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WATER-RESOURCES DATA FOR DEEP AQUIFERS OF EASTERN MONTANA

by

William B. Hopkins

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Open-File Report

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CONVERSION FACTORS

For those readers who may prefer to use metric units rather than English units, conversion factors used in this report are listed below:

English unit	Multiply by	To obtain metric unit
ft (feet)	0.3048	m (metres)
mi (miles)	1.609	km (kilometres)
mi^2 (square miles)	2.590	km^2 (square kilometres)
gal/min (gallons per minute)	.06309	l/s (litres per second)

Factors for converting English units to metric units are shown to four significant figures. However, in the text the metric equivalents are shown only to the number of significant figures consistent with the values and usage of the English units.

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ABSTRACT

Water from aquifers of Mesozoic and Paleozoic age in eastern Montana is little used. This report presents maps and tables to assist in the evaluation of the water in terms of possible utility. In the southern third of eastern Montana water from the Madison Group or from the Tensleep Sandstone contains less than 2,000 milligrams per litre dissolved solids and is available in amounts of as much as 3,700 gallons per minute (230 litres per second) from individual wells. Elsewhere, dissolved-solids concentrations of water from Mesozoic and Paleozoic aquifers commonly exceed 1,000 milligrams per litre, well yields range from 5 to about 1,500 gallons per minute (0.3 to 95 litres per second), and well depths generally are greater than 1,500 feet (460 metres).

INTRODUCTION

Purpose

Most ground water used for domestic, stock, municipal, irrigation, and industrial supplies in eastern Montana is from aquifers of Quaternary and Tertiary age. Older aquifers--herein called the deep aquifers--are of Mesozoic and late Paleozoic age at depths greater than 1,500 feet (460 m) below land surface; locally, however, they are at shallow depths in or near uplifted mountainous or domed areas.

Because few wells produce water from the deep aquifers, few data are available that describe the quality or quantity of water in the aquifer, and the available data are either unpublished or scattered throughout various publications. This report assembles hydrologic data from various sources and lists many of the reports describing the ground-water resources as a first step in evaluating the potential for development of this generally unused water resource.

Scope

Many reports of the U.S. Geological Survey and the Montana Bureau of Mines and Geology pertain to specific parts of eastern Montana, as shown on figure 1. Most of the reports include chemical analyses of ground water used in the respective areas. Much information in this report regarding the regional geology is from stratigraphic papers published by the Billings Geological Society (now the Montana Geological Society) in their annual guidebooks and symposia.

Chemical analyses in this report are of water from wells that were drilled primarily for water or from oil-test holes. Some analyses are of water from drill-stem tests, and some are of water produced in association with oil. The most comprehensive report on quality of oil-field water in Montana prior to this study is that done by Crawford (1942). A few analyses from Crawford's report are included herein. Other analyses were obtained from private chemical laboratories, an oil company, the Montana Oil and Gas Conservation Commission, the Montana Bureau of Mines and Geology, and the U.S. Geological Survey.

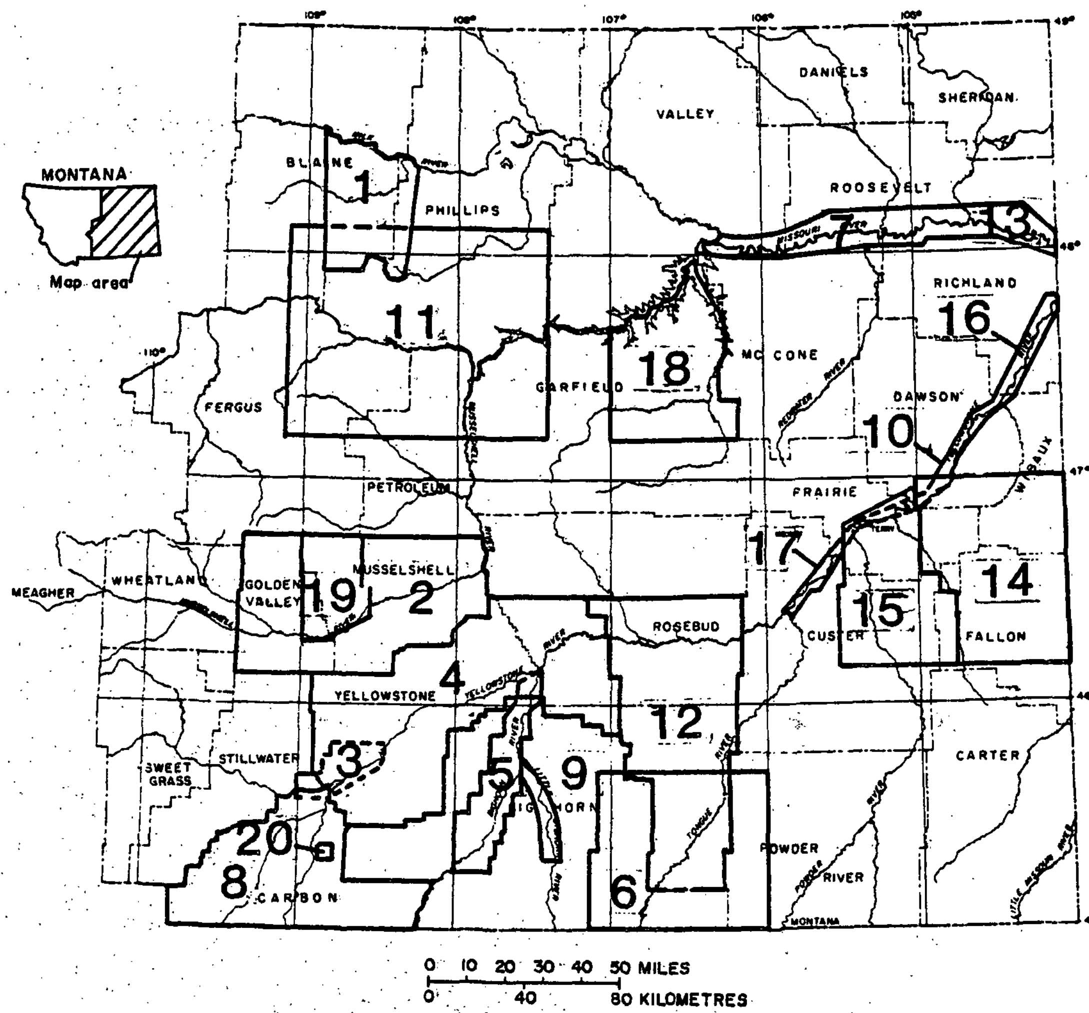
Present water use

Eastern Montana is principally an agricultural area, with dry-land farming and livestock production the major occupations. The upland areas are primarily used for pasture, hay, and wheat or other grains. Alfalfa, sugar beets, and truck crops are raised on irrigated valley bottoms and low terraces along the major streams. Commercial feedlots are an increasingly important business. Petroleum production is the principal nonagricultural source of income, but coal strip mines are becoming economically more significant.

Most ranchers and farmers depend on wells in the alluvium or in the bedrock aquifers of Tertiary or Cretaceous age for their domestic supplies and for most stock water. Domestic or stock wells exceed 1,200 feet (370 m) in depth in east-central Montana, but elsewhere wells more than 300 feet (90 m) deep are uncommon.

Ground water is used in a few places for irrigation, municipal, and feedlot supplies, for secondary recovery of petroleum; and for strip-mining purposes. Surface water is used for most irrigation and municipal purposes and for much of the stock-water supplies.

Water injected into oil fields promotes secondary recovery of petroleum. More than 30 oil fields in eastern Montana were using waterflooding in 1970. The average injection rate in December 1970 in these fields was 214,204 barrels/day, or about 6,200 gal/min (390 l/s). Most of the water used for injection was from formations within the interval from the Fox Hills-basal Hell Creek aquifer to the Madison Group (Montana Oil and Gas Conservation Commission, 1971, p. 5.).



1. Alverson (1965)	11. Osterkamp (1968)
2. Ellis and Meinzer (1924)	12. Renick (1924)
3. Gosling and Pashley (1973)	13. Swenson (1955)
4. Hall and Howard (1929)	14. Taylor (1968)
5. Hamilton and Paulson (1968)	15. Taylor (1968)
6. Hopkins (1973)	16. Torrey and Kohout (1956)
7. Hopkins and Tilstra (1966)	17. Torrey and Swenson (1951)
8. Montana Water Resources Board (1969)	18. Van Lewen and King (1971)
9. Moulder and others (1960)	19. Zimmerman (1956)
10. Moulder and Kohout (1958)	20. Zimmerman (1964)

Figure 1. Index map showing areas of previous investigations.

Well-numbering system

Wells and test holes are numbered in this report according to their location within the land subdivisions of the U.S. Bureau of Land Management. The first numeral of the well number denotes the township, and the letter following denotes whether it is north or south of the base line. The second numeral denotes the range, and the letter "E" following indicates that the range is east of the Montana principal meridian. The third numeral is the section number, followed by letters which show the location of the well within the section; the first letter indicates the quarter section and the second and third indicate successive quarterings. The appended letters A, B, C, and D are assigned in a counterclockwise direction beginning with A in the northeast quadrant. Thus, well 8S54E21ADA lies in the northeast quarter of the southeast quarter of the northeast quarter of section 21, Township 8 South, Range 54 East. (See fig. 2)

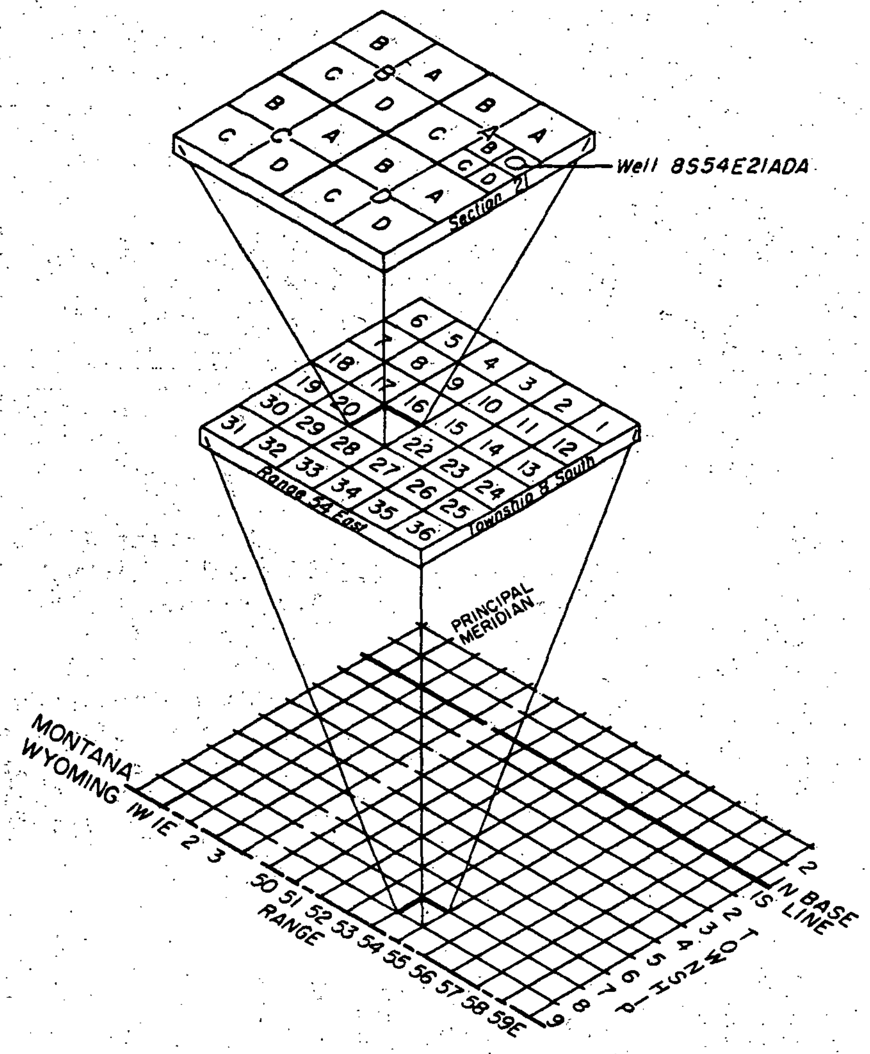


Figure 2.—Well-numbering system.

GEOLOGY

General geologic setting

Eastern Montana includes about 70,000 mi^2 (180,000 km^2) on the western edge of the Great Plains physiographic province. It is bordered on the south and west by mountains that are outliers from and part of the northern Rocky Mountains. Many aquifers that are deeply buried in the eastern part of the State are at shallow depth, exposed, truncated, or removed along the edges of some of the mountains.

The major structural features within the study area include the Bull Mountains basin, the north end of the Powder River basin, Porcupine dome, Cedar Creek anticline, and the western part of the Williston basin. These and other structural features are shown on figure 3.

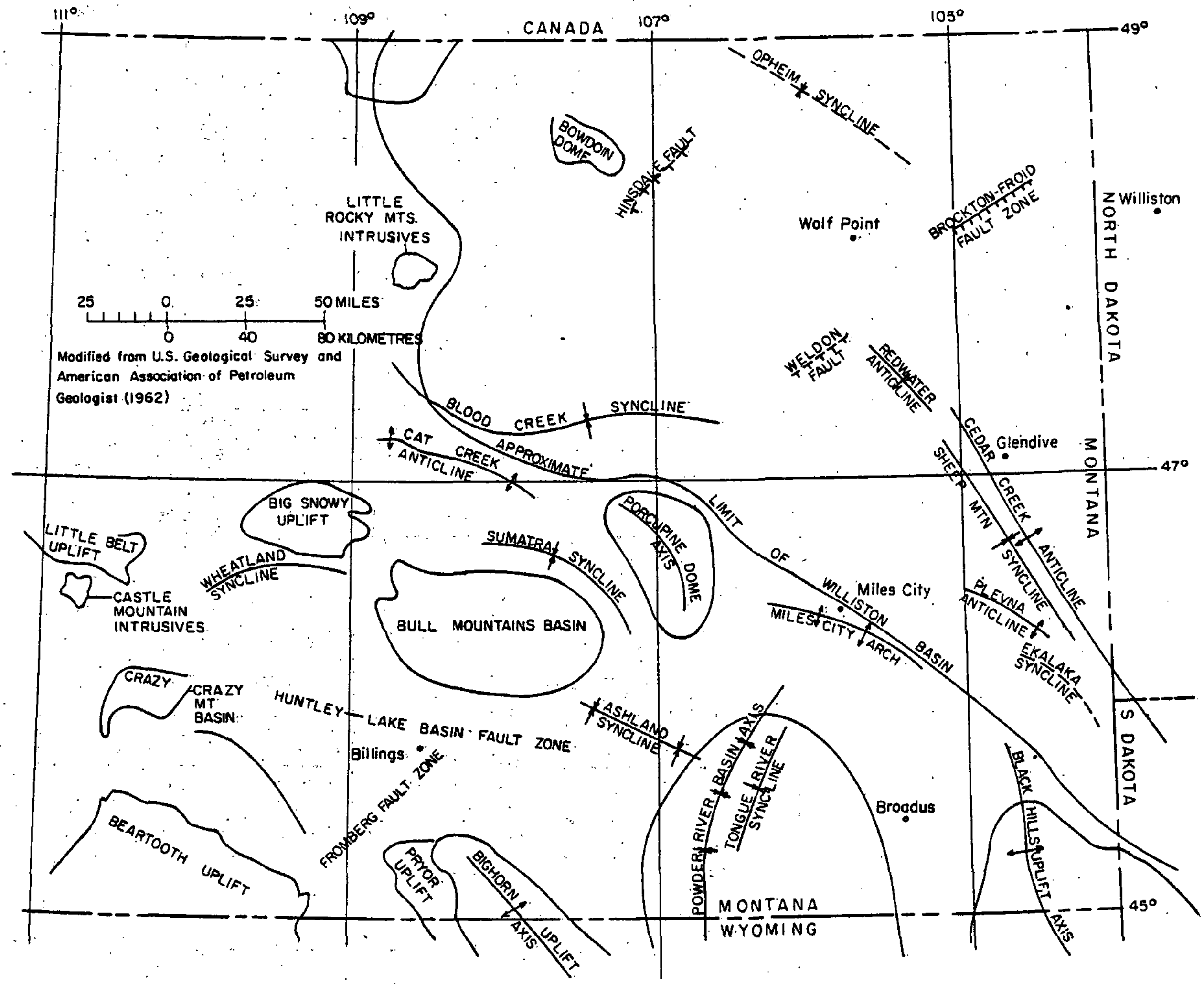


Figure 3.--Major structural features of eastern Montana.

Stratigraphy

No single stratigraphic column describes the formations throughout an area as large as eastern Montana; table 1 is designed to show the formations in various segments of the area. The columns are modified from the correlation chart prepared for the Montana Bureau of Mines and Geology (Balster, 1971). At specific sites some formations are absent, others not listed are present as members or lenses, and some are totally

Table 1.—Geologic formations and their water-bearing properties
(Modified from Balster, 1971)

Erathem	System	Series	Group or Formation	Little Belt-Big Snowy uplifts	South-central Montana, Pryor uplift	Northern Powder River basin	Southeastern Montana-Black Hills uplift
Cenozoic	Quaternary	Holocene		Alluvium	Alluvium	Alluvium	Alluvium
		Pleistocene					
				Terrace gravel	Terrace gravel	Terrace gravel	Pleistocene sediments
	Tertiary	Pliocene or Miocene					
		Paleocene	Fort Union Formation	Tongue River Member, Lebo Shale Member, Tullock Member		Tongue River Member, Lebo Shale Member, Tullock Member	Tongue River Member, Lebo Shale Member, Tullock Member
Mesozoic	Cretaceous	Upper Cretaceous	Hell Creek Formation	Hell Creek Formation	Hell Creek Formation	Hell Creek Formation	Hell Creek Formation
			Montana Group	Lennep Sandstone	Lennep Sandstone	Fox Hills Sandstone	Fox Hills Sandstone
				Bearpaw Shale	Bearpaw Shale	Bearpaw Shale	
				Judith River Formation	Judith River Formation—Parkman Sandstone	Judith River Formation—Parkman Sandstone	
				Claggett Formation	Claggett Formation	Claggett Formation	Pierre Shale
				Eagle Sandstone (includes Virgelle Sandstone Member)	Eagle Sandstone (includes Virgelle Sandstone Member)	Eagle Sandstone—Shannon Sandstone	
				Telegraph Creek Formation	Telegraph Creek Formation	Telegraph Creek Formation	
			Colorado Group	Niobrara Formation	Niobrara Formation	Niobrara Formation	Niobrara Formation
				Carlile Shale	Carlile Shale	Carlile Shale	Carlile Shale
				Colorado Group (in part)	Greenhorn Formation	Greenhorn Formation	Greenhorn Formation
					Frontier Formation; Belle Fourche Shale	Graneros Shale	Belle Fourche Shale
		Lower Cretaceous		Mowry Shale	Mowry Shale		Mowry Shale

unlike their counterparts a hundred miles (160 km) away. For example, the Tensleep Sandstone of Pennsylvanian age is missing in the northwest part of the study area but is more than 100 feet (30 m) thick near Porcupine dome; in eastern Montana the Tensleep equivalent is identified as the Minnelusa Sandstone. Changes in lithology within a formation can be significant; the Eagle Sandstone is a reliable aquifer in central Montana, but in the eastern part it grades into a shaly sandstone and is correlative with part of the Pierre Shale.

Montana part of Williston basin		Lithology, thickness, and hydrologic characteristics
Alluvium		Sand, gravel, clay, and silt; locally well sorted. May be as much as 150 feet thick. Yields as much as 1,600 gal/min to properly developed wells. Water quality ranges from good to poor and is generally a calcium bicarbonate type.
Glacial drift		Ranges from boulders to clay; poorly sorted except where deposited as outwash. Generally less than 100 feet thick. Unsorted till is a poor aquifer; outwash gravel is capable of yielding as much as 1,500 gal/min to wells. Water generally is hard.
Terrace gravel		Sand, gravel, clay, and silt; locally well sorted. Thickness generally less than 50 feet. Yields water to wells from well-sorted gravel and sand, but locally yields do not exceed 5 gal/min. Water quality ranges from fair to poor for irrigation and domestic uses.
Flaxville Gravel		Cobbles in sandy matrix. Thickness generally less than 70 feet. Locally yields as much as 1,200 gal/min to wells. Water is generally hard. Flaxville Gravel is limited to upland areas along interstream divides.
Tongue River Member, Lebo Shale Member, Tullock Member		Sandstone, shale, and coal beds. Less than 2,350 feet thick. Sandstone and coal beds in the Tongue River and Tullock Members yield as much as 50 gal/min to wells. Shallow water is hard; deeper water is fresh to slightly saline and of the sodium bicarbonate type. Lebo Shale Member is a confining bed.
Hell Creek Formation		Sandstone and shale containing thin lenticular coal beds locally. Average thickness is 650 feet. Water from the sandstone strata is a sodium bicarbonate type.
Fox Hills Sandstone		Lennep Sandstone ranges from 250 to 400 feet thick, and the Fox Hills Sandstone is as much as 500 feet thick. Fox Hills and basal Hell Creek sandstones are a single aquifer in southeastern Montana. Both Lennep and Fox Hills are adequate for domestic and stock supplies. Water generally is a sodium bicarbonate type. Fox Hills-basal Hell Creek aquifer generally yields less than 50 gal/min but may yield 200 gal/min to wells; it is the principal source of domestic, stock, and industrial water in southeastern Montana except along extension of Black Hills uplift and Cedar Creek anticline.
Bearpaw Shale		Bearpaw Shale is from 600 to 700 feet thick. In southeastern Montana, grades into Pierre Shale.
Judith River Formation		Interbedded shale and sandstone containing scattered thin coal beds. Thickness generally less than 400 feet. Dependable aquifer in western part of area; wells yield less than 10 gal/min of sodium bicarbonate type water. In eastern part of the area, yield is smaller as sandstone grades into Pierre Shale. Oil-field water from Judith River Formation is principally sodium chloride or sodium sulfate type.
Claggett Formation		Predominantly shale containing scattered sandstone lenses. Average thickness is 400 feet. Water in the sandstones is usually too highly mineralized for domestic or stock use, except in outcrop areas. In eastern part of area, Claggett grades into Pierre Shale.
Eagle Sandstone	Pierre Shale	Mostly sandstone; interbedded shale and lignitic beds in upper part. Total thickness less than 200 feet. In western part of area, the Eagle, particularly the Virgelle Member, is a reliable source of fresh to slightly saline sodium bicarbonate water. Well yields are less than 10 gal/min. Yield is reduced as sandstone grades into Pierre Shale in eastern part of State.
Telegraph Creek Formation		Sandy shale and sandstone, about 300 feet thick. Water is too highly mineralized for domestic supplies.
Upper part of Colorado Group		Marl, shale, shaly limestone; 100 to 200 feet thick. Not an aquifer.
		Silty and sandy bentonitic shale; as much as 650 feet thick. Not an aquifer.
Greenhorn Formation		Frontier Formation is a series of sandstones and shales containing minor thicknesses of coal; from 50 to 900 feet thick. Sandstones yield small amounts of moderately saline water. Greenhorn Formation consists of calcareous shale, shaly marl, and limy sandstone. Thickness is as much as 300 feet. Not known to yield water to wells in the study area.
Graneros Shale		Principally shale containing thin beds of sandstone. Thickness of Belle Fourche Shale ranges from 200 to 600 feet; Mowry Shale ranges from 125 to 250 feet in thickness. These formations are confining beds.

Table 1.—Geologic formations and their water-bearing properties—Continued

Erathem	System	Series	Group or Formation	Little Belt–Big Snowy uplifts	South-central Montana, Pryor uplift	Northern Powder River basin	Southeastern Montana–Black Hills uplift
Mesozoic	Cretaceous	Lower Cretaceous	Colorado Group	Colorado Group (in part)	Thermopolis Shale (includes Muddy Sandstone Member)	Newcastle Sandstone	Newcastle Sandstone
						Skull Creek Shale	Skull Creek Shale
				First Cat Creek Sandstone of Kootenai Formation	Cloverly Group: "Dakota"–Fall River Sandstone	"Dakota"–Fall River Sandstone	Inyan Kara Group: Fall River Sandstone
				Kootenai Formation	Fuson Shale	Fuson Shale	Fuson Shale
				Third Cat Creek Sandstone of Kootenai Formation	Lakota Sandstone	Lakota Sandstone	Lakota Sandstone
	Jurassic	Upper Jurassic	Morrison Formation	Morrison Formation	Morrison Formation	Morrison Formation	Morrison Formation
			Ellis Group	Ellis Group	Ellis Group	Sundance Formation	Sundance Formation
		Middle Jurassic				Gypsum Spring Formation	Gypsum Spring Formation
	Triassic	Lower Triassic			Chugwater Formation	Chugwater Formation	Spearfish Formation
					Dinwoody Formation	Spearfish Formation	
Paleozoic	Permian				Phosphoria Formation	Minnekahta Limestone	Minnekahta Limestone
						Opeche Formation	Opeche Formation
	Pennsylvanian				Tensleep Sandstone	Tensleep Sandstone	Minnelusa Sandstone
			Amsden Group	Amsden Group	Amsden Group	Amsden Group	
	Mississippian			Big Snowy Group			
				Madison Group	Madison Group	Madison Group	Pahasapa Limestone

Montana part of Williston basin	Lithology, thickness, and hydrologic characteristics
Newcastle Sandstone Skull Creek Shale	In south-central part of study area, the Thermopolis Shale is from 500 to 800 feet thick and includes the Muddy Sandstone Member, which is from 50 to 125 feet thick. In southeastern part of study area, the Thermopolis grades into Newcastle Sandstone and Skull Creek Shale. Water is saline. Bell Creek and Ranch Creek oil fields yield small amount of sodium chloride type water from the Muddy Member.
"Dakota"-Fall River Sandstone	Sandstone containing minor amount of interbedded shale, 50 to 160 feet thick. May contain water in western part of study area.
Fuson Shale	Kootenai Formation is composed of sandstone beds and interbedded claystone, 300 to 600 feet thick. Kootenai limited generally to western part of study area, where it yields less than 35 gal/min water to wells. Fuson Shale not known to yield water to wells.
Lakota Sandstone	Third Cat Creek and Lakota Sandstones contain sodium bicarbonate and sodium chloride bicarbonate types of water in Cat Creek area, Petroleum County. Yield more than 1,000 gal/min to wells locally. Both formations are 10 to 200 feet thick.
Morrison Formation	Variable lithology; includes marl, limestone, sandstone. Thickness is as much as 300 feet. Sandstones may yield water in western part of area near outcrops. Potential yield unknown.
Ellis Group	Ellis Group is subdivided (descending) into Swift, Rierdon, and Piper Formations; maximum thickness is 750 feet. Formations principally shaly; locally limestone, sandstone, or gypsum present. Piper contains highly mineralized water; Swift yields good water west of study area. Sundance and Gypsum Spring Formations not known to yield water to wells in study area.
Spearfish Formation	Chugwater and Dinwoody Formations limited to southwestern part of area; generally non-water-bearing shales, sandstones, and anhydrite. Thicknesses variable. Spearfish Formation includes shale, siltstone, and sandstone; interbedded salt, gypsum, and limestone. Thickness is about 350 feet. Not known to yield water to wells.
Minnekahta Limestone Opeche Formation	Minnekahta consists of as much as 50 feet of thin-bedded limestone in southeastern Montana; contains saline water. Opeche Formation consists of shale, shaly sandstone, and sandstone; total thickness is less than 130 feet; not known to yield water to wells. Phosphoria Formation generally less than 100 feet thick; contains limestone, sandstone, and shale in southwestern part of study area; is a confining bed.
Minnelusa Sandstone	Tensleep includes as much as 300 feet of sandstone. Yields as much as 3,700 gal/min of water to wells near Bighorn and Pryor Mountains. Water is slightly saline to very saline, but is usable for irrigation. Tensleep grades laterally into Minnelusa Sandstone in eastern part of Montana.
Tyler Formation	Amsden Group is divided (descending) into Devils Pocket, Alaska Bench, and Tyler Formations in Big Snowy Mountains and adjacent area. The group is a combination of sandstone, shale, and limestone that is collectively as thick as 600 feet but normally is much thinner. The Amsden contains calcium sulfate type water near the Bighorn Mountains. Yields as much as 1,450 gal/min to wells. Yields sodium chloride brine in northeastern part of State. Tyler Formation contains very saline water in Melstone area. Amsden Group is correlative with lower part of Minnelusa Sandstone in eastern part of area.
Big Snowy Group	Big Snowy Group is divided (descending) into Heath and Otter Formations and Kibbey Sandstone. Total thickness of the group is as much as 900 feet. Kibbey Sandstone is predominantly sandstone; contains sodium-rich water.
Madison Group	Madison Group is divided (descending) into Charles Formation, Mission Canyon Limestone, and Lodgepole Limestone. The group is predominantly limestone, but the Charles includes salt, anhydrite, dolomite, and shale beds. The Madison is as thick as 2,200 feet. In northeastern part of study area, water in the Charles and Mission Canyon is saline. In the southern part of the area, the Mission Canyon Limestone yields as much as 875 gal/min to wells. The Mission Canyon is potentially a major aquifer where solution openings have produced high permeability. Lodgepole Limestone yields 1,390 gal/min of moderately saline water to wells near Porcupine dome.

CHEMICAL QUALITY OF GROUND WATER

Ground water is a solution of water and varying amounts of ions that have been dissolved from the rocks through which the water has passed. Table 2 lists some of the constituents and properties of water and their significance in terms of use.

Table 2.—Source and significance of dissolved mineral constituents and properties of water

Substance or property	Source or cause	Significance
Calcium (Ca) and magnesium (Mg)	Dissolved from practically all soils and rocks, but especially from limestone, dolomite, and gypsum Found in large quantities in some brines.	Cause most hardness and scale-forming properties of water; soap consuming. Waters low in calcium and magnesium desired in electroplating, tanning, dyeing, textile manufacture.
Sodium (Na) and potassium (K)	From practically all rocks and soils; also in brines and sewage.	Large amounts in combination with chloride give a salty taste. Sodium salts may cause foaming in steam boilers; high concentrations may limit use of water for irrigation.
Bicarbonate (HCO_3) and carbonate (CO_3)	From action of carbon dioxide in water on carbonate rocks.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium form scale in steam boilers and cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing sulfur compounds.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate with other ions (such as magnesium) gives bitter taste and laxative effect.
Chloride (Cl)	Dissolved from rocks and soils. Found in large amounts in brines.	In large amounts with sodium, gives salty taste to water. In large quantities, increases corrosiveness of water.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils; includes some water of crystallization.	Waters containing more than 1,000 mg/1 dissolved solids are unsuitable for some uses.
Resistivity (ohm-metres at 20°C)	Mineral content of the water.	Indicates degree of mineralization. Varies inversely with the concentration of the constituents.
Hydrogen-ion concentration (pH)	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates and bicarbonates raise the pH.	A pH of 7.0 indicates neutrality of a solution; values higher than 7.0 indicate increasing alkalinity; values lower than 7.0 indicate increasing acidity.
Specific gravity	Relative mass	Specific gravity values increase above 1.000 with increased dissolved-solids concentrations.

Selected chemical analyses of water from deep aquifers in eastern Montana are presented in three appended tables. The analyses are subdivided on the basis of ages of the aquifers. Table 3 includes 67 analyses of water from rocks that range in age from Late Cretaceous (Fox Hills Sandstone) to Permian (Minnekahta Limestone). The majority (61) of the analyses in the table are of waters from rocks of Cretaceous age. Table 4 consists of 52 analyses from rocks of Pennsylvanian age, and table 5 consists of 93 analyses from rocks of Mississippian age. All analyses are rounded in accordance with U.S. Geological Survey standards in effect in 1972.

Classification of water

Ground water in eastern Montana ranges greatly in chemical quality because of its occurrence in a variety of geologic environments. In discussion of the water, the following classification adapted from Robinove and others (1958, p. 3) is used:

Classification	Dissolved solids (milligrams per litre)
Fresh.	Less than 1,000
Slightly saline.	1,000 to 3,000
Moderately saline.	3,000 to 10,000
Very saline.	10,000 to 35,000
Brine.	More than 35,000

Water is also identified as to type on the basis of predominant cations and anions, such as a calcium sulfate type, sodium bicarbonate type, and so on. Identification of the chemical type of water requires that the analytical results be expressed in comparable units. Concentrations in milligrams per litre are converted to milliequivalents per litre by miltiplying the milligram per litre value for each ion by its particular factor from the following table:

Cation:	Conversion factor
Sodium	0.04350
Potassium	.02557
Calcium	.04990
Magnesium	.08226
Anion:	
Chloride	.02821
Sulfate	.02082
Bicarbonate	.01639
Carbonate	.03333

Representation of chemical-quality data by diagrams facilitates identification of similarities and differences in relative abundance of specific ions. The diagrams used in this report are modified from a system suggested by Stiff (1951). The modified Stiff diagrams express ionic concentrations in milliequivalents per litre. Cations of sodium (plus potassium), calcium, and magnesium are plotted to the left of the centerline; anions of chloride, sulfate, and bicarbonate are plotted to the right. Because of the wide range in concentration, three scales were used to plot the data. Fresh to moderately saline waters are shown by unpatterned diagrams; very saline waters and brines that contained less than 100,000 mg/l (milligrams per litre) of dissolved solids are shown by stippled diagrams; and brines that contained more than 100,000 mg/l of dissolved solids are shown by shaded diagrams. The scale of the stippled diagrams is 10 times that of the unpatterned diagrams, and the scale of the shaded diagrams is 100 times that of the unpatterned diagrams.

Stiff diagrams of selected chemical analyses are presented according to major groups of aquifers, which are rocks of Cretaceous, Pennsylvanian, and Mississippian age.

Water from rocks of Cretaceous age

Sodium is the predominant cation in water samples from rocks of Cretaceous age, as shown on figure 4. The principal anions in most samples are chloride or bicarbonate. Sulfate is somewhat high in samples from relatively shallow wells in the Kootenai and Lakota Formations in the area northeast of Roundup. Most water from rocks of Cretaceous age more than 1,500 feet (460 m) deep is marginal or unusable for stock water or irrigation.

The Fox Hills-basal Hell Creek aquifer is the principal source of domestic, stock, and industrial water in southeastern Montana except along the extension of the Black Hills uplift and the Cedar Creek anticline. Most of the water is a sodium bicarbonate type. Yields are generally less than 50 gal/min (3 l/s).

The Judith River Formation and the Eagle Sandstone yield small quantities of usable water in the western part of eastern Montana; in the eastern part of the State both formations grade into sandy shale or shaly sandstone and produce meager quantities of saline water.

Water samples from the Muddy Sandstone Member of the Thermopolis Shale from oil-test holes in the eastern part of the State represent a moderately saline to very saline water. The moderately saline water contains principally sodium, chloride, and bicarbonate; all three very saline samples contain predominantly sodium and chloride.

The formations of Early Cretaceous age are aquifers in the west-central part of the study area. The Kootenai Formation, and the Lakota Sandstone and its equivalents, provide water whose quality ranges from fresh to moderately saline.

Water from rocks of Pennsylvanian age

In the west-central part of the area, the Tensleep Sandstone and the Amsden Group contain a sodium bicarbonate type water that is fresh to very saline. In the southern part of the study area, the Tensleep and Amsden contain water that is slightly saline to very saline; However, some water is usable for irrigation as it contains more calcium than sodium (fig. 5). Yields from some wells exceed 3,000 gal/min (190 l/s). In the southern part of the area, many wells that yield water from the Tensleep Sandstone may in fact be yielding water that has migrated into the Tensleep from the underlying Madison Group.

The Amsden Group yields a very saline sodium sulfate water near the Musselshell River in Musselshell and Rosebud Counties, an area which includes several small oil fields. The two samples from eastern Roosevelt County are typical of highly concentrated sodium chloride brine. Salt beds in the underlying Charles Formation of the Madison Group in this part of the Williston basin may be the source of the salt.

Water from rocks of Mississippian age

Rocks in the Big Snowy and Madison Groups yield water that ranges from fresh to brine and from calcium sulfate to sodium chloride type. Calcium sulfate water is found mostly in the southern and western parts of the area, sodium chloride brine is found principally in the northeastern part, and mixed water—containing principally sodium, sulfate, and chloride or sodium, calcium, chloride, and sulfate—is found in the rest of the area (fig. 6). Yields from wells are as large as 1,390 gal/min (87 l/s).

Solution of salt beds is probably responsible for the occurrence of highly concentrated sodium chloride brine in the northeastern part of the area. The water is unusable for many purposes; however, it is used in secondary recovery operations in oil fields.

SUMMARY

Most of the ground water used in eastern Montana is produced from wells less than 1,500 feet (460 m) deep. A few deeper wells produce water for industrial purposes from formations within the interval from

the Fox Hills-basal Hell Creek aquifer to the Madison Group. Few ground-water data are available that describe the quality and quantity of water contained in this interval.

The Fox Hills-basal Hell Creek aquifer is the most widely used aquifer of Cretaceous age. Other aquifers of Cretaceous age contain water that is too saline for most uses except in the west-central part of the study area where the Kootenai Formation and Lakota Sandstone provide fresh to moderately saline water. Aquifers of Pennsylvanian age contain saline to very saline water in most of the study area, except in the west-central and southern parts where the quality is better. Aquifers of Mississippian age yield water that ranges from fresh to brine. Water quality is best in the southern part of the area and worst in the northeastern part.

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Table 3.—Chemical analyses of water from rocks of post-Pennsylvanian age

[Chemical constituents in milligrams per litre]

Map number (fig. 4)	Well number	Aquifer[1]	Surface reference[2]	Depth sampled (feet)	Method of collection[3]	Date Yr Mo Day	Calcium (Ca)	Magnesium (Mg)	Na + K Sodium (Na)	Na + K Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)
1	1N21E24CC	K1DA	—	3,858-3,869	Prod.	39- 5-18	—	—	2,300		1,710	59
2	2N15E23BB	K5CL	—	4,158-4,163	Bailed	—	150	45	3,600		340	—
-	2N15E23BB	K3FR	—	5,757-5,801	Bailed	32-11 —	—	—	860		1,580	—
3	2N20E04CA	K3EA	KB 4,021	1,230-1,260	Prod.	60-11-25	10	2	760		830	59
-	2N21E27DB	K3FR	KB 3,998	2,900	Prod.	67- 1-30	290	85	10,000	40	769	—
-	2N21E27DB	K3FR	KB 3,998	2,854-2,859	Prod.	66-10-26	370	34	9,800	25	1,010	—
4	2N21E34DB	K3FR	KB 4,041	2,910-2,920	Prod.	58- 2- 5	31	12	630		1,050	—
5	2N51E36DC	K1DA	DF 3,016	5,196-5,219	DST	46- 9-16	43	13	460		760	—
6	3N23E18BD	K3DA	—	—	—	40- 5-28	—	—	1,300		3,120	—
7	3N31E04CBB	K1DA	LS 3,006	4,435-4,467	—	56-10-24	140	50	6,100		535	—
-	3N31E04CBB	J3MO	LS 3,006	4,777-4,805	—	56-10 —	46	11	2,400		930	118
8	4N19E13DB	K1KO	LS 4,225	3,372	Flow	46- 3-26	—	—	1,700		1,860	96
9	4N61E09CC	K1MU	KB 3,099	3,982-4,071	DST	68-11-12	30	12	3,600		1,170	—
-	4N61E12AD	K3EA	—	1,360-1,440	Prod.	42-10-15	120	69	5,800		310	—
10	4N62E19AC	K3EA	—	1,230-1,660	Flow	40-12-13	130	Tr	6,000		360	—
11	5N20E19AA	K1KO	—	2,465	Flow	46- 3-26	—	—	2,300		1,830	109
12	5N60E10DA	K3JR	—	750-904	—	42-10-14	79	22	3,000		205	—
13	6N14E20BA	K1LA	KB 5,101	3,147-3,188	DST	56- 4-29	8	7	480		740	84
14	6N15E02BDC	K1KO	LS 4,808	321-349	DST	57- 7- 8	Tr	Tr	410		200	217
15	6N16E31CC	K3EA	—	3,830-3,871	—	60- 8 —	6	2	570		1,200	59
16	6N22E28DDC	K3FR	LS 3,660	1,815-1,835	Prod.	32- 2- 9	43	17	4,700		775	Tr
17	7N08E23AA	K1LA	KB 5,908	519	—	58- 9- 2	10	2	320		598	132
-	7N08E23AA	J3MO	KB 5,908	750	—	58- 9- 2	11	1	350		671	84
18	7N22E27CA	K1LA	LS 3,568	3,072-3,103	DST	60- 9- 8	11	2	2,100		3,660	—
-	8N20E14CC	J3MO	KB 3,912	1,896-1,921	DST	65- 3-17	9	3	790	10	1,930	Tr
19	8N24E02B	K1LA	KB 3,640	4,357-4,364	Prod.	64- 8-31	6	12	2,300		2,310	337
20	9N23E20AA	K3EA	KB 3,695	323	Flow	68- 8-14	2	10	630		514	—
21	9N23E21BB	K1LA	KB 3,668	3,038-3,047	DST	64- 1-31	9	2	1,500		2,800	185
22	10N25E09DD	K1KO	—	885-998	Bailed	33- 2-20	—	—	1,200		1,220	—
23	10N29E18BD	K1KO	KB 3,093	3,262-3,332	DST	68- 7-30	3	2	1,200		1,650	185
24	11N23E20AAB	K1LA	—	740-758	Flow	33- 7- 1	15	Tr	280		600	—
25	11N31E07CC	K1LA	—	2,850-2,942	Flow	32-10-23	—	—	550		885	24
26	11N31E10	K3JR	—	—	—	60- 9-20	26	10	1,700		585	50
27	11N57E10CC	K3JR	—	830-896	Flow	27- 8-18	120	30	3,200		220	—
-	11N57E15AA	F-SP	—	5,420-5,470	DST	56-10- 3	1,800	260	80,000		76	0
28	12N56E02C	K3FH	—	80	Prod.	31- 8- 9	—	—	340		440	—
29	13N28E22D	K3EA	—	489-499	Bailed	38- 9-16	—	—	770		1,000	109
30	14N52E17BC	K1MU	KB 2,722	5,106-5,150	DST	69-10-29	12	12	3,000		2,160	0
31	15N29E09AC	K1KO	—	1,555-1,578	Flow	26- 1- 7	—	Tr	470		810	53
-	15N29E14AD	K1LA	—	1,650-1,680	Prod.	68-12- 4	2	1	500	2	598	Tr
32	15N30E21CA	K1DA	—	814-1,020	Flow	26- 1- 6	—	—	850		938	—
33	16N27E26BB	K1LA	LS 2,941	—	Flow	46- 3- 5	—	—	450		450	12
34	16N28E28CC	K1KO	LS 3,050	1,310	Flow	28- 4 —	—	—	350		415	—
35	16N49E17DD	K1MU	KB 3,381	5,595-5,711	DST	69-11-26	18	8	2,400		1,980	0
36	17N48E01CC	K1MU	KB 2,895	5,101-5,275	DST	69-11- 2	12	17	2,600		2,030	24
37	18N51E15CC	K1MU	LS 3,009	5,185-5,235	DST	69- 4-10	44	7	3,200	34	1,760	96
38	22N48E25BD	K1DA	LS 2,550	5,010-5,061	DST	52- 2- 1	6	—	1,900		1,980	50
39	27N47E15	K3JR	—	—	—	—	18	—	1,900		980	—
40	29N36E03CAA	K3FR	KB 2,461	1,454-1,492	Prod.	57-11-15	39	18	3,600		660	74
-	30N45E24AD	J2PI	LS 2,745	5,092-5,127	DST	56- 3- 2	760	150	13,000		346	—
41	31N34E02C	K3CR	—	760-815	Prod.	33- 9-26	59	64	3,300		310	—
42	32N31E09AB	K1KO	LS 2,415	2,626-2,700	Flow	69- 6-20	12	1	980	15	2,110	84
43	32N59E32CD	K1MU	LS 2,145	4,515-4,590	DST	68- 3-20	170	36	5,700	100	2,560	—
44	36N47E19B	K3JR	KB 2,562	1,570-1,710	DST	70- 7-31	88	24	3,000		195	—
45	37N46E32BB	K3JR	KB 2,573	—	DST	70- 7-10	900	110	1,400		890	—

Sulfate (SO_4)	Chloride (Cl)	Dissolved solids[4]	Resistivity[5]	pH	Specific gravity	Analysis by[6]	Remarks[7]
23	2,400	5,650	—	—	—	US	Pump 2 BWPD (0.06 gal/min), rep.
22	5,800	9,920e	—	—	—	US	
16	87	1,530	—	—	—	US	
13	630	1,880	3.41	8.7	1.002	Y	
Tr	16,000	26,400	.270	7.9	—	C	
10	15,000	26,600	.27	7.8	—	C	Analysis includes 7 mg/l lithium
Tr	450	1,640	3.90	7.0	—	Y	
390	99	1,380	—	—	—	US	
—	260	3,130	—	—	—	US, Cr	
57	9,400	16,000	.41	7.8	1.012	Y	
1,100	2,300	6,420	1.14	8.3	1.007	Y	
Tr	1,400	4,060	—	—	—	US	Flow 125 BWPD (4 gal/min), est.
5	5,000	9,320	.72	7.6	—	C	
23	9,100	15,200	—	—	—	US	
—	9,200	15,500	—	—	—	US	
Tr	2,400	5,780	—	—	—	US	Flow 25 BWPD (0.7 gal/min), est.
44	4,700	7,970	—	—	—	US	
260	53	1,260	7.7	8.3	—	Y	
240	83	1,050	7.3	9.4	—	Y	Muddy water; filtrate clear
54	83	1,360	5.44	8.2	—	Y	
—	7,000	12,200	—	—	—	US, Cr	
Tr	20	783	8.40	8.4	—	C	
76	20	874	8.20	8.6	—	C	
15	1,200	5,100	1.45	7.9	—	C	
Tr	130	1,890	4.10	8.3	—	C	Analysis includes trace of lithium
140	1,700	5,590	—	9.2	—	US	Initial flow 195 BWPD (5 gal/min), rep.
870	64	1,830	—	7.8	—	US	Flow when casing was pulled
0	460	3,510	2.21	8.6	1.003	Y	
45	1,200	3,040	—	—	—	US, Cr	
190	570	2,970	2.40	8.9	1.003	Y	Temp. 137°F. Flow 72 BWPD (2 gal/min), rep.
140	11	739	—	—	—	US, Cr	Flow 42,750 BWPD (1,240 gal/min), rep.
340	51	1,400	—	—	—	US, Cr	
2,500	440	—	1.88	8.3	—	Y	
—	7,000	11,500e	—	—	—	US, Cr	
3,000	120,000	208,000	.06m	6.5	1.143	C	
320	24	902	—	—	—	US	Water well
410	180	1,960	—	—	—	US, Cr	
18	3,400	8,480	.746	7.8	1.006	—	
240	28	1,620	—	—	—	US, Cr	Initial flow 350 BWPD (10 gal/min), rep.
300	24	1,120	7.00	8.2	—	C	
13	750	2,590	—	—	—	US, Cr	
480	59	1,220	—	—	—	US	Flow 1,000-1,500 BWPD (30-45 gal/min), est.
350	35	939	—	—	—	US, Cr	Flow 1,100 BWPD (32 gal/min), rep.
22	2,600	6,800e	.960	8.0	1.006	—	
32	2,800	7,200e	.874	8.2	1.005	—	
630	3,500	8,400	.86	8.3	—	C	Muddy water, light brown filtrate
970	1,100	5,020	1.60	8.0	—	C	
—	2,400	4,840	—	—	—	Cr	
21	5,200	9,320	.68	8.5	1.008	Y	
4,300	18,000	36,100	.22	6.6	1.032	C	
—	5,100	8,680	—	—	—	US, Cr	
58	180	2,370	3.18	8.3	—	C	Muddy water, clear filtrate
68	7,800	15,200	.47	7.8	—	C	
60	4,800	8,050	.81	6.9	1.006	Y	
2,800	1,500	7,180	1.00	7.0	1.006	Y	

Table 3.—Chemical analyses of water from rocks of post-Pennsylvanian age—Continued

Map number (fig. 4)	Well number	Aquifer1/	Surface reference2/	Depth sampled (feet)	Method of collection3/	Date Yr Mo Day	Calcium (Ca)	Magnesium (Mg)	Na + K Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)
46	1S52E31CC	K1MU	KB 3,234	4,975–5,040	DST	65-11-17	18	3	2,500		1,450	37
47	2S26E07DA	K1LA	———	1,181–1,192	Flow	41- 7-31	—	—	1,100		2,200	120
48	3S31E21AC	K1LA	KB 3,247	1,190–1,290	Flow	69-12-31	0	Tr	570		1,240	—
-	3S58E02DC	P-MI	KB 3,328	5,043–5,107	DST	64- 6-29	460	69	3,000		329	0
49	4S23E02ABA	K1LA	KB 3,454	1,045–1,210	DST	60-11-23	21	6	890		2,000	133
-	4S23E08AA	K3FR	LS 3,577	1,500	Prod.	57- 3-25	Tr	Tr	750		1,620	109
50	5S55E19DC	K1MU	KB 3,382	3,902–4,000	DST	70- 5- 9	91	0	4,000		1,110	—
51	6S53E17DC	K1MU	———	4,945–4,947	Prod.	68- 1-16	16	42	3,700		4,230	—
52	6S60E23BB	K1MU	LS 3,515	2,587–2,671	DST	68- 9- 5	330	120	10,000		330	0
53	8S51E35CA	K1MU	KB 3,615	5,635–5,653	Prod.	69-10-15	110	42	3,300		1,450	—
54	8S54E21	K3FH	———	———	Prod.	———	——	—	140		215	40
55	8S54E35CB	K1MU	LS 3,750	4,302–4,319	Prod.	68- 2-12	19	8	2,100	560	1,640	36

1/ List of aquifers and symbols:
K3FH, Fox Hills Sandstone
K3JR, Judith River Formation
K3EA, Eagle Sandstone
K5CL, Colorado Group
K3FR, Frontier Formation
K1MU, Muddy Sandstone Member of Thermopolis Shale
K1DA, Dakota Sandstone
K1KO, Kootenai Formation
K1LA, Lakota Sandstone
J3MO, Morrison Formation
J2PI, Piper Formation
F-SP, Spearfish Formation
P-MI, Minnekahta Limestone

2/ Surface reference: DF, drillings rig floor; KB, kelly bushing; LS, land surface; figures are altitude in feet above mean sea level

3/ Bailed, sample bailed from nonflowing oil-test hole; DST, drill-stem test; Prod., water extracted with oil or sample from water well; Flow, well flowed at land surface

Sulfate (SO_4)	Chloride (Cl)	Dissolved solids4/	Resistivity5/	pH	Specific gravity	Analysis by6/	Remarks7/
0	3,000	6,330	1.08	8.2	1.005	Y	
49	260	2,610	——	——	——	US	Flow 50 BWPD (1.5 gal/min), rep.
94	80	1,360	——	8.2	——	US	Converted to water well. Analysis includes 1.1 mg/l boron
4,000	2,500	10,200	——	——	——	——	
30	79	2,140	3.44	8.6	1.001	Y	
0	90	1,740	4.00	8.5	1.004	Y	
0	4,100	8,280	1.3	8.0	1.000	——	Bottom-hole temperature 107°F
22	3,400	11,700e	——	8.3	——	US	Pump 124 BWPD (4 gal/min) with oil
34	16,000	27,300	.26	8.0	1.019	Y	
2	4,600	9,650e	——	7.5	——	US	Analysis includes 10 mg/l boron
55	Tr	454	——	9.1	——	——	
Tr	2,800	6,320	——	8.3	——	——	

4/ Calculated as the sum of the constituents; e, residue on evaporation at 180°C

5/ Resistivity calculated in ohm-metres at 68°F unless otherwise noted; m, measured

6/ Analysis by: C, Chemical and Geological Laboratories, Casper, Wyo.
Cr, Crawford (1942)
US, U.S. Geological Survey
Y, Yapuncich, Sanderson, and Brown Laboratories, Billings, Mont.

7/ Abbreviations used: BWPD, barrels of water per day; 1 BWPD equals 0.029 gal/min
est., estimated
gal/min, gallons per minute; 1 gal/min equals 34.3 BWPD
rep., reported

Table 4.—Chemical analyses of water from rocks of Pennsylvanian age

[Chemical constituents in milligrams per litre]

Map number (fig. 5)	Well number	Aquifer[1]	Surface reference[2]	Depth sampled (feet)	Method of collection[3]	Date Yr Mo Day	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Na + K	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)
1	2N28E31DB	N-TE	———	3,932–3,936	Prod.	45–11 —	53	20		890		230	—
2	3N21E05BC	N-TE	———	3,045	Flow	46– 3–27	510	130		340		330	—
3	3N31E04CBB	N-TE	LS 3,006	5,465–5,486	——	56–11– 5	370	77		620		315	—
4	3N31E04CBB	N-AM	LS 3,006	5,540–5,554	——	56–11– 8	400	90		310		340	—
5	4N26E15DC	N-AM	LS 3,593	5,630–5,702	DST	44– 9– 4	270	46		500		325	—
6	5N61E35CB	G-ME	———	5,850–5,935	Flow	64– 4–29	400	59		900		188	—
7	6N14E20BA	N-AM	KB 5,101	3,708–3,724	DST	56– 4–29	12	40		300		645	—
8	6N15E02BDC	N-AM	LS 4,808	872–894	DST	57– 7– 8	240	130		520		465	—
9	7N08E23AA	N-AM	KB 5,908	1,347	——	58– 9– 2	630	100		82		183	0
10	8N21E28CB	N-AM	LS 4,063	2,130–2,184	Prod.	48– 6– 8	570	110		560		485	—
11	8N21E29CA	N-AM	LS 4,026	2,270–2,293	DST	49– 4– 5	470	120		730		695	—
12	8N36E33AA	N-AM	LS 2,718	4,365–4,377	Flow	57– 6–25	260	53		390		380	—
13	9N20E31BD	N-AM	KB 4,189	3,257–3,272	DST	65– 4– 1	8	3	1,100		10	1,650	180
14	9N23E20AA	N-AM	KB 3,695	3,591–3,606	——	64– 4– 8	42	8		1,300		2,680	—
15	9N26E21CA	N-AM	KB 3,584	6,006–6,040	Prod.	64–10– 5	170	26		4,400		813	—
16	10N22E09AC	N-AM	———	1,504	——	49 — —	64	39		1,900		4,850	121
17	10N28E03CC	N-TY	KB 3,132	3,948–3,965	DST	70– 6– 3	89	15		2,100		710	143
18	10N28E17AA	N-TY	LS 3,115	4,106–4,158	DST	60–10 —	400	60		6,100		805	—
19	10N30E01AA	N-TY	LS 3,051	4,724–4,769	Prod.	64– 4–27	29	31		3,800		738	95
20	10N31E11BB	N-TY	KB 2,849	4,765–4,780	Prod.	63– 9–30	16	76		460		511	75
21	10N33E27DD	N-AM	KB 3,111	4,825–4,845	DST	62–12– 6	120	35		4,200		891	Tr.
22	10N33E34BD	N-AM	DF 3,106	4,810	Prod.	62–11–28	160	44		5,400		655	51
23	10N39E09DBA	N-TE	———	2,310–2,320	Flow	30– 8–26	430	62		700		340	—
24	10N39E26B	N-TE	———	3,582–3,597	Flow	31–12– 1	550	140		570		315	—
25	11N23E29A	N-TE	———	———	——	———	280	79		1,000		305	—
26	11N31E11BC	N-TY	———	5,293–5,330	Flow	71– 4– 7	57	20	6,000		44	1,740	Tr.
27	11N31E29DB	N-TY	KB 3,040	4,397–4,408	Prod.	66– 5– 2	280	34	6,400		30	1,730	Tr.
28	11N31E32DB	N-TY	———	4,509	Prod.	68– 9–20	76	50	7,500		75	732	60
—	11N32E07DA	N-TY	———	———	Prod.	69– 4–10	290	27	3,500		46	854	—
29	11N32E07DA	N-TY	———	———	Prod.	68–11–25	190	27	4,500		31	988	48
30	11N33E27BCD	N-AM	KB 3,166	4,595–4,619	DST	55– 3–16	340	49		4,400		695	—
31	11N33E36BD	N-AM	DF 3,221	4,298–4,620	Prod.	55–10–25	100	40		3,900		1,540	—
32	12N25E05DC	N-TE	LS 3,876	———	——	———	60	34		520		440	—
33	13N26E04BD	N-AM	DF 3,166	2,120–2,135	DST	58–10– 6	83	37		2,000		671	60
34	15N55E25AB	N-AM	———	6,616–6,658	DST	60– 7–19	2,600	570		120,000		122	—
35	16N26E18AD	N-TE	LS 3,095	———	Flow	46– 3–16	44	28		320		230	24
36	22N48E25BD	N-AM	LS 2,550	6,260–6,320	DST	52– 2–10	510	50		19,000		560	—
37	30N57E35BB	N-AM	KB 2,295	7,008–7,031	DST	63– 3–23	1,600	290		90,000		195	—
38	30N58E27BC	N-AM	KB 2,305	7,332–7,350	DST	64– 3– 2	4,500	340	110,000		1,700	610	—
39	1S33E13DD	N-TE	———	3,333–3,420	Flow	36– 5–19	680	Tr.		360		230	—
40	4S44E03DA	G-ME	KB 3,191	7,689–7,734	DST	56–10– 2	350	60		9,900		365	Tr.
41	5S49E26BC	G-ME	KB 3,386	7,550–7,600	DST	62–11–13	310	40		1,000		244	0
42	6S24E04DD1	N-TE	LS 4,200	787	Flow	60– 3–31	260	39		2.5	.8	233	0
43	6S32E34ABB	N-AM	LS 3,640	1,749–1,755	Prod.	61– 8– 7	640	70		37		253	—
44	6S36E17BC	N-TE	KB 3,569	6,186–6,209	DST	66– 9–24	370	120		2,100		255	0
45	7S22E07BB	N-TE	LS 4,150	6,797–6,822	DST	51– 8– 8	440	86		110		256	—
46	7S60E31DD	G-ME	KB 3,422	3,360–3,397	DST	66– 9– 8	690	220		———		202	0
47	8S46E11AA	G-ME	KB 3,909	8,906–8,975	DST	64– 6–16	230	140		8,800		1,200	—
48	8S50E18CB	G-ME	KB 3,535	7,915–7,959	DST	64– 8–26	330	40		99		230	0
—	8S58E18CBA	G-ME	DF 3,527	3,419–3,449	DST	57–12–29	720	190		Tr.		145	0

Sulfate (SO_4)	Chloride (Cl)	Dissolved solids4/	Resistivity5/	pH	Specific gravity	Analysis by6/	Remarks7/
1,800	57	2,930	—	—	—	US	
1,900	220	3,250	—	—	—	US	Flow 150 BWPD (4 gal/min), est.
2,100	120	3,430	2.70	7.1	1.005	Y	
1,600	66	2,630	3.72	7.2	1.003	Y	
1,500	75	2,560	—	—	—	US	400 ft water-cut mud
1,600	1,000	4,000	—	7.7	—	US	Flow 5,000 BWPD (145 gal/min), est.
260	39	977	7.5	6.3	—	Y	
1,700	67	2,930	3.1	7.8	—	Y	
1,900	20	2,820	3.20	7.0	—	C	
2,200	300	3,980	—	—	—	US	Initial yield est. 50,000 BWPD (1,450 gal/min), flow. Yield 26 BWPD (0.75 gal/min), rep.
2,100	370	4,120	1.95	6.9	—	C	
1,200	94	2,230	3.15	6.9	1.006	Y	Flow 2,800 BWPD (80 gal/min), est.
500	270	2,930	2.60	8.8	—	C	Analysis includes 3 mg/l lithium. "Recovered 755 ft slightly mud cut sulfur water."
110	470	3,260	2.37	8.4	1.003	Y	
6,200	2,100	13,200	—	7.7	—	US	Pumping 50 BWPD (1 gal/min) with oil
—	160	4,690	—	7.5	—	C	
2,800	780	6,270	1.25	8.5	1.006	Y	
9,600	2,700	19,300	.49	7.4	1.016	Y	
2,800	3,400	10,500	—	8.5	—	US	
60	520	1,460	—	8.0	—	US	
5,900	7,600	12,500	.71	8.3	—	C	Flowed water for 10 minutes
7,600	2,700	16,300	—	7.8	—	US	Flow 65 BWPD (2 gal/min), rep.
2,200	280	3,840	—	—	—	US, Cr	Flow 10,000 BWPD (290 gal/min), est. No oil
2,200	440	4,040	—	—	—	US, Cr	Flow 125,000 BWPD (3,600 gal/min), est.
2,600	160	4,330	—	—	—	Cr	
8,400	2,200	17,600	.51	8.2	—	C	
8,500	3,300	19,400	.47	8.2	—	C	Analysis includes 4 mg/l lithium
5,800	7,200	21,100	.36	8.6	—	C	
4,400	2,300	11,100	.76	7.6	—	C	
5,600	2,600	13,400	.64	8.2	—	C	Black iron sulfide water, clear filtrate
6,500	2,300	13,900	.60	7.5	1.005	Y	
3,900	2,600	11,300	—	—	—	US	H_2S present
1,000	18	1,840	—	—	—	Cr	Flowed 15,000 BWPD (435 gal/min), rep.
3,700	190	6,410	1.42m	8.8	1.006	C	"Flowed fresh water in 25 minutes."
2,400	190,000	313,000	.045	4.4	—	C	"Recovered 100 ft drill mud. Thin mud."
580	59	1,170	—	—	—	US	
7,000	26,000	52,800	.18	6.9	—	C	"Sampled 1,000 ft above tester."
1,900	140,000	235,000	.147	7.6	—	C	"Bottom of fluid column. Recovered 1,736 ft muddy salt water."
1,800	170,000	288,000	.043	7.7	—	C	Analysis includes 20 mg/l lithium. "Thin mud, high water loss. Recovered 247 ft muddy water."
2,200	32	3,360	—	—	—	US	Flow 20,000 BWPD (580 gal/min), rep.
10,000	8,200	29,000	.32	8.2	—	Y	Bottom-hole temperature 202°F
2,700	84	4,420	2.00	7.5	1.004	Sh	
620	.5	1,160	—	7.2	—	US	Specific conductance 1,350 micromhos. Flow 127,000 BWPD (3,700 gal/min)
1,700	16	2,550	—	7.7	—	US	Flow 75 BWPD (2 gal/min), est.
5,100	300	8,060	1.25	7.6	1.006	Y	
1,400	51	2,160	—	—	—	US	
2,300	16	—	—	7.2	—		
9,000	6,900	25,700	.35	7.6	—	C	
870	82	1,530	5.97	7.1	1.001	Y	
2,300	49	3,320	3.40	6.2	—	Y	Water to surface on DST

Table 4.—Chemical analyses of water from rocks of Pennsylvanian age—Continued

Map number (fig. 5)	Well number	Aquifer1/	Surface reference2/	Depth sampled (feet)	Method of collection3/	Date Yr Mo Day	Calcium (Ca)	Magnesium (Mg)	Na + K Sodium (Na)	Na + K Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)
49	9S45E11BA	G-ME	KB 3,885	9,360-9,393	DST	61-12-29	380	81	4,000		660	—
50	9S58E29CD	G-ME	KB 3,537	2,004-2,083	DST	64-11-24	500	Tr.	2,900	25	281	36

1/ List of aquifers and symbols: G-ME, Minnelusa Formation
N-TE, Tensleep Sandstone
N-AM, Amsden Group
N-TY, Tyler Formation

2/ Surface reference: KB, kelly bushing; LS, land surface; DF, drilling rig floor; figures are altitude, in feet above mean sea level

3/ DST, drill-stem test; Prod., water extracted with oil or sample from water well; Flow, well flowed at land surface

Sulfate (SO_4)	Chloride (Cl)	Dissolved solids4/	Resistivity5/	pH	Specific gravity	Analysis by6/	Remarks7/
6,400	1,700	12,800	.70	8.1	——	C	
6,800	80	10,500	.95	9.2	——	C	Analysis includes 3 mg/l lithium. Fowed at rate of 3,600 BWPD (104 gal/min) on DST

4/ Calculated as the sum of the constituents
5/ Resistivity calculated in ohm-metres at 68°F unless otherwise noted; m, measured
6/ Analysis by: C, Chemical and Geological Laboratores, Casper, Wyo.
Cr, Crawford (1942)
Sh, Shell Oil Co.
US, U.S. Geological Survey
Y, Yapuncich, Sanderson and Brown Laboratores, Billings, Mont.
7/ Abbreviations used: BWPD, barrels of water per day; 1 BWPD equals 0.029 gal/min
est., estimated
gal/min, gallons per minute; 1 gal/min equals 34.3 BWPD
rep., reported

Table 5.—Chemical analyses of water from rocks of Mississippian age

/Chemical consitutents in milligrams per litre/

Map number (fig. 6)	Well number	Aquifer1/	Surface reference2/	Depth sampled (feet)	Method of collection3/	Date Yr Mo Day	Calcium (Ca)	Magnesium (Mg)	Na + K Sodium (Na)	Na + K Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)
-	1N28E01BAC	M5MA	LS 3,574	4,010–4,293	DST	57– 3–21	380	99	380		370	0
-	1N28E01BAC	M1MC	LS 3,574	4,300–4,479	DST	57– 3–25	520	150	110		—	—
1	2N20E29BB	M5MA	LS 4,100±	5,460–5,480	DST	56–12 —	340	84	400		195	—
2	2N41E34BA	M1MC	KB 3,236	8,103–8,113	Flow	71– 9– 7	220	35	170		148	0
3	2N51E36DC	M5MA	DF 3,016	7,598–7,687	DST	46– 9 —	350	60	310		245	—
4	3N19E07DA	M1MC	LS 4,394	5,227–5,275	DST	54–12–22	590	130	530		600	—
5	3N19E17CD	M5MA	———	4,325–4,330	Prod.	29–11 —	370	64	330		350	—
6	4N62E08	M5MA	———	6,740–6,786	DST	37– 4–15	370	70	620		270	—
-	4N62E17BAD	M5MA	LS 2,990	6,747–6,798	DST	36– 5–27	1,400	57	1,300		310	—
7	4N62E19D	M5MA	———	6,826–6,837	DST	41– 7–19	420	70	700		309	—
8	6N32E02CC	M3CH	LS 3,381	6,565–6,647	DST	44–10–27	270	41	590		275	—
9	6N32E02CC	M5MA	LS 3,381	6,930–6,973	DST	44–11– 4	580	68	1,400		355	—
10	7N08E23AA	M5MA	KB 5,908	4,178	——	58– 9–10	670	95	130		159	—
11	7N22E27CA	M3CH	LS 3,568	3,856–3,879	DST	60– 9– 8	570	120	380		305	—
12	7N59E01BB	M1MC	LS 2,958	7,020–7,260	Prod.	61– 7–21	330	52	830		254	—
—	7N59E01BBB	M3CH	LS 2,968	6,734–6,773	DST	55– 8–23	2,800	730	19,000		250	0
—	7N59E01BBB	M1MC	LS 2,968	7,155–7,200	DST	55– 8–27	1,500	290	12,000		320	0
—	7N59E01BBB	M1LO	LS 2,968	7,855–7,891	DST	55– 9– 4	480	120	820		350	0
—	9N58E15BC	M1MC	LS 2,918	7,283–7,305	DST	61– 7–19	350	60	1,200		260	0
13	10N30E03ABB	M3CH	LS 3,129	5,510–5,538	——	54– 5–26	2,800	640	32,000		278	—
—	10N58E21DA	M1MC	KB 2,743	7,518–7,552	DST	57– 6–19	450	91	2,700		248	—
14	10N58E33CA	M1MC	KB 2,867	7,304–7,336	Prod.	57–10–15	570	80	1,400		227	—
15	11N29E01CA	M3KI	———	———	——	48– 6– 1	290	54	2,000		280	109
16	11N30E08ABA	M3KI	———	4,433–4,577	Prod.	55–10–25	300	55	3,000		370	—
17	11N31E11	M5MA	———	6,797–7,212	Prod.	68– 2– 2	320	40	1,500	95	366	—
18	11N32E07DA	M3HE	KB 2,993	4,355–4,380	DST	55– 4–18	280	46	4,800		760	—
19	11N32E15AB	M1MC	KB 3,054	6,080–6,770	Flow	69– 9– 4	340	46	1,800		476	—
20	11N43E21CD	M1LO	DF 3,023	8,183–8,230	DST	56– 6 —	220	20	2,000		756	—
21	11N57E09AC	M1MC	———	7,517–7,540	DST	56– 4–13	1,300	100	14,000		313	—
22	12N39E09AA	M1MC	KB 2,982	5,040–5,103	DST	61– 8–23	500	75	890		415	—
23	14N55E27CD	M1MC	KB 2,236	7,436–7,600	Prod.	69–10–20	860	140	5,100		525	0
24	15N29E11DD	M1MC	KB 2,823	4,177–4,194	Flow	68–10–14	620	210	2,100		380	0
25	16N36E28CA	M3CH	DF 3,120	5,946–5,995	DST	53– 9–14	480	90	1,600		523	—
26	16N50E23CB	M3CH	DF 3,076	8,128–8,233	DST	52– 3–10	360	43	1,100		200	59
27	17N24E17CC	M1MC	———	3,221–3,359	DST	63– 7–10	810	210	2,200	40	159	—
28	18N51E15CC	M1MC	LS 3,009	8,404–8,495	DST	69– 3–20	4,700	580	46,000	1,800	512	—
29	19N34E32BD	M3CH	KB 3,110	5,787–5,818	DST	69– 4–25	500	120	1,600		560	0
30	19N34E32BD	M1MC	KB 3,110	6,062–6,076	DST	69– 4–29	390	69	1,300		450	0
31	21N45E12BB	M3KI	KB 2,606	5,938–6,010	DST	65– 9–10	360	47	4,400	70	488	—
32	22N44E18BB	M3CH	KB 2,550	5,794–5,840	DST	66–11– 1	370	76	2,300		295	37
33	22N46E22AA	M3KI	———	5,800–5,900	Prod.	65– 2–22	560	56	3,000		173	—
34	22N46E32AB	M3CH	KB 2,592	6,382–6,444	DST	65– 9–10	500	64	4,500	180	354	—
35	22N47E30BD	M3KI	LS 2,676	6,385–6,435	DST	65– 2– 2	1,300	220	9,500	200	207	—
36	23N41E04DC	M3CH	KB 2,500	5,185–5,225	DST	71– 7–30	44	5.9	1,900		490	—
37	23N50E19BCD	M1MC	LS 2,573	7,363–7,468	DST	52– 6–16	1,800	280	46,000		280	—
38	24N47E18CB	M3CH	LS 2,290	6,074–6,125	DST	66–11–20	1,300	180	22,000		305	42
39	24N50E19CB	M3KI	DF 2,409	6,345–6,390	——	65– 7–23	1,700	140	46,000	540	146	0
40	24N58E29BCA	M5MA	———	9,062–9,517	Prod.	63– 8 —	12,000	1,300	110,000		146	0
41	26N52E06CD	M5MA	KB 2,114	6,450–6,499	DST	64– 7–28	1,100	130	15,000	260	537	—
42	27N51E08DDD	M3CH	KB 1,958	5,784,5,825	DST	65–12–27	8,900	1,400	68,000		37	0

Sulfate (SO_4)	Chloride (Cl)	Dissolved solids[4]	Resistivity[5]	pH	Specific gravity	Analysis by[6]	Remarks[7]
1,800	44	2,780	3.6	7.4	1.007	Y	
1,800	52	2,740	3.7	6.8	1.005	Y	
1,700	110	2,910	—	—	—	—	
770	99	1,370	6.4	6.9	—	Y	Flow 600 BWPD (17 gal/min), rep.
1,300	170	2,340	—	—	—	US	
2,100	340	3,990	2.30m	7.5	1.004	C	
1,300	220	2,810e	—	—	—	US, Cr	Temp. 157°F. Flow 10,000 BWPD (290 gal/min), est. Crawford (1942) reported sample to be from Pennsylvanian Quadrant Formation.
1,400	620	3,210	—	—	—	US	Flow 36 BWPD (1 gal/min), rep.
1,420	3,400	7,720	—	—	—	US	
1,900	460	3,700	—	—	—	US	Flows
1,600	140	2,800	—	—	—	US	
3,900	280	6,450	—	—	—	US	
2,100	18	3,100	3.70	7.0	—	C	"Not considered harmful for stock."
2,200	160	3,560	2.50	7.9	—	C	
1,400	860	3,560	—	7.0	—	US	3,666 BWPD (106 gal/min) pumping, rep. 5-61
3,100	34,000	62,300	.14	6.7	1.042	Y	
3,900	19,000	36,200	.23	6.5	1.026	Y	
1,600	1,100	4,230	1.92	6.7	1.006	Y	
1,600	1,300	4,070	—	7.2	—	US	
2,200	54,400	92,200	.095	5.4	1.066	Y	
1,500	4,100	8,940	.82m	6.3	1.005	C	
1,300	2,300	5,800	1.27	6.7	—	C	
2,800	1,300	6,690	—	8.1	—	C	
5,400	2,500	12,400	—	—	—	US	
1,500	1,700	5,350	1.35	7.8	—	C	
10,000	260	15,800	.67	7.2	1.014	Y	Flow 720 BWPD (21 gal/min), rep.
1,600	2,100	6,120	1.18	—	1.005	Y	Flow 28,800 BWPD (835 gal/min); completed as water well
2,100	1,500	6,210	—	6.7	1.007	C	Flow 48,000 BWPD (1,390 gal/min); completed as water well
3,700	21,000	39,400	.20m	6.3	1.025	C	
2,200	640	4,570	1.90	6.8	—	C	Flowed fresh water in 15 minutes
940	8,800	16,400	.43	6.1	1.012	Sh	Converted to industrial water well
2,600	2,800	8,470	.92	6.9	1.006	Y	Flowed black sulfur water in 11 minutes
2,300	1,600	6,300	—	—	—	US	
1,600	1,100	4,310	1.90	8.3	—	C	
3,200	3,000	9,600	.810	7.3	—	C	Analysis includes 4 mg/l lithium. Flowed water in 13 minutes.
2,800	80,000	136,000	.071	6.7	—	C	
1,800	2,000	6,220	1.15	7.1	1.005	Y	Bottom-hole temperature 155°F
1,800	1,500	5,240	1.25	7.3	1.004	Y	Bottom-hole temperature 154°F
5,000	3,600	13,700	.600	7.4	—	C	Analysis includes 8 mg/l lithium
3,700	1,500	8,110	1.10	8.8	1.007	Y	
2,000	4,200	9,860	—	7.5	—	US	Flows; represents 6 wells
4,400	4,800	14,700	.530	7.4	—	C	Analysis includes 6 mg/l lithium
2,600	16,000	29,700	.250	7.5	—	C	Analysis includes 15 mg/l lithium
2,900	560	5,890	1.35	7.8	—	M	
4,200	72,000	125,000	.081	8.5	—	C	
7,900	31,000	62,400	.13	8.8	1.044	Y	
3,100	73,000	125,000	.074	7.1	—	C	Analysis includes 20 mg/l lithium
260	200,000	320,000	—	5.5	—	US	
2,600	24,000	42,900	.180	7.0	—	C	Analysis includes 4 mg/l lithium. Cloudy, black water. Black precipitate.
670	120,000	203,000	.054	6.3	1.134	Y	

Table 5.—Chemical analyses of water from rocks of Mississippian age—Continued

Map number (fig. 6)	Well number	Aquifer1/	Surface reference2/	Depth sampled (feet)	Method of collection3/	Date Yr Mo Day	Calcium (Ca)	Magnesium (Mg)	Na + K: Sodium (Na)	Na + K: Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)
43	28N39E20CA	M1MC	KB 2,127	4,450	——	71- 7-30	380	99	1,100	100	146	0
44	28N50E02AD	M3CH	KB 2,181	5,984-6,010	DST	65- 5- 9	2,900	780	120,000		260	—
—	28N51E02AC	M3CH	LS 2,111	5,668-5,814	Prod.	64- 9-14	970	120	73,000	500	207	—
45	28N51E12CC	M5MA	KB 2,179	5,550-5,920	Prod.	54-12- 9	1,000	140	77,000		239	—
—	28N51E25AC	M3KI	KB 2,178	5,349-5,378	DST	67- 1- 9	820	85	22,000	650	439	0
—	28N51E25AC	M3CH	KB 2,178	5,635-5,676	DST	67- 1- 9	1,000	150	63,000	500	378	0
—	28N51E27AC	M3HE	KB 2,167	4,958-4,970	DST	56- 1-24	1,400	230	22,000		475	—
46	28N52E18AC	M1MC	KB 2,135	6,025-6,077	DST	52- 5-17	890	130	18,000		262	0
47	29N31E24DC	M5MA	KB 2,411	3,495-3,500	Prod.	55- 1-20	520	150	160		156	—
—	29N50E05CC	M3CH	KB 2,636	6,446-6,461	DST	54-10- 6	5,300	810	75,000		121	—
—	29N50E15BB	M3CH	DF 2,383	6,172-6,180	Prod.	56- 1-24	260	110	6,800		205	Tr.
—	29N51E08CC	M3CH	KB 2,111	5,784-5,792	Prod.	56- 1-24	1,200	300	20,000		145	—
48	30N44E07DDD	M3CH	KB 2,805	5,564-5,600	DST	68- 7-26	690	170	9,600		370	0
49	30N45E24AD	M3CH	LS 2,745	5,933	DST	56- 3-16	10,000	2,000	110,000		162	—
50	30N48E20DD	M1MC	LS 2,603	6,705-6,721	DST	57- 1-30	880	130	21,000		551	85
51	30N57E35BB	M5MA	KB 2,295	8,664-8,668	DST	63- 4- 8	7,800	950	84,000	3,000	195	—
52	31N45E23AA	M1MC	KB 2,905	6,638-6,670	DST	57- 1- 1	480	190	9,200		259	64
53	31N45E23AA	M1MC	KB 2,905	6,533-6,547	DST	57- 1-31	1,300	240	23,000		551	—
54	31N47E33AC	M1MC	KB 2,721	6,586-6,640	DST	64-11-10	2,000	300	110,000	600	146	—
55	31N48E25BC	M3CH	KB 2,683	6,397-6,418	Prod.	66- 3-30	620	130	7,100		279	—
56	31N51E03BC	M3CH	KB 2,644	7,160-7,173	DST	65- 6- 3	2,200	240	110,000	1,400	146	—
57	31N51E04AA	M3CH	KB 2,658	7,121-7,145	Prod.	67- 8- 2	1,400	200	39,000	580	378	—
58	32N49E13DA	M3CH	LS 2,423	6,537-6,545	Prod.	55-10-22	840	210	16,000		294	—
—	32N50E19BC	M1MC	KB 2,420	6,828-6,843	DST	55- 8- 3	540	95	8,400		231	—
59	32N59E29A	M1MC	———	7,959-7,976	Prod.	60-10-26	12,000	1,600	110,000	4,200	110	—
60	33N43E16CA	M1MC	LS 2,844	6,159-6,199	DST	56- 8-24	430	79	840		465	—
61	33N49E34CB	M1MC	LS 2,684	7,313-7,349	DST	56- 5-16	1,600	280	29,000		259	—
62	33N56E03CC	M5MA	KB 2,235	7,442-7,536	DST	64- 9-14	750	140	110,000	3,500	232	—
63	33N56E05AB	M1MC	LS 2,229	7,730-7,805	DST	57- 8-30	1,400	320	62,000		356	—
64	37N58E05CA	M5MA	KB 2,201	6,439-6,478	Prod.	66- 9-28	5,000	890	110,000		173	—
—	1S33E13DD	M5MA	LS 3,000	3,560-3,570	DST	37-11-23	650	170	53		92	0
65	2S29E17BC	M5MA	KB 3,557	4,016-4,100	DST	44- 9-12	600	150	410		170	—
66	3S31E34BC	M5MA	LS 3,494	2,959	Prod.	55- 6-18	630	130	39		305	0
67	3S58E02DC	M3CH	KB 3,328	5,690-5,805	DST	64- 6-29	390	72	840		366	—
68	4S23E08AA	M5MA	LS 3,577	3,530-3,535	Prod.	57- 3-25	690	230	46		255	0
69	5S57E31AB	M1LO	LS 3,469	5,715-5,778	DST	50- 7-10	540	140	120		194	—
70	6S18E04BD	M5MA	LS 5,130	4,160-4,165	Prod.	44-10- 2	560	150	77		45	—
71	6S32E27CD	M5MA	LS 3,525	2,009-2,011	Flow	67-10- 6	230	75	5		190	—
—	6S32E34ACC	M5MA	LS 3,435	1,860-1,872	DST	61- 8- 8	170	64	11		190	—
72	7S59E03AB	M1MC	KB 3,496	4,496-4,650	DST	61- 9-13	530	140	120		255	0
73	8S46E11AA	M1MC	KB 3,909	9,580-9,650	DST	64- 6-16	230	34	110		232	Tr.
74	8S54E21ADA	M5MA	KB 3,631	6,990-7,190	Prod.	70-10-16	170	47	36		112	0
75	9S45E11BA	M1MC	KB 3,885	10,028-10,203	DST	62- 1-22	300	44	460		770	—

1/ List of aquifers and symbols: M3HE, Health Formation
M3KI, Kibbey Sandstone
M5MA, Madison Group
M3CH, Charles Formation
M1MC, Mission Canyon Limestone
M1LO, Lodgepole Limestone

2/ Surface reference: KB, kelly bushing; LS, land surface; DF, drillings rig floor; figures are altitude, in feet above mean sea level

3/ DST, drill-stem test; Prod., water extracted with oil or sample from water well; Flow, well flowed at land surface

Sulfate (SO_4)	Chloride (Cl)	Dissolved solids[4]	Resistivity[5]	pH	Specific gravity	Analysis by[6]	Remarks[7]
2,400	840	5,010	—	7.8	—	M	Analysis includes SAR 12.6,conductance 5,800 micromhos
150	190,000	315,000	.04	4.8	1.203	—	
2,200	110,000	190,000	.057	8.1	—	C	Analysis includes trace of lithium. "Clear water with precipitated iron sulfide."
2,600	120,000	201,000	—	—	—	US	Initial flow 214 BWPD (6 gal/min)
1,800	35,000	60,800	.130	7.1	—	C	
1,500	98,000	164,000	.062	6.8	—	C	
1,400	36,000	61,400	.14m	6.6	1.044	C	
2,400	28,000	50,000	.165	7.4	1.043	—	Disagreeable odor
1,900	100	2,890	3.20	6.4	1.005	Y	
2,100	130,000	210,000	.073m	5.7	—	C	
3,000	9,000	19,300	.39m	8.5	1.015	C	
120	33,000	54,300	.16m	6.5	1.039	C	
3,700	14,000	27,800	.27	7.2	1.020	Y	
510	190,000	310,000	.049m	6.0	1.211	C	
4,400	31,000	58,200	.15m	8.9	1.050	C	
540	150,000	244,000	.046	6.5	—	C	Analysis includes 4 mg/l lithium
2,300	14,000	26,000	.340m	8.0	1.012	C	
4,200	35,000	63,900	.140m	6.7	1.045	C	
3,700	170,000	282,000	.044	7.0	—	C	Analysis includes 50 mg/l lithium
2,400	10,000	20,800	—	7.5	—	US	Pumps 66 BWPD (2 gal/min), with oil
3,000	170,000	285,000	.048	6.4	—	C	Analysis includes 10 mg/l lithium
2,500	61,000	104,000	.86	7.7	—	C	
2,900	24,000	43,500	—	—	—	US	Flows
3,800	11,000	24,200	.325m	6.4	—	C	Black, salty, sulfur water; H_2S present
290	200,000	325,000	—	6.6	—	US	Flow 109 BWPD (3 gal/min)
1,500	900	3,980	2.40m	7.6	1.004	C	H_2S present
3,400	45,000	79,100	.185m	6.2	1.035	C	
840	180,000	296,000	.045	7.3	—	C	Analysis includes 10 mg/l lithium
3,400	96,000	163,000	.062m	6.3	1.110	C	
770	180,000	295,000	—	5.5	1.187	US	Represents several unitized wells
2,200	10	3,170	—	—	—	US	
2,600	120	3,780	—	—	—	US	
1,800	14	2,790	3.58	7.1	1.005	Y	
2,200	220	3,940	2.25	7.9	—	C	Analysis includes 2 mg/l lithium
2,300	100	3,530	3.32	7.2	1.005	Y	
1,900	35	2,810	3.95	7.1	—	C	
2,100	19	2,890	—	—	—	US	
700	12	1,110	—	7.6	—	US	Flow 10,000 BWPD (290 gal/min), rep.
510	12	860	—	7.6	—	US	
1,800	76	2,780	3.70	7.0	1.002	Y	
650	40	1,180	6.75	8.2	—	C	
470	57	860e	—	7.9	—	M	Analysis includes conductance 1,160 micromhos. Temp. 130°F. Flow 30,000 BWPD (875 gal/min), rep.
1,100	100	2,400	3.55	7.9	—	C	

4/ Calculated as the sum of the constituents; e, residue on evaporation at 180°C

5/ Resistivity calculated in ohm-metres at 68°F unless otherwise noted; m, measured

6/ Analysis by: C, Chemical and Geological Laboratories, Casper, Wyo.
Cr, Crawford (1942)
M, Montana Bureau of Mines and Geology
Sh, Shell Oil Co.
US, U.S. Geological Survey
Y, Yapuncich, Sanderson, and Brown Laboratories, Billings, Mont.

7/ Abbrevaitions used: BWPD, barrels of water per day; 1 BWPD equals 0.029 gal/min
est., estimated
gal/min, gallons per minute; 1 gal/min equals 34.3 BWPD
rep., reported
SAR, sodium-adsorption ratio

ERRATA - Table 5

WELL	CORRECTED DISSOLVED SOLIDS
2N20E29BB	2,910e
9N58E15BC	4,670
14N55E27CD	16,100
23N41E04DC	5,640
2S29E17BC	3,980