Prospects for Developing Stock-Water Supplies From Wells in Northeastern Garfield County, Montana

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1999-F

Prospects for Developing Stock-Water Supplies From Wells in Northeastern Garfield County, Montana

By M. C. VAN LEWEN *and* N. J. KING

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1999-F

Prepared as part of the Soil and Moisture Conservation Program of the Department of the Interior

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1971

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

Library of Congress catolog-card No. 79-610141

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

CONTENTS

ILLUSTRATIONS

TABLES

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

PROSPECTS FOR DEVELOPING STOCK-WATER SUPPLIES FROM WELLS IN NORTHEASTERN GARFIELD COUNTY, MONTANA

By M. C. Van Lewen and N. J. King

ABSTRACT

Ground-water resources in northeastern Garfield County, Mont., afford a practical and reliable source of stock water on the intermingled public and private grazing lands that together comprise an area of about 1,200 square miles.

The oldest formation exposed in the area is the relatively thick and impermeable Bearpaw Shale of Cretaceous age. Overlying the Bearpaw Shale in succession are the Fox Hills Sandstone and Hell Creek Formation of Cretaceous age, the Fort Union Formation of Tertiary age, and thin glacial deposits and alluvium of Quaternary age. All but the Bearpaw Shale and the glacial deposits are potential aquifers. Published geologic maps were found to be satisfactory after fitting contacts to the topographic base. Mapping, therefore, was limited mainly to outlining on aerial photographs the alluvial deposits in the stream valleys.

The major structural feature is the Blood Creek syncline, the axis of which plunges eastward 10–15 feet per mile across the southern part of the area. Beds generally dip 15–25 feet per mile toward the synclinal axis. Water in bedrock aquifers is under artesian pressure, and most wells in Big and Little Dry Creek valleys flow at the land surface.

The only bedrock aquifer having appreciable areal extent is a sandstone 30–70 feet thick that has been mapped by previous investigators as the upper part of the Fox Hills Sandstone. This aquifer crops out in the northern and northwestern parts of the area and dips about 20 feet per mile southeastward beneath younger beds. Most wells in the northern half of the area obtain water from this sandstone at drilling depths of less than 200 feet.

The depth to the Fox Hills Sandstone increases progressively southward, and most wells south of Woody Creek obtain water from irregularly distributed sandstone beds and lenses in the overlying Hell Creek and Fort Union Formations. The depth at which water may be obtained from these beds is not accurately predictable, but the depth seldom exceeds 300 feet.

The results of the investigation indicate that the prospects for obtaining ample water for livestock from wells drilled into the bedrock formations are very favorable in most of the area. The average depth of bedrock wells in the area is 195 feet.

Underflow in the alluvial deposits along all the larger stream valleys also affords a practical source of stock water.

Chemical analyses of samples collected at 43 wells and three springs show the water quality to be generally poor. Water from bedrock aquifers contains 530–5,340 milligrams per liter [1] total dissolved solids, whereas water from alluvium contains less than 1,500 milligrams per liter total dissolved solids. The predominant constituents are sodium, bicarbonate, and sulfate. So far as could be determined, all water supplies in the area are suitable for livestock.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

The area described in this report (fig. 1) consists of intermingled public and private lands in about equal amounts. The public lands are administered by the Bureau of Land Management, U.S. Department of the Interior, and are used principally for grazing livestock. Inadequate distribution of water for livestock has limited the use of much of the land and is a contributing factor to local overgrazing and accelerated erosion.

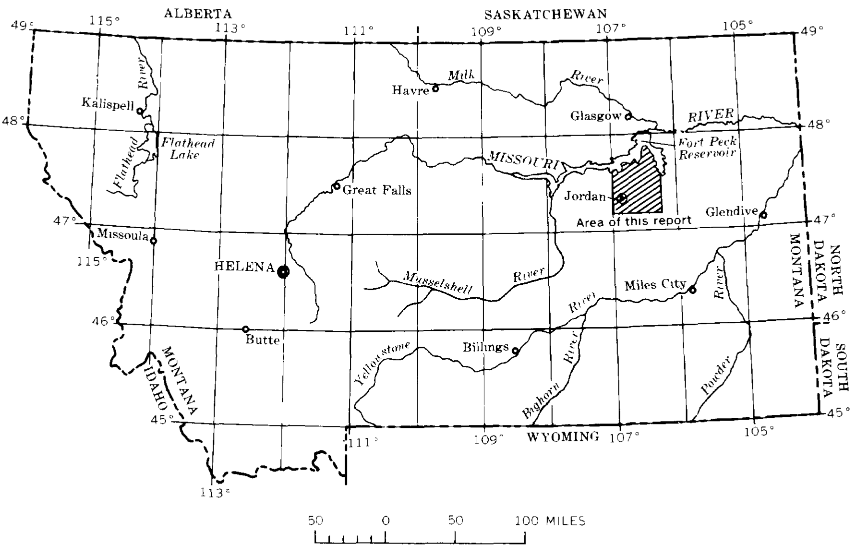

FIGURE 1.—Index map showing location of report area.

[1] As of Oct. 1, 1967, the U.S. Geological Survey reports results of chemical analyses in milligrams per liter (m/l) instead of in parts per million (ppm). Both units are equivalent to each other for the concentrations used in this report.

In the past, small reservoirs have been the principal type of stock-water development, but many of the reservoirs remain dry for extended periods and are not reliable sources of water for livestock. Wells provide a dependable source of water. The water produced from wells maintains a nearly constant year-round temperature, a definite advantage when compared to the wide temperature changes of surface water. Moreover, wells afford an effective means of grazing control. When it becomes desirable to restrict grazing in an area, the well furnishing the water to that area can be shut off, thereby forcing livestock to adjacent range where water is available.

Optimum management of the public domain lands will likely require the subdivision of community grazing allotments into private allotments. Any such division must be contingent on the availability of water for livestock. The Bureau of Land Management, therefore, requested in 1957 that the Geological Survey make a study of the occurrence of ground water in northeastern Garfield County, Mont., to determine the prospects for obtaining additional stock-water supplies from wells. In response to this request, a reconnaissance was made to determine the areal extent of the aquifers that can be reached at economic drilling depths; their depth and thickness; the artesian rise, if any, that might occur; and the general chemical character of the water.

PREVIOUS INVESTIGATIONS

Detailed geologic examinations have been made in western and southwestern Garfield County by Bowen (1916), Thom and Dobbin (1922), and Reeves (1926), in connection with oil and gas possibilities. Collier (1918), Thom and Dobbin (1924), Dobbin and Reeside (1930), and others have described the structure and stratigraphy of the Upper Cretaceous and Tertiary beds in northeastern Montana and adjacent areas of North and South Dakota. Dobbin and Erdmann (1955) have compiled a structure contour map of the Montana Plains, which includes the area under consideration.

Perry (1934) has reported on the geology and artesian water resources of northeastern Montana, although his reported observations in Garfield County were limited to measurements of flowing wells along the Missouri River and Big Dry Creek. Collier and Knechtel (1939) describe the geology and coal resources of McCone County, and Jensen and Varnes (1964) describe the geology of the Fort Peck area.

METHODS OF INVESTIGATION

The authors spent 4 weeks during the summer of 1957 completing a reconnaissance of the report area. Emphasis was placed on determining the areal distribution and water-bearing characteristics of the aquifers. Virtually all springs and wells in the area were visited and, when possible, were measured. Drillers' logs were obtained for a number of strategically located wells. Underflow conditions were noted in all the larger stream valleys, but no attempt was made to determine the availability of surface-water supplies.

The geologic map of Montana (Andrews and others, 1944; Ross and others, 1955) was found to be satisfactory after adjusting contacts to fit the topographic base map. Mapping, therefore, was limited to alluvial deposits, the outlines of which were determined from aerial photographs, and to approximating the contact between the Tullock and Lebo Shale Members of the Fort Union Formation in the area north of Big Dry Creek.

In September 1958 the authors returned to the area and spent several days measuring the shut-in pressure of flowing wells and collecting water samples for laboratory analyses of dissolved solids.

The investigation was made under the general supervision of K. R. Melin, Project Hydrologist, Soil and Moisture Project, Water Resources Division.

GEOGRAPHY

LOCATION AND EXTENT OF THE AREA

The report area lies in east-central Montana (fig. 1) in the northeast quarter of Garfield County. It is bounded by Fort Peck Reservoir on the north and McCone County on the east. The south boundary is about midway across T. 16 N., and the west boundary passes through R. 37 E. The area includes all or parts of 35 townships and comprises about 1,200 square miles.

TOPOGRAPHY AND DRAINAGE

The area is about centrally located in the Missouri Plateau section of the Great Plains physiographic province. Fenneman (1931) describes the Missouri Plateau section as characterized by a gently eastward-sloping surface formed on easily eroded Cretaceous and younger sedimentary formations. Isolated mountain masses occur on the plateau, but they occupy a relatively small part of the total area. Because of the semiarid climate and relative lack of protective vegetation, the easily eroded bedrock is susceptible to the development of badlands. Most of the physiographic unit, however, consists of only moderately dissected, gently sloping plains that support a good grass cover. Small buttes, pinnacles, and other erosional remnants are common surface features. In broad aspect, this description of the overall physiographic unit adequately portrays the report area.

That part of the report area north of Montana Highway 20 is separated into two distinct types of terrain by a northeastward-trending drainage divide. Northwest of this divide, finely dissected badlands drain to Fort Peck Reservoir through steep, deeply incised ephemeral streams (fig. 2). These streams, which have average gradients of about 100 feet per mile, are the result of rapid erosion along the margins of the deeply incised channel of the Missouri River. A few grass-covered benches have formed on the more resistant beds, but most of the land surface is steep and sparsely vegetated.

Southeast of the divide, ephemeral and intermittent streams drain southeastward through comparatively broad valleys to Big Dry Creek. Stream valleys are approximately parallel and spaced at intervals of about 4 miles. Gradients of the larger stream valleys average 20 feet per mile in their lower reaches, but steepen to as much as 100 feet per mile near the drainage divide. Interstream divides are characteristically formed by flat-topped ridges and buttes that rise 100–200 feet above the adjacent valleys (fig. 3). All but the steeper slopes generally support a fair to good grass cover.

South of Montana State Highway 20 the land surface rises in a series of grass-covered benches and steep barren slopes to the divide between Big Dry Creek and Little Dry Creek. South of the divide the land

FIGURE 2.—Badlands northwest of drainage divide. Much of the terrain is accessible to livestock only with difficulty.

411-336 O—71——2

FIGURE 3.—Stream valley southeast of drainage divide. Most of the terrain is readily accessible to livestock.

surface is moderately dissected to gently rolling and supports an excellent grass cover.

The Missouri River, Big Dry Creek, and Little Dry Creek are the principal streams in and adjacent to the area. Water impounded by Fort Peck Dam covers much of the valley of the Missouri River and the lower reach of Big Dry Creek. Streams rising on Haxby Point (pl. 1) drain northwestard to Fort Peck Reservoir or southeastward to the Big Dry Arm of Fort Peck Reservoir. Farther south all drainage is to Big Dry Creek or to its largest tributary, Little Dry Creek. Both streams are generally intermittent after about mid-July and have pools of water remaining in the channel throughout the year. Sand, Frazier, Woody, Flat, and Box Creeks are intermittent. Other streams in the area are ephemeral.

CLIMATE

Temperature and precipitation records for Jordan, Mont., have been published by the U.S. Weather Bureau (1968). The length of record is 39 years for temperature and 47 years for precipitation. Summary data are given in table 1.

The climate is semiarid and cool. There is a pronounced late spring and summer rainfall maximum. Jordan receives 60 percent of its average annual precipitation during the 4-month period May to August. The average rainfall in June is nearly twice that of any other month. Winters are normally cold and dry; snowfall is light and covers the ground for only a few days at a time.

TABLE 1.—*Average monthly and annual temperature and precipitation at Jordan, Mont.*

[Data from published records of the U.S. Weather Bureau]

Month	Mean temperature (°F)	Mean precipitation (inches)
January	17.7	0.34
February	18.7	.29
March	30.3	.52
April	44.7	.91
May	56.0	1.38
June	64.4	2.46
July	73.8	1.22
August	71.1	1.05
September	60.4	.79
October	48.4	.64
November	32.7	.37
December	24.3	.34
Annual	45.2	10.31

This section of the northern Great Plains is noted for its great range of temperature, both seasonal and diurnal. The range of mean January to July temperatures is nearly 55°F, and extreme winter to summer temperature differences of 120°F are not unusual. Diurnal temperature changes of 40°F are common because of the characteristically low humidity and lack of modifying influences.

The climate of the area is favorable to the growth of range forage grass but is marginal for dry-land farming. The length of the growing season is about 115 days.

DEVELOPMENT

Northeastern Garfield County, Mont., is sparsely settled and little developed. Jordan, the county seat and the only town in the area, has a population of about 700. Haxby and Van Norman were resident U.S. Post Offices at the time of the fieldwork, but are now only place names. Ranches are spaced at intervals of 1 or 2 miles along the valley of Big Dry Creek, but throughout most of the area, ranches are 5–10 miles apart. Excluding Jordan, probably fewer than 100 families live in the 1,200-square-mile area.

State Highways 20 and 22 meet at Jordan and cross the southern and southwestern parts of the area. In addition to these asphalt-paved highways, there are about 100 miles of improved county roads in the area. The greater part of the region, however, is accessible only by unimproved roads that are often impassable when wet. The nearest railroad is at Brockway, Mont., 61 miles east of Jordan. Mail and most staples reach the area by truck from Miles City, 85 miles southeast of Jordan.

Cattle ranching is the mainstay of the economy, although production of horses, sheep, and wheat furnish some income.

GEOLOGY

The occurrence and availability of ground water in the report area is dependent upon several geologic factors, the most important of which are the water-bearing characteristics of the rocks, their areal distribution, and the geologic structure. These factors are described in the following section for those formations that underlie the area at drilling depths that are economically feasible for stock-water wells. Several good aquifers underlie the area at depths of several thousand feet, but the availability of suitable supplies of stock water at shallower depth preclude their use.

STRATIGRAPHIC UNITS AND THEIR WATER-YIELDING PROPERTIES

All formations described in this report are sedimentary in origin and are composed largely of interbedded sandstone and shale. Their age, thickness, general character, and water-yielding properties are summarized in table 2. All except the Bearpaw Shale yield water suitable for livestock, although the yield and chemical character of the water differ considerably from one aquifer to another. Water from bedrock formations is characteristically obtained from sandstone beds or lenses in a predominantly shale section. The water is almost always under artesian pressure, and a considerable rise of water in a well may be expected. Several flowing wells are in the area.

CRETACEOUS SYSTEM

BEARPAW SHALE

The Bearpaw Shale is a thinly bedded dark-gray marine shale that contains numerous seams of bentonite and gypsum. Near the top of the formation, the shale becomes increasingly sandy and lighter in color forming a gradational contact with the overlying Fox Hills Sandstone. The Bearpaw has a total thickness of about 1,000 feet (Collier and Knechtel, 1939), of which only the uppermost 100–150 feet is exposed in the report area. This part of the unit crops out in an irregular band along the shoreline of Fort Peck Reservoir in the north and northwestern parts of the area (pl. 1).

The Bearpaw Shale does not yield usable water to any wells in the area. A few wells were attempted in the Bearpaw Shale in the lower reach of the valley of Big Dry Creek before water was impounded in Fort Peck Reservoir, but these wells are reported to either have been dry or to have obtained water too highly mineralized for domestic or stock use. The Bearpaw Shale, therefore, is not considered to be a potential aquifer in the report area.

FOX HILLS SANDSTONE

The Bearpaw Shale is overlain by sandy shale that grades upward into a gray to yellowish-brown very fine grained sandstone. The total thickness of the sequence is about 90–130 feet. The lower shaly section, which is considered by most workers to be marine in origin, commonly weathers to form rounded slopes. The overlying sandstone, considered to be of marine, brackish, and fresh-water origin, is, in many places, well cemented and forms low cliffs and benches.

TABLE 2.—*Generalized geologic section of northeastern Garfield County, Mont.*

System	Series	Subdivision		Thickness (feet)	Description	Water-yielding properties
Quaternary	Holocene	Alluvium		0–50±	Channel and flood-plain deposits in the larger stream valleys. Predominantly fine grained, but include permeable sand and gravel lenses and stringers.	Yields water to shallow and domestic wells along the larger drainage courses.
	Pleistocene	Glacial deposits		0–5	Scattered erratics and deposits of materials ranging in size from clay to boulders transported into the area by glaciers. Includes vestiges of fine-grained glacial-lake deposits.	None of the deposits are sufficiently thick or widespread in the report area to be potential aquifers.
Tertiary	Paleocene	Fort Union Formation	Tongue River Member	0–150±	Yellow to buff sandstone, sandy shale, and shale containing several coal beds. Locally contains red clinker beds.	Yields water to several wells in the extreme southeastern part of the area. Not an important aquifer in this area because of its limited extent.
			Lebo Shale Member	250±	Principally dark-gray clay shale and carbonaceous shale and some light-colored fluvial sandstone. Contains several thin coal seams in the lower part of the member and a fairly persistent bed as much as 20 ft thick at its base.	Sandstone beds yield water under artesian conditions to wells in the southeastern part of the area. Local occurrence of sandstone is unpredictable thereby introducing some risk of a dry hole.
			Tullock Member	250±	Light- to dark-gray shale interbedded with thin coal beds and tan to buff, crossbedded fluvial sandstone. Thin limestone beds form resistant layers.	Predominant aquifer in the central and southern parts of the report area. Yields water to flowing wells along Big Dry Creek between Jordan and Van Norman. Depth to individual water-yielding sandstone beds or lenses is locally unpredictable, but the formation as a unit is a reliable aquifer.

TABLE 2.—*Generalized geologic section of northeastern Garfield County, Mont.*—Con.

System	Series	Subdivision	Thickness (feet)	Description	Water-yielding properties
Cretaceous	Upper Cretaceous	Hell Creek Formation	200–250	Predominantly light-gray to somber shale interbedded with fluvial sandstone. Shales locally variegated. Sandstone beds are discontinuous and seldom can be traced for more than a few miles. Formation contains numerous dinosaur remains.	Sandstone beds and lenses are generally water bearing. Their local occurrence is unpredictable, but the formation as a unit is a reliable aquifer.
		Fox Hills Sandstone	120–200	Gray to buff sandy shale grading upward into fine-grained gray to yellowish-brown sandstone. A persistent fine- to medium-grained brown sandstone bed 30–70 ft thick unconformably overlies the fine-grained sandstone and forms the upper unit throughout the report area.	Sandstone in the upper part of the formation yields water under artesian conditions to most bedrock wells in the northern part of the area.
		Bearpaw Shale	900–1,000	Dark-gray marine shale containing seams of bentonite and gypsum. Upper part becomes increasingly sandy and grades into the overlying Fox Hills Sandstone.	Yields no water to wells in the area. Not a potential aquifer.

Overlying the very fine grained sandstone is a slightly darker conspicuously crossbedded yellowish-brown fine- to medium-grained sandstone 30–70 feet thick. Thin lenses of pebble conglomerate occur throughout its thickness (fig. 4). The sandstone bed contains dinosaur remains, and is separated from the underlying fine-grained sandstone by an apparent erosional unconformity. Measurements indicate that the combined thickness of the two sandstone beds ranges from 50 to 100 feet. One bed generally thickens at the expense of the other. Locally, the lower sandstone is entirely missing, and the upper bed forms the entire sandstone section.

East of Big Dry Creek in McCone County, Collier and Knechtel (1939) mapped the sequence of beds described above as Fox Hills Sandstone. They considered the two sandstone beds to be a unit and called it the Colgate Member after a precedent established by Thom and Dobbin (1924). Across the reservoir in the Fort Peck area, however, Jensen and Varnes (1964) describe the upper and lower sandstone beds in considerable detail and list several criteria for recognition of each. They emphasize the significance of the erosional unconformity between the two sandstones and, like Brown (1907) and Bauer (1925), conclude that this unconformity marks the top of the

FIGURE 4.—Upper sandstone unit of the Fox Hills Sandstone. Note prominent crossbedding and pebble conglomerate near center of the section.

Fox Hills Sandstone. Although the authors recognize that the sandstone just above the unconformity probably represents the basal unit of the Hell Creek Formation, the fact remains that this upper sandstone, together with the sandstone just below the unconformity, constitutes a single extensive aquifer. Furthermore, it is not possible on the basis of drillers' logs or other hydrologic data to separate these two units. For these reasons, and to retain agreement with available geologic maps of the area, it was decided for purposes of this report to include both sandstone units in the Fox Hills Sandstone. Thicknesses given in table 2 are reported accordingly.

The sandstone in the upper part of the Fox Hills Sandstone is stratigraphically the lowest aquifer in the report area from which it is practicable to develop stock-water supplies. It is also the most persistent aquifer. Artesian conditions prevail in all but the outcrop areas, and wells tapping this aquifer along Big Dry Creek downstream from Van Norman (pl. 1) generally flow at the land surface. Yields range from 10 to 100 gpm (gallons per minute), depending on local aquifer characteristics. The chemical character of the water differs considerably from one part of the area to another (p. F32), but nowhere is the water too highly mineralized for livestock use.

HELL CREEK FORMATION

The Hell Creek Formation consists of interbedded light-gray to somber shale and gray to buff sandstone and sandy shale (fig. 5). The shale commonly is variegated, a characteristic not exhibited by the overlying Fort Union Formation. Many of the sandstone beds are conspicuously crossbedded and appear to be fluvial in origin. They seldom persist over a large area, and are erratically distributed in the section. A few comparatively widespread carbonaceous shale beds and thin coal seams in the formation indicate a fresh-water environment of deposition.

On the basis of information furnished by W. L. Rohrer (oral commun., 1957) the top of the Hell Creek Formation was drawn at the base of the first prominent coal bed, which generally overlies a green shale. Locally, the green shale is missing, however, and the coal overlies a massive dark-brown sandstone about 30 feet thick.

The Hell Creek Formation underlies the surface throughout most of the area north of T. 20 N., and in the valleys of Flat, Woody, and Big Dry Creeks (pl. 1). The entire sequence of beds is well exposed in the badlands in the northwestern part of the area, but nowhere could the thickness be measured directly. Composite measurements and well logs indicate a thickness of 200–250 feet.

The numerous discontinuous sandstone beds and lenses throughout the Hell Creek Formation generally yield suitable stock-water supplies under artesian conditions. Their occurrence at any given locality

FIGURE 5.—Exposure of Hell Creek Formation on the divide between Snap Creek and Cottonwood Creek in sec. 10, T. 21 N., R. 42 E.

cannot be predicted with accuracy, however, and the water obtained is of poorer quality than that obtained from the underlying Fox Hills Sandstone.

TERTIARY SYSTEM

FORT UNION FORMATION

The Hell Creek Formation is conformably overlain by a comparatively thick sequence of interbedded sandstone, mudstone, shale, carbonaceous shale, coal, and thin limestone beds of Paleocene age that together constitute the Fort Union Formation. On the basis of lithology and color, the sequence has been divided in ascending order into the Tullock, Lebo Shale, and Tongue River Members (Ross and others, 1955).

TULLOCK MEMBER

The Tullock Member consists principally of light-gray to dark-gray shale alternating with sandy shale and erratically distributed gray to buff crossbedded sandstone. A number of thin limestone beds in the sequence form resistant layers that commonly cap buttes, ridges, and pinnacles. Coal is more abundant than in the underlying Hell Creek Formation; but individual coal beds are seldom more than a few feet thick, and none were considered to be reliable marker beds. The coal bed at the base of the Tullock ranges in thickness from 0 to 6 feet, and was regarded by Collier and Knechtel (1939) as probably representing a succession of lenses of coal in about the same stratigraphic position and not a single continuous bed.

Weathered exposures of the Tullock often present a somber appearance much like that of the underlying Hell Creek Formation. However, the Tullock can generally be recognized by the absence of variegated shale, the greater abundance of coal, and the resistant limestone layers.

The Tullock is well exposed along most of the interstream divides north of Frazier Creek and on the east side of Big Dry Creek just downstream from Van Norman. Here, nearly vertical cliffs of dark shale and buff sandstone rise 50–200 feet above the stream channel. Nowhere, however, could the thickness of the Tullock be measured directly. Composite measurements in the north-central part of the report area indicate a thickness of about 250 feet. This agrees closely with the thickness farther west near Hell Creek (W. L. Rohrer, oral commun., 1957), but is somewhat greater than the thickness reported by Collier and Knechtel (1939) in McCone County.

The Tullock is the predominant aquifer in the central and southern parts of the report area. Most of the pumped wells south of Woody Creek obtain their water from this member, as do virtually all the

411-336 O—71——3

flowing wells along Big Dry Creek between Jordan and Van Norman. Yields seldom exceed 20 gpm and are generally obtained from erratically distributed sandstone beds or lenses, although small yields may be obtained from coal beds. The local occurrence of these water-yielding beds is unpredictable. but taken as a unit, the Tullock is a reliable aquifer for stock-water supplies. The water is of suitable quality for livestock but is of poor quality for domestic use (p. F33).

LEBO SHALE MEMBER

The Lebo Shale Member consists of dark-gray clay shale and carbonaceous shale separated by light-colored sandy shale and crossbedded sandstone. Outcrops are easily recognized by the overall dark appearance of the unit. Thin beds of coal occur in the sequence, but the only persistent coal bed is at the base of the member. This impure coal bed has a thickness of as much as 20 feet and has been tentatively correlated with the Big Dirty bed of the Dakota coal field by Collier and Knechtel (1939, p. 19). The coal and lenticular crossbedded sandstone suggest a fresh-water fluvial origin.

The Lebo Shale is well exposed in the slopes of Big and Little Dry Creek valleys in the southeastern part of the report area, but nowhere could the thickness be measured directly. Composite measurements indicate a thickness of about 250 feet for the predominantly dark-colored sequence. This is somewhat less than the 400 feet reported by Collier and Knechtel (1939) a short distance east in McCone County. The authors attribute the difference to arbitrary selection of the contact with the overlying Tongue River Member rather than to rapid eastward thickening of the unit.

Sandstone beds and lenses in the Lebo, though not so prevalent as in other members of the Fort Union Formation, are generally permeable. They yield water under artesian conditions to wells in Spring Creek and Little Dry Creek valleys in the southeastern corner of the area. Wells on the valley floors commonly flow 1–2 gpm with shut-in pressures of less than 5 psi (pounds per square inch). Very likely, yields of as much as 50 gpm could be pumped from these wells. The quality of the water (p. F33) is generally poor for domestic use but is suitable for livestock.

TONGUE RIVER MEMBER

The Tongue River Member is principally light-colored sandstone and shale interbedded with dark carbonaceous shale and coal. Sandstone is more abundant than in other members of the Fort Union Formation. Weathered exposures have an overall yellowish appearance, locally altered by dark shale, coal, or red clinker beds formed by the burning of coal.

All vestiges of the Tongue River Member have been eroded from the area north of Montana State Highway 20, and all but the lower 150 feet have been removed from the uplands in the extreme southern part of the area. Exposures are generally covered with slope wash, which makes it difficult to determine the local character of the beds or to recognize the contact with the underlying Lebo Shale Member.

The Tongue River Member is an important aquifer throughout most of eastern Montana, but because of its limited occurrence in the report area, it supplies water to only a few wells in the extreme southern part of the area. The data available indicate yields adequate for watering livestock. The water is generally suitable for both domestic and stock use.

QUATERNARY SYSTEM

PLEISTOCENE GLACIAL DEPOSITS

Remnants of glacial moraines, comprised largely of scattered cobbles, and boulders as much as 2 feet in diameter, occur in the northernmost part of the area. Colton and others (1961) indicate that most of the area was once covered by a thin mantle of fine-grained sediments deposited in Lake Jordan, a glacial lake that existed during Wisconsin time. Only vestiges of these moraine and glacial lake deposits remain, and they are not sufficiently thick to be potential aquifers. Therefore, no attention was given them during the field studies. It is worthy of note, however, that the coarse fraction comprising the more permeable parts of the valley alluvium is largely derived from glacially transported material.

HOLOCENE ALLUVIUM

All larger stream valleys in the report area contain rather extensive alluvial deposits derived primarily from erosion of the adjacent uplands. Generally, the size of the deposit reflects the size of the contributing basin. For example, the alluvial fill along the lower reach of Big Dry Creek is more than 1 mile wide and more than 30 feet thick. Tributary stream valleys have correspondingly smaller alluvial deposits (table 3; pl. 1). The bulk of the alluvium is fine grained, although some permeable sand and gravel lenses and stringers apparently occur in all of the fills. The coarse fraction consists of sandstone and chert fragments derived locally and igneous granules and pebbles transported into the area by glaciers.

The alluvial deposits in all the larger stream valleys yield water to both domestic and stock wells. This readily available source of water was an important factor in the selection of individual homestead sites.

Adequate supplies were generally obtained by digging large diameter wells. The water obtained from the alluvium is characteristically hard and moderately mineralized (p. F33).

STRUCTURE

The general area under consideration lies on the Montana Plains about midway between Bowdoin dome on the north and Porcupine dome on the south. A structure map prepared by Dobbin and Erdmann (1955) shows that beds between these two uplifts have been down warped to form a shallow trough called the Blood Creek syncline. The axis of this syncline plunges eastward 10–15 feet per mile across the southern part of the report area closely approximating the course of Big Dry Creek in the reach between Jordan and Van Norman (pl. 1). Beds on the north limb of the syncline strike approximately N. 45° E. and dip southeastward about 20 feet per mile. Beds on the south limb of the syncline strike approximately S. 40° E. and dip northeastward 15–25 feet per mile.

The major structural features are shown on plate 1 by means of contours drawn on the base of the sandstone unit in the upper part of the Fox Hills Sandstone. Contours depicting the north limb of the syncline are based on altimeter measurements of surface exposures and on well data. Contours depicting the south limb of the syncline are based on inferred thicknesses of overlying rock units and are approximate only.

The major structure largely controls the areal pattern of ground-water movement. Recharge to artesian aquifers cropping out in the western part of the report area moves downdip towards the axis of the Blood Creek syncline. Data are not adequate to contour the piezometric surfaces [2] of the different artesian aquifers, but their configuration is similar to the structure contours. The slope of the piezometric surfaces of the various aquifers is toward the synclinal axis at gradients of 5–10 feet per mile, which is somewhat less than the dip of the beds or the slope of the land surface. Consequently, most wells on the floors of Big Dry Creek and Little Dry Creek valleys flow at the land surface. Shut-in pressures are characteristically low, seldom exceeding 5 psi.

Superposed on the major structure in the area north of Big Dry Creek are a number of small-scale anticlines and synclines, the axes of which trend southeastward at about right angles to the regional strike of the beds. Streams tributary to Big Dry Creek are generally alined along these minor synclines so that beds underlying the interstream divides dip toward the valleys at angles of 1°–2°. The close conformity

[2] The surface to which water from a given aquifer will rise under its full head.

of the drainage net to the apparent structure has led the authors to believe that the width and spacing of the valleys are a consequence of minor folding. Other workers, however (W. L. Rohrer, oral commun., 1957), speculate that the present drainage net may have formed on a virtually uniform dip slope and that the apparent warping of the beds may be a draping effect caused by soil creep and (or) differential compaction. As data are presently inadequate to warrant a conclusion, no attempt has been made to show the minor folds on plate 1.

The effect of the apparent minor warping on the local occurrence of ground water can only be inferred inasmuch as only a few wells have been drilled on the interstream divides. If the divides correspond to small-scale anticlines and the valleys to synclines, as the authors believe, the Fox Hills Sandstone is topographically somewhat higher on the divides and lower in the valley than the structure contours on plate 1 indicate. It should be stressed, however, that the valleys are invariably incised stratigraphically lower than the adjacent divides. The drilling depth to a given horizon or aquifer, therefore, will be greater on the divides than in the valleys. Several contact springs issue from truncated beds exposed along the valley side slopes. It seems probable that similar springs discharge to the valley floors beneath the alluvium, thus augmenting underflow in the stream alluvium.

Aerial photographs clearly show a number of linear features in the report area, but faults are few and apparently have little effect on the occurrence of ground water. The largest observed fault is in the SW¼ sec. 16, T. 21 N., R. 41 E. It strikes S. 45° W., dips 58° NW., and appears to have a maximum displacement of about 20 feet. A spring discharging about 5 gpm issues from a thin coal seam on the downthrown northwest side of the fault. No springs were observed along other faults or lineaments in the area.

STOCK-WATER DEVELOPMENT

SPRINGS AS A SOURCE OF STOCK WATER

Most springs in the report area are on privately owned land or in precipitous terrain where the limited forage may not warrant the cost of spring development. It seems unlikely, therefore, that these springs or seeps will become important sources of stock-water supplies on the public lands. Nevertheless, a few guides are offered as an aid to the development of those seeps or springs that have perennial flows.

Development [3] should be undertaken only where the seep area remains moist the year around and where phreatophytes (water-loving plants) indicate a perennial source of shallow water (Robinson, 1958).

[3] For suggestions on the development of springs and seeps, see Fuller (1910, p. 22–27).

Where yields are small, flows often may be substantially increased by minimizing water losses caused by evapotranspiration. This can be done by cleaning out and installing a head box or collecting system at the spring orifice and by eradicating wasteful vegetation. If the spring or seep has no well-defined orifice, water may be collected by a system of ditches or drains. Whatever the method of spring development, the cost is generally much less than the cost of wells or reservoirs.

UNDERFLOW AS A SOURCE OF STOCK WATER

Virtually all ephemeral and intermittent streams in the report area which have contributing areas of more than a few square miles perennially discharge water by percolation through the unconsolidated alluvial deposits that underlie the stream channels. This discharge is called underflow. Along the larger stream courses, pools of water often occur in those reaches where the alluvium has been scoured out, or where shallow bedrock forces the underflow to the surface. These pools are natural watering holes. For the most part, however, the only indication of underflow are growths of willows and (or) cottonwood trees along the stream channels. In these reaches either large diameter dug wells or underflow developments may provide permanent stock-water supplies.

Underflow developments, in contrast to dug wells, have the advantage of intercepting flow across the full width of the stream deposit and are thus more likely to obtain adequate yields than are wells. Figure 6 is a diagrammatic sketch of one type of development that has proved very successful on small ephemeral streams having limited underflow. The objective is simply to intercept the underflow and collect it in a sump where it can be pumped to watering facilities. To avoid the need for pumping, water may be drained directly through a pipeline to troughs located downstream at a lower altitude.

In practice, new underflow developments should be installed on narrow channel reaches during the late summer when flows are minimal. Details shown in figure 6 should be modified to utilize available materials and to fit the needs of individual installations. For example, the excavation need not extend to bedrock or cover the full width of the stream deposit in those valleys where less extensive developments are adequate. Similarly, it may not be necessary to use a ground-water dam to intercept an adequate flow.

Table 3 describes the general occurrence of underflow in most of the stream valleys in the report area. Plate 1 also provides a general guide to the local occurrence of underflow. Those channel reaches

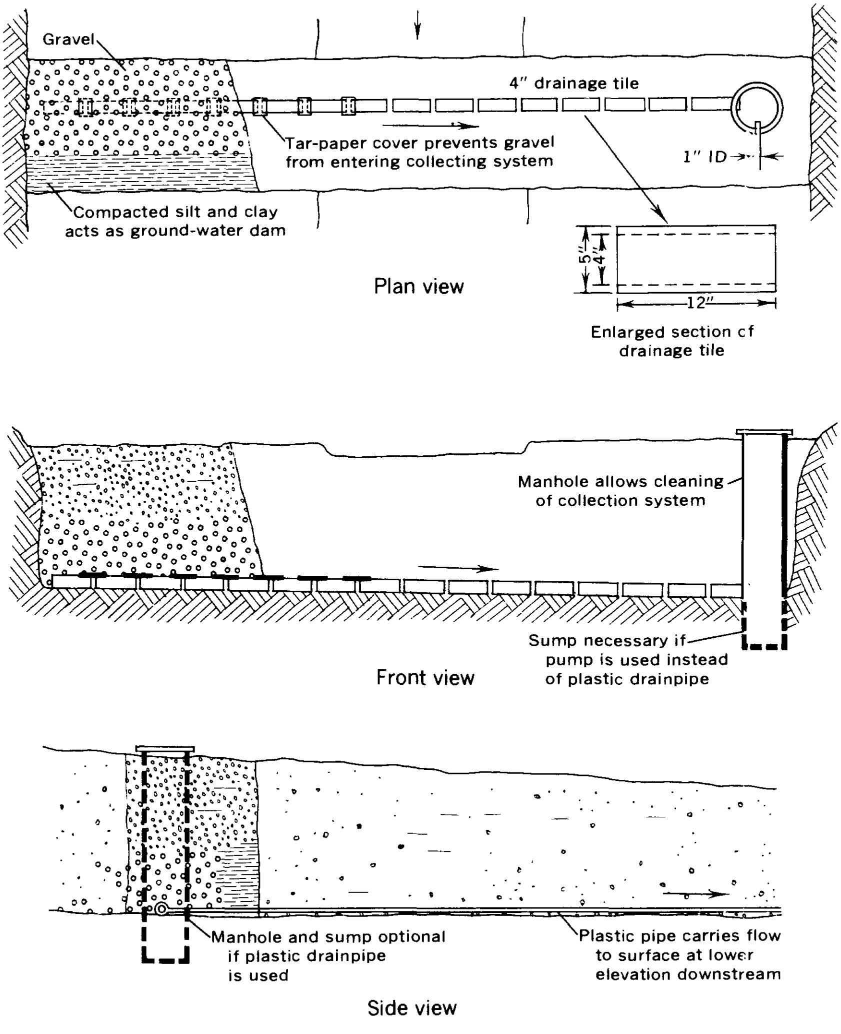

FIGURE 6.—Diagrammatic sketch of an underflow development.

where alluvium has been mapped are expected to yield adequate water for livestock to underflow developments. It should be kept in mind, however, that the amount of underflow, especially in the smaller stream channels, is limited. A single development may deplete most of the underflow for a considerable distance downstream. Care should be exercised, therefore, to avoid intercepting flow that feeds downstream developments.

TABLE 3.—*Occurrence of underflow along principal drainage courses*

Name of stream: Listed in downstream order; all are tributary to Big Dry Creek.
Length of stream valley within the report area: Length of main stem between mouth and drainage divide or margin of the area; includes valley meanders, but not stream meanders.
Average width of alluvium: Measured on aerial photographs.
Estimated thickness of alluvium below level of flood plain: Inferred from field observations.
Occurrence of underflow: Remarks apply to main stem unless stated otherwise. Occurrence inferred largely from vegetation and (or) presence of pools or moist spots in the channel bottoms.

Name of stream	Length of stream valley within the report area (miles)	Average width of alluvium (miles)	Estimated thickness of alluvium below level of flood plain (feet)	Occurrence of underflow
Vail Creek	5	0.2	20-30	Apparent underflow throughout channel length in report area.
Second Creek	10	.2	10-20	Apparent underflow downstream from bridge on State Highway 22.
Lone Tree Creek	9	.2	10-20	Intermittent to within 3 miles of drainage divide. Probably has underflow to within 1 mile of the divide.
Sand Creek	10	.4	30-40	Underflow throughout channel length in report area.
Unnamed creek [1]	12	.3	20-30	Underflow to within a few miles of drainage divide. Probably has underflow to within 1 mile of the divide.
L S Creek	8	.2	10-20	Apparent underflow for several miles upstream from State Highway 20. Probably small flows adequate for stock could be developed as far upstream as sec. 2, T. 18 N., R. 40 E.
Bear Creek	7	.2	10-20	Underflow in lower reach. Probably has underflow to within 1 mile of the drainage divide.
Wolf Creek	8	.2	20-30	Underflow as far upstream as Haxby Road.
Frazier Creek	19	.4	30-40	Underflow throughout channel length in report area. Shallow wells should generally obtain adequate yields for livestock. All larger tributaries have underflow in their lower reaches.
Taylor Creek	16	.2	20-30	Underflow throughout most of channel length. Probably has underflow to within 1 mile of the drainage divide.
Spring Creek	10	.2	20-30	Apparent underflow upstream to as far as SW¼ sec. 34, T. 18 N., R. 41 E.
Little Dry Creek	17	.5	30-40	Underflow throughout channel length in report area. Shallow wells should generally obtain adequate yields for livestock.
Woody Creek	23	.4	30-40	Underflow to within 1 mile of the drainage divide on North and South Forks of Woody Creek and on Fork Pass Creek. Shallow wells should provide adequate stock water in all but the headwater areas. Lower reach is an intermittent stream.
Flat Creek	16	.3	30-40	Underflow to within 2 miles of drainage divide. Stream is intermittent for about 5 miles upstream from junction with Big Dry Creek.
Snap Creek	7	.2	10-20	Apparent underflow to within 1 mile of the drainage divide.
Cottonwood Creek	12	.3	20-30	Underflow to within about 2 miles of the drainage divide.
Ash Creek	12	.3	20-30	Underflow almost to the drainage divide.
Box Creek (North, South,[3] and Middle Forks).	[2] 7	.2	10-20	Underflow almost to the drainage divide on each fork.
Big Dry Creek	40	.6	40-50	Intermittent throughout channel length in report area. Pools or shallow wells should provide water for livestock wherever needed.

[1] Heads in T. 16 N., R. 40 E. and drains area between Lone Tree and L S Creeks.
[2] Length of each fork measured from drainage divide to Fort Peck Reservoir.
[3] South Fork Box Creek locally called Cat Creek.

WELLS AS A SOURCE OF STOCK WATER

In 1957 at the time of the field reconnaissance there were about a hundred wells in the report area, most of which tap bedrock aquifers. Virtually all the wells are privately owned, and many are used for both domestic and stock-water supplies. Data for 83 wells are given in table 4. Most depths were reported by the owners or tenants from memory, and some are of questionable reliability. Commonly, it was reported that drilling was continued beyond the depth where the yield was adequate for anticipated needs. In some places better quality water was desired; in other places it was hoped that greater artesian rise could be obtained from lower beds. This was especially true of those wells that were drilled along Big Dry Creek and its larger tributaries. For example, the Flint well (table 4, No. 79) reportedly entered Bearpaw Shale at a depth of about 300 feet. The additional 400 feet of hole was drilled into impermeable shale in the expectation that a flowing well could be completed.

Despite the questionable accuracy of the reported depths of some wells, table 4 provides a good indication of the drilling depth required to obtain water from bedrock formations in the report area. The average depth of all bedrock wells is 195 feet, and almost 85 percent of the wells are less than 300 feet deep. The following tabulation shows the percentage of bedrock wells grouped by depth increments of 100 feet.

Percentage of bedrock wells (table 4)	*Depth (feet)*
19	Less than 100
44	100–200
21	200–300
9	300–400
5	400–500
2	500+

As might be expected, the average depth of wells started in the Lebo Shale Member is greater than for wells started in other aquifers that contain more sandstone. The tabulations on page F27 shows the average depth of wells started in the various rock units. The depth is believed to be indicative of the relative abundance of sandstone—that is, a shallow drilling depth indicates more sandstone in the unit than does a deeper drilling depth.

TABLE 4.—*Records of selected wells and springs*

No.: Refers to listing in table 5 and on plate 1.
Type of well: Dr, drilled; Du, dug; Sp, spring.
Depth of well: Reported depths are given in feet; measured depths are given in feet and tenths.
Diameter of well: Inside diameter.
Type of casing: P, metal pipe; SP, stove pipe; D, 55-gal steel drum; C, concrete or masonry.
Character of material: Ss, sandstone; S, sand; C, coal.
Geologic source: Kfh, Fox Hills Sandstone; Khc, Hell Creek Formation; Tft, Tullock Member of Fort Union Formation; Tfl, Lebo Shale Member of Fort Union Formation; Tftr, Tongue River Member of Fort Union Formation; Qal, unconsolidated alluvium.
Type of pump: Cy, cylinder; J, jet; S, submersible; N, none.
Type of power: E, electric motor; G, gasoline engine; H, hand operated; W, windmill; F, natural flow; N, none.
Use of water: D, domestic; S, stock; P, public supply; I, irrigation of garden.
Altitude of land surface: Determined by aneroid altimeter and approximate only.
Depth of water: Reported depths are given in feet; measured depths are given in feet and tenths; P, shut-in pressure of flowing well in pounds per square inch; F, flows at land surface.
Remarks: Ca, sample collected for chemical analysis; D, discharge in gallons per minute; P, perforated interval of casing in feet.

No.	Location			Owner	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Aquifer		Type of pump	Type of power	Use of water	Altitude of land surface (feet)	Depth to water below land surface (feet)	Remarks
	Quarter Section	Township (N)	Range (E)						Character of material	Geologic source						
1	SW 2	16	41	Barnes	Dr	130	4	P	Ss	Tftr	Cy	W	D, S	2,795	70	Good water.
2	NW 6	16	42	Ross	Dr	200	4	P	Ss	Tftr	Cy	W	S	2,820	------	
3	NW 25	17	38	Kirby	Dr	80	4	P	Ss	Tft	J	E	D	2,745	60	Ca.
4	NW 18	17	39	do	Dr	84+	4	P	Ss(?)	Tft	Cy	W	S	2,665	6	Ca.
5	SE 26	17	40	Schmidt	Dr	200	4	P	Ss	Tfl	Cy	----	D, S	2,875	130	D 3.
6	SE 3	17	41	Ross	Dr	77.0	4	P	Ss	Tftr	Cy	W	S	2,735	51.1	Good quality water.
7	NE 6	17	41	do	Dr	150	4	P	Ss	Tftr	Cy	G	S	2,760	------	
8	NW 19	17	41	Isaac	Dr	160.0	4	P	Ss	Tftr	Cy	N	S	2,770	7.1	
9	SW 31	17	41	do	Dr	103+	4	P	Ss	Tftr	Cy	W	S	2,780	59.8	Ca.
10	SE 33	17	41	do	Dr	129.9	4	P	Ss	Tftr	Cy	G	S	2,770	60.2	
11	NW 34	17	41	Ross	Dr	85	4	P	Ss	Tftr	Cy	W	S	2,745	33.2	Ca.
12	SE 1	17	42	Whiteside	Dr	114	4	P	Ss	Tfl	N	F	S	2,425	F	
13	NW 7	17	43	do	Dr	113	4	P	Ss	Tfl	N	F	D, S	2,425	P 1.7	Ca, D 1.
14	NW 17	18	38	Garfield County.	Dr	180(?)	4	P	Ss	Tft(?)	N	E	P	2,630	15	Ca.
15	NW 17	18	38	City of Jordan.	Dr	492	10	P	Ss	Kfh	N	N	P	2,620	12	P 430–470.

16	SW 15	18	39	Sullivan	Dr	139	4	P	Ss	Tft	N	F	D, S	2,550	P 1.7	Ca, D 2.
17	NE 28	18	39	Harbaugh	Dr	275	4	P	Ss	Khc	Cy	E	D, S	2,600	6	Ca; hole cased to 80 ft.
18	NW 1	18	40	Vial School House.	Dr	125	4	P	Ss(?)	Tft	Cy	H	D	2,465	25	
19	SW 1	18	40	Mahoney	Dr	65	4	P	Ss	Tft	------	----	S	2,490	30	Ca.
20	SW 1	18	40	do	Dr	165	4	P	Ss	Tft	J	E	D, S	2,490	60	Ca; water at 40, 60, and 90 ft.
21	NW 2	18	40	Swanson	Dr	104	4	P	Ss(?)	Tft	N	F	D, S	2,465	F	
22	SE 8	18	40	Isaac	Dr	130	4	P	Ss	Tft	N	F	D, S	2,480	F	Ca.
23	NE 1	18	41	McRae	Dr	620	3	P	Ss	Kfh	N	F	D, S	2,370	F	Ca, D 2; gas odor.
24	NE 12	18	41	Haight	Dr	208	4	P	Ss(?)	Tft	Cy	E	D, S	2,475	40	Ca.
25	SE 29	18	41	Ross	Dr	415	4	P	Ss	Tft	Cy	N	S	2,770	360	Seep at 250 ft.
26	SW 33	18	41	do	Dr	165	4	P	Ss	Tfl	Cy	E	D, S	2,800	90	Ca.
27	NW 18	18	42	Haight	Dr	318	4	P	Ss(?)	Tft	Cy	N	D, S	2,480	100	2½-in. casing inside 4-in. casing.
28	NW 32	18	42	Milroy	Dr	125	4	P	Ss	Tfl	N	F	S	2,510	F	Ca, D 4.
29	NW 17	18	43	Gibbs	Dr	232	4	P	Ss	Tfl	Cy	E	D, S	2,620	107	
30	NE 10	19	38	Nelson	Dr	290	4	P	Ss	Khc	Cy	E	D, S	2,690	120	Ca.
31	NE 31	19	38	------------	Dr	192	4	P	Ss	Khc	------	E	D, S	2,630	9	Ca.
32	SW 3	19	39	Binion	Dr	262.3	5	P	Ss(?)	Khc	Cy	W	S	2,620	126.0	Salt residue around well.
33	NE 7	19	39	Olson	Dr	168	4	P	Ss	Khc	J	E	D, S	2,620	35	Ca; hole cased to 64 ft.
34	SW 9	19	39	Binion	Dr	--------	4	P	Ss	Khc(?)	Cy	E	D, S	2,585	20	Ca.
35	NE 12	19	39	Wood	Dr	150.5	4	P	Ss	Tft	Cy	G	S	2,640	66.2	Fair-tasting water.
36	NE 24	19	39	do	Dr	118.8	4	P	Ss(?)	Tft	Cy	W	S	2,540	58.3	Water highly mineralized.
37	NW 19	19	40	do	Dr	107.4	6	P	Ss	Tft	Cy	W	D, S	2,530	22.8	Good-tasting water.

TABLE 4.—*Records of selected wells and springs*—Continued

No.	Location: Quarter Section	Location: Township (N)	Location: Range (E)	Owner	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Aquifer: Character of material	Aquifer: Geologic source	Type of pump	Type of power	Use of water	Altitude of land surface (feet)	Depth to water below land surface (feet)	Remarks
38	SW 21	19	40	Likes	Dr	150.0	4	P	Ss	Khc	Cy	E	D, S	2,495	27.7	First water at 70 ft.
39	SW 31	19	41	Zimmerman	Dr	128		P	Ss	Tft			D, S	2,425	5	
40	SW 32	19	41	Wilton	Dr	100	4	P	Ss	Tft	N	F	D, S	2,430	F	Ca.
41	NW 3	19	42	Ross Billings	Dr	290	4	P	Ss	Kfh	N	F	D, S	2,290	P 3	Ca, D 5, well caved; original D 70.
42	SW 3	19	42	Reg Billings.	Dr	300	4	P	Ss	Kfh	N	F	D, S	2,280	P 4	Ca, D 6, well caved; original D 60.
43	NE 9	19	42		Dr	91.2	4	P	Ss(?)	Khc	N	F	S	2,300	P 2	Ca, D 1.
44	SW 10	19	42	School	Dr	80	4	P	Ss	Khc	Cy	H	D	2,310	6.5	
45	NE 21	19	42	Kountz	Dr		4	P	Ss	Khc			D, S	2,330	12	
46	NW 26	19	42	Bill Kerr	Dr	130	4	P	Ss	Hhc	Cy	E	D, S	2,330	20	
47	SE 32	19	42	Hoverson	Dr	450	4	P	Ss	Kfh	Cy	E	D, S	2,400	2	Ca.
48	SE 24	20	38	Binion	Dr	160	5	P	Ss(?)	Khc	Cy	E	S	2,740		
49	SW 21	20	39	School House.	Dr	44.5	4	P	Ss(?)	Tft	Cy	H	D	2,740	32.5	
50	NW 22	20	39	Gagnon	Dr	360	4	P	Ss	Khc	Cy	E	D, S	2,800	230	Ca; P 300–360.
51	NW 12	20	40	Binion Ranch.	Dr	93.0	5	P	Ss	Khc	Cv	W	S	2,500	77.5	
52	SE 16	20	40	Binion	Dr	178+	4	P	Ss	Khc	Cy	W	S	2,670	164.5	Ca.
53	NE 28	20	40	do	Dr	56.5	5	SP	Ss(?)	Tft	Cy	W	S	2,715	39.4	Inoperative; water highly mineralized.

54	NW	32	20	40	do.	Dr	203.8	4	P	Ss(?)	Tft	N	N	S	2,715	135.1	
55	NE	14	20	41	-----	Dr	243.1	4	P	Ss	Khc	Cy	E	S	2,480	140.0	
56	NE	17	20	41	Binion	Dr	156.1	4	P	Ss	Khc	Cy	W	S	2,470	65.1	Ca.
57	NW	23	20	41	Burgess	Du	30	30	C	S	Qal	Cy	H	D, S	2,400	15	Ca; underflow on Woody Creek.
58	NW	23	20	41	do.	Dr	234	4	P	Ss	Kfh	Cy	E	D, S	2,400	8	Ca.
59	SE	14	20	42	McGerlick	Dr	180.0	4	P	Ss	Kfh	N	F	D, S	2,290	P 3.5	Ca, D 4.
60	NE	34	20	42	Bob Kerr	Dr	255	4	P	Ss	Kfh	N	F	D, S, I	2,290	P 8	Ca, D 65.
61	NE	24	21	38	-----	Dr	119.3	4	P	Ss(?)	Khc	Cy	W	S	2,740	42.5	Windmill broken.
62	SW	12	21	39	C. Coldwell.	Dr	308.0	4	P	Ss	Kfh	S	E	D, S	2,650	239.5	Ca.
63	NW	19	21	39	Binion	Dr	78.5	4	P	Ss	Tft	N	-----	S	2,740	42.7	Ca.
64	NE	22	21	39	Hays	Dr	284.1	5	P	Ss(?)	Khc	Cy	W	S	2,640	252.8	Inoperative.
65	SE	22	21	39	do.	Dr	49.6	4	P	Ss(?)	Khc	Cy	W	D, S	2,615	40	Ca.
66	SE	18	21	40	R. Coldwell.	Dr	260	4	P	Ss	Kfh	Cy	E	D, S	2,605	190	Ca.
67	NW	8	21	41	Taylor	Dr	310	4	P	Ss	Kfh	S	E	D, S	2,555	210	Ca, D 12+.
68	SE	8	21	41	Flat Creek School.	Dr	260	3	P	Ss	Khc	Cy	H	D	2,530	170	D 4+.
69	SW	12	21	41	Twitchell	Du	10	30+	C	S	Qal	Cy	H	D, S	2,565	5	Ca.
70	SW	12	21	41	do.	Dr	450	4	P	Ss	Kfh	Cy	E	D, S	2,570	120	Ca.
71	SW	16	21	41	-----	Sp	-----	-----	-----	-----	Khc	N	F	S	2,515	-----	Fault-line spring.
72	NE	18	21	41	Barclay	Dr	310	4	P	Ss	Kfh	Cy	E	D, S	2,520	140	
73	NE	10	22	39	LaBree	Sp	-----	-----	-----	Ss	Kfh	N	F	D, S	2,460	-----	Ca.
74	NW	4	22	41	Thomas	Du	11.0	36	C	S	Qal	Cy	W	S	2,535	8.2	Ca; water from underflow on Ash Creek.
75	NW	4	22	41	do.	Dr	300	4	P	Ss	Kfh	S	E	D, S	2,545	150	Ca; first water at 110 ft.
76	NW	10	22	41	E. Thomas	Dr	100	4	P	Ss	Khc	-----	-----	D, S	2,490	40	D8; P 40–100.
77	SE	10	22	41	W. Thomas	Dr	220	4	P	Ss	Kfh	-----	-----	D, S	2,480	125	

TABLE 4.—*Records of selected wells and springs*—Continued

No.	Location			Owner	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Aquifer		Type of pump	Type of power	Use of water	Altitude of land surface (feet)	Depth to water below land surface (feet)	Remarks
	Quarter Section	Township (N)	Range (E)						Character of material	Geologic source						
78	NE 27	22	42	Flint-Art Brown Place.	Sp	-------	-----	----	Ss	Khc	N	F	S	2,345	-------	Ca, D 2.
79	SW 27	22	42	Flint	Dr	700	4	P	Ss	Kfh	Cy	E	D, S	2,280	50	Ca; lower 400 ft of hole in Bearpaw Shale.
80	NE 14	23	41	Henning	Du	6	22	D	S	Qal(?)	Cy	H	D	2,360	2	
81	NW 23	23	41	do	Dr	110	4	P	Ss	Kfh	N	N	S	2,425	60	
82	SE 25	23	41	Boughton	Dr	80	4	P	Ss	Kfh	Cy	E	D, S	2,330	60	Ca, D 10.
83	NE 36	23	41	Cary	Dr	80	4	P	Ss	Kfh	Cy	E	D, S	2,310	27	
84	NW 32	23	42	Newman	Dr	180	2.5	P	Ss	Kfh	Cy	E	D, S	2,355	80	
85	NE 27	24	41	Edwards	Dr	50	4	P	Ss	Kfh	Cy	E	D	2,475	20	Ca; water contains iron, rusty color.
86	SW 34	24	41	Henning	Dr	70	4	P	Ss	Kfh	Cy	E	D, S	2,455	35	Ca.

Formation	Average depth of well started in outcrop area (feet)
Fort Union Formation:	
Tongue River Member	143
Lebo Shale Member	218
Tullock Member	195
Hell Creek Formation	[1] 186

[1] Does not include well 79, table 4.

Available data show that, contrary to what might be expected, wells on the uplands have an average depth slightly less than wells penetrating bedrock in the valleys. The anomaly, however, probably can be attributed to excessive drilling depth of many of the wells in the valleys in an attempt to obtain either better quality water for domestic use or to develop a flowing well.

So far as could be learned from area residents, many of whom were the original homesteaders, only five dry holes have been drilled in the report area. One, 260 feet deep, was drilled near the drainage divide in the NW¼ sec. 9, T. 23 N., R. 41 E. The hole penetrated 230 feet of Hell Creek Formation and Fox Hills Sandstone before entering Bearpaw Shale. The sandstone in the upper part of the Fox Hills Sandstone was reported to be damp,[4] but yielded no water to the open hole over a period of 48 hours. The reason for local ground-water drainage is not entirely clear, but a possible explanation is that the hole was drilled on the axis of a small anticline (p. F16–F17). The proximity of the outcrop (pl. 1) is such that minor upwarping of as little as 20–30 feet could drain the sandstone locally.

The second dry hole was drilled to a depth of 527 feet near the high drainage divide south of Big Dry Creek in the NE¼ sec. 33, T. 18 N., R. 41 E. The hole bottomed in the lower part of the Tullock Member of the Fort Union Formation about 140 feet below the level of Big Dry Creek at its nearest point (pl. 1). No permeable sandstone was penetrated. Very probably, continued drilling would have found water in the Hell Creek Formation.

The third dry hole was drilled to a depth of 342 feet on the east slope of Big Dry Creek Valley in the NE¼ sec. 19, T. 19 N., R. 43 E. The hole apparently bottomed in the Tullock Member of the Fort Union Formation about 150 feet below the level of Big Dry Creek at its nearest point (pl. 1). An apparently adequate supply of water was found in a sandstone in the lower part of the hole. Drilling operations were dis-

[4] The hole was drilled by air circulation rotary method using only air to remove the cuttings from the hole.

continued, and casing and a pump were installed. Upon completion, however, the well produced less than 1 gpm and was abandoned. Very probably, an adequate yield could have been obtained by proper well development or by continued drilling into the Tullock or underlying Hell Creek Formation.

The remaining two dry holes were drilled in the Tullock Member of the Fort Union Formation in sec. 32, T. 20 N., R. 38 E., and sec. 35, T. 20 N., R. 39 E. (pl. 1). Drilling was discontinued at depths of 208 and 230 feet, respectively. Water undoubtedly could have been obtained by continued drilling into the underlying Hell Creek Formation.

Drilling results to date, therefore, indicate that prospects are very good that ample water for livestock can be obtained from wells drilled almost anywhere in the report area. The depth to an aquifer probably will be less than 300 feet. Logically, the greatest drilling depth would be expected on the high drainage divides, but the erratic distribution of sandstone lenses in the formations that underlie the area is such that permeable lenses or stringers not actually truncated by the valley side slopes may be water bearing. Thus, the required drilling depth at a selected location is difficult to predict, although wells in the vicinity offer an indication of what can be expected.

A possible exception to the foregoing conclusion is the extreme northwestern part of the report area where, as indicated by the dry hole in the NW¼ sec. 9, T. 23 N., R. 41 E., sandstone beds may be drained near their outcrop areas. Drainage of these beds is indicated by a number of contact springs, such as spring 73 (table 4), that issue near the base of the sandstone section. More information is needed before the general prospects of obtaining wells in this part of the area can be evaluated.

Attempts to contour piezometric surfaces of the different artesian aquifers were generally unsuccessful. Irregularities in the piezometric surfaces are attributed largely to methods of individual well completion techniques, and may also be due in part to discrepancies in reported depths to water. Nevertheless, data clearly indicate that recharge occurs primarily in the western part of the area and that ground-water movement is towards the axis of the Blood Creek syncline in the direction of the dip of the beds (p. F16).

Because yields as low as 3 gpm may be adequate for watering livestock, wells should be drilled with cable-tool rigs to avoid the use of drilling muds that often seal off small yields. Rotary rigs are suitable for drilling small-diameter flowing wells so long as care is exercised to clean the hole after completion of drilling operations. All wells should be cased their entire depth, and the casing should be perforated at each water-yielding bed.

CHEMICAL QUALITY OF THE GROUND WATER

Water samples collected from 44 wells and two springs were analyzed (table 5) by the senior author to determine the major chemical characteristics of the water in relation to geologic source and to determine the usability of the water. Analyses were made by techniques described in Agriculture Handbook 60. To provide a check of the results thus obtained, six duplicate samples were analyzed by the Water Resources Division, Geological Survey laboratory, Lincoln, Nebr. The results of analyses by the laboratory are given in table 5 and are identified by the letter "a" following the sample number.

Constituents in table 5 are given in milligrams per liter (mg/l) and milliequivalents per liter (meq/1). Milligrams per liter expresses the concentration by weight of the chemical constituent—that is, the weight of the constituent divided by the weight of the solution. Milliequivalents per liter expresses the concentration of a chemical constituent or ion in terms of its equivalent or combining weight. The combining weight is the molecular weight of the ion divided by its ionic charge. Milliequivalents per liter, which indicate the concentration in terms of potential chemical effect, can be converted to milligrams per liter by multiplying by the combining weight of the ion.

Table 5 shows that virtually all water supplies in the report area contain appreciable amounts of sodium, bicarbonate, and sulfate. Calcium and magnesium are present in comparatively small amounts, exceeding 100 mg/l in only five samples. The carbonate and chloride content of all samples is low, and tests indicate only a trace of nitrate. The amount of potassium in any of the samples is also insignificant.

RELATIONSHIP OF CHEMICAL CHARACTER OF WATER TO GEOLOGIC SOURCE

Table 6 shows the range and average concentration of chemical constituents of water samples collected from the various aquifers. The least mineralized water in the area is obtained from sandstone in the upper part of the Fox Hills Sandstone where it crops out along the north and west sides of Haxby Point. Water from the Fox Hills Sandstone in this part of the area (table 5, samples 73, 85, 86) generally contains less than 1,000 mg/l total dissolved solids. Sodium is the predominant cation, although calcium and magnesium are present in significant amounts. Bicarbonate is the predominant anion; very small amounts of sulfate are present.

TABLE 5.—*Chemical analyses of water from selected*

Sample: Number indicates source (table 4); letter "a" indicates analysis by Water Resources Division, Geol. Survey Laboratory, Lincoln, Nebr.

Sample	Location				Geologic source	Depth of well (feet)	Calcium and magnesium Ca+Mg		Sodium Na	
	Sec.	quarter	T (N)	R (E)			meq/l	mg/l	meq/l	mg/l
3	NW	25	17	38	Tft	80	0.8	16	28.7	660
4	NW	18	17	39	Tft	84+	.3	6	28.7	660
9	SW	31	17	41	Tftr	103+	11.0	220	10.6	244
11	NW	34	17	41	Tftr	85	8.9	178	4.75	109
13	NW	7	17	43	Tfl	113	.2	4	23.4	538
13a	NW	7	17	43	Tfl	113	.56	11	31.32	720
14	NW	17	18	38	Tft(?)	180(?)	.2	4	28.4	653
16	SW	15	18	39	Tft	139	.1	2	23.4	538
17	NE	28	18	39	Khc	275	.4	8	22.6	520
19	SW	1	18	40	Tft	65	2.8	56	50.7	1,170
20	SW	1	18	40	Tft	165	0	0	23.4	538
22	SE	8	18	40	Tft	130	0	0	18.75	431
23	NE	1	18	41	Kfh	620	0	0	18.25	420
24	NE	12	18	41	Tft	208	1.6	32	65.0	1,490
26	SW	33	18	41	Tfl	165	4.8	96	44.0	1,010
28	NW	32	18	42	Tfl	125	.4	8	31.75	730
30	NE	10	19	38	Khc	290	.4	8	26.9	618
31	NE	31	19	38	Khc	192	.8	16	37.5	862
33	NE	7	19	39	Khc	168	1.4	28	49.5	1,140
34	SW	9	19	39	Khc(?)	----------	.5	10	35.1	807
40	SW	32	19	41	Tft	100	0	0	24.8	570
41	NW	3	19	42	Kfh	290	0	0	16.0	368
42	SW	3	19	42	Kfh	300	0	0	16.0	368
43	NE	9	19	42	Khc	91.2	0	0	16.5	379
47	SE	32	19	42	Kfh	450	0	0	14.0	322
50	NW	22	20	39	Khc	360	0	0	35.2	809
52	SW	16	20	40	Khc	178+	1.4	28	64.6	1,490
52a	SW	16	20	40	Khc	178+	2.52	50	66.12	1,520
56	NE	17	20	41	Khc	156.1	9.0	180	60.0	1,380
57	NW	23	20	41	Qal	30	6.6	132	9.75	224
58	NW	23	20	41	Kfh	234	1.6	32	47.6	1,090
58a	NW	23	20	41	Kfh	234	1.40	28	49.16	1,130
59	SE	14	20	42	Kfh	180.0	.1	2	23.8	547
60	NE	34	20	42	Kfh	255	.1	2	23.0	529
60a	NE	34	20	42	Kfh	255	.22	4	24.40	561
62	SW	12	21	39	Kfh	308.0	.8	16	42.5	978
63	NW	19	21	39	Tft	78.5	.1	2	16.0	368
65	SE	22	21	39	Khc	49.6	.2	4	25.4	584
66	SE	18	21	40	Kfh	260	0	0	38.8	892
66a	SE	18	21	40	Kfh	260	.76	15	41.28	949
67	NW	8	21	41	Kfh	310	.3	6	38.75	891
69	SW	12	21	41	Qal	10	6.5	130	8.5	195
70	SW	12	21	41	Kfh	450	.9	18	41.75	960
73	NE	10	22	39	Kfh	Sp	3.6	72	3.4	78
74	SW	4	22	41	Qal	11.0	2.0	40	11.25	259
75	SW	4	22	41	Kfh	300	.1	2	12.5	287
78	NE	27	22	42	Khc	Sp	3.8	76	15.5	356
79	SW	27	22	42	Kfh	700	.4	8	40.0	920
82	SE	25	23	41	Kfh	80	1.0	20	24.0	552
85	NE	27	24	41	Kfh	50	3.3	66	4.5	103
85a	NE	27	24	41	Kfh	50	2.14	43	6.05	139
86	SW	34	24	41	Kfh	70	2.5	50	7.1	163

wells and springs in northeastern Garfield County, Mont.

Geologic source: Kfh, Fox Hills Sandstone; Khc, Hell Creek Formation; Tft, Tullock Member of Fort Union Formation; Tfl, Lebo Shale Member of Fort Uhion Formation; Tftr, Tongue River Member of Fort Union Formation; Qal, unconsolidated alluvium.

Carbonate CO_3		Bicarbonate HCO_3		Sulfate SO_4		Chloride Cl		Total dissolved solids (mg/l)	Specific conductance (micromhos at 25° C)	pH
meq/l	mg/l	meq/l	mg/l	meq/l	mg/l	meq/l	mg/l			
0. 6	18	15. 1	921	14. 4	692	0. 4	14	2, 320	2, 630	8. 5
0	0	16. 3	995	14. 2	682	. 4	14	2, 360	2, 560	8. 1
0	0	8. 6	525	15. 2	730	. 3	11	1, 730	1, 920	7. 8
0	0	8. 8	537	6. 0	288	. 2	7	1, 120	1, 140	7. 4
0	0	11. 7	714	17. 1	821	. 9	32	2, 110	2, 860	7. 9
0	0	11. 34	692	18. 88	907	. 85	30	2, 360	2, 900	----
. 4	12	8. 0	488	23. 3	1, 120	. 9	32	2, 310	2, 780	8. 2
0	0	10. 7	653	17. 2	826	. 6	21	2, 040	2, 380	8. 1
0	0	12. 2	744	15. 5	744	. 5	18	2, 030	2, 320	8. 1
0	0	17. 8	1, 090	27. 0	1, 300	. 5	18	3, 630	4, 550	7. 7
0	0	12. 4	757	10. 2	490	. 5	18	1, 800	2, 130	8. 2
. 8	24	12. 0	732	6. 0	288	. 5	18	1, 490	1, 720	8. 6
0	0	14. 5	885	3. 1	149	1. 0	35	1, 490	1, 590	8. 5
0	0	22. 8	1, 390	50. 0	2, 400	. 8	28	5, 340	5, 560	7. 8
0	0	21. 0	1, 280	28. 2	1, 350	. 4	14	3, 750	4, 160	7. 5
0	0	18. 0	1, 100	21. 9	1, 050	. 6	21	2, 910	3, 120	8. 0
0	0	9. 2	561	20. 5	985	. 9	32	2, 200	2, 780	8. 2
. 8	24	18. 6	1, 130	23. 2	1, 110	. 3	11	3, 150	3, 700	7. 7
0	0	23. 0	1, 400	32. 5	1, 560	. 2	7	4, 130	4, 550	7. 8
0	0	18. 8	1, 150	18. 0	865	. 2	7	2, 840	3, 120	8. 0
0	0	12. 6	769	12. 0	576	. 6	21	1, 940	2, 220	8. 3
. 6	18	13. 4	818	6. 1	293	. 7	25	1, 520	1, 720	8. 4
. 4	12	13. 7	836	4. 9	235	. 7	25	1, 480	1, 780	8. 4
0	0	14. 2	866	3. 6	173	. 9	32	1, 450	1, 670	8. 4
0	0	14. 9	909	2. 3	110	1. 0	35	1, 380	1, 560	8. 4
0	0	13. 9	848	23. 1	1, 110	. 6	21	2, 790	3, 330	8. 4
0	0	22. 8	1, 390	46. 2	2, 220	. 3	11	5, 140	5, 560	8. 0
0	0	21. 80	1, 330	46. 85	2, 250	. 17	6	5, 160	5, 880	----
0	0	24. 2	1, 480	45. 6	2, 190	. 5	18	5, 250	5, 880	7. 3
0	0	9. 6	586	9. 9	475	. 2	7	1, 420	1, 510	7. 6
0	0	17. 0	1, 040	36. 0	1, 730	. 7	25	3, 920	4, 160	7. 9
0	0	16. 0	976	34. 14	1, 640	. 65	23	3, 800	4, 520	----
. 2	6	12. 1	738	11. 5	552	. 7	25	1, 870	2, 270	8. 4
0	0	12. 3	750	13. 8	663	. 6	21	1, 960	2, 180	8. 3
0	0	11. 67	712	11. 66	560	. 62	22	1, 860	2, 250	----
. 2	6	17. 7	1, 080	24. 3	1, 170	. 5	18	3, 270	4, 000	8. 1
0	0	14. 5	885	1. 8	86	. 1	4	1, 350	1, 390	8. 0
0	0	15. 5	946	9. 6	461	. 1	4	2, 000	2, 220	7. 9
0	0	14. 8	903	25. 7	1, 230	. 7	25	3, 050	3, 850	7. 9
0	0	13. 93	850	27. 48	1, 320	. 62	22	3, 160	3, 810	----
0	0	14. 9	909	22. 9	1, 100	. 6	21	2, 930	3, 570	8. 0
0	0	11. 2	683	4. 3	207	. 2	7	1, 220	1, 250	7. 5
. 8	24	22. 4	1, 370	25. 5	1, 220	. 3	11	3, 600	3, 850	8. 1
. 2	6	6. 3	384	. 2	10	0	0	550	610	8. 0
0	0	12. 1	738	1. 2	58	. 4	14	1, 110	1, 230	7. 8
0	0	12. 4	756	1. 1	53	. 1	4	1, 100	1, 350	8. 1
0	0	15. 0	915	7. 0	336	. 1	4	1, 690	1, 690	7. 9
. 4	12	16. 4	1, 000	32. 0	1, 540	. 6	21	3, 500	3, 850	8. 3
. 6	18	18. 1	1, 100	8. 5	408	. 2	7	2, 110	2, 380	8. 0
0	0	8. 1	494	0	--------	. 2	7	670	710	7. 6
0	0	6. 65	406	1. 42	68	. 14	5	661	743	----
0	0	8. 1	494	1. 0	48	. 2	7	762	850	8. 1

TABLE 6.—*Range and average concentration of principal dissolved*

Geologic source	Number of samples	Calcium+magnesium (Ca+Mg)		Sodium (Na)		Carbonate (CO_3)	
		Range	Average	Range	Average	Range	Average
Holocene alluvium	3	40–132	101	196– 259	226	0	0
Fort Union Formation:							
Tongue River Member	2	178–220	199	109– 244	177	0	0
Lebo Shale Member	3	8– 96	38	720–1, 010	820	0	0
Tullock Member	10	0– 56	12	368–1, 490	708	0–24	5
Hell Creek Formation	11	0–180	35	356–1, 520	816	0–24	2
Fox Hills Sandstone	17	0– 72	17	78–1, 130	567	0–24	6

Concentration, in milligrams per liter.

Several changes in the quality of water obtained from the Fox Hills Sandstone occur with increasing distance downdip from the outcrop area. Total dissolved solids in the water increases progressively from less than 1,000 mg/l to nearly 4,000 mg/l in the Burgess well (table 5, No. 58); calcium and magnesium are almost completely replaced by sodium; and sulfate about equals bicarbonate. Downdip from the Burgess well the water improves in quality. Samples collected from wells tapping the Fox Hills Sandstone along Big Dry Creek downstream from Van Norman (pl. 1) contain less than 2,000 mg/l total dissolved solids, and bicarbonate again becomes the predominant anion. The cause of this improvement in water quality is not apparent from available data, but the most plausible explanation is that dilution occurs as a consequence of mixing with better quality water from recharge along Big Dry Creek or from the south limb of the Blood Creek syncline. Another possible explanation is that the aquifer acts as an adsorption column and selectively removes some ions. The phenomenon presents an interesting problem for future investigation.

Water from sandstone beds in the Hell Creek Formation is generally of poorer quality than water from the Fox Hills Sandstone. Sodium is the predominant cation in all samples analyzed, and bicarbonate and sulfate are present in about equal amounts. The limited data available indicate that the areal pattern of water quality in the Hell Creek Formation is similar to that in the Fox Hills Sandstone. Total dissolved solids are least near the outcrop; they increase in the downdip direction to a maximum of 5,250 mg/l at well 56 (table 5), and then decrease to 1,450 mg/l in well 43 near Big Dry Creek.

Water from the Tullock Member of the Fort Union Formation is generally similar to water from sandstone beds in the Hell Creek *constituents in water samples collected from the various aquifers*

Concentration, in milligrams per liter—Continued							
Bicarbonate (HCO_3)		Sulfate (SO_4)		Chloride (Cl)		Total dissolved solids	
Range	Average	Range	Average	Range	Average	Range	Average
586– 738	669	58– 475	247	7–14	9	1, 110–1, 420	1, 250
525– 537	531	288– 730	509	7–11	9	1, 120–1, 730	1, 430
692–1, 280	1, 020	907–1, 350	1, 110	14–30	22	2, 360–3, 750	3, 010
488–1, 390	868	86–2, 400	846	4–32	19	1, 350–5, 340	2, 460
561–1, 480	1, 030	173–2, 250	1, 070	4–32	15	1, 450–5, 250	2, 970
384–1, 370	837	10–1, 640	616	0–35	18	550–3, 800	2, 060

Formation. Sodium is the predominant cation, and bicarbonate and sulfate are the predominant anions. The average of 10 samples shows about equal amounts of bicarbonate and sulfate, although individual samples generally show a predominance of one or the other. The quality of water from the Tullock is generally best in the western part of the report area, but data are inadequate to determine any areal pattern of water quality. The poorest quality water in the report area comes from the Tullock Member (table 5, sample 24).

Water from the Lebo Shale Member of the Fort Union Formation is very similar to water from the Tullock. Sodium, bicarbonate, and sulfate are the predominant constituents. Bicarbonate and sulfate are present in about equal amounts.

Two samples from the Tongue River Member of the Fort Union Formation show that water from this source is comparatively low in total dissolved solids (table 6). Sodium and calcium plus magnesium are present in about equal amounts. Bicarbonate predominates in one sample, and sulfate predominates in the other. Water from this source is considerably harder than water from other bedrock formations in the area.

Water from alluvium (table 6) contains less total dissolved solids than all but seven bedrock wells, five of which draw water from sandstone in the upper part of the Fox Hills Formation. Sodium is the predominant cation, although calcium and magnesium are present in sufficient amounts to make the water from this source very hard. Most residents consider this "hard" water to be more potable than the comparatively "soft" water from bedrock wells, but less desirable for washing and other household uses. Bicarbonate is the predominate anion in the three samples analyzed.

USABILITY OF THE WATER

STOCK USE

In describing quality limitations of water for stock use, Hem (1959, p. 241) states:

> Water to be used by stock is subject to quality limitations of the same type as those relating to quality of drinking water for human consumption. However, most animals seem to be able to use water considerably poorer in quality than would be considered satisfactory for human beings. * * * Range cattle in the western United States seem to be able to * * * use water containing 5,000 ppm or more of dissolved solids, and animals that have become accustomed to highly mineralized water have been observed * * * to drink water containing nearly 10,000 ppm of dissolved solids. A high proportion of sodium or magnesium and sulphate in such highly mineralized water would make them very undesirable for stock use, however. Probably a supply of considerably better quality than the upper limit of tolerance is generally desirable for the best growth and development of animals.
>
> In a publication * * * relating to practices in Western Australia, the officers of the Department of Agriculture of that State quote the following upper limits for dissolved-solids concentration in stock water:

	Parts per million
Poultry	2, 860
Pigs	4, 290
Horses	6, 435
Cattle (dairy)	7, 150
Cattle (beef)	10, 000
Adult sheep	12, 900

The highest concentrations of total dissolved solids in the samples analyzed was 5,340 mg/l. Although this value is well below the limits given for horses, cattle, and sheep in the above table, the large proportion of sodium sulfate in some water supplies may make them marginal for stock use. So far as could be determined, however, none of the water supplies in the report area has had a serious effect on livestock.

CONCLUSIONS

The present study indicates that bedrock wells and underflow developments afford practical sources of stock water throughout most of northeastern Garfield County, Mont. No attempt was made to determine quantitatively the hydraulic properties of the different artesian aquifers underlying the area, but it is unlikely that future development of stock-water supplies in the sparsely settled area will greatly modify the natural balance between recharge and discharge.

In the area north of Woody Creek, fair to good quality water for livestock can be obtained from sandstone in the upper part of the Fox Hills Sandstone. The required drilling depth ranges from less than 100 feet near Haxby Point to as much as 300 feet in the vicinity of

Woody Creek. Most streams are intermittent in their lower reaches and have underflow throughout most of their length.

Between Woody Creek and Big Dry Creek, water generally can be obtained from erratically distributed sandstone beds and lenses in the Hell Creek Formation or from the Tullock Member of the Fort Union Formation at drilling depths of 100–300 feet. The water, though high in total dissolved solids, should be suitable for livestock. Underflow can be developed in all the larger stream valleys.

South of Big Dry Creek, water can be obtained from erratically distributed sandstone beds and lenses in the Tullock, Lebo Shale, and Tongue River Members of the Fort Union Formation. Of these members, the Tongue River is the most reliable aquifer and yields the best quality water at the least drilling depth. Conversely, the Lebo Shale Member is the least reliable aquifer, and like the Tullock, yields water high in total dissolved solids. Drilling depths are generally greatest for wells started in the Lebo Shale Member. Underflow can be developed in all the larger stream valleys.

As a general rule, the depth to an aquifer should be greatest on the interstream divides and least on the valley floors. Successful completion of a well, however, depends on penetrating a permeable sandstone below the local level of saturation. This introduces the element of chance with all aquifers other than the persistent Fox Hills Sandstone. As more wells are drilled and better data become available, perhaps other sandstone beds will prove to be predictable aquifers for limited parts of the area. Meanwhile, data indicate that chances are very good that stock-water wells can be successfully completed almost anywhere in the report area.

It remains for future investigations to determine the hydraulic properties and interreationships of the different artesian aquifers and the configuration of their respective piezometric surfaces. Changes in the chemical character of the water in the downdip direction in the Fox Hills Sandstone also present an interesting problem for further study.

DRILLERS' LOGS OF WELLS

Copies of available drillers' logs are given in table 7. Other information, such as the size, type and amount of casing, the perforated interval, and the inferred geologic source, is given in table 4.

TABLE 7.—*Drillers' logs of wells*

Well 15, table 4. City of Jordan.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand and sandy clay	26	26	Rock		327
Blue clay	70	96	Clay	65	392
Sandy clay with streaks of sand rock	10	106	Soft sand rock	10	402
Multicolored clay	25	131	Clay	10	412
Soft sandstone	91	222	Rock		412
Rock		222	Clay	18	430
Sandy clay	10	232	Sand, clay, and soft sandstone	40	470
Sand	4	236	Soft clay	2	472
Blue clay	44	280	Rock	3	475
Sand streaks	3	283	Clay	9	484
Clay	3	286	Rock	4	488
Rock	5	291	Rock	4	492
Clay	36	327			

Well 17, table 4. Carl Harbaugh.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand	20	20	Sand, loose, water-bearing	30	230
Shale	180	200			

Well 30, table 4. Bill Nelson.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay	25	25	Sand, water-bearing	15	170
Sand and gravel	7	32	Shale	80	250
Shale	71	103	Sand, water-bearing	35	285
Rock	1	104	Shale	5	290
Shale	51	155			

Well 50, table 4. Edward Gagnon.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil	30	30	Sand (no water)	80	190
Coal	1	31	Blue shale	110	300
Gumbo	19	50	Sand	50	350
Blue shale	110	160	Blue shale	10	360

Well 68, table 4. Flat Creek School.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sandy shale	25	25	Water sand	45	235
Shale	190	215			

Well 70, table 4. Walter Twitchell.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay	20	20	Blue shale	39	330
Gravel	2	22	Shale rock	8	338
Blue shale	113	135	Blue shale	67	405
Sand	8	143	Rock	2	407
Blue shale	53	196	Sandstone	31	438
Rock	1	197	Hard rock	2	440
Blue shale	93	290	Sandstone	10	450
Rock	1	291			

TABLE 7.—*Drillers' logs of wells*—Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well 76, table 4. Edward Thomas.					
Sandy soil	10	10	Sandstone and shale	30	90
Dark shale	20	30	Blue shale	10	100
Blue shale	30	60			
Well 77, table 4. Walter Thomas.					
Sand and clay	18	18	Sandy black shale with sandstone streaks	89	182
Sand	51	69	Rock	1	183
Rock	2	71	Soft sandstone	37	220
Sandy shale	18	89			
Rock	4	93			

REFERENCES CITED

Andrews, D. A., Lambert, G.S., and Stose, G. W., 1944 Geologic map of Montana: U.S. Geol. Survey Oil and Gas Inv. (Prelim.) Map 25.

Bauer, C. M., 1925, Quartzite pebbles at the base of the Lance Formation in Montana: Am. Assoc. Petroleum Geologists Bull., v. 9, no. 2, p. 344.

Bowen, C. F., 1916, Possibilities of oil in the Porcupine dome, Rosebud County, Montana: U.S. Geol. Survey Bull. 621–F, p. 61–70.

Brown, B., 1907, The Hell Creek beds of the Upper Cretaceous of Montana: Am. Mus. Nat. History Bull. 23, p. 823.

Collier, A. J., 1918, Geology of northeastern Montana: U.S. Geol. Survey Prof. Paper 120–B, p. 17–39.

Collier, A. J., and Knechtel, M. M., 1939, The coal resources of McCore County, Montana: U.S. Geol. Survey Bull. 905, 80 p.

Colton, R. B., Lemke, R. W., and Lindvall, R. M., 1961, Glacial map of Montana east of the Rocky Mountains: U.S. Geol. Survey Misc. Geol. Inv. Map I–327.

Dobbin, C. E., and Erdman, C. E., 1955, Structure contour map of the Montana plains: U.S. Geol. Survey Oil and Gas Inv. Map OM 178–B.

Dobbin, C. E., and Reeside, J. B., 1930, The contact of the Fox Hills and Lance Formations: U.S. Geol. Survey Prof. Paper 158–B, p. 9–25.

Fenneman, N. M., 1931, Physiography of Western United States: New York, McGraw Hill, p. 61–79.

Fuller, M. L., 1910, Underground waters for farm use: U.S. Geol. Survey Water-Supply Paper 255, 58 p.

Hem, J. D., 1959, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 1473, p. 241.

Jensen, F. S., and Varnes, H. D., 1964, Geology of the Fort Peck area, Montana: U.S. Geol. Survey Prof. Paper 414–F, 49 p.

Perry, E. S., 1934, Geology and artesian water resources along Missouri and Milk Rivers in northeastern Montana: Montana Bur. Mines and Geology Mem. 11, 34 p.

Reeves, F., 1926, Geology of the Cat Creek and Devils Basin oil fields and adjacent areas in Montana: U.S. Geol. Survey Bull. 786–B, p. 39–98.

Robinson, T. W., 1958, Phreatophytes: U.S. Geol. Survey Water-Supply Paper 1423, 84 p.

Ross, C. P., Andrews, D. A., and Witkind, I. J., 1955, Geologic map of Montana: U.S. Geol. Survey scale 1:500,000.

Thom, W. T., Jr., and Dobbin, C. E., 1922, Oil and gas prospects in Garfield County, Mont.: Am. Assoc. Petroleum Geologists Bull., v. 6, no. 2, p. 144–150.

Thom, W. T., Jr., and Dobbin, C. E., 1924, Stratigraphy of Cretaceous-Eocene transition beds in eastern Montana and the Dakotas: Geol. Soc. America Bull., v. 35, p. 481–506.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Dept. Agriculture Handb. 60, 159 p.

U.S. Weather Bureau, 1960, Climatological data, Montana: Ann. Summary, v. 63, no. 13.

U. S. GOVERNMENT PRINTING OFFICE : 1971 O - 411-336

EXPLANATION

QUATERNARY — *Pleistocene and Holocene*

Qal

Alluvium
Unconsolidated clay, silt, sand and gravel in stream valleys. Yields water to shallow wells along all larger drainage courses

TERTIARY — *Paleocene*

Tftr
Tfl
Tft

Fort Union Formation
Predominantly light- to dark-gray shale and siltstone interbedded with erratically distributed buff to tan sandstone beds and lenses, thin limestone beds, and coal. Sandstone and coal beds are generally water bearing. Includes Tongue River Member, Tftr, *Lebo Shale Member,* Tfl, *and Tullock Member,* Tft

CRETACEOUS — *Upper Cretaceous*

Khc

Hell Creek Formation
Light-gray to somber shale interbedded with fluvial sandstone. Sandstone beds and lenses are generally water bearing

Kfh

Fox Hills Sandstone
Gray to buff sandy shale grading upward into sandstone. Sandstone is generally water bearing

Kb

Bearpaw Shale
Dark-gray marine shale containing seams of bentonite and gypsum. Not water bearing

Contact
Dashed where indefinite

U
D
Fault
U, *upthrown side;* D, *downthrown side*

Axis of syncline
Showing direction of plunge; dotted where concealed

2500
2400
Structure contours
Showing altitude of base of sandstone in Fox Hills Sandstone; dashed where indefinite. Contour interval 100 feet; datum is mean sea level

46 130
2310
Pumped well

12 114
2425
Flowing well

206
Dry hole

71 2515
Spring

Number to left refers to tables 4 and 5. Upper number to right is depth of well, in feet below land surface; lower number is altitude of water surface, in feet above mean sea level

Ca
Sample collected for chemical analysis

Base from U.S. Geological Survey
1:250,000, Jordan, 1964

APPROXIMATE MEAN DECLINATION, 1971

Bedrock geology modified after Andrews, Lambert, and Stose (1944) and Ross, Andrews, and Witkind (1955). Alluvial contacts mapped by M. C. Van Lewen in 1961 by photogeologic methods

GEOLOGIC MAP OF NORTHEASTERN GARFIELD COUNTY, MONTANA, SHOWING LOCATION AND HYDROLOGIC DATA FOR SELECTED WELLS AND SPRINGS

SCALE 1:125 000

CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL