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WATER RESOURCES OF THE CUT BANK AREA, GLACIER AND TOOLE COUNTIES, MONTANA

By
Everett A. Zimmerman

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Water Resources of the Cut Bank Area, Glacier and Toole Counties, Montana

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ABSTRACT

The Cut Bank area includes about 750 square miles in Glacier and Toole Counties in northwest Montana. Ground water from the Virgelle Sandstone and Two Medicine Formation is the principal source of fresh water for domestic, stock, and industrial use. Normal annual precipitation at Cut Bank is 11.53 inches. The climate is semiarid and surface drainage is poorly developed in parts of the area. Cut Bank Creek is the only stream having a sustained flow, and it seldom has a discharge of less than 10 cubic feet per second. It is the source of municipal water for Cut Bank.

Production and refining of oil are the principal industries. Pumping of water from the Virgelle Sandstone for secondary recovery of oil and for refinery operations, in conjunction with drought conditions, has caused concern over possible depletion of the water supply.

The Cut Bank area is underlain by sedimentary rocks that range in age from Precambrian to Recent. The Madison Group of Mississippian age and the Virgelle Sandstone and Two Medicine Formation of Cretaceous age are significant to the ground-water supply of the area. The Madison Group is deeply buried and contains saline water. It supplies most of the water used for secondary recovery of oil within the study area. Wells yielding 500 gallons per minute with pumping lifts exceeding 1,000 feet probably can be obtained.

The Virgelle Sandstone and Two Medicine Formation crop out in the area. The Virgelle is capable of yields of 250 gallons per minute, but the Two Medicine will yield 10 gallons per minute or less. In places, both formations are hydraulically connected; the higher yields from the Virgelle may be attributed to secondary fracturing.

Infiltration of precipitation along the outcrop and interformational leakage are the major means of ground-water recharge. From a topographically high, poorly drained area west of Sunburst, water in the Virgelle Sandstone moves principally northward to discharge areas in Canada and southeastward to discharge areas along Cut Bank Creek.

Surface water in the Cut Bank area is generally of good quality for most uses. It generally contains less than 500 parts per million of total dissolved solids and is hard to very hard. The chemical quality of the water varies with the stream discharge; the water of best quality is associated with high streamflow.

The ground water is commonly mineralized, hence its usefulness for many purposes is impaired. Water from the Madison Group is too mineralized for most uses, the dissolved solids concentration exceeding 7,000 parts per million. The water from the Virgelle Sandstone is similar to that from the Two Medicine Formation. Total dissolved solids concentration ranges from about 500 parts per million to about 5,000 parts per million. The quality is poorer at increasing distance from the outcrop as the formations become more deeply buried.

Rising water levels in the area during 1964 and 1965 suggest that, at present rates of use, depletion of ground-water supplies is not imminent.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

Ground water is the principal source of fresh water for domestic, stock, and industrial supplies in the Cut Bank area. The production and refining of oil are the principal industries. Declines in the water levels and yields from wells in part of the area along with proposed increases in use of fresh water for secondary recovery of oil by waterflooding had caused concern over possible depletion of the fresh water supply.

A cooperative investigation of the water resources of the area was begun in July 1964 by the U. S. Geological Survey and the Montana Bureau of Mines and Geology to provide information useful in planning the utilization of the available fresh water.

Information was to be obtained on (1) the quantity of water available from surface- and ground-water sources; (2) the character, thickness, and areal extent of the principal water-bearing formations, especially the Virgelle Sandstone; (3) the source, occurrence, and direction of movement of ground water; (4) the present and potential development of the water resources; and (5) the chemical quality of the water.

LOCATION OF THE STUDY AREA

The Cut Bank area includes parts of Glacier and Toole Counties in northwest Montana. The area is delineated on the east by the east edge of R. 4 W. in T. 32-34 N. and the east side of R. 3 W. in T. 35-37 N., on the north by the Canadian boundary, on the west by the west edge of R. 6 W., and on the south by the south edge of T. 32 N. Figure 1 shows the loca-

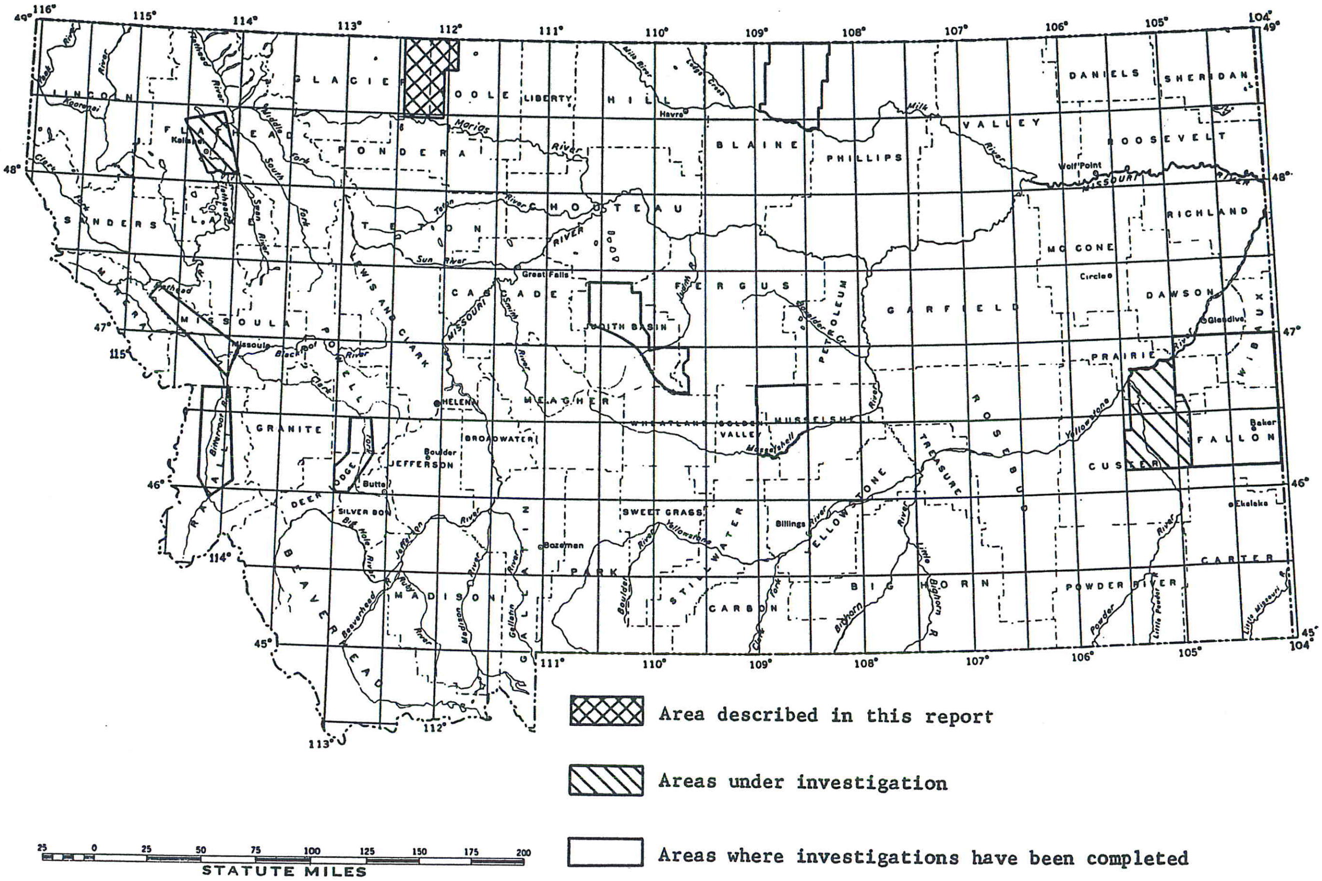

Figure 1.—Location of cooperative ground-water investigations in Montana, 1955-66.

tion of this study area and other areas studied as part of a program of cooperative investigations.

The towns or villages of Cut Bank, Santa Rita, Sweetgrass, Kevin, and Ethridge are in the study area; Sunburst and Shelby are short distances east of the area. The Cut Bank area includes about 750 square miles.

PHYSIOGRAPHY

The Cut Bank area is in the glaciated Missouri Plateau of the Great Plains physiographic province (Fenneman, 1931). The total relief is about 1,000 feet. Rolling plains with many small undrained depressions occupy much of the area. A fairly smooth plain north of Cut Bank, formerly the bottom of glacial Lake Cut Bank, occupies about 100 square miles.

An escarpment about 200 feet high marks the outcrop of the Virgelle Sandstone along an irregular line extending from a point about 5 miles east of Cut Bank to a point near Sweetgrass. Cut Bank Creek and Two Medicine Creek have incised steep-walled gorges about 200 feet deep south of Cut Bank. Melt water from glaciers cut steep ravines back into the Virgelle escarpment near Sweetgrass and Sunburst. Step-like terraces in the southwest part of the area are dissected by a few small streams.

DRAINAGE

Most of the study area is in the Marias River drainage. Cut Bank Creek is the principal stream. It joins with Two Medicine Creek to form the Marias River 12 miles south of Cut Bank. The main tributaries to Cut Bank Creek are Spring Creek, Snake Coulee, Rocky Coulee, and Little Rocky Coulee. The Red River drains some of the north part of the area. It flows north into Alberta, Canada, where it joins the Milk River.

Drainage is poorly developed in much of the study area. Small undrained depressions are numerous, especially in the northern part. Most of these are small intermittent potholes, but a few are small lakes filled with water in most years. The part of the area east of the Virgelle Sandstone escarpment is drained by small ephemeral streams that flow into intermittent lakes.

PREVIOUS INVESTIGATIONS

Erdmann, Beer, and Nordquist (1946) prepared a geologic and structural map of the area, a stratigraphic column, and cross section. Their mapping of the bedrock is used for this report (Pl. 2). Cobban (1955) discussed the stratigraphy of the Cretaceous rocks. Paulson and Zimmerman (1965) discussed the geology and ground-water resources of the Two Medicine Irrigation Unit on the Blackfeet Indian Reservation, which is west of the study area. Meyboom (1960) studied the geology and ground-water resources of the Milk River Sandstone (correlative with the Virgelle Sandstone) of southern Alberta. Many of his observations are applicable to ground water in the Virgelle Sandstone in northwest Montana.

Alden (1932) described the area in his report on the physiography and glacial geology of Montana east of the Continental Divide. The area is also included on the glacial map of Montana east of the Rocky Mountains by Colton, Lemke, and Lindvall (1961). A part of their map is used in this report to show the surficial geology (fig. 7). Stebinger (1917) mapped the bedrock geology of the study area as part of his study of anticlines on the Blackfeet Indian Reservation.

The Cut Bank area has been intensively studied by many petroleum geologists. Much of their work is unpublished but many articles have appeared in professional journals and guidebooks. Most of these articles are devoted to specific oil fields or stratigraphy of oil-bearing zones. The geology and production data of the oil fields are summarized in the Montana Oil and Gas Fields Symposium edited by the symposium committee of the Billings Geological Society (1958; supp. in 1961). The Billings Geological Society's guidebook for their sixth annual field conference (1955) contains several articles pertinent to the geology of the area.

SITE-NUMBERING SYSTEM

The wells and other sites listed in this report are numbered according to their location within the U. S. Bureau of Land Management's survey of the area (fig. 2). The first numeral of the well or site number denotes the township, the second the range, and the third the section in which the well or other site is located. Lowercase letters following the section number show the location of the well or site within the section. The first letter indicates the quarter section,

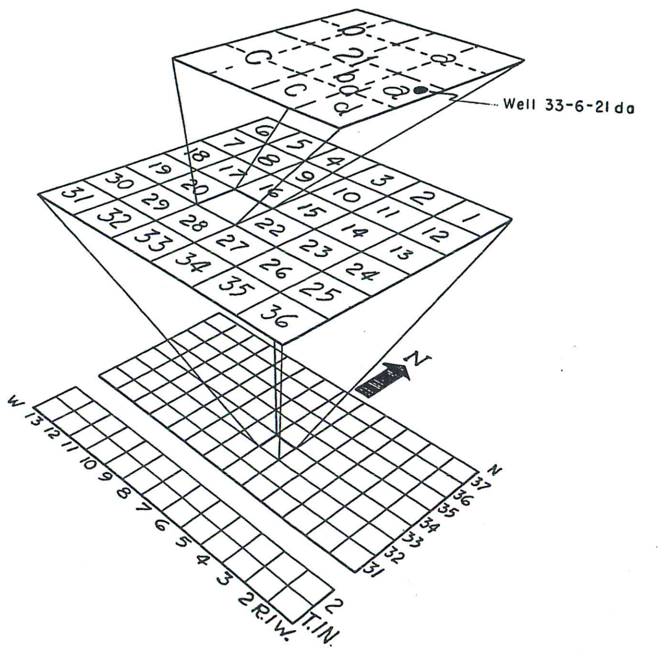

Figure 2.—Site-numbering system.

and the second the quarter-quarter section. These subdivisions of the section are lettered a, b, c, and d in a counterclockwise direction, beginning with the northeast quarter. If two or more wells or sites are located within the same quarter-quarter section (40-acre tract) they are distinguished by numerals following the lowercase letters.

ACKNOWLEDGMENTS

Thanks are extended to those individuals who supplied information about their wells and permitted access to their property. Oil company and municipal personnel contributed much information regarding water wells and aided greatly in measuring and testing some wells.

Special thanks are due well owners who permitted repeated measurements of their wells. Several drillers in the Cut Bank vicinity contributed logs and other information about wells that they constructed. County employees aided in providing access to well and ownership records.

DESCRIPTION OF THE HYDROLOGIC SYSTEM

Large quantities of water are stored in oceans, in continental surface and subsurface reservoirs, and in the atmosphere. Such storage is temporary insofar as there is a constant interchange of water from one environment to another. The endless interchange of water is known as the hydrologic cycle. Ground water represents one important phase of the hydrologic cycle.

In a local area the occurrence, storage, and movement of water is known as the hydrologic system. An investigation of the ground and surface water of the hydrologic system also involves a study of the climate, because precipitation is the principal source of all ground and surface water. The geology must also be considered, because the geologic formations form the framework for the storage and movement of ground and surface water.

HYDROLOGIC DEFINITIONS AND ABBREVIATIONS

The following definitions of terms used in this report are based on those given by Meinzer (1923). A few terms not included in the following list are defined where they are introduced in the text.

Aquifer, a formation, group of formations, or part of a formation that is water bearing.

Aquiclude, a formation that will not transmit water in appreciable quantities.

Artesian water, ground water that rises in a well above the point at which it is found in an aquifer; water confined under artesian pressure.

Discharge, ground-water, water moving out of the zone of saturation.

Drawdown, the lowering of the water level in a well as a result of withdrawal of water from it or from another well in the vicinity.

Effluent stream, a stream or reach of stream that receives water from the zone of saturation.

Evapotranspiration, the combined discharge of water to the air by direct evaporation and plant transpiration.

Flowing well, an artesian well through which water is forced above the land surface by hydrostatic pressure in the aquifer.

Hydrostatic pressure, the pressure exerted by the water at any given point in a body of water at rest.

Permeability, capacity of a rock (or other material) to transmit fluid.

Permeability, field coefficient of, the rate of flow of water in gallons per day under prevailing conditions, through a cross section of aquifer 1 foot high and 1 mile wide, under a hydraulic gradient of 1 foot per mile.

Piezometric surface, an imaginary surface to which the water in an aquifer would rise under its full head.

Porosity, the ratio of the volume of openings in a rock or soil to its total volume, usually expressed as a percentage.

Porous, containing voids, pores, interstices, or other openings, which may or may not interconnect.

Recharge, ground-water, water moving into the zone of saturation.

Runoff, the discharge of water through surface streams.

Specific capacity, a measure of the productivity of a well; the rate of yield, in gallons per minute, per foot of drawdown in a well.

Storage, coefficient of, a measure of an aquifer's capacity to store and release water; the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

Transmissibility, coefficient of, the product of the coefficient of permeability and the thickness of the saturated portion of the aquifer; it describes the ability of the aquifer to transmit water. The number of gallons of water per day, under prevailing conditions, flowing across each mile strip of the saturated thickness of the aquifer, under a hydraulic gradient of 1 foot per mile.

Water table, the upper surface of the zone of saturation except where that surface is formed by an impermeable layer; the water at the water table is under atmospheric pressure.

Zone of aeration, the zone in which the voids in the rocks are not (except temporarily) filled with water under hydrostatic pressure.

Zone of saturation, the zone in which the voids in the rocks are filled with water under hydrostatic pressure.

The following abbreviations are used in this report:

cfs, cubic feet per second; a unit of discharge equivalent to about 449 gpm.
epm, equivalents per million.
gpd, gallons per day.
gpd/ft, gallons per day per foot.
gpm, gallon(s) per minute.
gpm/ft, gallons per minute per foot.
mgd, million gallons per day.
ppm, part(s) per million.

CLIMATE

The climate of the Cut Bank area is closely related to regional hydrologic problems. The semiarid climate is part of the reason for the poorly established drainage in parts of the area and the shortage of perennial streams. Atmospheric water, mainly rain and snow, is the primary source of water that sustains the predominantly dryland agriculture.

Normal annual precipitation at Cut Bank is 11.53 inches. Figure 3 shows the distribution of the precipitation during the year. Normally, about half the annual precipitation falls during May, June, and July. These months are the main growing season, and this concentration of rainfall is favorable for presently established agricultural practices.

Precipitation varies greatly from year to year. The dryland agriculture of the region has adopted stripcropping and other methods to minimize the effects of an occasional dry year. Protracted periods of below-normal precipitation deplete soil moisture, curtail runoff, and cause ground-water levels to lower for lack of recharge and because of increased use. The

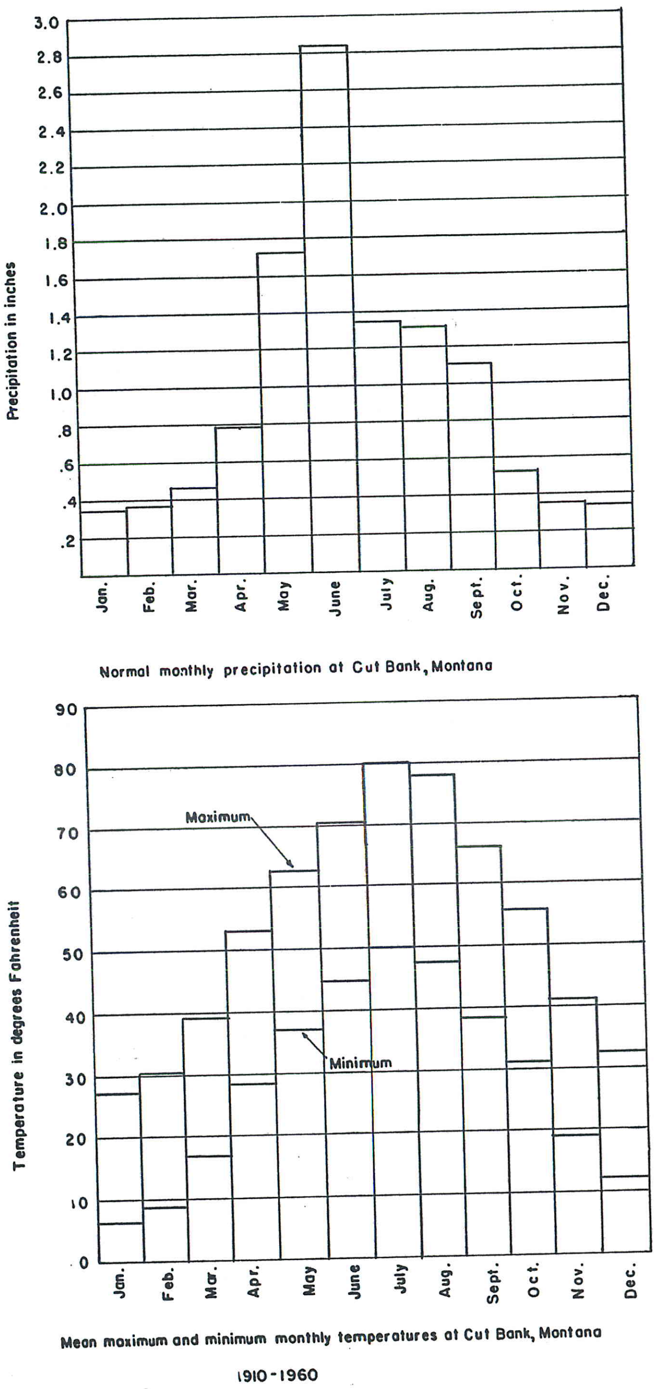

Figure 3.—Monthly distribution of precipitation and temperature at Cut Bank.

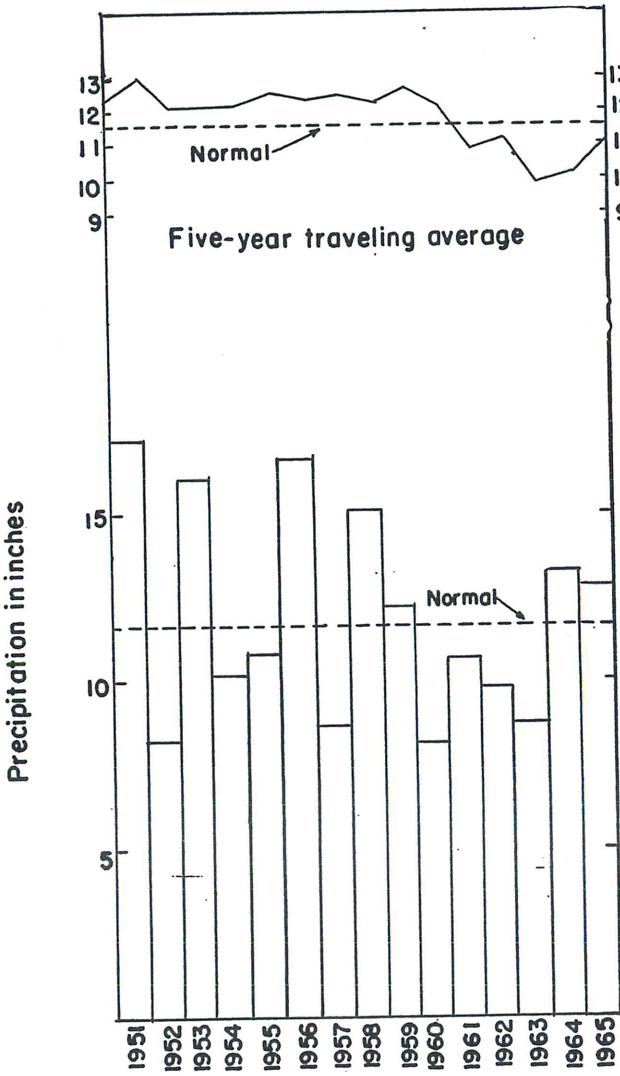

Figure 4.—Annual precipitation at Cut Bank, 1951-65.

annual precipitation at Cut Bank for the period 1951 to 1965 is shown on Figure 4. The 5-year traveling average, plotted above the annual precipitation, evens out extremes to make the trends more clear. Thus it can be seen that, despite several dry years, precipitation was generally above normal from 1951 to 1961 and below normal from 1961 to the end of 1965.

Temperature extremes are great. The highest temperature recorded is 107°F and the lowest temperature is -47°F. Only 4 or 5 days a year ordinarily have temperatures over 90°F. The average frost-free season is 116 days between May 23 and September 17. Evaporation, aided by moderate to strong winds, is about 50 inches per year.

SURFACE WATER

Cut Bank Creek, which drains an area of 1,065 square miles above the city of Cut Bank, originates in the mountains of Glacier National Park. Much of the spring and summer flow is derived from melting snow; fall and winter flow is sustained by ground-water discharge. The average discharge in 29 years of record (1905-19, 1922-24, and 1951-64) is 192 cfs. The maximum discharge recorded was 16,600 cfs in June 1964. A minimum of 4 cfs was recorded in December 1905, but discharge of less than 10 cfs is rare. Cut Bank Creek crosses the Blackfeet Indian

Reservation on much of its course above Cut Bank, and by treaty the Blackfeet Tribe has prior right to the water in the creek.

Tributaries to Cut Bank Creek are Spring Creek, which generally discharges about 4 cfs; Snake Coulee, which discharges about 2 cfs; and Rocky Coulee, which discharges about 2 cfs. The Red River, which drains northward to the Milk River in Alberta, is ephemeral in most of its course in Montana, but flows 1 to 2 cfs near the Canadian border.

Ponds and lakes are numerous in parts of the area. The largest of the lakes are Hay Lake, Grassy Lake, Long Lake, Fitzpatrick Lake, and Milky Lake. The ponds and lakes provide stock water when they contain water. Hay Lake, Grassy Lake, Long Lake, and Fitzpatrick Lake supply irrigation water at times. All of the lakes and ponds are subject to wide fluctuations in water level. Many of them contain water only seasonally, and most of them go dry during droughts lasting several years. A series of broad, shallow lakes occupies a glacial outwash channel extending southward from a point near Sweetgrass through Sunburst and Kevin. The lakes are dry during most years but fill after several years of above-normal precipitation. They contained water at the end of 1965 although they were dry in 1963.

GROUND WATER

Ground water has several inherent advantages over other sources of water. Among these are its widespread occurrence, uniform temperature, and comparative freedom from pollution. Because of these advantages there has been a marked increase in ground-water development in the last 50 years. Along with development has come more public interest in, and more scientific study of, the principles of ground-water hydrology. These studies have shown that (1) ground water obeys natural laws; (2) practically all ground water is originally derived from precipitation; (3) most usable ground water is an important part of the circulatory pattern of the hydrologic cycle; and (4) the occurrence of ground water is intimately associated with the geology of the locality.

Ground water is the most widespread source of domestic, stock, and industrial water in the study area. Almost all rural residents, the oil refineries at Cut Bank and Kevin, the oil-field secondary recovery projects, and the communities of Kevin, Sunburst, and Santa Rita depend on ground-water supplies. As part of this study, data were gathered on wells and springs in the study area. Data on 288 selected wells and springs are presented in Table 1. The distribution of the wells and springs is shown on Plate 1.

Ground water is stored in and transmitted through voids in the rocks. The rocks, or aquifers, serve as combined conduits, reservoirs, and filters. The voids can be divided into two general types. Primary voids or openings are those present when the rock was formed such as intergranular openings in sand. Secondary voids are created by forces acting on the rock after its formation; they include cracks, joints, and solution openings in soluble rocks.

Ground water moves in response to several forces. Among these are (1) gravity, (2) capillary force, (3) osmotic pressure, and (4) changes in state (such as from liquid to gas or gas to liquid). Of these, gravity is the most important in inducing the movement of economically recoverable water.

Part of the water falling on or flowing over the ground seeps into the soil zone and percolates downward through the zone of aeration until it reaches the zone of saturation. The zone of saturation is a vast underground reservoir, which stores and transmits water. Ground water moves very slowly as compared to surface water. The velocity of surface water is measured in feet per second; the velocity of ground water is measured in feet per day or feet per year. This slow rate of movement is the reason for the relative stability of ground-water sources during dry years and wet.

Water is discharged from the ground-water reservoir by both natural and artificial means. The natural forms of discharge include springs, seeps, transpiration by plants, and discharge into effluent streams. Wells and drains are the principal means of artificial discharge.

A ground-water reservoir has been likened to a bank account. Over a long period of time, deposits (recharge) and withdrawals (discharge) must balance. As a bank account stores money, a ground-water reservoir stores water. If discharge is increased by artificial means it must, over a long period, be balanced by reduction of natural discharge or increase of recharge. Water may be withdrawn faster than it is replenished, but only at the expense of storage. If withdrawal is continued long enough, the reservoir becomes depleted. This "mining" of ground water may be justified, as is mining of nonrenewable minerals or closing out a bank account, but if it is done blindly, hardship may result.

Changes in the water level in wells can be used to keep track of the changes in ground-water storage. Periodically during this study the water level in 19 observation wells was measured to indicate changes in storage. These measurements are presented in Table 2.

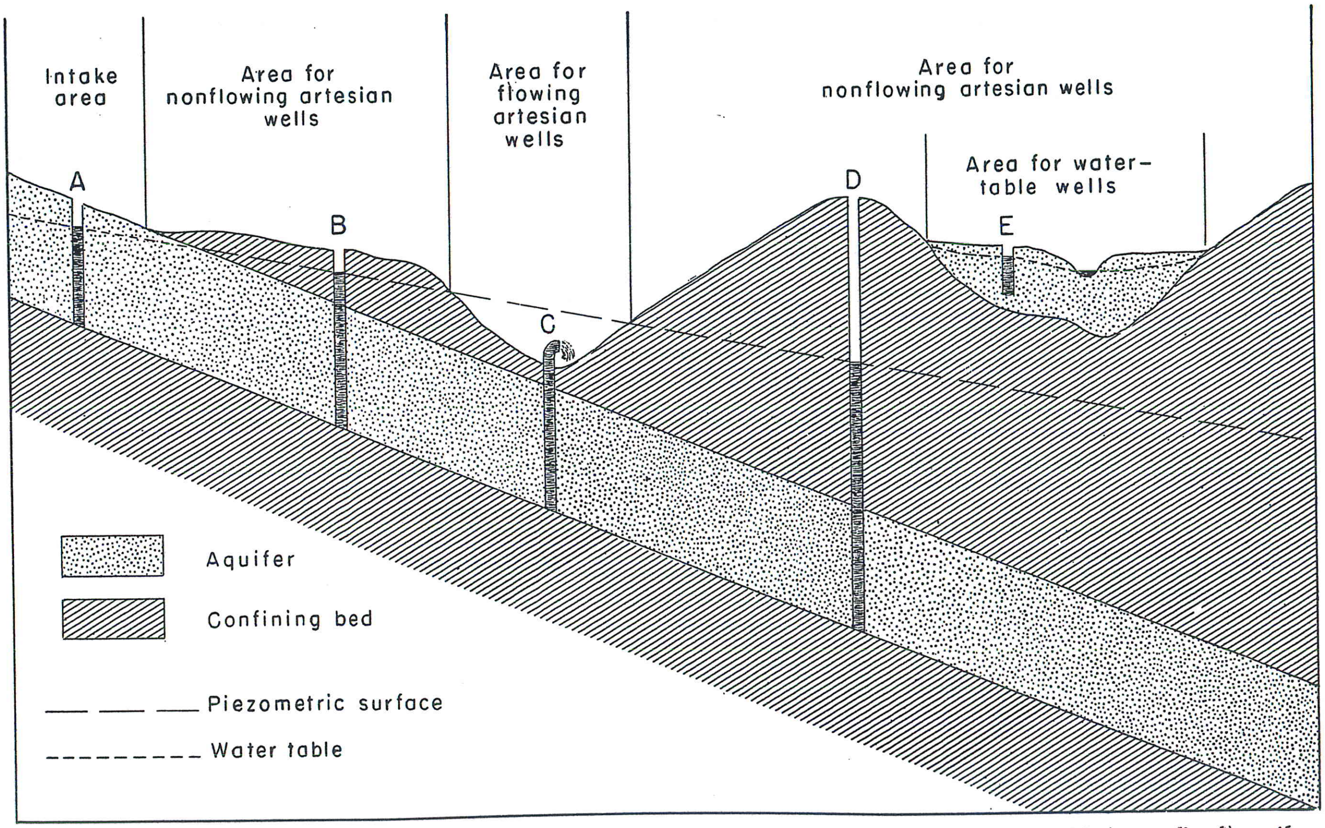

Figure 5.—Hypothetical section showing geologic conditions necessary for artesian (confined) and water-table (unconfined) aquifers. A and E are water-table wells; B and D are nonflowing artesian wells; and C is a flowing artesian well.

GEOLOGY AND ITS RELATIONSHIP TO THE HYDROLOGIC SYSTEM

Because ground water is contained in voids in the rocks, the relative abundance, size, and shape of these voids determine the amount of water the rocks can contain. Different types of rocks have characteristically different types and proportions of void space. Thus, a knowledge of the geology of an area is essential to an understanding of the ground-water hydrology.

Primary intergranular voids occur in most rocks but in many they are so small and few that they do not contain much water. Intergranular voids are characteristic of unconsolidated rocks, especially sand and gravel deposits. Rocks formed by consolidation of sand and gravel, i.e., sandstone and conglomerate, also contain appreciable intergranular void space.

Secondary voids are those created after the rock was formed. These include fractures of various kinds (faults, joints, and fissures) or voids created or enlarged by solution. Fractures occur in almost all rocks but tend to be closed or "healed" in unconsolidated or plastic rocks. Thus, open fractures are more important as water containers and conduits in rigid consolidated rocks. Sandstone and limestone are the principal rock types in the study area that are extensively fractured, although some beds of sandy shale and siliceous shale also are so fractured as to contain considerable water.

Rocks that are soluble in water or in water containing certain naturally occurring chemicals may contain solution cavities. These are especially abundant in carbonate rocks (limestone and dolomite) but the porosity of clastic rocks, such as sandstone, may be greatly increased by the solution and removal of cementing material.

Though the abundance, size, and shape of voids determine the porosity of a rock, its ability to yield water to wells depends on its permeability or ability to transmit water. In order to be permeable the rock must contain interconnections between the voids. Thus, some rocks are very porous but yield water slowly because the pores are poorly interconnected. If the pores or the interconnections are very small, molecular attraction so impedes movement that water can move only slowly.

The geology of the area determines whether the water in an aquifer is under artesion (confined) or water-table conditions. Figure 5 illustrates the relationships of aquifers and aquicludes for artesian and water-table conditions.

When a well begins discharging, the water level or head in the well declines and water in the surrounding aquifer moves toward the well. The level to which it declines (drawdown) for a given rate of discharge is such that the water movement toward the well equals the rate of discharge. An increase in discharge necessitates additional drawdown of the water level.

Under water-table conditions the zone of water-level lowering around a well takes the form of an inverted cone of dewatered material, called the "cone of depression". The well is the axis of the cone. The size and shape of the cone of depression depend on the permeability of the aquifer, its storage properties, the rate at which the water is discharged, and the time since discharge began. To supply a given amount of water to a well, permeable water-bearing materials require less drawdown (flatter cone of depression) than do materials of less permeability (fig. 6). The cone of depression around a pumped well will increase in depth and area until it intercepts recharge or reduces other discharge in an amount equal to the well discharge. The areal extent of the cone of depression is termed the "area of influence". The water level will be lowered in other wells within the area of influence of a well that is being pumped. This lowering is called "interference" if it affects other pumping wells.

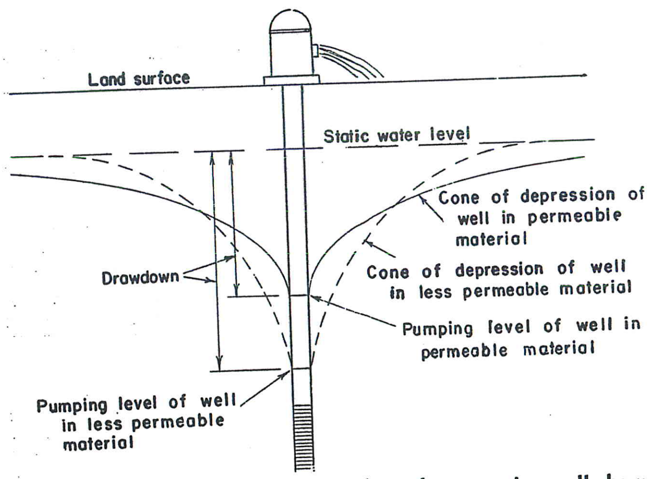

Figure 6.—Diagrammatic section through a pumping well showing the drawdown, the cone of depression, and differences in the shape of the cone of depression caused by a difference in the permeability of the water-bearing material for the same well yield.

The hydraulic characteristics discussed above apply also to artesian wells, except that the drawdown will be from the piezometric surface, which may be above the ground surface, and the cone of depression will be the lowering of the head or piezometric surface around the well.

The rate at which the area of influence of a pumping well expands depends upon the coefficients of storage and transmissibility of the aquifer. The area of influence of a well in an aquifer of high transmissibility will expand more rapidly than that of a well in an aquifer of low transmissibility if the storage coefficients of the two aquifers are equal. Thus, a well in a very transmissive aquifer has a higher specific capacity than one in a less transmissive aquifer but its area of influence becomes large and interference with other wells and springs becomes appreciable sooner than for a well in a less transmissive aquifer.

The head in an artesian well is not ordinarily lowered below the top of the aquifer, and thus the aquifer is not dewatered. The volume of water obtained per unit of head change in an artesian aquifer is derived from compaction of the aquifer and expansion of the water. The storage coefficient of an artesian aquifer is usually very small and may range from about 0.00001 to 0.001. Because of low coefficients of storage, wells in artesian aquifers usually develop large areas of influence very rapidly.

The behavior of wells provides the basis for determining aquifer characteristics. These characteristics can also be determined by laboratory tests conducted on samples of the aquifer material, but unavoidable sampling errors and disturbance of the samples make laboratory tests less reliable than field tests. Field tests, called "aquifer tests", rely on precise observations of the changes in water levels in wells in response to accurately measured discharge. Several basic simplifying assumptions must be made to interpret the observations obtained in an aquifer test. As the assumptions are rarely completely fulfilled in nature, some errors are introduced but these are generally small. Detailed discussion of aquifer-test analysis is beyond the scope of this report. The reader is referred to Ferris and others (1962) for a more extensive discussion.

Five aquifer tests were made during this study. Paulson and Zimmerman (1965) made five aquifer tests in surficial deposits west of the study area. The specific capacity of fifteen wells was computed from reported data and was used to estimate the coefficients of transmissibility in the vicinity of the wells. The hydrologic characteristics determined during this study are discussed with the other water-bearing characteristics of the formations in which the wells were constructed.

THE ROCKS AND THEIR WATER-BEARING CHARACTERISTICS

The Madison Group, of Mississippian age, is the oldest and deepest sequence tapped for water in the study area. Table 3 summarizes the stratigraphy and hydrologic character of the rocks in the Cut Bank area.

Table 3.--Summary of the stratigraphy and hydrologic character of the rocks in the Cut Bank area.

System	Series	Group	Stratigraphic unit	Maximum thickness (feet)	Physical characteristics	Hydrologic characteristics
Quaternary	Recent		Alluvium	25	Mainly clay, silt, and sand, some lenses of gravel.	Not extensive enough to be a good source of water. A few wells produce water from alluvium.
Quaternary	Pleistocene		Lower terrace deposits	15	Lenticular sand and gravel.	Yields water for domestic and stock use in valley of Spring Creek.
Quaternary	Pleistocene		Glacial drift undifferentiated	150	Includes: Outwash deposits, principally gravel and sand; glacial till, mostly fragments of granite and limestone in a sandy clay matrix; glacial lake deposits, consisting of laminated clay, sand, and gravel.	Generally not water yielding. Sand and gravel deposits locally will yield sufficient water for domestic and stock use.
Quaternary	Pleistocene		Higher terrace deposits	40	Gravel overlain in places by silt in unglaciated areas west of Cut Bank.	Yields water to many wells on irrigated land west of Cut Bank. Yields as much as 25 gpm. Water bearing only where fairly extensive.
Cretaceous	Upper Cretaceous	Montana Group	Two Medicine Formation	500	Mainly sandy shale and mudstone, some thin beds of sandstone; lower 250 feet is mostly massive fine-grained sandstone.	Widely used aquifer. Well yields are generally 10 gpm or less but are adequate for stock and domestic needs.
Cretaceous	Upper Cretaceous	Montana Group	Virgelle Sandstone	180	Massive gray to buff sandstone, occasional beds of shale.	One of the major aquifers in the Cut Bank area. Yields as much as 250 gpm to properly constructed, completely penetrating wells
Cretaceous	Upper Cretaceous	Montana Group	Telegraph Creek Formation	170	Gray sandy shale interbedded with thin beds of gray or buff sandstone.	Generally impermeable, but large yields have been obtained where structural deformation or gravity sliding has induced fracturing.
Cretaceous	Upper Cretaceous	Colorado Group	Marias River Shale	1,995	Mainly dark-gray shale; a few limestone concretionary layers and bentonite beds in the upper part. The lower 800 feet is mainly dark-gray calcareous shale interbedded with bentonite, sandstone, and concretionary beds.	Not an aquifer. Sandstone at the base is reported to be water bearing in oil test holes but is not exploited.
Cretaceous	? Lower Cretaceous	Colorado Group	Blackleaf Formation			
Cretaceous	Lower Cretaceous		Kootenai Formation	725	Red and green mudstone and siltstone interbedded with several beds of medium- to coarse-grained sandstone.	Not an aquifer in the study area. The sandstone beds yield oil in the oil fields of the area and some brine in some fields.
Jurassic	Upper and Middle Jurassic		Ellis Group	350	Mainly gray calcareous shale interbedded with discontinuous sandstone beds.	Not an aquifer in the Cut Bank area. Produces a small amount of brine with oil in some oil fields.
Mississippian	Upper and Lower Mississippian		Madison Group	1,060	Massive, white to cream-colored, dense crystalline limestone in upper part. Gray and dark-gray limestone and shale in alternating beds in lower part.	Fracture and cavernous porosity, erratically distributed, permits storage and movement of water. The source of most of the water used for oil-field water flood operations. Specific capacities of wells generally low and lifts great.

The areal distribution of the exposed rocks is shown on Plate 2. Logs of 24 water wells are given in Table 4.

Of the rocks described in this report, only the upper few hundred feet of the Colorado Group, the lower part of the Montana Group, and Quaternary beds are exposed in the study area.

Madison Group.—The Madison Group of Early and Late Mississippian age is 785 to 1,060 feet thick beneath the study area. Alternating beds of gray and dark-gray limestone and dark-gray shale compose the lower one-third and massive, white to cream-colored, dense crystalline limestone, some limy dolomite, and occasional beds of chert compose the upper two-thirds of the group.

The Madison is extensively fractured, and solution of the carbonates along fractures has increased the porosity and permeability, especially in the upper part. In the North Cut Bank and Red Creek oil fields, the Madison yields commercial quantities of oil along with saline water. Some of this water is injected into oil-producing beds for secondary recovery. Oil companies have drilled wells into the Madison to supply water for water-flood operations. By the end of 1964, the Madison supplied most of the water used for secondary recovery within the study area. Reported specific capacities and coefficients of transmissibility estimated from them are tabulated below.

Well number	Specific capacity (gpm/ft)	Length of test (min.)	Estimated coefficient of transmissibility
32-5-16ac	0.415	180	600
32-5-30bd1	.914	195	1,600
35-6-11cb	4.034	45	6,500

The estimates are based on reported drawdown data and interpolations from graphs presented by Walton (1962, p. 12). They are subject to many sources of error but give an idea of the coefficient of transmissibility of the Madison.

The variations in the transmissibility may be due to errors in the data or to changes in the characteristics of the rock from place to place. Fluids in the Madison move mainly through secondary voids, fractures, and solution cavaties, which have an erratic distribution. Therefore, the water-bearing characteristics vary considerably from place to place.

Ellis Group.—The rocks of the Ellis Group, Middle and Late Jurassic in age, are 100 to 350 feet thick. They consist of dark-gray calcareous shale intercalated with calcareous sandstone beds.

The Ellis is permeable enough to produce oil in the Kevin-Sunburst oil field, and it yields sulfurous water with some oil in other places. It is not a source of potable water, however.

Kootenai Formation.—The Kootenai Formation of Early Cretaceous age is 405 to 725 feet thick. Red and green nonmarine mudstone, siltstone, and sandstone beds compose the formation.

The Kootenai is a good aquifer in other parts of Montana but in the Cut Bank area it is an oil-bearing zone and produces little water with the oil. The formation includes several named oil sands: the Sunburst sand, the Cut Bank sand, and the Moulton sand.

Colorado Group.—The Colorado Group is composed of the Lower Cretaceous Blackleaf Formation and the Upper Cretaceous Marias River Shale. An unconformity separates the two formations. The total thickness of the group is 1,870 to 1,995 feet (Erdmann and others, 1946).

The Blackleaf is mostly dark-gray shale containing many sandstone beds. A sandstone bed about 75 feet thick called the Flood Member lies at the base of the formation.

The Marias River Shale is predominantly dark-gray shale containing many thin beds of limestone concretions. Only the uppermost 300 to 400 feet of the Marias River Shale is exposed in the study area.

The beds of the Colorado Group are generally unfavorable as a source of ground water. A few wells obtain meager supplies from weathered, fractured shale where it is exposed. Erdmann, Beer, and Nordquist (1946) indicated that the Flood Member at the base of the Colorado is water bearing, but it is not exploited.

Montana Group.—The Montana Group of Late Cretaceous age consists of the Telegraph Creek Formation, the Virgelle Sandstone, the Two Medicine Formation, the Bearpaw Shale, and the Horsethief Sandstone. The Bearpaw and the Horsethief are not present in the study area, however.

The Telegraph Creek Formation, 120 to 170 feet thick, is of Late Cretaceous age. The beds are chiefly medium-gray sandy or silty shale, siltstone, and fine to very fine grained shaly calcareous sandstone. It is increasingly sandy toward the top of the formation, and the sandstone beds are thicker and the grains slightly coarser.

The beds yield water to springs and some wells in the outcrop. The town of Kevin obtains much of its water supply from wells and springs producing from the Telegraph Creek beds. The largest well yields are obtained in structurally deformed areas or where sliding on steep slopes has caused fracturing. Except where extensively fractured, the Telegraph Creek will yield only moderate amounts of water.

The Virgelle Sandstone is the basal member of the Eagle Sandstone in other parts of Montana. Because the Claggett Shale, which overlies the Eagle at some localities, is not easily recognizable in the study area, the beds of late Eagle age are included in the overlying Two Medicine Formation, and the Virgelle is mapped as a separate formation. The Virgelle is equivalent to the Milk River Sandstone of Alberta, Canada, as discussed by Meyboom (1960).

The Virgelle is 115 to 180 feet thick but averages 160 feet. Light-gray to buff or whitish, fine- to medium-grained arkosic and slightly calcareous sandstone beds constitute most of the formation. The Virgelle forms steep cliffs along much of its outcrop. Brownish-weathering calcareous sandstone concretions are abundant in the upper part of the formation and cap many weirdly eroded mounds and columns (hoodoos) along the outcrop near the towns of Sweetgrass and Sunburst.

The Virgelle Sandstone is the principal aquifer for industrial and public supplies of ground water in the study area. Wells drilled into the Virgelle produce as much as 250 gpm. During this investigation, five aquifer tests were made with wells producing water from the Virgelle. The coefficients of transmissibility determined from the aquifer tests and estimated from reported drawdown data (on other wells in the Virgelle) are given in Table 5.

The coefficients of transmissibility range from 700 gpd/ft to 50,000 gpd/ft. Fracturing, induced by structural deformation, probably greatly affects the transmissibility locally. During the drilling of well 33-6-12aa2, one hole had to be abandoned and the drill rig moved when a fracture was penetrated and permitted the drill bit to drop about a foot. All circulation fluid was lost and circulation could not be restored. When well 33-6-12aa1 was pumped for an aquifer test the data indicated a nearby discharging boundary about 300 feet from the pumping well. A coefficient of transmissibility of about 34,000 gpd/ft was obtained from the early data and 15,000 gpd/ft from later data. The boundary may be related to faulting.

The Two Medicine Formation, of Late Cretaceous age, includes equivalents of the upper part of the Eagle Sandstone, the Claggett Shale, and the Judith River Formation of other parts of Montana. It is 1,650 to 1,950 feet thick but only the lowermost 500 feet is present in the study area.

The formation is mostly pale-greenish-gray, gray, or purplish mudstone and siltstone interbedded with lenticular, massive, commonly calcareous, fine to very coarse grained sandstone. Some thin beds of coal occur near the base.

The lenticular sandstone beds of the Two Medicine yield water to many wells in the Cut Bank area. Yields are generally 10 gpm or less but are adequate for stock and domestic use. The Two Medicine is hydraulically connected with the Virgelle in many places. To check the interconnection of the two formations and to utilize a municipal well in making an aquifer test, well 33-6-12aa2 was drilled through the Virgelle and perforated casing was set through the Two Medicine. A cement plug with an access tube extending to the surface was installed at the top of the Virgelle to allow separate measurement of the water level in the two formations. The water levels in the two formations differed only slightly and reacted similarly to pumping from a nearby well during an aquifer test. In some wells near the outcrop of the Virgelle, water can be heard cascading from the Two Medicine to the Virgelle indicating a difference in the water levels in the formations.

Reported drawdown in wells in the Two Medicine (wells 36-6-14ba and 36-6-25dd) indicates specific capacities of less than 0.15 gpm/ft; the estimated coefficients of transmissibility are less than 300 gpd/ft.

Quaternary deposits.—Deposits of Quaternary age in the Cut Bank area include high-level terrace deposits, glacial lake deposits, glacial till, glacial outwash, low-level terrace deposits, and alluvium. Higher level terrace deposits were mapped by Paulson and Zimmerman (1965) in unglaciated areas west of Cut Bank. These are Pleistocene in age. During Pleistocene time, continental glacial ice covered much of the study area, and tongues of ice from alpine glaciers approached the area from the west. The glacial ice blocked drainage and formed a large lake, called Lake Cut Bank. Lacustrine deposits of varved clay, sand, silt, and gravel accumulated in the lake to a maximum thickness of about 50 feet. As the glaciers melted, glacial till was deposited where the ice had been, and Lake Cut Bank was drained. Meltwater deposited sand and gravel in outwash channels. The areal distribution of glacial features, which are not indicated on Plate 2, is shown on Figure 7. After recession of the ice, lower-level terrace gravel was deposited along some of the drainage courses. During Recent time, streams have deposited alluvium along their channels.

All of the Quaternary deposits are composed of unconsolidated clay, silt, sand, and gravel. The terrace deposits, lake deposits, outwash deposits, and alluvium have been washed, sorted, and stratified, whereas the glacial till is a heterogeneous mixture of clay, silt, sand, and gravel or cobbles. The water-bearing characteristics of the Quaternary deposits vary greatly. Terrace gravel deposits yield moderate amounts of water to stock and domestic wells where the deposits are areally extensive. Paulson and Zim-

Table 5.—Coefficients of transmissibility of the Virgelle Sandstone as determined by aquifer tests or estimated from specific capacities.

Well number	Depth of well (feet)	Diameter (inches)	Pumping rate (gpm)	Drawdown in pumped well (feet)	Length of test (minutes)	Specific capacity (gpm/ft)	Coefficient of trans-missibility[1] (gpd/ft)	Estimated coefficient of trans-missibility[2] (gpd/ft)	Remarks
32-5-30bb	332	8⅝	73	29	1,440	2.5	----------	4,000	
30bd2	400	8⅝	67	5	1,440	13.4	----------	25,000	
32-6-24da	400	9⅝	47	35	1,440	1.3	----------	2,000	
25ad	445	8⅝	49	21.5	1,440	0.4	----------	800	
33-5- 6cb	212	7	1.5	14.7	?	9.8	----------	20,000	Yields water from Virgelle Sandstone and Two Medicine Formation
22bc	250	5	83	--------	1,285	------	18,300	----------	Could not measure pumped well
29ca	302	7	122	6	2,940	20.3	50,000	----------	
30aa	294	7	109	26	2,730	4.2	----------	8,000	
32ad	282	7	80	10	360	8.0	----------	13,000	
33-6-12aa1	238	12	254	--------	580	------	34,000	----------	Discharging boundary indicated at 300 ft.
35-4-12bd2	238	10¾	20.5	38	?	.5	----------	700	
35-5-22cb	221	6	2	0.48	180	4.2	11,000	8,000	
35-6-10bc	402	7	62.5	79	?	.8	----------	1,600	
36-4-14ab2	159	12½	200	9.7	?	20.6	----------	40,000	
14ac1	155	12½	170	--------	2,880	------	34,000	----------	Could not measure pumped well
35aa	257	7	17.2	15	?	1.1	----------	1,700	

[1] from aquifer test.
[2] from specific capacity.

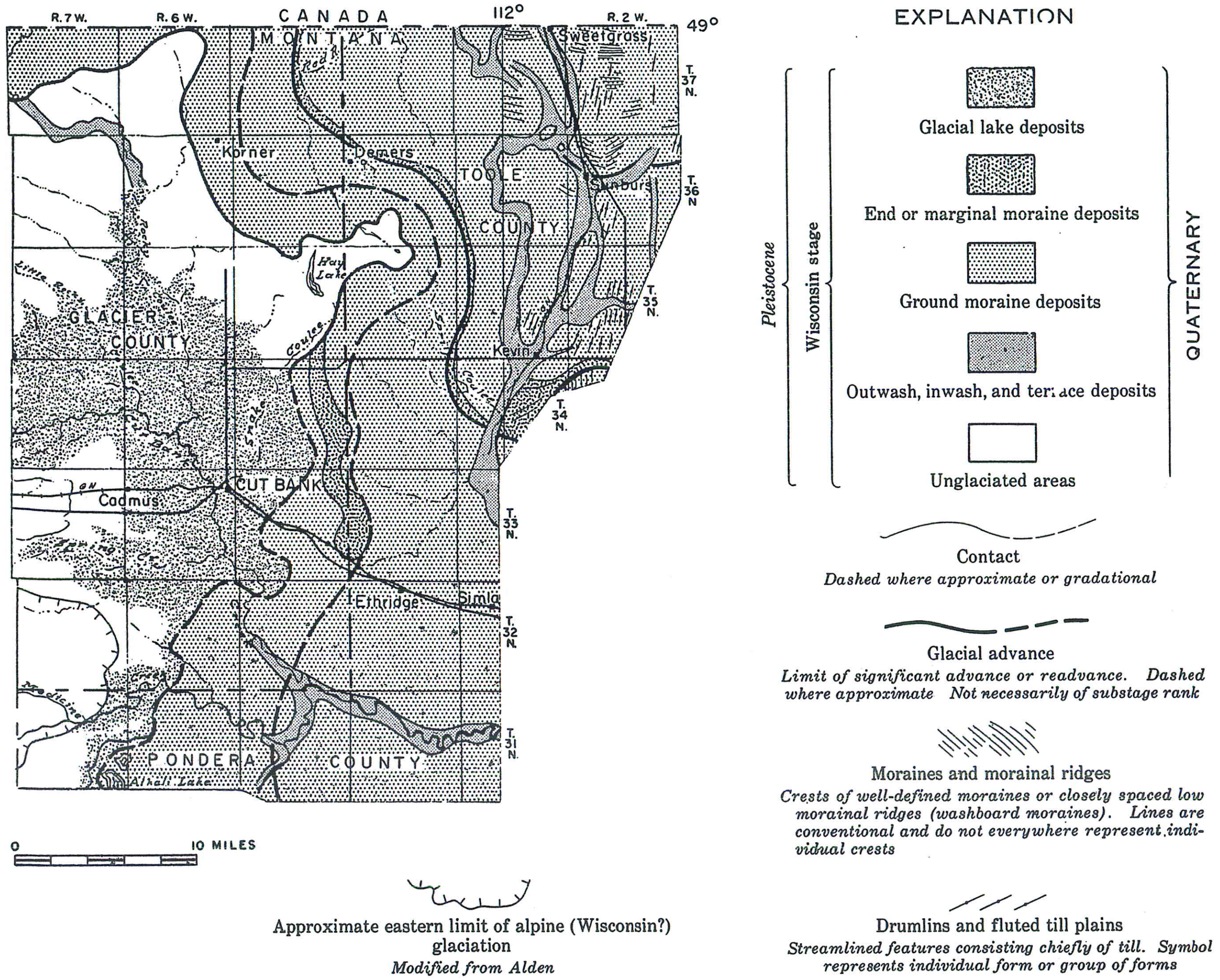

Figure 7.—Glacial map of the Cut Bank vicinity (after Colton, Lemke, and Lindvall, 1961).

merman (1965, p. 47) conducted tests on five wells in the most extensive of the terrace deposits west of the study area. They determined coefficients of transmissibility for the deposits ranging from 2,800 to 9,000 gpd/ft.

The outwash deposits may be potentially good aquifers but have not been adequately tested. The refinery at Kevin formerly used water from several wells drilled into outwash deposits. As far as known, the wells yielded an adequate supply of water but the quality was unsuitable for the refinery's needs.

Alluvium is very limited in areal extent, hence is of comparatively little importance as a source of ground water in the Cut Bank area. The Cut Bank airport obtains its water from a large-diameter well in alluvium near Cut Bank Creek. Several farms near the Canadian border obtain adequate supplies from alluvium along Red River.

The lake deposits are not known to produce water. They lie above the water table generally. Glacial till is also a poor source of ground water.

STRUCTURE

The structure of the rocks underlying the Cut Bank area is shown by means of structure contours on Plate 2. As may be noted, the dip of the rocks is generally westward away from the dominant structural feature of the region, the Sweetgrass Arch. This westward dip is important to the ground-water regimen of the Virgelle Sandstone in that it establishes geologic conditions favorable for the occurrence of artesian water in much of the area.

Superimposed on the general westward dip are many small folds. These have influenced the location of some of the oil and gas fields of the area, though most of the fields are stratigraphic traps. Faulting and fracturing of the rocks in the vicinity of Cut Bank probably have enhanced the permeability of the Virgelle, permitting fairly large well yields.

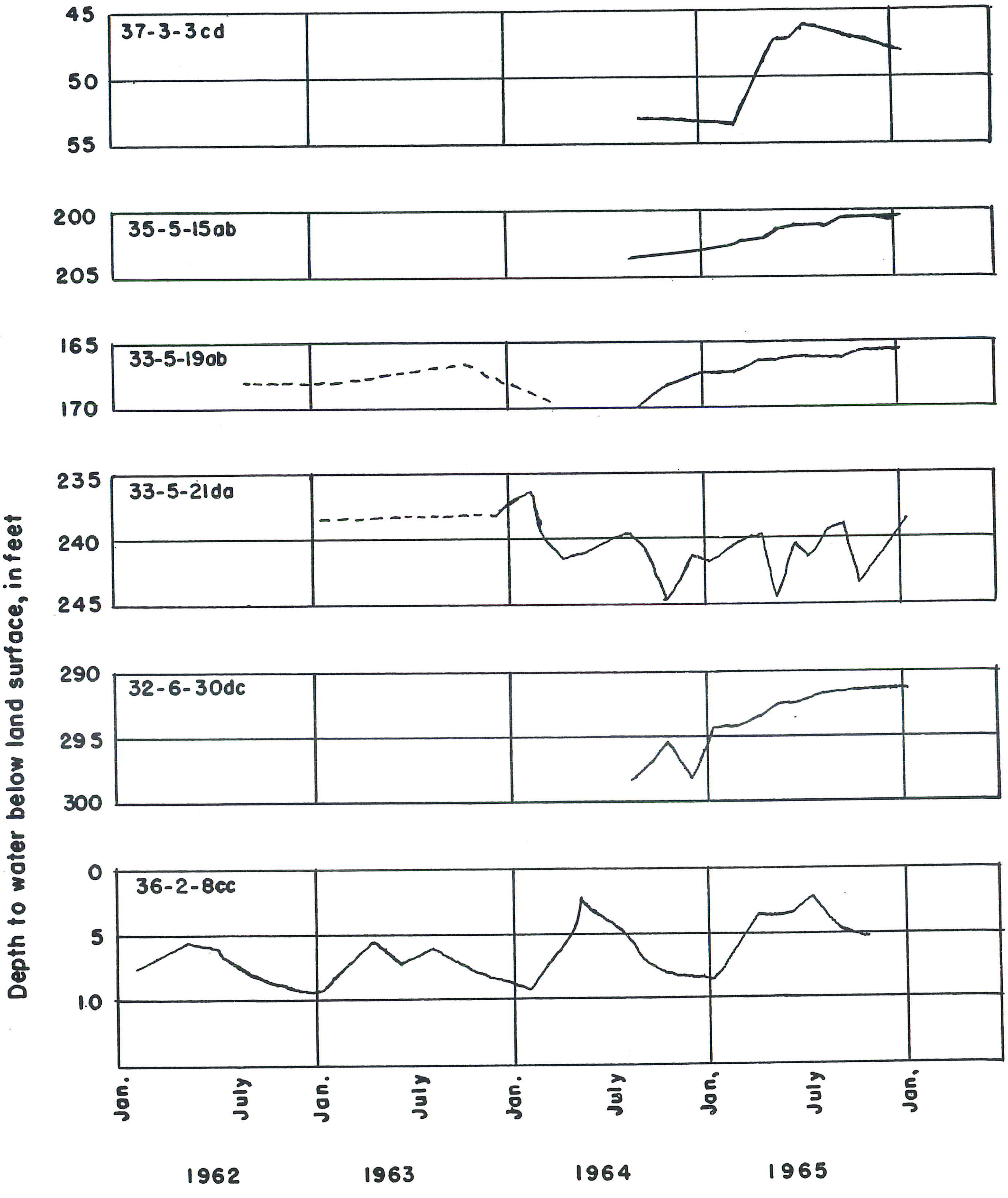

Figure 8.—Graphs of water levels in selected wells.

OPERATION OF THE HYDROLOGIC SYSTEM

GROUND-WATER RECHARGE

Infiltration of precipitation along the outcrop and interformational leakage are the major means of ground-water recharge in the Cut Bank area. The piezometric surface in the Virgelle Sandstone as shown by means of contours on Plate 1 indicates that water in the Virgelle moves southwest and north from a ground-water divide in T. 36 N., R. 4 and 5 W. Much of the land in this vicinity is topographically high and covered by glacial till containing many ponds in undrained depressions. Much of the recharge entering the Virgelle seeps downward through the till and, in some places, through part of the Two Medicine Formation.

GROUND-WATER DISCHARGE

NATURAL DISCHARGE

The piezometric contours on Plate 1 suggest that water in the Virgelle flows to discharge points along Cut Bank Creek south of Cut Bank and north toward outcrops of the Milk River Sandstone (equivalent to the Virgelle) near the confluence of Red River with the Milk River in Alberta (Meyboom, fig. 16, p. 42). No large springs in the Virgelle were found along Cut Bank Creek, but many seeps flowing less than 1 gpm each and many "alkali" patches caused by evaporation of slowly discharging water were noted. Springs are common along the Virgelle escarpment on the east side of the area, especially where coulees cut back into the Virgelle. The town of Kevin gets much of its municipal supply from such springs.

ARTIFICIAL DISCHARGE

Ground water is discharged by hundreds of wells in the Cut Bank area. Most of the wells provide domestic and stock water. The rate of discharge for stock and domestic wells is low; their aggregate discharge is about 500,000 gpd.

The town of Kevin obtains its municipal water supply from the Virgelle and from the Telegraph Creek. The town of Sunburst, 2 miles east of the study area, obtains its water from the Virgelle. Kevin uses about 86,000 and Sunburst about 229,000 gpd (U. S. Department of Health, Education, and Welfare, 1964, p. 31, 33). Cut Bank has a standby well to supplement the surface-water supply. The well will yield more than 250 gpm (360,000 gpd) of water but the amount of dissolved solids contained has increased so much it is used only in emergencies.

The Union Oil Company of California refinery east of Cut Bank and the Big West Oil Company refinery at Kevin are among the leading industrial users of water in the study area. The Big West refinery gets its water from the Kevin public supply. The Union refinery depends on three wells tapping the Virgelle Sandstone. Two are pumped almost continuously and the third is a standby well. They produce about 288,000 gpd.

Water injection for secondary recovery of oil is another industrial use of water in the study area. The injection of this water is expected to extend the life of the oil fields by as much as 17 years and to nearly double the amount of oil recovered. At the end of 1965, ten secondary recovery projects were operating in oil fields in the Cut Bank area. Seven of these used about 1,000,000 gpd of water from the Madison and three used about 93,000 gpd of water from the Virgelle (Oil and Gas Conservation Commission of the State of Montana, 1965). Prior to May 1963 and June 1964, two of the water flood projects now using Madison water were using Virgelle water.

STORAGE

Changes in the amount of water stored in the aquifers in the Cut Bank area are indicated by fluctuations in water levels in observation wells. Water levels in 17 wells were measured periodically during the study (Table 2). Graphs of the water levels in six of them are shown in Figure 8.

Water levels in most of the observation wells rose during 1964 and 1965. The graphs of water levels in wells 37-3-3cd, 35-5-15ab, 33-5-19ab, and 32-6-30dc illustrate the water-level rise. The rise may be attributed to above-normal precipitation or, in places, to reduction in pumping. The graph of the water level in well 36-2-8cc is included to show the effects attributable to climate. The well is a shallow water-table well east of the study area near Sunburst. It is in outwash deposits, which are readily recharged by precipitation, and seasonal fluctuations of the water level are pronounced. These seasonal fluctuations are not noticeable in water levels of wells in the Virgelle.

The fluctuations of the water level in wells 33-5-21da and 33-5-19ab may be attributable in part to local pumping. Well 33-5-21da is 750 feet from the standby supply well for the Union Oil Company refinery (33-5-22bc), and the pronounced dips in the water-level graph are probably caused by pumping of the standby well. Well 33-5-19ab is within 2 miles of the wells used for the refinery and two wells used in 1963 and early 1964 for water flood operations in the South-Central Cut Bank oil field. Part of the decline in the water level in 1964 may be due to pumping for both purposes. Figure 9 shows the theoretical effect that a pumping well has on other wells in the

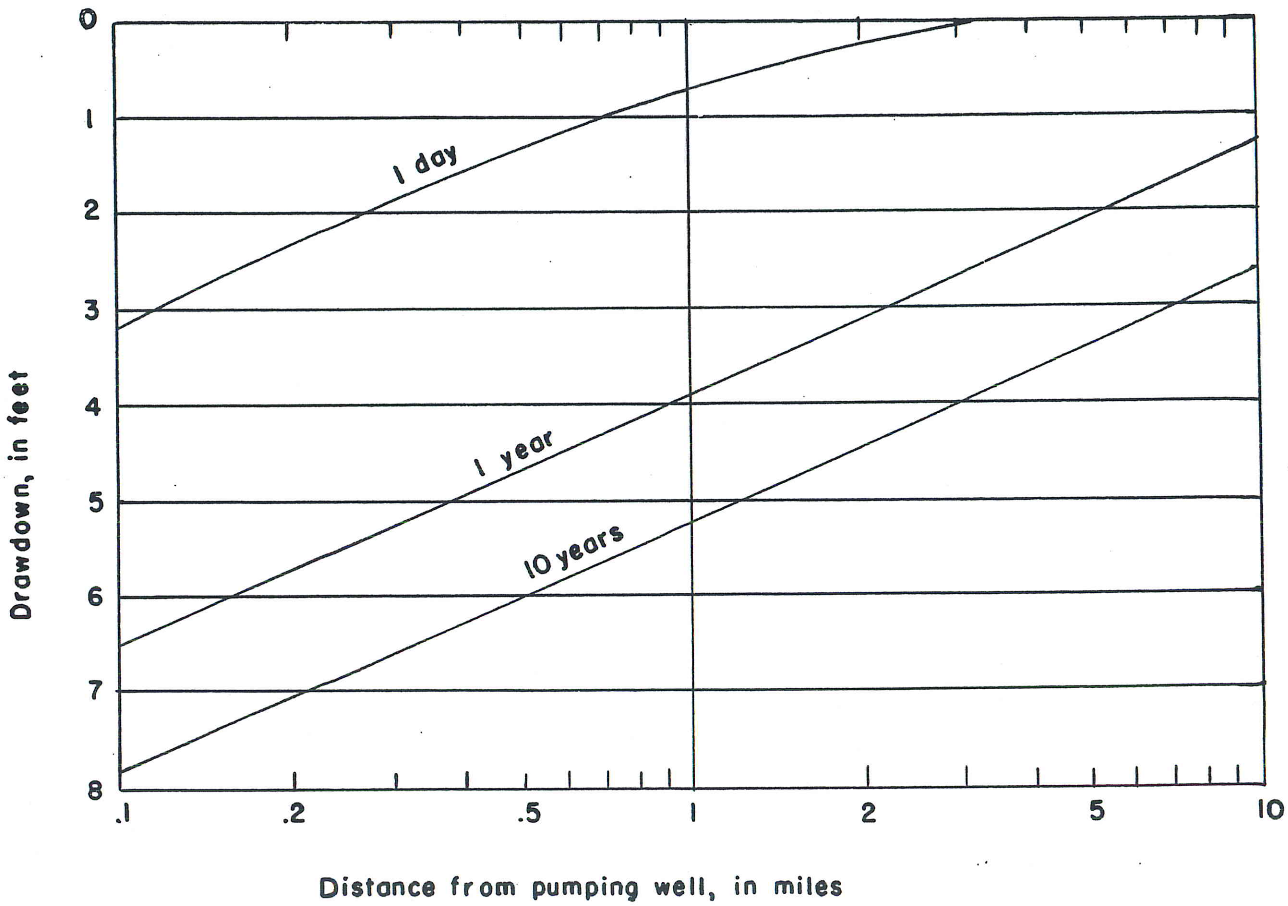

Figure 9.—Drawdown caused by pumping a well at 100 gpm. Assuming T = 20,000 gpd/ft. and S = 0.00008.

vicinity. The diagram is based on arbitrary but reasonable values of transmissibility and storage coefficients for the Virgelle and assumes an ideal aquifer of infinite areal extent and no recharge or other discharge. Although these assumptions are generally not met under field conditions, the diagram gives useful approximations of the effects to be expected. Thus, in a well 1 mile from another well pumping 100 gpm, a drawdown of about 4 feet can be expected after a year of pumping. For wells situated where they are affected by several pumping wells, the effects are additive. For instance, if a well in the aquifer is 1 mile from a well pumping 100 gpm and 3 miles from another well pumping at the same rate, the drawdown due to the first would be about 4 feet and the drawdown from the second would be about 3 feet or a total of 7 feet after a year of pumping.

Because of cessation of a part of the industrial pumping before this study began and lack of water-level data before and during the period of heaviest pumping, the effects of industrial pumping cannot be accurately assessed. The fact that the oil refinery has, through the years, abandoned several wells that went dry and drilled new wells down-dip indicates that there has been local lowering of water levels.

Before 1961, the Texas Company operated a refinery at Sunburst. Wells were drilled to supply the refinery and the town of Sunburst. When the refinery was closed, some of the wells were turned over to Sunburst for public supply. While the refinery was operating, water levels reportedly declined in the vicinity of the wells supplying the refinery; several ceased to flow. Since the closing of the refinery, water levels have risen in many of the wells. One of these, well 36-5-14ac, when first measured October 24, 1964, had a water level 12.09 feet below land surface. By January 12, 1966, the water level had risen to 3.53 feet below land surface.

QUALITY OF THE WATER

CHARACTER OF THE WATER

Natural water is rarely pure but is a solution of various ions. The principal ions dissolved in water are calcium, magnesium, sodium, bicarbonate, sulfate, and chloride.

The suitability of water for various uses depends greatly on its chemical quality. As part of this study, samples of water were collected from representative wells in the various aquifers and from Cut Bank Creek. The samples were analyzed by the Montana State Board of Health. Additional analyses were obtained from the files of the Conservation Division of the U. S. Geological Survey at Great Falls, Montana, from files of the State Board of Health, and from well owners. The analyses are given in Table 6. The locations of the sampling points are shown on Plate 1.

RELATION TO USE

The value of water of a given chemical quality depends on the uses proposed for it. Thus, water unfit for drinking may be suitable for irrigation or industrial cooling. The principal requirements for the major uses of water in the Cut Bank area are summarized below. The reader is referred to Hem (1959) for a more detailed discussion.

Domestic use.—The U. S. Public Health Service (1962) has established standards for sanitary, bacteriological, and chemical requirements of water used for drinking and culinary purposes on interstate common carriers. The standards have been adopted by the American Water Works Association as recommended limits for all public water supplies. Although the standards are not compulsory for water that is used locally, they are measures of the suitability of water for domestic use. The standards for some of the chemical constituents are given in the following table.

Maximum recommended concentration, in parts per million, of various constituents in drinking water

Constituent	Maximum
Iron and manganese (Fe + Mn)	0.3
Magnesium (Mg)	125
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride (F)	1.7[a]
Dissolved solids	500[b]

[a]Where 5-year average of maximum daily air temperature is 50.0° to 53.7°F.

[b]1,000 ppm permitted if water of better quality is not available. Lower limit for warmer climate (U. S. Public Health Service, 1962, p. 8).

Although specific limits are not established for hardness, water having a hardness of less than 60 ppm is regarded as soft; 60 to 120 ppm, moderately hard; 120 to 200 ppm, hard; and more than 200 ppm, very hard. Soft water is suitable for most uses without further softening; very hard water requires softening for most uses in the home.

Nitrate is another constituent that may affect the suitability of water for domestic use. Excessive concentrations (more than 44 ppm) of nitrate in water used for mixing infant formulas have been linked with infant cyanosis (blue babies). Inasmuch as nitrate is one of the principal minerals in sewage effluent or barnyard wastes, the presence of concentrations of nitrate may indicate contamination.

Industrial use.—Industrial uses of water and the quality requirements of each are many and varied. The principal industrial use of water in the study area is for the production and refining of oil. Water injection for secondary recovery of oil is the principal use in oil production. The water-quality requirements for this purpose are not especially restrictive. The corrosiveness of the water as caused by dissolved solids or gases creates problems, but the water is commonly treated with various additives to inhibit corrosion.

Water for cooling is the most significant use in oil refining. Quality requirements for this purpose are not very stringent. Low concentrations of dissolved solids and gases are desirable from the standpoint of corrosion control, and soft water is desirable to minimize encrustation. Water that does not meet these requirements can be treated or tolerated, however.

Agricultural use.—Stock watering and irrigation are the principal agricultural uses of water in the Cut Bank area. Little is known of the relation of the quality of water to health of stock. Apparently stock can become accustomed to the use of water containing as much as 5,000 ppm of dissolved solids. Excessive concentrations of magnesium, sodium, and sulfate can cause scours, and stock are generally healthier on water containing much less than the maximum concentration of dissolved solids.

The suitability of water for irrigation depends on salinity and the concentration of sodium in relation to other cations. Water having a total dissolved solids concentration of more than about 1,500 ppm has a very high salinity hazard and is unsuitable for irrigation under most circumstances. If water containing a large proportion of sodium ions in relation to calcium and magnesium ions is used for irrigation, the sodium tends to be adsorbed on clay particles in the soil. This causes deflocculation of the soil and impairment of drainage.

RELATION TO SOURCE

Precipitation is the first stage of the hydrologic cycle. In this stage the water contains only a small amount of dissolved solids derived from dust in the air. It is of excellent quality for most purposes, though dissolved gases may make it slightly corrosive.

Surface water in the Cut Bank area is generally of good quality for most uses. As may be noted in Table 6, the water samples from Cut Bank Creek contained less than 500 ppm dissolved solids. It would be classed as hard to very hard. Cut Bank Creek was the only surface-water source sampled during the study. Surface-water supplies commonly vary in chemical quality in response to variations in discharge and may be readily polluted. When the discharge is low, as during the winter, the concentration of dissolved solids is higher than when the creek is in flood. The quality of water in Cut Bank Creek is affected seasonally by return flow from irrigation on the benchland west of Cut Bank. The city of Cut Bank uses a lagoon system for sewage disposal. Sometimes, during wet weather, the lagoon capacity is inadequate and some sewage is discharged into Cut Bank Creek through Snake Coulee.

Ground water in the Cut Bank area is commonly strongly mineralized and its usefulness for many purposes is impaired. Plate 3 shows by means of circle diagrams the variations in quality at selected points for the various sources of water. The diameters of the circles are proportional to the total dissolved solids concentration in ppm, and the divisions of the circles show the percent of the constituent ions in epm. Generally, the dissolved solids concentration increases downdip, but several exceptions may be noted.

The deep, unexposed aquifers contain water too mineralized for most uses. Water from the Madison Group is, however, injected for secondary recovery of oil.

The Virgelle Sandstone produces water of poor to fair quality. Sodium is the predominant cation, and bicarbonate and sulfate are the predominant anions. The quality of water from the Virgelle varies considerably from place to place.

Water from the Two Medicine Formation is similar to that from the Virgelle. Sodium and bicarbonate ions predominate, but in places the concentration of sulfate exceeds that of bicarbonate. In water from both the Virgelle and the Two Medicine, sulfate is likely to exceed bicarbonate in water containing much dissolved solids.

Quaternary deposits were not studied during this investigation. Langford (in Paulson and Zimmerman, 1965) found that the water in the terrace deposits west of Cut Bank is hard but otherwise of good quality. An analysis provided by the Big West Oil Company of water from a well in Quaternary deposits at their refinery at Kevin shows the water to be strongly mineralized there.

FACTORS AFFECTING WATER QUALITY

The chemical quality of water in the Cut Bank area changes not only from place to place but with time. The quality of surface water is particularly changeable. Generally, the concentration of dissolved solids in the water is inversely related to the discharge of the stream. Thus, when streams are high, the dissolved solids concentration is low.

Ground water is less subject to changes in chemical quality, but in the Cut Bank area sharp changes have been noted. For many years the Cut Bank city well (33-6-12aa1) produced water having a dissolved solids concentration of 1,100 to 1,300 ppm. In 1964, analyses showed an increase in dissolved solids to 2,000 ppm and by August 1965 the concentration exceeded 5,500 ppm. By June 1965 the use of the water had been discontinued except for emergencies. The owners of wells 35-6-23cd, 35-5-22cb2, and 37-5-29dd reported temporary production of poor water, black and smelling of hydrogen sulfide.

Many factors cause changes in chemical quality. In a stable hydrologic environment, a gradual reduction of the dissolved solids concentration would be expected over a long period of time as soluble salts are leached from the rocks through which the water percolates. If drought or changes in discharge change the natural pattern of flow, however, water from different parts of the aquifer or from other aquifers may flow to the well. The Virgelle transmits much of its contained water along fractures. In parts of the rock not freely connected with the fracture system, water of poorer quality may be held. When the artesian pressure is reduced as by pumping, some of this poorer quality water may be released to flow to discharging wells. In the instances cited above, this may be the cause of the quality changes.

In the Cut Bank Gas Field the discharge of natural gas was noted in several water wells. Much of the gas may be from leaks in the casing or around the annular space of gas wells. The presence of natural gas in water in the Milk River Sandstone (equivalent to the Virgelle) in adjacent areas of Canada was reported by Meyboom (1960, p. 66), and a certain amount probably occurs naturally in the Virgelle in the Cut Bank area. Reduction of sulfates by bacteria in the presence of methane gas probably produces hydrogen sulfide gas noted in many wells. The reaction is as follows:

$$SO_4^{=} + CH_4 \xrightarrow{\text{(bacteria)}} HS^{-} + H_2O + HCO_3^{-}$$

(Hem, 1959, p. 223). The HS^{-} ion commonly would associate with a hydrogen ion to form H_2S (hydrogen sulfide) gas.

CONCLUSIONS

Ground water from the Virgelle Sandstone and the Two Medicine Formation and surface water from Cut Bank Creek are the only dependable sources of fresh water in the Cut Bank area. The Virgelle is capable of yields of 250 gpm and the Two Medicine will yield 10 gpm or less. The average discharge of Cut Bank Creek at Cut Bank for 29 years of record is 192 cfs. A minimum flow of 4 cfs has been recorded. Saline water supplies of 500 gpm probably can be obtained from wells drilled to the Madison Group.

The rising water levels in observation wells in the Cut Bank area during 1964 and 1965 suggest that depletion of fresh ground-water supplies in the Virgelle is not now (1966) imminent. The increased recharge from above-normal precipitation in 1964 and 1965 after a period of dry years and a reduction in the number of wells pumping water from the Virgelle for oil-field waterflood projects are the principal causes of the rising water levels.

Some waterflood supply wells formerly pumping from the Virgelle have been abandoned in favor of a supply from the Madison. As the waterflood projects progress, the amount of water produced with the oil will no doubt increase. If the water is reinjected, the demand for fresh water will probably decline. If additional waterflood projects are started, no danger to the shallow aquifers is anticipated if water for flooding is obtained from the Madison.

The cost of pumping water from the Madison at a depth of 1,000 feet or more may make it uneconomic for some secondary recovery operations, and shallower sources may be in demand. If more water is pumped from the Virgelle, precautions should be taken to minimize interference with existing wells. Water levels should be monitored by periodic measurements of observation wells.

In the vicinity of Cut Bank, where heavy pumping may result in declines in the water level in the Virgelle, alternative sources of water should be considered. Alternative sources are Cut Bank Creek and the Cut Bank municipal water supply. Utilization of Cut Bank Creek must consider prior Indian treaty rights to the water. Present facilities of the Cut Bank municipal supply are inadequate for increased demand in the summer. Some expansion of the plant might be feasible if a long-term, revenue-producing demand could be assured.

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Table 1.--Records of wells and springs in the Cut Bank area, Montana

(1) The well numbering system used is explained in the text of this report.
(2) C, creek bank; H, hillside; L, level or nearly so; S, gentle slope; U, undulating topography.
(3) Dr, drilled well; Du, dug well; S, spring.
(4) Reported depths below the land surface are given in feet; measured depths are given in feet and tenths below measuring points.
(5) C, concrete (brick tile or pipe); P, iron or steel pipe; N, none.
(6) G, gravel; Sd, sand; Ss, sandstone; Ls, limestone; Sh, shale.
(6a) Geologic source: Qal; alluvium; Qow, glacial outwash; Qgm, glacial till; Ktm, Two Medicine Formation; Kv, Virgelle Sandstone; Ktz, transition zone; Mm, Madison Group; Kk, Kootenai Formation.
(7) Method of lift: C, horizontal centrifugal; Cy, cylinder; P, natural flow; N, none; S, submersible turbine; T, turbine; J, jet; A, air.
(8) D, domestic; I, irrigation; In, industrial; N, not being used; O, observation; PS, public supply; S, stock.
(9) Measured depths to water level are given in feet, tenths and hundredths; reported depths to water level are given in feet.
(10) Remarks: L, log; CA, chemical analysis.

Well number (1)	Owner or tenant	Year drilled	Topographic location (2)	Type of well (3)	Depth of well (feet) (4)	Diameter of well (inches)	Type of casing (5)	Principal water-bearing bed: Character of material (6)	Principal water-bearing bed: Geologic source (6a)	Method of lift (7)	Use of water (8)	Altitude of land surface (feet)	Depth to water below land surface (feet) (9)	Date of measurement	Remarks
32-4- 8cb	Bert Hartman	----	U	Dr	96.5	7	P	Ss	Ktz	Cy	S	-----	7.61	10/19/64	
18ab	Ernest Drader	----	U	Dr	500	----	N	Ss	Kv and Ktz	N	N	-----	80	--------	Seismograph hole--Owner proposes t develop in futur
20bb	Walter Hollenberg	----	S	Dr	119	4	P	Ss	Kv	Cy	N	-----	69.6	10/15/64	
20da	Estelle Long	----	U	Dr	71.6	4	P	Ss	Kv	N	N	3,777.94	63.17	10/15/65	
21ba	Grover Warren	----	U	Dr	118.0	4	P	Ss	Kv	N	O	3,800.4	70.18	10/15/65	
27bb	Babe and Jardar Hjartarson	1916	U	Dr	116	6	P	Ss	Kv	Cy	D	-----	75	--------	
28aa	-----do-----	1953	U	Dr	97.2	6	P	Ss	Kv	N	N	3,793.8	57.76	10/15/65	
28ab	-----do-----	1958	U	Dr	150	4	P	Ss	Kv	Cy	D	-----	30 or 40	--------	CA
32-5-10db	------------	----	-	--	290	----	-	Ss	Kv	--	-	-----	-------	--------	CA
11dd	Ernest Drader	----	U	Dr	185	5	P	Ss	Kv	Cy	D	-----	175	--------	CA
13ab	-----do-----	----	U	Dr	500	----	N	Ss	Kv	N	N	-----	60	--------	Seismograph hole
14aa	-----do-----	----	U	Dr	500	----	N	Ss	Kv	N	N	-----	175	--------	Seismograph hole
14da	Ted Suta	1915	U	Dr	200	5	P	Ss	Kv	Cy	D	-----	180	--------	
16ac	Texaco Inc.	----	U	Dr	3,401	10 3/4	P	Ls	Mm	S	In	-----	1,300	--------	L, Drawdown 366 f after pumping 1 gpm for 3 hrs.
16bc	-----do-----	1943	U	Dr	305	4 3/4	P	Ss	Kv	T	N	3,784	228.30	8/17/65	L
22ad	Elmer Long	----	U	Dr	165	5 1/2	P	Ss	Kv	J	D	-----	40	--------	L
23bb	Jacob Drisckell	----	S	Dr	146.6	5	P	Ss	Kv	N	O	3,724	116.33	10/14/64	
24db	Charles Sullivan	----	U	Dr	95.2	4	P	Ss	Kv	Cy	N	3,658.28	41.61	10/15/64	
25aa	R. Townsend	----	U	Dr	63.9	4	P	Ss	Kv	N	N	3,669.99	62.50	10/15/64	
25dd	Harold Nelson	----	U	Dr	86.2	4	P	Ss	Kv	N	O	3,669.77	74.52	10/15/64	
30bb	Phillips Petroleum	1962	U	Dr	332	8 5/8	P	Ss	Kv	N	N	-----	257	--------	L, Drawdown 29 ft after 24 hr. pumping 73 gpm (reported)
30bd1	-----do-----	1963	-	Dr	3,310	8 5/8	P	Ls	Mm	T	In	3,636	1,085	--------	Drawdown 35 ft. after pumping 32 gpm for 3 1/ hrs. (reported)

30bd2	-----do-----	1962	U	Dr	400?	8 5/8	P	Ss	Kv	N	In	-----	222	--------	L, drawdown 5 ft. after pumping 67 gpm for 24 hrs.
30dc	-----do-----	----	U	Dr	323.8	5	P	Ss	Kv	N	O	3,710.94	298.65	8/13/64	
32-6- 1ac	------------	----	U	Dr	288.4	4	P	Ss	Ktm	N	O	3,719.69	249.59	9/15/64	CA
24da	Phillips Petroleum	----	U	Dr	400	9 5/8	P	Ss	Kv	N	In	3,676	305	--------	L, Drawdown 35 ft. after pumping 47 gpm for 24 hrs.
25ad	-----do-----	1962	U	Dr	445	8 5/8	P	Ss	Kv	N	In	3,681.89	258.60	8/19/65	L, Drawdown 49 ft. after pumping 12 1/2 gpm for 24 hrs.
33-4-31bd	Bert Hartman	----	S	Dr	120.2	6	P	Ss	Kv	N	O	3,675.42	37.27	10/19/64	CA, oil test site
31dd	-----do-----	----	U	Dr	138.1	5	P	Ss	Ktz	Cy	S	3,642.15	9.74	10/19/64	
33-5- 3ba	Len Proefrock	----	U	Dr	192.7*	5	P	Ss	Kv	N	O	3,852.47	144.74	10/22/64	* Poor depth measurement
3dc	Edward J. Peoples	1960	U	Dr	205	6	P	Ss	Kv	S	D,S	3,876.95	170.99	10/18/65	CA
5ba	Carl Shelby	----	L	Dr	100	6	P	Ss	Kv	S	D	3,745 (est.)	43.75	10/25/65	
6bb	Duane Sammons	----	L	Dr	-----	7	P	Ss	Kv	T	I,D,S	-----	154	--------	L
6bc	Glacier Electric	1965	S	Dr	126	4 1/2	P	Ss	Ktm	S	In	-----	58	--------	
6cb	H. C. Neidhart	1963	S	Dr	212	7	P	Ss	Kv	Cy	D	3,713.20	18.59	6/ 2/65	L
7db	George Therrie	----	U	Dr	254.2	6	P	Ss	Ktm	N	S	3,810.90	116.77	3/ 4/65	
8cc	Hans Ness	----	U	Dr	88.5?	6	P	Ss	Ktm	N	N	3,827	83.77	9/11/64	
8cd	-----do-----	1933	S	Dr	260	6 5/8	P	Ss	Kv	N	N	3,823	22.62	9/11/64	
11ab	Emmett Peterson	----	U	Dr	155.6	6	P	Ss	Kv	Cy	O	3,844.91	124.98	8/17/64	
12cc	Emil Luedtke	1915	U	Dr	204	----	P	Ss	Kv	Cy	D,S	-----	150	--------	
13bb	Victor Luedtke	----	U	Dr	180	4	P	Ss	Kv	Cy	S	3,871	150.35	10/ 7/65	
13cc	M. O. Hegg	----	L	Dr	-----	5	P	Ss	Kv	Cy	N	3,874	138.55	10/25/65	
17ad	Richard Rossman	----	L	Dr	247	4	P	Ss	Kv	--	D	-----	220	--------	
17da1	Vernon Swenson	1934	U	Dr	310	4	P	Ss	Kv	N	D	3,879.78	dry	8/18/64	
17da2	-----do-----	1963	U	Dr	-----	4	P	Ss	Ktm	Cy	D	3,879.78	166.45	8/18/64	
19ab	Union Oil Co.	1952	S	Dr	301	7	P	Ss	Kv	N	O	3,752.92	169.80	9/11/64	
20da	Leroy Wacker	1940	H	Dr	350	5 1/2	P	Ss	Kv	Cy	D	3,918.29	301.42	10/ 6/64	
21bb1	Consolidated Freightways	1945	L	Dr	307	7	P	Ss	Kv	Cy	In,O	3,880.05	265.36	8/18/64	
21bb2	Union Oil Company	1945	L	Dr	311	7	P	Ss	Kv	T	In	3,892.92	270.1	5/28/65	CA
21bc	-----do-----	1949	L	Dr	343	7	P	Ss	Kv	T	In	3,891.27	250	--------	
21da	Walter Christopherson	1948	U	Dr	285	7	P	Ss	Kv	Cy	D,O	3,888.42	239.74	8/18/64	CA
22ab	Harry Morgan	----	L	Dr	-----	4	P	Ss	Kv	N	N	-----	170	--------	
22bc	Union Oil Company	1942	L	Dr	250	10 to 5	P	Ss	Kv	T	In	3,866.24	184	8/ 9/65	
23bb	Clyde Monroe	1964	U	Dr	270	----	N	Ss	Kv	N	N	-----	145.95	9/ 4/64	
26ab	Steve and Antonio Keros	----	U	Dr	20.8	5	P	Ss	Kv	N	N	-----	13.09	10/19/64	
29ca	Union Oil Company	1963	S	Dr	302	7	P	Ss	Kv	T	In	3,789.10	195.63	10/ 7/64	L, Drawdown 6 ft. after pumping 122 gpm for 49 hrs.
30aa	-----do-----	----	S	Dr	294	7	P	Ss	Kv	T	In	3,755.77	163.53	10/ 6/64	L, Drawdown 26 ft. after pumping 109 gpm for 45 1/2 hrs.
32ad	-----do-----	1963	L	Dr	282	7	P	Ss	Kv	T	In	3,824	220	--------	Drawdown 10 ft. after pumping 80 gpm for 3 hrs.
33-6- 3ca	Alfred Allison	1953	-	Dr	74	6	P	Ss	Ktm	J	D,S	-----	30	--------	L
10bb	------------	----	-	--	200+	----	-	Ss	Ktm	--	N	-----	--------	--------	CA, Well abandoned
11bd	Brenner Service	----	H	Dr	343	5 1/2	P	Ss	Kv	Cy	D	-----	--------	--------	CA
12aa1	City of Cut Bank	----	U	Dr	238	12	P	Ss	Ktm and Kv	T	PS	3,746.88	--------	--------	CA
12aa2	U.S. Geological Survey	1965	H	Dr	400	4	P	Ss	Ktm and Kv	N	O	3,753.19	52.38	9/ 1/65	L, Dual observation well in both Ktm and Kv

Well number (1)	Owner or tenant	Year drilled	Topographic location (2)	Type of well (3)	Depth of well (feet) (4)	Diameter of well (inches)	Type of casing (5)	Principal water-bearing bed: Character of material (6)	Principal water-bearing bed: Geologic source (6a)	Method of lift (7)	Use of water (8)	Altitude of land surface (feet)	Depth to water below land surface (feet) (9)	Date of measurement	Remarks
33-6-14ca	J. L. Steen	1963	H	Dr	145	4	P	Ss	Ktm	S	S	-----	35	--------	
24bb	Cut Bank airport	----	C	Du	50	192	C	Sd	Qal	T	PS	-----	30	--------	
25cb	------------	----	-	--	2,445	----	-	Ss,Sh	Kc	--	N	-----	-------	--------	Sampled oil test hole, CA
34-4-31ba	Edward J. Peoples	1961	-	--	153	----	-	Ss	Ktz	Cy	S	-----	100	--------	
34-5- 3bb	Abandoned school	----	L	Dr	72.1	6	P	Ss	Kv	Cy	N	3,874.98	47.77	10/22/64	CA
3cc	Don P. Fugle	1945	U	Dr	201	5 1/2	P	Ss	Kv	Cy	D,S	-----	100	--------	CA, Gas bubbles audibly in well
5bc	Orville Schuette	1911	L	Dr	120	6	P	Ss	Ktm	Cy	D,S	-----	117	--------	
9aa	Don Fugle	----	S	Dr	305	6	P	Ss	Kv	Cy	D,S	-----	100	--------	Some gas reported
9bd	Mary Everson	----	U	Dr	108.3	6	P	Ss	Kv	Cy	N	3,837.36	96.16	10/22/64	
10aa	Jim Kruger	----	U	Dr	58.2	5 1/2	P	Ss	Ktm?	N	N	-----	Less than 40	--------	
18cc	Richard Atkins Richard Broadhead Ralph Broadhead	----	L	Dr	150	7	P	Ss	Kv	S	D	-----	90	--------	L
20bb	Gordon Rice	1908	U	Dr	124	4	P	Ss	Kv	Cy	S	3,784	67.01	10/ 8/65	CA
20dd	Orville Clough	----	U	Dr	112.2	6	P	Ss	Kv	Cy	N	3,799.37	99.08	10/20/64	
29da1	Harold Tomscheck	----	L	Dr	160	7	P	Ss	Kv	S	D,S	3,750.76	56.94	10/20/64	CA
29da2	-----do-----	----	L	Dr	70	4	P	Ss	Ktm	N	N	-----	30	--------	
30bb	Jay Wilcox	----	L	Dr	100	5	P	Ss	Ktm	Cy	D	-----	70	--------	
31bc	Ty Coleman	----	L	Dr	160	4	P	Ss	Kv	Cy	S	-----	90	--------	
31cd	Brady Kennedy	----	L	Dr	164	7 to 5 1/2	P	Ss	Kv	S	D	3,726	26.79	10/ 9/65	CA
32cc	Gertrude O'Brien	----	L	Dr	64.9	6	P	Ss	Ktm	Cy	N	-----	26.5	9/23/65	
34bb	E. O. Peterson	----	-	--	-----	----	-	Ss	Kv	--	D	-----	270	--------	
35dc	Vic Luedtke	----	L	Dr	136.8	6	P	Ss	Kv	Cy	D,S	3,858.49	97.85	10/22/64	CA, Inadequate yi
34-6- 2cb	Don Kiesser	1928	L	Dr	130	8	P	Ss	Ktm	S	D	-----	114	--------	
11ba	------------	----	-	--	2,693	----	-	Ss	Kk	--	N	-----	-------	--------	CA, Oil test
11cc	Clinton Schnee	----	L	Dr	42.0	8	P	Ss	Ktm	N	N	-----	37.13	10/ 6/65	
12cc	Herman and Dale Vermulum	1964	L	Dr	135	4	P	Ss	Ktm	S	D	3,808	90.89	10/ 9/65	CA
13ac	W. H. Bauman	----	L	Dr	135.5	6	P	Ss	Ktm	S	S	3,789	81.54	10/ 5/65	
13bc	Herman Vermulum	1909	L	Dr	111.1	6	P	Ss	Ktm	Cy	N	-----	91.34	10/ 7/65	
14ba	Don Mason	----	L	Dr	90	6	P	Ss	Ktm	N	N	-----	53.09	10/ 6/65	
14bc	Roy Bittner	1944	H	Dr	219.9	6	P	Ss	Ktm	J	D,S,I	3,793	94.41	10/ 5/65	CA
14dd1	Gladys Haglund	----	L	Dr	202	7	P	Ss	Kv	Cy	D	3,797	190	--------	CA
14dd2	-----do-----	----	L	Dr	150.2	6	P	Ss	Ktm	N	N	3,797	36.94	10/ 5/65	
24da	------------	----	-	--	230	----	-	Ss	Kv	--	-	-----	-------	--------	CA, Data from USG files--well destroyed
36ad	Kenneth Sammons	----	U	Dr	138.3	7	P	Ss	Ktm	N	O	-----	65.80	7/24/64	
35-3-18ca	U.S. Government	1942	H	Dr	110.4	10	P	Ss	Kv	N	N	4,060	65.00	9/ 8/64	
35cd1	Big West Oil Co.	----	L	Dr	67.8	8	P	Sd,Sh	Qow	N	N	-----	34.38	9/ 9/64	CA, About 7 ft. o oil in well whe measured

35cd2	-----do-----	----	L	Dr	348	10 3/4	P	Sd	Qow	A	In	-----	100	--------	
35-4- 1db	Ole Enneberg	----	H	Dr	170.0	6	P	Ss	Kv	N	N	-----	119.21	10/21/65	
2ca	-----do-----	----	U	Dr	158.9	5	P	Ss	Kv	N	N	-----	55.98	10/21/65	
3aa1	Phil Spencer	----	U	Dr	215	6	P	Ss	Kv	Cy	D	-----	80		
3aa2	-----do-----	1962	U	Dr	215	6	P	Ss	Kv	N	N	4,198.64	166.20	8/ 2/65	
11aa	Town of Kevin	----	H	Dr	90	13	P	Ss	Kv	S	PS	4,030	49.25 ±.05	9/ 9/64	
11dc1	-----do-----	----	U	Dr	63.5	10	P	Ss	Ktz	S	PS	-----	50	--------	
11dc2	-----do-----	----	H	S	-----	----	-	Ss	Kv	F	PS	-----	-------	--------	
11dd	A. H. Goeddertz	1961	U	Dr	134.8	10	P	Ss	Ktz	F	S	-----	-------	--------	Flows about 1 gpm CA
12bb	Town of Kevin	----	H	Dr	120	13	P	Ss	Kv	S	PS	-----	90	--------	
12bc	-----do-----	----	H	Dr	127	13	P	Ss	Kv	S	PS	-----	52	--------	Water can be heard cascading from one zone to another in well
12bd1	-----do-----	----	U	Dr	144.6	13	P	Ss	Kv and Ktz	N	PS	-----	20.52	9/ 9/64	
12bd2	Big West Oil Co.	----	U	Dr	238	10 3/4	P	Ss	Kv	N	N	4,159	181.00	9/ 9/64	L
12ca	Town of Kevin	----	H	Dr	74	10	P	Ss	Kv and Ktz	S	PS	-----	60	--------	
12cb1	-----do-----	----	H	Dr	44.5	10	P	Ss	Ktz	S	PS	-----	flowing	--------	Flowing at time of inventory
12cb2	-----do-----	----	H	S	-----	----	-	Ss	Kv	F	PS	-----	-------	--------	
35-5- 1cc	------------	----	-	--	75+	----	-	Ss	Ktm	--	N	-----	-------	--------	CA, Well destroyed
2aa	Stanley Hjartarson	----	S	Dr	127	6	P	Ss	Ktm	J	D,S	-----	13.55	10/ 1/65	CA
4aa	------------	----	-	--	280+	----	-	Ss	Kv	--	N	-----	-------	--------	CA, Well destroyed
5ad	Axel G. Hansen	1913	U	Dr	85	6	P	Ss	Ktm	Cy	S	-----	20	--------	
5dd	William A. Van Alstine	----	L	Dr	327	7	P	Ss	Kv	Cy	D,S	-----	200	--------	CA
7bb	Montana Power Co.	1948	H	Dr	365	5 1/2	P	Ss	Kv	T	In	-----	80	9/23/64	CA
7cc	Alvin Boxwell	1963	H	Dr	490	5 3/4	P	Ss	Kv	Cy	D,S	-----	410	--------	
12cc	Ella Berger	----	U	Dr	215	5	P	Ss	Kv	Cy	D,S	4,108.89	180.84	10/21/64	CA
15ab	Montana Power Co.	1948	U	Dr	260	6 5/8	P	Ss	Kv	N	O	4,119.73	203.95	8/14/64	
15dc	Glenn Lindberg	1943	U	Dr	280	4	P	Ss	Kv	Cy	D,O	4,152.55	262.85	8/11/65	CA
16ac	Paul Johnson	1962	H	Dr	224	4 1/2	P	Ss	Kv	Cy	S	-----	150	--------	L
19cb	-----do-----	----	S	Dr	108.1	5	P	Ss	Ktm?	N	N	-----	21.01	6/11/65	
20bb1	-----do-----	----	S	Dr	185	5	P	Ss	Ktm	S	D	-----	140	--------	
20bb2	-----do-----	1957	S	Dr	327	5 1/2	P	Ss	Kv	S	S	-----	85 or 90*	--------	* Electric tape reads unsteadily at 85 ft.--water can be heard cascading in well. CA
20dc	-----do-----	----	U	Dr	133.3	5	P	Ss	Kv	N	N	3,955	81.05	9/28/65	
21da	Montana Power Co.	1932	S	Dr	205.2	4	P	Ss	Ktm	N	N	-----	176.62	10/26/64	
22cb1	Montana Power Co.	1940	U	Dr	221	6	P	Ss	Kv	Cy	D,O	4,060.66	186.60	8/17/64	
22cb2	-----do-----	1960	U	Dr	326	5 1/2	P	Ss	Kv	--	D	4,130.24	90	--------	Ca
23da	George DeZort	----	U	Dr	83.8	5	P	Ss	Ktm	Cy	S	-----	39.94	9/30/65	
27cc	Montana Power Co.	----	L	Dr	210	4	P	Ss	Kv	Cy	N	3,978.94	113.88	9/29/65	
30ad	Melvin Berkram	----	L	Dr	-----	4	P	Ss	Kv	Cy	S	3,888	59.84	9/30/65	Gas or cascading water clearly audible in well
34ab	George DeZort	1912	L	Dr	100.9	6	P	Ss	Kv	Cy	D,S	3,974	76.23	9/30/65	CA
34bb1	Louis DeZort	1910	S	Dr	135	6	P	Ss	Kv	S	D	-----	100	--------	
34bb2	-----do-----	1949	S	Dr	160	6	P	Ss	Kv	Cy	D,S	-----	125	--------	
34da	Phillip Schuette	----	U	Dr	134	5	P	Ss	Kv	Cy	S	-----	54	--------	L
34dc	-----do-----	1958	-	Dr	238	7	P	Ss	Kv	Cy	S	-----	230	--------	L
35-6- 2aa	C. L. Proefrock	----	L	Dr	224.3	10	P	Ss	Ktm	N	N	4,016	47.26	8/18/65	
2dd	-----do-----	----	U	Dr	85	6	P	Ss	Ktm	Cy	S	-----	30	--------	
10bc	Humble Oil Co.	----	H	Dr	402?	7	P	Ss	Kv	T	In	3,958.27	223	--------	Original pumping level was 302 ft. while pumping 62.5 gpm

Well number (1)	Owner or tenant	Year drilled	Topographic location (2)	Type of well (3)	Depth of well (feet) (4)	Diameter of well (inches)	Type of casing (5)	Principal water-bearing bed: Character of material (6)	Principal water-bearing bed: Geologic source (6a)	Method of lift (7)	Use of water (8)	Altitude of land surface (feet)	Depth to water below land surface (feet) (9)	Date of measurement	Remarks
35-6-11cb	Texaco Inc.	1963	U	Dr	3,300	4 1/2 to 10 3/4	P	Ls	Mm	T	In	3,980	1,126	--------	Drawdown 57.67 ft. after 45 minutes pumping 234 gpm
12cc	Alvin Boxwell	----	H	Dr	100+	5	P	Ss	Ktm	Cy	N	-----	8.03	9/28/65	
14cb	------------	----	-	--	280+	----	-	Ss	Kv	--	N	-----	-------	--------	CA, Well destroyed
15bd	------------	----	-	--	245	----	-	Ss	Kv	--	N	-----	-------	--------	CA, Well destroyed
21ab	S. E. Tweedy	----	S	Dr	151	4	P	Ss	Ktm	J	D	-----	40	--------	
21bc	Jack and Bill Tweedy	----	U	Dr	139.0	7	P	Ss	Ktm	N	O	-----	69.00	8/12/64	
21cb	Texaco Inc.	1964	U	Dr	575	8 5/8	P	Ss	Kv	T	In	3,884.9	168	1/ 7/66	CA
23cd	John Quist	----	L	Dr	200	5	P	Ss	Kv	Cy	D,S	3,891	152.22	10/19/65	CA
26cd	------------	----	-	--	180	----	-	Ss	Kv	--	N	-----	-------	--------	CA, Well destroyed
32ac	George Rice	----	S	Dr	176.6	7	P	Ss	Ktm	Cy	N	-----	88.20	10/ 7/65	
34ad	Texaco Inc.	----	L	Dr	174	5 1/2	P	Ss	Ktm	S	D	-----	130	--------	
34bc	Abandoned school	----	U	Dr	79.7	4	P	Ss	Ktm	Cy	N	-----	39.90	10/ 1/65	
34dd	Harry Womble	----	L	Dr	82.6	7	P	Ss	Ktm	N	N	-----	76.04	10/ 6/65	
35cc	Texaco Inc.	1952	L	Dr	3,062	10 3/4 to 7	P	Ls	Mm	T	In	-----	1,138	--------	
36-3- 3cb	Herman Simmons	----	C	Dr	73.1	4	P	Ss	Ktz	F	S	-----	-------	5-21-65	Flows an estimated 1/2 gpm
6ba	Richard Dunk	----	H	Dr	208.2	6	P	Ss	Kv	Cy	D,S	3,921.81	172.70	6/24/65	
7db	Rimrock Colony	----	C	S	-----	----	-	Ss	Kv	F	S	-----	-------	6/24/65	Yields an estimated 50 gpm
18ab	-----do-----	1958	U	Dr	91	6	P	Ss	Kv	Cy	S	3,966.94	75.63	6/24/65	
19bb	Richard Dunk	1959	U	Dr	141	4	P	Ss	Kv	Cy	S	4,026.02	110.33	6/30/65	
19cc	Earl Gillespie	----	U	Dr	150	5	P	Ss	Kv	Cy	S	4,061	114.76	7/30/65	CA
30cb	A. H. Goeddertz	----	U	Dr	-----	6	P	Ss	Kv	--	S	-----	183	--------	
30dd	-----do-----	----	U	Dr	-----	6	P	Ss	Kv	--	S	-----	183	--------	
32cd	Earl Gillespie	----	U	Dr	300	----	-	Ss	Kv	--	S	-----	280	--------	
36-4- 4aa	G. Peter Suta	1963	U	Dr	255	5	P	Ss	Kv	Cy	S	-----	224.40	8/ 2/65	
7ac	Ralph Swenson	----	U	Dr	170.8	4	P	Ss	Ktm	Cy	S	3,979.82	138.08	8/ 2/65	
9bb	G. Peter Suta	----	U	Dr	149	5	P	Ss	Ktm	Cy	S	-----	106.41	8/ 2/65	
11bb	Rimrock Colony	1959	S	Dr	222	8	P	Ss	Kv	S	D,S	4,009.60	197.62	6/24/65	
11dd	-----do-----	----	S	Dr	170 or 175	12	P	Ss	Kv	Cy	D,S	3,998.79	101.47	6/24/65	
14aa	Town of Sunburst	1940	U	Dr	174	12 1/2	P	Ss	Kv	N	N	4,029.74	116.79	8/20/64	CA
14ab1	Rimrock Colony	----	U	Dr	68	11	P	Ss	Kv	N	N	-----	66.41	8/20/64	
14ab2	Town of Sunburst	1951	U	Dr	159	12 1/2	P	Ss	Kv	T	PS	3,982	89	--------	CA, Drawdown 7.7 ft. pumping 150 gpm or 9.7 ft. pumping 200 gpm
14ac	-----do-----	1936	U	Dr	155	12 1/2	P	Ss	Kv	T	PS	4,020	141	--------	CA
14ad	-----do-----	1940	U	Dr	146.7	10	P	Ss	Kv	N	N	4,065.80	127.16	5/ 7/65	
15ac	Rimrock Colony	----	U	Dr	204.0	4	P	Ss	Kv	Cy	S	4,097.37	68.10	10/26/64	
21dc	C. D. Gerrish	1919	H	Dr	250	6	P	Ss	Kv	Cy	D	-----	230	--------	

22ad	George W. Baldwin	1940	U	Dr	201	6	P	Ss	Kv	S	D	-----	160	--------	
22dc	Earl E. Gillespie	----	U	Dr	145	5	P	Ss	Ktm	Cy	S	4,196	118.40	7/30/65	CA
25ab	Ole Enneberg	1963	U	Dr	230	4	P	Ss	Kv	Cy	S	-----	171.48	10/21/65	
26ca	Earl Gillespie	----	U	Dr	160?	5	P	Ss	Kv	Cy	S	-----	60	--------	
33bb	Glacier Colony	----	U	Dr	146.7	10	P	Ss	Kv	S	S	4,124.20	115.89	8/ 3/65	
34ad	C. D. Gerrish	----	U	Dr	111.5	6	P	Ss	Kv	Cy	N	4,169.02	104.34	7/27/65	
35aa	Big West Oil Co.	1964	U	Dr	257	7	P	Ss	Kv	N	N	-----	195	--------	L
35ab	-----do-----	1964	U	Dr	225	7	P	Ss	Kv	N	S	4,166.06	124.97	9/11/64	L, CA
35ad1	-----do-----	1964	U	Dr	225	7	P	Ss	Kv	N	N	-----	110	--------	L
35ad2	-----do-----	1964	U	Dr	210	7	P	Ss	Kv	N	N	-----	100	--------	L
36da	Ole Enneberg	----	U	Dr	225	8	P	Ss	Kv	Cy	N	4,193.85	114.18	7/27/65	
36-5- 1dc	Town of Sunburst	1945	H	Dr	475	12 1/2	P	Ss	Kv	S	PS	4,047	219	11/25/57	CA
4ab	G. K. Bilstad	----	U	Dr	137	4	P	Ss	Ktm	Cy	S	3,912	123.69	8/ 6/65	CA
4db	------------	----	-	--	2,814+	----	-	Ss	Kk	--	N	-----	-------	--------	CA, Oil test
9db	G. K. Bilstad	----	U	Dr	150	5	P	Ss	Ktm	Cy	S	-----	120	--------	
11ba	Ralph Swenson	1955	U	Dr	152	5 1/2	P	Ss	Ktm	Cy	S	3,960.63	8.90	8/ 9/65	
11bd	Bert Swenson	----	S	Dr	152	5 1/2	P	Ss	Ktm	Cy	N	3,960.70	17.20	8/ 9/65	
12ac	Town of Sunburst	----	U	Dr	524	12 1/2	P	Ss	Kv	N	N	4,084.03	309.90	6/11/65	
12dc	-----do-----	1943	U	Dr	407	12 1/2	P	Ss	Kv	T	PS	-----	90	--------	CA
13aa	-----do-----	1945	U	Dr	520	12 1/2	P	Ss	Kv	T	PS	4,086	299	--------	CA
14ac	George Gjertson	----	U	Dr	450	4	P	Ss	Kv	N	O	3,984.23	12.09	10/24/64	CA
14bd	-----do-----	----	U	Dr	105	6	P	Ss	Ktm	J	D,S	-----	7.83	10/24/64	CA
17ba	Sam Johnson and Tom Eney	----	S	Dr	72	5	P	Ss	Ktm	Cy	N	-----	54	--------	
19bc	D. F. Stufft	----	U	Dr	64	7	P	Ss	Ktm	N	N	-----	20.53	8/ 9/65	
23ac	Ray Peterson	1938	U	Dr	105	6	P	Ss	Ktm	J	D,S	-----	48.71	8/ 5/65	
24da	-----do-----	----	S	Dr	100	6	P	Ss	Ktm	F	S	-----	-------	--------	Leaks around casing
26ba	Glacier Colony	----	U	Dr	160	3	P	Ss	Ktm	Cy	S	-----	80	--------	
27cd	Ray Peterson	1961	-	Dr	85	4	P	Ss	Ktm	Cy	S	-----	43.96	8/ 5/65	
31bc	Phil Nelson	----	U	Dr	204.0	5 1/2	P	Ss	Ktm	Cy	D,S	4,064	17.70	10/23/64	
32bc	Don Bradley	----	U	Dr	100	5	P	Ss	Ktm	S	D	-----	28	--------	
33bc	Russel Johnson	----	U	Dr	102	4	P	Ss	Ktm	Cy	D,S	-----	29	--------	
35cd	Glacier Colony	----	U	Dr	190	6	P	Ss	Kv	Cy	D,S	-----	90	--------	
36-6- 2da	------------	----	-	--	170?	----	-	Ss	Kv	--	N	-----	-------	--------	CA, Well destroyed
12ac	------------	----	-	--	3,125	----	-	Ls	Mm	--	In	-----	-------	--------	CA, Oil well--water produced with oil
12bc	Conrad Bradley	1940	U	Dr	452	6	P	Ss	Kv	Cy	S	4,082	124.79	8/10/65	
13aa	Sam Johnson and Tom Eney	----	S	Dr	51.7	5	P	Ss	Ktm	Cy	N	-----	27.54	8/10/65	
14ba	Conrad Bradley	1961	U	Dr	161	4 1/2	P	Ss	Ktm	Cy	S	-----	100	--------	L
25dd	Ed Huebner	----	H	Dr	136	4 1/2	P	Ss	Ktm	--	D	-----	30	--------	L, Drawdown 100 ft. after 8 hrs pumping 7 gpm
34dd	C. L. Proefrock	----	C	S	-----	----	-	Ss	Ktm	F	S	-----	-------	--------	Flows an estimated 50 gpm
35da	-----do-----	----	L	Dr	85	8	P	Ss	Ktm	J	D,S	-----	18	--------	
35dc	-----do-----	----	L	Dr	106.0	4	P	Ss	Ktm	N	N	-----	32.76	8/18/65	
37-3- 2ab	U.S. Government	----	U	Dr	180+	----	-	Ss	Kv	Cy	N	-----	-------	--------	CA
2ac	Vince Arneson	----	H	Dr	110	6	P	Ss	Kv	Cy	N	3,513.94	55.23	8/ 4/65	
2ba	William Fyfe	----	L	Dr	148.5	6	P	Ss	Kv	N	N	3,535.67	74.70	8/ 3/65	
2bd1	Leo Campanion	----	U	Dr	125	6	P	Ss	Kv	S	S	-----	95	--------	
2bd2	-----do-----	----	U	Dr	27.8	7	P	Ss	Kv	N	N	-----	25.71	9/15/64	
2ca	Homer Dye	1910	U	Dr	115	6	P	Ss	Kv	Cy	S	3,565.20	81.20	4/29/65	CA
3cd	Harold Darner	1923	U	Dr	600	12	P	Ss	Kv	N	O	3,554.61	53.23	9/10/64	
4ad	Toole County Cemetery District	----	U	Dr	186	7	P	Ss	Kv	S	I	3,511.42	47.41	8/ 4/65	CA
4dd	Hillside Colony	1957	H	Dr	30	6	P	Ss	Kv	Cy	S	3,429.02	12.95	5/12/65	
7ba	-----do-----	1961	C	Dr	56	6	P	Ss	Kv	Cy	S	3,523.26	46.09	5/12/65	
10bd	Arne Farbo	1916	U	Dr	120	4	P	Ss	Kv	Cy	D,S	-----	90	--------	
11cb	Lyle Akelstad	----	U	Dr	133.5	6	P	Ss	Kv	Cy	N	3,621.16	90.26	4/29/65	
12ca	Anita Gallup	----	S	Dr	85.9	6	P	Ss	Kv	Cy	N	3,475.36	25.86	4/29/65	
14aa	Henry Gauss	----	S	Dr	157.8	6	P	Ss	Kv	Cy	N	3,684.85	113.50	4/29/65	

Well number (1)	Owner or tenant	Year drilled	Topographic location (2)	Type of well (3)	Depth of well (feet) (4)	Diameter of well (inches)	Type of casing (5)	Principal water-bearing bed: Character of material (6)	Principal water-bearing bed: Geologic source (6a)	Method of lift (7)	Use of water (8)	Altitude of land surface (feet)	Depth to water below land surface (feet) (9)	Date of measurement	Remarks
37-3-17db	Hillside Colony	1958	C	Du	21	24	P	Sd,G	Qal	Cy	S	-----	13	--------	
21bd1	Maurice Kelleher	----	U	Dr	122	6	P	Ss	Kv	Cy	D,S	-----	110	--------	
21bd2	-----do-----	----	U	Dr	112	6	P	Ss	Kv	Cy	S	-----	95	--------	
21db	Junia Dye	1938	U	Dr	117	6	P	Ss	Kv	Cy	S	3,723	84.41	5/10/65	CA
22ac	Maurice Kelleher	----	S	Dr	126	6	P	Ss	Kv	Cy	S	3,712	85.63	5/ 7/65	
22db	Junia Dye	1939	S	Dr	87	6	P	Ss	Ktz	Cy	D,S	3,636	30.19	5/10/65	
23aa	Hillside Colony	----	C	Dr	80	6	P	Sd,G	Qal(?)	Cy	S	-----	7.06	5/12/65	
31aa	John McAlpine	1946	U	Dr	150	6	P	Ss	Kv	Cy	D,S	-----	110	--------	
32dd	Herman Simmons	----	-	Dr	135	6	P	Ss	Ktz	Cy	S	-----	45	--------	
33bc	Maurice Kelleher	----	C	S	-----	----	-	Ss	Kv	F	S	-----	-------	--------	Flows an estimated 15 gpm. Temperature 46°F
37-4- 1cb1	Lawrence Bye	----	U	Dr	338	6	P	Ss	Kv	Cy	S	-----	160	--------	
1cb2	-----do-----	----	U	Dr	160	6	P	Ss	Kv	Cy	D,S	-----	80	--------	Some gas reported in the well
1db	-----do-----	----	U	Dr	146	6	P	Ss	Kv	Cy	S	3,610.78	100.85	5/13/65	
2dd1	Pat Buckley	1929	S	Dr	120	7	P	Ss	Kv	Cy	S	3,642.33	88.55	5/13/65	
2dd2	-----do-----	1940	U	Dr	120	7	P	Ss	Kv	Cy	D	-----	98	--------	Water unfit for huma consumption (reported)
5cb	Mike Buckley	1954	C	Du	18	48	P	G	Qal	J	D	-----	17.51	5/21/65	
12ba	Lawrence Bye	----	U	Dr	55.5	6	P	Ss	Kv	N	N	3,621.33	47.78	5/13/65	
12db1	Hillside Colony	1957	S	Dr	50	6	P	Ss	Kv	J	D	3,599.61	24.62	5/12/65	CA
12db2	-----do-----	1950	H	Dr	110	6	P	Ss	Kv	Cy	D,S	-----	70	--------	
15bc	Tom McAlpine	1960	U	Dr	130	6	P	Ss	Kv	Cy	S	3,701.93	94.60	5/26/65	
18cc	Wm. S. McAlpine	1955	U	Dr	140	6	P	Ss	Kv	J	D,S	3,725	109.44	6/ 3/65	
25cc	Dan McAlpine	1959	U	Dr	165.3	6	P	Ss	Kv	Cy	S	3,896	140.29	5/11/65	
27cb1	Alvin Boxwell	1961	S	Dr	170	6	P	Ss	Kv	S	D	-----	135	--------	CA
27cb2	-----do-----	1917	L	Dr	160	6	P	Ss	Kv	Cy	D	-----	130	--------	
28dc	Rudolph Suta	1957	U	Dr	197	6	P	Ss	Kv	J	D,S	-----	130	--------	Reported unfit for drinking. Specifi conductance 3,000 micromhos
29da	Stanley Bunyak	----	U	Dr	250	6	P	Ss	Kv	Cy	N	-----	195	--------	
29db	-----do-----	----	U	Dr	57	6	P	Ss	Ktm	Cy	N	-----	47	--------	
31ac	John Fitzpatrick	1948	-	Dr	110	5	P	Ss	Ktm	J	D,S	-----	40	--------	
34dd	Edmund Altenburg	1956	U	Dr	107	5	P	Ss	Kv	J	D	-----	30	--------	
37-5- 6cb	Gilbert Lozing	1944	U	Dr	80	4	P	Ss	Ktm	Cy,F	D,S	-----	-------	--------	Flows about 1/2 gpm
7ad	Jacob Lozing	----	L	Dr	155	6	P	Ss	Ktm	J	D,S	4,010	24.67	10/19/65	Ca
8dd	Wesley Tuma	1957	U	Dr	135	5	P	Ss	Ktm	S	S	-----	40	--------	
10dc	Ralph Swenson	----	L	Dr	142	6	P	Ss	Kv	S	D,S	-----	125	--------	CA
12aa	Wm. McAlpine	----	C	Du	12	72	C	G	Qal	C	D,S	-----	3 or 4	--------	
13ad	Bert Swenson	1939	S	Dr	120	6	P	Ss	Ktm	Cy	D,S	-----	60	--------	
15da	Rudolf Kruger	----	L	Dr	132.9	6	P	Ss	Kv	Cy	D,S	3,753.15	113.17	6/ 8/65	CA

19da	William Lozing	1948	U	Dr	115	6	P	Ss	Ktm	Cy	S	4,011	72.88	6/14/65	CA
20dc	Frederick Berkram	----	U	Dr	136	6	P	Ss	Ktm	S	D,S	-----	70	--------	
21ab	Toralv Berkram	1949	U	Dr	100	6	P	Ss	Ktm	S	D	-----	60	--------	
24ba	Rudolph Kruger	----	S	Dr	127.1	6	P	Ss	Kv	N	N	-----	19.85	6/ 8/65	
26cb	Woodrow Bunyak	1959	U	Dr	183	5	P	Ss	Kv	S	D	3,839.78	170.6	6/ 4/65	CA
29dd	Rufina Jacobsen	1945	U	Dr	90	4	P	Ss	Ktm	J	D,S	-----	42.31	6/ 9/65	CA
30dd	A. E. Freed	----	U	Dr	120	6	P	Ss	Ktm	J	D	-----	30	--------	
34ad	Ted Vasboe	----	L	Dr	166.5	6	P	Ss	Kv	Cy	N	3,842.3	156.70	6/ 8/65	
34dd1	Ken Berkram	1912	U	Dr	88.1	6	P	Ss	Ktm	N	N	-----	80.94	6/ 8/65	
34dd2	-----do-----	1964	-	Dr	287	4	P	Ss	Kv	Cy	D	-----	180	--------	
35cd	Elmer Berkram	1939	U	Dr	185	6	P	Ss	Kv	S	D,S	3,858.94	144.75	6/ 7/65	CA
37-6- 1cb	Jacob Belke	----	U	Dr	58.4	6	P	Ss	Ktm	N	N	-----	0.51	6/10/65	
3da	Liane Johnson	1962	C	Dr	120	4 5/8	P	Sd,G	Qgm	S	D,S	-----	7.38	4/28/65	
24ab	Oswald Bradley	1941	U	Dr	142	6	P	Ss	Ktm	Cy	S	-----	60	--------	
24cd1	-----do-----	1935	U	Dr	130	6	P	Ss	Ktm	Cy	D	-----	40	--------	
24cd2	-----do-----	1943	U	Dr	130	6	P	Ss	Ktm	Cy	S	-----	40	--------	
26ac	-----do-----	1916	U	Dr	133	6	P	Ss	Ktm	Cy	S	-----	36	--------	
35cb	R. J. Halvorson	----	S	Dr	110	6	P	Ss	Ktm	Cy	S	-----	50.80	8/17/65	
36dd	-----do-----	----	S	Dr	100	6	P	Ss	Ktm	Cy	S	-----	50+	--------	Couldn't get tape below 50 feet

Table 2.--Measurements of depth to water in observation wells
(In feet below land surface datum)

32-4-21ba

Date	Water level	Date	Water level
Oct. 16, 1964	73.61	July 20, 1965	69.88
Dec. 9	73.96	Aug. 19	69.81
Mar. 3, 1965	73.23	Sept. 23	70.23
Apr. 20	71.73	Oct. 15	70.18
May 19	72.28	Jan. 12, 1966	71.80
June 15	72.80		

32-4-21ba

Date	Water level	Date	Water level
Oct. 16, 1964	73.61	June 15, 1965	72.80
Dec. 9	73.96	July 20	69.88
Mar. 3, 1965	73.23	Aug. 19	69.81
Apr. 20	71.73	Sept. 23	70.23
May 19	72.28	Oct. 15	70.18
		Jan. 12, 1966	71.80

32-5-23bb

Date	Water level	Date	Water level
Oct. 14, 1964	116.33	July 20, 1965	117.11
Dec. 8	117.05	Aug. 19	117.00
Mar. 3, 1965	116.59	Sept. 23	116.32
May 19	116.71	Oct. 15	116.86
June 15	116.71	Jan. 12, 1966	117.08

32-5-25dd

Date	Water level	Date	Water level
Oct. 15, 1964	74.52	July 20, 1965	74.79
Dec. 8	74.43	Aug. 19	72.61
Mar. 3, 1965	75.67	Sept. 23	71.78
Apr. 20	75.86	Oct. 15	71.60
May 19	75.74	Jan. 12, 1966	Obstructed
June 15	75.48		

32-5-30dc

Date	Water level	Date	Water level
Aug. 13, 1964	298.05	May 19, 1965	292.81
Sept. 16	297.03	June 15	292.57
Oct. 25	295.43	July 21	292.00
Dec. 8	298.40	Aug. 19	291.97
Jan. 14, 1965	294.38	Sept. 23	291.98
Mar. 3	294.21	Oct. 16	291.56
Apr. 20	293.13	Jan. 12, 1966	291.58

32-6-1ac

Date	Water level	Date	Water level
Sept. 15, 1964	249.59	Jan. 14, 1965	249.72
Oct. 25	249.55	Mar. 3	249.57
Dec. 8	253.48	May 18	Obstructed

33-4-31bd

Date	Water level	Date	Water level
Oct. 19, 1964	37.27	July 21, 1965	36.68
Dec. 9	37.09	Aug. 19	36.69
Mar. 3, 1965	37.02	Sept. 23	36.55
Apr. 21	36.89	Oct. 16	36.50
May 19	36.94	Jan. 12, 1966	36.30
June 15	36.86		

33-5-3ba

Date	Water level	Date	Water level
Oct. 22, 1964	144.74	July 19, 1965	143.99
Dec. 9	144.20	Aug. 19	143.56
Mar. 3, 1965	145.20	Sept. 23	142.76
Apr. 22	144.98	Oct. 18	142.39
May 19	144.17	Jan. 12, 1966	141.98
June 22	144.13		

33-5-11ab

Date	Water level	Date	Water level
Aug. 17, 1964	124.98	June 22, 1965	124.50
Oct. 2	125.10	July 21	124.17
Dec. 9	124.91	Aug. 19	123.13
Mar. 3, 1965	125.09	Sept. 23	122.08
Apr. 22	125.00	Oct. 18	121.83
May 19	124.75	Jan. 12, 1966	121.45

33-5-19ab

Date	Water level	Date	Water level
July 1952	260?[a]/	Mar. 3, 1965	167.34
Aug. 30, 1962	168[a]/	Apr. 21	166.81
Feb. 19, 1963	168[a]/	May 19	166.70
Oct. 14	166.83[a]/	June 23	166.37
Apr. 15, 1964	170[a]/	July 21	166.19
July 13	170[a]/	Aug. 19	166.29
Sept. 11	169.80	Sept. 23	166.24
Oct. 26	168.19	Oct. 18	165.99
Dec. 8	167.71	Jan. 12, 1966	165.62

a/ Measurements by Union Oil Co. personnel

33-5-21bb1

Date	Water level	Date	Water level
Aug. 18, 1964	265.36	May 19, 1965	258.06
Oct. 2	269.69	June 23	264.98
Oct. 26	260.85	July 21	264.09
Dec. 8	261.96	Aug. 19	263.67
Jan. 13, 1965	261.06	Sept. 23	265.54
Mar. 4	269.74	Oct. 18	258.86
Apr. 22	270.43	Jan. 12, 1966	266.75

33-5-21da

Date	Water level	Date	Water level
Jan. 13, 1963	238.5[a]/	Jan. 13, 1965	241.93
Dec.	238[a]/	Mar. 3	240.11
Jan. 10, 1964	237[a]/	Apr. 22	239.74
Feb. 11	236.5[a]/	May 19	244.77
Mar. 2	240[a]/	June 23	240.46
Apr. 15	241.5[a]/	July 21	241.38
July 13	240[a]/	Aug. 19	239.41
Aug. 18	239.74	Sept. 23	238.93
Sept. 16	240.75	Oct. 18	243.39
Oct. 26	244.83	Jan. 12, 1966	238.60
Dec. 8	241.34		

a/ Measured by Union Oil Co. personnel

33-6-12aa

Date	Water level	Date	Water level
Aug. 10, 1965	53.90	Oct. 18, 1965	52.04
Aug. 31	52.56	Jan. 12, 1966	55.67
Sept. 23	52.00		

33-6-12aa2

Date	Water level	Date	Water level
Aug. 10, 1965	53.79	Oct. 18, 1965	51.67
Aug. 31	52.31	Jan. 12, 1966	55.24
Sept. 23	51.73		

34-6-36ad

Date	Water level	Date	Water level
July 24, 1964	65.80	May 19, 1965	64.84
Oct. 26	65.43	July 19	64.70
Dec. 9	65.04	Aug. 19	64.76
Jan. 13, 1965	64.90	Sept. 23	64.46
Mar. 3	64.86	Oct. 18	64.31
Apr. 22	64.66	Jan. 12, 1966	64.02

Table 2.--Measurements of depth to water in observation wells--continued

35-5-15ab

Date	Water level	Date	Water level
Aug. 14, 1964	203.95	June 23, 1965	201.41
Oct. 1	203.64	July 15	201.36
Dec. 9	203.23	Aug. 20	201.29
Jan. 13, 1965	203.18	Sept. 24	200.90
Mar. 3	202.87	Oct. 18	200.79
Apr. 22	202.35	Jan. 12, 1966	200.70
May 18	201.81		

35-5-15dc

Date	Water level	Date	Water level
Aug. 11, 1964	262.85	May 20, 1965	250.98
Oct. 1	261.92	June 23	250.95
Oct. 26	251.98	July 22	250.71
Dec. 9	263.00	Aug. 20	250.84
Jan. 14, 1965	251.73	Sept. 24	250.91
Mar. 4	256.09*	Oct. 19	250.03
Apr. 23	251.50	Jan. 12, 1966	249.95

* Pumped

35-5-22cb1

Date	Water level	Date	Water level
Aug. 17, 1964	186.60	May 20, 1965	186.79
Oct. 1	186.01	June 23	186.66
Oct. 26	pumping	July 21	185.89
Dec. 9	186.95	Aug. 20	185.53
Jan. 13, 1965	187.00	Sept. 24	184.80
Mar. 3	187.08	Oct. 18	184.72
Apr. 22	187.28	Jan. 12, 1966	185.53

35-6-21bc

Date	Water level	Date	Water level
Aug. 12, 1964	69.00	June 22, 1965	70.08
Oct. 2	67.82	July 19	67.90
Oct. 26	67.56	Aug. 20	66.39
Dec. 9	67.85	Sept. 23	66.15
Jan. 13, 1965	68.40	Oct. 19	66.21
Apr. 22	70.85	Jan. 13, 1966	67.51
May 19	69.88		

36-5-14ac

Date	Water level	Date	Water level
Oct. 24, 1964	12.09	July 15, 1965	8.69
Dec. 9	10.47	Aug. 20	9.49
Mar. 3, 1965	9.88	Sept. 24	8.33
Apr. 23	8.82	Oct. 18	6.96
May 18	8.73	Jan. 12, 1966	3.53
June 23	8.96		

37-3-3cd

Date	Water level	Date	Water level
Sept. 10, 1964	53.23	June 23, 1965	47.05
Oct. 26	53.21	July 15	46.00
Dec. 9	53.33	Aug. 20	46.39
Jan. 14, 1965	53.43	Sept. 24	46.75
Mar. 4	53.60	Oct. 19	46.94
Apr. 23	49.33	Jan. 12, 1966	47.94
May 18	47.08		

Table 4.--Drillers' logs of wells in the Cut Bank area, Montana
(Thicknesses and depths below land surface are given in feet.)

From	To	Thick-ness	Lithology
		32-5-16ac	
0	2,934	2,934	Alternating sandstone and shale
2,934	2,996	62	Cut Bank sandstone
2,996	3,130	134	Ellis Group(?)
3,130	3,401	71	Madison Limestone
		32-5-16bc	
0	20	20	Shale, yellow, medium hard
20	70	50	Shale, yellow, hard (small amount of water at 70 ft.)
70	125	55	Shale, gray, medium hard
125	135	10	Shale, yellow, medium hard
135	175	40	Sandstone, gray, medium hard
175	205	30	Shale, yellow, medium hard
205	225	20	Sandstone, gray, hard
225	255	30	Sandy shale, gray, medium hard
255	265	10	Lime shell, gray, medium hard
265	300	35	Sandstone, gray, medium hard (water increased between 285 and 300 ft.)
300	305	5	Shale, gray, medium hard
		32-5-22ad	
0	15	15	Surface soil
15	60	45	Sandstone, gray
60	75	15	Sand
75	92	17	Sandstone, brown
92	105	13	Sandstone, brown, hard
105	112	7	Sandstone, gray, hard
112	140	28	Shale, gray
140	165	25	Sandstone, gray--water
		32-5-30bb	
0	65	65	Clay and dirt
65	85	20	Gravel
85	125	40	Shale
125	130	5	Sandstone (water)
130	310	180	Shale, gray
310	332	22	Sandstone, gray (water)
		32-5-30bd2	
0	50	50	Surface dirt and clay
50	80	30	Gravel
80	190	110	Shale, gray
190	195	5	Sand (water)
195	230	35	Shale, gray, sandy
230	235	5	Water sand
235	400	165	Gray sandy shale

From	To	Thick-ness	Lithology
		32-6-24da	
0	25	25	Soil and yellow clay
25	95	70	Sandy shale
95	100	5	Shell
100	142	42	Shale and shells
142	146	4	Sandstone and bentonite
146	235	89	Shale, gray
235	260	25	Sandstone, hard
260	270	10	Gray shale and shells
270	340	70	Gray shale
340	360	20	Sandstone
360	370	10	Shale
370	390	20	Sandy shale
390	400	10	Gray shale
		32-6-25ad	
0	50	50	Dirt, clay and gravel
50	130	80	Gray shale
130	135	5	Water sand
135	165	30	Gray shale
165	185	20	Sandstone with water
185	306	121	Gray shale
306	390	84	Sandstone, gray (water)
390	445	55	Shale, gray
		33-5-6bb	
0	3	3	Surface clay
3	5	2	Sand
5	55	50	Gumbo
55	61	6	Coarse gravel (water cased out)
61	100	39	Shale
100	170	70	Intermittent shale and sandstone
170	180	10	Sandstone (Virgelle) (water rose to 26 ft. from surface)
		33-5-6cb	
0	7	7	Clayey sand
7	24	17	Sandstone, hard, buff, fine- to medium-grained
24	26	2	Soft drilling break
26	27	1	Shale, brittle, black, platy
27	38	11	Pebble conglomerate, medium hard, buff, medium- to fine-grained sandstone layers
38	46	8	Sandstone, fine-grained and layers of fine pebbly sandstone. Trace black shale partings. Softer drilling
46	57	11	Sandstone, hard, gray, fine-grained
57	61	4	Shale, firm, dark-gray, platy
61	70	9	Sandstone, hard, gray, rough drilling, with occasional conglomerate and hard shale streaks
70	95	25	Silty sand, medium hard, light-gray, clayey, fine-grained--makes mud
95	100	5	Sandstone, hard, gray, fine-grained, clayey

Table 4.--Drillers' logs of wells in the Cut Bank area, Montana--continued

33-5-6cb--continued

From	To	Thickness	Lithology
100	110	10	Shale, hard, greenish-gray, fine-grained
110	126	16	Sandstone, hard, fine-grained, rough drilling with occasional pebbles of gray sand--not clayey, slightly cleaner with some green shale streaks
126	133	7	Silty sand, softer, fine-grained, smooth drilling
133	150	17	Sandstone, harder, light-gray, very fine-grained, bentonitic, rough drilling
150	165	15	As above with streaks of dark-brown shale
165	170	5	Sandstone, firm, medium-gray, very fine-grained, with occasional streaks of greenish-gray shale
170	198	28	Sandstone, medium-hard, medium-gray to brownish-gray, fine-grained, streaks of white bentonitic sandstone. Drilling break--slightly rough--coal seam
			Momentary loss of returns--started taking water at 195 ft.
198	212	14	Sandstone, brownish-gray, medium-grained, porous

33-5-29ca

From	To	Thickness	Lithology
0	34	34	Surface
34	40	6	Shell
40	60	20	Shale
60	95	35	Shale and sand
95	142	47	Shale
142	157	15	Sandstone (dry)
157	181	24	Shale
181	190	9	Sandstone (dry)
190	194	4	Shale
194	201	7	Sandstone (dry)
201	214	13	Shale
214	228	14	Sand, shaly
228	240	12	Sandstone (water)
240	267	27	Shale
267	287	20	Sandstone
287	302	15	Sandstone (water)

33-5-30aa

From	To	Thickness	Lithology
0	28	28	Surface
28	30	2	Shell
30	55	25	Shale
55	62	7	Sandstone (water)
62	167	105	Shale with stringers of sandstone
167	170	3	Shell
170	182	12	Shale
182	187	5	Shell
187	230	43	Shale
230	234	4	Shale, sandy
234	268	4	Sandstone, shaly
268	270	2	Shell
270	275	5	Sandstone
275	291	16	Sandstone, water-bearing
291	294	3	Shale

33-6-3ca

From	To	Thickness	Lithology
0	10	10	Top soil and clay
10	48	38	Gravel
48	49	1	Shale
49	69	20	Sandstone, water-bearing
69	70	1	Shale
70	74	4	Clay

33-6-12aa2

From	To	Thickness	Lithology
0	10	10	Clay, tan, sandy--medium-grained sand in clay--some thin sandstone streaks
10	20	10	Clay, buff, slightly sandy and silty--harder sandstone layer at 20 ft.
20	22	2	Sandstone, hard, gray, medium-grained
22	30	8	Alternating clay and sandstone, dark-gray and tan
30	45	15	Sandstone, moderately hard drilling, gray, medium-grained with some fine-grained streaks--occasional streaks of brown clayey siltstone
45	57	12	Sandstone, moderate to hard drilling, gray, salt and pepper type, medium-grained
57	58	1	Sandstone, hard, gray, medium-grained
58	63	5	Sandstone, firm, gray, medium-grained, salt-and-pepper, no loss of drilling fluid to 60 ft.
63	71	8	Shale, firm, dark-gray, chunky
71	73	2	Sandstone, hard, sharp grains--slow, rough drilling
73	84	11	Sandstone, moderate to soft drilling, gray, fine-grained, bentonitic
84	99	15	Sandstone, hard drilling, medium to coarse-grained, gray, salt-and-pepper
99	105	6	Sandstone, very hard drilling, gray, fine- to medium-grained, salt-and-pepper
105	115	10	Shale, soft, gray or green
115	116.5	1.5	Sandstone(?), hard drilling, dark-gray
116.5	122	5.5	Bentonite, soft, gray or gray-green, sandy
122	127	5	Sandstone, hard, very fine-grained
127	128	1	Shale, soft, gray-green
128	128.5	0.5	Sandstone, hard, very fine-grained
128.5	130	1.5	Sandstone, soft, gray, fine-grained, poorly cemented, bentonitic
130	131	1	Sandstone, hard
131	162	31	Shale, soft smooth drilling, dark-gray with some green or dark-brown streaks, bentonitic, sandy
162	162.5	0.5	Hard streak (sandstone?)
162.5	176	13.5	Shale, soft, light-gray, sandy, bentonitic--hard zone from 167 to 168 ft.

Table 4.--Drillers' logs of wells in the Cut Bank area, Montana--continued

From	To	Thickness	Lithology
			33-6-12aa2--continued
176	185	9	Sandstone, firm, gray, salt-and-pepper, fine- to medium-grained
185	190	5	Hard, rough drilling--some fluid loss--fractured zone?
190	193	3	Shale, smooth drilling
193	200	7	Sandstone, hard, gray, salt-and-pepper, sharp, medium-grained alternating with shale, soft, greenish-gray and brownish-gray
200	205	5	Shale, smooth drilling, brown and greenish-gray
205	209	4	Bentonite, smooth, soft drilling, cream or white
209	221	12	Bentonite, sandy, gritty with occasional streaks of black, carbonaceous shale
221	224	3	Shale, hard rough drilling, black, sandy
224	230	6	Bentonite, smooth drilling, white, sandy
230	235	5	Sandstone, gray, salt-and-pepper, bentonitic, fine-grained, well-rounded grains--white, rose, and a few green quartz grains
235	240	5	Sandstone, fairly smooth drilling, salt-and-pepper (about 1/2 white and 1/2 black grains), medium-grained
240	242	2	Coal, soft drilling
242	245	3	Sandstone, medium-grained, subrounded grains--fluid loss--bran added
245	290	45	Sandstone, firm, light-gray, fine-grained, gritty, subangular grains
290	295	5	Sandstone, very hard, fine-grained
295	304	9	Sandstone, medium-hard, gray, uniformly fine-grained
304	333	29	Sandstone, medium-hard, gray, salt-and-pepper
333	338	5	Sandstone, friable, gray, salt-and-pepper, medium-grained, slightly calcareous--losing fluid
338	380	42	Sandstone, moderately hard drilling, medium-grained, salt-and-pepper, calcareous, occasional streaks of dark-gray shale
380	400	20	Shale, smooth drilling, dark-gray, sandy
			34-5-18cc
0	85	85	Clay, yellow
85	110	25	Sandstone, soft, gray
110	140	30	Sandstone, hard, gray
140	145	5	Sandstone, gray, water-bearing
145	150	5	Sandstone, gray
			35-4-12bd2
0	16	16	Sand and medium-sized gravel
16	60	44	Sandstone, hard, buff
60	100	40	Silty, clayey sand, highly argillaceous, buff with intervals slightly soft (may cave) and beds of hard, gray sandstone
100	110	10	Sandstone, firm to hard, gray and medium-brown
110	155	45	Sandstone, gray, fine-grained
155	180	25	Sandstone, gray, medium-grained, water-bearing
180	205	25	Sandstone, fine-grained interbedded with green siltstone and gray shale--shale increasing downward
			35-5-16ac
0	25	25	Clay, sandy
25	30	5	Sandstone
30	75	45	Clay and sandstone, brown
75	152	77	Clay, blue and sandstone
152	224	72	Sandstone
			35-5-34da
0	8	8	Sand, brown and medium-size gravel
8	15	7	Sandstone, firm, buff, medium-grained
15	29	14	Sandstone, firm, buff, medium- to fine-grained
29	31	2	Sandstone, soft, brown, shaly
31	36	5	Sandstone, firm, buff with soft shaly streaks
36	40	4	Sandstone, very hard, gray, medium-grained
40	75	35	Sandstone, medium-gray, medium- to fine-grained
75	85	10	Sandstone, gray, medium-grained, water-bearing (main water from 78 ft. to 85 ft.)
85	103	18	Sandstone, gray, medium- to fine-grained, moderately bentonitic
103	106	3	Sandstone, very hard, gray, fine-grained
106	134	28	Sandstone, dark-gray, shaly and siltstone with layers of hard, dark-gray shale
			35-5-34dc
0	5	5	Clay
5	12	7	Clay, sandy
12	21	9	Sand
21	26	5	Sandstone, hard
26	69	43	Sandstone, soft
69	75	6	Shale, hard
75	141	66	Sandstone, soft
141	150	9	Shale, hard
150	200	50	Sandstone, soft
200	238	38	Shale, hard and sandstone

Table 4.--Drillers' logs of wells in the Cut Bank area, Montana--continued

From	To	Thickness	Lithology
			36-4-35aa
0	2	2	Top soil
2	60	58	Clay, brown
60	90	30	Clay, gray with occasional cobbles and thin seams of gravel from 80 to 90 ft.
90	95	5	Sandstone, firm, buff (Virgelle)
95	113	18	Sandstone, hard, buff
113	116	3	Sandstone, soft, brown, clayey; clayey siltstone
116	144	28	Sandstone, firm, buff, medium- to fine-grained
144	149	5	Sandstone, very hard, gray, calcareous with a trace of coal at the base
149	162	13	Sandstone, firm, buff, medium- or fine-grained, clayey matrix with occasional streaks of gray shale and hard, gray, tight sandstone
162	165	3	Sandstone, hard shell, gray
165	180	15	Sandstone, buff, medium fine-grained, clay matrix (hole drilled with air to 180 ft.--dry)
180	205	25	Sandstone, firm, gray, fine-grained with occasional bentonite seams
205	220	15	Sandstone, friable, gray, medium- to fine-grained, water-bearing--occasional gray shale seams
220	225	5	Sandstone, firm, gray, generally as above, probably porous, moderately friable
225	230	5	Sandstone and shale, hard
230	250	20	Sandstone, friable, brownish-gray, fine- to medium-grained, clean--trace gray shale partings--water-bearing
250	257	7	Sandstone, gray, fine-grained with a band of light-gray shale
			36-4-35ab
0	35	35	Gravel, coarse with some layers of sand and pea gravel
35	42	7	Sandstone, very hard, buff
42	48	6	Sandstone, firm, buff
48	54	6	Siltstone, soft, clayey to sandstone, buff, very fine-grained
54	63	9	Sandstone, hard, buff (bailed--hole dry)
63	70	7	Sandstone, hard, gray, fine-grained
70	80	10	Sandstone, medium-hard, buff, fine-grained
80	108	28	Sandstone, medium-hard, buff, fine- to medium-grained
108	113	5	Sandstone, very hard, buff grading to gray
113	120	7	Sandstone, gray, fine-grained, slightly shaly
120	130	10	Sandstone, brown and gray, fine-grained
130	150	20	Sandstone, gray, fine-grained, bentonitic

From	To	Thickness	Lithology
			36-4-35ab--continued
150	160	10	Sandstone, brownish-gray, fine-grained, slightly bentonitic
160	170	10	Sandstone, brownish-gray, fine-grained, cleaner than above, water at 165 ft.
170	180	10	Sandstone, brownish-gray, fine-grained, clean, water-bearing
180	190	10	Sandstone, as above but slightly shaly
190	200	10	Sandstone, friable, gray, fine-grained, slightly bentonitic
200	220	20	Shale and sandstone, light-gray, bentonitic
220	225	5	As above with increases in shale content
			36-4-35ad1
0	25	25	Gravel, coarse with sand layers
25	30	5	Pea gravel and sand
30	40	10	Sand with some clay
40	67	27	Clay, gray and occasional gravel seams
67	75	8	Sandstone, very hard (top of Virgelle Sandstone)
75	85	10	Sandstone, medium-hard
85	90	5	Sandstone, hard
90	130	40	Sandstone, firm, brown, fine-grained
130	140	10	Sandstone, gray, fine-grained with some gray shale partings
140	150	10	Sandstone, gray, fine-grained, cleaner than above
150	170	20	Sandstone, hard, gray, medium- to fine-grained, clean, water-bearing
170	190	20	Sandstone, gray, medium- to fine-grained, water-bearing
190	200	10	Sandstone, gray interbedded with some fine-grained sandstone and gray shale
200	210	10	Sandstone, gray, fine-grained
210	220	10	Shale, medium-gray, and interbedded siltstone and fine-grained sandstone
220	225	5	Shale, medium-gray and some siltstone
			36-4-35ad2
0	3	3	Top soil, sandy silt
3	10	7	Sand, brown, silty with some fine gravel
10	30	20	Sand, brown medium- and coarse-grained with gravel seams
30	52	22	Clay, light-gray with coarse gravel seams
52	68	16	Sandstone, hard, buff
68	79	11	Sandstone, hard, buff, medium-grained
79	82	3	Sandstone shell, very hard, calcareous (bailer test--hole dry)

Table 4.--Drillers' logs of wells in the Cut Bank area, Montana--continued

36-4-35ad2--continued

From	To	Thickness	Lithology
82	83	1	Sandstone, very hard, calcareous
83	120	37	Sandstone, firm, buff, water-bearing (bailer test--27 gallons per hour)
120	135	15	Sandstone, firm, buff and gray, bedded
135	150	15	Sandstone, hard, gray, fine-grained
150	185	35	Sandstone, moderately friable, gray, medium-grained, porous, water-bearing
185	210	25	Sandstone, very fine-grained, siltstone and shale, gray. Shale content increases with depth

36-6-14ba

From	To	Thickness	Lithology
0	18	18	Clay, sandy and gravel
18	62	44	Clay, yellow
62	140	78	Clay, blue with some streaks of sandstone
140	161	21	Sandstone with some clay, water-bearing

36-6-25dd

From	To	Thickness	Lithology
0	33	33	Clay, yellow, sandy
33	90	57	Clay, blue with some sandstone
90	120	30	Sandstone, with some blue clay
120	136	16	Sandstone, water-bearing

Table 6.--Chemical analyses of water in the Cut Bank area, Montana
(Analysis by Montana State Board of Health unless otherwise indicated)

Location	Date of collec- tion	Depth of well (feet)	Tem- pera- ture (°F)	Iron (Fe)	Cal- cium (Ca)	Mag- ne- sium (Mg)	Sodium (Na) plus potas- sium (K)	Bicar- bonate (HCO_3)	Car- bon- ate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluo- ride (F)	Ni- trate (NO_3)	Total dis- solved solids *	Hard- ness	Specific conduct- ance (micro- mhos at 25°C)	Color	Remarks
										Outwash deposits								
35- 3-35cd1	--------	67.8	--	-----	-----	-----	-------	-------	---	4,960	24	----	-----	6,760	400	-----	-----	Partial analysis--furnished by owner
										Two Medicine Formation								
32- 6- 1ac	3/17/37	288.4	--	-----	-----	-----	548	600	50	436	116	----	-----	1,445	-----	-----	-----	USGS files
33- 6-10bb	8/24/36	184-200	--	-----	51	T	255	440	---	255	38	----	-----	815	-----	-----	-----	USGS files Analyst--Crawford
34- 6-12cc	10/14/65	135	--	0.14	78	35	555	550	30	937	43	1.3	0.0	1,856	340	-----	Clear	
34- 6-14bc	10/ 5/65	219.9	--	.00	4	1	420	717	45	229	18	7.5	.0	1,066	15	-----	Clear	
34- 6-14dd1	10/ 5/65	202	46	.80	34	18	570	708	0	623	116	1.6	.0	1,692	160	-----	Clear	
35- 5- 1cc	7/18/33	70-75	--	-----	-----	-----	844	965	T	932	52	----	-----	2,303	-----	-----	-----	USGS Files Analyst--Crawford
35- 5- 2aa	10/ 1/65	127	46	1.84	62	28	86	384	15	97	9	0.4	.0	504	270	-----	Clear	
36- 4-22dc	10/20/65	145	--	1.36	68	62	138	342	0	392	16	.4	10.6	862	425	-----	Clear	
36- 5- 4ab	10/15/65	137	--	.00	14	44	1,130	630	45	1,950	33	1.3	2.3	3,420	215	4,000	-----	
36- 5-14bd	10/24/64	105	--	.24	8	0	322	540	21	216	15	1.1	.0	832	20	1,290	Clear	
37- 5- 7ad	10/19/65	155	46	.0	6	2	450	610	66	338	26	1.1	1.8	1,154	25	1,800	Clear	
37- 5-19da	10/19/65	115	44	18.4	156	89	925	1,037	---	1,780	34	1.2	1.6	3,440	775	3,500	Rusty	
37- 5-29dd	10/19/65	90	--	13.6	90	78	725	1,060	0	1,165	20	.8	.5	2,364	545	-----	-----	Hydrogen sulfide gas appeared in 1964
										Virgelle Sandstone								
32- 4-28ab	10/16/64	150	47	0.34	57	46	90	250	9	264	22	0.5	0.9	622	332	900	Clear	
32- 5-10db	5/26/34	290	--	-----	-----	-----	406	620	67	210	31	----	-----	1,019	-----	-----	-----	From USGS files Analyst--Crawford
32- 5-11dd	10/15/65	185	--	.00	34	27	325	548	0	418	9	.9	.9	1,070	195	-----	-----	
33- 4-31bd	9/23/65	120	--	7.48	12	13	333	317	0	470	27	.5	23.4	984	85	1,610	Slightly murky	Well long unused
33- 5- 3dc	10/24/64	205	--	.80	102	81	220	360	0	705	21	.7	-----	1,368	587	1,610	Clear	
33- 5-21bb2	10/26/64	311	51	.00	18	21	397	475	33	452	58	.8	.0	1,220	133	1,600	Clear	Hydrogen sulfide gas present
33- 5-21da	10/12/64	285	53	.20	74	55	266	543	0	500	14	.6	.0	1,102	408	1,680	Clear	
33- 6-11bd	10/23/65	343	--	.54	18	40	565	427	33	927	45	1.7	-----	1,804	210	-----	Clear	
33- 6-12aa1	12/26/46	238	--	-----	-----	-----	-------	-------	---	-----	-----	----	-----	1,130	-----	-----	-----	State Board of Health files--produces partly from Two Medicine Formation
---do---	3/ 2/49	238	--	-----	-----	-----	-------	-------	---	-----	-----	----	-----	1,310	-----	-----	-----	------do------
---do---	3/19/49	238	--	.2	316	43	358	580	0	549	-----	----	-----	1,295	-----	-----	-----	------do------
---do---	1/29/59	238	--	.7	50	56	271	555	0	437	21	.4	.4	1,113	-----	-----	-----	------do------
---do---	6/ 3/64	238	--	.14	101	73	735	600	0	1,510	53	.7	.7	2,775	552	-----	-----	------do------
---do---	8/26/64	238	--	-----	90	62	623	583	0	1,220	56	1.0	1.1	2,345	480	-----	-----	------do------
---do---	9/ 1/65	238	47	.00	108	125	1,375	450	9	3,090	108	1.4	.0	5,080	785	-----	Clear	Produces partly from Two Medicine Formation

34- 5- 3bb	10/22/64	72.1	46	8.60	51	17	128	393	0	135	8	.3	1.8	538	199	810	Slightly yellow	
34- 5- 3cc	10/16/65	201	48	.00	14	9	385	756	63	50	94	2.9	-----	1,006	70	-----	Clear	Gas bubbles present
34- 5-20bb	10/ 8/65	124	47	1.32	90	45	191	494	0	378	15	.4	.0	940	410	-----	-----	
34- 5-29da1	10/20/64	160	47	2.24	51	53	184	372	0	404	11	.5	.0	384	347	1,420	Clear	
34- 5-31cd	10/26/65	164	--	5.00	40	28	370	580	0	465	41	1.2	.0	1,200	215	-----	Clear	
34- 5-35dc	10/23/65	136.8	--	6.40	370	372	492	226	0	2,880	80	1.4	269	4,956	2,450	-----	-----	
34- 6-24da	11/ 7/32	230	--	-----	-----	-----	607	755	---	537	99	----	-----	1,614	-----	-----	-----	USGS files Analyst--Crawford
35- 5- 4aa	9/12/33	280+	--	-----	-----	-----	796	620	42	997	83	----	-----	2,223	-----	-----	-----	------do------
35- 5- 5dd	10/23/64	327	47	.00	12	1	870	705	12	1,225	34	1.9	1.1	2,770	36	3,000	Clear	
35- 5- 7bb	10/23/64	365	--	.14	4	0	550	740	24	495	29	1.8	.0	1,486	10	2,050	Clear	Hydrogen sulfide ga present
35- 5-12cc	10/24/64	215	46	.00	4	0	421	674	9	308	26	2.0	.0	1,100	10	1,550	Clear	------do------
35- 5-15dc	10/22/64	280	47	.00	4	0	439	677	15	340	22	1.9	.4	1,170	10	1,700	Clear	
35- 5-20bb2	9/28/65	327	46	3.70	166	97	1,020	650	0	2,330	39	1.5	8.8	3,944	810	-----	Clear	
35- 5-22cb2	7/22/60	326	--	-----	T	T	422	585	59	288	29	----	-----	1,080	T	1,400	Clear	Yapuncich, Sanderso and Brown analysi courtesy of owner
35- 5-34ab	9/30/65	100.9	47	.00	46	56	106	450	0	151	12	.0	8.2	604	345	-----	Clear	
35- 6-14cb	3/30/34	235-280	--	-----	-----	-----	553	785	---	391	109	----	-----	1,439	-----	-----	-----	USGS files Analyst--Crawford
35- 6-15bd	5/12/33	65 and 245	--	-----	19	-----	1,162	640	24	1,863	48	----	-----	3,431	-----	-----	-----	------do------
35- 6-21cb	10/22/65	575	--	.30	34	13	2,120	265	0	10	3,200	1.6	.0	5,210	140	-----	Clear	Hydrogen sulfide ga present
35- 6-23cd	10/ 9/65	200	--	.10	8	5	950	653	18	1,420	40	3.7	1.6	2,714	40	-----	-----	
35- 6-26cd	9/16/33	140 and 180	--	-----	-----	-----	386	665	T	265	14	----	-----	992	-----	-----	-----	USGS files Analyst--Crawford
36- 3-19cc	10/21/65	150	--	19.0-	24	42	50	293	12	69	7	.1	10.0	350	230	-----	Brown	
36- 4-14aa	9/ 8/54	174	--	1	56	41	170	488	---	247	11	----	-----	790	-----	-----	-----	State Board of Heal files
36- 4-14ab2	2/10/54	159	--	.4	70.1	46.7	124.9	462.5	0	231.2	10	----	-----	739	366	-----	-----	------do------
36- 4-14ac	6/30/65	155	46	.24	28	41	259	412	0	430	9	.2	0	944	240	-----	Clear	Hydrogen sulfide ga present
36- 4-35ab	9/24/65	225	46	5.72	32	37	151	427	0	190	8	.0	.0	626	230	-----	Clear	Well long unused
36- 5- 1dc	3/18/54	475	--	.3	3	5	377	506	65	257	23	----	-----	975	-----	-----	-----	State Board of Heal files
36- 5-12dc	6/21/54	407	--	.12	2	4	366	488	42	215	12	----	-----	820	-----	-----	-----	------do------
36- 5-13aa	6/21/54	520	--	.22	1	2	430	614	54	273	38.5	----	-----	1,050	-----	-----	-----	------do------
36- 5-14ac	9/24/65	450	48	3.30	2	0	221	370	57	43	15	.6	16.7	514	5	-----	Yellow, rusty	Unused well
36- 6- 2da	2/23/33	135-170	--	-----	-----	-----	546	575	37	454	129	----	-----	1,449	-----	-----	-----	USGS files. Part c water may be fro Two Medicine Formation
37- 3- 2ab	2/18/36	180+	--	0	28	17	428	666	0	464	25.5	----	-----	1,375	140	-----	-----	State Board of Hea files
37- 3- 2ca	10/19/65	115	48	4.0	20	13	925	740	0	1,410	18	1.0	9.6	2,800	105	-----	Rusty	
37- 3- 4ad	8/ 4/65	186	--	.00	88	64	332	387	0	820	19	.4	1.1	1,524	485	1,780	Clear	
37- 3-21db	10/20/65	117	46	2.14	100	71	480	600	0	1,022	15	.7	2.3	1,932	540	-----	Clear	
37- 4-12db1	10/20/65	50	48	.00	75	43	228	370	36	505	45	.6	19	1,156	363	-----	Clear	
37- 4-27cb1	10/22/65	170	--	.22	4	0	432	674	57	280	8	1.3	.7	1,150	10	-----	Clear	State Board of Hea analysis furnish by owner
37- 5-10dc	1/21/49	142	--	T	47	31	543	799	18	641	48	----	-----	1,690	245	-----	-----	
37- 5-15da	10/18/65	132.9	--	.00	70	71	495	680	33	795	33	.8	65	1,860	468	2,700	Clear	
37- 5-26cb	10/18/65	183	--	.00	4	1	366	583	39	242	10	1.0	.0	920	15	-----	Clear	
37- 5-35cd	10/15/65	185	--	.00	62	70	68	268	0	200	114	.2	2.7	648	440	-----	Clear	

Table 6.--Chemical analyses of water in the Cut Bank area, Montana
(Analysis by Montana State Board of Health unless otherwise indicated)

Location	Date of collection	Depth of well (feet)	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) plus potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids *	Hardness	Specific conductance (micromhos at 25°C)	Color	Remarks
									Transition zone									
35- 4-11dd	10/22/65	134.8	48	2.20	64	28	307	442	0	545	6	0.0	0.8	1,130	275	1,600	Clear	
									Colorado Group									
33- 6-25cb	5/21/36	2,425 to 2,445	--	-----	200	T	6,641	720	---	33	10,152	----	-----	17,380	-----	-----	-----	USGS files Analyst--Crawford
									Kootenai Formation									
34- 6-11ba	3/14/33	2,540 to 2,693	--	-----	35	T	4,269	1,685	T	-----	5,667	----	-----	10,800	-----	-----	-----	USGS files Analyst--Crawford
36- 5- 4db	2/14/40	2,814+	--	-----	73	30	2,866	5,750	---	-----	1,296	----	-----	7,092	-----	-----	-----	------do------
									Madison Group									
36- 6-12ac	3/18/47	3,125	--	-----	43	62	2,735	2,825	298	951	1,782	-----	-----	7,260	-----	-----	-----	USGS files Analyst--Clark Water produced with oil
									Cut Bank Creek									
32- 5-28dc	10/23/65	----	43	0.10	42	22	64	214	6	125	12	0.4	0.0	344	195	-----	Clear	
33- 6- 2ca	1/29/59	----	--	-----	47	35	24	226	0	117	4	.1	.4	340	260	-----	-----	State Board of Health files

T - Trace
* Calculated