the occurrence of the water largely in channel sandstones that trend generally northward, it may be possible to economize in test drilling by first locating test holes on an east-west line. Then, any favorable holes could be supplemented by additional holes to the north or south; those would have a better-than-average chance of penetrating similar favorable materials. A rectangular area about 6 miles long and 2 miles wide along line C-D (see pl. 1) is the most favorable area for prospecting for lenticular sandstone in the Wasatch formation.

Fort Union Formation

Water in the Fort Union formation occurs mainly in thin beds of fine-grained gray sandstone, but to a lesser extent also in jointed coal and in red clinker and red shale. Most of the wells in sandstone and coal encountered water under artesian pressure, but flows are not to be expected in the vicinity of Gillette because the reservoir rocks dip in the direction of topographic rise. Gas was encountered at the top of the Roland coal in well 8 (pl. 1). Water from the coal subsequently entered the well and rose about 259 feet above the point at which it was encountered.

Unconfined ground water occurs in outcrop areas of the red clinker and shale of the Fort Union formation. Many springs issue from the large area of clinker beds northeast of Gillette. The water from these springs issues at the contact between clinker and underlying fine-grained material, generally clay, along the sides of valleys. Moyer spring (No. 58), now owned by Charles Marshall, has an estimated yield of about 200 gallons a minute and is the largest spring known in the area. The yields of the smaller springs range from 5 to 12 gallons a minute. Well 15 is a shallow pit dug into shattered red shale adjacent to Ditto Lake and seems to be supplied from the lake. This well is pumped at about 1,500 gallons a minute with a drawdown of approximately 8 inches.

The water level in wells that produce from sandstone ranges from about 250 feet below land surface in wells 16, 17, and 18 to 373 feet in wells 43, 44, and 45. The water level in well 8 was only 125.76 feet below land surface on August 8, 1949, but this high level may be due to gas pressure.

During a pumping test the railroad well (No. 45) yielded only 93 gallons a minute with a drawdown of 134.5 feet. The specific capacity of the well thus is only 0.69 gallon a minute per foot of drawdown, indicating that the sandstone has a low permeability. Each of the three railroad wells is pumped at about 45 gallons a minute to decrease the drawdown and to avoid pumping fine sand. Wells 16, 17, and 18, owned by the Wyodak Manufacturing Co., are capable of yields ranging from 35 to 58 gallons a minute.

Water in Pre-Tertiary Rocks

Information about water in the pre-Tertiary rocks in this area was obtained from the records of deep oil tests by the Texas Co. and deep drilling by the City of Gillette. Potential aquifers in pre-Tertiary stratified rocks include sandstone beds of the Lance formation, the Fox Hills, Fall River ("Dakota"), and Lakota sandstones, sandstone in the Sundance formation, and the Pahasapa limestone. These formations are recharged at their outcrops mainly from streams and in small part from precipitation. As the aquifers dip beneath the surface, the water is trapped beneath confining beds of shale and percolates down the dip toward the center of the Powder River Basin. In the vicinity of Gillette water under some artesian pressure might be obtainable at depths ranging from 2,200 to 10,000 feet from such of these units as are sufficiently permeable. Flowing artesian wells could not be obtained from any of these formations in the vicinity of Gillette, however, as the city lies about 200 feet higher than the intake area.

Ground water in the Lance formation occurs in fine-grained sandstones. These sandstones range in thickness from 10 to 50 feet and are separated by beds of shale and coal. In the outcrop area 18 to 25 miles east of Gillette this formation supplies water to stock and domestic wells. Because of the depth, which is excessive in view of the fine-grained character of the sandstone beds, the aquifer is of little economic importance at Gillette.

The Fox Hills sandstone contains water under artesian pressure at Gillette. Two deep wells drilled by the City of Gillette obtain highly mineralized water from this formation (see analysis for well 40). According to the available information, the nonpumping water level in these wells is about 505 feet and the pumping level about 750 feet below the land surface. Accurate records of the yield of these deep wells are not available but the large drawdown suggests a low permeability.

The Fall River and Lakota sandstones, lying at probable depths ranging from 7,800 to 8,060 feet at Gillette, contain artesian water. These formations are notable aquifers near the margin of the Black Hills uplift. The Texas Co. recovered 900 feet of water in a 45-minute drill-stem test of the Fall River sandstone at a depth of 7,615 feet. No chemical analysis of the water was made; however, it was reported to be cool and palatable.

Ground water under artesian pressure in sandstone of the Sundance formation can be anticipated at Gillette. A drill-stem test of the sandstone at a depth of 7,965 feet by the Texas Co. recovered water. No chemical analysis of this water was made but it was reported to be of poor quality.

Water encountered in the Pahasapa limestone by the Texas Co. at a depth of 9,750 feet contained about 3,070 parts per million of dissolved solids. Although the Pahasapa limestone is notably cavernous at the edge of the Black Hills uplift, it had only small porosity in the Texas Co.'s deep oil test.

The quantity of water that could be expected from wells penetrating these deep aquifers is not known but probably would not be large.

QUALITY OF GROUND WATERS

Chemical Character of the Ground Water

The differences in chemical character of ground waters in the vicinity of Gillette generally reflect differences in geologic formations from which the waters are derived. The quality of the ground water in a single formation varies from place to place, and properties such as total mineralization and hardness show little relation to well depths. The three aquifers of chief importance, however, yield waters of distinctive chemical character and are discussed individually. In view of their potential use as a municipal water supply, spring waters are discussed separately. Figure 1 (p. 22) is a map of the Gillette area showing points where ground water samples were collected. Chemical analyses are given in table 2 and shown graphically in figure 2. (See pp. 23 and 24.)

Wasatch Formation

The Wasatch formation yields water containing moderate to large amounts of dissolved solids, ranging in concentration from 252 to 2,320 parts per million. In both dilute and concentrated waters, calcium and sulfate are usually found in significant amounts. Water in this formation has a considerable range in hardness; for 6 samples, the total hardness as calcium carbonate ($CaCO_3$) ranges from 120 to 1,530 parts per million. Iron is found in objectionable quantities in several of the waters from the Wasatch formation and is traceable to limonitic concretions and streaks in the yellowish-brown sandstones. Studies of the available analyses show no significant relation between the chemical character of the waters and the depth of the wells either in the Wasatch formation or in the other two principal water-bearing formations.

Fort Union Formation

Ground water in the Fort Union formation is somewhat lower in both total mineralization and hardness than waters in the Wasatch formation, though the range in both is considerable. Sodium, bicarbonate, and sulfate are the principal ions in the waters from the deeper wells. For four samples of water from the Fort Union, the range in dissolved solids and total hardness is 276 to 1,490 parts per million and 38 to 947 parts per million, respectively. The waters from the Fort Union are hard with the exception of the Wyodak Manufacturing Co. well (No. 17, 540 feet deep), which yields a very soft water, 38 parts per million. Iron is present in low concentrations.

Fox Hills Sandstone

The City of Gillette is pumping water from a deep well (40), 3,445 feet in depth, penetrating the Fox Hills sandstone, and this water is one of the sources of the municipal supply. A sample of this water, from well 40, was found to be very soft; the dissolved solids (1,150 parts per million) consist largely of sodium bicarbonate. The fluoride content of 8 parts per million is cause for concern, although mixing this water with other sources of supply may reduce the fluoride content considerably. The amount of iron present, 0.01 part per million, is insignificant.

Spring Waters

Complete chemical analyses of two samples from springs in the Gillette area are presented in table 2. The Michael Elmore spring (56), which issues from the Fort Union formation, yields water low in dissolved solids and hardness, 286 and 177 parts per million, respectively. A sample from the Charles Marshall spring (58), which probably issues at about the contact of the Fort Union and Wasatch formations, has a higher mineralization and hardness; the total dissolved solids and hardness are 1,080 and 712 parts per million, respectively. No general statements concerning the quality of the spring waters can be made on the information available at present.

Relation of Chemical Character to Use

Various standards have been proposed from time to time to evaluate a water for drinking purposes. In general, natural waters containing less than 0.2 part per million of iron and having low concentrations of magnesium sulfate or sodium sulfate are usually acceptable. The United States Public Health Service (1946) recommends as drinking-water standards for common carriers in interstate commerce the following maximum limits of chemical substances in natural or treated waters:

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

The above standards, together with other sanitary, chemical, and biological requirements of the Public Health Service, are helpful in evaluating private and public water supplies.

Use of waters that exceed these suggested standards is common. Consumers in rural areas, accustomed to drinking a water containing 1,500 parts per million or more of dissolved solids, may find unpalatable an urban supply that contains 100 to 200 parts per million. Although several of the analyses in table 2 indicate high concentrations of dissolved solids, most of the waters sampled are satisfactory for drinking and cooking purposes unless iron or fluoride is present in objectionable amounts.

Hardness, which is related to the amount of calcium and magnesium in solution, receives most attention with reference to domestic and industrial supplies. This characteristic of water is recognized by the quantity of soap required to produce a lather and by the objectionable curd formed in washing processes. Water having a hardness of less than 60 parts per million is generally considered soft. Hardness between 60 and 120 parts per million is usually satisfactory for most purposes except for use in steam boilers and in some industrial processes. Waters with hardness ranging from 121 to 200 parts per million are considered hard and in the upper ranges may be profitably softened for laundry and industrial use. Waters having a hardness in excess of 200 parts per million preferably should be softened before being used for most purposes, though such waters are widely used without treatment.

The percentage of sodium, which is the result obtained by dividing the equivalents per million of sodium by the equivalents per million of the cations (calcium, magnesium, sodium, and potassium) and multiplying by 100, has a bearing on the suitability of water to be used for irrigation and lawn and garden sprinkling. Waters in which the percentage of sodium is more than 60 may be injurious to certain types of soils, particularly if adequate drainage is not provided. High concentrations of sodium in solution tend to replace the calcium and magnesium in the mineral and organic complexes of the soil, with the result that the soil becomes gelatinous or "sticky" and relatively impermeable to the downward movement of the water. The very soft water from the deep well pumped by the City of Gillette is unsuitable for irrigation use because of the high percentage of sodium.

Summary

On the basis of samples analyzed for this study, waters from the Fort Union formation and waters from springs offer the most promise for development of additional municipal supplies. However, proper evaluation of the present municipal supply or of the spring-water potential cannot be made in view of the small number of samples analyzed. Water of the Wasatch formation probably would be objectionable because of high iron content and excessive hardness. The water from the Fox Hills sandstone as represented by a sample from the deep well owned by the City of Gillette, has a high fluoride content and percentage of sodium.

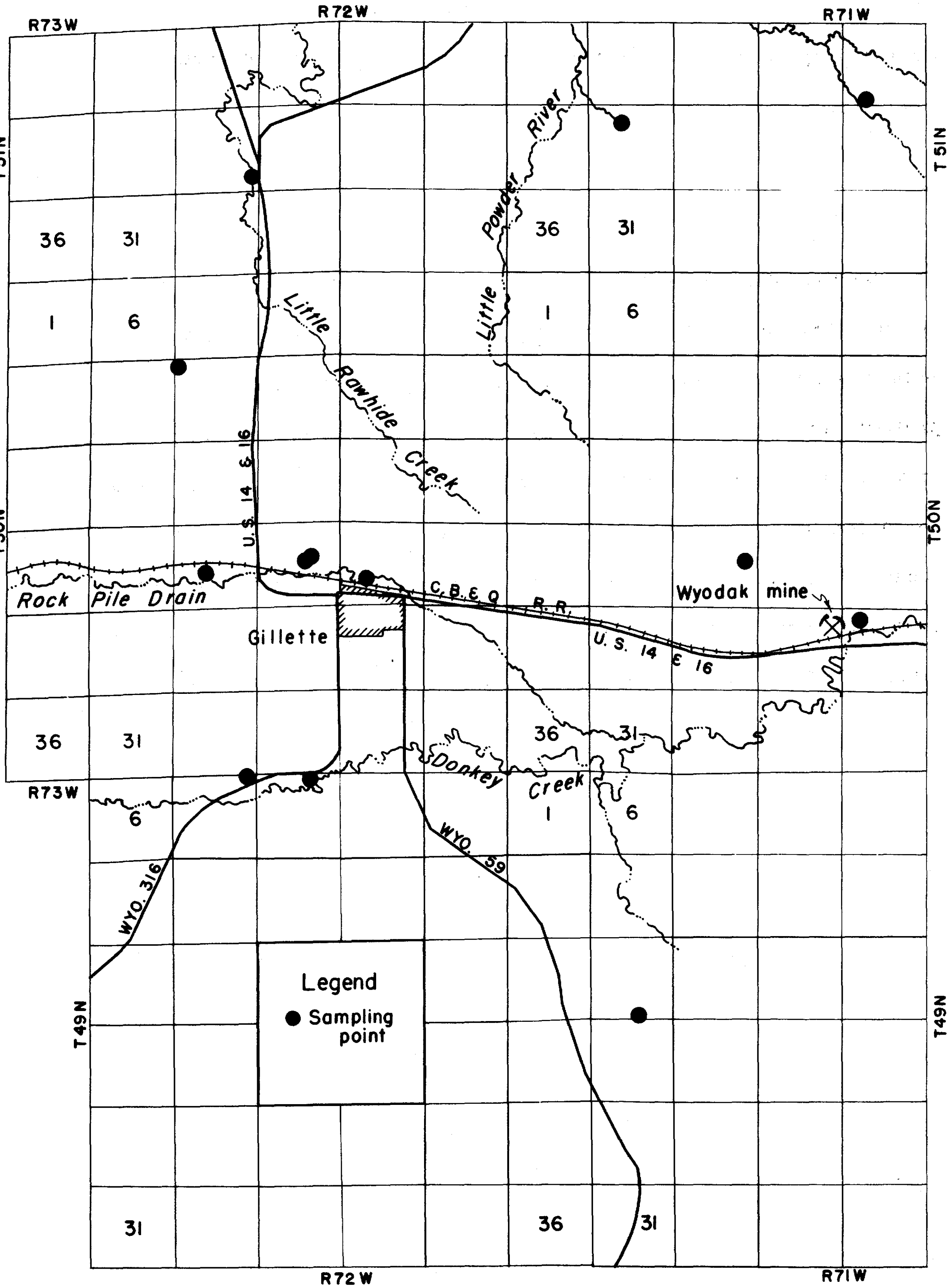

Figure 1.__ Map of Gillette area showing ground water sampling points

Table 2.--Chemical analyses of ground waters in the Gillette area, Wyo.
/Results given in parts per million/

Well number	Location	Date sampled (1949)	Depth (feet)	pH	Specific conductance, at 25° C. (micromhos)	Silica (SiO_2)	Total Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium
																			Total	Noncarbonate	
								Wasatch formation													
	T. 49 N., R. 71 W.																				
3	SW SE sec. 18	5-26	204	7.0	514	13	15	36	19	9.1	3.2	123	80	4.0	0.8	0.8	0.11	252	168	67	10
	T. 49 N., R. 72 W.																				
10	NE NE sec. 5	6-14	120	7.0	2,210	12	11	365	114	40	9.2	46	1,370	4.0	.6	4.6	.27	1,940	1,380	1,340	6
	T. 50 N., R. 72 W.																				
25	NW NW sec. 8	5-20	380	7.5	1,180	12	.85	25	14	254	5.6	823	2.4	8.0	.8	.2	.08	740	120	0	81
37	NE SW sec. 20	5-21	160	7.6	667	17	.27	85	32	9.1	5.6	249	149	4.0	.9	2.4	.00	454	344	140	5
39	SW NE sec. 21	6-14	210	7.6	2,280	22	3.3	341	150	43	14	373	1,170	7.0	.2	4.7	.22	1,940	1,470	1,160	6
	T. 51 N., R. 72 W.																				
61	SE SE sec. 29	5-20	34	7.5	2,690	19	2.2	275	204	144	14	266	1,480	21	.6	29	.20	2,320	1,530	1,310	17
								Fort Union formation													
	T. 49 N., R. 72 W.																				
8	NW NE sec. 4	8- 7	387	7.5	2,030	8.7	.....	58	45	311	11	627	476	21	1.2	.2	.07	1,250	330	0	66
	T. 50 N., R. 71 W.																				
15	SE NE sec. 20	5-23	6	7.3	1,890	30	.01	195	112	58	67	304	856	8.0	.9	6.9	.63	1,490	947	698	11
17	SW NW sec. 27	5-21	540	7.7	471	11	.....	8.0	4.2	91	2.8	283	3.2	7.0	1.0	.2	.19	276	38	0	83
	T. 50 N., R. 72 W.																				
44	NE SW sec. 22	5-31	840	7.7	1,190	13	.51	50	24	177	7.6	432	238	15	1.4	3.4	.15	766	224	0	62
								Fox Hills sandstone													
	T. 50 N., R. 72 W.																				
40	SW NE sec. 21	5-31	3,445	8.2	1,830	20	.01	5.0	1.0	473	5.2	1,220	2.0	31	8.0	4.3	.26	1,150	16	0	98
								Spring waters													
	T. 51 N., R. 71 W.																				
56	SE SW sec. 22	6- 9	.....	7.7	438	25	.01	53	11	14	11	164	79	3.0	1.0	7.0	.23	286	177	43	14
58	NE NW sec. 30	6- 8	.....	7.4	1,380	25	.03	193	56	43	27	192	636	3.0	.9	2.5	.71	1,080	712	555	11

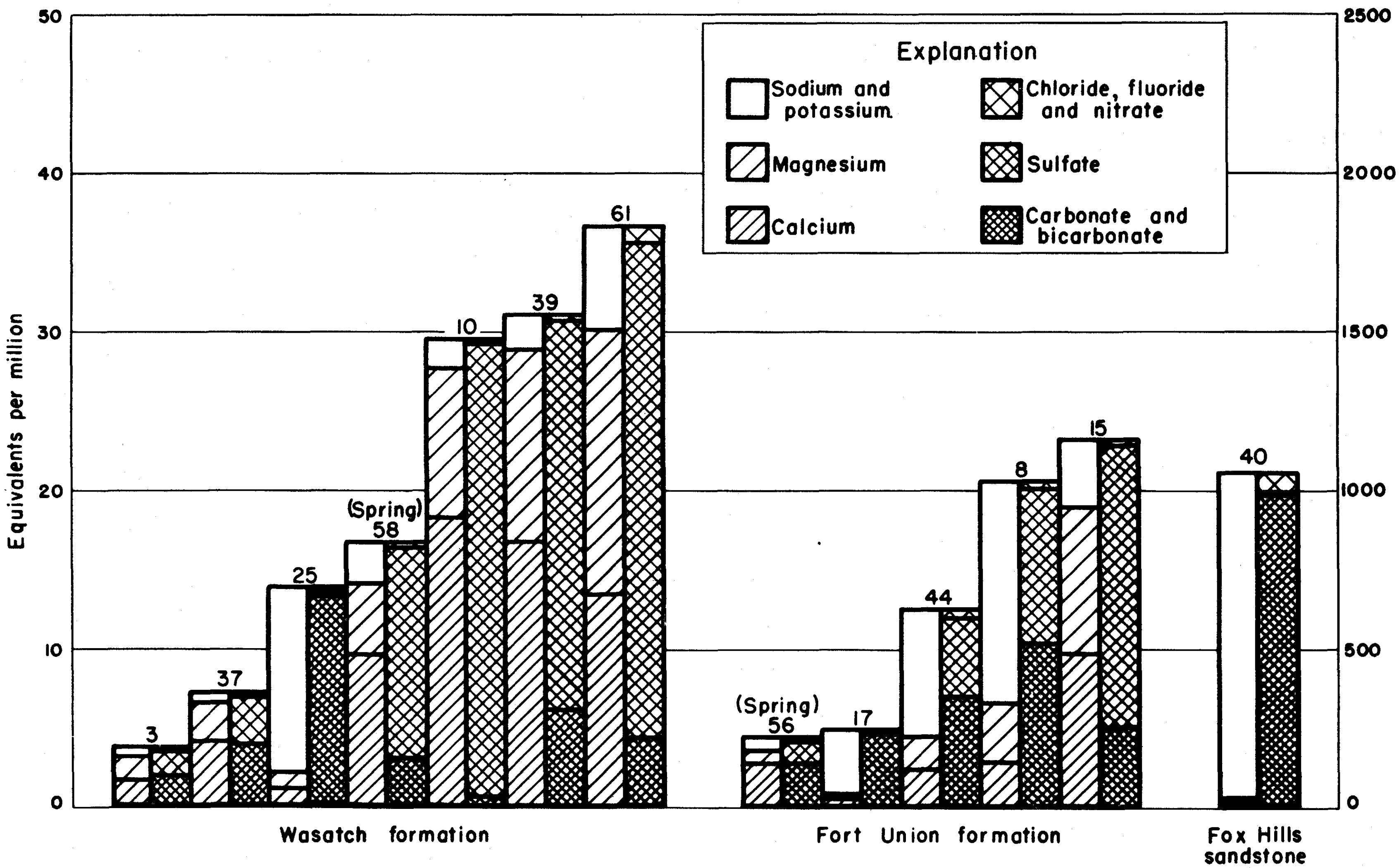

Figure 2.—Principal mineral constituents of ground waters in the Gillette area

Numbers refer to analyses in table 2

City of Gillette

History of Development

The early history (1898-1925) of municipal water-supply development at Gillette was reviewed by Kirk Bryan (1925). For some 15 years after its founding in 1891, the city was supplied with water by the Chicago, Burlington and Quincy Railroad from two deep wells that penetrated sandstones in the Fort Union formation. As the waters from these wells were highly mineralized, the wells were abandoned by the railroad in 1908, at which time the city embarked upon a program to develop ground-water supplies from shallow wells. This program included some test drilling in the immediate vicinity of Gillette and concluded with the development of four wells in sandstones of the Wasatch formation at the site of the present well field. At the time of Bryan's visit in June 1925 the city was obtaining its entire supply from these four wells. The reported depths of the wells ranged from 160 to 165 feet.

Present Supply

Owing to the poor quality of the shallow water and declining water levels brought on by the drought of the 1930's, city officials looked to the possibilities of deep drilling. In 1937-38 and in 1940-41 two wells were drilled to depths of 3,445 (?) and 3,470 feet, penetrating the Fox Hills sandstone of Upper Cretaceous age. The water from these deep wells is soft; however, it contains an excessive amount of dissolved solids, including 8 parts per million of fluoride.

The quantity of water obtained from the two deep wells was not sufficient to meet the demands of the city and a mixture of the shallow and deep waters is now being used. In view of the disappointing results obtained in deeper drilling, additional shallow wells were drilled to depths averaging about 250 feet. The water from these wells is obtained from a rather extensive lenticular sandstone containing abundant limonite.

In 1948 the city attempted to shoot one of the deep wells at the horizon of the sandstone beds in the Fort Union formation; the depths of the beds were determined from a gamma-ray log. The explosion caused the casing to collapse, however, and the well was abandoned.

Currently, the city is pumping eight shallow wells and the remaining deep well. Peak consumption is about 420,000 gallons a day but, if additional water were available, peak demands of 650,000 gallons a day could be expected. The system has a storage capacity of 600,000 gallons above ground and 100,000 gallons underground.

Wyodak Manufacturing Co.

The Wyodak Manufacturing Co. is situated at the site of its large open-pit coal mine about 5½ miles east of Gillette. This company, which is owned by the Homestake Mining Corp. of Lead, S. Dak., is engaged primarily in mining the Roland coal. Much of the coal mined is shipped by rail to Lead, S. Dak., where it is used by the parent company. Much coal is sold locally and the company also sells electric power to the City of Gillette.

Water for industrial use at the mine is obtained from three wells (Nos. 16, 17, and 18) that penetrate sandstones in the Fort Union formation, which lies at depths ranging from 296 to 536 feet. The reported yields of these wells range from 35 to 58 gallons a minute. The chemical quality of the water is suitable for most uses, but water of better quality would be desirable.

Prior to drilling wells the company made a brief study of the available water in springs some 6 miles north of the mine. Company officials concluded after a brief investigation that the cost of piping the water from these springs was too great for the supply available.

Chicago, Burlington and Quincy Railroad

Former Supply

The first water supply obtained by the Chicago, Burlington and Quincy Railroad was from a well drilled in 1898 to a depth of 865 feet. In 1906 an attempt was made to obtain a greater quantity of water of better quality by drilling a second well to a depth of 1,560 feet. Neither objective was accomplished, so the wells were abandoned and the railroad built a diversion dam on Donkey Creek in sec. 5, T. 49 N., R. 72 W., and constructed a ditch to conduct the flood waters of the stream to Burlington Lake, a natural depression lying just north of the City of Gillette. This water was suitable for engine-boiler use, but the supply was not wholly dependable because the lake dried up during periods of drought.

Present Supply

During the sustained drought of the 1930's, railroad officials decided to abandon the use of reservoir water and to obtain water for boiler use at other stops in the Powder River Basin. In 1939 a well was drilled to a depth of 852 feet, in 1943 a second well was drilled to a depth of 840 feet, and in 1947 a third well was drilled to a depth of 850 feet. Currently two of the wells are pumped at a rate of about 45 gallons a minute each for general use at the railroad yards.

Possibilities of Developing Additional Ground-Water Supplies

From information compiled during this investigation, there appear to be only three possible sources of additional ground water for municipal or industrial use in the vicinity of Gillette. Named in order of feasibility they are (1) water in the sandstones of the Wasatch and Fort Union formations, (2) springs that issue from clinker beds in the Fort Union formation about 14 miles northeast of Gillette, and (3) deep aquifers of pre-Tertiary age that lie at depths ranging from 2,200 feet to possibly 10,000 feet.

It seems likely that enough water is available in the sandstones of the Wasatch and Fort Union formations to supply the city's present and future needs. In the vicinity of Gillette these sandstones generally are saturated but are predominantly fine-grained and consequently have low permeability. Test drilling would be needed to locate sandstones of sufficient thickness and lateral extent (see p. 12).

The springs about 14 miles northeast of Gillette would supply sufficient water for the city's need if properly developed, but a collecting system, pipe line, and pumping station would be required. The combined yield of the springs is estimated to be about 390,000 gallons a day. This estimate includes Moyer Spring (No. 58) and all smaller springs, some of which are just northeast of the area covered by plate 1. These springs occur within an area of about 16 square miles and range in altitude from 4,400 feet to 4,500 feet.

The third and least likely possibility of obtaining additional water would be from wells drilled to deep aquifers of pre-Tertiary age. However, the water in the Lance and Fox Hills formations is not of suitable quality, and the scanty information available about the chemical quality of water in the deeper artesian aquifers introduces an element of considerable risk into any program of deeper drilling.

DOMESTIC AND STOCK WATER SUPPLIES

In the vicinity of Gillette domestic and stock water is obtained from wells that tap fine-grained sandstones in the Wasatch formation. The water is confined under some artesian pressure but, as pointed out above, the wells do not flow at the surface.

Most of the wells currently in use are equipped with cylinder pumps that are powered by wind or by gasoline motors. The capacity of these pumps rarely exceeds 10 gallons a minute.

RECORDS OF WELLS, TEST HOLES, AND SPRINGS

Records of 62 wells, test holes, and springs in the vicinity of Gillette are given in table 3.

Table 3.--Records of wells, test holes, and springs in the Gillette area

Table 3.--Records of wells, test holes and springs in the Gillette area, Wyoming

Well number[1]	Location	Owner or tenant	Type[2]	Depth of well (feet)	Diameter of well (inches)	Geologic source[3]	Method of lift[4] Type of power[5]	Use of water[6]	Measuring point: Description[7]	Measuring point: Height above land surface (feet)	Depth to water level below measuring point (feet)[8]	Date of measurement	Yield and drawdown[9]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	T. 49 N., R. 71 W.												
1	SW SW NW sec. 6	R. A. Steinhofel	Dr	.....	6	....	Cy,H	S	TC	0.7	42.24	5-24	....
2	SE NW NW sec. 7	.....do.........	Dr	72	6	Tw	Cy,W	D,S	TC	1.9	34.76	5-24	....
(3)	SW SW SE sec. 18	Henry Wolff.....	Dr	204	4	Tw	Cy,W	S	TC	1.2	49.64	5-26	....
4	NE SW SW sec. 20	Vincent Wolff...	Dr	181	6	Tw	Cy,G	S	TC	1.8	129.34	5-26	....
5	NE SW SE sec. 29	Charles Roark...	Dr	263	6-4	Tw	......	N	LS	.0	166.36	6- 7	Y, 18
	T. 49 N., R. 72 W.												
6	NE NE NE sec. 3	Seth Wadell.....	Dr	79	6	Tw	Cy,W,H	D,S	TC	.7	26.67	5-24	....
7	NE NE NW sec. 3	Charles Hitt....	Dr	.....	6	Qal	Cy	I	LS	.0	26	6-13	....
(8)	NE NW NE sec. 4	LeRoy Christinck	Dr	387	6-4	Tfu	......	.....	TC	4.0	129.76	8- 8	....
9	NE SW SE sec. 4	William Apple...	Dr	56	6	Tw	Cy,W	S	LS	.0	30	6- 6	....
(10)	NW NE NE sec. 5	LeRoy Christinck	Dr	120	6	Tw	Cy,W	S	TC	.0	54.76	5-27	....
11	NE SE SW sec. 9	John Heiland....	Dr	125	6	Tw	Cy,W	S	TC	.2	98.18	5-26	....
12	NE NW SW sec. 10	A. B. Maycock...	Dr	204	8-6	Tw	Cy,W	D,S	LS	.0	90	6- 6	....
	T. 50 N., R. 71 W.												
13	SW NW NW sec. 18	O. H. Kenitzer..	Dr	206	4	....	Cy,W	D,S	....	....	......	....	....
14	SW SW SW sec. 19	Alva Potter.....	Dr	.....	6	....	Cy,W	S	TBC	.4	29.04	5-24	....
(15)	SW SE NE sec. 20	John Cos........	Du	6	.....	Tfu	C,G	I	....	....	......	....	....
16	NE NW NW sec. 27	Wyodak Mfg. Co..	Dr	340	13-10	Tfu	T,E	D,In	....	....	......	....	Y, 35
(17)	NW SW NW sec. 27	.....do.........	Dr	540	12-10	Tfu	T,E	D,In	....	....	......	....	....
18	NW SW NW sec. 27	.....do.........	Dr	546	15-8	Tfu	T,E	D,In	TCB	.7	264.90	5-21	Y, 58

19	SE NE SW sec. 30	State Exp. Farm.	Dr	145	4	Tw?	Cy,W	S	TC	1.5	98.13	6- 4	....
	T. 50 N., R. 72 W.												
20	NE NW NE sec. 4	Clifford Davis..	Du	50	36-24	Tw	Cy,E,W	D,S	TBC	1.0	33.86	5-20	....
21	SE SW NE sec. 4	.....do..........	Dr	160	6-4	Tw	Cy,W,H	D,S	TBC	.5	32.12	5-20	....
22	SW NW NW sec. 4	Test hole.......	T	400	.....	Qal, Tw	......	....	LS	.0	5.56	6-14	....
23	SE NE NE sec. 6	R. G. Frye (gas test)	Dr	1,250	10-5	Tw, Tfu	......	....	TC	3.9	92.27	5-26	....
24	SE NE NE sec. 8	J. W. Cole.......	Dr	95	6	Tw	Cy	N	TC	2.1	29.09	5-20	Y, 25
(25)	NW NW NW sec. 8	.....do..........	Dr	380	6-4	Tw	Cy,G	D,S	LS	.0	160	5-20	Y, 10
26	SW NW SW sec. 9	Mrs. E. R. Smith	S	.....	.....	Tw	......	S	....	....	......	....	Y,0.06
27	SE SW SW sec. 9	.....do..........	Du	.....	48	Tw	Cy,W	S	TBC	2.2	13.30	5-25	....
28	SE SE SE sec. 9	W. P. Schmidt...	Dr	120	.....	Tw	Cy,W	S	TC	.5	67.99	5-25	....
29	SE NW NW sec. 11	Test hole........	T	100	.....	Tw	......	....	LS	.0	26.86	5-25	....
30	NW NW SE sec. 12	Henry Kluver....	Dr	180	4	....	Cy,W	S	....	....	......	....	....
31	SW NW SE sec. 13	.....do..........	Dr	217	6-2	Tfu	Cy,W	S	TC	.8	102.52	5-25	....
32	NW NW NW sec. 14	Test hole........	T	90	.....	Tw	......	....	LS	.0	19.24	5-25	....
33	SE SE SE sec. 17	.....do..........	T	400	.....	Tw	......	....	LS	.0	80.72	7-15	....
34	SW SW SW sec. 19	.....do..........	T	300	.....	Tw	......	....	LS	....	......	....	....
35	SE SW SW sec. 19	H. L. Barlow....	Du	16	54	Tw	Cy,W	S	....	....	......	....	....
36	SE SE NE sec. 20	Test hole........	T	320	3	Tw	......	O	LS	.0	77.26	6- 9	....
(37)	NE NE SW sec. 20	E. E. Littleton.	Dr	160	6	Tw	Cy,W	D,S	....	....	......	....	....
38	NE NE SW sec. 20	Test hole........	T	235	6	Tw	......	....	LS	.0	113.04	6- 9	....
(39)	SW SW NE sec. 21	City of Gillette	Dr	210	8	Tw	T,E	P	....	....	......	....	Y, 40
(40)	SW SW NE sec. 21	.....do..........	Dr	3,445	.....	Kfh	T,E	P	LS	.0	750	....	Y, 90; DD, 240
41	SE NE SW sec. 21	Glen Baker......	Dr	96	6	Tw	Cy,G	D,S	TC	.7	77.08	6- 9	....
42	NW SW SW sec. 21	Test hole.......	T	113	.....	Tw	......	....	LS	.0	84.97	6- 3	....
43	SE NE SE sec. 21	C, B & Q RR.....	Dr	850	3	Tfu	T,E	In	LS	.0	583	5-31	....
(44)	SE NW SW sec. 22	.....do..........	Dr	852	6-4	Tfu	......	....	LS	.0	373	5-31	Y, 93; DD,134.5
45	SW NE SW sec. 22	.....do..........	Dr	840	6	Tfu	T,E	In	....	....	......	....	Y, 42; DD, 125
46	SW SE NW sec. 23	Harry Hanslip...	Dr	65	6	Tw	Cy,W	D,S	TC	.4	43.85	6- 1	....

See footnotes at end of table.

Table 3.--Records of wells, test holes and springs in the Gillette area, Wyoming--Continued

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	T. 50 N., R. 72 W.--Cont.												
47	SW NW NE sec. 25	State Exp. Farm.	Dr	160	6-4	Tw	Cy,W	D,S	TBC	0.2	109.92	5-24	....
48	NW NE SW sec. 25	Lawrence Shippy.	Dr	204	6-4	Tw	Cy,W,H	D,S	TC	.0	78.57	5-24	....
49	NE NW SW sec. 26	M. B. McCann....	Dr	118	6	Tw	Cy,W	D,S	TC	.8	50.82	5-24	....
50	SW SE NW sec. 27	City of Gillette	Dr	340	6	Tw	T,E	P	....	....	......	....	Y, 40
51	NE NE NE sec. 29	Lee Newton......	Dr	140	6-3	Tw	Cy,E	S,In	LS	.0	100	5-20	Y, 50
52	NE NW NW sec. 30	L. H. Barlow....	B	30	6	Tw	Cy,W	D	....	....	......	....	Y, 20
53	SE NW NE sec. 34	M. B. McCann....	Dr	70	.....	Tw	Cy,G	S	....	....	......	....	....
	T. 50 N., R. 73 W.												
54	NE NW NW sec. 24	James McKenzie..	Dr	145	6	Tw	Cy,H	S	TBC	.2	74.21	5-28	....
55	NW SW SE sec. 25	LeRoy Christinck	Dr	227	6-4	Tw	Cy,W	S	TC	.6	99.39	5-28	....
	T. 51 N., R. 71 W.												
(56)	SW SE SW sec. 22	Michael Elmore..	S	.....	.....	Tfu	......	S	....	....	......	....	Y, 6
57	NW SW NE sec. 27	Eugene Springen.	S	.....	.....	Tfu	......	S	....	....	......	....	Y, 12
(58)	SE NE NW sec. 30	Charles Marshall	S	.....	.....	Tw?	......	S	....	....	......	....	Y, 200
	T. 51 N., R. 72 W.												
59	NW SE NW sec. 20	A. Vandekoppel..	Dr	58	6	Tw	Cy,W,G	D,S,I	TC	.0	39.42	6-14	....
60	SE NW SW sec. 22	R. E. Kelley....	Du	12	.....	Qal	Cy,W	S	TBC	.2	4.57	5-20	....
(61)	NE SE SE sec. 29	E. E. Hladky....	Du	34	60-48	Tw	Cy,W	S	TBC	1.0	30.98	5-20	....
62	SW SW NW sec. 33	Clifford Davis..	Dr	32	6	Qal	Cy,W	S	TC	.4	10.33	5-20	....

1 Well number in parentheses indicates that analysis of water is given.

2 B, bored well; Dr, drilled well; Du, dug well; S, spring; T, test hole.

3 Kfh, Fox Hills sandstone; Qal, alluvium; Tfu, Fort Union formation; Tw, Wasatch formation.

4 Method of lift: C, centrifugal pump; Cy, cylinder pump; T, turbine pump.

5 Type of power: E, electric; G, gasoline or diesel; H, hand; W, wind.

6 D, domestic; I, irrigation; In, industrial; N, none; O, observation; P, public; S, stock.

7 LS, land surface; TBC, top of board cover; TC, top of casing; TCB, top of concrete block.

8 Measured depths to water level are given in feet, tenths, and hundredths; reported depths to water level are given in feet.

9 Y, yield in gallons a minute; DD, drawdown in feet.

LOGS OF TEST HOLES AND WELLS

On the following pages are tabulated the logs of six test holes and four wells in the Gillette area. The test holes were drilled by the hydraulic-rotary method. Logs entitled "sample logs" are those for which the drill cuttings available for each 5-foot interval were studied by the writer; the "driller's logs" were obtained from drillers or from other sources.

Sample log of test hole 22, approximately 1,090 feet south and 390 feet east of NW cor. sec. 4, T. 50 N., R. 72 W.

	Thickness (feet)	Depth (feet)
Alluvium: Sand, silt, and clay	15	15
Wasatch formation:		
Siltstone, buff to gray, containing abundant gypsum	18	33
Sandstone, gray, fine-grained; composed mainly of angular grains of quartz, with accessory ferromagnesian minerals and crystals of pyrite	2	35
Clay, gray, waxy	15	50
Sandstone, gray, fine-grained; composed of angular grains of quartz with accessory ferromagnesian minerals	3	53
Clay, gray, sandy (sand, very fine), contains abundant crystals of pyrite and gypsum	12	65
Sandstone, gray, fine-grained; composed of angular grains of quartz and abundant crystals of pyrite	10	75
Clay, gray, interbedded with fine-grained sandstone	10	85
Coal, interbedded with carbonaceous shale	5	90
Clay, gray to dark-gray, calcareous, interbedded with streaks of coal and a few thin beds of siltstone	60	150
Fort Union formation:		
Coal, interbedded with carbonaceous shale and thin beds of clay	60	210
Clay, gray, sandy (sand fine) to waxy; contains thin streaks of white bentonite and irregularly distributed brown limy concretions; interbedded with thin streaks of coal and a few thin beds of fine-grained sandstone and siltstone	190	400

Sample log of test hole 33, approximately 200 feet west and 75 feet north of SE cor. sec. 17, T. 50 N., R. 72 W.

Alluvium: Sand, silt, and clay; weathered; contains fragments of red "porcellanite"	20	20
Wasatch formation:		
Sandstone, buff to gray, medium- to fine-grained, poorly cemented with limonite; contains abundant concretions of iron	30	51

Sample log of test hole 33--Continued

	Thickness (feet)	Depth (feet)
Wasatch formation--Continued		
Shale, carbonaceous, containing streaks of limonite; interbedded with thin streaks of coal	4	55
Clay, gray, silty to waxy; contains a few streaks of fine-grained gray sandstone	27	82
Coal, brittle, impure	3	85
Clay, gray, sandy (fine sand)	25	110
Sandstone, gray, fine-grained; composed of angular grains of quartz; interbedded with thin beds of clay	55	165
Coal, interbedded with carbonaceous shale and streaks of fine-grained sandstone	10	175
Siltstone, gray, containing thin streaks of coal	10	185
Sandstone, gray, very fine grained; interbedded with siltstone and clay	65	250
Clay, gray, waxy, containing mica, pyrite, and thin streaks of coal	35	285
Coal, containing thin streaks of clay	15	300
Clay, sandy (sand very fine), stratified; interbedded with streaks of coal and a few beds of gray siltstone	50	350
Siltstone, gray, soft, calcareous	5	355
Sandstone, light-gray, very fine grained, soft, calcareous, containing streaks of clay	28	383
Clay, gray, soft, waxy	7	390
Sandstone, gray, very fine grained; almost a siltstone	10	400

Sample log of test hole 34 at the SE cor. sec. 19, T. 50 N., R. 72 W.

Alluvium: Slope wash and wind-blown sand	15	15
Wasatch formation:		
Sandstone, gray to buff, fine-grained, poorly cemented, calcareous	33	48
Coal; interbedded with clay, carbonaceous shale, and thin streaks of fine-grained sandstone	7	55
Clay, gray; interbedded with thin streaks of coal, carbonaceous shale, and siltstone	25	80
Siltstone, gray; interbedded with clay and coal	20	100

Sample log of test hole 34--Continued

	Thickness (feet)	Depth (feet)
Wasatch formation--Continued		
Clay, gray, silty; interbedded with thin streaks of coal and carbonaceous shale	25	125
Coal, black, dense, brittle, containing streaks of carbonaceous shale (Felix coal)	17	142
Clay, gray and light-gray	3	145
Coal, black, hard, dense, containing clay partings (Felix coal)	8	153
Clay, gray, sandy (very fine sand); interbedded with thin streaks of coal and carbonaceous shale	12	165
Clay, gray, silty; interbedded with thin streaks of siltstone and fine-grained sandstone	58	223
Sandstone, gray, fine-grained, tightly cemented, containing occasional streaks of clay	12	235
Clay, gray, interbedded with thin streaks of siltstone and fine-grained sandstone	65	300

Sample log of test hole 36, on right-of-way of U. S. Highway 14-16, 30 feet west and 2,380 feet south of NE cor. sec. 20, T. 50 N., R. 72 W.

Alluvium: Clay, yellow, weathered	15	15
Wasatch formation:		
Sandstone, buff to gray, soft, poorly cemented; consists of angular grains of quartz; lower part contains abundant concretions of limonite and sparse streaks of coal and carbonaceous material	137	152
Coal, black, dense; interbedded with carbonaceous shale	8	160
Clay, gray, waxy, containing thin streaks of coal	5	165
Siltstone, gray, soft, poorly cemented	2	167
Coal	3	170
Sandstone, gray, very fine grained; interbedded with clay and thin streaks of coal	35	205
Siltstone, gray, soft, containing thin streaks of coal	20	225
Sandstone, gray, fine-grained	5	230
Siltstone, gray, containing streaks of clay	10	240
Sandstone, gray; interbedded with thin streaks of clay and siltstone	35	275
Clay, gray, silty	25	300
Coal, black, containing thin streaks of clay and carbonaceous shale	20	320

Sample log of test hole 38 at E. E. Littleton farm, 20 feet SE of windmill, 320 feet west and 850 feet south of the center of sec. 20, T. 50 N., R. 72 W.

	Thickness (feet)	Depth (feet)
Alluvium: Clay, sand, and fragments of red shale....	25	25
Wasatch formation:		
Clay, gray, waxy; interbedded with fine-grained sandstone....	20	45
Sandstone, buff, highly stained with limonite, loosely cemented, friable, containing a few streaks of clay and coal....	85	130
Clay, gray to light-gray, calcareous; interbedded with fine-grained sandstone....	30	160
Sandstone, gray, fine- to medium-grained, containing abundant crystals of pyrite interbedded with thin streaks of coal and clay.....	30	190
Clay, gray, calcareous; interbedded with thin streaks of fine-grained sandstone....	5	195
Sandstone, very fine grained, gray, calcareous, poorly cemented, containing a few thin streaks of clay and coal....	28	223
Clay, gray, sandy; interbedded with streaks of brown carbonaceous shale....	7	230
Shale, brown, carbonaceous, containing abundant crystals of gypsum and pyrite....	5	235

Sample log of test hole 42, 180 feet east and 1,290 feet north of SW cor. sec. 21, T. 50 N., R. 72 W.

Alluvium: Sand, silt, and clay, containing some fine gravel derived from red shale......	33	33
Wasatch formation:		
Sandstone, gray to buff, tightly to poorly cemented, calcareous; composed mainly of angular grains of quartz; contains abundant concretions of limonite throughout....	80	113

Driller's log of well 8, approximately 150 feet south and 1,950 feet west of NE cor. sec. 4, T. 49 N., R. 72 W.

Alluvium: Soil....	10	10
Wasatch formation:		
Sand, yellow....	10	20
Sand, coarse (hard water)....	10	30

Driller's log of well 8--Continued

	Thickness (feet)	Depth (feet)
Wasatch formation--Continued		
Clay and shale	100	130
Clay, blue	10	140
Sand (hard water)	25	165
Coal	5	170
Sand (hard water)	10	180
Clay	5	185
Sand (hard water)	40	225
Sandstone, hard, tight, calcareous	3	228
Sand (dry, lost water)	57	285
Clay, gray	59	344
Coal	1	345
Clay (gas, 382 feet)	40	385
Fort Union formation: Coal (Top of Roland coal; water)	2	387

Driller's log of well 17, approximately 1,370 feet south and 390 feet east of NW cor. sec. 27, T. 50 N., R. 71 W.

	Thickness (feet)	Depth (feet)
Alluvium: Sand, gray, and mud	20	20
Fort Union formation:		
Clay, blue	5	25
Sand, gray, fine (water)	15	40
Sand, gray, fine	20	60
Lime rock	5	65
Sand, gray, and lime rock	15	80
Shale and clay	55	135
Clay, bluish-gray	10	145
Shale, gray, clay, and sand	31	176
Clay, gray, containing stringers of coal	9	185
Sandstone, white	1	186
Shale, gray	9	195
Clay, bluish-gray	10	205
Clay, gray, containing shale and streaks of coal	35	240
Sand, containing gray and black pebbles (water hardness, 115 grains per gallon)	36	276
Clay, black	9	285
Clay, black, containing streaks of coal	10	295
Clay, gray, and shale	7	302
Sand, gray, and black and gray shale (water hardness 4.4 grains per gallon)	23	325
Shale and clay, black and gray	30	355
Sand, gray, containing streaks of coal	10	365
Shale and clay, bluish-gray	20	385

Driller's log of well 17--Continued

	Thickness (feet)	Depth (feet)
Fort Union formation--Continued		
Sand and shale, gray (water)	10	395
Shale, black, and gray clay	40	435
Shale, gray, clay, and streaks of coal	10	445
Shale, black, gray sand, and streaks of coal	28	473
Coal	5	478
Shale, black, sand, and streaks of coal	7	485
Shale, black	3	488
Shale, black (water)	7	495
Quicksand, gray (water)	7	502
Clay, bluish-gray	4	506
Sand, gray and white, quartz (water hardness 3.6 grains per gallon)	10	516
Shale, gray, and clay	9	525
Clay, blue, and shale	10	535
Clay, black, and coal	5	540

Driller's log of well 23, approximately 710 feet south and 190 feet west of NE cor. sec. 6, T. 50 N., R. 72 W.

	Thickness (feet)	Depth (feet)
Alluvium: Sand	18	18
Wasatch formation:		
Clay, sandy	12	30
Sand, yellow	10	40
Clay, yellow	5	45
Sand (water)	25	70
Carbonaceous material (?)	13	83
Shale, blue	47	130
Shale, dark-blue	10	140
Shale, blue, carbonaceous	23	163
Lime and sand rock	5	168
Shale, gray	16	184
Lime rock	6	190
Shale, blue	16	206
Sandstone (water)	244	450
Shale, blue	12	462
Fort Union formation:		
Coal	80	542
Clay	13	555
Sand, gray (wet gas)	5	560
Shale and carbonaceous material (some gas)	72	632
Hard rock (?)	2	634
Shale and carbonaceous material	151	785
Sand, gray (some gas and oil)	30	815

Driller's log of well 45, approximately 1,710 feet north and 1,290 feet east of the SW cor. sec. 22, T. 50 N., R. 72 W.

	Thickness (feet)	Depth (feet)
Alluvium: Sand, brown, clayey	36	36
Wasatch formation:		
Sand, yellow, clayey	22	58
Clay, black, and coal	5	63
Shale, gray	22	85
Sand, white (very little water in top of sand body but water gradually increased with depth to about 17½ gallons a minute)	122	207
Shale, brown	6	213
Shale, gray	19	232
Coal	5	237
Shale, gray (hole caving badly)	46	283
Shale, light-gray	12	295
Shale, light-gray, sandy	25	320
Fort Union formation:		
Shale, black	15	335
Coal (a little more water)	50	385
Shale, black	18	403
Shale, gray	18	421
Sand, light-gray	14	435
Sand	15	450
Shale, yellow, containing streaks of coal	10	460
Shale, gray, sandy	25	485
Coal	25	510
Shale, gray	187	697
Coal	4	701
Sand, gray (good water)	25	726
Shale, dark, containing some coal	60	786
Sand, gray (good water)	64	850
Shale	2	852

Bryan, Kirk, 1925, Report on city water supply of Gillette, Wyo. Unpublished memorandum in the files of the U. S. Geol. Survey, Washington, D. C.

Dobbin, C. E., and Barnett, V. H., 1927, The Gillette coal field, northeastern Wyoming: U. S. Geol. Survey Bull. 796-A, pt. 1, pp. 1-50, pls. 1-10.

McLaughlin, T. G., 1946, Geology and ground-water resources of parts of Lincoln, Elbert, and El Paso Counties, Colo.: Colorado Water Cons. Board, Ground-Water Ser., Bull. 1, Denver, Colo., p. 106.

Thom, W. T., Jr., 1927, The Minturn district and the northwestern part of the Gillette field: U. S. Geol. Survey Bull. 796-A, pt. 2, pp. 50-64, pls. 11-13.

U. S. Pub. Health Service, 1946, Public Health Service drinking water standards: Reprint 2697, p. 13.

Williams, C. C., 1948, Water-supply possibilities from wells at Newcastle, Wyo.: U. S. Geol. Survey mimeographed report, p. 19.