Ground-Water Resources and Geology of Niobrara County Wyoming

By HAROLD A. WHITCOMB

With a section on

CHEMICAL QUALITY OF THE GROUND WATER

By T. RAY CUMMINGS

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GROUND-WATER RESOURCES AND GEOLOGY OF NIOBRARA COUNTY, WYOMING

By Harold A. Whitcomb

ABSTRACT

Niobrara County occupies an area of about 2,600 square miles in east-central Wyoming. The region lies in the western part of the High Plains and is characterized by rolling grasslands, isolated low mountains, and local badlands. The climate is typical of the northern High Plains—a region of low precipitation, high rate of evaporation, and a wide range in temperature. The economy of Niobrara County is based principally on ranching and farming.

The rocks exposed in Niobrara County are mostly sedimentary deposits that range in age from Cambrian to Recent. Igneous and metamorphic rocks of Precambrian age crop out in the core of the Hartville uplift in the southcentral part of the county. Throughout much of the area, older rocks are overlain by deposits of Late Cretaceous and Tertiary age. Aquifers of pre-Cretaceous age generally lie too deep to be considered potential sources of ground water in the area.

The 150 to 300 feet of interbedded sandstone and shale that composes the basal unit of the Cretaceous System in Niobrara County is designated as the Inyan Kara Group in the northern part of the report area and the Cloverly Formation in the southwestern part. Although the correlation between these formations has not been established, they are believed by some authors to be lithogenetic equivalents. In this report, the Inyan Kara Group and the Cloverly Formation are considered to be a single hydrologic unit having similar water-bearing characteristics. The Inyan Kara Group and Cloverly Formation yield small quantities of water to domestic and stock wells drilled in or near areas of outcrop and moderate quantities to wells supplying the Lance Creek oil field. The water is generally under artesian pressure, and one of the Lance Creek wells flowed when completed.

The Inyan Kara Group is overlain by as much as 4,500 feet of principally shale and claystone of Cretaceous age. These deposits are not considered to be water bearing except for small quantities of water that might be obtained from the Newcastle Sandstone where it crops out on the eastern flank of the Old Woman anticline.

The Fox Hills Sandstone of Late Cretaceous age yields small quantities of water to stock and domestic wells in the northeastern part of Niobrara County. The water is under artesian pressure, and wells drilled along the western border of the outcrop might flow. The generally steep dip of the beds causes the formation to lie at progressively increasing depths west of the Fox Hills-Lance contact. The formation is about 500 feet thick in the southern part of the outcrop and apparently thins northward.

The Lance Formation of Late Cretaceous age and the Fort Union Formation of Paleocene age are the principal sources of stock and domestic water in the northwestern part of Niobrara County. In most areas, the yield to wells may be expected to increase with depth and the number of water-bearing beds penetrated. The thickness of the formations increases from a thin eroded edge along the east margins of their outcrops to an estimated combined thickness of about 4,000 feet at the county line between Niobrara and Converse Counties.

The White River Group of Oligocene age, which unconformably overlies older rocks ranging in age from Early Cretaceous to Paleocene, yields small quantities of water to stock and domestic wells in the central part of the report area. Larger quantities might be obtained from coarse channel deposits that occur at some places in the formation. The thickness of the White River Group ranges from a thin edge overlapping older rocks to about 550 feet in the eastern part of the outcrop area.

The Arikaree Formation of Miocene age is the only known source of large quantities of ground water in Niobrara County. It yields water to many stock and domestic wells, 16 irrigation wells, and the wells supplying the communities of Lusk and Manville. Most of the irrigation wells are capable of yielding as much as 500 gpm (gallons per minute) and several would probably produce 1,000 gpm with suitable pumping equipment. Even larger yields may be expected from wells penetrating greater saturated thicknesses of the aquifer. The Arikaree is thin where it wedges out against the Hartville uplift but is estimated to be 600 to 700 feet thick in the vicinity of the Nebraska State line.

The Alluvial deposits of Quaternary age in the valleys of the Cheyenne River and Lance Creek yield water to a few stock and domestic wells and to several irrigation wells. These deposits are the principal potential source of moderate to large quantities of ground water in the northern part of Niobrara County. Reported yields of irrigation wells range from 170 to 300 gpm, and wells of larger capacity probably can be developed in some areas. The thickness of the alluvium ranges from a few feet in the upper reaches of Lance Creek to a reported 100 feet near the confluence with the Cheyenne River.

Most of the water utilized in Niobrara County is obtained from drilled wells because surface-water supplies are ephemeral and unpredictable. Some water is pumped for irrigation from Lance Creek and the Cheyenne River during periods of intermittent flow, and perennial flow in the Niobrara River provides water for irrigation along the lower reaches in Niobrara County. In most areas the pumpage of ground water could be increased appreciably without noticeably affecting water levels or seriously decreasing the quantity of water in storage.

Recharge to the ground-water reservoir is principally from precipitation, which averages about 15 inches per year in Niobrara County. Recharge to the Arikaree Formation has been estimated to be only about 0.33 inch per year; probably, a somewhat smaller amount reaches the ground-water reservoir in the finer grained rocks underlying most of the northern part of the county.

Ground-water discharge in Niobrara County is principally by underflow through the aquifers. Smaller quantities are discharged by springs and seeps, evapotranspiration, and discharge from wells. Approximately 5 to 8 million gallons of water per day moves as underflow through the Arikaree Formation eastward across the Nebraska State line. Appreciably larger quantities of ground water probably move westward through the Fox Hills Sandstone and the Lance and Fort Union Formations into the Powder River Basin. A study of the use of ground water by cottonwood trees along Lance Creek indicates that at least 4 million gallons of ground water is withdrawn daily from alluvial deposits.

Water derived from the White River Group and from the Arikaree Formation in Niobrara County has the best quality for general use. Although water from both formations has certain undesirable characteristics for some uses, a well drilled into one or the other would probably provide water of better quality than can be obtained from the other geologic sources in the area. Because of the diversity of dissolved constituents, which cause water from some of the wells to be objectionable, the development of water from either formation for uses requiring a specific quality should be preceded by a chemical analysis.

The Inyan Kara Group is capable of yielding water of fair to good quality at certain locations from relatively shallow depths, although the quantities obtainable may not be large.

Water from the Pierre Shale, Fox Hills Sandstone, Lance Formation, Fort Union Formation, and the alluvium seems suitable for stock supplies but may or may not be suitable for irrigation use, depending upon location. In general, for domestic use these supplies should be considered acceptable only if no other supplies are available.

INTRODUCTION

LOCATION AND EXTENT OF AREA

Niobrara County occupies an area of about 2,600 square miles in east-central Wyoming (fig. 1). Its outline is a rectangle measuring about 62 miles in a northerly direction and about 42 miles in an easterly direction. The county includes 60 complete townships and parts of 26 others, lying approximately between lat 42°37′ and 43°30′ N. between long 104°03′ and 104°53′ W.

PURPOSE AND SCOPE OF INVESTIGATION

The investigation of the ground-water resources of Niobrara County is part of the program of ground-water studies being made in Wyoming by the U.S. Geological Survey in cooperation with the Wyoming State Engineer. The study was made under the supervision of H. M. Babcock and E. D. Gordon, successive district supervisors in charge of ground-water investigations in Wyoming. The quality-of-water study was made under the general supervision of T. F. Hanly, district engineer of the Quality of Water Branch for Wyoming. The quantitative analysis of water-bearing materials were made under the supervision of A. I. Johnson, chief of the Hydrologic Laboratory of the Geological Survey at Denver, Colo.

At the request of the Wyoming State Engineer, the investigation of the ground-water resources of Niobrara County was started in the summer of 1957 as a cooperative study of the availability of ground water for irrigation along the valley of the Niobrara River in the southeastern part of the county. The study was later expanded to include the entire county. The purpose of this investigation was to evaluate the ground-water resources of the area to determine the possibilities of developing new or additional supplies of ground water in areas where present supplies are unsuitable or inadequate. The work included a study of the character, thickness, and extent of the principal water-bearing formations and the occurrence, movement, quantity, and quality of the ground water contained in them.

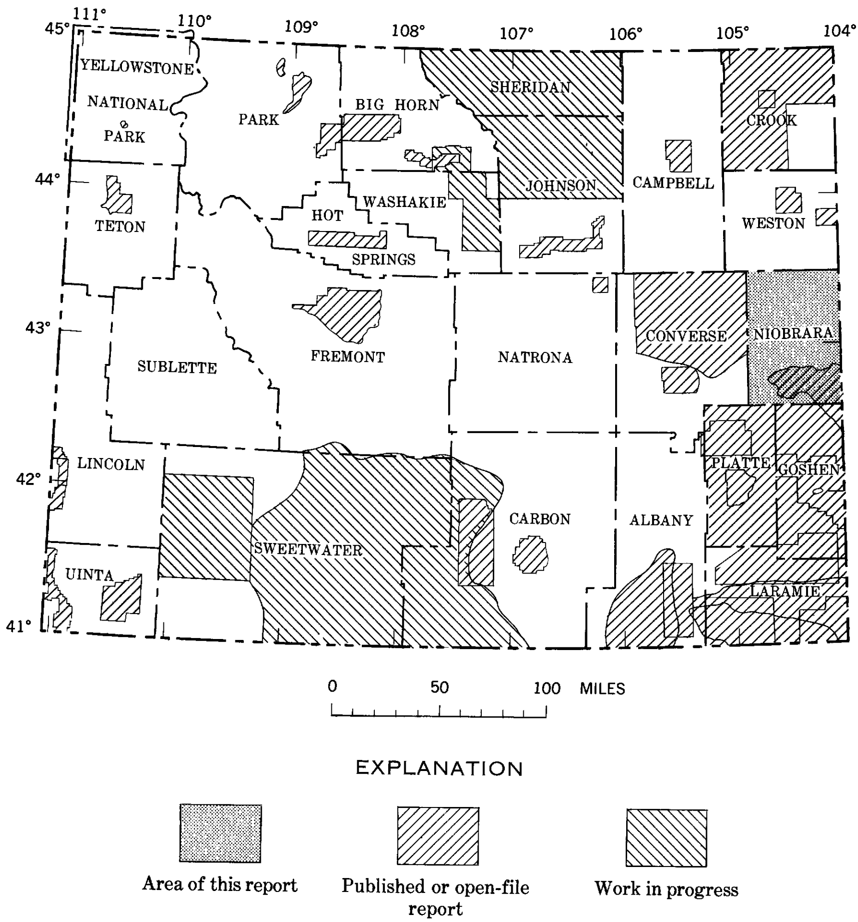

Figure 1.—Area described in this report and other areas for which ground-water reports have been released or where work is in progress.

PREVIOUS INVESTIGATIONS

Several geologic investigations of areas including parts of Niobrara County have been made in the past, and the results of these studies have been published by the U.S. Geological Survey or by State agencies. One of the earliest of these reports was by Hancock (1920), who described the geology in the vicinity of the Lance Creek oil and gas field. Dobbin and Reeside (1929) described the contact between the Fox Hills Sandstone and Lance Formation in outcrops exposed in northern Niobrara County. A study of the Permian and Pennsylvanian strata of the Hartville Hills by Condra and Reed (1935) of the Nebraska Geological Survey included that part of the Hartville uplift lying in southwestern Niobrara County. In 1940, the Nebraska Geological Survey published a correlation of the stratigraphy of the Laramie Range, Hartville uplift, Black Hills, and western Nebraska (Condra and others, 1940).

Two Oil and Gas Investigations Maps covering parts of southwestern Niobrara County were published by the U.S. Geological Survey in 1949. Preliminary Map 92 (Love and others, 1949) shows and describes the geology and structure of the Glendo area of Platte County, and Preliminary Map 102 (Denson and Botinelly, 1949) provides similar information for the Hartville uplift. A report on the geology and ground-water resources of the Upper Niobrara River basin (Bradley, 1956) includes a small part of southeastern Niobrara County. Babcock and Keech (1957) estimated the underflow in the Niobrara River basin across the Wyoming-Nebraska State line. Dobbin, Kramer, and Horn (1957) mapped the geology and structure of the southeastern part of the Powder River Basin of Wyoming, which includes approximately the northern two-thirds of Niobrara County. This map and the geologic maps of the Hartville uplift and the Glendo area have been adapted for use in this report.

METHODS OF INVESTIGATION

The geologic study of the pre-Tertiary formations of Niobrara County consisted of a brief examination of rock outcrops and a study of drillers' records and logs of rocks in the subsurface. These formations have been mapped and described by earlier workers, and much of the published data has been utilized in the preparation of this report. A more intensive study was made of the Tertiary rocks to establish and map the contact between the White River Group of Oligocene age and the Arikaree Formation of Miocene age. No attempt was made to subdivide the Arikaree into the various lithologic units recognized in Nebraska because of the negligible value of such a detailed study to this report.

Water level data were collected for representative wells throughout the county. Most of the wells, however, are south of T. 34 N. where the data were used to sketch contours on the water table in the Arikaree Formation and thus determine the direction and rate of ground water movement in that area. Records of water wells and oil-test holes are given in table 9. The depth of the well and the depth to water were measured by the author when possible; otherwise, the data were obtained from the well owner or driller. Information regarding the construction of the well, its discharge, and the character and thickness of the water-bearing material was obtained from drillers' records, when available, or from the well owners. Drillers' logs of water wells and oil-test holes are given in table 10.

Pumping tests were made at six irrigation wells to determine the pumping capacity of the wells and, when possible, the hydrologic properties of the water-bearing materials. The physical and hydrologic properties of 29 samples of the Arikaree Formation and the White River Group were determined in the Hydrologic Laboratory of the U.S. Geological Survey at Denver, Colo. Chemical analyses were made of 34 water samples collected from wells in the area.

The geologic and hydrologic field data were recorded directly on a base map adapted from the Wyoming State Highway planning map for Niobrara County and are incorporated in the geologic map included in this report (pl. 1). Aerial photographs were used in the field to insure maximum accuracy of location of all data in areas where map detail was lacking. Topographic maps of Niobrara County were not available; therefore, altitudes of the water table (pl. 1) were determined with a surveying aneroid barometer, using points of known altitude obtained from established bench marks and from records of the Wyoming State Highway Department.

WELL-NUMBERING SYSTEM

Water wells and oil-test holes shown on the accompanying map (pl. 1) are numbered according to the Federal system of land subdivision. The number shows the location of the well or test hole by township, range, section, and position within the section, as illustrated in figure 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. The lowercase letters following the section number indicate the position of the well within the section. The first letter denotes the quarter section and the second letter the quarter-quarter section (40-acre tract). The subdivision of the sections and quartersections are lettered a, b, c, and d in a counter clockwise direction beginning in the northeast quarter. Where more than one well is in a 40-acre tract, consecutive numbers beginning with 1 are added to the well number.

ACKNOWLEDGMENTS

The writer is indebted to the several well drillers operating in Niobrara County who, from their records and memories, furnished much well data that could not have been otherwise obtained. Ranch owners or tenants permitted and often assisted the writer in collecting hydrologic data and water samples. The Niobrara County Agricultural Stabilization and Conservation Office at Lusk, Wyo., provided records of water wells drilled under the conservation program.

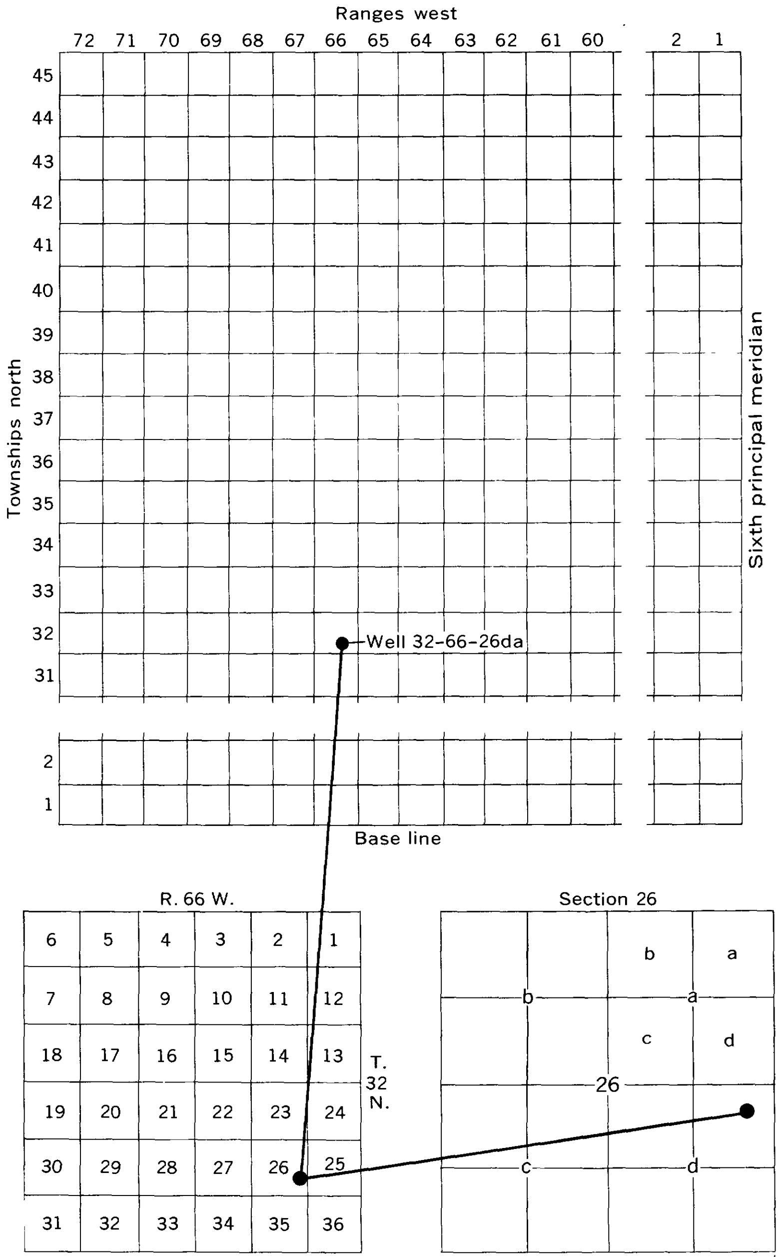

FIGURE 2.—Well-numbering system.

Information regarding public-supply wells was obtained from the water superintendents of Lusk, Manville, and Lance Creek, and from records of the Continental Oil Co. at Lance Creek oil field. The Planning Division of the Wyoming Highway Department provided a reproducible print of the map of Niobrara County, which was used as a base for the geologic map and the depth-to-water map included in this report.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

The surface features of Niobrara County may be separated into three main physiographic units (pls. 1 and 2): (1) the upland area, which includes approximately the southern one-third of the county, (2) the lowland area, which occupies most of the remaining two-thirds of the county, and (3) that part of the Hartville Hills, known locally as Rawhide Butte, which projects into the southwestern part of the county.

THE UPLAND AREA

The surface of the upland area is for the most part a rolling tableland of only moderate relief. The area is terminated abruptly along its north margin by an irregular but persistent escarpment 300 to 500 feet high that extends from the east to the west border of the county. From a high, rather deeply dissected area north of Lusk and Manville the terrain slopes away to the east, south, and west to coalesce with the surface of the High Plains of eastern Wyoming and western Nebraska. Altitudes range from about 4,700 feet at the State line to 5,500 feet northwest of Lusk. Consequently, the maximum relief on the upland surface is only about 800 feet, and the average relief is considerably less.

The Niobrara River system drains the southeastern part of Niobrara County and flows eastward to join the Missouri River in northeastern Nebraska. Throughout most of its reach in Wyoming, the Niobrara River meanders over the floor of a broad shallow valley that in places is poorly defined. West of Lusk, however, where the river has cut into the less permeable and more resistant rocks of the Hartville uplift, the stream valley deepens and narrows abruptly.

The gradient of the stream channel between Lusk and the Wyoming-Nebraska State line is only about 10 feet per mile. Between Lusk and Manville the gradient steepens to nearly 25 feet per mile. Upstream from Lusk, flow in the Niobrara River is intermittent; however, some stretches contain water throughout the year. East of Lusk, the stream channel is mainly dry or marshy for a distance of about 10 miles; east of this area, the flow in the Niobrara River is perennial. The discharge of Niobrara River, measured at the Wyoming-Nebraska State line from October 1955 to September 1959, ranged from an average of 1.85 cfs (cubic feet per second) during September 1959 to an average of 10.2 cfs during May 1957. The mean discharge for this period, however, is 4.46 cfs. The monthly discharges of Niobrara

River at the Wyoming-Nebraska State line and monthly precipitation at Lusk are shown in figure 3.

Muddy Creek drains the southwest corner of Niobrara County. The stream has cut a deep narrow valley along the northwestern flank of the Hartville Hills, and its tributaries have dissected the adjacent plains surface into numerous radiating valleys separated by steep-flanked ridges. Streamflow in the Muddy Creek drainage system moves southwestward and joins the North Platte River. The flow in the stream is intermittent throughout most of its course in Niobrara County, with perennial flow in some reaches of the channel.

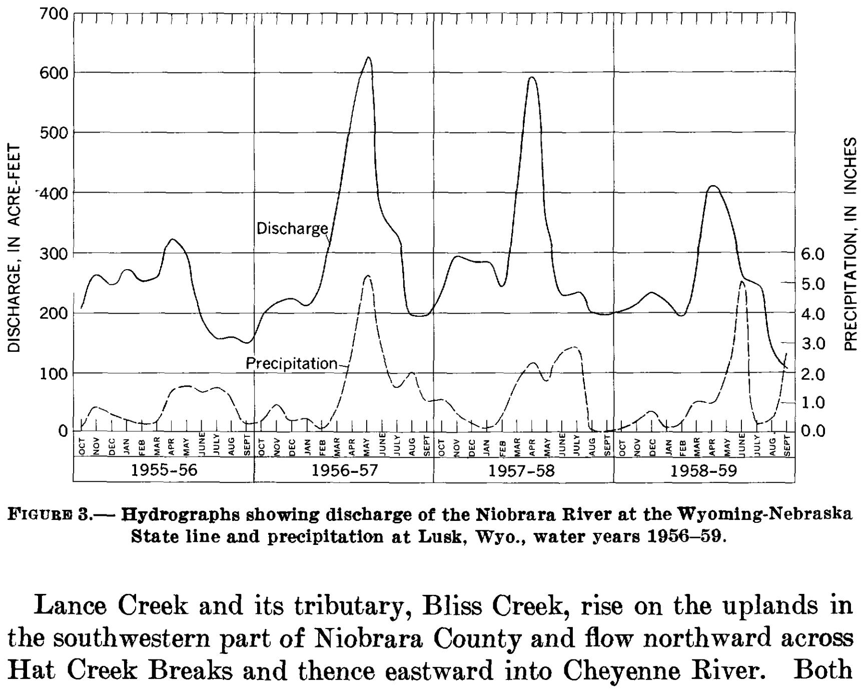

FIGURE 3.— Hydrographs showing discharge of the Niobrara River at the Wyoming-Nebraska State line and precipitation at Lusk, Wyo., water years 1956–59.

Lance Creek and its tributary, Bliss Creek, rise on the uplands in the southwestern part of Niobrara County and flow northward across Hat Creek Breaks and thence eastward into Cheyenne River. Both Lance Creek and Bliss Creek have perennial flow in their upper reaches, and the flow in Lance Creek persists for an appreciable distance north of the Breaks before it subsides into the streambed or disappears by evaporation.

THE LOWLAND AREA

The lowlands lying north of Hat Creek Breaks consist of a plains surface that has been rather deeply and irregularly eroded by widespread stream action. Sandstone-capped ridges, mesas, and buttes, separated by narrow steep-sided valleys, are typical of much of the area The monotonous terrain is broken in some areas by colorful local badlands carved in the variegated shale of the White River

Group. Only the broad valleys of Lance Creek and the Cheyenne River and their major tributaries provide a favorable environment for agricultural development.

Surface runoff on the lowlands moves northward via Lance Creek and its major tributaries, Lightning Creek and Old Woman Creek, and empties into the east-flowing Cheyenne River in the northeastern part of Niobrara County. The Cheyenne joins the Missouri River in north-central South Dakota. Stream gradients are low, and stream patterns are characteristically meandering.

Surface runoff in Lance Creek and the Cheyenne River is extremely erratic, ranging from no flow for many days throughout the year, chiefly during the winter months, to discharges of several thousand cubic feet per second after heavy or prolonged rains. Several thousand acre-feet of water is withheld from Lance Creek and the Cheyenne River by about 2,000 small reservoirs used for storage of stock and irrigation water. Additional water is pumped directly from the river for irrigation. Because of the diversion of surface runoff, no attempt was made to correlate the flows of Lance Creek and the Cheyenne River with precipitation on the drainage areas.

RAWHIDE BUTTE

Rawhide Butte, the northern extension of the Hartville Hills lying in southwestern Niobrara County, rises abruptly more than 1,000 feet above the surrounding plains to a maximum altitude of about 6,100 feet.

The rocks of Precambrian and early Paleozoic age, which were uplifted to form the Hartville Hills, have been deeply dissected by recurrent erosion. The floors of the deeper valleys and canyons are carpeted with deposits of late Tertiary age, which are intra-mountain extensions of the upland surface. The crest of Rawhide Butte is craggy, and the flanks are scarred by deep narrow ravines. The upturned edges of sedimentary strata surrounding the Hartville Hills form asymmetrical foot-hill ridges with steep inward-facing slopes. North of Rawhide Butte, rocks of the Hartville Hills extend as a low but well-defined ridge as far as the Niobrara River. North of the river, a few isolated outcrops of similar strata indicate that the hills once had a greater northward extension.

Surface runoff from precipitation on the relatively impermeable rocks of Rawhide Butte is predominantly westward into Muddy Creek. Runoff moving down the eastern slopes of the mountain apparently is rapidly absorbed into the more permeable sandstone underlying the plains, because well developed drainage patterns adjacent to the mountain quickly lose their identity, and surface flows rarely reach the Niobrara River.

CLIMATE

The climate of Niobrara County is typical of the northern High Plains—a region of low precipitation, high rate of evaporation, and wide ranges in temperature. The normal annual precipitation at Lusk for the period 1931–59 was 15.25 inches, of which about 50 percent occurred during April, May, and June. Snowfall during the winter months is generally light and is only about 10 percent of the annual precipitation. The annual and average monthly precipitation at Lusk is shown in Table 1. Summer rains are generally brief but heavy and often are accompanied by thunder and lightning and occasionally by strong winds and hail. Winter storms are frequently driven by strong winds, and in the past blizzards have caused widespread loss of livestock. Average monthly temperatures for the period 1931–59 at Lusk and Redbird, Wyo., are given in table 2. Minimum and maximum temperatures during this period were −35°F and 105°F. The growing season is relatively short, averaging about 115 days between late May and the middle of September.

TABLE 1.—*Precipitation, in inches, at Lusk, Wyo., 1931–59*

[From the records of the U.S. Weather Bur.]

Annual precipitation

1931	9. 39	1942	23. 87	1953	12. 82
1932	16. 11	1943	13. 34	1954	10. 29
1933	15. 01	1944	15. 51	1955	16. 55
1934	12. 83	1945	15. 61	1956	9. 77
1935	18. 38	1946	18. 68	1957	18. 70
1936	12. 40	1947	18. 09	1958	13. 25
1937	13. 48	1948	14. 74	1959	13. 98
1938	17. 02	1949	19. 32		
1939	14. 19	1950	14. 16	Average	15. 25
1940	13	1951	14. 68		
1941	23. 57	1952	13. 56		

Average monthly precipitation

January	0. 50	May	2. 57	September	1. 16
February	. 49	June	2. 87	October	. 90
March	. 83	July	1. 61	November	. 62
April	1. 94	August	1. 15	December	. 47

TABLE 2.—*Average monthly temperatures, in degrees Fahrenheit, for the period 1931–59 at Lusk and Redbird, Wyo.*

[Length of record at Lusk, 29 yr; at Redbird, 13 yr. From the records of the U.S. Weather Bur.]

	Lusk	Redbird
January	24. 2	20. 8
February	27	26. 6
March	32. 6	31. 9
April	43. 2	44. 7
May	53. 1	55. 7
June	62. 6	65. 2
July	70. 6	72. 6
August	68. 9	71. 7
September	59	61. 3
October	48. 1	48. 9
November	34	32. 8
December	27. 6	25. 9
Average	45. 9	46. 5

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AGRICULTURE AND INDUSTRY

The economy of Niobrara County is based primarily on the raising of livestock and the cultivation of crops to support the livestock industry. The Wyoming Department of Agriculture (1955–56) reported that the number of cattle and sheep was nearly equal on Niobrara County farms and ranches in 1956. Most of the cattle are raised for beef; less than 2 percent are dairy cows. Sheep are raised for both wool and mutton. Hay is the largest farm crop raised in the county and utilizes about 75 percent of the total acreage devoted to crops. Corn, oats, and barley also are raised for livestock consumption. Wheat is the only crop cultivated on a large scale that is not used principally for stock feed. Irrigation in the county has been on a relatively small scale, and most crops are raised by dryfarming methods.

Niobrara County produces an appreciable part of Wyoming's oil and gas. Lance Creek produced nearly 20 million barrels of oil per year in the peak production years 1940 and 1941. The annual production in 1954 had decreased to a little more than 1 million barrels. Smaller quantities of oil have been pumped from the Lance Creek East and Mule Creek fields.

TRANSPORTATION

Niobrara County is served by the Chicago and North Western Railway, which crosses the southern part of the area. The only east-west highway, U.S. 20, parallels the tracks of the Chicago and North Western Railway. It is intersected at Lusk by U.S. 85, which traverses the county northeastward. Most of the remaining roads in the county are either gravel topped or have a natural surface.

SUMMARY OF STRATIGRAPHY

Niobrara County is underlain by a thick sequence of sedimentary rocks of Cambrian to Tertiary age that lie on crystalline rocks of Precambrian age (See fig. 4.) Only rocks of Cretaceous age and younger are significant to the study of ground-water conditions in the report area. The age, thickness, physical character, and water-bearing properties of these formations are summarized in table 3. A more detailed discussion is devoted to those formations that are presently yielding water to wells in Niobrara County or that may be potential sources of ground water in the future. For more complete descriptions of the geologic formations not discussed in this report, the reader is referred to the bibliography of this report.

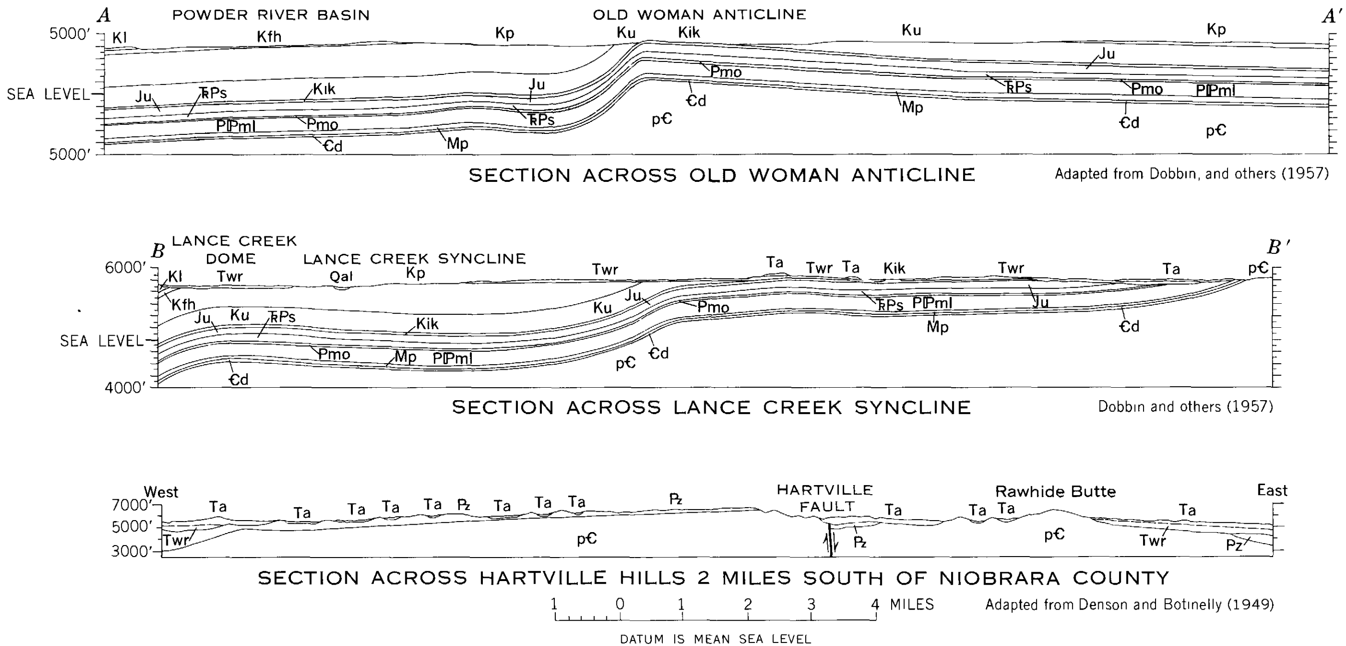

Figure 4.—Geologic sections across Old Woman anticline, Lance Creek syncline, and the Hartville Hills, Niobrara and Goshen Counties, Wyo. (Lines *A–A′* and *B–B′* shown in pl. 1.)

TABLE 3.—*Generalized section of the geologic formations in Niobrara County, Wyo.*

System	Series	Subdivision	Thickness (feet)	Physical characteristics	Water supply
Quaternary	Recent and Pleistocene	Alluvium Flood-plain and terrace deposits	0–100	Fine sand, silt, and clay containing lenses of poorly sorted coarse sand and gravel of variable thickness and extent.	Yields water to a few stock and domestic wells and six irrigation wells on Lance Creek and Cheyenne River. Supplies water to village of Lance Creek.
Tertiary	Miocene	Arikaree Formation	0–600±	Light- to brownish-gray sandstone that is very fine to fine grained, loosely to moderately cemented; contains silty zones, coarse sand lenses, and many concretionary layers and nodules. Coarse conglomerate at base in many areas.	Yields water to many stock and domestic wells, and 16 irrigation wells. Source of water for the communities of Lusk and Manville.
	Oligocene	White River Group	500±	Pinkish-gray siltstone in upper part and variegated gray, red, and green claystone in lower part; locally, units contain channel deposits of fine- to coarse-grained loosely cemented sandstone and conglomerate.	Yields small quantities of water to many stock and domestic wells. Channel deposits and fractured zones may yield moderate to large supplies of water where saturated, extensive, and subject to recharge.
	Paleocene	Fort Union Formation	2,000±	Sandstone interbedded with gray shale containing thin beds of coal. Sandstone beds are light to yellowish gray, fine to medium grained, friable, thin to thick bedded, crossbedded, and lenticular.	Sandstones yield small quantities of water to many stock and domestic wells in northwestern Niobrara County; the quantity obtained is dependent upon number of water-bearing beds penetrated. Deep wells may yield moderate supplies of water sufficient for limited irrigation or small industrial use. Water generally under some artesian pressure.
		Lance Formation	1,600–2,500	Sandstone interbedded with gray and black claystone containing a few thin beds of carbonaceous shale; some coal near base. Sandstone is white to yellowish gray and brown, fine to medium grained, well sorted, friable, thin bedded to massive, crossbedded, and lenticular.	
		Fox Hills Sandstone	350–550	Predominantly sandstone containing thin beds of dark sandy shale. Sandstone is light gray, yellow, and brown, fine to medium grained, poorly cemented, and argillaceous.	Yields small quantities of water to stock and domestic wells in outcrop area. Generally is deeply buried west of Fox Hills-Lance contact. Water under artesian pressure.
		Pierre Shale	2,500–3,100	Dark-gray shale containing lenticular masses and beds of calcareous rock and a few moderately thick sandstone beds.	

Cretaceous	Upper Cretaceous	Niobrara Formation	100–250	Gray to black shale containing some shaly limestone and chalk beds; contains thin bentonite beds in some areas.	
		Carlile Shale	460–540	Dark-gray to black shale, locally sandy; contains beds of limestone concretions in some areas.	Not considered aquifers in Niobrara County; water generally is highly mineralized. Pierre Shale yields small quantities of water to a few stock and domestic wells in areas where other aquifers are not economically accessible.
		Greenhorn Formation	30–70	Gray shale containing some light-gray thin-bedded limestone and layers of limestone concretions.	
		Belle Fourche Shale	400–850	Dark-gray to black shale, locally sandy; contains bentonite layers and beds of concretionary limestone and iron.	
	Lower Cretaceous	Mowry Shale	220±	Dark-gray to black siliceous shale that contains many thin bentonite beds; forms silvery-gray shale-covered slopes.	
		Newcastle Sandstone	0–100	Sandstone containing dark-gray siltstone and claystone interbeds. The sandstone is light gray, fine to medium grained, in places conglomeratic, thin bedded to massive, and lenticular.	Probably will yield small quantities of water to wells but generally is deeply buried in area.
		Skull Creek Shale	160–200	Black shale containing some ferruginous sandstone and iron concretions.	Not considered an aquifer in Niobrara County.
		Inyan Kara Group (Cloverly Formation in southwestern part of area)	150–300	Predominantly sandstone containing interbedded gray to black shaly siltstone and claystone. Variegated shales may occur near the middle in some areas. The sandstone is light to yellowish gray, fine to medium grained, firmly cemented to quartzitic, slabby to thick bedded, and crossbedded.	Sandstones yield small quantities of water locally to a few stock and domestic wells and relatively large quantities to wells supplying Lance Creek oil field. Water is generally under artesian pressure, and wells in topographically low areas may flow. Deeply buried throughout most of county.
Pre-Cretaceous rocks			2, 500±	A thick series of preponderantly marine deposits comprising sandstones, siltstones, claystones, limestones, dolomites, and anhydrites overlying igneous and metamorphic rocks of Precambrian age.	Ground-water possibilities not known; generally too deeply buried to be developed.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING CHARACTERISTICS

ROCKS OF PRE-CRETACEOUS AGE

Rocks of pre-Cretaceous age in the report area are not considered to be potential sources of ground water as they are within a practicable drilling depth in only a few small areas where local structural features have uplifted older rock and where subsequent erosion has removed much of the overlying sediments. Also, the uppermost 1,200 to 1,300 feet of pre-Cretaceous strata principally consists of fine-grained clastic material that normally transmits water very slowly.

CRETACEOUS SYSTEM

INYAN KARA GROUP AND CLOVERLY FORMATION

Inyan Kara Group is the name applied by Rubey (1930, p. 5) to the Lakota Sandstone, Fuson Formation, and Fall River Sandstone in the northern part of the Black Hills, because of the difficulty of differentiating between these formations in some parts of the area. Recent changes in Black Hills terminology reduce the Fuson Shale from formational rank as recognized by Darton (1909, p. 45–48) to a member of the Lakota Formation (Waagé, 1959, p. 32–33). Rocks of Inyan Kara lithology have been traced southward from the Black Hills to the vicinity of Manville in southern Niobrara County (Dobbin and others, 1957), and although the name Inyan Kara Group was applied to these strata, the Fuson Shale was retained as a formation. In keeping with revised Inyan Kara terminology, the Fuson is now considered a member of the Lakota Formation of the Inyan Kara Group in this area.

In southwestern Niobrara County, the interbedded sandstone and shale that compose the basal unit of the Cretaceous System and that occupy a stratigraphic position similar to that of the Inyan Kara Group elsewhere in the county are assigned to the Cloverly Formation of Early Cretaceous age. These rocks have not been correlated with the Inyan Kara of the Black Hills, but Waagé (1959, p. 15) postulated that the Cloverly Formation of the Bighorn Basin is probably the lithogenetic equivalent of the Inyan Kara Group of the eastern Powder River Basin. For the purpose of this report, the Cloverly Formation is considered to be continuous with the Inyan Kara as a hydrologic unit and to have similar water-bearing characteristics. In the area of this report, both the Cloverly Formation and the Inyan Kara Group are underlain by the Morrison Formation of Late Jurassic age. South of this area the Cloverly Formation is overlain by the Thermopolis Shale. In the northern part of the area the Inyan Kara Group is overlain by the Skull Creek Shale.

DISTRIBUTION

Strata of the Inyan Kara Group and Cloverly Formation underlie most of Niobrara County, generally at great depths. They crop out in the central part of the map area in the crest of a few widely dispersed minor domes and folds, and in the southwest corner of the county, where older rocks are exposed in the Hartville uplift.

LITHOLOGY AND THICKNESS

Exposures of the full thickness of the Inyan Kara Group and Cloverly Formation are rare in Niobrara County. Generally, where the base is exposed, upper beds have been removed by erosion. The following lithologic description of the Cloverly Formation was extracted from geologic studies made in adjacent Platte County (Denson and Botinelly, 1949); it probably also applies reasonably well to the Inyan Kara Group of Niobrara County.

The Cloverly Formation is composed principally of thin- to thick-bedded sandstone, locally altered to quartzite, containing thin beds of gray to black shaly siltstone and claystone. Lenticular beds of conglomerate are common in places near the base. The sandstones are generally light to yellowish gray, brown weathering, and fine to medium grained; they are commonly described as "clean" and "sparkly." In some areas, variegated gray to black and pink shale separates the lower and upper sandy units. The thickness of the Cloverly Formation or the Inyan Kara Group ranges from about 150 to 300 feet throughout most of Niobrara County, but the thickness, as well as the physical character of the formation, probably differs somewhat from place to place.

WATER-BEARING CHARACTER

The sandstones of the Inyan Kara Group yield water for domestic and industrial use to three wells supplying oil-field camps maintained by the Continental Oil Co. and Ohio Oil Co. in the Lance Creek oil field and to a few stock and domestic wells drilled in outcrops of the Inyan Kara Group. Throughout most of the area the sandstones are too deep to be an economical source of ground water.

The wells of the Continental Oil Co., and Ohio Oil Co., are 265 to 498 feet deep and penetrate the Inyan Kara Group at depths ranging from about 130 to 220 feet. (See logs of wells 34–65–1bc and 35–65–35ab, table 10.) The water is under artesian pressure, and well 35–65–35ab flowed when completed in 1941. Additional data on these wells are given in table 9. At the time of the investgiation, the average pumpage from the three wells was about 120 gpm (gallons per minute). Records of monthly measurements of the water level made between October 25, 1958, and September 25, 1959, in an observation well about 1,300 feet from well 35–65–35ab indicate that the artesian head in this part of the well field has declined an average of about 87 feet since the wells were drilled.

In areas where drilling of the sandstones of the Inyan Kara Group or Cloverly Formation is economically feasible, these rocks are potential sources of small to moderate supplies of water. The water is generally under artesian conditions, but artesian pressures will be generally low in the outcrop areas, and the upper sandstones in the formations may be completely dry.

To obtain the maximum amount of water from the Inyan Kara Group or Cloverly Formation, wells should be drilled as far from the outcrop areas as economically feasible and should penetrate the entire thickness of the formation. Drilling should be terminated when the variegated claystone of the Morrison Formation is reached because quantities of water sufficient for most purposes probably cannot be obtained from rocks of pre-Cretaceous age.

Outcrops of the Cloverly Formation or Inyan Kara Group lying north and northwest of Manville may be completely dry because their altitudes are about 500 and 700 feet, respectively, above outcrops of the Inyan Kara Group yielding water to wells in the lowlands north of Hat Creek Breaks. The artesian pressure in the aquifer is probably insufficient to raise water to this height.

Chemical analyses of water samples obtained from two relatively shallow wells drilled in the Inyan Kara Group (table 8) indicate that the water is of good quality for domestic use. Samples of water obtained from deep oil-test holes in the Inyan Kara Group are reportedly much more highly mineralized and, in some localities, unsuitable for most domestic uses but may be used for stock consumption.

UNDIFFERENTIATED ROCKS OF CRETACEOUS AGE

Overlying the Inyan Kara Group and the Cloverly Formation is 3,000 to 5,000 feet of predominantly dark-gray and black shale containing minor amounts of interbedded shaly sandstone and limestone. These marine deposits comprise, in ascending order, the Skull Creek Shale, Newcastle Sandstone, Mowry Shale, Belle Fourche Shale, Greenhorn Formation, Carlile Shale, Niobrara Formation, and Pierre Shale. None of these formations are considered to be potential sources of ground water in Niobrara County, although small yields may be expected from sufficiently deep wells. One sample of water obtained from the Pierre Shale is of moderate mineralization but very hard. (See table 8.) This sample is not representative of water in the formation because in some areas the Pierre yields water that is reportedly unfit for livestock. Water contained in the other formations probably has a similar wide range in chemical quality.

FOX HILLS SANDSTONE

The Fox Hills Sandstone was deposited, near the end of the Cretaceous Period, in the shallow marginal waters of the Cretaceous sea as the sea retreated to the southeast. At its base, the Fox Hills Sandstone grades into the black marine clays of the Pierre Shale, and its upper limit is considered to be at the horizon above which sediments are composed principally of fresh- and brackish-water deposits containing remains of fresh-water invertebrates and reptilian land animals. The contact with the overlying Lance Formation is conformable and is marked in some areas by an abrupt transition from massive marine sandstones below to sandy carbonaceous shales and thin coal beds above. In other outcrops, the Fox Hills-Lance contact is gradational and difficult to establish.

DISTRIBUTION

The Fox Hills Sandstone is exposed in the northeastern part of Niobrara County in an irregular but generally broad outcrop that, for the most part, lies just west of and parallel to U.S. 85. The outcrop is deflected sharply westward and narrows abruptly as the dip of the beds steepens in T. 37 N., R. 63 W., in the vicinity of the Old Woman anticline and Lance Creek dome. The upwarped sandstone forms a prominent hogback that outlines the northern border of the Lance Creek dome. West of the village of Lance Creek the Fox Hills Sandstone disappears beneath overlapping Tertiary deposits.

Because the Fox Hills Sandstone is generally soft, outcrops of the formation form gentle slopes and rounded ridges that are concealed beneath a grass cover at many places. Exposures are rare except along the truncated edges of the upturned strata or where stream valleys have cut deeply into the sandstone.

LITHOLOGY AND THICKNESS

The Fox Hills is predominantly a marine sandstone locally containing some shale and siltstone. The sandstone beds are light gray to yellow and brown, generally fine to medium grained, weakly cemented, and thin bedded to massive. In many outcrops, limonitic sandstone concretions occur throughout the formation. The interbedded shale and siltstone are generally dark gray, sandy, and lenticular and range from a few inches to several feet in thickness. In Niobrara County, the shaly facies normally composes a relatively small part of the formation; however, farther north the shales become more abundant and locally may make up a large part of the Fox Hills section.

Measured thicknesses of the Fox Hills Sandstone in Niobrara County range from about 400 to 500 feet; however, these sections may not represent either the maximum or minimum thickness in the report area. The formation persists in the subsurface for some distance west of the area of outcrop, but the regional dip causes it to lie at an increasingly greater depth toward the center of the Powder River Basin (fig. 4). Logs of deep oil-test holes indicate that the Fox Hills cannot be distinguished from strata of the overlying Lance Formation in the deep part of the basin. A section measured east of the village of Lance Creek, where a small tributary of Crazy Woman Creek cuts through the hogback formed by the Fox Hills Sandstone, and a section measured near the Niobrara-Weston County line illustrate the lithologic character of the formation in the outcrop area.

Section of the Fox Hills Sandstone east of Lance Creek in SW¼ sec. 14 T. 36 N., R. 64 W.

[Adapted from Dobbin and Reeside (1929, p. 20)]

	Thickness (feet)
Lance Formation:	
Sandy shale; contains thin beds of coal	25
Fox Hills Sandstone:	
Sandstone, white, massive	60
Sandstone, yellowish, massive; contains brown concretions	20
Sandstone, brown thin-bedded	25
Sandstone, white, massive	75
Shale, soft, sandy; contains thin sandstone beds in which are marine fossils of Fox Hills age	30
Sandstone, brown, shaly	5
Sandstone, white, massive	60
Sandstone, brown and gray, thin-bedded	130
Sandstone, yellowish, massive; contains concretions in which are Fox Hills fauna	100
Measured thickness of Fox Hills Sandstone	505
Pierre Shale:	
Black shale	

Section of the Fox Hills Sandstone near the Niobrara-Weston County line in sec. 18, T. 40 N., R. 61 W. and secs. 11 and 13, T. 40 N., R. 62 W.

[Adapted from Dobbin and Reeside (1929, p. 19–20)]

	Thickness (feet)
Lance Formation (part):	
Shale, somber-colored; contains abundant remains of turtles and dinosaurs	50
Shale, carbonaceous, and coal	3
Fox Hills Sandstone:	
Sandstone, brown, concretionary	50
Sandstone, gray	23
Sandstone, gray, and soft sandy shale	74
Sandstone, yellowish, hard; capped by ripple-marked fossil concretions	4
Shale, dark gray, and light-gray soft sandstone; contains concretions of brown platy sandstone	70

Section of the Fox Hills Sandstone near Niobrara-Weston County—Continued

	Thickness (feet)
Fox Hills Sandstone—Continued	
Sandstone, brown, hard, platy	1
Claystone, somber-colored	10
Concealed; probably interbedded sandy shale and sandstone	80
Sandstone, gray, platy	10
Sandstone, brown, limonitic, hard, and platy	12
Sandstone, yellow, soft, massive; contains large hard brown calcareous concretions	40
Sandstone, gray, shaly	23
Measured thickness of Fox Hills Sandstone	397
Pierre Shale:	
Black shale	

WATER-BEARING CHARACTER

Many stock wells and a few domestic wells obtain water from the Fox Hills Sandstone. Most of the wells are in the outcrop area because the depth to the formation a short distance west of the Fox Hills-Lance contact is too great for the economical development of ground water.

The Fox Hills generally provides adequate supplies of water for stock and domestic use; yields will differ from place to place, however, depending upon the relative proportions of sandstone and shale and the number of concretionary zones penetrated in drilling. Yield to wells will normally increase with the thickness of saturated material penetrated. Depths to water are greater along the east edge of the outcrop where altitudes are generally higher and the sandstone has been partly drained by stream valleys cut into the dip slope and by the movement of ground water down the dip of the beds into the Powder River Basin to the west.

Along the west margin of the Fox Hills outcrop, water in the formation is normally under some artesian pressure. Water levels in relatively shallow wells are generally near the land surface, and wells drilled to the base of the Fox Hills (350 to 500 ft) may flow. Flows will probably be weak, however, and artesian heads low. The yield of wells will probably not be increased by drilling below the base of the Fox Hills Sandstone, and drilling should be terminted when the Pierre Shale is reached. If the well fails to yield the quantity of water desired, an alternative site might be tested or a second well drilled to supplement the first. Chemical analyses of water from the Fox Hills Sandstone (table 8) indicate the water contains dissolved solids in amounts that generally exceed 500 ppm (parts per million)—the recommended limit for domestic use (U.S. Public Health Service, 1961)—though the quality apparently differs from place to place in the formation.

LANCE FORMATION

The continental deposits of the Lance Formation are indicative of the final withdrawal of the Cretaceous sea from eastern Wyoming and mark the end of the Cretaceous Period in Niobrara County. Because this depositional environment persisted into early Tertiary time, strata of the conformably overlying Fort Union Formation of Paleocene age are distinguished with difficulty from those of the Lance Formation. Brown (1958, p. 112) placed the contact between Cretaceous and Tertiary strata at the horizon above the highest dinosaur-bearing beds, where the first coal seams occur.

DISTRIBUTION

Outcrops of the Lance Formation occupy an area in north-central Niobrara County that is 10 to 20 miles wide and that extends from the middle of T. 36 N. to the Niobrara-Western County line and beyond. The west margin of the outcrop maintains a rather uniform north-south trend and the east boundary has an alinement of about N. 30° E. In sec. 14, T. 36 N., R. 64 W., the east boundary of the Lance Formation swings sharply westward, and the breadth of outcrop west of the village of Lance Creek is reduced to only a little more than a mile owing to the steep dip of strata in the Lance Creek dome. Overlapping Tertiary deposits have covered much of the formation to the southwest.

The soft sandstone and shale of the Lance Formation underlie a terrain of low grass-covered ridges and broad valleys. The slightly more resistant sandstones are indicated only by poorly defined benches in the exposed sides of isolated buttes and ridges. The poor exposures prevent a precise determination of formational boundaries at many places.

LITHOLOGY AND THICKNESS

The Lance Formation consists of a nonmarine sequence of interbedded light-colored sandstone and dark-gray shaly claystone and siltstone containing a few beds of carbonaceous shale near the base. In some areas the formation can be divided into two distinct units. The lower part consists of a thick sequence of interbedded black carbonaceous shale and thin beds of coal, gray siltstone, and dark- to light-gray sandstone. The upper part is principally a series of lighter colored sandstone and soft shale containing a few thin beds of dark carbonaceous shale and impure coal.

The sandstones of the Lance Formation are white to yellowish gray and brown, generally fine to medium grained, calcareous, and friable. They may be thin to thick bedded and are commonly crossbedded. The sandstone units are lenticular, and their thickness ranges from only a few inches to several feet. The thicker beds locally contain loglike masses of concretionary sandstone that reach lengths of several feet.

The thickness of the Lance Formation in Niobrara County, as determined from logs of oil-test holes, reportedly ranges from 1,600 to 2,500 feet; it increases toward the center of the Powder River Basin. The scarcity of good exposures of Lance strata and the difficulty of establishing the contact with the overlying Fort Union Formation prevent an accurate determination of the thickness at many places.

A partial description of the lower part of the Lance Formation in an exposure north of Lance Creek village follows:

A section of the lower beds of the Lance Formation measured in sec. 23, T. 36 N., R. 65 W

[Adapted from Hancock (1920, p. 105–6)]

	Thickness (feet)
Lance Formation (part):	
Sandstone, light-yellow, soft, and sandy shale	12
Shale, sandy; weathers pink	2
Sandstone, light-gray to brown, hard	10
Shale, containing thin layers of sandstone; weathers pinkish to light gray	35
Sandstone, yellowish-brown, soft, thick-bedded, crossbedded; contains carbonaceous shale in lower 25 ft	103
Sandstone, soft, thin-bedded	6
Shale, dark-gray, carbonaceous; very sandy at top	14
Sandstone, light-yellow, soft, massive	6
Coal	5
Sandstone, soft; contains carbonaceous shale	5
Sandstone, white, massive	15
Poorly exposed, mainly sandy carbonaceous shale	25
Shale, black, carbonaceous; contains thin seams of coal	10
Sandstone, white, soft, massive; contains thin hard reddish-brown layers in lower part	143
Shale, sandy	40
Sandstone, rust-colored, hard	5
Measured thickness of Lance Formation	**436**
Fox Hills Sandstone:	
Contact with Lance poorly defined.	

WATER-BEARING CHARACTER

The Lance Formation is one of the principal aquifers in northern Niobrara County and is generally a dependable source of ground water for many stock and domestic wells. In the south half of the county, most of the formation was removed during early Tertiary time by erosion that accompanied the uplifting of Lance Creek dome. Where the Lance is present, however, it generally lies too deep to be considered a potential source of water, except in the narrow outcrop west of Lance Creek.

Wells drilled in outcrops of the Lance Formation are generally completed after 100 to 150 feet of saturated material has been penetrated. Yields of wells depend upon the number, permeability, thickness, and extent of the water-bearing sandstones penetrated; consequently, yields differ from well to well throughout the area. Because of the predominantly fine-grained texture of the Lance, however, yields will generally be small, although moderate supplies might be obtained in some areas from deep wells penetrating a thick section of saturated material. The saturated thickness is least along the east edge of the outcrop, where the formation is thinnest and has been deeply dissected and partly drained by the valleys of the Cheyenne River and Lance Creek and their many tributaries. The construction of successful wells in this area may require drilling into the underlying Fox Hills Sandstone or testing the alluvial deposits underlying the valleys of the Cheyenne River and Lance Creek and possibly the lower reaches of Old Woman and Crazy Woman Creeks.

The saturated thickness of the Lance Formation increases westward to the contact with the overlying Fort Union Formation, where the Lance reaches its full thickness of about 2,500 feet. To obtain the maximum amount of water available, wells should be drilled as deeply as possible, and the casing should be perforated at each significant water-bearing bed. West of the Lance-Fort Union contact, drilling depths to the Lance Formation increase abruptly owing to the regional dip of strata and to the increase in the altitude of the land surface underlain by the Fort Union.

Depths to water in areas underlain by the Lance Formation are generally greater in the western part of the outcrop, where land-surface altitudes are higher and the terrain is more rugged and more deeply dissected than in the eastern part. Artesian pressure in the confined aquifers causes water levels in some of the deeper wells to rise appreciably above the general water table in the area, but probably only wells drilled in topographically low areas will flow.

The quality of the water in the Lance Formation ranges from marginal for human consumption to fair for stock consumption. The results of chemical analyses of samples of water from the Lance Formation are given in table 8.

TERTIARY SYSTEM

The Tertiary System in Niobrara County comprises rocks of Paleocent, Oligocene, and Miocene age; no deposits of Eocene age have been identified in the area. Moderately to loosely consolidated deposits of coarse sand and gravel containing cobbles and small- to medium-sized boulders locally capping ridges and buttes may be of Pliocene age. Because these deposits generally occupy topographically high areas and probably are rapidly drained of any recharge received by them, they are not a source of ground water in the region, and on the geologic map are included in the formations with which they are most closely associated. These deposits may play a part, however, in retarding runoff and increasing the amount of water that reaches the underlying aquifers.

PALEOCENE SERIES

FORT UNION FORMATION

The Fort Union Formation in northeastern Wyoming has been subdivided into three members listed in ascending order: the Tullock, the Lebo Shale, and the Tongue River Members (Love and Weitz, 1951). In western Niobrara County, Dobbin (Dobbin and others, 1957) recognized the Tullock Member, but used the term "unnamed unit" to designated the overlying sequence of interbedded sandstone and shale. Because of the lithologic similarity of the units from the hydrologist's point of view, there is little reason for differentiating between them in this report, and Fort Union strata are mapped simply as the Fort Union Formation. The Wasatch Formation of Eocene age, which overlies the Fort Union in adjacent areas, has not been identified in Niobrara County. In the southwestern part of the county, strata of the Fort Union are overlapped by deposits of the White River Group of Oligocene age.

DISTRIBUTION

The Fort Union Formation crops out along most of the west border of Niobrara County in a broad band about 10 miles wide. The outcrop narrows abruptly south of T. 36 N. as its east margin swings westward around the Lance Creek dome. The formation is exposed for several miles west of the line between Niobrara and Converse Counties.

The land surface underlain by the Fort Union Formation has been deeply dissected by the converging streams of north- and east-flowing drainage systems. The area is characterized by sharp-crested and gullied ridges and deep narrow ravinelike valleys. Some areas have been reduced to badlands; elsewhere, isolated sandstone-capped buttes and mesas rise above the general surface. The rough terrain is in sharp contrast to the rolling grasslands characteristic of the topography of the Lance to the east.

LITHOLOGY AND THICKNESS

In Niobrara County the Fort Union Formation is composed of a thick sequence of interbedded gray sandstone, darker gray siltstone, and shale containing beds of lignitic coal. The occurrence of a generally greater number of persistent coal beds in the Fort Union, which produce a marked banding effect, is a commonly adopted field method of distinguishing the Fort Union from the underlying Lance Formation. The sandstones are light to yellowish gray, generally fine to medium grained, and friable. The beds range in thickness from a few inches to several feet and are generally lenticular, thin to thick bedded, and crossbedded.

The thickness of the Fort Union Formation exposed in Niobrara County ranges from a relatively thin eroded edge along much of the east margin of the outcrop to a reported maximum of about 2,270 feet (Dobbin and others, 1957) in the western part of the county.

WATER-BEARING CHARACTER

In areas of outcrop of the Fort Union Formation in Niobrara County, wells generally yield sufficient water for stock and domestic use. In adjacent areas, deep wells drilled in the formation produce appreciably larger quantities of water. However, the rough terrain, characteristic of outcrops of the Fort Union, is best adapted to stock raising, and, generally, there is little need for larger supplies, which in most areas could be obtained only at the expense of proportionately higher pumping lifts. Saturated thicknesses are least along the east edge of the outcrop and increase westward because of the dip of the beds and the increase in surface altitudes.

Depths to water in areas of outcrop of the Fort Union Formation generally are relatively great because the upper beds in many areas have been drained by the many narrow stream valleys eroded deeply into the upland surface. Owing to the irregularity of the topography, the depth at which water will be found in drilling at any specific site is difficult to estimate. Water levels measured during the investigation ranged from at the land surface in one well to more than 400 feet below land surface in another well. The shallow water levels are probably due to the fact that the wells either were drilled in topographically low areas along stream valleys or penetrated the formation deeply enough to tap water under artesian pressure. Nearly all the wells having deep water levels are in elevated areas dissected by deep stream valleys.

Drilling in the Fort Union Formation should be confined, when possible, to stream valleys or lower slopes of ridges, where water levels are normally nearer the surface, and the crests of ridges and hills should be avoided. This is not everywhere feasible, however, because many sites at low altitudes are not suitable for the successful operation of wind-powered pumps. As in the Lance Formation, wells should be drilled as deeply as economic consideration will permit to obtain the maximum amount of water. Casing should be perforated at each potential water-bearing bed below the water table.

The quality of the water in the Fort Union Formation is variable, but, generally, the water is unsuitable for most domestic use because of high concentrations of dissolved solids and iron. It is classified as fair for stock consumption.

OLIGOCENE SERIES

WHITE RIVER GROUP

Rocks of Oligocene age in Niobrara County are represented by the Chadron Formation and the overlying Brule Formation. Although both the Chadron and Brule can be recognized in Niobrara County, the group has not been divided in this report and is mapped and discussed as a single unit. The White River Group is overlain unconformably by the Arikaree Formation of Miocene age.

DISTRIBUTION

Outcrops of the White River Group are almost entirely confined to the south half of the area, where they overlap most of the older sedimentary rocks and, in places, have buried them beneath as much as 550 feet of claystone and siltstone. Older rocks are exposed only where pre-Tertiary surfaces stood high enough to avoid inundation or where erosion subsequently has removed the Oligocene cover. The uppermost White River deposits are best exposed in cliffs and steep slopes where the soft strata are protected from erosion by the more resistant beds of the overlying Arikaree Formation. Elsewhere the formation is generally concealed beneath rolling grasslands.

LITHOLOGY AND THICKNESS

The White River Group is composed principally of silty claystone and siltstone containing some very fine sandstone. Channel deposits of coarse sand and gravel are common throughout the sequence. The lower 200 feet (Chadron Formation) is predominantly a silty claystone that is distinguished in many outcrops by its colorful gray, red, and green banding. The upper 350 feet (Brule Formation) is a massive pinkish-gray siltstone containing subordinate amounts of very fine sandstone and claystone. The results of laboratory analyses of samples of the White River Group are given in tables 4 and 5. A section measured near Whitman, Wyo. (fig. 12), shows about 15 feet of medium to coarse sandstone near the middle of the Brule Formation.

The thickness of the White River Group ranges from a thin eroded edge where the strata overlap older rocks along the north and west margins of the outcrop to about 550 feet exposed between the base of the Arikaree and the top of the Pierre Shale near Whitman, Wyo. The thickness of White River deposits, however, differs from place to place because the sediments were deposited on an erosion surface of considerable relief. The thickness of the group increases eastward in Nebraska where nearly 700 feet has been reported. The average thickness in Niobrara County, where the entire section is present, is about 500 feet.

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WATER-BEARING CHARACTER

Rocks of the White River Group yield water to both stock and domestic wells in Niobrara County. The claystone and siltstone characteristically have a low permeability (table 5), and successful wells generally must penetrate an appreciable thickness of saturated material. In some areas in southeastern Wyoming, the upper part of the White River (Brule Formation) yields large quantities of water to irrigation wells from fracture zones, fissures, and coarse-grained channel deposits (Rapp and others, 1953, p. 41; 1957, p. 33). No attempts have been made to develop large supplies of water from the White River Group in Niobrara County, but careful test drilling could probably locate permeable lenses of sand and gravel (fig. 5) and possibly reveal fracture zones and fissures, as shown in the idealized section illustrating hydrologic conditions occurring in the White River elsewhere (fig. 6).

The success of wells drilled in areas of outcrop of the White River Group is unpredictable. Water levels differ greatly, commonly within short distances and, in some wells, without any apparent relation to the altitude of the land surface. The depths of successful wells differ, depending upon the type of material penetrated. Wells penetrating massive siltstone and claystone must generally be deep to supply even a small quantity of water, whereas wells completed in fractured and fissured zones or channel deposits may be relatively shallow.

In most areas it is advisable to test the formation with several shallow test holes, rather than drill a deep well. The formation probably becomes less permeable with depth because of compaction of the deposits by the weight of overlying strata. Zones of fissures and fractures are likely to be less numerous and extensive, and deeply buried channel deposits receive little recharge. In prospecting for water in areas of outcrops of the White River Group, sites that are underlain by alluvial deposits along small streams or draws should be tested first. Water contained in the alluvium may not be sufficient to supply a stock well, but it might be a welcome supplement to any water developed in the underlying bedrock.

Five samples of water from the White River Group were low in concentration of dissolved solids (less than 500 ppm), although high concentrations of iron, fluoride, and silica in some samples may limit use of the water for domestic purposes.

MIOCENE SERIES

ARIKAREE FORMATION

The Arikaree Formation in Niobrara County includes all bedrock strata above the White River Group, and is considered to be the stratigraphic equivalent of the Arikaree Group of western Nebraska, which is of Miocene age. Rocks of later Tertiary age either are not

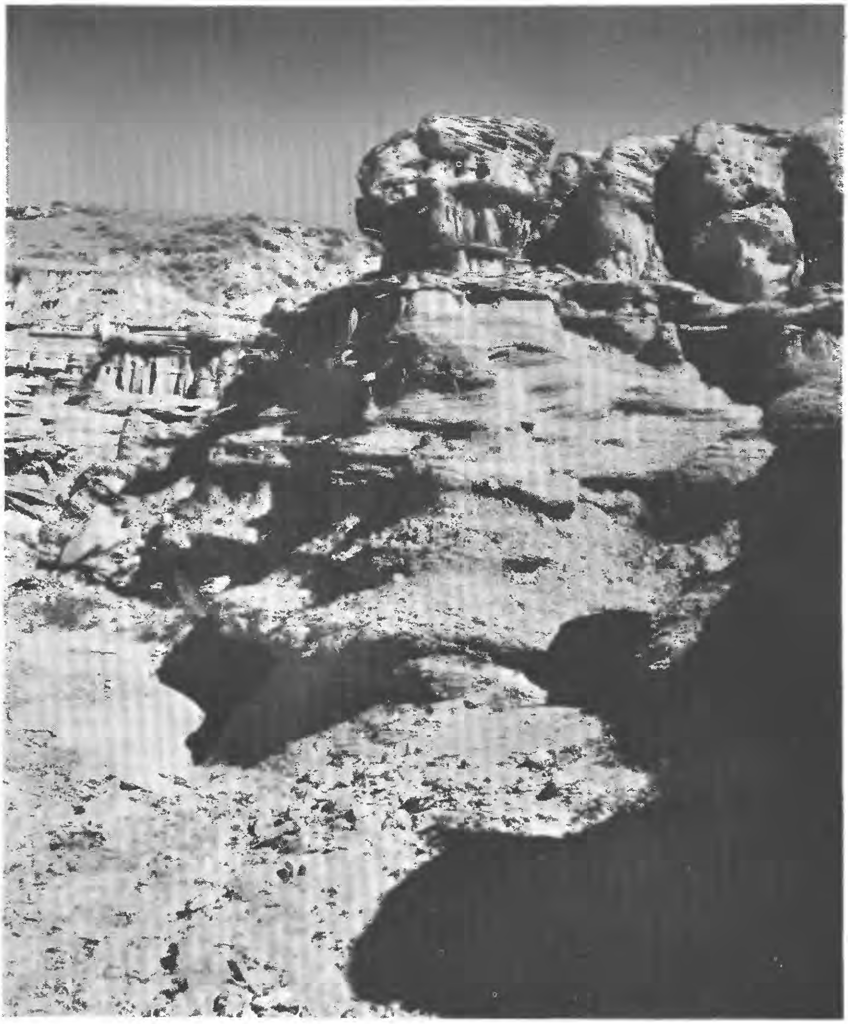

FIGURE 5.—Channel deposit in the White River Group showing its coarse-grained and friable texture.

present or have not been recognized in the report area. No attempt was made to subdivide the Arikaree in Niobrara County because the purpose of this investigation does not warrant the detailed study that would be required. Owing to its generally homogeneous character, the Arikaree is considered a single hydrologic unit and is mapped and discussed as the Arikaree Formation.

DISTRIBUTION

The Arikaree Formation underlies most of the southern one-third of Niobrara County, and outliers of the Arikaree surface form extensive mesas and buttes north of Hat Creek Breaks. Outcrops of the

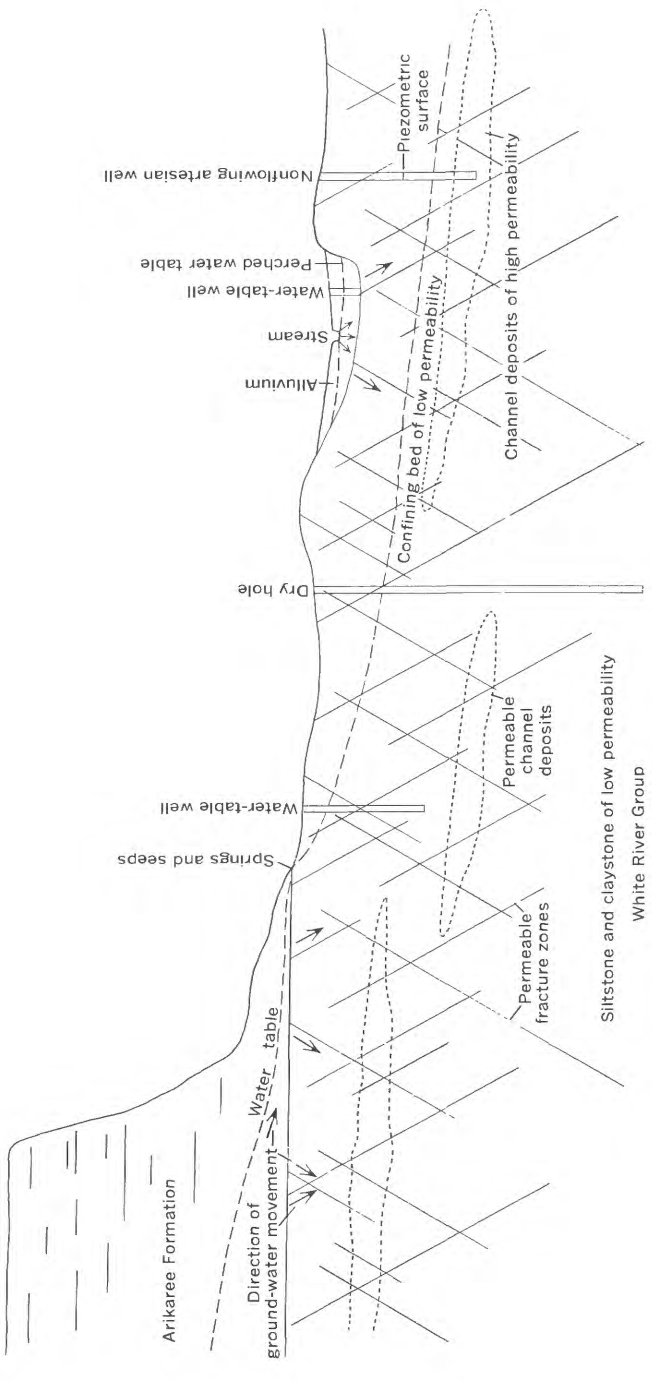

FIGURE 6.—Diagrammatic section illustrating various ground-water conditions that may exist in the White River Group in Niobrara County, Wyo.

Arikaree Formation extend eastward for many miles into Nebraska, south and southwest into Goshen and Platte Counties, and westward into Converse County. The broad upland surface underlain by the Arikaree is gently to roughly rolling and generally grass covered. Consequently, the best exposures of the formation are in the escarpment which forms Hat Creek Breaks.

LITHOLOGY AND THICKNESS

The Arikaree Formation is predominantly a massive sandstone containing beds of siltstone, thin lenticular layers of hard concretionary sandstone and soft volcanic ash, and a generally persistent coarse basal conglomerate. The outcrops are commonly light gray to light brownish gray, although at some places the lower beds have the pale pinkish tint characteristic of the upper beds of the underlying White River Group. Where the basal conglomerate is absent, the contact between the Arikaree and the upper part of the White River Group appears to be gradational because of similarity in color and, at many places, lithology.

The sandstone is typically very fine to fine grained, although a few lenses of coarse-grained channel deposits occur in some of the thicker beds. The sandstone is loosely to moderately cemented and generally massive, though locally it may be thin bedded and crossbedded. Layers and nodules of concretionary sandstone are dispersed throughout the formation but they are more numerous at some horizons than others. The limy layers are lenticular and generally thin, ranging from a few inches to 2 feet in thickness. They commonly form shelves and benches on weathered outcrops. Nodular zones appear as irregularly shaped protuberances of very fine sandstone and siltstone ranging from small globular and pipelike concretions to limy masses several feet wide and thick. (See fig. 7.)

The conglomerate, which marks the base of the Arikaree Formation for many miles along the Hat Creek Breaks escarpment, was laid down as widespread channel deposits upon the White River Group erosional surface. In consists of medium to coarse sand and gravel, of a wide variety of rock types, that generally are firmly cemented, but in some outcrops the conglomerate is poorly consolidated and very friable. Twenty-four rock samples of the Arikaree Formation were collected for laboratory analysis, and the results are given in tables 4 and 5.

The upper beds of the Arikaree Formation apparently have been extensively fractured adjacent to the Rawhide fault (pl. 1), where evidence of post-Miocene movements along the fault zone is found in outcrops of faulted and slickensided sandstone (Denson and Botinnelly, 1949). Drillers' reports confirming the fractured character of the Arikaree at depth are further supported by the unusually high yields of at least two wells drilled in the area. Some fracturing has probably occurred in the lower beds of the Arikaree north of Hat Creek Breaks where a few minor fracture zones were noted near the base of the outcrop in sec. 35, T. 34 N., R. 64 W. and secs. 27 and 28, T. 34 N., R. 65 W.

FIGURE 7.—Concretionary zone in the Arikaree Formation showing characteristic nodular structures occurring at some horizons.

Large-scale jointing was observed in an outcrop of the Arikaree near the top of the escarpment of Hat Creek Breaks, west of the highway about 6 miles north of Lusk (fig 8). Jointing was not noted elsewhere, but it is probably not a local phenomenon.

Three sections of the Arikaree Formation were measured in the escarpment of Hat Creek Breaks (figs. 12, 13, 14). The formation is about 600 feet thick near Whitman, 420 feet thick about 12 miles west of Whitman (along the old road from Lusk to Hat Creek), and 500 feet thick along the highway from Manville to Lance Creek. The average thickness of the formation at the Wyoming-Nebraska State line is estimated to be about 700 feet. Thicknesses of as much as 1,000 feet have been reported in Goshen County. Adjacent to Rawhide Butte and other uplifted areas the formation thins to an eroded edge where it overlaps topographically higher older rocks.

WATER-BEARING CHARACTER

The Arikaree Formation yields water to many stock and domestic wells, several irrigation wells, and the community wells at Lusk and Manville. The yield of wells differs from place to place, depending upon the relative proportion of sandstone and siltstone and the num-

FIGURE 8.—A system of joints in the upper part of the Arikaree Formation exposed in the escarpment west of U.S. 85 about 6 miles north of Lusk, Wyo.

ber and extent of concretionary zones penetrated. Figure 9 illustrates the different hydrologic conditions that may be found by wells drilled in the formation.

In areas of outcrop of the Arikaree Formation, water is generally easily obtainable, and most stock and domestic wells yield adequate supplies with relatively shallow penetration of the aquifer. In areas where the Arikaree consists principally of sandstone or where the formation has been extensively fractured, moderate to large yields may be expected from properly constructed wells. (See table 6.)

Depths to water differ in relation to the altitude of the land surface, and are least along the valley of the Niobrara River and its tributaries, where the water table is generally at, or only a few feet below, the valley floor. Depths to water increase progressively north and south of the river and reach a maximum of about 340 feet along the rim of Hat Creek Breaks escarpment. The water table lies at a relatively great depth in much of the southwest corner of Niobrara County also, where water in the upper part of the Arikaree Formation has been drained into the many deep valleps eroded by Muddy Creek and its tributaries. Depths to water in the Arikaree Formation, based on measured and reported data, are shown in plate 3.

Yields of wells in most areas can probably be increased appreciably by drilling deeper into the aquifer to penetrate a greater thickness of saturated material. Wells of larger diameter would probably yield greater quantities of water, but yields do not vary directly with well

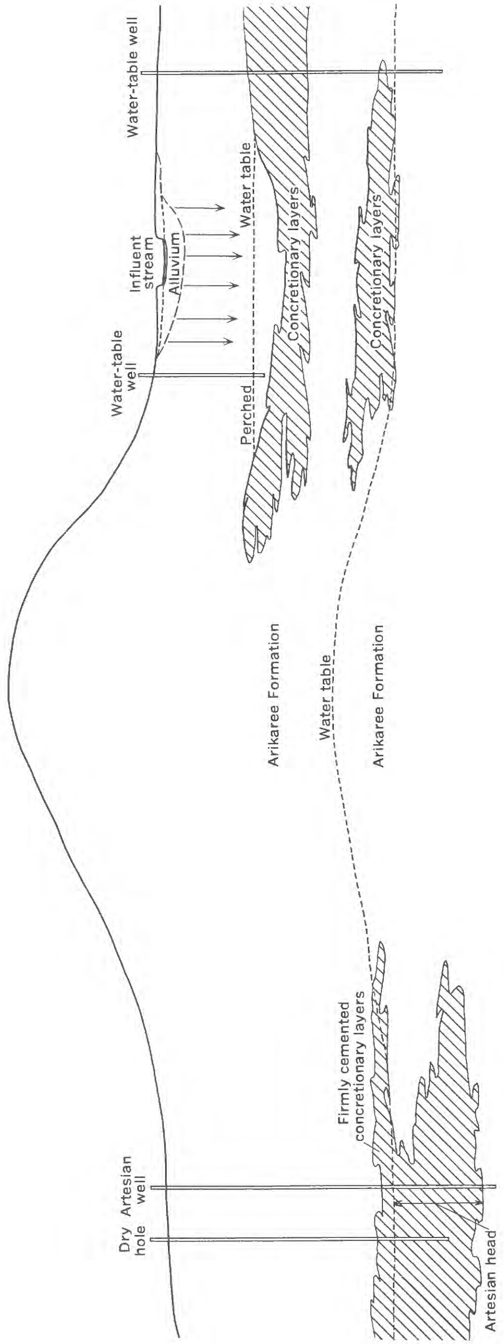

FIGURE 9.—Diagrammatic section illustrating ground-water conditions in the Arikaree Formation.

diameter. For example, a fourfold increase in the diameter of a well will increase the yield only about 25 percent with the same drawdown. Before a larger diameter irrigation well is constructed in the Arikaree Formation, the area should be prospected by means of small-diameter test holes to determine the depth to water, the character of the water-bearing material, and, if possible, the approximate yield of the aquifer.

Prospecting for water in the upland areas of the outcrop of the Arikaree Formation south of Hat Creek Breaks should be done first in topographically low areas, where water levels are generally nearest the land surface. Depth-to-water areas outlined on plate 3 are necessarily generalized but should be of value in determining where water levels are shallow and where depths to water are so great that the cost of pumping large quantities of water would be prohibitive. Drilling for large supplies of water in the lower part of the Arikaree, along the base of Hat Creek Breaks, should be continued through the basal conglomerate, where present, and terminated at the top of the underlying White River Group. If the supply is inadequate, it is generally preferable to drill a second well to supplement the first rather than drill into the White River Group in an attempt to intercept water-bearing channel deposits or fissured zones. Water from the Arikaree Formation is hard but otherwise of good quality for domestic and irrigation use. (See table 8.)

QUATERNARY SYSTEM

The Quaternary System in Niobrara County is represented principally by unconsolidated deposits that probably range in age from Pleistocene to Recent. Isolated outcrops of semiconsolidated sand and gravel capping ridges and buttes of Tertiary strata may be of early Quaternary age but are probably older. Because of their generally small areal extent and thickness, no attempt was made during this investigation to distinguish between these deposits and the underlying White River Group or Arikaree Formation. These deposits are therefore mapped as a part of the formation with which they are most closely associated.

ALLUVIUM

DISTRIBUTION

Alluvial deposits of sufficient thickness and extent to be considered potential sources of ground water in the report area occur principally along Lance Creek and its major tributary, Old Woman Creek, and along the Cheyenne and Niobrara Rivers. Alluvium underlying the valleys of some of the smaller streams contains some ground water at times, but the quantity generally will be small and the supply dependent upon seasonal runoff. These deposits are not shown on the geologic map.

LITHOLOGY AND THICKNESS

The alluvium underlying the valleys of the Cheyenne River and Lance Creek, as seen in exposures in riverbanks and roadcuts, is composed mostly of fine-grained clastic material ranging from clay to very fine sand containing pebbles and cobbles of fine- to medium-grained sandstone. Alluvial deposits having a wide range of grain size, however, commonly contain lenses of coarse sand and gravel of variable thickness and extent. These lenses mark the position of a buried former stream channel.

Alluvial deposits underlying much of the valley of Niobrara River probably are predominantly intermixed fine sand and silt derived from the Arikaree Formation. Coarser material probably occurs in the upper reaches of the valley, where the stream and its tributaries have access to the more resistant rocks of Rawhide Butte; however, the thickness and areal extent of these deposits are probably not great.

Little information is available on the thickness and composition of alluvial deposits in the report area, because few wells have been dug or drilled into them. The alluvium of the Niobrara River valley probably is a relatively thin, perhaps not more than 20 feet thick anywhere in Niobrara County. The alluvium of the Cheyenne River and Lance Creek is much thicker in places; some drilled wells reportedly have penetrated as much as 100 feet of unconsolidated deposits.

WATER-BEARING CHARACTER

Alluvial deposits underlying the valleys of the Cheyenne River and Lance Creek yield water to a few stock wells and to six irrigation wells. The yield of wells will differ from place to place, depending upon the thickness, extent, and permeability of the saturated material penetrated and the rate of recharge to it. Small supplies of water can probably be obtained from alluvial deposits at most places in the valleys of the Cheyenne River and Lance Creek and their major tributaries. Moderate supplies, adequate for limited irrigation, can be developed at some locations where the alluvium is thick and contains extensive lenses of saturated sand and gravel.

The fine-grained sand and silt, which compose most of the alluvium in the valley of the Niobrara River, probably will yield enough water to properly constructed wells to meet stock and domestic needs, but the common practice in the area is to drill into the underlying Arikaree Formation, in which the water level is generally within a few feet of the land surface. The deeper, but relatively trouble-free wells drilled in the Arikaree are generally more economical. Deposits of coarser material, which may occur locally in the upper reaches of the Niobrara River valley, are probably much more permeable and may be capable of yielding moderate quantities of water to wells in some areas. The alluvium is not considered an important source of ground water in the valley of the Niobrara River, however, because it is generally underlain by the more productive Arikaree Formation.

The quantity of ground water contained in alluvial deposits underlying the major stream valleys in Niobrara County probably remains fairly constant because in most areas a large part of the recharge is supplied by seepage from underlying and adjacent bedrock formations. Two geologic settings illustrating this hydrologic situation are shown in figure 10.

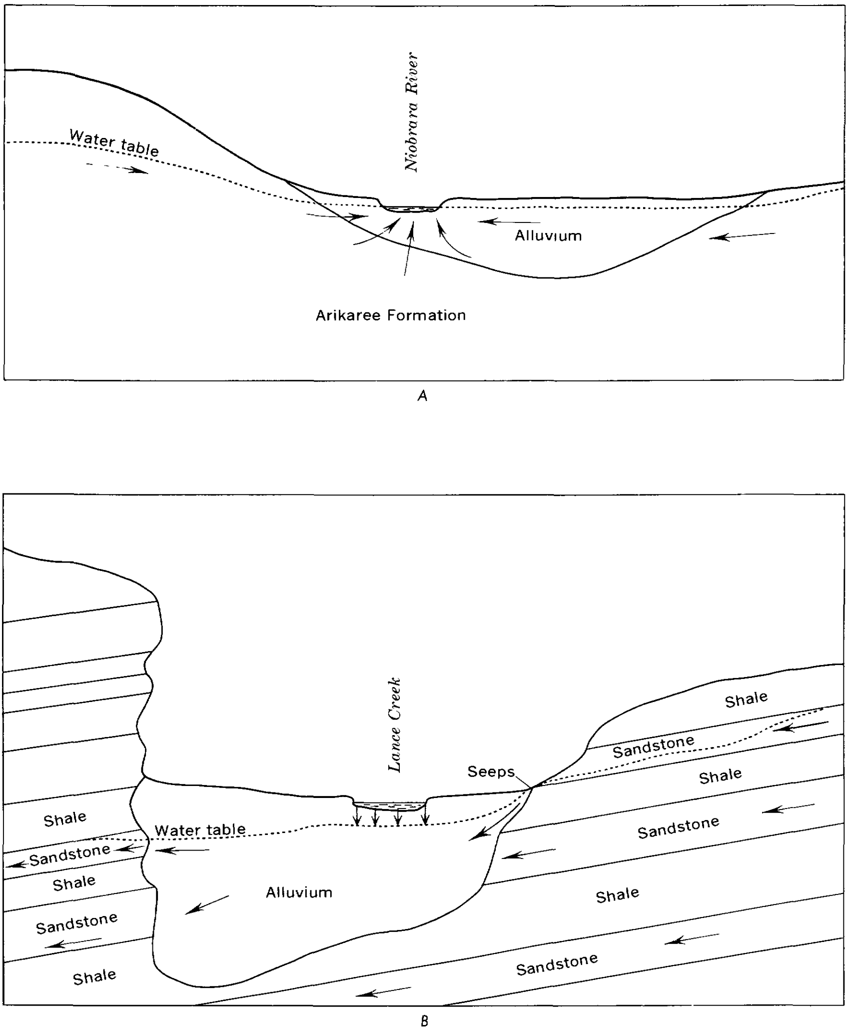

FIGURE 10.—Direction of movement of ground water in alluvium and adjacent bedrock. *A*, Niobrara River valley; *B*, Lance Creek valley. Most of underflow in alluvium is in direction of stream gradient.

In figure 10–*A* the alluvium overlies the massive and relatively permeable Arikaree Formation. The water table in the alluvium and Arikaree Formation is continuous because water moves freely between the two. Water levels in the Arikaree normally fluctuate within a very narrow range, thus, water levels in the alluvium remain relatively constant. Recharge to the alluvium from surface runoff is rapidly dispersed in the common ground-water reservoir and has little effect upon the water table. Water in the valley fill moves as underflow in the general direction of the slope of the water table in the alluvium (pl. 1), which is also the direction of the stream gradient.

In figure 10–*B*, the alluvium overlies water-bearing sandstones of the Lance Formation throughout most of Lance Creek valley. Water moving down the dip of the beds recharges and maintains a relatively constant water table in the alluvium. Continuous measurements of the water level in the alluvium of Lance Creek from March 24 to September 10, 1960, were obtained by installing a water-stage recorder on an unused irrigation well. The water table declined gradually and reached a maximum of 0.78 foot on August 24. The decline probably was appreciably influenced by the frequent pumping of a nearby irrigation well and the use of ground water by alfalfa being cultivated in the area. Undoubtedly, sporadic flows in Lance Creek contribute some recharge to the alluvium, but they are generally infrequent and of short duration. Surface flow during the summer of 1960 was below average due to far below-normal precipitation.

Before an expensive, large-diameter irrigation well is constructed in alluvial deposits it is generally advisable to prospect the area by drilling a series of small-diameter test holes across the trend of the valley. Unless the test drilling is carefully planned and systematically done, however, the results may not warrant the expense. The purpose of the test drilling is to locate the thickest and most permeable water-bearing beds, which normally occupy former stream channels that were subsequently buried beneath more recent alluvium. Where possible, the test holes should be drilled in a straight line and at regularly spaced intervals. If the holes are drilled to the underlying bedrock and properly logged, a section across the valley fill is obtained which shows the position of the buried channel and the type of material lying in it.

Wells drilled in areas underlain by alluvial deposits along the Cheyenne River, Lance Creek, and the lower reaches of Old Woman Creek will generally yield sufficient water for stock and domestic use. If the valley fill does not yield the quantity of water desired, small supplies can generally be developed from the underlying Lance Formation or Fox Hills Sandstone, Where the alluvium is thick, saturated, and permeable, supplies adequate for limited irrigation can be developed. There is little possibility of appreciably increasing the yield of an irrigation well by drilling into the underlying bedrock.

No water samples were obtained for chemical analysis from the alluvium of Niobrara River, but the quality is probably comparable to that in the Arikaree Formation. Chemical analyses of two water samples obtained from wells drilled in the alluvium of Lance Creek and one from the alluvium of the Cheyenne River (table 8) show that the water is unsuitable for most domestic uses.

GROUND WATER

OCCURRENCE AND MOVEMENT

Water in the zone of saturation in the rocks below the surface of the earth is called ground water. Because not all saturated rocks are sufficiently permeable to yield measurable quantities of water to wells or springs and seeps, for all practical purposes ground water might be defined as that water occurring below the land surface that is recoverable in usable quantities from wells or by the development of natural outlets. The water-bearing material, or aquifer, from which man can extract water is called the ground-water reservoir. Thomas (1951, p. 29) wrote:

> Because there is usually movement of water through a ground-water reservoir, the connotation is not quite the same as for surface reservoirs, which are constructed to halt and accumulate the flow of streams. But movement underground is generally so slow, compared with that of streams or in the atmosphere, that it represents a definite retardation in the hydrologic cycle. Ground-water reservoirs thus provide slow-moving storage from which man may obtain water as he requires. If an analogy is permitted with the distribution system for manufactured goods, the ground-water reservoirs might correspond to giant warehouses in which the movement of goods in ton-miles is far slower than the rail, plane, or trucking phases of the system. Nevertheless, an essential characteristic of ground-water reservoirs is movement of water through them. Most of the saturated materials underground are dense rocks, shales, clays, and glacial tills. They are not suitable reservoirs at all as far as man is concerned, for they hold water in pores so small that it cannot be transmitted in usable quantities to wells and springs.
>
> Wells will yield a perennial supply only to the extent that water can be transmitted to them through the entire course of the aquifer from the place where the water enters the ground. Even without wells, the ground-water phase of the hydrologic cycle is one of movement from the places where water enters the aquifer—the "recharge" areas—to the place where the water is discharged from the ground, either by evapotranspiration [evaporation from land and water surfaces and transpiration by plants], by springs, or by seepage to streams or lakes or directly into oceans. Thus, as a rule, usable ground water does not remain at rest under a piece of land until the owner is ready to use it but is moving continually to some point of discharge at the surface.

A detailed discussion of the principles of occurrence and movement of ground water was given by Meinzer (1923).

PHYSICAL AND HYDROLOGIC PROPERTIES OF WATER-BEARING MATERIALS

The quantity of water that a rock formation will transmit, and therefore, yield to wells depends upon the physical and hydrologic properties of the water-bearing material composing the formation. The examination of rock outcrops and the study of drillers' logs are useful in determining the physical properties of the rock formations, but the determination of the hydrologic properties requires more comprehensive analysis of the materials by means of laboratory and field tests. Laboratory procedure involves the mechanical analysis of a sample of the water-bearing material, and the values obtained apply only to the analyzed rock sample and rarely to the formation as a whole. The results of laboratory studies are therefore of limited use, unless supported by pumping tests to determine the water-bearing character of the formation under field conditions.

Following are brief definitions of terms commonly used in a discussion of the physical and hydrologic properties of water-bearing materials and the performance of wells drilled in them.

Grain size. A particle-size analysis of granular material consists of separating the grains of different sizes into groups and determining the percentage, by weight, of the total sample each size group constitutes. The results of the particle-size analyses of the materials are given in table 4, and a graph of a particle-size distribution curve that is most nearly representative of the average grain size of the samples collected is given in figure 11.

Porosity. The porosity of a saturated rock is the percentage of the total volume of rock that is occupied by water. The quantity of water the rock can yield is generally somewhat less than that contained in its pore spaces. Some rocks, such as clay and slit, may have a high porosity but will yield very little water to wells.

Specific retention and specific yield. Specific retention is the quantity of water that a material will retain against the pull of gravity if the material is drained after having been saturated and is expressed as the ratio of the retained water to the total volume of material. The specific yield of a water-bearing material is defined as the ratio of the volume of water that a saturated aquifer will yield by gravity to its own volume and is numerically equal to the porosity minus the specific retention.

Coefficient of permeability. The coefficient of permeability of a rock, as determined in the laboratory, is the number of gallons of water per day, at 60°F, that is transmitted laterally through 1 square foot of the rock sample under a hydraulic gradient of 1 foot per foot.

Field coefficient of permeability. The field coefficient of permeability of an aquifer, is the number of gallons of water per day transmitted under prevailing conditions through a cross section of aquifer 1 mile wide and 1 foot thick, under a hydraulic gradient of 1 foot per mile.

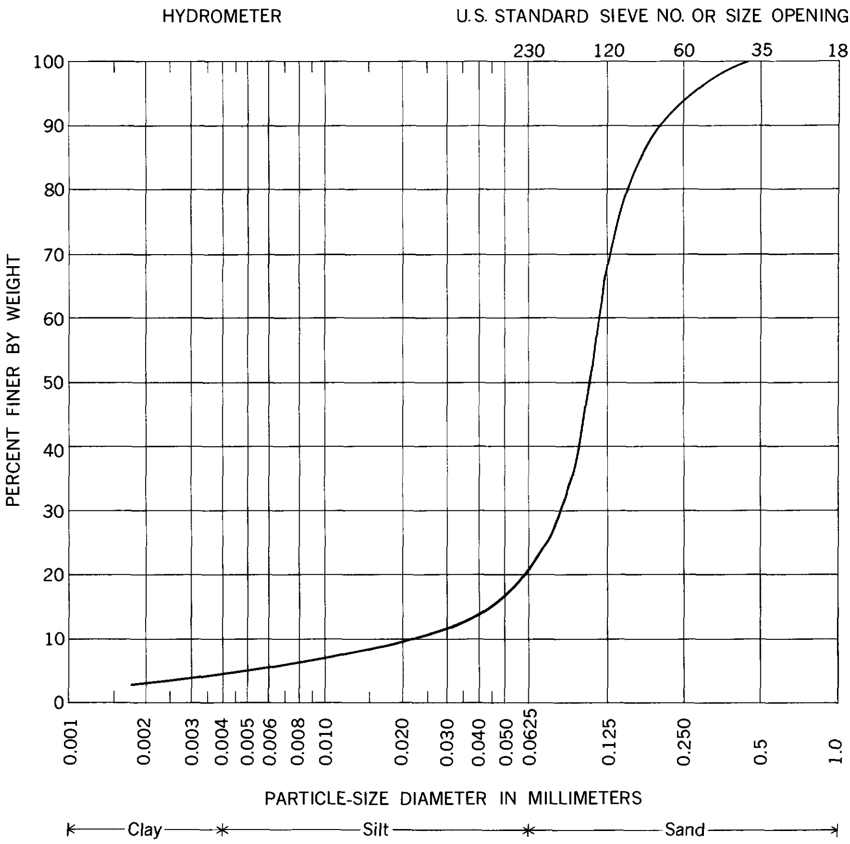

FIGURE 11.—Particle-size distribution curve for a sample of the Arikaree Formation representative of the average grain size of samples analyzed.

Coefficient of transmissibility. The coefficient of transmissibility is the number of gallons of water per day transmitted under prevailing conditions through a cross section of aquifer 1 mile wide and extending through the entire thickness of the saturated material, under a hydraulic gradient of 1 foot per mile. Thus, transmissibility is the permeability multiplied by the saturated thickness of the aquifer being tested.

Coefficient of storage. The coefficient of storage is the volume of water an aquifer releases from, or takes into, storage per unit surface area with each unit change in the component of head normal to that surface. More simply, if the head on a column of the aquifer with a base 1 foot square declines 1 foot, the volume of water, in cubic feet, released from storage from the column of the aquifer is the coefficient of storage. The coefficient is expressed as a decimal number and merely indicates the relation between the volume of aquifer affected and the volume of water recovered.

Specific capacity of wells. The specific capacity of a well, or yield per unit of drawdown, is expressed as the number of gallons per minute that a well yields for each foot of drawdown of the water level in the well. The amount of drawdown is influenced by the construction and development of the well; however, a comparison of specific capacities is useful in estimating the permeability of aquifers and the relative efficiency of wells.

LABORATORY DETERMINATIONS

Twenty-four samples of the Arikaree Formation and five of the White River Group were analyzed in the hydrologic laboratory to determine their physical and hydrologic properties. The results of these studies are summarized in tables 4 and 5. The stratigraphic sections from which these samples were taken are shown in figures 12, 13, and 14.

FIELD DETERMINATIONS

Pumping tests were made at four irrigation wells drilled in the Arikaree Formation and at one irrigation well drilled in the alluvium of Lance Creek. The selection of the wells was governed by the suitability of the pumping equipment and the proximity of one or more observation wells in which the effect of pumping upon the water level in the aquifer could be observed. It also was desired to obtain as broad a picture as possible of the permeability of the Arikaree Formation both vertically and areally. One well (34–62–29cd) penetrates the lower part of the formation at the foot of Hat Creek Breaks; two (32–63–2cc and –33bb) are where the Arikaree is relatively thin adjacent to the Hartville uplift; and the fourth (32–62–17cd) penetrates the upper part of the Arikaree about 6 miles east of Lusk, where the formation has nearly full thickness. Only one well drilled in alluvial deposits met the requirements for a potentially successful pumping test. The results of pumping tests are given in table 6.

WATER-TABLE AND ARTESIAN CONDITIONS

Water in the unconsolidated alluvial deposits and in the outcrop areas of stratified sedimentary aquifers is generally under water-table conditions and, when tapped by wells, does not rise above the level at which it is penetrated. The water table in alluvial deposits that depend principally upon surface runoff for recharge to the ground-water reservoir generally fluctuates in response to seasonal variations in the flow of streams. These fluctuations may be large or

TABLE 4.—*Physical properties of samples of rocks from Arikaree and Brule Formations of Tertiary age in Niobrara County*

Sample	Depth (feet below top of section)	Particle-size distribution (percent by weight) for indicated size class (mm)									
		Clay (< 0.004)	Silt (0.004–0.0625)	Sand					Gravel		
				Very fine (0.0625–0.125)	Fine (0.125–0.25)	Medium (0.25–0.5)	Coarse (0.5–1.0)	Very coarse (1.0–2.0)	Very fine (2.0–4.0)	Fine (4.0–8.0)	Medium (8.0–16.0)
ARIKAREE FORMATION											
Profile 1											
[Near Whitman, Wyo., between sec. 8, T. 34 N., R. 60 W. and sec. 5, T. 33 N., R. 60 W. Measured by D. A. Morris]											
1	145	5	5.8	42.8	38.9	5.1	1.8	0.6			
2	145	6	8	37.4	40.8	7.4	.4	0			
3	265	6.5	7	37.7	34.2	12.2	2	.4			
4	445	4.5	31	43.5	17	3.6	.2	.2			
WHITE RIVER GROUP (BRULE FORMATION)											
6	665	25.0	39.4	6.6	11.2	17.4	0.2	0.2			
ARIKAREE FORMATION											
Profile 2											
[Along old highway between Lusk and Hat Creek, Wyo., measured in secs. 24, 25, 36, T. 34 N., R. 63 W., sec. 31, T. 34 N., R. 62 W., and sec. 6, T. 33 N., R. 62 W.]											
11	0	4	4.8	49.6	35.6	5.6	0.4				
12	20	5	19	54	14.4	3.2	4.4				
13	70	4.6	30.2	47	12.4	5.8					
14	140	4.1	6.7	13.9	24.1	21.5	15.1	14.6			
15	200	4.2	16.2	46.6	26.4	6.6					
16	240	6.5	11.5	61.4	19.4	1.2					
17	260	5.2	24	47	17	6.8					
18	270	3.9	12.5	34	36	13.6					
19	295	3.8	7.8	78.2	10	.2					
20	320	4.3	17.8	31.4	32.2	13.3	1				
Profile 3											
[Along highway between Manville and Lance Creek, Wyo., measured in secs. 2, 11, 12, T. 33 N., R. 65 W.]											
21	0	3	15	52.4	21.6	8					
22	30	3.5	13.7	48.8	25.2	8.8					
23	50	3.5	4.9	42.8	40.8	8					
24	240	3.3	6	24.3	32.7	18.3	7.8	4.2	2.5	0.8	0.1
25	330	4.2	11.9	48.3	24.3	5.5	1.6	2.3	1.7	.2	
26	330	3.5	3	25.2	27.5	16.8	11.5	8	3	1.5	
27	440	5	5	44.8	35.2	10					
28	450	4.2	28.6	50.8	13.2	3.2					
29	460	5.4	11.8	32.4	25.2	11.2	4.8	9.2			

small. Water levels in thick consolidated sediments, such as the Arikaree Formation, that obtain recharge principally from direct infiltration of precipitation may be affected only after several exceptionally wet years or a long period of drought. Fluctuations occur slowly and are generally small.

The regional westerly dip of strata in the northern part of Niobrara County produces widespread artesian conditions. Many of the aquifers consist of relatively permeable sandstone alternating with nearly impermeable claystone and siltstone. Water entering the more

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TABLE 5.—*Hydrologic properties of samples of rocks from White River Group and Arikaree Formation of Tertiary age in Niobrara County*

Sample	Depth (feet below top of section)	Specific retention [1]	Porosity [1]	Specific yield [1]	Coefficient of permeability gal per day per sq ft [2]		
					Vertical [3]	Horizontal [3]	Repack
ARIKAREE FORMATION							
Profile 1							
[Near Whitman, Wyo., between sec. 8, T. 34 N., R. 60 W. and sec. 5, T. 33 N., R. 60 W. Measured by D. A. Morris]							
1	145				80		
2	145				20		
3	265				80		
4	445				.003		
5	585				.002		
WHITE RIVER GROUP (BRULE FORMATION)							
6	665				0.0007		
7	821				.03		
8	906				.0002		
WHITE RIVER GROUP (CHADRON FORMATION)							
9	980				0.001		
10	1,000				.002		
ARIKAREE FORMATION							
Profile 2							
[Along old highway between Lusk and Hat Creek, Wyo., in sec. 24, 25, 36, T. 34 N., R. 63 W.; sec. 31, T. 34 N., R. 62 W.; and sec. 6, T. 33 N., R. 62 W.]							
11	0	12.4	39.2	26.8	2	2	41
12	20	17.6	44	26.4	1	1	
13	70	18.1	40.2	22.1	.05	.4	
14	140	11.5	31.6	2.01	.9	2	
15	200	18.2	33.5	15.3	.6		
16	240	10.2	43	32.8	11	21	18
17	260	16.9	33.1	16.2	.07		9
18	270	5.2	5.2		.005	.006	
19	295	9.9	54	44.1			42
20	320	19.9	33.5	13.6	.5	1	7
ARIKAREE FORMATION							
Profile 3							
[Along highway between Manville and Lance Creek, Wyo., in secs. 2, 11, 12, T. 33 N., R. 65 W.]							
21	0	25.7	41.6	15.9	2	2	20
22	30	30.8	40.5	9.7	.4	.5	
23	50	26.6	37	10.4	1	.9	50
24	240	15	18.3	3.3	2		42
25	330	8.1	53.7	45.6	2		
26	330	4.7	44.8	40.1			46
27	440	7.5	36.7	29.2	6		
28	450	16.8	40.6	23.8	1		
29	460	6.1	16.2	10.1	.005		21

[1] Percent of volume of material.
[2] At 60° F.
[3] Undisturbed sample.

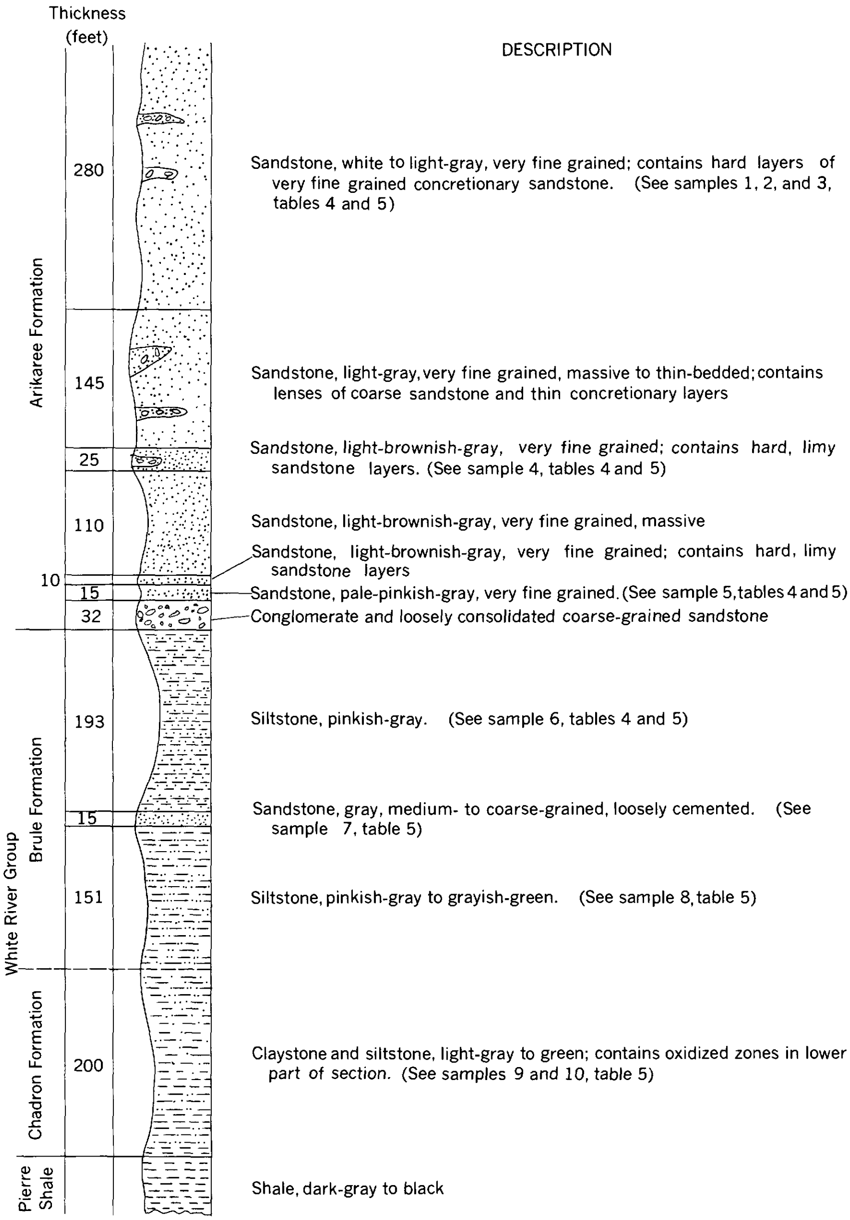

FIGURE 12.—Stratigraphic section of rocks of Tertiary age measured near Whitman, Wyo., between sec. 8, T. 34 N., R. 60 W., and sec. 5, T. 33 N., R. 60 W. Adapted from Babcock and Keech (1957, pl. 1.)

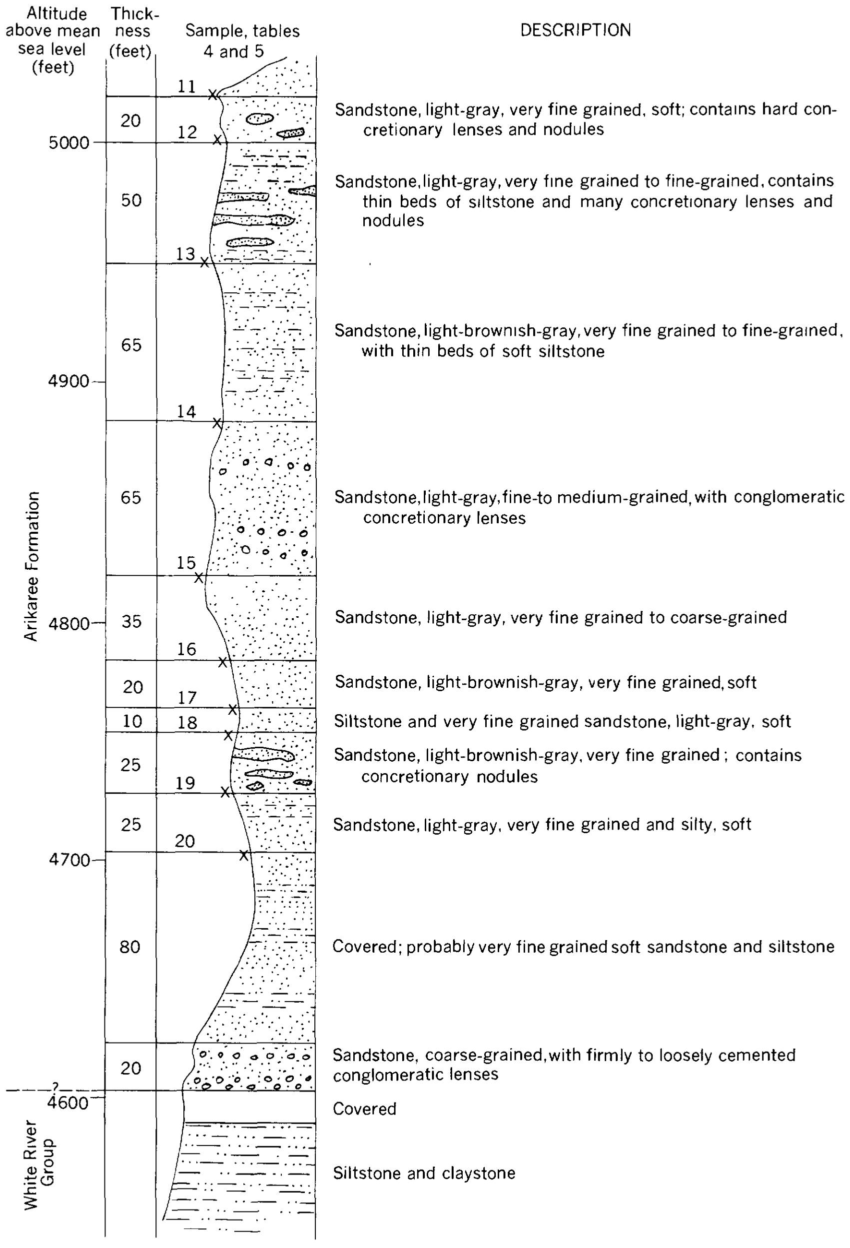

FIGURE 13.—Stratigraphic section of the Arikaree Formation measured along old highway from Lusk to Hat Creek in secs. 24, 25, 36, T. 34 N., R. 63 W.; sec. 31, T. 34 N., R. 62 W.; and sec. 6, T. 33 N., R. 62 W.

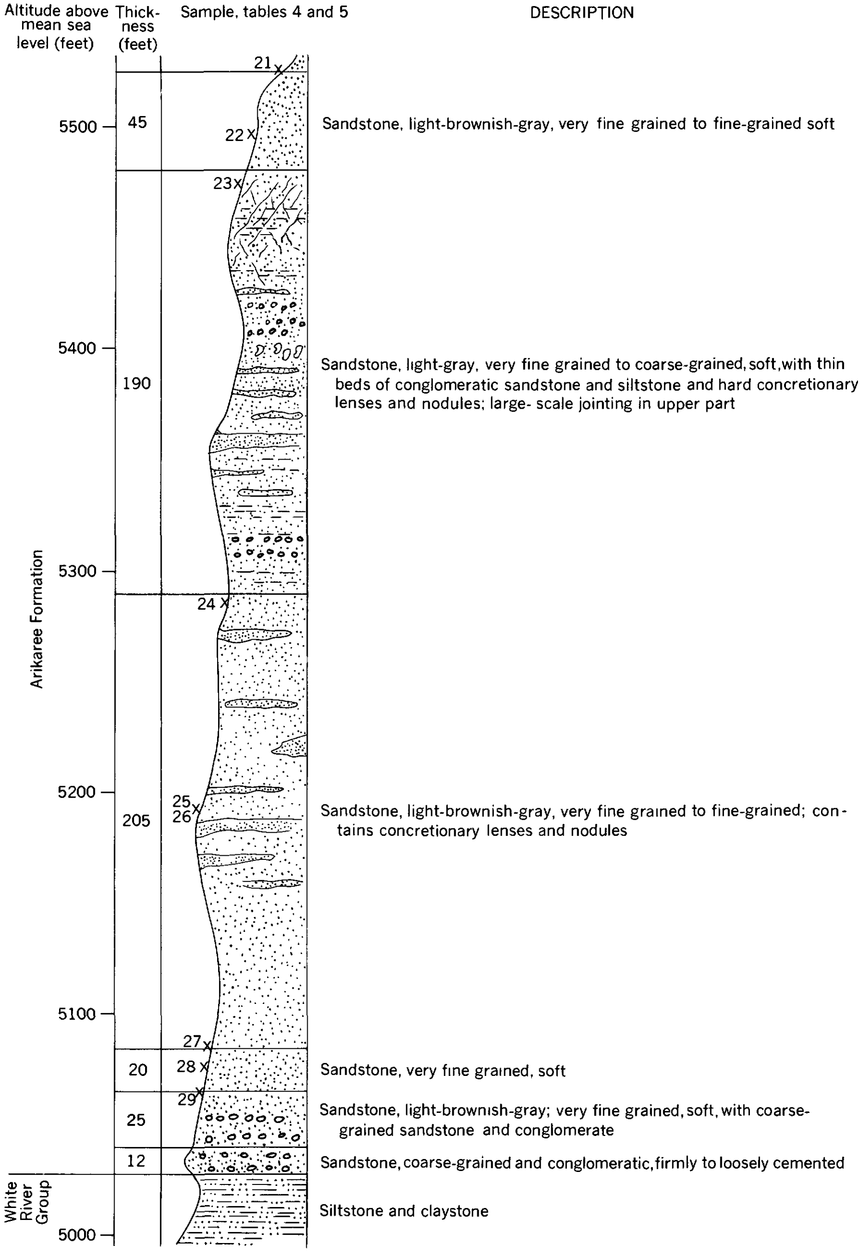

FIGURE 14.—Stratigraphic section of the Arikaree Formation measured along highway from Manville to Lance Creek in secs. 2, 11, 12, T. 33 N., R. 65 W.

permeable beds in areas of outcrop moves by gravity down the dip of the beds between the confining layers. The water is under artesian pressure and rises in wells that penetrate water-bearing beds.

TABLE 6.—*Results of pumping tests on wells*

Well	32-62-17cd	32-63-2cc	32-63-33bb	32-64-24da	34-62-29cd	38-63-30cd1
Water-bearing formation	Arikaree	Arikaree	Arikaree	Arikaree	Arikaree	Alluvium
Date of test	Nov. 1958	June 1959	Nov. 1957	June 1960	Nov. 1957	Mar. 1960
Duration of pumping...hr	96	115	16	72	17	24
Average rate of discharge gpm	730	370	160	[1] 650	195	295
Drawdown at pumped well ft	47.4	10.4	20.2	2.8	[2] 30	36.1
Specific capacity of pumped well...gpm per foot of drawdown	15	36	8	230	6	8
Estimated saturated thickness of aquifer...ft	500	250	250	40	100	50
Percent of saturated thickness penetrated	25	50	80	30	50	100
Cofficient of transmissibility gpd per ft	32,000	77,000	8,000	------------	10,000	33,000
Average field coefficient of permeability gpd per sq. ft	64	310	30	------------	100	660
Storage coefficient	1.5×10^{-3}	2×10^{-3}	------------	------------	------------	------------

[1] Reported discharge.
[2] Measurement approximate.

DEPTH TO WATER

Depths to water in Niobrara County were determined only for that part of the area underlain by the Arikaree Formation in which water-table conditions exist and the water table is virtually continuous. The water levels in wells throughout much of the north half of the county do not coincide with the regional water table because of widespread artesian conditions, and depths to water differ greatly and often have no relation to the altitude of the land surface. The depth-to-water map (pl. 3) was prepared from water-level measurements made principally during the late summer and fall of 1958. In some areas, however, because of the inability to obtain measurements, depths are necessarily inferred. Also, local differences probably exist that were not detected or were identified as anomalies on the regional water table. Depths range from land surface where stream channels intersect the water table to 343 feet below the land surface in a well drilled near the edge of the escarpment north of Lusk.

The water table is not a stationary surface but moves up or down as water is added to or withdrawn from the ground-water reservoir. Water-level fluctuations in thick and extensive aquifers such as the Arikaree Formation are small and are generally not detectable except after long periods of drought or above-normal precipitation. Ten observation wells were selected for periodic measurement of water levels to record the fluctuations of the water tabel in the Arikaree Formation and alluvial deposits.

RECHARGE

Ground water in Niobrara County is derived chiefly from precipitation falling directly on the land surface; lesser quantities are obtained by infiltration from streams flowing across areas of outcrop and by seepage from stock ponds and irrigation reservoirs of water diverted from the Cheyenne River and Lance Creek. In the lowland areas north of Hat Creek Breaks, most of the precipitation is diverted to surface runoff due to the low permeability of the soil, the generally impervious character of the underlying rocks, and the relative scarcity of vegetative cover. The numerous well formed stream patterns indicate large surface flows at times. The uplands in the southern part of Niobrara County, which are underlain by the more permeable Arikaree Formation, show a marked difference in the development of drainage systems. The stream channels are few and generally poorly defined. A relatively large part of the precipitation falling on the Arikaree surface, which is well covered with grass, percolates directly downward into the underlying rocks to enter the ground-water reservoir. Most of the county, however, is underlain by fine-grained rocks of low permeability, and the total amount of recharge to the ground-water reservoir, therefore, is small in proportion to the amount of water lost as surface runoff and by evaporation.

DISCHARGE

Ground water moves out of Niobrara County as streamflow derived from effluent seepage and springs, as underflow through the aquifers, as evapotranspired moisture from the land surface, and as discharge from wells. The loss of ground water to streams and underflow through water-bearing formations are the major factors contributing to the discharge of ground water in the area. Loss through evaporation and transpiration by plants is small except where the water table is at, or very close to, the land surface such as in the bottom lands along the Niobrara and Cheyenne Rivers and Lance Creek. The estimated average maximum depth from which plants can transpire ground water is less than 20 feet, and the depth from which water can be raised to the land surface by capillary action is less than 10 feet. Discharge from wells also is meager because of the small capacity of most of the pumps used. The quantity of water discharged by stock and domestic wells and from the few irrigation wells drilled in the Arikaree Formation is a small part of the total quantity of water available. The irrigation water that is not lost to evapotranspiration returns to the ground-water reservoir by downward seepage.

STREAMS

Most of the water flowing in the Niobrara River is derived from precipitation stored in the Arikaree Formation. The amount of flow as measured at the Wyoming-Nebraska State line varies with the seasons, generally being lowest during late summer, when evapotranspiration along the river is greatest, and highest in late winter and early spring, when snowmelt and spring rains increase the recharge to the Arikaree and contribute some runoff directly to the stream. Average discharges for the period of record (water years 1956–59) range from about 6 acre-feet per day during August and September to about 14.5 acre-feet during April and May. These extremes reflect the effect of evapotranspiration and precipitation on streamflow in the Niobrara River. The base flow (when no surface runoff is entering the stream and no water is being lost through evaporation) is estimated to be about 7.2 acre-feet per day at the Wyoming-Nebraska State line (Babcock and Keech, 1957, p. 10). No data are available on the quantity of ground water moving out of Niobrara County through Muddy Creek.

Very little ground water is discharged into streams in the Cheyenne River drainage basin. A few seeps and small springs occur where river channels have cut water-bearing strata, but the water is normally lost by evaporation and transpiration within a short distance. The discharge of numerous other seepage areas probably evaporates as soon as it reaches the surface. Ground-water discharge from aquifers whose outlets are buried beneath the alluvium of stream valleys is largely protected from evaporation and may contribute appreciable quantities of water to underflow in the valley fill. (See fig. 10.) Generally speaking, however, ground water discharge into streams north of Hat Creek Breaks probably is relatively small.

SUBSURFACE OUTFLOW

Most of the ground water in Niobrara County leaves the area as subsurface outflow. In the northern part of the county, water in the Fox Hills Sandstone and the Lance and Fort Union Formations generally moves westward down the dip of the beds into the Powder River structural basin. Very little ground water is transmitted through the relatively impermeable White River Group except where the strata contain interconnected fissures and fractures or extensive channel deposits. The Pierre Shale, which occupies much of the northeastern part of the county, is practically impervious to ground-water movement. In the southern part of the county, water in the Arikaree Formation, as shown by contour lines on the water table (pl. 1), moves radially from the high area north of Lusk and Manville. The direction of movement is at right angles to the contour lines. Most of the water in the Arikaree Formation moves to the north toward Hat Creek Breaks and to the southeast across the Wyoming-Nebraska State line. Smaller quantities move to the west and southwest into Converse and Platte Counties, respectively. Babcock and Keech (1957) estimated the underflow in the Arikaree Formation across the Wyoming-Nebraska State line to be between 5 million and 8 million gpd (gallons per day). The estimate was based on data obtained by two entirely different methods: (1) permeability of the aquifer × hydraulic gradient × cross-sectional area, and (2) ground-water discharge from the Arikaree into the Niobrara River.

During the present investigation, water levels were measured and altitudes were determined at more than 200 wells to determine the direction of movement of ground water through the Arikaree Formation and the slope of the water table. The water-table contours shown on plate 1 are based on the altitude of the water levels in these selected wells. The additional control used in mapping water-level contours provided a more precise definition of the shape of the water table and established the presence of some local anomalies but did not materially change the position of the contour lines established by Babcock and Keech (1957).

The results of the pumping tests, however, indicate such a wide range in the permeability of the Arikaree Formation that it is impossible to arrive at a reasonable average. (See table 6.) The permeability data probably apply only to that part of the aquifer penetrated by the well and could not be applied to the entire formation; however, the data obtained from the test on well 32–62–17cd is probably more characteristic of the Arikaree Formation as a whole than those obtained from the other wells. The well penetrates strata that seem to be typical of the major part of the Arikaree—very fine to fine-grained sandstone containing some interbedded siltstone. There is no indication that any coarser material or fractured zones were penetrated during the drilling.

The results of the pumping test at well 32–62–17cd indicates a transmissibility for the Arikaree Formation at that site to be about 32,000 gpd. This figure agrees with the estimate of Babcock and Keech (15,000 to 30,000 gpd), even though the coefficient of permeability used in the calculations for this test was somewhat greater (64 gpd per sq ft) than that used by Babcock and Keech (40 gpd per sq ft) in their calculations. However, because this well penetrates approximately the upper 25 percent of the aquifer, the specific capacity and the calculated transmissibility would probably be appreciably greater if the well penetrated the entire thickness of the Arikaree Formation. If the strata penetrated by well 32–62–17cd are representative of the Arikaree as a whole, the quantity of water moving as underflow across the Wyoming-Nebraska State line may be somewhat greater than that determined by Babcock and Keech. But, as pointed out by the authors of the underflow study, any computation of the amount of underflow in the Arikaree Formation based on information presently available is subject to certain errors. A more accurate estimate would require carefully planned test drilling to determine the thickness and character of the Arikaree Formation in the vicinity of the State line and controlled pumping tests to evaluate the permeability of the formation in this area.

EVAPORATION AND TRANSPIRATION

Records of the U.S. Weather Bureau show that the average rate of evaporation from the surface of lakes and other large bodies of water is about 44 inches per year in Niobrara County. (See Kohler and others, 1959.) In other words, nearly 4 acre-feet of water is lost each year by evaporation from an acre of free-water surface. Where such water bodies are supplied by ground-water discharge, this loss of water constitutes a draft on the ground-water reservoir. Ground water is also discharged by evaporation from land surfaces in areas where the water table is sufficiently close to the land surface. The height to which soil capillarity will raise water above the water table depends upon the texture of the soil and is greater in fine material than in coarse. There are few extensive exposures of free-water surface in Niobrara County, except for the relatively short reach of the Niobrara River that has a perennial flow, and in only a few small areas is the water table close enough to the land surface to permit evaporation from the capillary fringe. Consequently, relatively little ground water is lost by evaporation in the report area.

Transpiration is the process by which water is extracted from the soil by plant roots and subsequently discharged into the atmosphere as vapor from leaf surfaces. Plants that obtain all or most of their water from the ground-water reservoir are called phreatophytes. In areas of dense vegetation, large quantities of ground water are consumed annually. The quantity of water used by the different species differs greatly, ranging from only a few inches per year for some plants to several feet per year for some trees. The quantity of water consumed by each species is determined principally by the depth to water, density of growth, and climatic conditions.

The climatic factors influencing the use of ground water by vegetation, as enumerated by Robinson (1958, p. 17), are temperature, relative humidity, wind movements, precipitation, length of growing season, hours of sunlight, and altitude. The element that exerts the greatest effect is temperature, because it not only controls the length of the growing season but also the rate of water use during the growing season. For example, saltgrass was found to require about twice as much water at a temperature of 70° F as at 54° F. It seems logical to assume that this general relation of increased use of water to increase in temperature holds true for all phreatophytes. However, water use may not increase with temperature at the same rate for all species.

The use of ground water by phreatophytes varies inversely with relative humidity. A low relative humidity combined with a high air temperature is conducive to a high rate of evaporation and, thus, transpiration.

The rate of evaporation is also affected by wind movement, which removes the humid air overlying a surface of evaporation and replaces it with drier air. Wind movement is therefore effective in increasing the rate of transpiration by keeping the relative humidity low next to the plant leaves.

The effect of rainfall in the growing season is to supply some of the water needs of phreatophytes and to thus reduce the draft on ground water. The plant temporarily obtains part of its supply from the increased moisture in the soil, and transpiration is reduced because of the rise in humidity and decrease in temperature generally accompanying the precipitation.

The length of the growing season and hours of sunlight, other factors being equal, directly affect the amount of ground water used by vegetation.

The effect of altitude on the consumption of ground water by phreatophytes is largely the result of its effect on temperature and length of the growing season, which generally decrease as the altitude increases. Thus, a decrease in the use of ground water by phreatophytes occurs at higher altitudes.

During this investigation, an attempt was made to determine the quantity of water consumed by cottonwood trees growing along the valley of Lance Creek between its confluence with the Cheyenne River and Lance Creek village. To estimate the total area supporting thick stands of cottonwood trees along Lance Creek, a map (R. F. Hadley, unpub. data) showing the extent of alluvial deposits in the valley of Lance Creek was used. Available aerial photographs (scale, 2 in.=1 mile) permitted an estimate to be made of the density of cottonwoods along the stream. This estimate was supported by actual field inspection of various stands of trees where the foliage cover appeared to be about 100 percent. Areas of heavy growth were measured with a polar planimeter, and the density of each area was estimated by using areas of 100 percent density as a reference. It is calculated that stands of cottonwood trees in the valley of Lance Creek, between Cheyenne River and the village of Lance Creek, occupy an equivalent of about 1,450 acres of 100 percent density.

During this investigation quantitative data were not obtained on the use of ground water by cottonwoods. Consequently, the writer had to draw on the results of studies and controlled experiments made by investigators in other areas. Estimated transpiration by phreatophytic vegetation—grasses, shrubs, and trees—is about 18 inches per year in Scotts Bluff County, Nebr. (Wenzel and others, 1946, p. 118). This figure can probably be applied to Niobrara County. The quantity used by cottonwood trees, however, is appreciably greater than the average of 18 inches for all types of vegetation. Studies made by the U.S. Bureau of Reclamation (1952) of the consumption of water by irrigated crops in the North Platte Irrigation Project of eastern Wyoming and western Nebraska show that the average use during the normal 5-month growing season, for the period of record 1926–50, was about 2 acre-feet per acre.

Data obtained from an intensive study of the use of ground water by phreatophytes growing along the Gila River in Safford Valley, Ariz., indicate that in areas of 100 percent density of foliage cover, where the depth to water ranges from 4 to about 30 feet, cottonwood trees annually transpire an estimated 6 acre-feet of ground water per acre (Gatewood and others, 1950, p. 195).

Available data suggest that deep-rooted cottonwood trees in Lance Creek valley use appreciably more ground water per unit area of 100 percent density than field crops grown on the North Platte Project and somewhat less than the amount estimated for the cottonwoods used in the Safford Valley study. Although 6 acre-feet per year is probably a more realistic rate of consumptive use than 2 acre-feet per year, the conservative value of 3 acre-feet was used in computing the quantity of ground water transpired annually by cottonwood trees in the valley of Lance Creek. Therefore, if the draft on the ground-water reservoir is assumed to be 3 acre-feet per acre per year, the annual consumption of ground water by 1,450 acres of cottonwoods of 100 percent density is about 4,350 acre-feet. This consumption of water is equivalent to about 12 acre-feet, or nearly 4 million gpd. If it is further assumed that most of this discharge occurs during the growing season (normally about 5 months), the draft on the ground-water reservoir during the summer months, when water is in greatest demand, may exceed 20 acre-feet per day.

Stands of cottonwood trees are of value, both economically and esthetically, to the ranches and farms occupying the valleys of Lance Creek and Cheyenne River. The trees serve as windbreaks, furnish shelter for livestock from winter storms and summer heat, and aid in retarding surface runoff and resulting land erosion. They also provide a pleasant contrast to the otherwise bleak and generally treeless terrain. In some areas, however, dense growths of cottonwoods could probably be thinned appreciably without reducing their economic value. The elimination of unnecessary trees would reduce the draft on the ground-water reservoir and thus result in a generally higher water table in the alluvial deposits. In some areas, if the water table were raised only a few inches, it is probable that perennial flows might occur in some reaches of stream channels, which at the present time are dry during much of the year. For example, R. F. Hadley (oral commun. 1961) noted that many ephemeral streams in this area begin to flow shortly after the first killing frost in the fall and continue to flow until the start of the growing season in late spring or early summer. Transpiration by plants does not cease entirely during the nongrowing season, but the rate is greatly reduced.

A higher water table would result in the discharge of larger quantities of ground water to streams and thus provide additional surface water for irrigation and stock watering. The decreased depth to water would probably promote a heavier growth of alfalfa and native grasses, especially in areas where these plants no longer had to compete with cottonwood trees.

The rate of discharge of ground water to the atmosphere by evaporation from water and soil surfaces will increase appreciably as the water table rises. In most areas, however, evaporation loss would be confined principally to stream channels, where the water table rises above the streambed or sufficiently close to the surface to permit evaporation from the capillary fringe. The total area thus affected would be relatively small, and the discharge of ground water by evaporation would probably be proportionately low in comparison with that discharged by transpiration.

RECOVERY OF GROUND WATER

SPRINGS AND SEEPS

The perennial flow in the Niobrara River and in the streams rising at the foot of the escarpment of Hat Creek Breaks is supplied by many small springs and seeps in the Arikaree Formation where the stream channel has dissected the water table (depression springs) or the downward percolation of ground water is retarded by a relatively impermeable bed (contact springs). Springs and seeps occur also in the Fox Hills Sandstone and the Lance and Fort Union Formations, generally at the contact between permeable and relatively impervious beds. Water issuing from springs and seep areas is chiefly used for watering livestock. Few attempts have been made to develop springs and conserve the water, and unused water is soon lost to vegetation and evaporation.

WELLS

Drilled wells supply water for most stock and domestic use in Niobrara County; a few dug wells serve where the water table is sufficiently close to the surface. All irrigation and industrial supplies and most public supplies are obtained from drilled wells. The wells are generally cased with steel pipe ranging in diameter from 2 inches for stock wells to a reported 30 inches for one irrigation well. Most wells, however, are 4 to 6 inches in diameter. In areas where the walls of the well stand without caving, only the upper part of the hole is cased to protect the pump column and cylinder or bowls. Elsewhere, properly constructed wells are cased throughout their entire length with pipe containing perforated or screened sections.

Most of the domestic and stock wells in the area are equipped with cylinder pumps powered by wind, gasoline, or electricity. Some farms and ranches have installed electricially operated jet pumps for the house supply. Irrigation and public supply wells are generally equipped with turbine pumps powered by electric motors or gasoline engines.

UTILIZATION OF GROUND WATER

At present (1962), most of the ground water developed in Niobrara County is for stock and domestic use. No attempt was made to inventory all stock and domestic wells in the county; instead, the collection of data was confined principally to areas where information was most needed. All pertinent data on the wells inventoried during the investigation are given in table 9, and the locations of the wells are shown in plate 1.

DOMESTIC AND STOCK SUPPLIES

Although domestic and stock wells develop most of the ground water used in Niobrara County, their combined yield in most areas is only a small part of the total amount of available ground water. The discharges of the small-capacity pumps have little effect upon the amount of water in storage in the ground-water reservoir, except where the water-bearing material is of small extent and thickness and where the amount of water available for recharge is small. It is impossible to estimate from available data the quantity of water used annually for stock and domestic supplies. In some areas, notably along the base of Hat Creek Breaks, seeps and springs provide perennial supplies of ground water for stock use.

In some parts of the county, especially in the northeast part, the chemical quality of the ground water limits its domestic use; however, the water is generally suitable for livestock consumption.

PUBLIC AND INDUSTRIAL SUPPLIES

The community of Lusk (population 1,847 in 1960) operates the largest public supply system in Niobrara County. The system is supplied by five drilled wells that reportedly produced 112 million gallons of water from April 1, 1958, to April 1, 1959. This is about 310,000 gpd, or an average of about 215 gpm. Except for the relatively small amount of water used by one oil refinery, there is little industrial consumption of water. The wells range from 130 to 180 feet in depth, and all obtain water from the Arikaree Formation. The water is low in mineral content but hard.

Manville, with an estimated population of 150, consumed about 6½ million gallons of water during 1959. An additional 14,156,000 gallons were sold for use in highway construction during the year. The two community wells are 185 and 200 feet deep and penetrate 145 to

160 feet of saturated Arikaree Formation. The water is of similar quality to that at Lusk.

The village of Lance Creek obtains water from a large diameter well dug in the alluvium of Lance Creek valley. The well is 11 feet deep and at the time of measurement contained 4.65 feet of water. The water level fluctuates with the flow in Lance Creek and generally becomes very low during the summer. The well supplied an estimated 1,300,000 gallons of water in 1959 to the eight residences, bar, cafe, and service station. The water, although soft, is of poor quality for domestic use.

The Continental Oil Co. and Ohio Oil Co. at Lance Creek oil field operate a joint water supply system for industrial needs and domestic use of resident employees. The water is supplied by three wells drilled into the Inyan Kara Group about 5 miles south of Lance Creek village. The wells range in depth from 265 to about 500 feet and are reported to yield 60 to 300 gpm each by pumping. The water is under artesian pressure, and one of the wells flowed with a low head when completed. During the water year, September 1958 to September 1959, about 62,300,000 gallons of water was pumped and piped to the oil field; however, most of the water was consumed in industrial processes and by lawn and garden irrigation. The water is of good quality though hard. The Chicago and North Western Railway formerly had wells at Van Tassell, Lusk, and Manville, but since the advent of diesel locomotives these wells have been abandoned or put to other use. Small quantities of ground water are pumped for industrial use at the Mule Creek oil field.

IRRIGATION SUPPLIES

The study of the water resources of Niobrara County was made principally to determine the availability of ground water for irrigation. During the investigation, 22 irrigation wells were inventoried; 6 of these were tested by pumping to determine the yield characteristics of the wells and, where possible, the hydrologic properties of the aquifer. Statistical data on the wells are contained in table 7 and the results of the pumping tests are given in table 6. The fact that most of the wells were drilled in the late 1950's indicates that the irrigation potential of some areas has become known only recently. Most of the irrigation water used in Niobrara County is pumped from the Arikaree Formation; smaller quantities are obtained from the alluvial deposits of Lance Creek and Cheyenne River. The more productive wells are generally in the vicinity of Lusk and along the Niobrara River valley to the east where water levels are at relatively shallow depths.

The quantity of water pumped during 1959 by the eight irrigation wells that account for the major draft on ground water in the Arikaree Formation was calculated from records of power consumption sup-

TABLE 7.—*Records of irrigation wells drilled in Niobrara County*

Well number: See text for description of well-numbering system.
Depth of well: Measured depths are given in feet and tenths below land surface; reported depths are given in feet.
Finish: G, gravel packed; P, perforated; Oh, open hole.
Water level: Measured depths to water are given in feet and hundredths, reported depths are given in feet.
Yield: M, measured; R, reported.
Drawdown: Measured drawdowns given in feet and tenths; reported drawdowns in feet.
Remarks: Ca, chemical analysis in table 8; L, drillers log in table 10.

Well	Owner	Year drilled	Depth of well	Diameter of well (inches)	Cased to (feet)	Finish	Water level (feet below land surface)	Date measured	Yield (gpm)	Draw-down (feet)	Specific capacity (gpm per foot of draw-down)	Remarks
Arikaree Formation												
31-61-4ba	J. Christian	1933	158	8	10	Oh	0	June 1959	150R			Ca.
32-61-32bc	do	1935	200	8	10	Oh	0	Nov. 1958	500R	10	50	
62-17cd	Mrs. R. Larson	1952	114.5	18	60	G, P	16.52	do	730M	47.4	15.4	See pumping-test data, table 6; L.
20aa	do	1954	130	12	10	Oh	14.82	do	1,100R			Discharge of pump probably somewhat less than reported yield.
20ab	L. Christeson, N. Larson.	1952	127	18	96	Oh	22.38	do	750R	60	12.5	
20bd	do	1954	131	12	21	Oh	40.01	do	950R	30	31.7	Reported depth 150 ft.

63-2cc	L. Schaefer	1952	179	24	20	Oh	44.59	June 1959	370M	10.4	35.6	See pumping-test data, table 6; L.
8dd	F. Christian	1955	122	18	18	Oh	18.75	May 1960	500R	40	12.5	Reported depth 135 ft.
11bb	L. Schaefer	1952	184	24	20	Oh	44.03	June 1959	500R			Reported depth 300 ft.
33bb	E. Quigley	1949	205	18	205	G, P	40.89	Nov. 1957	160M	20.2	7.9	See pumping-test data, table 6; Ca.
64-18bd	N. Lamb	1949	110	26	12	Oh	66.10	Oct. 1958	1,000R	14	71.5	Discharge of pump probably somewhat less than reported yield, L.
24da	I. Lamb	1955	59	18	10	Oh	45.43	Sept. 1959	650R	2.8	234	Discharge of pump probably somewhat less than reported yield.
25da	Johnson Sisters	1959	82	16		G, P	19.31	do	350R	45	8	L.
65-1cb	A. Knudsen	1950	108	8	12	Oh	21.38	do	350R	14	25	
34-62-29ca	R. Roberts	1955	80	15	80	P	24.91	Oct. 1958	600R			
29cd	do	1950	80	12	80	P	30.10	do	195M	30.0±	6.5±	See pumping-test data. table 6; Ca.
Alluvium												
38-63-22ab	T. Jones		39	18	39	G, P	10	Oct. 1959	300R	25	12	
$30cd_1$	Johnson Sisters	1959	58.2	16	64	G, P	6.69	Mar. 1960	295M	36.1	8.2	See pumping-test data, table 6; L.
$30cd_2$	do	1959	44.6	16	46	G, P	7.55	do	250R	22	11.4	Reported depth 46 ft, Ca.
$30cd_3$	do	1959	68	14	68	G, P	7.41	do	280R	50	5.6	
64-22aa	do	1959	39	16	39	G, P	19.20	June 1959	170R	16	10.6	L.
40-64-1dc	G. Hansen	1959	21	28	21	P	8.11	Sept. 1959	250R	10	25	Ca.

plied by the office of the Niobrara Electrification Association and by distributors of butane gas, and from measurements of the power input and well discharge made during the investigation. The total pumpage of water for irrigation from these wells for the year is estimated to be about 700 acre-feet. An additional 100 acre-feet of water might have been pumped from the Arikaree Formation by the eight other irrigation wells operated on a small scale during the year.

Five of the irrigation wells inventoried are in the alluvial deposits of Lance Creek, and one is in the alluvium of the Cheyenne River. The yields of these wells range from a reported 170 gpm to 295 gpm measured during a pumping test. No attempt was made to estimate the annual pumpage from alluvial deposits, but it is probably very small.

POSSIBILITIES OF DEVELOPING ADDITIONAL LARGE SUPPLIES OF GROUND WATER

The development of large supplies of water adequate for irrigation use is unlikely except from the Arikaree Formation and from alluvial deposits in the valleys of Lance Creek and the Cheyenne River. Yields adequate for small-scale irrigation might be obtained from deep wells drilled in the Fox Hills Sandstone and the Lance and Fort Union Formations in some areas, but pumping lifts would probably be excessive for most purposes.

ARIKAREE FORMATION

Sixteen irrigation wells drilled in the Arikaree Formation penetrate saturated strata ranging in thickness from 14 to 200 feet; the average is about 96 feet. The yields of these wells reportedly range from 150 to 1,100 gpm; however, only two wells are reported to yield less than 500 gpm, and the average is about 650 gpm. Pumping tests made on four of the wells indicated that specific capacities of the wells ranged from 7.9 to 35.6 gpm per foot of drawdown. One well drilled in a fractured zone had a drawdown of ony 2.8 feet after pumping 7 hours at a reported average discharge of 650 gpm. The more productive wells are uncased except for surface pipe.

The Arikaree does not have a uniform permeability because of local cemented zones and silty beds. The yield of water is influenced by the number and extent of these relatively impermeable beds penetrated in drilling. At most places, however, the Arikaree should be capable of yielding at least 5 gpm for each foot of drawdown, and at many places, particularly from deeper wells, yields of perhaps 30 gpm per foot of drawdown could be pumped. In areas where the formation contains fractures and fissures much larger yields might be obtained.

To the north and south of the shallow water-table area underlying the Niobrara River valley and along the pediment at the base of Hat

Creek Breaks, the higher pumping lifts or unfavorable topography limit the economic development of irrigation water. High pumping costs and small irrigable acreage restrict the crops that can be grown profitably to those having high cash values. Before irrigation wells are constructed in these areas, test holes should be drilled to determine the depth to water and the quantity available.

At present (1962), there is no evidence that discharge by wells has affected the amount of ground water in storage in the Arikaree Formation and the position of the water table. Undoubtedly much larger quantities of water could be pumped from existing irrigation wells or from additional wells without noticeably affecting water levels or the amount of discharge of ground water into the Niobrara River.

ALLUVIAL DEPOSITS

Several attempts have been made to develop irrigation supplies in the alluvium of Lance Creek and the Cheyenne River to supplement water derived from sporadic runoff in the streams. Diminished flow in the streams in recent years has spurred the development of ground water for irrigation; however, at the time of this investigation little systematic exploration has been undertaken. Specific capacities of six irrigation wells drilled in the valleys of Lance Creek and Cheyenne River are given in table 7.

Drilling in alluvial deposits has met with varying success; yields reportedly range from 170 to 300 gpm. Wells of equal or greater capacity can probably be developed in other areas where extensive deposits of saturated sand and gravel are present. No evidence is present at the surface to indicate the position of the more permeable deposits; so, the only effective method of locating these deposits is by test drilling.

The amount of water that can be withdrawn from alluvial deposits without causing excessive permanent lowering of the water table depends upon the capacity of, and the amount of recharge to, the ground-water reservoir. If water is pumped from the ground-water reservoir at an average rate greater than the average rate of recharge, the water level declines and the supply is eventually depleted. If the recharge during the nonpumping period replaces the pumped water, the discharge can exceed the average rate of recharge for short periods of time without causing serious lowering of the water level. In this way the aquifer could be used as a storage reservoir, to which water could be added or from which water could be withdrawn. To develop the maximum amount of ground water from the valley fill, water must be pumped in excess of the rate of recharge during the growing season. This water will normally be replaced during the nongrowing season, when the rate of recharge exceeds the discharge from the aquifer.

CHEMICAL QUALITY OF THE GROUND WATER

By T. Ray Cummings

This section describes the chemical quality of ground water from each of the geologic sources discussed in this report and evaluates its suitability for domestic, municipal, irrigation, and livestock uses. Conclusions on the quality of ground water available in Niobrara County are based on the chemical analyses of 41 water samples obtained from 8 different stratigraphic units. The data were collected by the U.S. Geological Survey, and analyses are tabulated in table 8.

Table 8.—*Chemical analyses of ground*

[Results in parts per million except as indicated.

Well	Depth (Feet)	Approximate yield (gpm)	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
Inyan Kara										
34-64-9db	145	10	Dec. 4, 1959	47	9.8	0.01	53	6.8	56	11
34-65-1bc	265	220	Oct. 13, 1959		9.6	.03	21	2.3	57	6.6
35-65-4b [1]		Not known	Not known						1,300	
5d [1]	3,400–	do	do						834	
36-65-35c [1]	3,700	do	do						731	
37-63-25a [1]		do	do				15	7	520	
39-60-19al [1]	800–	do	do						304	
39-61-14a2 [1]	1,200	do	do						336	
14a3 [1]		do	do						338	
Pierre										
35-65-15ad	80	5	Dec. 3, 1959		29	0.01	61	18	123	11
Fox Hills										
37-63-13cb	300+	5	Dec. 1, 1959		12	0.20	46	37	325	4.1
38-62-17aa	110		do	45	8.0		14	3.2	1,040	2.9
38-63-23dc	105	5	do	42	9.8	.14	37	13	598	4.5
Lance										
36-65-14db	73	5	Dec. 2, 1959		15	0.03	89	30	221	12
37-65-7bb	128	3	do	53	6.7	8.6	12	1.5	432	1.7
38-63-30cc	70	10	Dec. 1, 1959		22	.33	99	32	301	7.6
39-65-21cc	280	5	do	44	17	.01	47	3.5	922	4.0
21dc	250	5	do		20	.04	29	11	574	3.1
40-63-33bb	400	3	do		9.9	.07	4.5	.2	596	2.0
40-64-1aa	112	5	do	45	9.5	.02	13	2.6	675	2.3
Fort Union										
36-66-15ba	275	5	Dec. 2, 1959	46	7.6	0.42	14	4.9	486	3.5
37-66-10cc	290	5	do		11	.13	136	88	474	6.4
38-66-4ad	213		do	56	9.5	6.9	4.5	1.2	456	3.8
39-66-10aa	132	5	Dec. 1, 1959	36	12	.68	151	73	333	8.2

See footnote at end of table.

Although analyses of some samples are more comprehensive than others, all the analyses provide useful information about the chemical quality of the water.

The Arikaree Formation and the White River Group yield water of the best general quality in Niobrara County. Water from both formations has some undesirable characteristics, but these characteristics are not necessarily the same for the two formations. The Inyan Kara Group, the Pierre Shale, and the Lance Formation will probably yield water of fair to good quality for most purposes.

waters, Niobrara County, Wyo.

Analyses by U.S. Geol. Survey]

Bicarbonate (HCO_3)	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
							Calculated	Residue at 180° C	Calcium, magnesium	Noncarbonate					
Group															
274	0	55	10	0.3	13	0.07	350	351	160	0	41	1.9	565	7.5	7
210	0	15	2.8	.5	.1	.05	218	218	62	0	64	3.1	368	7.4	----
2,880	----	----	324	----	----	----	----	3,040	----	----	----	----	----	----	----
2,120	----	----	52	----	----	----	----	1,930	----	----	----	----	----	----	----
1,280	60	86	252	----	----	----	----	1,760	----	----	----	----	----	----	----
795	----	50	350	----	----	----	----	1,340	----	----	----	----	----	----	----
315	59	233	44	----	----	----	----	795	----	----	----	----	----	----	----
380	37	298	32	----	----	----	----	890	----	----	----	----	----	----	----
620	37	63	70	----	----	----	----	813	----	----	----	----	----	----	----
Shale															
344	0	203	15	0.4	1.9	0.14	631	644	224	0	53	3.6	950	7.6	6
Sandstone															
528	0	543	9.0	0.2	5.9	0.27	1,240	1,240	268	0	72	8.6	1,800	7.7	6
380	0	1,970	23	.6	.2	.48	3,250	3,290	48	0	98	65	4,440	7.8	7
380	0	1,120	11	.3	2.6	.31	1,980	2,000	144	0	90	22	2,780	7.7	6
Formation															
384	0	393	80	0.5	0.4	0.23	1,030	1,040	347	32	57	5.2	1,540	7.5	----
515	0	523	6.7	1.5	6.9	.18	1,250	1,250	36	0	96	31	1,880	7.8	----
548	0	553	9.9	.8	.8	.10	1,300	1,310	379	0	63	6.7	1,840	7.4	----
676	0	1,500	15	.2	13	.14	2,850	2,900	132	0	94	35	3,940	7.6	----
666	0	752	7.4	.4	7.3	.12	1,730	1,740	116	0	91	23	2,470	7.6	----
1,370	0	.3	110	5.4	.2	.62	1,400	1,430	12	0	99	75	2,270	7.8	----
1,050	0	611	6.5	.7	5.1	.17	1,840	1,870	43	0	97	45	2,720	7.7	----
Formation															
558	0	583	3.7	0.8	8.7	0.13	1,390	1,400	55	0	95	28	2,070	7.6	----
744	0	1,050	18	.9	2.9	.15	2,150	2,190	701	91	59	7.8	2,900	7.0	----
398	37	562	20	.7	2.7	.06	1,300	1,310	16	0	98	50	1,970	8.6	----
806	0	775	8.8	.0	11	.09	1,770	1,780	676	15	51	5.6	2,380	7.6	6

TABLE 8.—*Chemical analyses of ground*

Well	Depth (Feet)	Approximate yield (gpm)	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
White River										
34-61-6cd	9	6	Sept. 14, 1957	58	54	3.3	8.5	0.2	121	9.6
17ca	50	5	Oct. 2, 1957	-------	60	.01	73	2.9	62	26
34-65-4cb	1,615	-------	Oct. 12, 1957	55	9.2	.11	3.2	.0	131	3.4
35-62-15ac	105	5	Sept. 11, 1957	-------	49	.06	6.5	.2	167	10
35-64-26cb	126	5	Dec. 4, 1959	-------	31	5.7	26	3.6	124	11
Arikaree										
31-61-4ba	158	150	Oct. 7, 1952	49	54	0.01	50	13	10	7.6
31-66-26da	-------	5	Sept. 29, 1957	51	54	.48	62	6.7	19	8.6
32-62-28ad	110	5	Dec. 2, 1959	44	57	.01	102	21	14	7.8
32-63-7bb1	172	450	Apr. 8, 1958	51	57	.00	54	7.3	11	5.2
32ad	180	-------	Dec. 2, 1959	51	-------	-------	-------	-------	-------	-------
33bb	205	160	Nov. 12, 1957	50	56	.00	83	17	17	7.8
32-65-1bc2	200	125	Dec. 2, 1959	37	54	.01	55	15	18	10
34-62-29cd	80	195	Nov. 14, 1957	-------	60	.05	51	10	8.9	7.5
Allu-										
35-60-27ba	15	5	Nov. 12, 1959	-------	29	3.1	95	22	176	17
35-65-3cc	11	16	Nov. 11, 1957	-------	22	2.7	102	31	230	15
38-63-30cd2	46	250	Dec. 1, 1959	-------	20	.30	60	25	306	7.7
40-64-1dc	21	250	do	41	7.7	1.9	37	42	527	10

[1] Crawford (1940). Analyses from oil test holes drilled prior to 1940 and not located on geologic map.

REPORTING OF DATA

In presenting chemical-quality data, the concentrations of dissolved chemical constituents are generally expressed in parts per million (ppm). A part per million is one unit weight of a constituent in one million unit weights of water. Frequently, it is more convenient to work with equivalents per million (epm) when studying special problems of water chemistry and the effects of irrigation waters on soils. An equivalent per million is one unit chemical combining weight of a constituent in one million unit weights of water and is calculated by dividing the concentration of the constituent in parts per million by its chemical combining weight. For convenience in making this conversion, the reciprocals of chemical combining weights of the most commonly reported constituents (ions) are given in the following table:

Cation	*Factor*	*Anion*	*Factor*
Calcium (Ca^{+2})	0.04990	Bicarbonate (HCO_3^{-1})	0.01639
Magnesium (Mg^{+2})	.08224	Carbonate (CO_3^{-2})	.03333
Sodium (Na^{+1})	.04350	Sulfate (SO_4^{-2})	.02082
Potassium (K^{+1})	.02558	Chloride (Cl^{-1})	.02820
		Fluoride (F^{-1})	.05263
		Nitrate (NO_3^{-1})	.01613

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Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Calculated	Dissolved solids: Residue 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
Group															
307	0	25	12	1.2	3.9	0.12	387	383	22	0	88	11	553	8.0	-----
268	0	44	57	.4	22	.08	479	491	194	0	37	1.9	720	7.7	-----
318	0	2.0	9.8	5.0	.1	.37	320	324	8	0	96	20	536	7.7	-----
360	0	40	33	1.9	10	.28	495	500	17	0	92	18	746	8.0	-----
386	0	25	11	.6	.4	.06	428	428	80	0	74	6.0	670	7.4	-----
Formation															
214	0	16	5.0	0.2	10	0.01	271	276	178	3	10	0.3	370	8.1	-----
224	0	24	9.0	.2	14	.04	308	302	182	0	18	.6	444	7.6	-----
270	0	21	29	.4	102	.06	487	535	342	121	8	.3	730	7.3	-----
219	0	9.9	3.0	.3	3.9	-----	260	234	165	0	12	.4	370	7.5	-----
-----	-----	-----	-----	-----	49	-----	-----	-----	-----	-----	-----	-----	626	-----	-----
294	0	29	11	.3	46	.08	412	412	278	37	11	.4	604	7.7	-----
237	0	26	10	.5	5.1	.07	311	317	198	4	16	.6	477	7.2	-----
218	0	10	4.0	.3	3.8	.03	263	261	169	0	10	.3	371	7.7	-----
vium															
429	0	348	14	0.4	0.5	0.23	915	922	326	0	52	4.2	1,330	7.1	-----
419	0	495	19	.5	.4	.29	1,120	1,140	382	38	56	5.1	1,610	7.1	-----
533	0	454	11	1.0	.4	.10	1,150	1,160	253	0	72	8.3	1.680	7.6	-----
340	0	1,080	21	.7	3.5	.11	1,900	1,920	264	0	81	14	2,670	7.5	-----

One equivalent per million of a positively charged ion (cation) will react with one equivalent per million of a negatively charged ion (anion). Because the positive and negative charges are balanced in a solution, the total equivalents per million of the common cations (calcium, magnesium, sodium, and potassium) are approximately equal to the total of the equivalents per million of the common anions (bicarbonate, carbonate, sulfate, chloride, fluoride, and nitrate).

CHEMICAL QUALITY IN RELATION TO USE

Ground water in the report area is primarily used for domestic and livestock purposes. Although ground water is used for irrigation in Niobrara County, irrigation is not as extensive as in many other parts of Wyoming. Future water-supply development in many areas will depend upon the availability of water having suitable chemical quality. In the evaluation of the suitability of a water for use, certain water-quality criteria generally accepted as valid should be considered. A discussion of these criteria follows.

DOMESTIC USE

Chemical-quality standards for water used for drinking and culinary purposes on interstate commerce carriers were established in 1914 by the U.S. Public Health Service. These standards have been revised several times, and recently an advisory committee to the U.S. Public Health Service (1961) has suggested further revision. Although these standards establish recommended allowable concentration limits for water used on common carriers, many municipal and domestic water supplies in Wyoming exceed these limits in some respects. The absence of other supplies and the high cost of treatment prevents strict adherence to suggested standards. Some of the limits on chemical constituents in drinking water are as follows:

Constituent	*Maximum allowable concentration (ppm)*	*Constituent*	*Maximum allowable concentration (ppm)*
Iron (Fe)	0.3	Fluoride (F)	[1].8–1.7
Manganese (Mn)	.05	Nitrate (NO_3)	45
Sulfate (SO_4)	250	Dissolved solids	500
Chloride (Cl)	250		

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

Hardness, a property of water familiar to many people, is principally caused by high concentrations of calcium and magnesium. Water has been arbitrarily classified in terms of hardness as follows: 60 ppm or less, soft; 61 to 120 ppm, moderately hard; 121 to 180 ppm, hard; and 181 ppm or greater, very hard.

AGRICULTURAL USE

Although investigations relating the chemical quality of water to its suitability for agricultural purposes are not numerous, guidelines generally considered reliable have been proposed (Beath, in Miller, 1956; Beath and others, 1953; Eaton, 1950; Scofield, 1936; U.S. Salinity Lab. Staff, 1954). The information in this section was extracted from the summary of the published results of these investigations; however, many supplies of water that do not meet these requirements have been used for many years for agricultural purposes.

The primary agricultural uses of water are for stock watering and irrigation. Although many chemical constituents or properties of water affect its suitability for irrigation purposes, the two main criteria for determining a suitable supply are (1) the dissolved-solids content and (2) the sodium content and its concentration relative to the calcium and magnesium concentrations. Also, concentrations of bicarbonate, boron, and selenium are detrimental under certain conditions, which are described later.

The application of water having a high dissolved-solids content (salinity) tends to upset the salt balance of the soil. The use of saline water in the absence of a favorable salt balance increases the osmotic pressure of the soil solution and thus results in a retardation of plant growth. As a rule, the higher the salinity of a water, the less suitable the water is for use. Because the salinity of a water is directly related to its specific conductance, an easily measured property of water, the following classification has been established. The salinity hazard for a water having a specific conductance between 100 and 250 micromhos per centimeter is classed as low; between 250 and 750, medium; between 750 and 2,250, high; and greater than 2,250, very high (U.S. Salinity Lab. Staff, 1954).

If an irrigation water containing a high concentration of sodium relative to the calcium and magnesium concentration is used, sodium tends to replace the calcium and magnesium adsorbed on the soil colloids. Soil colloids then tend to disperse and restrict the movement of air and water through the soil, a condition resulting in a soil of poor tilth and poor permeability. 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 hazard entailed in using water of high sodium content and is calculated as follows:

$$\mathrm{SAR}=\frac{epm\ \mathrm{Na}^{+1}}{\sqrt{\dfrac{epm\ \mathrm{Ca}^{+2}+epm\ \mathrm{Mg}^{+2}}{2}}}$$

For water whose specific conductance is 750 micromhos per centimeter, the following approximate relations between the SAR and the sodium (alkali) hazard of a water have been established (U.S. Salinity Lab. Staff, 1954):

SAR (approx.)	*Sodium (alkali) hazard*	*SAR (approx.)*	*Sodium (alkali) hazard*
0– 6	Low.	12–18	High.
6–12	Medium.	18 +	Very high.

The sodium hazard increases as the specific conductance increases, even though the SAR value remains constant. Similarly, as the specific conductance decreases, the sodium hazard decreases even though the SAR remains the same.

Bicarbonate, when present in sufficient concentration, also may make the use of water for irrigation objectionable. The carbonates of calcium and magnesium tend to precipitate, increasing the relative proportion of sodium in the soil solution. This, in effect, is the same as applying irrigation water of initially high sodium content. The harmful effects of excessive concentrations of bicarbonate are often measured and expressed as "residual sodium carbonate" (Eaton, 1950), which is equal to the concentrations (epm) of carbonate plus bicarbonate minus the concentrations (epm) of calcium plus magnesium. Water whose residual sodium carbonate value is less than 1.25 epm is probably safe, 1.25 to 2.5 epm is marginal, and greater than 2.5 epm is unsafe.

Studies by Scofield (1936) indicate that a significant reduction of crop yield may occur if water having a boron concentration as low as 0.67 ppm is used for boron-sensitive crops, as low as 1.33 ppm for semitolerant crops, and as low as 2.00 ppm for tolerant crops.

Where even small amounts of selenium are present in irrigation water, accumulation may take place in plants and vegetation in sufficient quantities to be toxic to humans and animals. Beath (in Miller, 1956) suggested the following standards:

Selenium (ppm)	*Effect*
0.00–0.10	No plant toxicity expected.
0.11–0.20	Usable, may accumulate over long periods of time.
0.21–0.50	Probably toxic accumulation in plants if conditions are favorable.
More than 0.50	Nonusable under any conditions.

The relation of the quality of water consumed to the health of livestock is not well defined, but water of very high sodium content may cause adverse effects. With respect to dissolved-solids content, the following classification has been established (Beath and others, 1953):

Classification	*Dissolved solids (ppm)*
Good	less than 1,000
Fair (usable)	1,000–3,000
Poor (usable)	3,000–5,000
Very poor (questionable)	5,000–7,000
Not advised	more than 7,000

CHEMICAL QUALITY IN RELATION TO SOURCE

In discussing the quality of water from the various aquifers in Niobrara County, only those characteristics that seem to be of special significance are mentioned. The suitability of water for present and future uses is also discussed. Figure 15 illustrates the diverse chemical quality of water from the different formations. As indicated by the diagrams, the chemical quality of water in some formations may be very variable and in others, comparatively uniform.

INYAN KARA GROUP

Chemical analyses of nine samples of water from aquifers in the Inyan Kara Group indicate that the water is generally of the sodium bicarbonate type. Results of the analyses are given in table 8. Although calcium and magnesium were not specifically determined in some of the analyses of water from the deeper wells, sufficient data are available to show that the two cations were very low in concentration. Calcium in solution probably has been replaced by sodium as a result of cation exchange with aquifer material. Water from the deeper wells also contains high concentrations of bicarbonate. The relatively high concentration of bicarbonate may have been formed

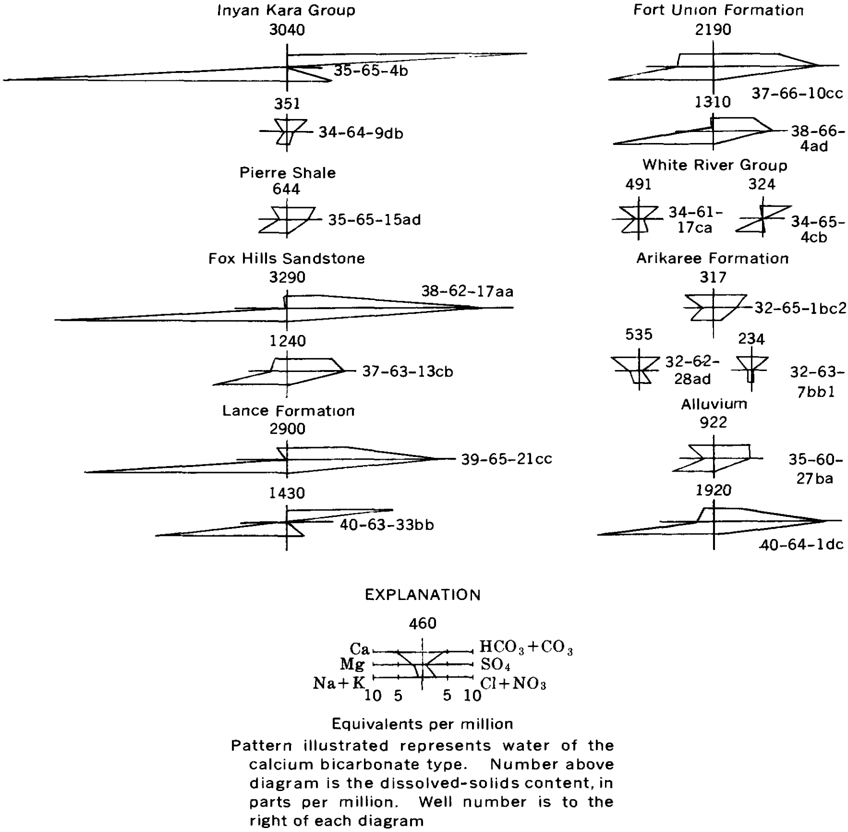

FIGURE 15.—Chemical characteristics of ground waters, Niobrara County, Wyo.

by the reduction of sulfate. In the presence of carbon or hydrocarbons and certain bacteria, sulfate may be reduced to form hydrogen sulfide and bicarbonate. The reaction is 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 suitability for domestic use of water from most of the deeper sources of the Inyan Kara Group is questionable. The high sodium and bicarbonate concentrations preclude use of the water for irrigation, even if wells of sufficient yield could be obtained. As a stock supply, the water ranges from good to poor. Analyses of water samples from wells 34–64–9db and 34–65–1bc indicate that water of good quality for most uses may be obtained at some places where the Inyan Kara Group lies at relatively shallow depths.

LANCE FORMATION

Water from the Lance Formation ranges in dissolved-solids content from 1,040 to 2,900 ppm. Sodium content exceeds 60 percent of the total cations on all but one of the analyses and is more than 95 percent on three. The low concentrations of calcium (only 4.5 ppm on one analysis) suggest some cation change. In all but one sample (well 40–63–33bb) from the Lance Formation, sulfate and bicarbonate are the dominant anions. In that sample, bicarbonate (1,370 ppm) is dominant and sulfate (4.5 ppm) is almost absent. The low concentration of sulfate indicates that reduction of sulfate is a factor in determining the chemical quality of the sample of water from well 40–63–33bb.

All but one of the wells sampled are used as domestic supplies; however, water from none of the wells meets drinking water standards of the U.S. Public Health Service (1961). Dissolved-solids content of all supplies exceed the recommended maximum of 500 ppm, and only one sulfate content is less than the recommended maximum of 250 ppm. Hardness of the water ranges from 12 ppm in well 40–63–33bb to 379 ppm in well 38–63–30cc. The water from well 38–63–30cc, in addition to being very hard, contains 0.33 ppm of iron. Water from well 37–65–7bb contains 8.6 ppm of iron. Water from well 40–63–33bb has a fluoride concentration of 5.4 ppm, which impairs its suitability for domestic use. High sodium concentrations make Lance Formation water generally unsuitable for irrigation, although some of the water might be used satisfactorily on tolerant crops under good drainage conditions. For stock purposes, this water may be regarded as fair.

FORT UNION FORMATION

Chemical analyses of four samples of water from the Fort Union Formation indicate that the formation contains a sodium sulfate type of water. The dissolved-solids content of the water ranges from 1,310 to 2,190 ppm. Hardness of the four samples analyzed ranges from 16 (soft) to 701 ppm (very hard), and iron concentrations range from 0.13 to 6.9 ppm. High iron, sulfate, and dissolved-solids contents make water from this formation generally unsuitable for domestic use. High concentrations of sodium would prevent indiscriminate use of the water for irrigation, although under proper conditions the water might be acceptable for certain crops. Except for the generally high iron concentrations, the water may be classified as fair for use as stock supplies.

WHITE RIVER GROUP

The dissolved-solids content of ground water from the White River Group ranges from 324 to 500 ppm, which is lower than that of water from the aquifers that have been discussed. Each of the five analyses represent water high in bicarbonate, and in all but one well (34–61–17ca) sodium is the dominant cation. With one exception (well 34–61–17ca), water represented by these samples may be considered as soft to moderately hard. Silica content ranges from 9.2 to 60 ppm and iron from 0.01 to 5.7 ppm. The maximum fluoride content is 5.0 ppm. Although the White River Group generally yields water of low dissolved-solids content (less than 500 ppm), some of the water from this group may prove unsuitable for domestic use because of high concentrations of iron, fluoride, or silica. Thus, each supply should be evaluated on its own merits.

Water from the White River Group should be suitable for use by livestock, except where high concentrations of iron make the water unpalatable and where the precipitation of iron may tend to clog distribution systems. Although sodium-adsorption-ratios may be expected to be high for some of the samples, a salinity hazard of no greater than medium may be anticipated.

ARIKAREE FORMATION

Water from the Arikaree Formation is of the calcium bicarbonate type. Eight analyses of water show a range in dissolved-solids content of 234 to 535 ppm. Hardness ranges from 165 to 342 ppm, high enough to class the water as hard to very hard. Water from three of the sampled wells, two of which are used for domestic supplies, had nitrate concentrations of 46, 49, and 102 ppm. Silica ranged from 54 to 60 ppm.

Water from the Arikaree Formation is suitable for irrigation and is the best supply from sources sampled in the report area. Sodium-adsorption-ratios are very low, and mineralization is moderate. As a stock supply, the water may be classified as good. As a domestic supply, however, the hardness of the water requires the use of large amounts of soap when used for washing. As just indicated, wells in some areas yield water containing concentrations of nitrate that exceed 45 ppm, the upper limit recommended for infant feeding (U.S. Public Health Service, 1961); however, this high concentration of nitrate is apparently a local phenomenon. Two of the sampled wells, one owned by the City of Lusk and the other by the town of Manville, serve as public supplies. Water from both wells has a low nitrate concentration, and, although hard, is somewhat less hard than most water from the Arikaree Formation.

ALLUVIUM

Although usable, water from the alluvium is somewhat poorer in quality than that from either the Arikaree Formation or White River Group. Dissolved solids range from 922 to 1,920 ppm. Analyses show that the water in the alluvium tends to be of the sodium sulfate type, although bicarbonate concentrations, as a percentage of the anions, may be nearly as high as the sulfate concentrations. Despite high sodium concentrations, hardness ranged from 253 to 382 ppm. Iron concentrations ranged from 0.30 to 3.1 ppm.

As domestic supplies, water from the alluvium has several objectionable characteristics: mineralization is high; sulfate exceeds recommended concentrations; and iron is high enough to cause a taste problem and staining and to be subject to precipitation. Well 35–65–3cc, however, is used by the village of Lance Creek as a public supply.

As stock supplies, water from the alluvium is classed as fair, although iron might present some problems. For irrigation, the alkali hazard is generally low, but the salinity hazard is high; therefore, good soil drainage is a necessity. Water from well 38–63–30cd2, which is currently being used for irrigation, is probably unusable under any circumstances, on the basis of the criteria of Eaton (1950). It has a "residual sodium carbonate" of 3.69 epm, exceeding the suggested maximum of 2.5 epm.

CONCLUSIONS

Ground water in Niobrara County occurs in both unconfined (water-table) and confined (artesian) aquifers. Water-table conditions prevail in the southern part of the county, where the thick and massive Arikaree Formation is the principal aquifer. Artesian conditions are widespread through the northern part of the county in aquifers such as the Inyan Kara Group, Fox Hills Sandstone, and the Lance and Fort Union Formations. Unconfined water occurs principally in alluvial deposits of Lance Creek and the Cheyenne River and their major tributaries.

At the present time (1962), shallow wells drilled in the Arikaree Formation, which is the best ground-water reservoir in Niobrara County, furnish moderate to large quantities of ground water for irrigation. Larger yields could probably be obtained from wells penetrating a greater thickness of saturated aquifer. Supplies of water adequate for small-scale irrigation may be developed at some places from the alluvium along Lance Creek and the Cheyenne River. Sufficiently deep wells drilled in the Lance Formation, the Fox Hills Sandstone, and the Inyan Kara Group may yield moderate supplies of water, if properly constructed, but none of the wells in these formations is likely to yield sufficient water for economical irrigation. Water in these formations is normally under some artesian pressure, and water levels in the deeper wells may rise to within a relatively short distance below the land surface. Generally, only small quantities of water may be expected from the other water-bearing formations in the county.

Ground water in Niobrara County is derived principally from precipitation within the county, although some water may enter the area as underflow through deep aquifers exposed on the flanks of the Black Hills to the east and north. Ground water moves out of the county mostly as underflow through artesian aquifers into the Powder River Basin to the west and as underflow through the Arikaree Formation into Nebraska to the east. The estimated underflow across the Wyoming-Nebraska State line is between 5 and 8 million gpd. Smaller quantities of ground water are discharged by streams, wells, and evapotranspiration. An estimated average of at least 4 million gpd of ground water is transpired by cottonwood trees along Lance Creek, and the rate of transpiration is probably much greater during the summer months. In 1959, the discharge of irrigation wells in the Arikaree Formation was about 800 acre-feet, or about 700,000 gpd. During the same year, the City of Lusk used about 300,000 gpd, and the town of Manville used an estimated 60,000 gpd. No attempt was made to estimate the yield of stock and domestic wells.

Water from the White River Group and from the Arikaree Formation in Niobrara County is of the best quality for general use. Although water from these sources has certain undesirable characteristics for some uses, a well drilled into one of these rock units would probably provide water of better quality than water obtained from other rock units in the area. Because of the diversity of dissolved constituents, which cause water from some of the wells to be objectionable, water from either of these sources intended for purposes requiring a specific quality should be chemically analyzed.

At certain locations, the Inyan Kara Group is capable of yielding water of fair to good quality from rather shallow depths, although the quantities obtainable may not be great.

Water from the Pierre Shale, Fox Hills Sandstone, Lance and Fort Union Formations, and alluvium is generally suitable for stock supplies but may not be suitable for irrigation at some locations. In general, water from these sources should be considered usable only if no other supplies are available.

RECORDS OF WELLS AND OIL-TEST HOLES IN NIOBRARA COUNTY

Table 9 contains records of 441 water wells and oil-test holes. Much of the data was obtained from well owners or tenants, well drillers, or records of the Niobrara County Agricultural Stabilization and Conservation Office at Lusk. The depth to water and the depth of the well were measured by the author when possible. The locations of the wells and test holes are shown on plate 1.

TABLE 9.—*Records of wells and oil-test holes in Niobrara County, Wyo.*

Well number: See text for description of well-numbering system.
Type of well: D, drilled well; Du, dug well.
Depth of well: Measured depths are given in feet and tenths below land surface; reported depths are given in feet.
Type of casing: C, concrete; N, none; P, iron or steel pipe; R, rock; W, wood.
Type of material: Cls, claystone; G, gravel; S, sand; Sh, shale; Sls, siltstone; Ss, sandstone.
Geologic source (listed alphabetically): Kbm, Belle Fourche and Mowry shales; Kcl, Carlile Shale; Kc, Cloverly Formation; Kfh, Fox Hills Sandstone; Kik, Inyan Kara Group; Kl, Lance Formation; Knc, Newcastle Sandstone; Kp, Pierre Shale; pK, pre-Cretaceous rocks; Qal, alluvium; Ta, Arikaree Formation; Tfu, Fort Union Formation; Twr, White River Group.
Method of lift and type of power: C, cylinder; Cf, centrifugal; F, flows; J, jet; N, none; T, turbine; E, electric; G, gasoline or gas; H, hand operated; N, none; W, windmill.
Use of water: D, domestic; I, irrigation; In, industrial; N, none; P, public; S, stock.
Water level: Measured depths to water are given in feet and hundredths, reported depths are given in feet.
Remarks: Ca, sample collected for chemical analysis; D, discharge in gallons per minute (E, estimated; M, measured; R, reported); DD, drawdown in feet while discharging at the preceding rate; L, log of well given in table of well logs; T, temperature in degrees Fahrenheit.

Well	Owner or tenant	Year	Type of well	Depth of well (feet)	Diameter of well (inches)	Type and amount of casing (feet)	Principal aquifer		Method of lift and type of power	Use of water	Water level		Date of measurement	Remarks
							Type of material	Geologic source			Distance above (+) or below land surface (feet)	Altitude above mean sea level (feet)		
31-60-17da	Chicago and North Western Ry. Co.		D	97	12	P	Ss, Sls	Ta	N	N	25.97	4,716	Nov. 1952	Abandoned.
19cb	L. Adams		D		6		Ss, Sls	Ta	C, W	S	92.84		June 1958	
31cd	L. Lewis	1953	D	250	7	P, 20	Ss, Sls	Ta	C, W	S	190		do	
31-61-3ac	J. Bruegger		D	125	7	P, 20	Ss, Sls	Ta	C, W	S	47.60	4,779	June 1956	
4ba	J. Christian	1933	D	158	8	P, 10	Ss, Sls	Ta	Cf, G	I	0		June 1958	Two wells, T49, Ca, D150R.
11dc	A. McMasters	1955	D	130	18	P, 22	Ss, Sls	Ta	C, W	S	11.20		do	L, observation well.
25bd	H. M. McKelvey		D		6	P	Ss, Sls	Ta	C, W	S	155.20		do	
28dd	A. McMasters	1956	D	210	12	P, 20	Ss, Sls	Ta	C, W	S	115	4,755	do	
29cd	O. H. Burnham		D	230	8	P, 20	Ss, Sls	Ta	C, W	S	185.20		July 1958	L.
31-62-11ca	H. Densborn	1957	D	165	6	P, 21	Ss, Sls	Ta	C, W	S	60.12		June 1959	
18cc	M. C. Kaan		D	125	8	P	Ss, Sls	Ta	C, W	S	49.50	4,880	Sept. 1958	
19cd	do		D	145	8	P, 24	Ss, Sls	Ta	C, W	S	133.40		do	
23db	J. Shane	1958	D	107	6	P, 107	Ss, Sls	Ta	C, W	S	60.40		Oct. 1958	
31cd	H. Baars	1955	D	210	6	P, 21	Ss, Sls	Ta	C, W	S	163.32	4,837	do	
35cb	O. H. Burnham	1954	D	170	6	P, 20	Ss, Sls	Ta	C, W	S	55.60		do	

31-63-6ba	R. McLain	1952	D	190	6	P, 20	Ss, Sls	Ta	C, W	S	79.41	4,981	do	
9cb	W. W. Culver		D	210	8	P	Ss, Sls	Ta	J, E	D	99.98		do	
10cb	H. Kaan	1954	D	150	6	P, 24	Ss, Sls	Ta	C, W	S	80		do	
29ac	do	1953	D	258	6	P, 20	Ss, Sls	Ta	C, W	S	176.40		Sept. 1958	
34bd	M. C. Kaan	1955	D	250	6	P, 21	Ss, Sls	Ta	C, W	S	130		do	
36aa	do	1954	D	155	6	P, 40	Ss, Sls	Ta	C, W	S	137.24		do	
31-64-7bc	A. C. Brooks		D	120		P	Ss, Sls	Ta	C, W	S	50.93	5,409	Oct. 1958	
24ac	C. Canfield	1957	D	285	6	P, 20	Ss, Sls	Ta	C, W	S			do	
36db	M. C. Kaan		D	97.0	6	P	Ss, Sls	Ta	C, W	D, S	67.43		do	
31-65-1ca	Joss Ranches	1959	D	120	6	P, 120	Ss, Sls	Ta	C, W	S	105		do	D8R.
5cb	do	1958	D	210	5	P, 210	Ss, Sls	Ta	C, W	S	180		do	D15R, DD30R.
15bc	R. W. Reed	1953	D	99	6	P, 12	Ss, Sls	Ta	C, W	S			do	
18cb	L. J. Bowen	1954	D	190	6	P, 36	Ss, Sls	Ta	C, W	S	157.40	5,178	do	L, D5R.
31-66-10ca	J. Ringer	1954	D	225	6	P, 24	Ss, Sls	Ta	C, W	S	9.95		do	D5R.
12cd	L. J. Bowen	1955	D	200	6	P, 39	Ss, Sls	Ta	C, W	S	147.00		July 1955	
18ba	J. Smith	1956	D	160	6	P, 24	Ss, Sls	Ta	C, W	S	149.75		Nov. 1958	
20cc	do	1959	D	60	6	P, 60	Ss, Sls	Ta	C, W	S	29.90		do	D10R, DD10R.
26da	B. J. Jones		D		6	P	Ss, Sls	Ta	C, W	D, S	76.15	5,175	do	T51, Ca, D5R.
35ca	E. G. Hughes		D	132.4	6	P	Ss, Sls	Ta	C, W	S	21.47		do	
31-67-1cc	K. Mariegard		D			P	Ss, Sls	Ta	C, W	S	160.00	4,970	do	
25ab	N. F. Hester		D	200		P	Ss, Sls	Ta	C, W	S	143.90	4,916	do	
36ad	W. Ziska	1944	D	140	6	P	Ss, Sls	Ta, Kc(?)	C, W	S	84.30	4,896	do	
36cb	do	1944	D	120	6	P	Ss, Sls	Ta, Kc(?)	C, W	S	74.91	4,870	do	
32-60-8bd	J. H. Christian		D	210	6	P	Ss, Sls	Ta	C, W	S	183.66	4,818	Nov. 1952	
29bc	A. E. Larson	1952	D	270	6	P, 20	Ss, Sls	Ta	C, W	S	211.50	4,768	June 1956	
32dd	H. Zerbe	1952	D	200	6	P, 20	Ss, Sls	Ta	C, W	S			do	
32-61-2cd	J. Siemsen	1956	D	210	6	P, 22	Ss, Sls	Ta	C, W	S			do	
15ab	do	1955	D	230	6	P, 21	Ss, Sls	Ta	C, W	S			July 1958	
16bd	F. Bruegger		D	150	6	P, 150	Ss, Sls	Ta	C, W	S	134.10	4,856	do	
28ad	J. Christian		D	200	6	P	Ss, Sls	Ta	C, W	S	141.22	4,819	do	
32bc	do	1935	D	200	8	P	Ss, Sls	Ta	N	I	0		Nov. 1958	Three wells, D500R. Water table at land surface.
32-62-6bc	J. Sturman	1954	D	235	6	P, 21	Ss, Sls	Ta	C, W	S			do	L.
17ad	Mrs. R. Larson		D	150	6	P, 20	Ss, Sls	Ta	C, W	S	14.10		Aug. 1958	
17cd	do	1952	D	124	18	P, 60	Ss, Sls	Ta	T, E	I	16.52		Nov. 1958	L, D730M, DD47.4M. Observation well. Measured depth 114.5 ft.
20aa	do	1954	D	134	12	P, 10	Ss, Sls	Ta	T, E	I	14.82		do	D1,100R. Measured depth 130 ft.
20ab	L. A. Christeson and N. F. Larson.	1952	D	127	18	P, 96	Ss, Sls	Ta	T, E	I	22.38		do	D750R, DD60R.
20bd	do	1954	D	150	12	P, 21	Ss, Sls	Ta	T, E	I	40.01	4,886	do	L, D950R, DD30R. Measured depth 131 ft.

TABLE 9.—*Records of wells and oil-test holes in Niobrara County, Wyo.*—Continued

Well	Owner or tenant	Year	Type of well	Depth of well (feet)	Diameter of well (inches)	Type and amount of casing (feet)	Principal aquifer: Type of material	Principal aquifer: Geologic source	Method of lift and type of power	Use of water	Water level: Distance above (+) or below land surface (feet)	Water level: Altitude above mean sea level (feet)	Date of measurement	Remarks
32-62-28ad			D	110	6	P, 12	Ss,Sls	Ta	J,E	D	42	4,887	Nov. 1958	T44, Ca, D5E.
34cc	J. Pfister	1940	D	27.6	8	P	Ss,Sls	Ta	N	N	4.28	4,881	do	Observation well.
36ab	M. C. Kaan	1957	D	60	6	P, 60	Ss,Sls	Ta	C,W	S	10		do	
32-63-2cc	L. Schaefer	1952	D	200	24	P, 20	Ss,Sls	Ta	T,E	I	44.59		June 1959	L, D370M, DD10.4M. Measured depth 179 ft.
5aa	do	1955	D	150	14	P, 10	Ss,Sls	Ta	C,E	S	120		do	
7bb1	City of Lusk	1953	D	172	13	P, 172	Ss,Sls	Ta	T,E	P	24		Sept. 1959	T51, Ca, D450R (Well 1).
7bb2	do	1938	D	130	16	P	Ss,Sls	Ta	T,E	P	40		do	L, D375R (Well 2).
8db1	do	1946	D	180	8	P	Ss,Sls	Ta	N	N	23.40		May 1960	Unused (Well 3).
8db2	do	1949	D	151	14	P	Ss,Sls	Ta	T,E	P	35		Sept. 1959	L, D280R (Well 4).
8db3	do	1954	D	160	16	P	Ss,Sls	Ta	T,E	P	36		do	D700R (Well 5).
8dd	F. Christian	1955	D	135	18	P, 18	Ss,Sls	Ta	T,G	I	18.75	4,981	May 1960	D500R, DD40R. Observation well. Measured depth 122 ft.
11bb	L. Schaefer	1952	D	300	24	P, 20	Ss,Sls	Ta	T,E	I	44.03	4,931	June 1959	D500R. Observation well. Measured depth 184 ft.
19dd	M. Larson	1955	D	74	8	P, 20	Ss,Sls	Ta	C,W	S	50		Sept. 1958	
23bc	H. B. Klemke	1954	D	105	6	P, 66	Ss,Sls	Ta	C,W	S	45.00		do	
32ad		1957	D	180	6	P, 66	Ss,Sls	Ta	J,E	D			Nov. 1959	T51, Ca.
33bb	E. Quigley	1949	D	205	18	P, 205	Ss,Sls	Ta	T,G	I	40.89	4,950	Nov. 1957	T50, Ca, D160M, DD20.2M. Observation well.
32-64-7dc	V. Hinrichsen		D	75	4	P	Ss,Sls	Ta	C,H	D	46.05	5,214	Sept. 1958	Observation well.
14ba	E. J. Plumb		D	225	6	P, 24	Ss,Sls	Ta	C,W	S			do	L.
18bd	N. V. Lamb	1949	D	110	26	P, 12	Ss,Sls	Ta	T,E	I	66.10	5,213	Oct. 1958	L, D1,000R, DD14R.
24da	I. Lamb	1955	D	59	18	P, 10	Ss,Sls	Ta	T,E	I	45.43	5,015	Sept. 1959	L, D650R, DD2.8M. Observation well.

25da	Johnson Sisters	1959	D	82	16	P	Ss, Sls	Ta	T, E	I	19.31	5,030	do	L, D350R.
35ca	J. Sager	1952	D	125	6	P, 24	Ss, Sls	Ta	C, W	S	59.00	5,031	do	
32-65-1bc1	Town of Manville	1913	D	185	8	P	Ss, Sls	Ta	T, E	P	40.44		do	D150R.
1bc2	do		D	200	8	P	Ss, Sls	Ta	S, E	P	40.40		do	T37, Ca, D125R, DD4R.
1cb	A. R. Knudsen	1950	D	108	8	P, 12	Ss, Sls	Ta	T, E	I	21.38		do	D350R, DD14R. Observation well.
1da	E. Rogers	1955	D	105	6	P, 24	Ss, Sls	Ta	C, W	S	47.00		do	
6cc	D. Grant		D	170.0	6	P	Ss, Sls	Ta	C, E	D	136.33		do	
34aa	Joss Ranches	1958	D	160	5	P, 160	Ss, Sls	Ta	C, W	S	120		do	
35bb	H. A. Fosher	1955	D	150	10	P, 20	Ss, Sls	Ta, pK(?)	T, G	I	110		Nov. 1959	L.
32-66-2dd	E. Tobler	1956	D	210	6	P, 20	Ss, Sls	Ta	C, W	S	90		Aug. 1958	
3db	C. Freeman	1953	D	131	6	P, 24	Ss, Sls	Ta	C, W	S	55		do	
5ac	J. Smith	1957	D	140	6	P, 140	Ss, Sls	Ta	C, W	S	90		do	
7da	F. Mahnke	1956	D	224	6	P, 24	Ss, Sls	Ta	C, W	S	152.20	5,108	do	
17cc	H. Poage	1958	D	200	6	P, 200	Ss, Sls	Ta	C, W	S	30		do	D60R, DD170R.
26da	C. Gaukel	1955	D	174	6	P, 24	Ss, Sls	Ta	C, W	S	68.42		do	L.
29db	A. Meier	1957	D	225	6	P, 30	Ss, Sls	Ta	C, W	S	125		do	
34ba	do	1955	D	125	6	P, 24	Ss, Sls	Ta	C, W	S	45.27		do	Water at 60 ft.
32-67-3ac	K. E. Wright	1956	D	130	6	P, 130	Ss, Sls	Ta	C, W	S			Mar. 1956	
11dd	C. W. Freeman	1955	D	195	6	P, 24	Ss, Sls	Ta	C, W	S	130		Oct. 1958	L.
33-60-9db	L. F. Christian	1954	D	310	6	P	Ss, Sls	Ta	C, W	S	286	4,764	June 1956	
18cc	R. L. Zumbrunnen		D		6	P	Ss, Sls	Ta	C, W	S	154.50	4,898	do	
33-61-17db	A. Thompson		D	330	6	P	Ss, Sls	Ta	C, W	S	272.80	4,877	July 1959	
19ba	W. Zerbst	1958	D	335	6	P, 335	Ss, Sls	Ta	C, W	S			do	
19dd	G. Mill	1958	D	362	6	P, 362	Ss, Sls	Ta	C, W	S			do	
21ba	H. Lohrm		D	287.0	8	P	Ss, Sls	Ta	C, W	D	263.05	4,912	Nov. 1952	
23db	J. H. Hanmond	1953	D	290	6	P, 20	Ss, Sls	Ta	C, W	S			do	
35bd	J. Siemsen		D	250	7	P, 15	Ss, Sls	Ta	C, W	S			May 1956	
33-62-6cb	J. Mudra	1956	D	340	8	P, 340	Ss, Sls	Ta	C, W	S	300		July 1957	
6db	C. E. Kilmer	1954	D	361	6	P, 20	Ss, Sls	Ta	C, W	S	322.00	4,788	Oct. 1957	
13bc	L. James	1954	D	300	6	P, 30	Ss, Sls	Ta	C, W	S			Sept. 1958	
15cb	K. Woods	1956	D	360	6	P, 325	Ss, Sls	Ta	C, W	S	301.70	4,863	do	
21db	W. Jassman	1955	D	275	6	P, 20	Ss, Sls	Ta	C, W	S			do	
23ac	L. James		D	300	6	P, 20	Ss, Sls	Ta	C, W	S	288.00	4,882	do	
27ab	A. Jassman		D	270	6	P, 20	Ss, Sls	Ta	C, W	S	247.80	4,897	do	
33-63-5ba	L. Schaefer	1956	D	150	10	P, 20	Ss, Sls	Ta	C, W	S	100		June 1956	
23dc	C. H. McConaughey	1956	D	200	7	P, 28	Ss, Sls	Ta	C, W	S	140		Aug. 1958	
25ba	D. McConaughey	1957	D	220	6	P, 183	Ss, Sls	Ta	C, W	S	163		Mar. 1957	
30cc		1944	D	450					N, N	N				L. Oil test.
33-64-14aa	H. E. Hansen	1954	D	65	6	P, 27	Ss, Sls	Ta	C, W	S	32		Aug. 1958	
25db	Atlantic Refining Co.	1959	D	1,240					N, N	N				L. Oil test.
27bc	H. B. Klemke	1958	D	235	6	P, 225	Ss, Sls	Ta	C, W	S	172.30		July 1958	
33-65-11bd	C. Pinkerton	1953	D	215	6	P, 20	Ss, Sls	Ta	C, W	S	200		Aug. 1959	
14ca	do		D	220	6	P	Ss, Sls	Ta	C, W	S	180	5,250	do	
17dc	B. Fullerton	1959	D	225	6	P, 225	Ss, Sls	Ta	C, W	S	40		do	D5E, DD 20R.
20bc	do	1953	D	84	6	P, 27	Ss, Sls	Ta	C, W	S	27.20		do	
27aa	E. Sharp		D	125	6	P	Ss, Sls	Ta	C, W	S	36.20	5,269	do	
35ba1	C. Parmely	1955	D	90	6	P, 27	Ss, Sls	Ta	C, W	S	29.19		do	
35ba2	Continental Oil Co.	1954	D	2,140					N, N	N			do	L. Oil test.

TABLE 9.—*Records of wells and oil-test holes in Niobrara County, Wyo.*—Continued

Well	Owner or tenant	Year	Type of well	Depth of well (feet)	Diameter of well (inches)	Type and amount of casing (feet)	Principal aquifer: Type of material	Principal aquifer: Geologic source	Method of lift and type of power	Use of water	Water level: Distance above (+) or below land surface (feet)	Water level: Altitude above mean sea level (feet)	Date of measurement	Remarks
33-66-5ac	R. Heine	1954	D	135	6	P, 24	Ss, Sls	Ta	C, W	S			Sept. 1954	
7bb	E. H. Martin	1956	D	185	6	P, 185	Ss, Sls	Ta	C, W	S	135.70	5,240	do.	
8ac	L. M. Lee	1954	D	100	6	P, 23	Ss, Sls	Ta	C, W	S	80		do.	
8ca	do.	1956	D	120	6	P, 120	Ss, Sls	Ta	C, W	S	20		do.	
9ba	Atlantic Refining Co.		D	1,795					N, N	N				L. Oil test.
18db	Texas Co.	1945	D	1,970					N, N	N				Do.
20ac	Atlantic Refining Co.	1959	D	1,390					N, N	N				Do.
20dc	A. Lindquist	1957	D	125	6	P, 24	Ss, Sls	Ta	C, W	S	63.45		Sept. 1954	Water at 80 ft.
27db	F. Coen	1954	D	110	6	P, 24	Ss, Sls	Ta	C, W	S	34.00	5,036	Nov. 1958	Water at 58 ft.
32aa	R. Heine	1954	D	200	6	P, 24	Ss, Sls	Ta	C, W	S	72		do.	
33-67-1dc	E. Martin	1953	D	220	6	P, 20	Ss, Sls	Ta	C, W	S	57.20	5,203	do.	L.
14db	K. Wright	1955	D	165	6	P, 28	Ss, Sls	Ta	C, W	S	111.33	5,189	July 1957	
15cd	M. Nelson	1956	D	210	6	P, 24	Ss, Sls	Ta	C, W	S	200		do.	L.
24bd	F. Engebretson	1956	D	160	6	P, 30	Ss, Sls	Ta	C, W	S	75		do.	Water at 87 ft.
25bb	do.	1955	D	180	6	P, 180	Ss, Sls	Ta	C, W	S	125		do.	Water at 140 ft.
34-60-4cb	M. Wolfe		Du	20.4	36	R, 20	S, G	Qal	C, W	S	17.78		Oct. 1959	
9db	F. Swope		Du	17.5	36	R, 17	S, G	Qal	C, W	D, S	9.20		do.	D6E, DD6.29M.
28ba	M. Keel	1956	D	185	6	P, 24	Sls, Cls	Twr	C, W	S			do.	L.
30aa	E. Whitman		D	50	6	P, 12	Sls, Cls	Twr	C, W	S	22.80		do.	
30dc	do.		D	225	6	P, 12	Sls, Cls	Twr	C, W	D	45.00		do.	
34-61-1ab	D. Piper		D	80	6	P	S, G	Qal	C, W	S	23.11		do.	D5E, DD6.20M.
6ab1	W. J. Greene	1951	D	265.0	6	P	Sls, Cls	Twr	C, W	S	99.75		Nov. 1959	D4E, DD70R.
6ab2	do.	1951	D	147.0	8	P	Sls, Cls	Twr	N		61.20		do.	
6cd	M. W. Jensen		Du	9	30	R	S, G	Qal	C, W	S	1.82		do.	T58, Ca.
8bd1	J. C. Klemke	1958	D	125	6	P, 125	Sls, Cls	Twr	C, W	S	5		do.	D3E, DD120R.
8bd2	do.	1947	D	160	6	P	Sls, Cls	Twr	N		160+		do.	Dry.
17ca	P. Percival		D	50	6	P	Sls, Cls	Twr	C, W	D	15.83	4,504	Sept. 1958	Ca, D5E.
33da	R. Louthan	1958	D	275	6	P, 275	Ss, Sls	Ta	C, W	S			do.	
34-62-1ad	J. Klemke		D	125	6	P, 116	Sls, Cls	Twr	C, W	S	6.72		do.	D4E, DD9.93M.
5ab	R. A. Johnson		D	100	6	P	Sls, Cls	Twr	C, W	S	45.65		Oct. 1958	
7dd	M. J. Fields		D	50	5	P	Sls, Cls	Twr	C, W	S	9.21	4,451	do.	
12bb	J. Jensen		D	250	6	P, 24	Sls, Cls	Twr	N		92.17	4,308	do.	
12bc	do.		D	21.2	8	P	Sls, Cls	Twr	N		18.16	4,382	do.	

14ac			D	77.3	6	P	Sls, Cls	Twr	C, W	S	50.32	4,430	July 1958	
19cc	R. Roberts		D	150	5	P	Ss, Sls	Ta	C, W	S	99.91	4,540	Oct. 1958	
26ca	C. B. Cook		D		6	P	Sls, Cls	Twr	C, W	S	96.72		do	
28bb	Mill Ranches		D	362	6	P, 362	Ss, Sls	Ta	C, W	S	280		do	L.
29ca	R. Roberts	1955	D	80	15	P, 80	Ss, Sls	Ta	T, G	I	24.91		do	
29cd	do	1950	D	80	12	P, 80	Ss, Sls	Ta	T, G	I	30.10	4,589	do	Ca, D195M, DD30+M.
34-63-2dd			D	317					N, N	N				L. Oil test.
3da		1957	D	1,300					N, N	N				Do.
4bc	J. E. Goddard	1900	D	72.4	5	P, 75	Sls, Cls	Twr	N		49.22		Sept. 1959	
6ac	do	1952	D	129.0	6	P, 140	Sls, Cls	Twr	C, W	S	58.86		do	
12ba	D. Fields		D	80	6	P	Sls, Cls	Twr	C, W	D	28	4,467	do	
13bb	do		D	90	6	P, 90	Sls, Cls	Twr	C, W	S	39.13	4,536	do	
18da	R. W. Bonsell		D	132	5	P	Sls, Cls	Twr	C, W	D	10.20		Aug. 1959	
20ac	do		D	101.2	6	P	Sls, Cls	Twr	N		19.60		do	
26ca	M. Heth		D	150	6	P, 36	Ss, Sls	Ta	C, W	D, S	68.56		do	D7E, DD15R.
34-64-9ac	W. L. Magoon	1952	D	100	8	P, 100	Sls, Cls	Twr	C, E	S	21.24		Oct. 1959	D6E, DD4R.
9db	do	1946	D	145.3	5	P, 20	Ss, Sh	Kik	J, E	D	29.80		do	T47, Ca, D10R.
14ca	D. Atler	1946	D	300.0+	7	P, 310	Ss, Sh	Kik	N		82.20		do	
18ba	W. L. Magoon		D	400		N	Sls, Cls	Twr	N		400+		do	Dry.
22cc	do		D	150	5	P, 150	Sls, Cls	Twr	C, W	S	67.13		do	
34-65-1bb	Continental and Ohio Oil Co	1946	D	384	8	P, 287	Ss, Sh	Kik	T, E	P, In	110	4,710	do	D60R, DD50E.
1bc	do	1946	D	265	8	P, 265	Ss, Sh	Kik	T, E	P, In	140	4,740	do	L, Ca, D220R, DD50E.
4cb		1955	D	1,615	8	P	Sls, Ss	Twr, Kik(?)	F	S	+		do	T55, Ca, L. Oil test. Water charged with gas.
14aa	Spaugh Land & Livestock Co		D	77.1	6	P	Ss, Sls	Ta	C, W	S	45.13		do	
19cd	do		D		5	P	Ss, Sls	Ta	N		22.80	4,787	July 1958	
23bc	do		D	52.1	6	P, 52	Sls, Cls	Twr	C, W	S	24.32		Sept. 1959	
24bc	do		D		6	P	Sls, Cls	Twr	C, W	S	131.10	4,780	do	
35cc	do		D	93.3	6	P	Sls, Cls	Twr	C, W	S	78.22	4,942	do	
34-66-10bb			Du	18.7	30	R	S, G	Qal	C, W	S	17.37		do	
13aa	F. Mulligan		D		5	P	Sls, Cls	Twr	N		116.20		do	
22bb			D	99.0	6	P	Sls, Cls	Twr	C, W	D, S	19.21		do	
34-67-13cd	C. D. Nuttall		D	400	6	N	Ss, Sh	Tfu	N		400+		Oct. 1959	Dry.
25cd	do		D	94.0	6	P, 94	Ss, Sls	Ta	C, W	D, S	65.57		do	
27bb	do	1955	D	243	4	P, 243	Ss, Sh	Tfu	F, C, W	S	+		do	L. Flow very weak.
27cc	E. Wilson	1956	D	150	6	P, 90	Ss, Sh	Tfu	C, W	S			do	
35aa	B. Fullerton		D	60			Sls, Cls	Twr	C, W	S	21.82		do	
35-60-18ba	R. Thompson	1954	D	30	6	P, 30	S, G	Qal	C, W	S	20		Nov. 1959	
27ba	D. E. Jordan	1945	Du	15	48	C, 15	S, G	Qal	C, W	D, S	12.66		do	Ca, D5E, DD4.37M.
31cc	V. Chard		Du	15	30	C	S, G	Qal	C, W	D	12		do	
35-61-7db	Boner Bros	1956	D	150	10	P, 20	Ss, Sls	Ta	C, W	S	110		Feb. 1956	
15bc	R. Thompson	1953	D	95	6	P, 95	Sls, Cls	Twr	C, W	S			Oct. 1953	
22bd	do		Du	8.5	36	P	S, G	Qal	C, W	S	5.21		Oct. 1959	
27da	D. Piper	1956	D	65	6	P, 65	Sls, Cls	Twr	C, W	S	43.08		do	
33da	do	1956	D	35	6	P, 20	Sls, Cls	Twr	C, W	S	8		do	

TABLE 9.—*Records of wells and oil-test holes in Niobrara County, Wyo.*—Continued

Well	Owner or tenant	Year	Type of well	Depth of well (feet)	Diameter of well (inches)	Type and amount of casing (feet)	Principal aquifer: Type of material	Principal aquifer: Geologic source	Method of lift and type of power	Use of water	Water level: Distance above (+) or below land surface (feet)	Water level: Altitude above mean sea level (feet)	Date of measurement	Remarks
35-62-5bb	E. E. Hales		D	60	6	P	Sls, Cls	Twr	N		24.81		Oct. 1959	
7cd	W. Dainton		D	60	6	P	Sls, Cls	Twr	C, W	S	14.92		do	
8bb	do		D	80	6	P	Sls, Cls	Twr	C, W	S	52.70		do	
8cb	do	1954	D	295	6	P, 260	Sls, Cls	Twr	C, W	S	50		do	L.
13dd	Boner Bros		D	150	10	P, 20	Ss, Sls	Ta	C, W	S	65.44		do	
15ac	E. H. Himes		D	105	6	P, 5	Sls, Cls	Twr	C, W	D	59.12		Sept. 1959	Ca, D5E, DD30R.
20dc	R. Scott	1917	D	40	6	P	S, G	Qal	C, W	D	18.76		do	
26ab	M. Heth		D				Sls, Cls	Twr	C, W	D, S	151.0+		do	
29bb	Range States Oil Co	1957	D	623					N, N	N				L. Oil test.
32aa	D. Fields		D		10		Sls, Cls	Twr	N		290.0+		Oct. 1958	
35da	M. W. Jensen	1948	D	103	6	P, 12	Sls, Cls	Twr	C, W	S	22.30		do	D3E, DD78R.
35-63-6ab	D. Fullerton	1956	D	105	6	P, 105	Sh	Kp	C, W	S			Mar. 1956	
10bb	D. Hanson		Du	15.2	30	R	S, G	Qal	C, W	S	13.83		Oct. 1958	
15dc	Crusader Corp	1952	D	2,605					N, N	N				L. Oil test.
27dd	do	1954	D	200	6	P, 170	Ss, Sh	Kik	C, W	S			Dec. 1954	L.
33cc	J. E. Goddard		D	105.0	5	P, 105	Sls, Cls	Twr	C, W	D	54.30		Sept. 1959	
35-64-5ca	R. Provost	1957	D	240	6	P, 200	Sh	Kp	C, W	S	70		do	L.
7ca	C. W. Spacht Ranches		D	160	6	P, 160	Sls, Cls	Twr	C, W	S	53.89		Oct. 1959	
11cc	C. Blagg	1954	D	175	6	P, 175	Sls, Cls	Twr	C, W	S	150		Nov. 1954	
14bc	do		D	187	6	P, 187	Sls, Cls	Twr	C, W	S	82.35		Oct. 1959	
17da	E. Garhart	1956	D	230	6	P, 230	Sls, Cls	Twr	C, W	S	39.92		do	
20ac	C. Blagg	1955	D	210	6	P, 210	Sls, Cls	Twr	C, W	S	194		do	L.
26cb	W. L. Magoon	1941	D	126.0	6	P	Sls, Cls	Twr	C, W	S	54.33		Nov. 1959	Ca, D5R.
32cd	R. A. Martin		D	73.4	6	P	Ss, Sls	Ta	N		57.20		do	
35-65-3cc	Lance Creek village		Du	11.0	144	W, 11	S, G	Qal	Cf, E	P	6.35		do	Ca, D16R, DD2R.
15ad	do	1952	D	80	5	P, 80	Sh	Kp	J, E	D	45		do	Ca, D5E, DD45R.
16ba	do	1958	D	325	6	N	Cls, Sh	Twr, Kp	N		325+		do	Dry hole.
27cd	G. Mosier		D	230	6	P	Sls, Cls	Twr	C, W	S	60		Oct. 1959	
31ca	J. Moore, Jr	1959	D	130	6	P, 130	Sls, Cls	Twr	C, W	S	85		May 1959	
32da	Bullock Bros	1956	D	1,625					N, N	N				L. Oil test.
34dd	M. Bruch		D	55.0	6	P	Sls, Cls	Twr	N		25.23		May 1959	

35ab	Continental and Ohio Oil Cos.	1941	D	498	8	P, 398	Ss, Sh	Kik	T, E	P	55		Oct. 1959	L, D300R. Well flowed 140 gpm with 35-ft artesian head, 1941.
35ba	do	1941	D	571	8	P, 260	Ss, Sh	Kik	N	N	88.93		do	Water level 3 ft below land surface, 1941.
35-66-1ad			D	65.2	6	P	Ss	Kfh	C, W	S	4.20		do	
11bd	J. Lamb Est.		D	500	6	P	Ss, Sh	Kl	C, W	S	148.0+		do	
12dc	do		Du	13.0	36	R	S, G	Qal	C, W	S	11.42		do	
35-67-11aa	Joss Ranches		D	30.0	6	P	S, G	Qal	C, W	S	1.62		do	
36-61-5bb	Boner Bros.	1954	D	1,275	6	P	Ss	Knc	S, E	D, S	180		do	D25R.
36-62-3ac	A. H. Clark	1958	D	350	5	P, 300	Ss, Sh	Kik	C, G	D, S	10		do	
3bc	do		D	85	4	P, 85	Ss, Sh	Kik	F	S	+		do	D3R.
3cc	do	1939	D	200	6	P	Ss, Sh	Kik	C, W	S	50		do	Source of domestic water for several ranches in area.
5cb	G. L. Story		Du	15		P	S, G	Qal	Cf, E	D	7		do	
21bb	A. E. DeGering	1955	D	125	6	P	Cls, Ss	Twr, Kik(?)	C, W	D, S	75		do	Quality of water reported good.
21dd	do		D	40			Sls, Cls	Twr	C, W	S	25		do	
36-63-1ca	R. Johnson		D	125	6	P	Sh	Kp	C, W	S	100		do	
7cc	do		D	90	6	P	Sh	Kp	C, W	S	50		do	
26ca	H. W. Graham	1953	D	70	6	P, 70	Sls, Cls	Twr	C, W	S			do	
34ad	D. Hanson	1953	D	210	6	P, 168	Sls, Cls	Twr	C, W	S			do	L.
36-64-3ca	R. Johnson	1957	D	205	6	P, 203	Ss, Sh	Kl	C, W	S	148		do	Quality of water reported good.
3cb	do	1954	D	170	6	P, 20	Ss, Sh	Kl	C, W	S			do	
5ba	S. Sides	1953	D	200	6	P, 200	Ss, Sh	Kl	C, G	S	40		do	Do.
9ab	F. Provost	1940	D	212		P	Ss, Sh	Kl	C, W	S	40		do	
10db	R. Johnson		D	200	6	P, 25	Ss, Sh	Kl	C, W	S	150		do	
14dc	W. Walter		D	180		P, 180	Ss	Kfh	C, W	D, S	60		do	
15db	R. Johnson	1959	D	187	6	P, 187	Ss, Sh	Kl	C, W	S	152		do	
17bb	L. Thompson	1954	D	206	4	P, 206	Ss, Sh	Kl	C, W	S	130		do	
18cc			D	153.6	6	P	Ss	Kfh	C, W	S	55.57		Nov. 1959	D3E, DD47.5M.
29bb	S. Sides	1957	D	350	6	P, 350	Sh	Kp	C, W	S	40		do	L. Water unfit for stock.
36-65-14db	L. A. Penfield	1940	D	73	6	P	Ss, Sh	Kl	C, W	D, S	45		do	Ca, D5E.
23ad	Ohio Oil Co.	1954	D	52	8	P	S, Ss	Qal, Kl	Cf, E	D	30		do	Water reported hard.
31cd	L. Ong	1956	D	120	6	P, 117	Ss	Kfh	C, W	S	45.22		do	
36-66-15ba	Joss Ranches	1956	D	275	4	P, 275	Ss, Sh	Tfu	C, W	S			do	L, T46, Ca, D5E.
31cb	H. Manning	1941	D	80	5	P, 80	Ss, Sh	Tfu	C, W	D			do	
32dc	Joss Ranches		D	182.0	5	P	Ss, Sh	Tfu	D, W	S	131.04		do	
37-61-19cd	H. Boner	1920	Du	23	24	C, 23	S, G	Qal	C, W	S	12		do	
29cc	do	1950	D	25	6	P, 20	S, G	Qal	C, W	S	10		do	D4E, DD10R.
37-62-3bb	G. Langley	1946	D	22	6	P, 22	S, G	Qal	C, W	S	17		do	
4bb	H. W. Graham	1954	D	240	5	P, 200	Ss	Kfh	C, W	D, S	80		1954	Casing perforated 230–240 ft.
5da	G. Langley	1956	D	255	6	P, 255	Ss	Kfh	C, W	S	80		Oct. 1959	L.
10ac	R. Montgomery		D	40	6	P, 40	S, G	Qal	C, W	D, S	25		do	
33bb	C. Walts	1948	D	50	5	P, 50	Sh	Kbm	C, W	S	8		do	

TABLE 9.—*Records of wells and oil-test holes in Niobrara County, Wyo.*—Continued

Well	Owner or tenant	Year	Type of well	Depth of well (feet)	Diameter of well (inches)	Type and amount of casing (feet)	Principal aquifer: Type of material	Principal aquifer: Geologic source	Method of lift and type of power	Use of water	Water level: Distance above (+) or below land surface (feet)	Water level: Altitude above mean sea level (feet)	Date of measurement	Remarks
37-63-2bb	J. Wasserberger	1959	D	240	6	P, 240	Ss	Kfh	C, W	S	140		Oct. 1959	L, D6E, DD100R.
13ca	do		D	200+	6	P, 12	Ss	Kfh	C, W	S	80.40		do	D5E, DD20 R.
13cb	H. Wasserberger		D	300+	6	P, 12	Ss	Kfh	C, W	S	145		do	Ca, D5E,DD140R.
19da	R. Johnson		D	132	6	P	Ss	Kfh	C, W	S	35		do	
30dd	Johnson Ranches	1956	D	84	6	P, 80	Sh	Kp	C, W	S			do	
31ac	do		D	100	6	P, 45	Sh	Kp	C, W	S	45		do	
34bc	J. A. Wood	1953	D	225	7	P, 30	Ss	Kfh	C, W	S	190		do	L.
37-64-6cd	J. Traphagen	1956	D	150	6	P, 150	Ss, Sh	Kl	C, W	S	30		Nov. 1959	
16ca	R. Johnson	1959	D	288	6	P, 288	Ss, Sh	Kl	C, W	S	107		do	
22da	L. Krejci	1931	D	204	8	P, 24	Ss, Sh	Kl	C, W	D, S	130		do	
28db	do		D	100	5	P, 100	Ss, Sh	Kl	C, W	S	90		do	
34ac	F. Pascal	1954	D	162	6	P, 162	Ss, Sh	Kl	C, W	S			do	
37-65-3ad	S. Sides		Du	15	60	C, 15	S, G	Qal	C, W	D	13.10		do	
5ad	A. D. Kruse		D	106.0	6	P, 106	Ss, Sh	Kl	C, W	S	69.88		do	
7bb	do	1956	D	128	4	P	Ss, Sh	Kl	C, W	S	23.20		do	T53, Ca, D3E.
8ba	do	1953	D	92	6	P, 92	Ss, Sh	Kl	C, W	S	15.25		do	
21ac	do	1956	D	270	6	P, 214	Ss, Sh	Kl	C, W	S	174.76		Oct. 1959	L.
23cc			D	431	6	P	Ss,Sh	Kl	C,W	S	123.0+		Nov. 1959	
37-66-8dd	Lightning Creek Livestock Co.	1959	D	180	4	P, 120	Ss,Sh	Tfu	C,W	S	51.04		Oct. 1959	
10cc	A. D. Kruse	1959	D	290	6	P	Ss,Sh	Tfu	C,W	S	52.54		do	Ca, D5R.
12bc	do		D	64.5	8	P	Ss,Sh	Kl	C,W	D,S	46.20		do	
14cc	do		D	97.5	8	P	Ss,Sh	Kl	C,W	D	10.98		do	
20ad	Lightning Creek Livestock Co.		D	360	3	P	Ss,Sh	Tfu	C,W	D,S	12		Nov. 1959	
37-67-12dd	do		D	300	4	P, 300	Ss,Sh	Tfu	C,W	S	190		do	
23db	R. Thompson		D	200	6	P, 125	Ss,Sh	Tfu	C,W	D,S	30		do	
26dd1	do	1953	D	255	4	P, 26	S,Ss	Qal, Tfu	N,N	N	9		1956	D10E, DD2R. Well gravel packed through alluvium.
26dd2	do		D	25	5	P, 35	S,G	Qal	N,N	N	10.24		Nov. 1959	L.
38-61-21cb	L. Christenson	1958	D	50	6	P, 50	Sh	Kp	C,W	S	11.00		Oct. 1959	

38-62-4dc	C. R. Brewster	1938	D	170			Ss	Kfh	C,W	S	120		do	
9cd	B. Brewster	1956	D	140	6	P, 140	Ss	Kfh	C,W	S			do	
17aa	C. R. Brewster		D	110	6	P, 110	Ss	Kfh	J,E	D	0.60		do	T45, Ca.
19ba	R. Pfister		D	150	6	P	Ss	Kfh	C,W	S	94.07		do	
21ad	S. V. Brewster		D	52	8	P	Ss	Kfh	C,W	D,S	46		do	
30bc	R. Pfister		D	150	6	P, 150	Ss	Kfh	C,W	S	104.73		do	
32db	H. Graham	1956	D	300	6	P, 300	Ss	Kfh	C,W	S			do	L.
34ab	E. Pfister	1933	D	20		P, 20	S,G	Qal	C,W	D,S	17		do	
38-63-1ca	Miller-Walker		D	90	6	P, 90	Ss, Sh	Kl	J, E	D, S	80.50		do	D15R.
3bc	do		D	115	6	P, 115	Ss, Sh	Kl	C, W	S	74.05		do	
5aa	do		D	60	6	P, 60	Ss, Sh	Kl	C, E	D, S	28.06		do	
20cb	O. Cockreham		D	100	6		Ss, Sh	Kl	C, W	S	11.10		do	
21cd	do		Du	35	60		S, G	Qal	C, W	S	9.11		do	
22ab	T. Jones		D	39	18	P, 39	S, G	Qal	Cf, G	I	10		do	D300R, DD25R.
22ac	do		D	90	5	P, 81	Ss, Sh	Kl	J, E	D	30		do	D30R.
23dc	J. Wasserberger		D	105	6	P, 105	Ss	Kfh	J, E	D, S	45		Mar. 1960	T42, Ca, D5E.
25bd	do		D	80	6	P, 80	Ss	Kfh	C, W	D, S	25		Oct. 1959	D100R, DD40R.
27dd	O. Pate	1956	D	275	6	P, 275	Ss	Kfh	C, W	S			do	L.
30cc	Johnson Ranches		D	70	6	P	Ss, Sh	Kl	C, W	D	44.20		Dec. 1959	Ca, D10R.
30cd1	do	1959	D	67	16	P	S, G	Qal	T, G	I	6.69		Mar. 1960	L, D295M, DD36.10M.
30cd2	do	1959	D	46	16	P, 46	S, G	Qal	T, G	I	7.55		do	Ca, D250R, DD22R. Measured depth 44.6 ft. Observation well.
30cd3	do	1959	D	68	14	P, 68	S, G	Qal	N, N	N	7.41		do	D280R, DD50R.
38-64-1bb	P. McDaniel		D	140	6	P	Ss, Sh	Kl	C, W	S	50		do	D2R.
12ab	R. DeGering	1956	D	250	6	P, 214	Ss, Sh	Kl	C, W	S			do	L.
18ac	J. N. Peterson		D	104.0	6	P	Ss, Sh	Kl	C, W	S	18.34		do	D6E, DD31R.
22aa	Johnson Ranches	1959	D	39	16	P, 39	S, G	Qal	N, N	I	19.20		June 1959	L, D170R, DD16R.
25ac	do	1959	D	70	6	P	Ss, Sh	Kl	C, W	S	25		Oct. 1959	
25dc	do		D	214	6	P, 210	Ss, Sh	Kl	C, W	S	150		do	
31ca	S. Sides	1953	D	255	7	P, 32	Ss, Sh	Kl	C, W	S			do	
38-65-3ca	F. Johnston		D	65.0	6	P	Ss, Sh	Kl	C, W	S	53.98		do	
15bc	J. N. Peterson		D	300	6	P	Ss, Sh	Kl	C, W	S	176.30		do	
19ba	J. L. Thompson		D	544	4	P, 544	Ss, Sh	Kl	J, E	D	50		do	
23dc	J. M. Peterson		D	49.7	6	P	Ss,Sh	Kl	C,W	S	27.46		do	
38-66-4ad	Lightning Creek live-stock Co.		D	213	4	P, 213	Ss,Sh	Tfu	C, W	S			do	T56, Ca.
5dd	do		D	52.7	5	P	Ss,Sh	Tfu	N,N	N	41.56		do	
6ca	G. E. Baker		D	46.0	5	P, 35	Ss,Sh	Tfu	C,H	D	18.24		do	
10cc	A. D. Kruse	1959	D	152	6	P, 152	Ss,Sh	Tfu	C,W	S	80		do	D6E, DD30R.
13ca	J. L. Thompson		D	35	6	P, 35	S,G	Qal	C,W	S	31.40		do	
26aa	do	1953	D	160	4	P, 160	Ss,Sh	Tfu	C,W	S			do	
38-67-24da			D	302	4	P	Ss,Sh	Tfu	C,W	S	81.27		Nov. 1959	
39-60-4bc	O. M. Hathaway	1913	Du	24.0	48	R, 24	S,G	Qal	C,W	S	20.12		Oct. 1959	
17ca	H. C. Sheaman		Du	20		R, 20	S,G	Qal	C,W	S	9.10		do	Water level in well affected by amount of water in nearby stock pond.
18ad	do	1957	D	85.0	6	N, 0	Sh	Kcl	N,N	N	20.43		do	Dissolved solids 10,800 ppm.
21cb	do		Du	15.0		R, 15	S,G	Qal	C,W	S	9.60		do	
34bb	W. T. Beebe	1950	D	980	6	P, 380	Sh	Kbm	C,W	S	197		do	Water contains 8,041 ppm dissolved solids.

TABLE 9.—*Records of wells and oil-test holes in Niobrara County, Wyo.*—Continued

Well	Owner or tenant	Year	Type of well	Depth of well (feet)	Diameter of well (inches)	Type and amount of casing (feet)	Principal aquifer		Method of lift and type of power	Use of water	Water level		Date of measurement	Remarks
							Type of material	Geologic source			Distance above (+) or below land surface (feet)	Altitude above mean sea level (feet)		
39-61-6bc	M. J. Rennard	1959	D	30	6	P, 30	S,G	Qal	C,G	S	18.18		Oct. 1959	
6db	do	1947	D	80	5	P, 80	Sh	Kp	C,W	D	71.56		do	
24aa	Sioux Oil Co.		D	1,239	7	P	Ss,Sh	Kik	C,G	In	700		do	
39-62-1cc	J. Kane	1957	D	100	20	P, 18	S,G	Qal	N		9.25		do	
3ab	H. Hammell	1958	D	335	6	P, 335	Ss	Kfh	C,W	S	120		do	D4E, DD22R.
7ba	F. C. Reed		D	20	6	P, 20	S,G	Qal	C,W	S	14		do	
11dc	D. Spencer	1948	D	41	5	P, 41	S,G	Qal	C,G	D,S	17		do	
17aa	C. M. Hanson	1905	Du	14		R, 14	S,G	Qal	C,W	D,S	12		do	Water reported suitable for domestic use.
39-62-17da	R. Pfister		D		8	P	Ss, Sh	Kl	C, W	S	103.25		do	
23ba	J. Kane		D	50	5	P, 50	Ss	Kfh	C, W	S	31.47		do	
34ac	Reiecke	1936	D	52	6	P	Ss	Kfh	C, W	S	40		do	
39-63-8cd	P. H Marchant		D	180	6	P, 160	Ss, Sh	Kl	C, W	S	84.93		do	
9ca	do	1956	D	293	6	P, 293	Ss, Sh	Kl	C, W	S	189.95		do	L, D12R.
11ba	A. Ketchum	1953	D	123	6	P, 123	Ss, Sh	Kl	C, W	S	95		do	D6R.
12cd	do		D	112	6	P, 112	Ss, Sh	Kl	C, G	S	15.72		do	D5R.
22bd	G. Francis		D	306	6	P	Ss, Sh	Kl	C, W	D	97.50		do	
25ac	Miller-Walker		D	125	6	P, 125	Ss, Sh	Kl	C, W	S	71.20		do	
31db	McKay Drilling Co.	1959	D	180	6	P	Ss, Sh	Kl	C, W	S	82		do	D35R.
33aa	R. Pfister		D	150	6	P, 150	Ss, Sh	Kl	C, W	S	92.14		do	D3R.
39-64-10cd	J. Zerbst		D	100	6	P, 100	Ss, Sh	Kl	C, W	S	17.08		do	D30+R.
12aa	E. C. Reed		D	132.0	6	P	Ss, Sh	Kl	C, W	S	62.24		do	
13cc	J Black		D	100	6	P, 80	Ss, Sh	Kl	C, W	S	20		do	D15R.
20bd	Zerbst Bros		D	250	6	P	Ss, Sh	Kl	C, W	S	240		do	D5R.
23dc	J. Black		D	200	5	P	Ss, Sh	Kl	C, W	S	90		do	D1.5R.
32dd	F. Johnson		D	178	6	P, 170	Ss, Sh	Kl	C, W	S	108		do	D30R, DD25R.
34cd	A. J. Beardsley		D	300	6	P	Ss, Sh	Kl	C, W	D	156		do	D15-20R.
39-65-13ab	F. Johnson		D	256	6	P, 256	Ss, Sh	Kl	C, W	S	108		do	
15ca	W. Rankin		D	259.0	5	P	Ss, Sh	Kl	C, W	S	238.23		do	
21cc	do		D	280	6	P	Ss, Sh	Kl	C, W	D	70		do	T44, Ca, D5E.
21dc	do		D	250	6	P	Ss, Sh	Kl	C, W	D, S	10		do	Ca, D5E.
22ac	do		D	350	5	P, 350	Ss, Sh	Kl	C, W	S	193.45		do	
28cd	do		D	285	4	P, 285	Ss, Sh	Kl	C, W	S	124.06		do	
32bd	do		D	71.0	6	P, 71	Ss. Sh	Kl	C, W	S	39.52		do	

39-66-10aa	T. Schmidt	1933	D	132	6	P	Ss, Sh	Tfu	C, W	S	108.65		do	T36, Ca, D5E.
20ac	W. Schmidt		D	315	6	P, 315	Ss, Sh	Tfu	C, W	S	202.30		do	
21db	F. A. Slagle		D	210	6	P, 210	Ss, Sh	Tfu	C, W	S	24.50		do	
24ac	W. Rankin		D	280	5	P, 280	Ss, Sh	Tfu	C, W	S	71.16		do	
30ab	C. E. Baker		D	327	5	P, 327	Ss, Sh	Tfu	C, W	S	150		do	
39-67-1ac	Sadler		D	285	6	P, 285	Ss, Sh	Tfu	C, W	S	185+		do	
24ac	E. A. Slagle		D	190	6	P, 190	Ss, Sh	Tfu	C, W	S	123.35		do	
40-60-21ca	D. Hathaway		Du		40	R, 12	S, G	Qal	C, W	S	7.41		do	
40-61-14da	F. R. Campbell	1950	D	263	8	P	Sh	Kcl	C, W	S	58.13		do	
15dd	do		D	260	9	P	Sh	Kcl	N, N	N	23.88		do	Water reported unfit for domestic use.
19da	C. Cooksey		D	40		P, 40	S, G	Qal	C, W	S	34		do	Water reported to be soft.
20ab	O. Kropatch	1958	D	25	7	P, 25	S, G	Qal	C, W	S	14		do	D5E, DD11R.
21ba	L. Sedgwick	1954	D	28	12	P	S, G	Qal	C, W	S	21		do	
22ab	F. B. Campbell		Du	14	36	R, 14	S, G	Qal	C, G	D, S	10.45		do	
30cd	A. Glasby	1958	D	50	5	P, 50	S, G	Qal	C, W	S	42		do	D8R, DD8R.
34bd	L. Sedgwick	1954	D	30	12	P, 25	S, G	Qal	C, W	S			do	
35dd	do	1953	D	350	6	P, 335	S, Ss	Qal, Kik	C, W	S	35		do	L.
40-62-1cd	B. Petty	1946	D	60	6	P, 60	Ss	Kfh	C, W	S	19.89		do	Water reported unfit for domestic use.
8dc	A. Glasby	1942	D	200	4	P, 200	Ss, Sh	Kl	N		110.80		do	Abandoned.
14ac	do	1948	D	200	4	P, 200	Ss	Kfh	C, W	S	25		do	Well pumps dry at 5 gpm.
15aa	W. O. Hanson		D	90	6	P, 90	Ss	Kfh	C, W	S	18.32		do	
23cc	do	1951	D	110		P, 110	Ss	Kfh	C, W	S	20.60		do	
25cc	A. Glasby	1939	D	40	6	P	Ss	Kfh	C, W	S	30		do	D10R. Water reported unfit for domestic use.
40-62-35da	F. Mahnke	1952	D		6	P	Ss	Kfh	C, W	S	62.36		do	
40-63-2bb	Whitney Bros		D	392	6	P, 390	Ss, Sh	Kl	C, W	S	290+		do	D15R.
9db	do		D	300		P, 270	Ss, Sh	Kl	C, W	S	200		do	
15ac	C. Christensen		D	160	6	P	Ss, Sh	Kl	C, W	S	26.09		do	
18bb	P. R. Gaskill		D	125	6	P, 105	Ss, Sh	Kl	C, G	S	65.70		do	
21bb	E. C. Reed	1954	D	280	6	P, 260	Ss, Sh	Kl	C, W	S	65		do	
26db	C. Christensen	1954	D	212	6	P, 212	Ss, Sh	Kl	C, W	S	103.68		do	L.
33bb	E. C. Reed	1930	D	400	6	P, 350	Ss, Sh	Kl	F, N	D, S	+		do	Ca, D3E.
34db	C. Christensen		D	150	6	P, 100	Ss, Sh	Kl	C, W	D, S	45		do	
40-64-1aa	G. Hansen	1959	D	112	6	P	Ss, Sh	Kl	C, W	D	27.84		Sept. 1959	T45, Ca, D5E.
1dc	do	1959	Du	21.0	28	G, 21	S, G	Qal	Cf, E	I	8.11		do	T41, Ca, D250R, DD10R.
13cb	P. R. Gaskill		D	46	6	P, 40	S, G	Qal	J, E	D, S	40		do	
15ca	do	1958	D	205	6	P, 200	Ss, Sh	Kl	C, W	S	75.00		do	D30R, DD70R.
21ac	Zerbst Bros		D	165	6	P, 160	Ss, Sh	Kl	C, W	S	40		do	
25cc	L. Gibbs		D	35	6	P, 35	S, G	Qal	Cf, E	D	18		do	
28ba	Zerbst Bros		D	210	6	P, 200	Ss, Sh	Kl	C, W	S	48.07		do	
29cc	J. Gibbs		Du	28			S, G	Qal	C, G	D, S	18		do	
35ba	L. Gibbs		D	240	6	P	Ss, Sh	Kl	C, W	S	180		do	D24R.

TABLE 9.—*Records of wells and oil-test holes in Niobrara County, Wyo.*—Continued

Well	Owner or tenant	Year	Type of well	Depth of well (feet)	Diameter of well (inches)	Type and amount of casing (feet)	Principal aquifer: Type of material	Principal aquifer: Geologic source	Method of lift and type of power	Use of water	Water level: Distance above (+) or below land surface (feet)	Water level: Altitude above mean sea level (feet)	Date of measurement	Remarks
40-65-4ad	R. Dixon		D	320	6	P, 320	Ss, Sh	Kl	C, W	S	216.12		Sept. 1959	
22ad	H. Dixon	1950	D	90	6	P, 90	Ss, Sh	Kl	C, W	D	35		do	Water reported strongly alkaline.
33ab	R. Dixon		D	150	4	P, 150	Ss, Sh	Kl	C, W	D, S	142		do	
33ca	do		D	150	4	P, 150	Ss, Sh	Kl	C, W	S	146		do	
40-66-6ca	Schmidt Bros	1958	D	320	6	P, 320	Ss, Sh	Tfu	C, W	S	90		do	
19dc	do	1953	D	325	6	P, 250	Ss, Sh	Tfu	C, W	S	178.72		do	L.
21dc	do		D	240	5	P	Ss, Sh	Tfu	C, W	S	120		do	
27dd	E. Ballard		D		5	P	Ss, Sh	Tfu	C, W	S	22.70		do	
40-66-31dc	T. Schmidt	1953	D	160	6	P, 160	Ss, Sh	Tfu	C, W	S			do	
33da	E. Ballard		D	93	6	P, 93	Ss, Sh	Tfu	C, W	D	26.66		Oct. 1959	
35ac	do		D	60	4	P, 60	Ss, Sh	Tfu	C, W	D	25.25		do	
40-67-10dc	Schmidt Bros		D	348	6	P, 348	Ss, Sh	Tfu	C, W	S	105+		do	
11da	do	1957	D	290	6	P, 290	Ss, Sh	Tfu	C, W	S	65		do	
22bb	do		D	150	6	P	Ss, Sh	Tfu	N, N	N	45.06		do	
22da	do		D	170.0	4	P	Ss, Sh	Tfu	C, W	S	83.56		do	
23dd	T. Schmidt		D	116.0		P	Ss, Sh	Tfu	C, W	D, S	78.76		do	D4E, DD19.0M.
25ab	Schmidt Bros		D	360	6	P, 360	Ss, Sh	Tfu	C, W	S	250		do	L, D10E, DD30R.
27cb	do		D	74.4	4	P	Ss, Sh	Tfu	N, N	N	37.92		do	
41-62-32cb	C. Christensen		D	90	6	P, 90	Ss	Kfh	C, W	S	33.45		do	
41-63-26dd	Whitney Bros		Du	14	6	P, 12	S, G	Qal	C, W	S	8		do	D5R.
27cc	do	1929	D	240	6	P	Ss, Sh	Kl	C, W	D, S	175		do	D15R.
41-64-26cb	Mahnke		D	45.0	6	P	S, G	Qal	C, H	D, S	28.26		do	D5R, DD5R.
33dd	F. G. Thompson		D	100	6	P	Ss, Sh	Kl	C, W	S			do	
41-65-29cb	C. O. Gaskill	1957	D	220	6	P, 220	Ss, Sh	Kl	C, W	S			do	
33bb			D	124.0	6	P	Ss, Sh	Kl	C, W	S	114.78		do	
41-66-26dd	W. Gaskill	1955	D	401	6	P, 404	Ss, Sh	Tfu	C, W	S			do	L.

DRILLERS' LOGS OF WATER WELLS AND OIL-TEST HOLES IN NIOBRARA COUNTY

The following pages (table 10) contain logs of 59 water wells and oil-test holes drilled in Niobrara County. The data were obtained principally from drillers' records, well owners, and files of the Niobrara County Agricultural Stabilization and Conservation Office at Lusk. The descriptive terminology used is mainly that of the driller. Most stratigraphic interpretations were made by the author. The locations of wells and oil-test holes for which logs are available are shown on the geologic map (pl. 1) and are numbered according to the system used for numbering wells as previously described.

TABLE 10.—*Drillers' logs of water wells and oil-test holes in Niobrara County, Wyo.*

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
31-61-11dc					
Alluvium:			Arikaree Formation—Continued		
Quicksand	20	20	Sandstone, brown	50	80
Arikaree Formation:			Hard rock	20	100
Hard rock	10	30	Sandstone, brown	30	130
31-61-29cd					
Alluvium:			Arikaree Formation—Continued		
Topsoil	10	10	Sandstone	160	200
Arikaree Formation:			Sandstone, brown (water at 200 ft)	30	230
Butte rock (sandstone)	30	40			
31-65-18cb					
Alluvium:			Arikaree Formation—Continued		
Topsoil	15	15	Chalk rock (tuffaceous layer?)	2	130
Arikaree Formation:			Sandstone (water at 185 ft)	60	190
Sandstone	113	128			
32-62-6bc					
Alluvium:			Arikaree Formation:		
Topsoil	10	10	Sandstone	225	235
32-62-17cd (Log of test hole about 60 ft from well)					
Alluvium:			Arikaree Formation—Continued		
Topsoil	6	6	Limestone, hard [1]	2	56
Silt	2	8	Sandstone, soft	68	124
Sand and gravel	2	10	Limestone, hard [1]	2	126
Arikaree Formation:			Sandstone	10	136
Limestone, hard [1]	2	12	Limestone, hard [1]	2	138
Sandstone, fine, soft	24	36	Sandstone, soft, layers of hard limestone	30	168
Limestone, hard [1]	1	37			
Sandstone, soft	17	54			

[1] Concretionary sandstone or siltstone.

TABLE 10.—*Drillers' logs of water wells and oil-test holes in Niobrara County, Wyo.*—Continued

32–62–20bd

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Alluvium:			Arikaree Formation—Continued		
Topsoil	10	10	Gravel [2]	30	80
Arikaree Formation:			Sandstone, brown	7	87
Lime shell, sandy [1]	5	15	Gravel, hard shell [2]	3	90
Sandstone, gray and brown	10	25	Sandstone, brown	13	103
Lime, shell, hard, sandy [1]	5	30	Gravel, hard [2]	3	106
Sandstone, brown (water at 40 ft)	20	50	Sandstone, brown	44	150

[1] Concretionary sandstone or siltstone.
[2] Conglomerate.

32–63–2cc

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Alluvium:			Arikaree Formation—Continued		
Sand and gravel	17	17	Sandstone	4	70
Arikaree Formation:			Chalk rock, fractured [2]	3	73
Sandstone, fractured	34	51	Sandstone and clay	2	75
Limestone, hard [1]	1	52	Sandstone, soft	25	100
Sandstone, soft	5	57	Sandstone, hard	15	115
Limestone, hard [1]	1	58	Sandstone, soft	19	134
Sandstone	7	65	Sandstone, hard	16	150
Limestone [1]	1	66	Sandstone, soft	50	200

[1] Concretionary sandstone or siltstone.
[2] Tuffaceous layer.

32–63–7bb2

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Alluvium(?):			Arikaree Formation—Continued		
Sandy loam	65	65	Sandstone	15	115
Arikaree Formation:			Gravel, fine [1]	13	128
Sandstone	10	75	Chalky silt [2]	2	130
Gravel, fine [1]	25	100			

[1] Conglomerate.
[2] Tuffaceous layer.

32–63–8db2

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Alluvium(?):			Arikaree Formation—Continued		
Sandy loam	60	60	Gravel, fine [1]	20	120
Arikaree Formation:			Sandstone	6	126
Sandstone	10	70	Gravel, coarse [1]	24	150
Gravel, fine [1]	20	90	Chalky silt [2]	1	151
Sandstone	10	100			

[1] Conglomerate.
[2] Tuffaceous layer.

32–64–14ba

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Alluvium:			Arikaree Formation—Continued		
Sandy clay	10	10	Sandstone	30	220
Arikaree Formation:			Precambrian:		
Sandstone (water)	170	180	Granite, red	5	225
Clay (claystone or siltstone)	10	190			

32–64–18bd

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Alluvium:			Arikaree Formation—Continued		
Topsoil	6	6	Sandstone, soft fractured	17	70
Arikaree Formation:			Sandstone, hard	14	84
Sandstone, hard	35	41	Hard rock (Hartville(?) Formation)	26	110
Chalk rock, hard (tuffaceous layer)	12	53			

TABLE 10.—*Drillers' logs of water wells and oil-test holes in Niobrara County, Wyo.*—Continued

32-64-24da

[Log of test hole about 30 ft from well]

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Alluvium:			Arikaree Formation—Continued		
Clay, sandy	10	10	Sandstone, broken	60	90
Arikaree Formation:			Shale, sandy	10	100
Limestone (concretionary sandstone or siltstone)	20	30			

32-64-25da

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Alluvium:			Arikaree Formation—Continued		
Silt, sand, and gravel	10	10	Limestone, fissured, and loose rock [1]	2	51
Clay	3	13	Sandstone, soft	4	55
Arikaree Formation:			Limestone [1]	4	59
Limestone [1]	1	14	Sandstone, soft	8	67
Sandstone, hard; limestone chips	7	21	Sandstone, hard	6	73
Sandstone, moderately hard	21	42	Limestone, broken [1]	2	75
Limestone, fissured [1]	2	44	Sandstone	7	82
Sandstone	5	49			

[1] Concretionary sandstone or siltstone.

32-65-35bb

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Alluvium:			Arikaree Formation—Continued		
Silt and fine sand	10	10	Sandstone, brown (water at 110-120 ft)	20	120
Arikaree Formation:			Hard shell [1]	10	130
Sandstone, brown, hard	80	90	Sandstone, brown (water)	10	140
Hard shell [1]	10	100	Chalk rock [2]	10	150

[1] Concretionary sandstone or siltstone.
[2] Tuffaceous layer.

32-66-26da

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Alluvium:			Arikaree Formation—Continued		
Dirt	4	4	Chalk rock (tuffaceous layer)	1	81
Arikaree Formation:			Sandstone (water at 170 ft)	93	174
Sandstone	76	80			

32-67-11dd

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Alluvium:			Arikaree Formation—Continued		
Dirt	1	1	Sandstone (water at 141 and 192 ft)	182	195
Arikaree Formation:					
Chalk rock (tuffaceous layer)	12	13			

33-62-6cb

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Alluvium:			Arikaree Formation:		
Topsoil	5	5	Sandstone (water at 310 ft)	335	340

33-63-30cc (oil test)

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
White River Group or Arikaree:			Precambrian:		
Formation	248	248	Schist, brown, micaceous	62	350
White wash sand(?)	40	288	Schist and shale, green	65	415
			Schist, black, micaceous	35	450

TABLE 10.—*Drillers' logs of water wells and oil-test holes in Niobrara County, Wyo.*—Continued.

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
33-64-25db (oil test)					
Arikaree Formation and White River Group	525	525	Quartzite of Cambrian(?) age:		
Conglomerate(?)	255	780	Sandstone, red	21	909
Guernsey Formation:			Sandstone, red and purple	37	946
Limestone and dolomite, gray	55	835	Precambrian(?):		
Sandstone, pink	21	856	Shale, green and yellow	39	985
Limestone, pink	19	875	Shale, green, metamorphosed	243	1,228
Sandstone, pink	13	888	Schist, black	12	1,240
33-65-35ba2 (oil test)					
Arikaree Formation and White River(?) Group:			Carlile(?) Shale:		
Sandstone, clear, white, pink, and brown, fine- to coarse-grain, unconsolidated to slightly calcareous; contains weathered glauconite and biotite	500	500	Siltstone, light-gray, calcareous, containing gray, green, and brown bentonitic shale and sandstone	216	1,402
Sandstone as above, becoming more calcareous	550	1,050	Greenhorn Formation	88	1,490
Sandstone, containing flakes of biotite	75	1,125	Belle Fourche and Mowry Shales	406	1,896
Sandstone	61	1,186	Newcastle Sandstone and Skull Creek Shale	244	2,140
33-66-9ba (oil test)					
Arikaree Formation and White River Group	985	985	Morrison Formation	207	1,364
Inyan Kara Group	172	1,157	Sundance Formation	408	1,772
			Spearfish Formation	23	1,795
33-66-18db (oil test)					
Arikaree Formation	750	750	Minnekahta Limestone	50	1,910
White River Group	490	1,240	Opeche Formation	60	1,970
Spearfish Formation	620	1,860	Minnelusa Formation	--------	--------
33-66-20ac (oil test)					
Arikaree(?) Formation	695	695	Minnelusa Formation—Con.		
White River(?) Group	295	990	Sandstone, claystone, limestone, and dolomite	240	1,390
Minnelusa Formation:					
Sandstone	160	1,150			
33-67-1dc					
Alluvium:			Arikaree Formation—Continued		
Topsoil	10	10	Sandstone and conglomerate	20	110
Arikaree Formation:			Sandstone, layers of hard chalk rock	110	220
Sandstone	70	80			
Chalk rock, hard, and sandstone	10	90			
33-67-15cd					
Alluvium:			Arikaree Formation—Continued		
Topsoil	1	1	Chalk rock [1]	1½	91½
Arikaree Formation:			Sandstone	33½	125
Sandstone	17	18	Chalk rock [1]	2	127
Chalk rock [1]	1	19	Sandstone	79	206
Sandstone	71	90	Conglomerate (water)	4	210

[1] Tuffaceous layer.

TABLE 10.—*Drillers' logs of water wells and oil-test holes in Niobrara County, Wyo.*—Continued.

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
34-60-28ba					
Alluvium:			White River Group—Continued		
Clay and silt	10	10	Shale	40	160
White River Group:			Coarse sandstone and gravel (conglomerate), soft	25	185
Shale, variegated (water)	50	60			
Shale, blue	60	120			
34-62-28bb					
Alluvium:			Arikaree Formation:		
Topsoil	5	5	Sandstone	357	362
34-63-2dd (oil test)					
White River Group:			White River Group—Continued		
Shale, light-yellow; red and sandy at base	116	116	Sandstone; grains all colors and shapes	12	212
Sandstone, white and brown	2	118	Shale, yellow, blue, dark-red, and purple	38	250
Shale, yellow and blue	3	121	Sandstone, gray and variegated	33	283
Sandstone, variegated	3	124	Shale, blue, gray, purple, sandy	14	297
Shale, yellow and brown	2	126	Sandstone, variegated, fine-grained, and black and brown shale	13	310
Sandstone, brown, white, yellow, and pink	43	169	Shale, black; some white fine-grained sandstone	7	317
Shale, blue and yellow	2	171			
Limestone, blue, brown, and pink	7	178			
Shale, blue, pink, and yellow	10	188			
Sandstone, gray and brown	10	198			
Limestone, sandy	2	200			
34-63-3da (oil test) [Log of tops of formations only]					
White River group		Surface	Morrison Formation	--------	355
Inyan Kara Group	--------	170	Total depth	--------	1,300
34-65-1bc					
White River Group	133	133	Inyan Kara(?) Group—Continued		
Inyan Kara(?) Group:			Sandstone, brown	34	250
Sandstone (water)	77	210	Shale, variegated	15	265
Shale, sandy	6	216			
34-65-4cb (oil test)					
White River Group	349	349	Inyan Kara Group	239	1,042
Belle Fourche(?) Shale	101	450	Morrison Formation	198	1,240
Mowry Shale	168	618	Sundance Formation	361	1,601
Newcastle Sandstone and Skull Creek(?) Shale	185	803	Spearfish Formation	14	1,615
34-67-27bb					
Alluvium:			Fort Union Formation—Con.	10	190
Topsoil	20	20	Sandstone (water)	53	243
Fort Union Formation:			Shale		
Shale	160	180			

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TABLE 10.—*Drillers' logs of water wells and oil-test holes in Niobrara County, Wyo.*—Continued.

35-62-8cb

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Alluvium:			White River Group—Continued		
Clay	10	10	Shale	10	200
White River Group:			Sandstone (water)	20	220
Shale	20	30	Shale	10	230
Sandstone	70	100	Sandstone (water)	10	240
Shale	40	140	Shale	55	295
Sandstone (water)	50	190			

35-62-29bb (oil test)

[Log of tops of formations only]

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
White River Group		Surface	Inyan Kara Group		600
Newcastle Sandstone		440	Total depth		623
Skull Creek Shale		480			

35-63-15dc (oil test)

[Log of tops of formations only]

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
White River Group		Surface	Sundance Formation		1,000
Inyan Kara Group		465	Total depth		2,605
Morrison Formation		760			

35-63-27dd

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Alluvium:			Inyan Kara Group—Continued		
Sandy clay	10	10	Sandstone	10	110
Inyan Kara Group:			Shale	20	130
Sandstone	20	30	Sandstone (water)	10	140
Shale	10	40	Iron rock (quartzite)	10	150
Shale, blue	10	50	Sandstone (water)	10	160
Iron rock (quartzite)	30	80	Shale	10	170
Red beds (red shale)	10	90	Sandstone (water)	30	200
Shale	10	100			

35-64-5ca

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Alluvium:			White River Group—Continued		
Sandy clay	10	10	Shale	100	180
White River Group:			Sandstone (water)	20	200
Shale	60	70	Shale (water)	40	240
Sandstone (water)	10	80			

35-64-20ac

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Alluvium:			White River Group—Continued		
Topsoil	10	10	Shale, yellow	80	190
White River Group:			Sandstone, green	15	205
Shale, yellow	70	80	Pierre Shale:		
Sandstone, green	30	110	Shale, black	5	210

35-65-32da (oil test)

[Log of tops of formations only]

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
White River Group		Surface	Inyan Kara Group		735
Mowry Shale		376	Sundance Formation		1,466
Newcastle Sandstone		543	Total depth		1,625

TABLE 10.—*Drillers' logs of water wells and oil-test holes in Niobrara County, Wyo.*—Continued.

35-65-35ab

[Log of test hole about 500 ft from well]

Material	Thickness (feet)	Depth (feet)
Alluvium	16	16
White River Group:		
Shale, light-gray, soft	22	38
Shale, light-gray (some green and blue streaks), slightly sandy	92	130
Shale, light-gray to blue; coarse-grained conglomeratic sandstone near base	28	158
Shale, light-brown to pink, blue and green	62	220
Inyan Kara(?) Group:		
Sandstone, coarse-grained, conglomeratic; finer grained toward base; consists of grains of quartz and chert	18	238
Inyan Kara(?) Group—Con.		
Sandstone, brown, fine- to coarse-grained; coarser toward base; consists of quartz grains	72	310
Sandstone, medium-grained, interbedded with coarse-grained conglomeratic sandstone; consists of quartz and chert grains	30	340
Shale, reddish-brown; coarse-grained sandstone near base	20	360
Sandstone, gray, medium- to fine-grained; consists of quartz grains	34	394
Sandstone, gray, medium-grained	9	403
Not logged	95	498

36-63-34ad

Material	Thickness (feet)	Depth (feet)
White River Group:		
Shale	30	30
Sandstone	50	80
Shale, blue	20	100
White River Group—Continued		
Sandstone (water)	80	180
Shale, blue	30	210

36-64-29bb

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Clay and silt	10	10
Pierre Shale:		
Shale, black	10	20
Sandstone	10	30
Shale, black	260	290
Pierre Shale—Continued		
Sandstone	10	300
Shale, sandy	10	310
Sandstone (water)	10	320
Shale, black	30	350

36-66-15ba

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Clay, sandy	10	10
Fort Union Formation:		
Shale	50	60
Sandstone	30	90
Shale	100	190
Fox Union Formation—Con.		
Sandstone	20	210
Shale	10	220
Sandstone (water)	40	260
Shale	15	275

37-62-5da

[Water at 170 and 240 ft]

Material	Thickness (feet)	Depth (feet)
Fox Hills Sandstone:		
Shale, yellow	40	40
Shale, blue	80	120
Sandstone	80	200
Fort Hills Sandstone—Continued		
Shale, blue, sandy	30	230
Sandstone	25	255

37-63-2bb

Material	Thickness (feet)	Depth (feet)
Alluvium:		
Topsoil	10	10
Fox Hills Sandstone:		
Sandstone	40	50
Sandstone, hard, ferruginous	10	60
Sandstone	10	70
Fox Hills Sandstone—Continued		
Mudstone	60	130
Sandstone (water)	30	160
Sandstone	65	225
Sandstone, hard, ferruginous	5	230
Sandstone	10	240

TABLE 10.—*Drillers' logs of water wells and oil-test holes in Niobrara County, Wyo.*—Continued.

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
37-63-34bc [Water at 190 ft]					
Alluvium:			Lance Formation—Continued		
Clay, yellow	10	10	Shale, blue	40	120
Fox Hills Sandstone:			Shale, yellow, sandy, calcareous	30	150
Sandstone	20	30	Shale, gray, sandy, calcareous	75	225
Shale, yellow, sandy	50	80			
37-65-21ac					
Alluvium:			Fox Hills Sandstone—Continued		
Topsoil	10	10	Sandstone, blue	60	120
Lance Formation:			Shale, blue	65	185
Sandstone	10	20	Sandstone (water)	15	200
Shale, brown	20	40	Shale, blue	70	270
Shale, blue	20	60			
37-67-26dd2					
Alluvium:			Alluvium—Continued		
Topsoil	4	4	Sand, coarse, and gravel	13	25
Sand, fine, and silt	8	12			
38-62-32db					
Alluvium:			Fox Hills Sandstone—Con.		
Clay	20	20	Sandstone, blue	30	180
Fox Hills Sandstone:			Shale, blue	80	260
Shale, black	130	150	Sandstone (water)	40	300
38-63-27dd					
Alluvium:			Fox Hills Sandstone—Con.		
Topsoil	10	10	Sandstone (water)	10	110
Fox Hills Sandstone:			Shale, blue	10	120
Shale, yellow	10	20	Sandstone, brown, hard	10	130
Sandstone, brown	20	40	Shale, gray	60	190
Shale, gray	20	60	Sandstone, blue (water)	30	220
Sandstone, brown	20	80	Shale, blue	30	250
Shale, blue	20	100	Sandstone, blue	25	275
38-63-30cdl					
Alluvium:			Lance Formation—Continued		
Topsoil	5	5	Sandstone, blue, soft, conglomeratic	3	58
Clay, silt, sand, and gravel	40	45	Shale, black	9	67
Lance Formation:					
Shale, blue, sandy	10	55			
38-64-12ab					
Lance Formation:			Lance Formation—Continued		
Shale	50	50	Sandstone (water at 160-170 ft)	50	180
Sandstone (water at 110-220 ft)	70	120	Shale	70	250
Shale	10	130			
38-64-22aa					
Alluvium:			Lance Formation:		
Topsoil	5	5	Shale, blue	2	39
Clay, black	9	14			
Sand and gravel; clay and silt	23	37			

TABLE 10.—*Drillers' logs of water wells and oil-test holes in Niobrara County, Wyo.*—Continued

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
39–63–9ca					
Alluvium:			Lance Formation—Continued		
Sand	10	10	Shale	12	142
Lance Formation:			Sandstone	18	160
Shale	12	22	Shale	22	182
Sandstone	18	40	Sandstone	18	200
Shale	32	72	Shale	20	220
Sandstone	18	90	Sandstone (water)	10	230
Shale	24	114	Shale	50	280
Sandstone	16	130	Sandstone (water)	13	293
40–61–35dd					
Alluvium:			Inyan Kara Group:		
Sand and gravel	20	20	Sandstone (water)	12	272
Mowry Shale	140	160	Shale	52	324
Newcastle Sandstone:			Sandstone and shale	12	336
Sandstone (water)	40	200	Sandstone (water)	8	344
Skull Creek Shale:			Shale, gray	8	346
Shale, sandy	40	240	Shale, red	4	350
Sandstone and shale	20	260			
40–63–26db					
Alluvium:			Lance Formation—Continued		
Topsoil	10	10	Shale	70	100
Lance Formation:			Sandstone (water)	10	110
Shale	10	20	Shale	90	200
Sandstone	10	30	Sandstone (water)	12	212
40–66–19dc					
Alluvium:			Fort Union Formation—Con.		
Sand and gravel	20	20	Shale, gray	30	200
Fort Union Formation:			Sandstone (water)	20	220
Shale, dark, sandy	150	170	Shale, dark, sandy	105	325
40–67–25ab					
Alluvium	25	25	Fort Union Formation—Con.		
Fort Union Formation:			Sandstone and coal	10	170
Shale	25	50	Shale	60	230
Sandstone	10	60	Sandstone	20	250
Shale	10	70	Shale	10	260
Sandstone	40	110	Sandstone	90	350
Shale	10	120	Shale	10	360
Sandstone	40	160			
41–66–26dd					
Alluvium	5	5	Fort Union Formation—Con.		
Fort Union Formation:			Shale, gray, sandy (water)	350	370
Shale, brown, sandy	5	10	Sandstone (water)	31	401
Sandstone	10	20			

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