WATER RESOURCES OF BIG HORN COUNTY, WYOMING

By Maria Plafcan, Earl W. Cassidy, and Myron L. Smalley

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CONTENTS

CONTENTS--Continued

PLATES [Plates are in pocket]

FIGURES

FIGURES--Continued

TABLES

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To obtain
acre	4,047	square meter
acre	0.4047	hectare
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square meter
foot (ft)	0.3048	meter
foot squared per day (ft^2/d)	0.0929	meter squared per day
gallon	0.003785	cubic meter
gallon per minute (gal/min)	0.06309	liter per second
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter
gallon per day per square foot [$(gal/d)/ft^2$]	4.720×10^{-7}	meter per second
inch (in.)	2.54	centimeter
mile (mi)	1.609	kilometer
million gallons (Mgal)	3,785	cubic meter
million gallons per day (Mgal/d)	0.04381	cubic meter per second
pound per square inch (lb/in^2)	6.895	kilopascal
square mile (mi^2)	2.590	square kilometer

Temperature can be converted to degrees Fahrenheit (°F) or degrees Celsius (°C) as follows:

$$°F = 9/5\ (°C) + 32$$

$$°C = 5/9\ (°F - 32)$$

Shut-in pressure at the wellhead, in pounds per square inch (lb/in^2), can be converted to hydraulic head, in feet of water above land surface, as follows:

$$(lb/in^2) \times 2.31 = \text{feet of water above land surface}$$

Use of conversion factor of 2.31 assumes that water is at a temperature of 4 degrees Celsius with a density of 1.0 gram per cubic centimeter.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called *Sea Level Datum of 1929.*

Abbreviated water-quality units used in this report:

L	liter
mg/kg	milligram per kilogram
mg/L	milligram per liter
mrem/yr	millirem per year
pCi/L	picocurie per liter
µg/kg	microgram per kilogram
µg/L	microgram per liter
µm	micrometer
µS/cm	microsiemens per centimeter at 25 degrees Celsius

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ABSTRACT

Ground water in unconsolidated aquifers is the most reliable and accessible source of potable water in Big Horn County, Wyoming. Well yields generally ranged from 25 to 200 gal/min (gallons per minute), however, yields of 1,600 gal/min are reported from wells in the gravel, pediment, and fan deposits.

Bedrock aquifers that yield the most abundant water supplies are the Tensleep Sandstone, Madison Limestone, Bighorn Dolomite, and Flathead Sandstone. The aquifers with the most potential for development as a water supply, predominately composed of sandstone, are the Lance, Mesaverde, and Frontier Formations.

The Madison Limestone, the Darby Formation, and the Bighorn Dolomite form the Madison-Bighorn aquifer. Reported yields from the aquifer ranged from 40 to 14,000 gal/min. Flowing wells from the Madison-Bighorn aquifer had shut-in pressures ranging from 41 to 212 pounds per square inch (95 to 490 feet above land surface).

Shut-in pressures from flowing wells in bedrock indicate declines, from the time the wells were completed to 1988, as much as 390 feet. Flows have also decreased over time.

Water samples from wells completed in unconsolidated aquifers have concentrations of dissolved solids less than 2,000 mg/L (milligrams per liter). Water from unconsolidated aquifers are classified as a calcium sulfate type, a sodium sulfate type, and sodium-calcium sulfate type.

Water samples from wells completed in aquifers in Paleozoic and Precambrian rocks had median concentrations of dissolved solids ranging from 111 to 275 mg/L. Water samples from wells in Tertiary and Cretaceous rocks had a median concentration of dissolved solids ranging from 1,107 to 3,320 mg/L. Water types for these aquifers were usually sodium sulfate.

Perennial streams originate in the mountains and ephemeral streams originate in the Bighorn Basin. Irrigation return-flow to streams maintains perennial flow in what would otherwise be ephemeral streams. Streams that originate in the Bighorn Basin have specific conductance values generally greater than 1,000 mg/L, whereas streams that originate in the Bighorn Mountains have specific conductance values generally less than 1,000 mg/L. The predominant dissolved constituents are calcium or sodium and bicarbonate or sulfate.

Concentrations of pesticides detected in surface-water samples were less than the U.S. Environmental Protection Agency (USEPA) maximum contaminant levels. The detected concentrations of pesticides in streambed material in the organochlorine insecticide class ranged from 0.1 to

8.0 micrograms per kilogram. Pesticides detected in ground-water samples included dicamba and picloram at a concentration of 0.40 µg/L (micrograms per liter), atrazines (0.40 µg/L), aldicarb sulfone (1.44 µg/L), aldicarb sulfoxide (0.52 µg/L), and malathion (0.02 µg/L).

Analyses of ground-water samples for radionuclides indicate that concentrations from four municipal wells exceeded the maximum contaminant level established by the USEPA. Of these four wells, concentrations in water samples from the municipal well at Frannie consistently exceeded the USEPA maximum contaminant level for dissolved gross alpha activity of 15 pCi/L (picocuries per liter) and radium-226 plus radium-228 (5 pCi/L). The source of the radioactivity is postulated to be the Madison Limestone.

Surface water accounts for 96 percent and ground water accounts for 4 percent of total offstream water use in Big Horn County, Wyoming. Irrigation is the largest offstream use of both surface and ground water. About 99 percent of offstream surface water and 55 percent of ground water is used for irrigation. Eighty-two percent of the water used for irrigation is consumed, which includes a 37-percent conveyance loss and 45 percent consumed by the irrigated crops. Ground water supplies 89 percent of water used for domestic purposes and about 16 percent of water used for public supplies, which shows that ground water is a primary domestic water supply in rural areas where public supplies are not available.

INTRODUCTION

Big Horn County, which covers 3,177 mi^2 on the eastern flank of the Bighorn structural basin in northwestern Wyoming, is the 12th largest county in the State (fig. 1). Eighty percent of the land is managed under Federal authority. The eastern boundary of the county generally is delineated by the crest of the northwesterly trending Bighorn Mountains. The steeply dipping western flanks of these mountains abruptly give way to uplands and plains that are dissected by perennial and ephemeral streams that join the northerly flowing Bighorn River.

The area west of the Bighorn Mountains is about 4,000 ft above sea level and is arid. The intensive irrigation practiced there creates large demands for water. Major population centers are along the Bighorn River and its tributaries. Sources of public water supply in the county are diverse. Treated surface water predominantly is used by the larger municipalities (Basin, Greybull, and Lovell). Smaller towns, including Burlington, Byron, Frannie, Cowley, Manderson, and Hyattville, have developed ground-water supplies for potable water. Because of water-supply and water-quality problems, many towns have not developed public-supply systems and must purchase and haul drinking water.

Water-supply needs have slowly increased with the growth of industrial needs. The population of the county (about 12,000 in 1987), as well as percentage of land devoted to farms (25 percent) and crops (6 percent), has remained nearly constant for the past 20 years (Wyoming State Department of Administration and Fiscal Control, 1987). The most substantial increases in water demand have been from oil exploration during the late 1970s and increased water demands for use in secondary oil-recovery operations. Future demands for water resources likely will originate from the private sector.

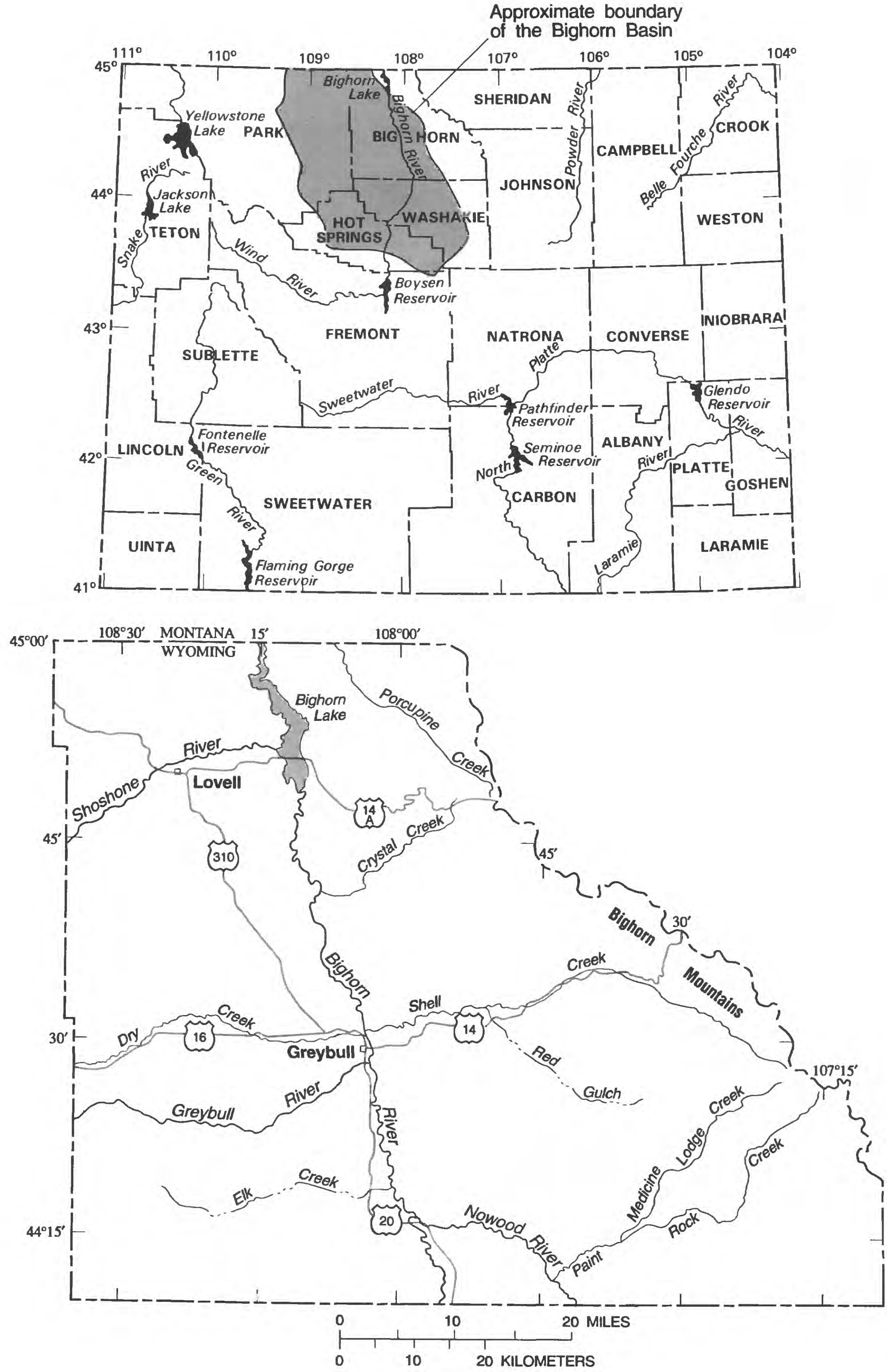


Figure 1.--Location of Big Horn County.

To obtain the kinds of information that is needed to plan for and manage the increased demands for water in Big Horn County, the U.S. Geological Survey (USGS), in cooperation with the Wyoming State Engineer, conducted a study to describe and quantify the water resources of the county. Additional hydrologic data were collected as part of the study where such data were lacking or considered inadequate and where water quality was a concern.

Purpose and Scope

The purpose of this report is to describe the water resources in Big Horn County using data and information currently (1989) available or collected during this study. It is one of a series of reports on the water resources of Wyoming counties. This report includes the following: (1) evaluation of water yields from wells and shut-in pressure trends in artesian wells; (2) summary of water-quality analyses of water samples collected from wells developed in unconsolidated deposits and bedrock; and (3) a summary of data on agricultural pesticides detected in surface water, ground water, and streambed materials.

The principal water resources are streamflow and ground water; streamflow is described first, but the emphasis is on ground water, which is used extensively by landowners for domestic needs and agriculture. Components of the geohydrology of the county are described, including the physiography, climate, and geology, as well as the occurrence, recharge, movement, and discharge of ground water. Both surface- and ground-water occurrence and chemical quality in relation to water use are included.

Most of the existing data were compiled from records of the U.S. Geological Survey and the Wyoming State Engineer. These data are supplemented with data collected primarily during the summers of 1987 and 1988. About 50 percent of the water-quality analyses were from samples collected during 1988. All of the ground-water pesticide data were collected during 1987 and 1988. No effort was made to inventory every well, spring, or drain in the county but rather to select representative wells and springs that yield water from representative aquifers for evaluation and water-quality analysis. Pursuant to this goal, data from 388 ground-water sites and 174 water-quality samples were evaluated.

Physiography

Big Horn County is in the Middle Rocky Mountains province on the eastern flank of the Bighorn Basin (Fenneman, 1946). The county may be further divided into the Bighorn Mountains and the comparatively flat and dry areas west of the mountain front (fig. 2). The mountains, which trend northwesterly, rise to about 13,100 ft near Cloud Peak with granite and gneissic rocks of Precambrian age at the highest altitudes and a broad mantle of sedimentary shales, carbonates, and sandstones of Paleozoic age at lower altitudes. The thick sedimentary sequence is nearly horizontal in the higher altitudes of the mountains. The dip of the strata increases toward the basin. At many locations along the mountain front the strata are nearly vertical, forming abrupt and spectacular flat-iron cliffs. Steep canyons containing deeply incised, westwardly flowing streams originate in the mountains. The mountain front effectively delineates the north-eastern edge of the Bighorn Basin.

To the west of the mountain front, a broad northwesterly trending area 25 to 30 mi wide displays ridges and hogbacks of predominantly Mesozoic strata. South of Greybull the western extent of this area is located approximately by the northward flowing Bighorn River. North of Greybull the western extent of the area is west of the Bighorn River and trends progressively westward. At some locations the Mesozoic strata are flat-lying and eroded into butte-like landforms, but cuestas, domes, and asymmetrical plunging folds are more common. At Cedar Mountain south of Hyattville, and Sheep Mountain north of Greybull, Paleozoic rocks are exposed at the surface in spectacular folds. Northwesterly trending asymmetric folds and strike valleys are other prominent features. Many small streams that dissect the area are ephemeral. Prominent features include where the Bighorn River traverses the fold axes of Sheep Mountain and Little Sheep Mountain, demonstrating examples of stream superposition.

Farther west, a broad area of flat-lying to gently dipping Tertiary strata is exposed. In the eastern part of this area the Fort Union Formation of Paleocene age crops out and is seen dominantly to the west of the Bighorn River; thinly bedded carbonaceous shale and coal are present here. Farther west and continuing to the western county boundary, the multicolored shales and siltstones of the Willwood Formation of early Eocene age dominate the landscape. This formation forms badlands where eroded and conceals underlying structural features. Terrace deposits, which are extensively cultivated, overlie the Willwood Formation between Table Mountain and Dry Creek along the Emblem Bench. Prominent features in this area include Table and Tatman Mountains.

Several perennial streams are present in the county, including the Bighorn, Nowood, Greybull, and Shoshone Rivers, and Paint Rock and Shell Creeks. The Bighorn River is the major river in the county. Most of the smaller streams are ephemeral.

Climate

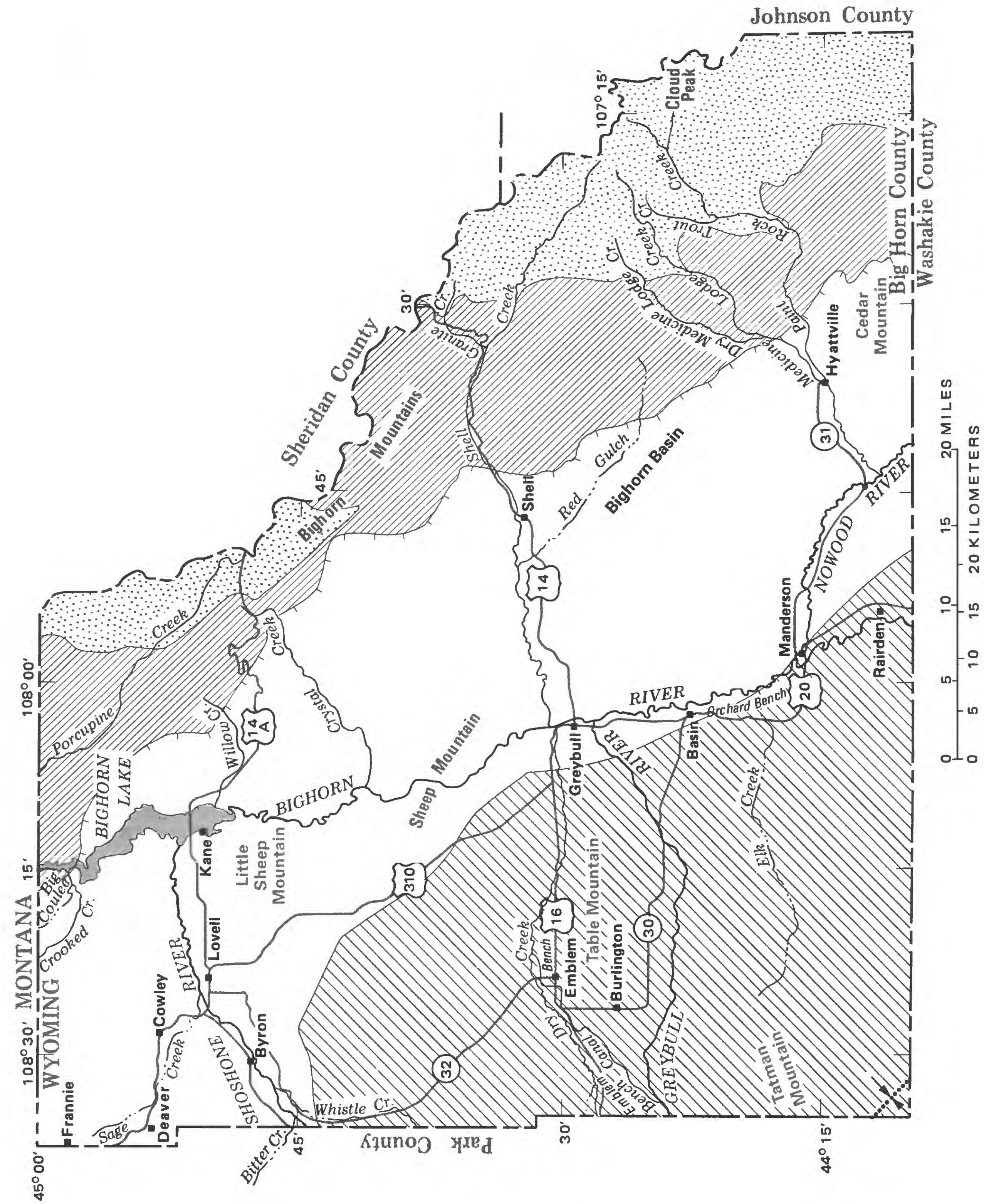
For the period of record (1951-80), the mean annual precipitation in Big Horn County ranged from 5.5 in. at Deaver in the northwestern part of the county to about 30 in. in the alpine and alpine tundra areas in the Bighorn Mountains (fig. 3). The area west of the Bighorn Mountains, which includes the most populated sections in the county, on the average receives less than 10 in. of precipitation per year. This meets the recognized criterion for classification as desert (Martner, 1986, p. 6).

Variations in precipitation and temperature are related to changes in altitude. Graphs of average monthly precipitation and temperature are shown in figure 4 for weather stations at Emblem in the Bighorn Basin and Burgess Junction (east of Big Horn County in Sheridan County) in the Bighorn Mountains. The widest range in temperature occurs in the Bighorn Basin. At Emblem, the mean monthly temperature ranges from 70.8 °F in July to 15.5 °F in January. Whereas, in the Bighorn Mountains, the mean monthly temperature in July at Burgess Junction is almost 16 degrees cooler than it is at Emblem. The mean monthly temperature at Burgess Junction ranges from 55 °F in July to 14.7 °F in January. All data are from Martner (1986, p. 291, 304, 321, 332, 347, 370, 391, 403).

Geology

Big Horn County is on the eastern limb of a deep asymmetrical syncline that forms the Bighorn Basin. The axis of the syncline passes through the southwest corner of the county near Tatman Mountain and follows a northwesterly trend (fig. 2). The structural relief on the Precambrian rocks between the basin axis and the top of the Bighorn Mountains is at least 34,000 ft (Prucha and others, 1965, p. 970). Major structural trends and features are illustrated on plate 2.

The basin is bordered on the east by the westwardly concave, arching Bighorn Mountains, a compressional uplift formed during the time of the Laramide orogeny from Late Cretaceous to Middle Eocene time. The mountain uplift was formed, in part, by large scale displacements along basement faults typical of the structural style in the Rocky Mountain foreland. Several major east-west lineaments cross the study area (Cooley, 1983; Hoppin, 1974).


Johnson County
Sheridan County
Big Horn County
Washakie County
Park County
MONTANA
WYOMING
Cloud Peak
107° 15′
108° 00′
108° 30′
45° 00′
44° 15′
15′
30′
45′
Bighorn Mountains
Bighorn Basin
BIGHORN LAKE
BIGHORN RIVER
SHOSHONE RIVER
GREYBULL RIVER
NOWOOD RIVER
Porcupine Creek
Willow Cr.
Crystal Creek
Shell Creek
Granite Cr.
Dry Medicine Lodge Creek
Medicine Lodge Creek
Paint Rock Creek
Trout Creek
Red Gulch
Crooked Cr.
Big Coulee
Sage Creek
Bitter Cr.
Whistle Cr.
Dry Creek
Elk Creek
Emblem Bench Canal
Orchard Bench
Frannie
Deaver
Cowley
Byron
Lovell
Kane
Shell
Greybull
Basin
Emblem
Burlington
Manderson
Hyattville
Rairden
Little Sheep Mountain
Sheep Mountain
Table Mountain
Tatman Mountain
Cedar Mountain
14A
14
310
16
30
32
20
31
0 5 10 15 20 MILES
0 5 10 15 20 KILOMETERS

EXPLANATION

Bighorn Basin

PLAINS, BUTTES, BENCHES, LOWLANDS, AND TERRACES--Most landforms are erosion products of generally flat-lying sediments of the Willwood Formation of Eocene age in the central area of the Bighorn Basin

IRREGULAR RIDGES, HOGBACKS, AND SUBPARALLEL RIDGES AND VALLEYS--Landforms are eroded from folded and faulted sedimentary rocks that range in age from Tertiary through Permian in an area between the central area of the Bighorn Basin and the Bighorn Mountains

Bighorn Mountains

STRIPPED SURFACES, DEEP CANYONS AND CLIFFS, AND UPLANDS--Landforms from Pennsylvanian through Cambrian age are eroded into sedimentary rocks below the range crest area in the Bighorn Mountains

STRIPPED SURFACES AND GLACIAL FEATURES--Rocks of Cambrian and Precambrian age in the summit area of the Bighorn Mountains are eroded and scoured by glaciation and severe weathering

MOUNTAIN FRONT--Approximate delineation of the edge of the Bighorn Mountains and the Bighorn Basin

CONCEALED SYNCLINE--Concealed axis of the Bighorn Basin in the Tensleep Sandstone

Figure 2.--Generalized physiographic features (from Fenneman, 1931).

EXPLANATION

—14— LINE OF EQUAL MEAN ANNUAL PRECIPITATION--
Interval is 2 and 10 inches

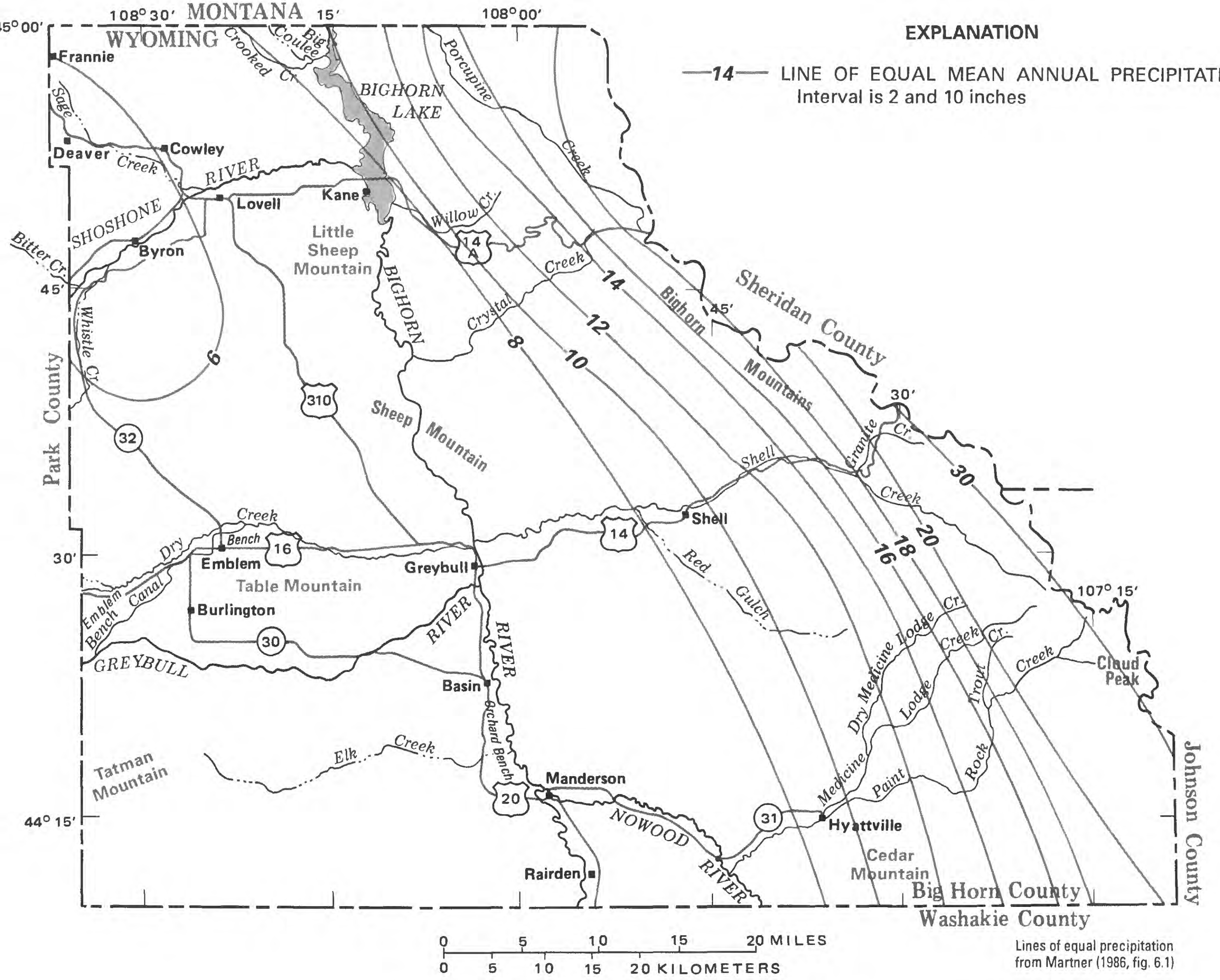


Figure 3.--Mean annual precipitation, 1951-80.

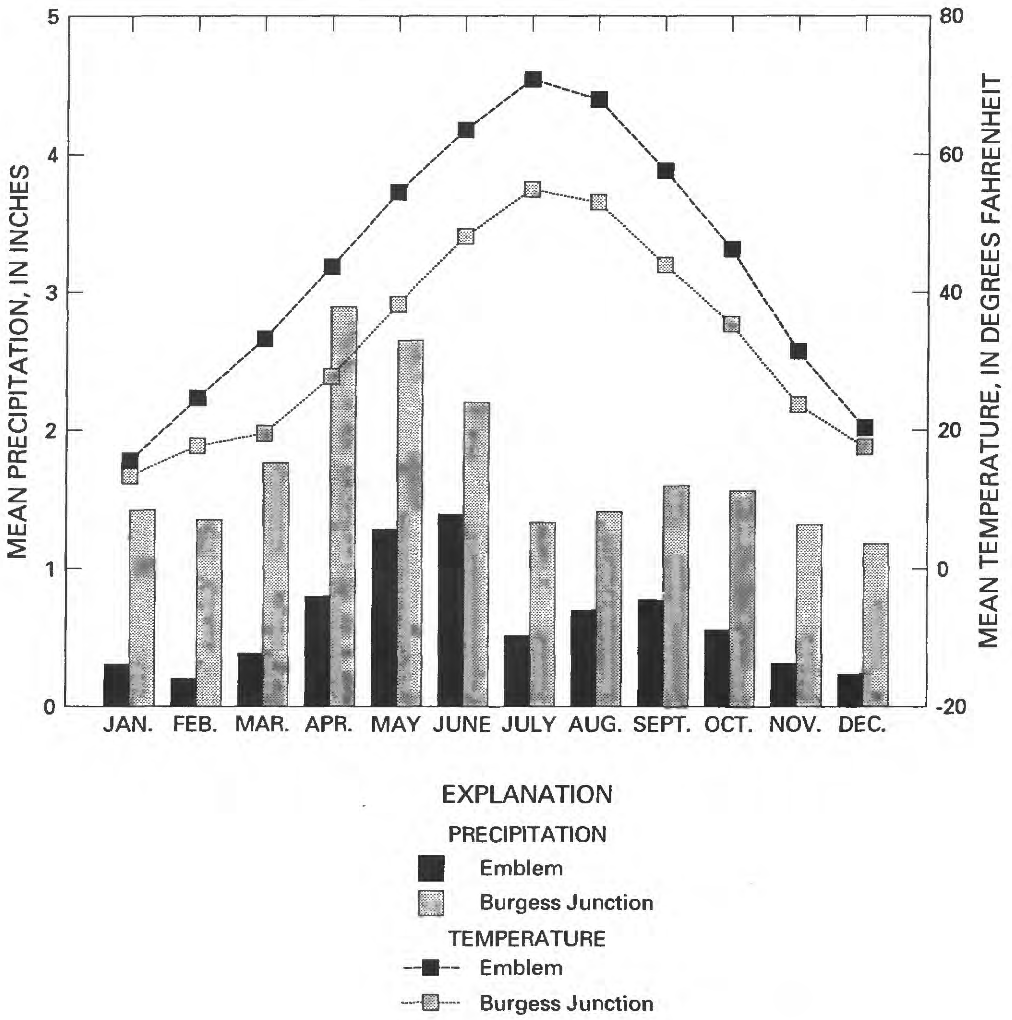


Figure 4.--Mean monthly precipitation and air temperatures at Emblem, 1951-80 and Burgess Junction, 1960-80 (data from Martner, 1986).

The western outcrops of Tensleep Sandstone of Late and Middle Pennsylvanian age generally mark the boundary between the basin and the mountains (pl. 1). In most of the county, the transition from basin to mountains is a steep, unbroken, westwardly dipping homocline.

Thirty geologic units ranging from Cambrian to Quaternary age have been identified in the thick sequence of sedimentary rocks and deposits that overlie basement rock of Precambrian age in the basin area of Big Horn County. The range of thickness and lithologic description of each of the geologic units is presented in stratigraphic sequence in table 1. The associated water-yielding characteristics, most common well yields, and reported specific capacities of each unit also are presented. The distribution of geologic units cropping out in the county is shown on plate 1.

Water-Right Administration

By Richard G. Stockdale, Wyoming State Engineer's Office

According to article 8, section 1 of the Wyoming State constitution, "The water of all natural streams, springs, lakes or other collections of still water, within the boundaries of the state, are hereby declared to be property of the state." Anyone desiring to use water beneficially in Wyoming must apply for and obtain an approved permit from the State Engineer to appropriate water prior to initiating construction of water-diversion structures, such as dams, headgates, spring boxes, and wells. Once a permit to appropriate water has been obtained from the State Engineer, the permittee may proceed with construction of the water-diversion works and with beneficial use of the diverted water for the purposes specified in the permit. Such diversion and beneficial use must be made in accordance with statutory provisions. After the permittee has beneficially used the diverted water for all of the permitted uses at all of the permitted point(s) or area(s) of use, proof of beneficial use is filed, and the water right is adjudicated (finalized). The adjudication process fixes the location of the water-diversion structure, the use, quantity, and points or areas of use for the water right.

Wyoming water rights are administered using the Doctrine of Prior Appropriation, commonly referred to as the "First in time, first in right" system. Article 8, section 3 of the Wyoming constitution states: "Priority of appropriation for beneficial uses shall give the better right." The priority date of an appropriation is established as the date when the application for permit to appropriate water is received in the State Engineer's Office.

Water-right administration is conducted by the State Engineer and the Water Division Superintendents. Article 8, section 5 of the Wyoming constitution provides for the appointment of a State Engineer, and section 4 provides for the creation of four Water Divisions in the State and the appointment of a superintendent in each division. The State Engineer is Wyoming's chief water-administration official and has general supervision of all waters of the State. The superintendents, along with their staff of hydrographers and water commissioners, are responsible for the local administration of water rights and the collection of hydrologic data in their respective divisions.

Deviations from the standard water-right administrative system of "First in time, first in right" might exist. Such deviations might be caused by conditions in compacts, court decrees, and treaties or through the creation of special water-management districts. Virtually every stream exiting the State is subject to a compact, court decree, or treaty that dictates to some degree how the appropriations on that specific stream are administered. While the interstate nature of ground water and the interconnection of ground water with streams are recognized, the development of interstate agreements on use of water from aquifers is still in its infancy. The reason that few ground-water compacts exist is twofold. First, there is a lack of sound technical data on which to base appropriate administrative allocations of ground water between adjoining states, and, second, there is not sufficient competition between Wyoming and adjoining states to require binding interstate agreements or allocations of ground-water resources.

Table 1. Lithologic description and water-yielding characteristics of geologic units, Big Horn County, Wyoming

[modified from Lowry and others, 1976, and Libra and others, 1981; Abbreviations: ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot; --, no data; <, less than]

Erathem	System	Series	Geologic unit	Range of approximate thicknesses (ft)	Lithologic description	Water-yielding characteristics	Range of most common yields (gal/min)	Range of specific capacity (gal/min)/ft of drawdown
Cenozoic	Quaternary	Order does not indicate age	Alluvium and colluvium	0-50	Mixtures of unconsolidated clay, silt, sand, gravel, and boulders. Alluvium is coarser toward the mountains and might contain buried terrace deposits.	Might yield large quantities of water to wells. Yields as large as 600 gal/min are reported.	25-50	0.2-200
Cenozoic	Quaternary	Order does not indicate age	Gravel, pediment, and fan deposits	0-60	Well sorted to poorly sorted stratified and unstratified clay, silt, sand, gravel, and boulders. Might be mantled with slope wash where adjacent topography is steep.	Might yield large quantities of water to wells where saturated by irrigation water. Yields as large as 1,600 gal/min are reported.	100-200	0.5-300
Cenozoic	Quaternary	Order does not indicate age	Glacial deposits	--	Predominantly consists of unstratified and unsorted clay, silt, sand, gravel, and boulders derived from Paleozoic and Precambrian rocks.	Might yield quantities of water sufficient for domestic or stock use.	5-10	<1.0
Cenozoic	Quaternary	Order does not indicate age	Landslide deposits	--	Mixtures of angular fractured rocks. Might be buried by slope wash from adjacent highlands.	Horizontal collection galleries yield water from the toes of landslides at some locations.	5-10	--

Table 1. Lithologic description and water-yielding characteristics of geologic units, Big Horn County, Wyoming--Continued

Erathem	System	Series	Geologic unit	Range of approximate thicknesses (ft)	Lithologic description	Water-yielding characteristics	Range of most common yields (gal/min)	Range of specific capacity (gal/min)/ft of drawdown
Cenozoic	Lower Quaternary and Tertiary	Pliocene and Miocene	Terrace gravel	--	Partly consolidated gravel.	Unknown	--	--
Cenozoic	Tertiary	Oligocene	White River Formation	--	Sand, volcanic ash, gravel, and boulders. Present only as erosional remnants of limited extent in the Bighorn Mountains.	Not known to be developed as a water supply in Big Horn County. Not considered to have potential as an aquifer because of its limited areal extent.	--	--
Cenozoic	Tertiary	Eocene	Tatman Formation	375-725	Interbedded claystone, shale, mudstone marl, sandstone, with minor coal beds. Present only near Tatman Mountain; of limited extent.	Not known to be developed as a water supply in Big Horn County. Not considered to be a potential aquifer because of its small areal extent and topographic position.	--	--
Cenozoic	Tertiary	Eocene	Willwood Formation	1,500-2,300	Variegated, interbedded mudstone, claystone, siltstone, drab thin discontinuous sandstone, and carbonaceous shale. Averages about 25 percent sandstone.	Might yield enough water from sandstones for domestic or stock use. Yields as large as 120 gal/min are reported.	<10	0.03-8.5

Table 1. Lithologic description and water-yielding characteristics of geologic units, Big Horn County, Wyoming--Continued

Erathem	System	Series	Geologic unit	Range of approximate thicknesses (ft)	Lithologic description	Water-yielding characteristics	Range of most common yields (gal/min)	Range of specific capacity (gal/min)/ft of drawdown
Cenozoic	Tertiary	Paleocene	Fort Union Formation	2,000-8,000	Interbedded sandstone, siltstone, claystone, carbonaceous shale, and thin coal beds. Cliff-forming sandstone near the base. Averages about 25 percent sandstone.	Might yield enough water from sandstones for domestic or stock use. Yields as large as 30 gal/min are reported.	10-15	0.08-3.0
Mesozoic	Cretaceous	Upper Cretaceous	Lance Formation	800-1,800	Upper part contains weakly indurated sandstone interbedded with claystone, carbonaceous shale and minor coal beds. Massive sandstone near base.	Yields as large as 65 gal/min are reported, usually from discontinuous sandstones. Principal water supply for the town of Maderson. Most potential for future development as a water supply out of all the Mesozoic rocks in the county.	25-30	0.8-13.3
Mesozoic	Cretaceous	Upper Cretaceous	Meeteetse Formation	450-1,000	Interbedded lenticular and discontinuous claystone, shale, siltstone, and weakly indurated silty sandstone. Bentonite and thin coal beds are also present.	Sandstones might yield enough water for domestic or stock use. Yields are estimated to be less than 10 gal/min.	--	--

Table 1. Lithologic description and water-yielding characteristics of geologic units, Big Horn County, Wyoming--Continued

Erathem	System	Series	Geologic unit	Range of approximate thicknesses (ft)	Lithologic description	Water-yielding characteristics	Range of most common yields (gal/min)	Range of specific capacity (gal/min)/ft of drawdown
Mesozoic	Cretaceous	Upper Cretaceous	Mesaverde Formation	650-1,300	Upper part is dominantly coarse sandstone. Middle part is interbedded sandstone and siltstone. Lower part is a ledge-forming sandstone.	Sandstones might yield enough water for domestic or stock use. Yields as large as 35 gal/min are reported. Potential for development as a water supply.	20-25	0.2-3.8
Mesozoic	Cretaceous	Upper Cretaceous	Cody Shale	2,100-3,250	Upper part consists of discontinuous interbedded sandy shale and sandstone. Lower part is predominantly brown and black marine shales.	Predominantly not a aquifer but thin sandstones might yield enough water locally for domestic or stock use. Yields as large as 25 gal/min are reported.	<5	0.7-1.2
Mesozoic	Cretaceous	Upper Cretaceous	Frontier Formation	450-600	Predominantly consists of argillaceous sandstone and sandy bentonitic shale; it also contains some bentonite and lignite beds. Conglomeratic sandstone are present near top of formation. Contains less than 50 percent sandstone.	Discontinuous sandstones might yield enough water for domestic or stock use. Yields as large as 16 gal/min are reported. Some potential for future development as a water supply based on lithology and permeability data.	5-16	0.2-0.6

Table 1. Lithologic description and water-yielding characteristics of geologic units, Big Horn County, Wyoming--Continued

Erathem	System	Series	Geologic unit	Range of approximate thicknesses (ft)	Lithologic description	Water-yielding characteristics	Range of most common yields (gal/min)	Range of specific capacity (gal/min) /ft of drawdown
Mesozoic	Cretaceous	Upper Cretaceous	Mowry Shale	300-400	Dominantly brittle brown and black siliceous shale containing a few thin beds of siltstone, sandstone and bentonite.	Brittle shales and thin sandstones, where fractured, might yield very limited quantities of water to wells, but generally the unit does not yield water.	<5	--
Mesozoic	Cretaceous	Lower Cretaceous	Thermopolis Shale	400-600	Black soft shale that deforms plastically. Contains some interbedded bentonite. The Muddy Sandstone Member, ranges from 10 to 100 ft in thickness, is 175-200 ft above the base and thins toward the north.	The shale does not yield water, but wells developed in the Muddy Sandstone Member are reported to yield enough water for domestic or stock use.	10-15	--
Mesozoic	Cretaceous	Lower Cretaceous	Cloverly Formation	150-500	Upper part contains Sykes Mountain Member, which consists of interbedded sandstone, siltstone and shale. Middle part is shaly with lenticular sandstone and sandy clay. Lower part is a variegated mudstone, shale and sandstone with local conglomerate.	Sandstones might yield enough water for domestic or stock use. Yields as large as 20 gal/min are reported.	10-15	--

Table 1. Lithologic description and water-yielding characteristics of geologic units, Big Horn County, Wyoming--Continued

Erathem	System	Series	Geologic unit	Range of approximate thicknesses (ft)	Lithologic description	Water-yielding characteristics	Range of most common yields (gal/min)	Range of specific capacity (gal/min)/ft of drawdown
Mesozoic	Jurassic	Upper Jurassic	Morrison Formation	75-300	Predominantly interbedded multicolored shale, mudstone and silty sandstone. Fresh-water marl, limestone and thin discontinuous lenses of conglomerate also are present.	Sandstones can yield enough water for domestic or stock supplies.	10-15	--
Mesozoic	Jurassic	Upper Jurassic	Sundance Formation	250-375	Upper part consists of well-sorted sandstone with interbedded shale and occasional microcrystal line limestone. Thickness is about 150-200 ft. Lower part contains interbedded glauconitic sandstone, oolitic limestone, and carbonaceous shale. Thickness is about 100-175 ft.	Sandstones can yield enough water for domestic or stock supplies.	10-15	--
Mesozoic	Jurassic	Middle Jurassic	Gypsum Spring Formation	175-225	Consists of reddish siltstone and shale interbedded with thin dolomite and limestone and gypsum beds. Upper sequence consists of layers of shale and carbonate. Lower part is massive white gypsum beds.	Solution zones in gypsum beds might yield water. Yields as large as 20 gal/min are reported.	10-15	--

Table 1. Lithologic description and water-yielding characteristics of geologic units, Big Horn County, Wyoming--Continued

Erathem	System	Series	Geologic unit	Range of approximate thicknesses (ft)	Lithologic description	Water-yielding characteristics	Range of most common yields (gal/min)	Range of specific capacity (gal/min)/ft of drawdown
Mesozoic	Triassic	Upper and Lower Triassic	Chugwater Formation	500-700	Red fine-grained sandstone, siltstone, and shale with thin lenticular beds of limestone and gypsum.	Sandstones might yield enough water for domestic or stock supplies.	10-15	--
Mesozoic and Paleozoic	Triassic and Permian		Goose Egg Formation	25-625	Sheldon (1963) indicated an intertonguing relation between the Park City Formation (western facies) and the Goose Egg Formation (eastern facies). The longitude of Worland in Washakie County (107°57'30") approximates the facies boundary. The Park City Formation is a cherty dolomitic carbonate sequence. Thickness ranges from 25-325 ft. The Goose Egg Formation is an evaporite sequence of gypsiferous siltstone, mudstone, and silty shale. Thickness ranges from 100-300 ft. Phosphoria Formation is equivalent to the Goose Egg Formation.	Might yield small quantities of water to wells as a result of dissolution of gypsum. When shales are present, the formation confines the underlying Tensleep Sandstone. Yields as large as 35 gal/min are reported.	10-15	--

Table 1. Lithologic description and water-yielding characteristics of geologic units, Big Horn County, Wyoming--Continued

Erathem	System	Series	Geologic unit	Range of approximate thicknesses (ft)	Lithologic description	Water-yielding characteristics	Range of most common yields (gal/min)	Range of specific capacity (gal/min) /ft of drawdown
Paleozoic	Pennsylvanian	Upper and Middle Pennsylvanian	Tensleep Sandstone	50-200	White and tan massive and cross-bedded sandstone. Predominantly a well-sorted fine- to medium-grained sandstone cemented by carbonate and silica. Upper part is considered to be an eolian sand and contains cherty dolomite. Lower part contains discontinuous marine limestone and dolomite.	Flowing wells along the western flank of the Bighorn Mountains yield large and dependable supplies of potable water. Yields as large as 200 gal/min are reported.	10-30	0.2-0.3
Paleozoic	Pennsylvanian and Mississippian	Middle and Lower Pennsylvanian and Upper Mississippian	Amsden Formation	120-300	Upper part is limestone, middle part is red and green shale. Lower part is the Darwin Sandstone Member that ranges from 5-80 ft thick.	Lower sandstone might yield enough water for domestic and stock use. Confining unit for the underlying Madison-Bighorn aquifer.	10-15	--

Table 1. Lithologic description and water-yielding characteristics of geologic units, Big Horn County, Wyoming--Continued

Erathem	System	Series	Geologic unit	Range of approximate thicknesses (ft)	Lithologic description	Water-yielding characteristics	Range of most common yields (gal/min)	Range of specific capacity (gal/min)/ft of drawdown
Paleozoic	Mississippian	Upper and Lower Mississippian	Madison Limestone	500-800	Predominantly consists of limestone and dolomite in the upper part, which contains solution features and is commonly cavernous in outcrop. Lower part contains massive blue-gray limestone and dolomite. Both upper and lower parts contain thin chert beds and shale.	Flowing wells along the mountain front yield large and dependable supplies of potable water. Yields are especially large for wells drilled near anticlines. In hydrologic connection with the underlying Jefferson Formation and Bighorn Dolomite forming the Madison-Bighorn aquifer. Yields as large as 14,000 gal/min are reported. An important water supply for several county municipalities.	350-1,200	0.1-5.2
Paleozoic	Devonian	Upper Devonian	Darby Formation	0-200	Yellow and greenish-gray shale and dolomitic siltstone underlain by fetid brown dolomite and limestone. Equivalent to the Three Forks and Jefferson Formations. The Jefferson Formation is an argillaceous dolomite (Sandberg, 1965), and contains more than 50 percent argillaceous and silty material.	Might hydrologically separate the overlying Madison Limestone from the underlying Bighorn Dolomite. No wells are known to produce exclusively from the Jefferson Formation.	--	--

Table 1. Lithologic description and water-yielding characteristics of geologic units, Big Horn County, Wyoming--Continued

Erathem	System	Series	Geologic unit	Range of approximate thicknesses (ft)	Lithologic description	Water-yielding characteristics	Range of most common yields (gal/min)	Range of specific capacity (gal/min) /ft of drawdown
Paleozoic	Ordovician	Upper Ordovician	Bighorn Dolomite	350-450	Upper part consists of massive and thin-bedded dolomite breccia or conglomerate near the base. Distinctive mottled appearance in outcrop. Lower part is massive dolomite and dolomitic limestone overlain by thinly bedded and blocky dolomite. Thin discontinuous cherty beds and nodules are present throughout the formation.	In combination with the Madison Limestone and Jefferson Formation forms the Madison-Bighorn aquifer, which produces large and dependable supplies of potable water. An important water supply for several county municipalities.	350-1,200	0.1-5.2
Paleozoic	Cambrian	Upper Cambrian	Gallatin Limestone	400-500	Gray-green glauconitic shale interbedded with pebbly limestone and minor sandstone.	Not known to be developed as a water supply in Big Horn County. In combination with the underlying Gros Ventre Formation forms a confining layer for the Flathead Sandstone.	--	--

Table 1. Lithologic description and water-yielding characteristics of geologic units, Big Horn County, Wyoming--Continued

Erathem	System	Series	Geologic unit	Range of approximate thicknesses (ft)	Lithologic description	Water-yielding characteristics	Range of most common yields (gal/min)	Range of specific capacity (gal/min)/ft of drawdown
Paleozoic	Cambrian	Upper and Middle Cambrian	Gros Ventre Formation	400-500	Glauconitic and sandy limestone with interbedded gray-green shale, sandy limestone and infrequent limey sandstone.	Not known to be developed as a water supply in Big Horn County. Thin sandstone beds indicate potential for small yields. In combination with the overlying Gallatin Limestone, it forms a confining layer for the Flathead Sandstone.	--	--
Paleozoic	Cambrian	Middle Cambrian	Flathead Sandstone	0-170	Coarse tan and pink arkosic and quartzitic sandstone with interbedded shale in upper part.	Flowing wells in the southern part of the county yield large and dependable supplies of potable water. In the southern part of the county, yields as large as 3,000 gal/min are reported.	100-1,000	1.0-1.4
Precambrian	--	--	Igneous and metamorphic rocks	--	Tan and pink crystalline granite and gneiss.	Predominantly not an aquifer, but in the mountains intensively weathered rocks within 100 ft of the surface might yield sufficient quantities of water for domestic or stock use.	5-10	0.2-2.8

Acknowledgments

The authors gratefully acknowledge the assistance and cooperation of farmers, ranchers, and drillers of Big Horn County, who not only provided directions and access to their wells, but also often assisted in testing. Officials associated with public-supply systems and water-resources management also were extremely helpful in allowing access to wells and records.

STREAMFLOW

The principal stream in Big Horn County is the Bighorn River, which enters from Washakie County, flows northerly through the central part of the county and exits into Montana. Major tributaries entering the Bighorn River in the county are the Nowood River and Shell Creek from the east, and the Greybull and Shoshone Rivers from the west.

Streamflow Data

The U.S. Geological Survey, in cooperation with State, municipal, county, and other Federal agencies, has collected stage, streamflow, and water-quality data in Big Horn County since 1897. Streamflow records at a station can be either continuous or partial. Continuous streamflow records are obtained from discrete streamflow measurements and a continuous record of stage that is collected annually. Partial streamflow records are obtained from discrete streamflow measurements and continuous records of stage that are collected seasonally. Continuous streamflow records can be used for computing the instantaneous streamflow, the average streamflow for the period of record, and, if the length of the record is adequate, the streamflow characteristics. Partial streamflow records are collected for special purposes, such as peak flow or seasonal flow information, and have limited applications.

The location of streamflow stations with continuous or partial streamflow records are shown on plate 1. Drainage area, type of data collected, period of record for each station, and stream type are included in table 2.

In addition to the data collected at continuous and partial streamflow record stations, data also are collected on a nonrecurring basis for special purposes at miscellaneous streamflow sites and might consist of only one measurement. Information on miscellaneous, as well as continuous and partial streamflow record sites, is published in the U.S. Geological Survey Water-Data Report for the year in which the data were collected (U.S. Geological Survey, 1965-1988).

Streamflow Characteristics

Streamflow characteristics can be illustrated and analyzed using hydrographs and statistical techniques. Hydrographs typically are used to illustrate seasonal variations in streamflow, which are related to stream type. Graphs or tables of the mean discharge illustrate the variability in discharge for which the statistic is computed, either from month to month or year to year for the period of record considered. The mean annual discharge represents the average discharge for all years considered. Flow-duration curves describe the distribution of streamflow at a gaged site for the period that the record is computed. Low-flow data describe the minimum quantity of water that might be available for any extended period, and provide information about water supplies for municipal and industrial uses, irrigation, instream fisheries, and waste disposal. High-flow data describe the magnitude and frequency of floods, aid in planning for floods, and aid in the design of structures, such as bridges, culverts, and dams.

Table 2. U.S. Geological Survey surface-water stations in Big Horn County, Wyoming

[mi^2, square miles; --, not computed]

Site number (pl. 1)	Station number	Station name	Drainage-basin area (mi^2)	Period of record, in water years: Discharge: Daily or monthly	Period of record, in water years: Discharge: Annual peak	Period of record, in water years: Quality: Chemical	Period of record, in water years: Quality: Sediment	Stream type
1	06269000	Bighorn River near Manderson	11,020	1949-54 1956		1949-53 1967-70	1949-53 1956	Regulated
2	06269500	Bighorn River at Manderson	11,048	1941-49		1947-49	1946-49	Regulated
3	06271500	Paint Rock Creek below Lake Solitude	16.0	1946-53				Perennial
4	06272000	Paint Rock Creek at Longview ranger station, near Hyattville	79.9	[1]1912				Perennial
5	06272500	Paint Rock Creek near Hyattville	164	1920-27 1941-53		1951-53		Perennial
6	06273000	Medicine Lodge Creek near Hyattville	86.8	1943-73		1951-53		Perennial
7	06273500	Paint Rock Creek near Bonanza	376	1910-14 1915-23		1951-53 1968-84		Irrigation return flow
8	06274000	Nowood River (Creek) at Bonanza	1,730	1910-28				Regulated
9	06274190	Nowood River tributary No. 2 near Basin	1.51		1965-84			Ephemeral
10	06274200	Nowood River tributary No. 2 near Manderson	1.59		1961-71			Ephemeral
11	06274220	Nowood River at Manderson	[2]2,000			1965-86	1965-67	Regulated
12	06274250	Elk Creek near Basin	96.9		1959-81			Irrigation return flow

Table 2. U.S. Geological Survey surface-water stations in Big Horn County, Wyoming--Continued

Site number (pl. 1)	Station number	Station name	Drainage-basin area (mi^2)	Period of record, in water years: Discharge: Daily or monthly	Discharge: Annual peak	Quality: Chemical	Quality: Sediment	Stream type
13	06274300	Bighorn River at Basin	13,223	[3]1984-88		[3]1984-88		Regulated
14	06277000	Bench Canal near Burlington		1930-38				Regulated
15	06277500	Greybull River near Basin	1,115	1930-73		1951-53 [3]1965-88	1965-67	Regulated
16	06277750	Dry Creek tributary near Emblem	.65		1960-68 1970-81			Ephemeral
17	06277950	Dry Creek near Greybull	432	1979-81		1979-81	1979-81	Regulated
18	06278000	Dry Creek at Greybull	433	1951-54 1956-60		1951	1951-53 1957-60	Regulated
19	06278300	Shell Creek above Shell (Creek) Reservoir	23.1	[3]1957-88				Perennial
20	06278400	Granite Creek near Shell Creek Ranger Station, near Shell	11.1		1961-74			Perennial
21	06278500	Shell Creek near Shell	145	[3]1941-88		1951 1982		Regulated
22	06279000	Shell Creek at Shell	256	1911-23				Regulated
23	06279020	Red Gulch near Shell	47.8		1967 1970-81			Irrigation return flow
24	06279050	Shell Creek at Porter Gulch, near Greybull	--			[3]1983-88		Regulated

Table 2. U.S. Geological Survey surface-water stations in Big Horn County, Wyoming--Continued

Site number (pl. 1)	Station number	Station name	Drainage-basin area (mi^2)	Period of record, in water years: Discharge: Daily or monthly	Discharge: Annual peak	Quality: Chemical	Quality: Sediment	Stream type
25	06279090	Shell Creek near Greybull	560			1951 1965-86	1965-67	Regulated
26	06279500	Bighorn River at Kane	15,765	[3]1928-88		1947-53 1955-57	1946-64 [3]1970-88	Regulated
27	06279700	Willow Creek near Kane	14.0		1961-75			Ephemeral
28	06284500	Bitter Creek near Garland	80.5	1950-54 1958-60 1969-87		1958-61 [3]1969-88		Irrigation return flow
29	06284800	Whistle Creek near Garland	101	1958-60 1969-87		1958-60 1969-87		Return flow
30	06285000	Shoshone River at Byron	2,345	1929-66		1947-49 1965-66		Regulated
31	06285100	Shoshone River near Lovell	[2]2,350	[3]1967-88		[3]1967-88	1972-82	Regulated and irrigation return flow
32	06285400	Sage Creek at Sidon Canal near Deaver	341	1958-60 1969-87		1958-60 1969-87		Irrigation return flow
33	06285500	Sage Creek near Lovell	381	1951-60			1951-53	Irrigation return flow

Table 2. U.S. Geological Survey surface-water stations in Big Horn County, Wyoming--Continued

Site number (pl. 1)	Station number	Station name	Drainage-basin area (mi^2)	Period of record, in water years: Discharge: Daily or monthly	Discharge: Annual peak	Quality: Chemical	Quality: Sediment	Stream type
34	06286000	Shoshone River at Lovell	2,832	1897-98 [1]1899				Perennial[4]
35	06286200	Shoshone River at Kane	2,989	1958-68		1951-53 1958-68 [3]1976-88	1960-64	Regulated and irrigation return flow
36	06286250	Bighorn River near Lovell	[2]18,900	1965-66				Regulated
37	06286258	Big Coulee near Lovell	30.1	1970-78			1970-78	Ephemeral
38	06286260	Crooked Creek near Lovell	[2]119	1965-68				Regulated
39	06286270	Porcupine Creek near Lovell	[2]135	1965-68				Perennial

[1] Gage heights or gage heights and discharge measurements only.

[2] Approximate.

[3] Currently in operation (water year 1988).

[4] Stream type during period record was collected.

Stream Types

Streams in Big Horn County can be either ephemeral or perennial; each type exhibits unique flow characteristics. The flow of both stream types may be affected by human activities that include irrigation and reservoir storage practices. Stream types in table 2 were determined for flow at the streamflow-gaging station and do not necessarily apply to the entire reach of the stream. For example, Shell Creek above Shell (Creek) Reservoir (site 19) has perennial flow; whereas, Shell Creek near Shell (site 21) has flow affected by regulation.

Ephemeral streams in Big Horn County originate primarily in the Bighorn Basin, and are characterized by long periods of no flow separated by shorter periods of runoff from precipitation. The magnitude and duration of the streamflow in ephemeral streams is related to the magnitude and duration of the precipitation and the characteristics of the drainage basin. Maximum streamflows can occur when accumulated snow is melted during a winter or spring thaw, or can be the result of runoff from intense thunderstorms. Big Coulee near Lovell (site 37) is an example of an ephemeral stream in Big Horn County (pl. 1 and fig. 5).

Streams of high mountain origin that have drainage areas of hundreds of square miles are generally perennial. Sustained streamflow results from more precipitation, less evapotranspiration, possible ground-water contribution, and a larger capacity for storage than those originating in the arid lowlands. Moisture stored in near-permanent snowpacks and water stored in aquifers that is released at a slow rate serve to sustain streamflow when intercepted by the stream. Mountain streams generally reach maximum discharges during the spring and early summer as a result of snowmelt runoff. An example of a perennial stream is Shell Creek above Shell Reservoir (site 19) (pl. 1 and fig. 5).

The two types of human activities that affect streamflow in the county are irrigation return-flow and regulation of reservoirs for irrigation supply. The effects of these activities are superposed on the normal characteristics of the stream.

Irrigation return-flow maintains perennial, or nearly perennial flow, in what would otherwise be ephemeral streams and increases low flow during nonirrigation periods in all streams in irrigated areas. The base flows of the irrigation return-flow streams generally are ground-water return during a time when evapotranspiration is at a minimum. Maximum flows in this type of stream might be the result of snowmelt runoff in unaffected tributaries, rainfall runoff in ephemeral tributaries, overflow when storage capacity of upstream reservoirs is exceeded, or a combination of these effects. Bitter Creek near Garland (site 28) is an example of a stream affected by irrigation return-flow with some degree of storm runoff drainage (fig. 5).

The dam at Boysen Reservoir (62 mi south of the county line in Fremont County) regulates flow in the Bighorn River for irrigation supply. Bighorn River at Kane (site 26, fig. 5) is an example of a stream affected by regulation for irrigation supply. Streams affected by regulation have nonzero minimums or perennial flows. Reservoirs store water for future use, and, therefore, decrease the peak flow downstream, but may increase the low flow during the nonirrigation season to meet minimum streamflow and power-generation requirements.

The hydrographs in figure 5 show the differences in streamflow characteristics for the stream types present in Big Horn County. Water year 1978 was used because rainfall caused an increase in streamflow at each site. The hydrograph for Big Coulee near Lovell (site 37) illustrates that streamflow occurs only after rainfall or because of snowmelt runoff, which is characteristic of an ephemeral stream. The hydrograph for Shell Creek above Shell Reservoir (site 19) illustrates a perennial stream. In this example, the stream responds to individual rainstorms, but differs from the ephemeral stream by having a much longer snowmelt runoff and having flow throughout the year. An example of a stream affected by irrigation return-flow is shown in the hydrograph for Bitter Creek near Garland (site 28). The hydrograph shows a marked increase in streamflow at the beginning of the irrigation season and only minor response to rainfall. A small amount of streamflow is

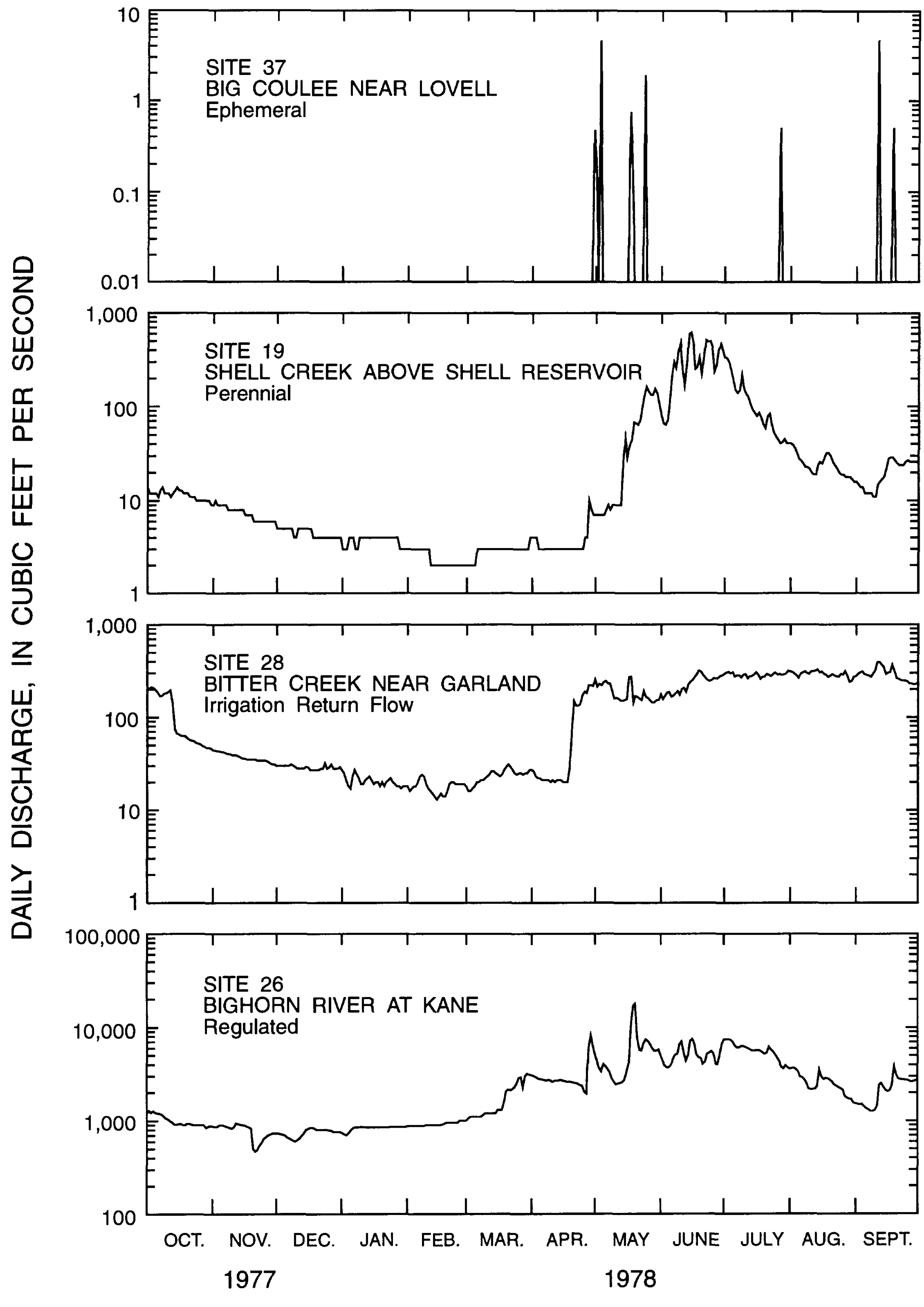


Figure 5.--Daily discharge for selected ephemeral and perennial streams and streams affected by irrigation return flow and regulation for water year 1978.

sustained during the nonirrigation season by delayed drainage for ground water affected by irrigation return-flow. The hydrograph for the Bighorn River at Kane (site 26) shows a more consistent sustained streamflow because of regulation and controlled releases from Boysen Reservoir.

Flow Duration

Streamflow duration is dependent on the following basin characteristics: climate, physiography, geology, and land use. Where these conditions are similar, basins can have similar streamflow characteristics. Generally, the duration of high flows is governed largely by the climate, physiography, and plant cover of the basin. The duration of low flows is controlled mainly by the basin geology. Streamflow duration is the result of variable precipitation and the basin characteristics previously mentioned. The effects of precipitation are reduced by storage, either on the surface or in the ground (Searcy, 1959).

To illustrate the variability of streamflow in Big Horn County, flow-duration curves were developed for streams at selected gaging stations that represent each stream type (figs. 6 and 7). The flow-duration curve is a cumulative frequency curve of discharges that show the percentage of time that specified discharges were equaled or exceeded during a period of record. This curve does not account for the chronological sequence of hydrologic events, but combines the flow characteristics of a stream throughout the measured range of discharge. The total-period method outlined by Searcy (1959, p. 3-12) was used to develop the flow-duration curve. It is important that data used for the flow-duration curve use only complete years, though the years need not be consecutive, and that records used represent periods during which human activities such as reservoir storage and irrigation diversions remained unchanged.

The flow-duration curve for each site in figures 6 and 7 applies only to the period for which the curve was drawn. For each site, all available records were used. Extended high flows of a wet year (or extended low flows of a dry year) tend to skew the curve on the high-flow (or low-flow) end, and care should be used in applying such curves to specific years. The converse also is true, in that curves representing a short period of record do not necessarily represent long-term flow characteristics.

Hydrologic and geologic characteristics of a drainage basin generally are the major factors that determine the shape of the flow-duration curve. Steep slopes generally indicate variable streamflow dependent on direct runoff, as shown by the flow-duration curve for Big Coulee near Lovell (site 37, fig. 6).

The flat slope in the high-flow range of the flow-duration curve for Shell Creek above Shell Reservoir (site 19, fig. 6) indicates high streamflows primarily sustained by snowmelt. The slightly flatter slope in the low-flow range indicates sustained base flow and characterizes storage in the basin.

Bitter Creek near Garland (site 28, fig. 6) also has a flat slope in the high-flow range which could be the result of drainage from floodplain storage or irrigated acreage. The flat slope in the middle-flow range (15-30 ft^3/s) indicates storage of irrigation return-flow, probably in the alluvial aquifers underlying the irrigated land upstream. The subsequent steep slope in the low-flow range indicates that these areas can reach a drained condition.

The effect of human activities on long-term streamflow characteristics is indicated by the flow-duration curves for the Big Horn River at Kane (site 26, fig. 7). The period of record used for the flow-duration curves was water years 1930-87. Upstream storage at Boysen Reservoir began in October 1951. Separating the streamflow record prior to surface-water storage in Boysen Reservoir from the record following storage and computing flow-duration curves for each period illustrate the effects of regulation by the reservoir on streamflow. As expected, the flow-duration curves indicate a decrease in high flows and a corresponding increase in lower flows

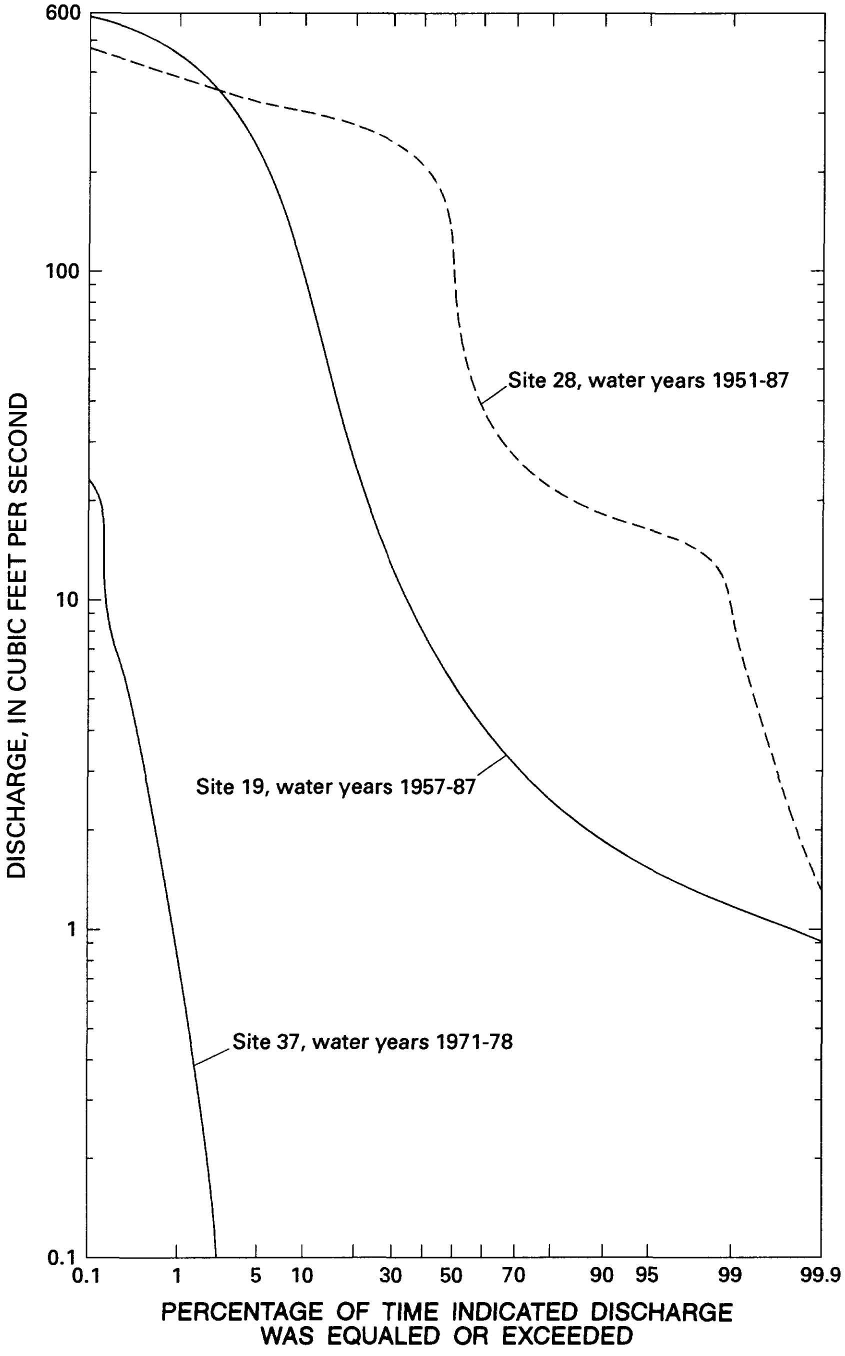


Figure 6.--Duration of daily mean discharge for Shell Creek above Shell Reservoir (site 19), Bitter Creek near Garland (site 28), and Big Coulee near Lovell (site 37).

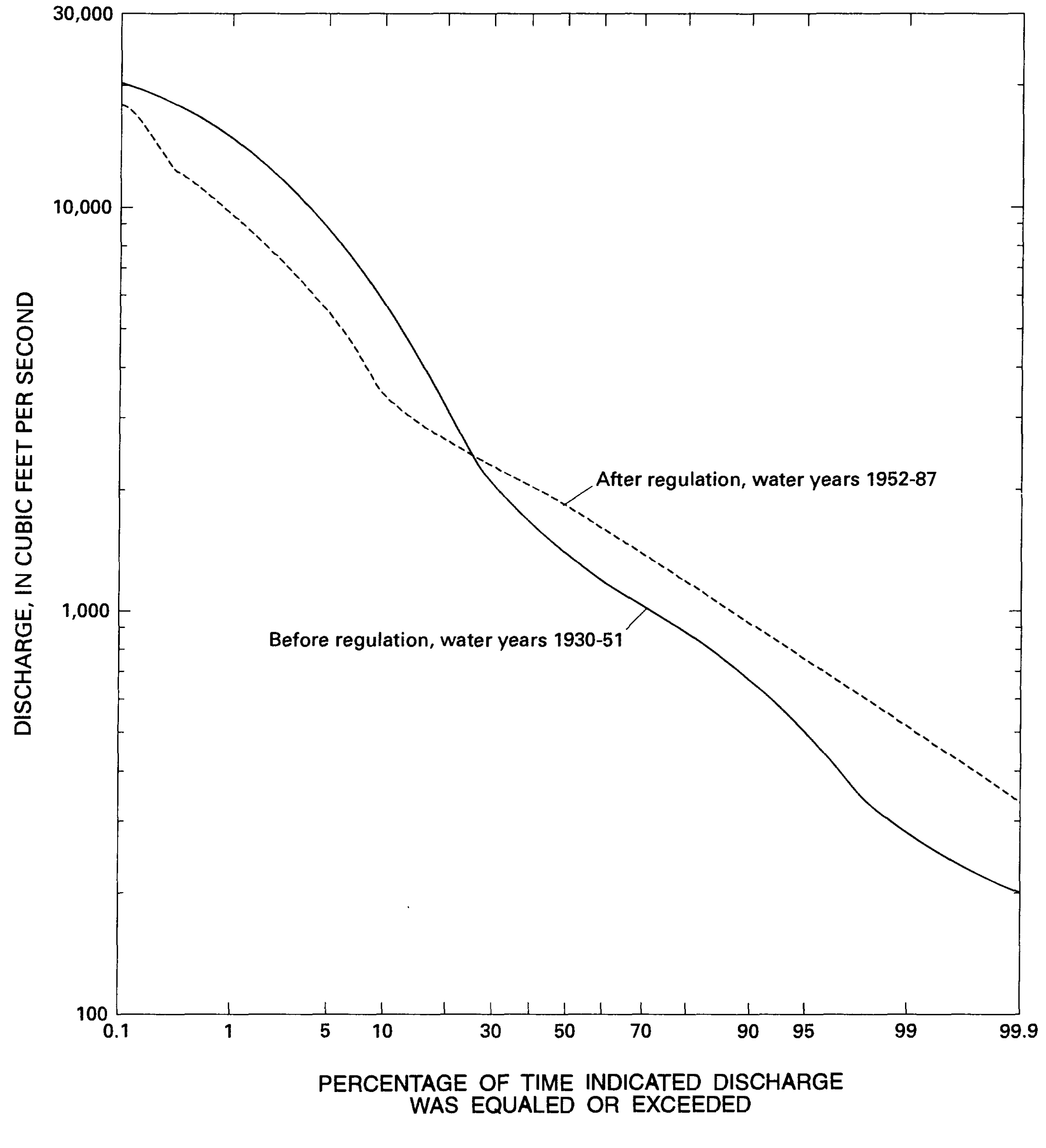


Figure 7.--Duration of daily mean discharge for site 26, Bighorn River at Kane, before and after regulation.

as the reservoir is used to store flood-stage runoff for later release to downstream users. It should be noted that 36 years of record (water years 1952-87) was used to develop the postreservoir duration curve, and that only 22 years (water years 1930-51) was available prior to operation of the reservoir.

Low Flows

Low-flow characteristics of the stream types in Big Horn County indicate marked differences. For the ephemeral streams common to the lowlands west of the Bighorn River, low flow is no flow, and low-flow statistics have little value. Both the perennial streams and streams affected by regulation for irrigation supply and irrigation return-flow generally have nonzero low flows that typically occur during the winter months (normally October through April), barring unusual circumstances. For the mountain streams, lowest flows will be noted at times when storage in aquifers and near-permanent snowpack is nearly depleted, and generally when snow is not melting. Similarly, streams affected by irrigation return-flow either will stop flowing or reach minimum flows outside the irrigation season and at a time of least available storage. Streams affected by regulation for irrigation supply, such as the Shoshone and Bighorn Rivers, tend to follow the same general pattern as perennial streams, but regulation by upstream reservoirs alters the natural pattern of streamflow. Minimum flow commonly occurs during the irrigation season in the downstream reaches of the Shoshone River in the Lovell area and eastward and at the downstream end of the Greybull River.

Indices generally used to define low-flow characteristics of streams are the smallest mean discharges for 7 consecutive days having recurrence intervals of 2 and 10 years. For simplicity, these indices are referred to as follows: for a recurrence interval of 2 years, as the 7-day Q_2 ($7Q_2$) discharge; and for a recurrence interval of 10 years, as the 7-day Q_{10} ($7Q_{10}$) discharge. These discharges are taken from a frequency curve of annual values of the smallest mean discharge for seven consecutive days. Low-flow characteristics of selected streams are shown in table 3. The $7Q_2$ and $7Q_{10}$ yield, or discharge per square mile, also are shown in table 3 for comparison. For this table, records for Bighorn River at Kane (site 26) were divided into periods prior to and following the beginning of storage and regulation by Boysen Reservoir. Low-flow statistics for Big Coulee near Lovell (site 37) could not be computed because of extended no-flow periods.

Table 3. Seven-day low-flow statistics for selected streamflow-gaging stations in Big Horn County, Wyoming

[mi2, square miles; ft3/s, cubic feet per second; $(ft^3/s)/mi^2$, cubic feet per second per square mile of drainage basin area]

Site number	Station name	Drainage basin area (mi^2)	Length of record (years)	Seven-day low flow for indicated recurrence interval: 2 years, Discharge (ft^3/s)	2 years, Yield [$(ft^3/s)/mi^2$]	10 years, Discharge (ft^3/s)	10 years, Yield [$(ft^3/s)/mi^2$]
5	Paint Rock Creek near Hyattville	164	17	16.8	0.1	13.1	0.08
6	Medicine Lodge Creek near Hyattville	86.8	28	8.9	.1	7.8	.09
26	Bighorn River at Kane						
	(water years 1930-51)	15,765	21	440	.03	240	.02
	(water years 1952-87)	15,765	34	830	.05	530	.03

The $7Q_2$ and $7Q_{10}$ discharge values in table 3 were determined using U.S. Geological Survey streamflow data and the log Pearson Type III probability distribution program (Riggs, 1972). This program mathematically fits a frequency curve to the discharge data, and the $7Q_2$ and $7Q_{10}$ values then are taken from the curve generated by the program. If a stream is dry during any part of the year, however, this procedure is not directly applicable, and a graphic solution for determining the low-flow characteristics must be used.

Extrapolation of the $7Q_2$ and $7Q_{10}$ discharge and yield in table 3 to other reaches on the streams or to other streams in the basin should not be attempted without knowledge of the basin characteristics and without knowledge of the effects of intervention by humans.

High Flows

The characteristics of high flows in streams of Big Horn County vary depending on the type of stream. High flows in the low-elevation ephemeral streams occur as snowmelt runoff during a winter or spring thaw or as rainfall runoff after summer thunderstorms. Snowmelt runoff usually is smaller in magnitude and longer in duration, while rainfall runoff from intense thunderstorms can be extremely large and short in duration. Magnitudes and durations of rainfall runoff depend on drainage-basin characteristics and on the pattern of precipitation. Most ephemeral streams in Big Horn County have peak flows from rainfall runoff that are reached quickly, with an equally rapid recession. Peak flows are nearly impossible to measure on a stream like Big Coulee near Lovell (site 37) at the time of occurrence because peak-flow duration is short and stage changes occur suddenly. Peak flows on ephemeral streams are measured by indirect methods. Timing for maximum discharge on ephemeral streams is difficult to predict.

Perennial streams originating in the high mountains generally exhibit a large discharge as snowpacks melt. Typical of the snowmelt are daily variations in streamflow, with successive discharges increasing as daylight hours and temperatures increase. This pattern, if uninterrupted by changing weather, will continue to the yearly peak flow and gradually subside as snowpacks diminish. A general rule for perennial streams originating in the high mountains in Big Horn County is that the snowmelt season usually begins in late May, and peak flows often occur in mid-June.

High flows on streams affected by regulation for irrigation supply and irrigation return-flow are affected by many factors. Many of the larger streams, like the Bighorn, Shoshone, and Greybull Rivers, are subject to the effects of inflow from ephemeral and perennial tributaries. These streams also are subject to regulation by reservoirs and diversions upstream as management decisions are implemented. A combination of any or all of these events can cause streams of this type to reach maximum discharge. Streams affected by irrigation return-flow like Bitter Creek near Garland (site 28) are less subject to natural inflow effects, but intense rainfall during summer storms and lowland snowmelt can cause substantial rises in these streams as well.

Streams carrying irrigation return-flow reach flood stage occasionally when a canal in an irrigation distribution system fails and drains into a local stream. Evidence of this effect was noted at the discontinued (1987) streamflow-gaging station, Bitter Creek near Garland (site 28). The maximum recorded discharge during the 27 water years of operation at this station was 1,230 ft^3/s. A peak flow on May 7, 1988, was estimated at 2,100 ft^3/s and resulted from intense rainfall in the drainage area that totaled 2.64 in. (recorded at the University of Wyoming Research and Extension Center at Powell, Wyo.) for May 6 and 7 (P.B. McCollam, U.S. Geological Survey, oral commun., 1988). Runoff from this rainstorm was sufficient to reach flood stage and cause a failed canal that drained into Bitter Creek.

A clarification of terminology is often necessary in describing high flow characteristics. The term "flood" has many definitions that generally refer to magnitude of flow and is often synonymous with "high," "extreme," or "peak" flow. A distinction should be made between flood as a discharge and flood as a stage or depth of water. A common occurrence on larger low-gradient streams, in climates similar to Big Horn County, is accumulation of slush and anchor ice during low winter temperatures. Ice jams accumulating in channel constrictions can obstruct natural flow and often cause flood stage even though discharge is low. Winter flood stage can be more devastating than their summer counterparts because they carry the potential for severe damage from ice and usually occur at times of low temperatures. Backwater from ice has caused flood stages in recent years along the Shoshone River at Byron (site 30) and at Lovell (site 34), and on the Bighorn River at Manderson (site 2), at Basin (site 13), and Greybull (not a gaged site).

The record of peak discharge for surface-water stations in Big Horn County is listed in table 4. Drainage-basin area upstream from the station and daily or monthly discharge record also are listed in table 4. For streamflow-gaging stations in operation (water year 1988), records of peak discharge are complete through September 30, 1987 (table 4).

High-flow statistics can be developed using streamflow data (indexed in table 2) for daily mean discharge. Individual yearly peak discharges are needed for instantaneous flood-frequency studies. These values are available through the records, but no statistical data on floods were included in this report. For additional information on floodflows, see Lowham (1988).

GROUND WATER

Ground water in Big Horn County is present under confined and unconfined conditions. Water in aquifers of unconsolidated deposits is unconfined, and the water table generally is at a shallow depth. The shallow water table, medium to large yields, and recharge from one or a combination of sources, including precipitation, irrigation, and streamflow, makes these aquifers reliable sources of ground water. However, their areal extent is limited mainly to floodplains and terraces along primary and secondary streams.

Water in bedrock aquifers is under either confined or unconfined conditions. The largest yields usually are from confined aquifers. However, water-yielding properties and yields from the geologic unit(s) associated with each aquifer commonly differ because of diverse depositional environments and the development of secondary permeability. In general, however, aquifers predominately composed of thick porous and permeable sandstone, limestone, or dolomite, such as the Tensleep Sandstone, Madison Limestone and Bighorn Dolomite (Late Ordovician to Mississippian age), and Flathead Sandstone (Middle Cambrian age), yield the most abundant supplies. The aquifers with the most potential for development as a water supply are predominately composed of sandstone, such as the Lance Formation, Mesaverde Formation, and Frontier Formation (Upper Cretaceous age). Those aquifers dominated by fine-grained sediments of mudstone, siltstone, claystone, and shale, such as the Willwood, (Late Cretaceous age), Gypsum Spring (Middle Jurassic age), and Chugwater Formations (Triassic age), are present under unconfined conditions and typically yield only limited water supplies.

The lithologic description and water-yielding properties of the geologic units in the county are listed in table 1. The distribution of these geologic units is shown on plate 1.

Ground-Water Data

The ground-water data collected consist of water levels, shut-in pressures, well yields, and water quality. For more information on water-quality data, the reader is referred to the water-quality section of this report. Ground-water data in Big Horn County have been collected for specific studies in the area on a periodic, and, in some cases, long-term basis. Until this study, when a continuous- record pressure gage was installed on a Worland municipal well, continuously recorded ground-water data had not been collected.

Table 4. Records of peak discharge and average discharge at surface-water stations in Big Horn County, Wyoming

[mi^2, square miles; ft^3/s, cubic feet per second]

Site number (pl. 1)	Station number	Station name	Drainage basin area (mi^2)	Period of discharge record, in water years: Daily or monthly	Period of discharge record, in water years: Annual peak	Instantaneous: Peak date	Instantaneous: Discharge (ft^2/s)	Average discharge (ft^2/s)
1	06269000	Bighorn River near Manderson	11,020	1949-54 1956		06-01-51	10,600	1,325
2	06269500	Bighorn River at Manderson	11,048	1941-49		06-04-44	17,900	1,847
3	06271500	Paint Rock Creek below Lake Solitude	16.0	1946-53		06-11-53	543	33.3
5	06272500	Paint Rock Creek near Hyattville	164	1920-27 1941-53		06-24-45	8,200	146
6	06273000	Medicine Lodge Creek near Hyattville	86.8	1943-73		06-24-45	1,160	34.6
7	06273500	Paint Rock Creek near Bonanza	376	1910-14 1915-23		06-12-18	3,390	155
8	06274000	Nowood River (Creek) at Bonanza	1,730	1910-28		06-15-24	5,160	
9	06274190	Nowood River tributary No. 2 near Basin	1.51		1965-84	08-09-81	302	
10	06274200	Nowood River tributary No. 2 near Manderson	1.59		1961-71	08-10-62	329	
12	06274250	Elk Creek near Basin	96.9		1959-81	06-06-67	4,260	
13	06274300	Bighorn River at Basin	13,223	[1]1984-88		[2]06-09-86	11,600	

Table 4. Records of peak discharge and average discharge at surface-water stations in Big Horn County, Wyoming--Continued

Site number (pl. 1)	Station number	Station name	Drainage basin area (mi^2)	Period of discharge record, in water years: Daily or monthly	Period of discharge record, in water years: Annual peak	Instantaneous: Peak date	Instantaneous: Discharge (ft^2/s)	Average discharge (ft^2/s)
15	06277500	Greybull River near Basin	1,115	1930-73		06-16-63	19,400	180
16	06277750	Dry Creek tributary near Emblem	.65		1960-68 1970-81	06-23-67	245	
17	06277950	Dry Creek near Greybull	432	1979-81		09-16-80	970	
18	06278000	Dry Creek at Greybull	433	1951-54 1956-61		09-19-61	[3]7,200	23.2
19	06278300	Shell Creek above Shell (Creek) Reservoir	23.1	[1]1957-88		[2]06-15-63	1,870	35.5
20	06278400	Granite Creek near Shell Creek Ranger station, near Shell	11.1		1961-74	06-10-68	415	
21	06278500	Shell Creek near Shell	145	[1]1941-88		[2]06-24-45	3,020	[4]119
22	06279000	Shell Creek at Shell	256	1911-23		06-11-18	1,910	142
23	06279020	Red Gulch near Shell	47.8		1967 1970-81	[5] - -67	2,820	
26	06279500	Bighorn River at Kane	15,765	[1]1928-88		[2]06-16-35	25,200	2,283
28	06284500	Bitter Creek near Garland	80.5	1950-54 1958-60 1969-87		07-04-75 05-07-88	1,230 [3]2,100	143

Table 4. Records of peak discharge and average discharge at surface-water stations in Big Horn County, Wyoming--Continued

Site number (pl. 1)	Station number	Station name	Drainage basin area (mi^2)	Period of discharge record, in water years: Daily or monthly	Period of discharge record, in water years: Annual peak	Instantaneous: Peak date	Instantaneous: Discharge (ft^2/s)	Average discharge (ft^2/s)
29	06284800	Whistle Creek near Garland	101	1958-60 1969-87		07-03-75	4,780	25.9
30	06285000	Shoshone River at Byron	2,345	1929-66		09-19-61	16,000	917
31	06285100	Shoshone River near Lovell	[6]2,350	[1]1967-88		[2]06-10-81	16,400	978
32	06285400	Sage Creek at Sidon Canal near Deaver	341	1958-60		06-08-58	2,250	65.0
				1969-87				
33	06285500	Sage Creek near Lovell	381	1951-60		07-31-58	1,290	106
35	06286200	Shoshone River at Kane	2,989	1958-68		09-19-61	13,200	1,141
37	06286258	Big Coulee near Lovell	30.1	1970-78		07-05-75	1,840	.087

1 Currently in operation (water year 1988).
2 Based on records through Sept. 30, 1987.
3 Estimated peak discharge outside period of record.
4 Average discharge computed from 31 years of record (1941-71).
5 Date not known.
6 Approximate.

Data from selected wells, springs, drains, and collection galleries inventoried throughout Big Horn County are compiled in table 15 (at back of report). The compilation consists of the local number, type of site, year drilled, depth of well, open interval, diameter of casing above the first open interval, the primary aquifer, the primary use of water, land surface altitude, static water level (distance to water above or below the land surface), water temperature, specific conductance of water, discharge, and dates of these measurements. The location of selected wells, springs, drains, and collection galleries is shown on plate 1.

The local number for wells, springs, drains, and collection galleries is based on the location according to the Federal system of land subdivision (for example, 51-96-22bab02). The first number denotes the township, the second number the range, and the third number the section. The first letter following the section number denotes the quarter section (160-acre tract), the second letter, if shown, the quarter-quarter section (40-acre tract), and the third letter the quarter-quarter-quarter section (10-acre tract). These subsections are designated a, b, c, and d in a counterclockwise direction, beginning with the northeast quarter. The last two characters form a sequence number indicating the order of inventory. For example, in figure 8, well 51-96-22bab02 is the second well inventoried in the northwest quarter of the northeast quarter of the northwest quarter of section 22, T. 51 N., R. 96 W. All wells in Big Horn County are north and west of the principal meridian.

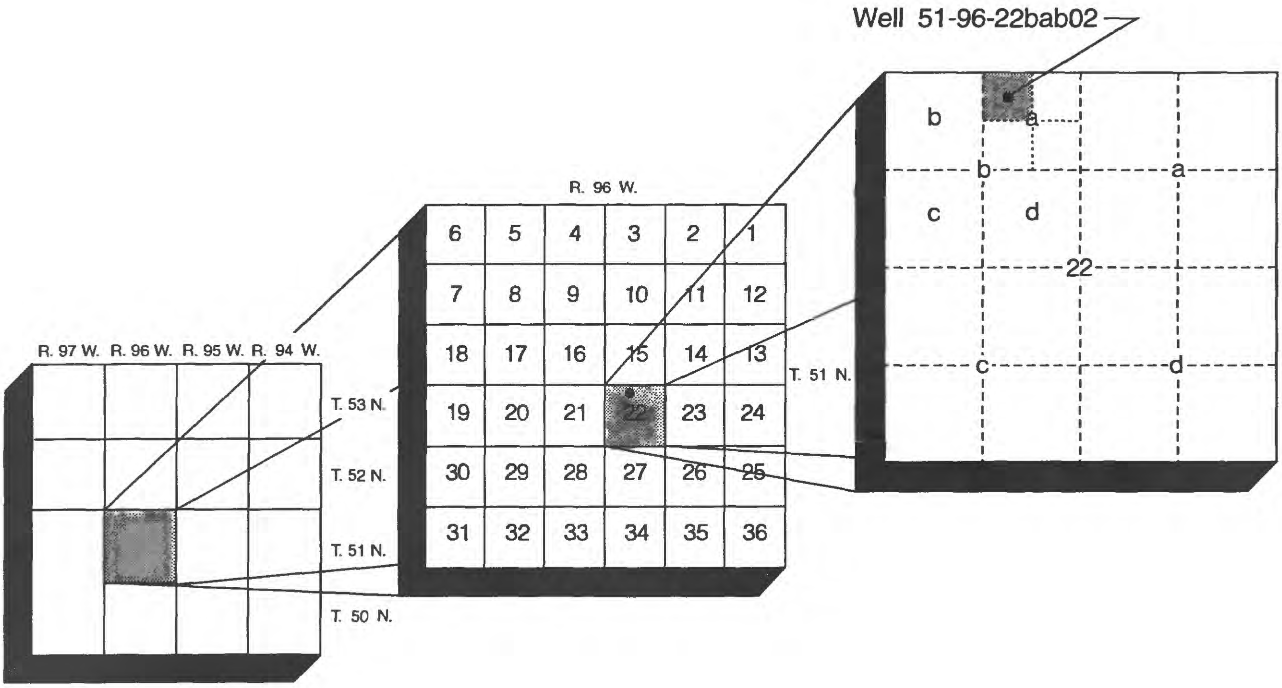


Figure 8.--System of numbering wells, springs, drains, and collection galleries.

Unconsolidated Aquifers

The principal unconsolidated aquifers developed as water supplies in Big Horn County are the alluvium and colluvium, and the gravel, pediment, and fan deposits of Holocene and Pleistocene age. The water-yielding properties of glacial and landslide deposits of Holocene and Pleistocene age, primarily found in the Bighorn Mountains, are not well known.

The alluvium and colluvium and the gravel, pediment, and fan deposits along the larger streams in the county, such as Greybull, Nowood, and Shoshone Rivers, are among the most productive and predictable sources of ground water in the county. Thickness of these deposits is as much as 100 ft (Lowry and others, 1976, sheet 1). Depth to water generally is 3 to 14 ft below land surface, but varies with season and the effects of irrigation. Most ground water is within 10 ft of the surface during the irrigation season (May through September). The location of wells completed in these aquifers where data were collected is shown on plate 1, map B.

Alluvium and Colluvium

Alluvium and colluvium of Holocene age consist of floodplain alluvium, terrace deposits, minor colluvium, and alluvial fan deposits (table 1). Generally, the floodplain alluvium deposits are less than 30 ft thick.

The recharge, movement, and discharge of water in the alluvium and colluvium is different along different streams in Big Horn County. Alluvium and colluvium receive recharge from precipitation. In addition, impoundments on the Bighorn, Greybull, and Shoshone Rivers regulate streamflow that not only provides a source of irrigation water, but also a potential recharge source to the alluvium and colluvium.

The direction of ground-water flow generally is from areas of higher water-table altitude to areas of lower water-table altitude. Contours of the water table in the alluvium and colluvium along the Shoshone River (fig. 9) near Lovell indicate that ground-water movement is toward the river.

Discharge from the alluvium and colluvium is to streams, wells, springs, drains, collection galleries, and evapotranspiration. When the water-table altitude in the alluvium and colluvium is higher than the water surface in an adjacent stream, water discharges to the stream. Water levels in wells completed in the alluvium and colluvium near Lovell (fig. 9) indicate that these deposits lose water to the Shoshone River. Yields from wells completed in alluvium and colluvium ranged from about 5 to 140 gal/min, but a yield of 600 gal/min was reported for a well along the Greybull River by Cooley and Head (1979, p. 16-18). Most wells yield less than 50 gal/min. Reported specific capacities ranged from less than 1 to 200 (gal/min)/ft of drawdown in wells along the Greybull and Nowood Rivers and Shell Creek; the median was 6.8 (gal/min)/ft of drawdown (6 wells). In three wells completed in alluvium and colluvium in the Bighorn Mountains specific capacities ranged from 0.2 to 2.0 (gal/min)/ft of drawdown. Information on yields from springs, drains, and collection galleries inventoried in Big Horn County was not available. When the water-table altitude is near the land surface, water is lost to evapotranspiration. The depth at which the effect of evapotranspiration is zero could vary and probably is dependent on soil type and vegetation. Depth to water in the alluvium and colluvium ranged from 1.2 to 28.6 ft below land surface.

Gravel, Pediment, and Fan Deposits

Gravel, pediment and fan deposits consist of terraces, pediment deposits, minor colluvium, and alluvial fan deposits (table 1). The deposits generally are coarser and thicker than the alluvium and colluvium. These deposits are composed of coarser materials along the Greybull River and Dry Creek than along Paint Rock Creek or the Nowood River.

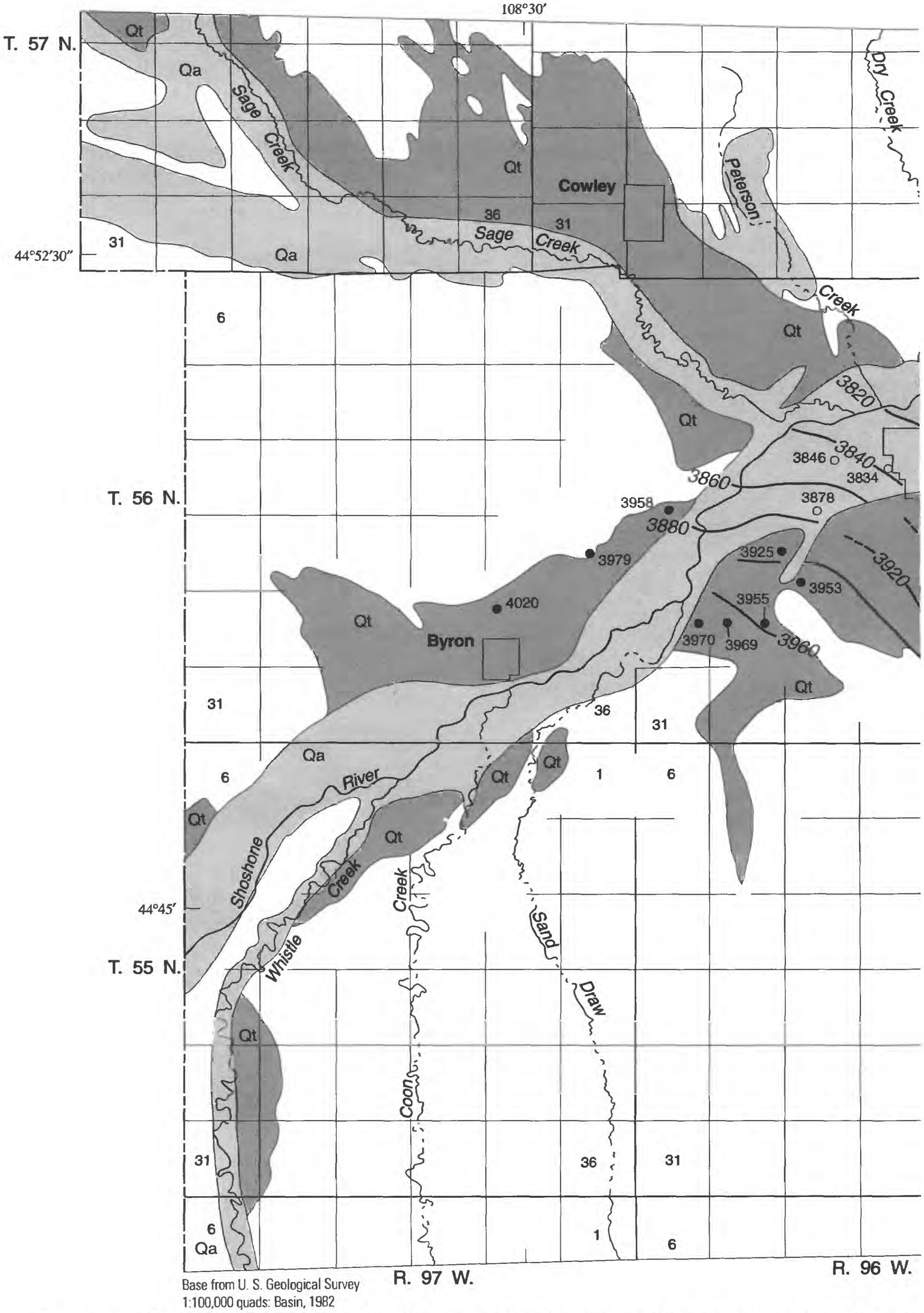
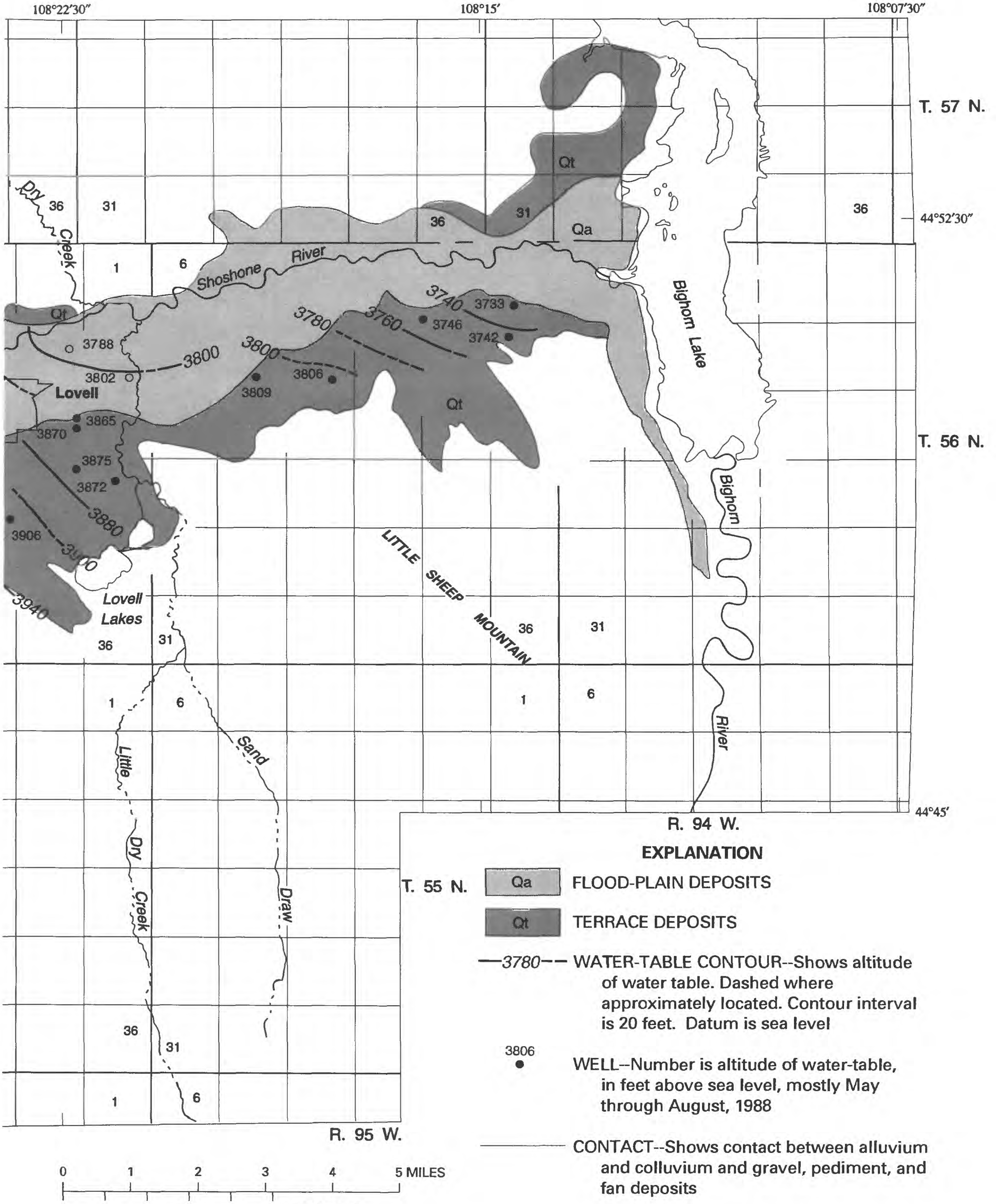


Figure 9.--Water-table contours for alluvium and colluvium and for gravel, pediment, and fan deposits along the Shoshone River, mostly May through August 1988.


108°22'30"
108°15'
108°07'30"
T. 57 N.
44°52'30"
T. 56 N.
44°45'
T. 55 N.
R. 94 W.
R. 95 W.
Qt
Qa
Dry Creek
Shoshone River
Bighorn Lake
Bighorn River
Lovell
Lovell Lakes
LITTLE SHEEP MOUNTAIN
Little Dry Creek
Sand Draw
3740
3733
3780
3760
3746
3742
3788
3800
3802
3806
3809
3865
3870
3875
3872
3880
3906
3900
3940
36
31
1
6
EXPLANATION
Qa FLOOD-PLAIN DEPOSITS
Qt TERRACE DEPOSITS
3780 WATER-TABLE CONTOUR--Shows altitude of water table. Dashed where approximately located. Contour interval is 20 feet. Datum is sea level
3806 WELL--Number is altitude of water-table, in feet above sea level, mostly May through August, 1988
CONTACT--Shows contact between alluvium and colluvium and gravel, pediment, and fan deposits
0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS

Surface water diverted from rivers by canals and ditches along with natural precipitation are major recharge sources to gravel, pediment and fan deposits, which are higher in altitude than the alluvium and colluvium. Many irrigation ditches are unlined and leak water into underlying sediments. During the irrigation season, ground water near irrigation canals is at about the same altitude as water in the canals.

Ground water in the gravel, pediment, and fan deposits is perched above the streams by impermeable strata in the underlying bedrock and is not in direct connection with either the rivers or the creeks. Water-table contours in the gravel, pediment, and fan deposits along the Shoshone River and Orchard Bench and Emblem Bench (figs. 9, 10 and 11) indicate that ground-water movement generally is in the downstream direction or toward the river. Contours of the water table in the gravel, pediment, and fan deposits along Shoshone River and Emblem Bench shown in figures 9 and 11 indicate that ground-water movement is in the downstream direction. In the terrace deposits along Orchard Bench (fig. 10) ground-water movement is toward the river.

Discharge from the gravel, pediment, and fan deposits is to wells, drains, springs, and evapotranspiration. Reported yields from wells completed in gravel, pediment, and fan deposits ranged from 3 to 1,600 gal/min; the median was almost 200 gal/min (28 samples). Yields ranging from 10 to 900 gal/min are reported from wells along the Greybull River (Cooley and Head, 1979, p. 16-18). Gravel, pediment, and fan deposits generally are thicker than alluvium and colluvium and might attain a greater saturated thickness resulting in a larger well yield. Specific capacities ranged from 0.5 to 300 (gal/min)/ft of drawdown; the median specific capacity was 16.7 (gal/min)/ft of drawdown (27 samples). One drain (52-095-10ddb01) completed in the gravel, pediment, and fan deposits yielded 1,350 gal/min. Three springs issuing from the gravel, pediment, and fan deposits were inventoried, but information on yields was not available. Water might be lost to evapotranspiration in areas where the water-table altitude is near the land surface. Depth to water in wells completed in gravel, pediment, and fan deposits ranged from 2.0 to 39.3 ft.

Bedrock Aquifers

Bedrock aquifers are developed as water supplies in Cenozoic, Mesozoic, Paleozoic, and Precambrian rocks (table 1). Inventoried wells that develop these aquifers are shown on plate 1. In Big Horn County, yields of wells are similar in wells completed in formations of all ages that are dominated by fine-grained lithologies. Differences in saturated thickness and secondary permeability account for most of the yield differences.

In some areas of Big Horn County and along major streams in the county, bedrock is overlain by unconsolidated deposits. Depth to bedrock in these areas ranges from about 1 to 60 ft. Wells commonly are completed in both the unconsolidated and bedrock aquifers which might hydraulically connect the units. Interformational flow between unconsolidated deposits and bedrock aquifers also might occur in fractured zones associated with anticlines. In areas not developed by wells, the units probably are in poor hydraulic connection, as indicated by perched water tables.

Cenozoic and Mesozoic Rocks

Cenozoic (Tertiary) and Mesozoic (Cretaceous, Jurassic, and Triassic) rocks crop out primarily to the west of the Bighorn Mountains. With the exception of widely distributed stock wells, Cenozoic and Mesozoic rocks have been developed as water supplies principally in populated areas along streams.

Depth to water in the Cenozoic and Mesozoic rocks generally was greater than that in the unconsolidated deposits and ranges from 2 to 202 ft below land surface. Data are sparse for many aquifers because they commonly are too deep to be economically developed. As a result, the direction of water movement in these aquifers has not been determined.

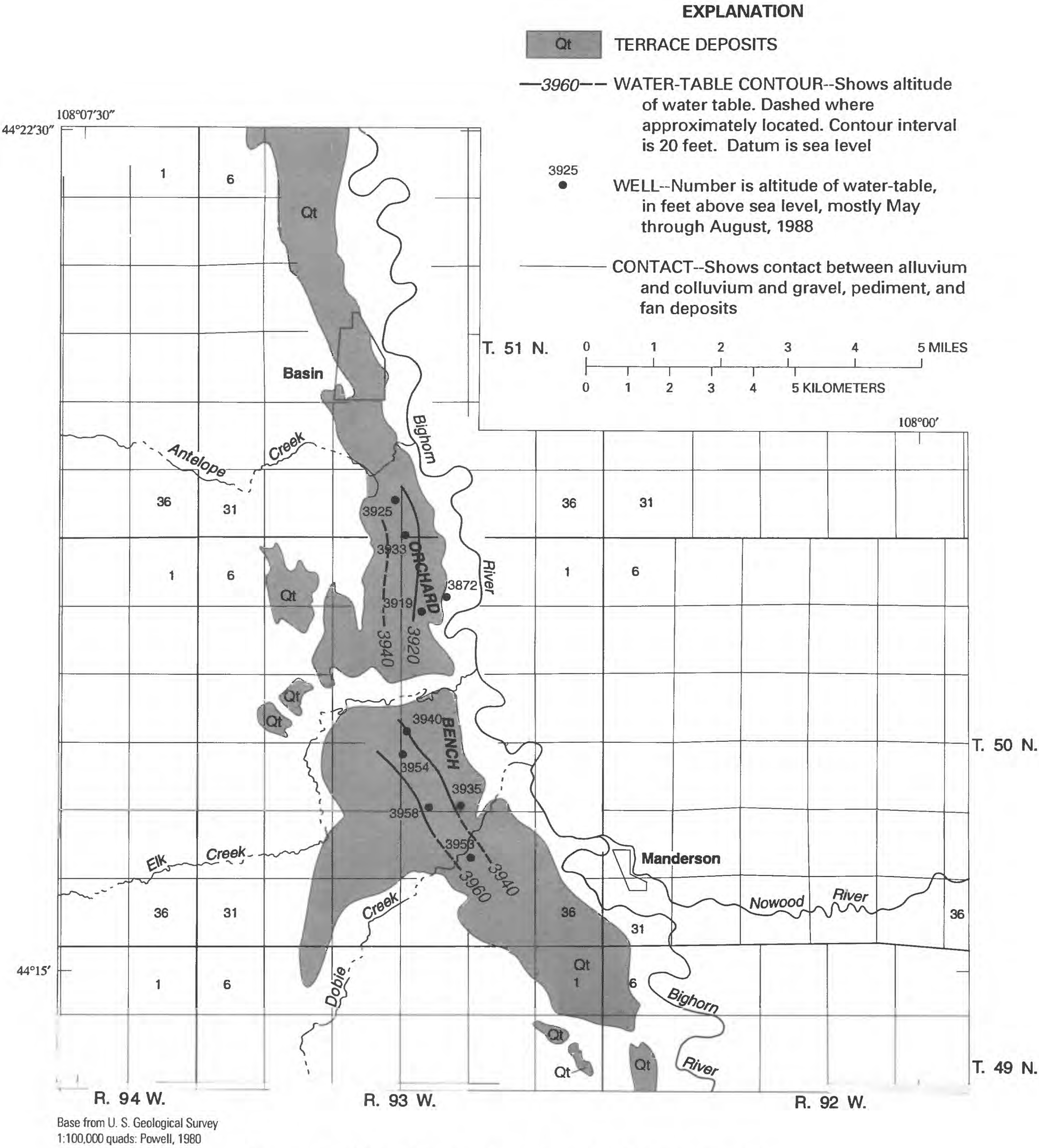
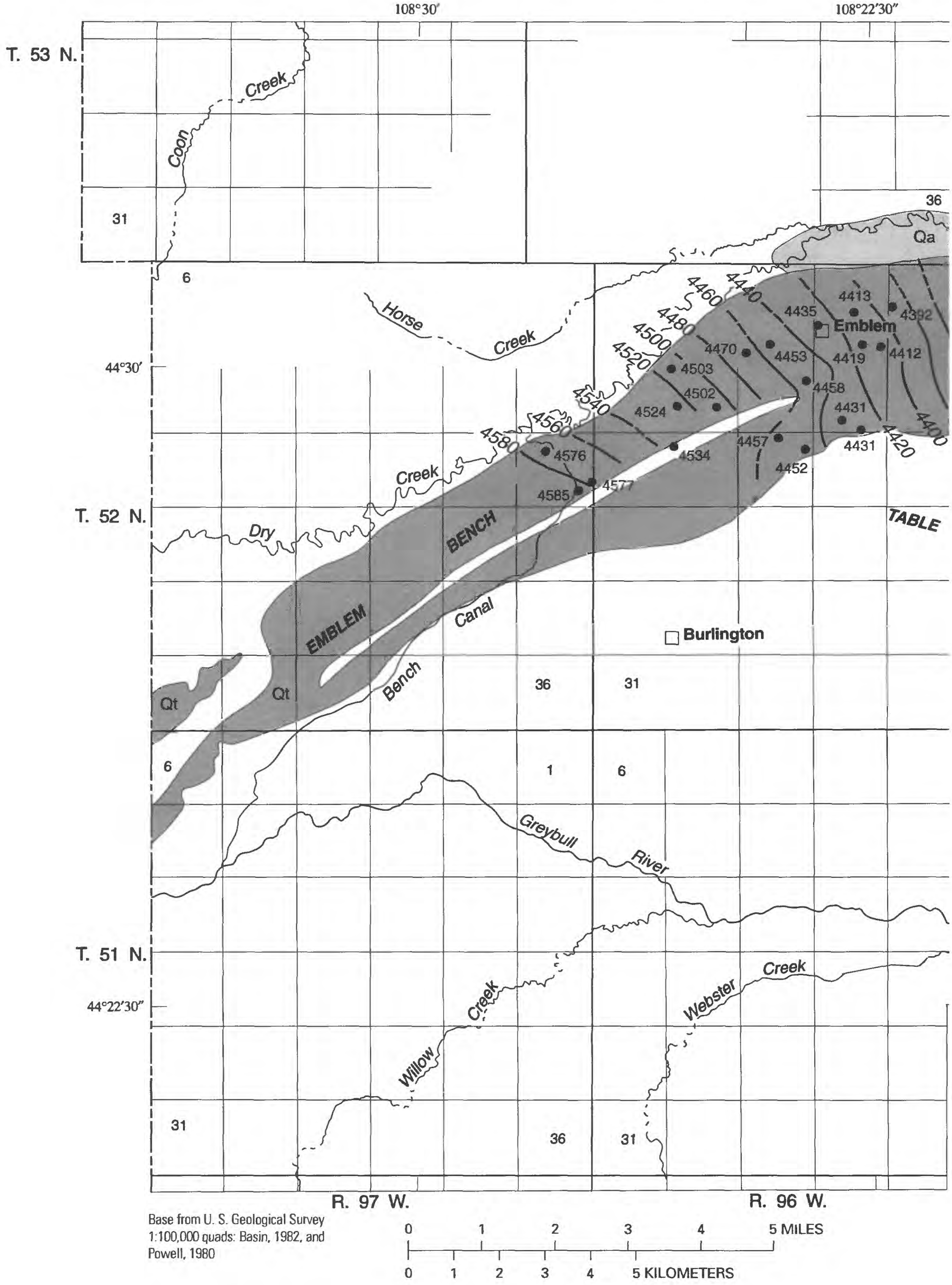


Figure 10.--Water-table contours for gravel, pediment, and fan deposits along Orchard Bench.


108°30′
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T. 53 N.
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R. 97 W.
R. 96 W.
Coon
Creek
Horse
Creek
Dry
Creek
EMBLEM
BENCH
TABLE
Canal
Bench
Greybull
River
Willow
Creek
Webster
Creek
Emblem
Burlington
Qa
Qt
4460
4440
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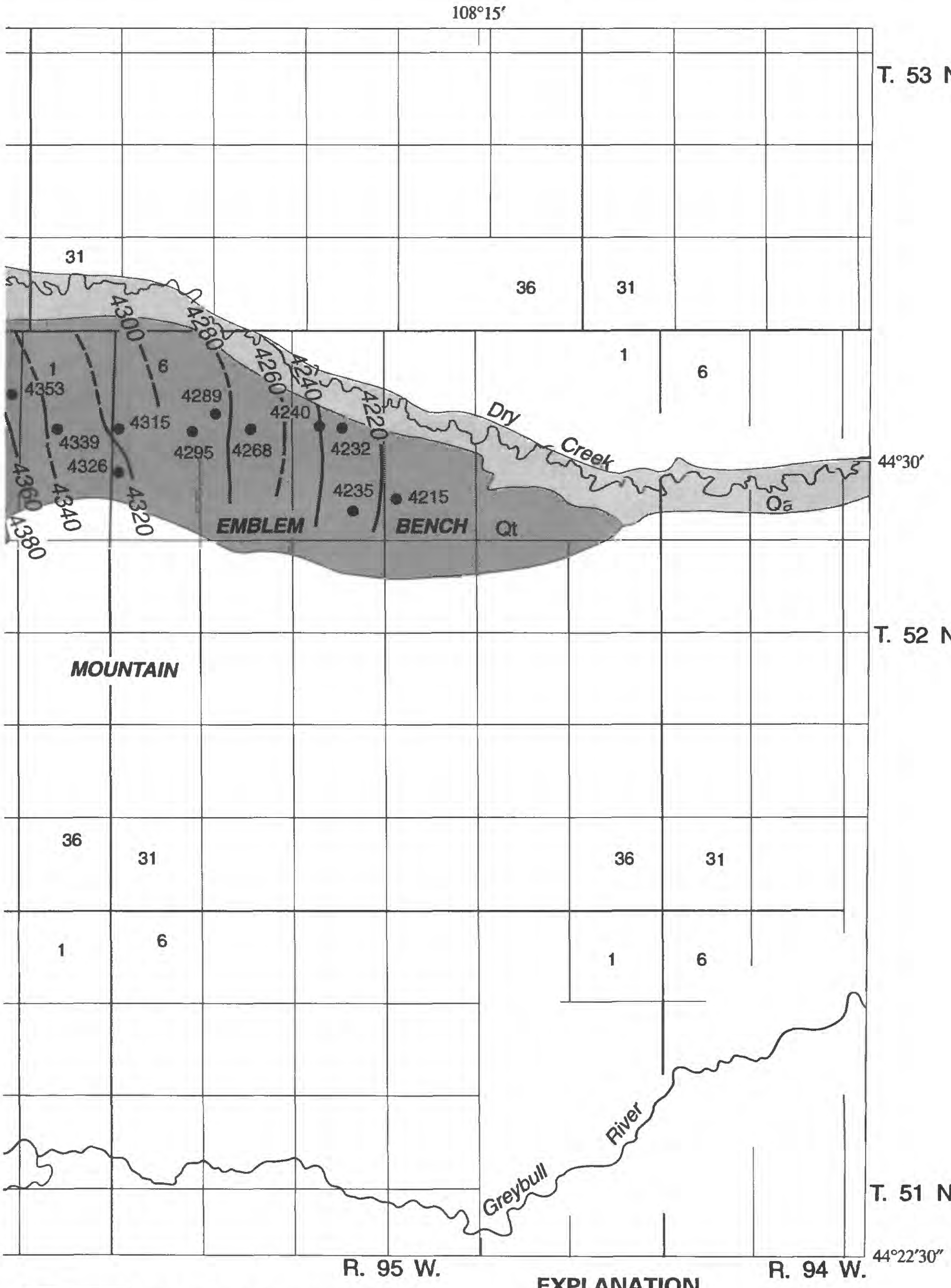
Base from U. S. Geological Survey 1:100,000 quads: Basin, 1982, and Powell, 1980
0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS



EXPLANATION

Qa	FLOOD-PLAIN DEPOSITS
Qt	TERRACE DEPOSITS
—4340— —	WATER-TABLE CONTOUR--Shows altitude of water table. Dashed where approximately located. Contour interval is 20 feet. Datum is sea level
4326 •	WELL--Number is altitude of water-table, in feet above sea level, mostly May through August, 1988
———	CONTACT--Shows contact between alluvium and colluvium and gravel, pediment, and fan deposits

Figure 11.--Water-table contours for gravel, pediment, and fan deposits along Emblem Bench.

Tertiary rocks

The most complete data for Tertiary rocks are from the Willwood Formation along the Greybull River and Emblem Bench and from the Fort Union Formation along the Bighorn River. The White River Formation of Oligocene age and the Tatman Formation of Eocene age are not described because of their limited areal extent and because they are not known to be developed as water supplies in Big Horn County.

Willwood Formation.--The Willwood Formation of early Eocene age consists of flat-lying multicolored beds of interfingered mudstone, claystone, siltstone, thin sandstone, and carbonaceous shale. The formation was deposited in a fluvial environment characteristic of meandering streams. The average percentage of sandstone in the formation is about 25 percent (Lowry and others, 1976). The channel sandstones are laterally discontinuous, seldom extending for more than 0.5 mi, and average 2 ft in thickness but are as much as 35 ft thick (Neasham and Vondra, 1972). The Willwood Formation is about 2,300 ft thick near Basin and thins westwardly to 1,500 ft in the county.

The formation is developed as a water supply primarily along the Greybull River and Emblem Bench where it is usually overlain by thin unconsolidated deposits. Although reported yields ranged from less than 1 to 120 gal/min, aborted attempts to produce adequate domestic water supplies from wells completed in this formation are common; most common yields are less than 10 gal/min. The large variation in the deposition of sediments in fluvial systems makes the probability of drilling into a water-bearing sandstone lens small. Some of the larger yields reported for wells completed in the Willwood Formation are probably coproduction from overlying unconsolidated deposits. Reported specific capacities ranged from 0.03 to 8.5 (gal/min)/ft of drawdown; the median was 0.5 (gal/min)/ft of drawdown (11 wells). Libra and others (1981) reported a similar average [0.4 (gal/min)/ft of drawdown] for 48 wells completed in the Willwood Formation throughout the Bighorn Basin. Depth to water in wells completed in the Willwood Formation ranged from 4.8 to 80.8 ft.

Fort Union Formation.--The Fort Union Formation of Paleocene age consists of interbedded sandstone, siltstone, claystone, and thinly bedded coal. The formation contains an average of about 25 percent sandstone (Lowry and others, 1976), but sandstone lenses are seldom continuous for more than a few hundred yards. A cliff-forming sandstone is present near the base of the unit. The formation thickness ranges from about 2,000 to 8,000 feet (Moore, 1961, figure 2, p. 204), thickening to the southwest.

The Fort Union Formation is developed as a water supply primarily where it crops out west of the Bighorn River. Reported yields from wells in the county ranged from 5 to 30 gal/min and specific capacities ranged from 0.08 to 3.0 (gal/min)/ft of drawdown. Libra and others (1981) reported that yields for wells completed in the Fort Union Formation were generally less than 20 gal/min and specific capacities ranged from 0.016 to 0.17 (gal/min)/ft of drawdown throughout the Bighorn Basin. Depth to water in wells completed in the Fort Union Formation ranged from 3.4 to 140.2 ft.

Cretaceous rocks

Upper Cretaceous rocks.--The Upper Cretaceous rocks are the Lance, Meeteetse, and Mesaverde Formations, the Cody Shale, and the Frontier Formation (table 1). The rock types in these formations are mostly fine grained and include claystone, siltstone, and shale. Sandstone can be found interbedded or in the lower part of the Lance, Meeteetse, and Mesaverde Formations. The upper parts of the Meeteetse Formation and Cody Shale contain sandstone, and 50 percent of the Frontier Formation is sandstone (table 1). The range of thickness for all of the Upper Cretaceous rocks is from 4,450 to about 7,950 ft.

The Lance Formation has been developed as a water supply primarily near Manderson and on the Orchard Bench. The Manderson municipal water-supply well develops this unit. Reported well yields in the county ranged from 20 to 65 gal/min. Reported specific capacities ranged from 0.8 to 13.3 (gal/min)/ft of drawdown. Depth to water in nine wells completed in the Lance Formation ranged from 4.9 to 202 ft. Of all the Mesozoic rocks in the county, the Lance Formation has the most potential for development as a water supply.

Libra and others (1981, p. 43) estimated that yields from wells completed in the Meeteetse Formation would be less than 15 gal/min in the Bighorn Basin. On the basis of reported yields for other formations having similar lithologies, yields less than 10 gal/min are more probable for wells completed in this formation. Depth to water in one well completed in the Meeteetse Formation was 35 ft.

The Mesaverde Formation contains sandstone that is lenticular and laterally discontinuous. These sandstone lenses range in thickness from 5 to 40 ft. Reported well yields ranged from 10 to 35 gal/min, and specific capacities ranged from 0.2 to 3.8 (gal/min)/ft of drawdown. Depth to water in 17 wells completed in the Mesaverde Formation ranged from 2.4 to 176 ft. This formation has potential for development as a water supply in Big Horn County.

Reported yields from wells completed in the Cody Shale ranged from less than 5 to 25 gal/min, but commonly yields are less than 5 gal/min. Specific capacities ranged from 0.7 to 1.2 (gal/min)/ft of drawdown. These data indicate the presence of fractured sandstone beds in the formation. It is probable that well yields would be less than 5 gal/min where only the shale is penetrated by wells. Depth to water in wells completed in the Cody Shale ranged from 3.7 to 38.7 ft. Although the formation is not considered a regional aquifer, locally it could yield enough water for domestic or stock use.

The Frontier Formation has some potential for development as a water supply on the basis of lithology, well-yield, and permeability data. The formation contains less than 50 percent sandstone (Lowry and others, 1976). Reported yields for three wells ranged from 5 to 16 gal/min, and reported specific capacities ranged from 0.2 to 0.6 (gal/min)/ft of drawdown. Reported porosities from oil-field data throughout the Bighorn Basin ranged from 10 to 26 percent, and permeability ranged from 0 to 1.4 [(gal/d)/ft^2] (Libra and others, 1981, p. 42). Depth to water in three wells completed in the Frontier Formation ranged from 8.1 to 120 ft.

Lower Cretaceous rocks.--Three Lower Cretaceous formations are present in Big Horn County--the Mowry and Thermopolis Shales, and the Cloverly Formation. These formations are composed mostly of siltstone and shale with some interbedded sandstone. Total thickness of the formations ranges from 850 to 1,500 ft.

Well yields from the Mowry Shale are less than 5 gal/min. The formation might contain secondary permeability associated with folds and faults because the siliceous shale is brittle.

Most of the Thermopolis Shale is not an aquifer. This shale deforms plastically and does not develop substantial fracture permeability. The Muddy Sandstone Member of the Thermopolis Shale might yield enough water for domestic or stock use; most common yields are 10 to 15 gal/min. The Muddy Sandstone Member is 175 to 200 ft above the base of the Thermopolis Shale and consists of massive sandstone interbedded with mudstone, siltstone, shale, bentonite, with occasional chert-pebble conglomerate (Paull, 1962, p. 105). The sandstones can be weakly indurated. The thickness of the Muddy Sandstone Member ranges from about 10 to 100 ft; it is thickest in the southern part of the county and thins toward the north (Libra and others, 1981, p. B-10).

Although well yields as large as 20 gal/min are reported, most common yields from wells completed in the Lower Cretaceous Cloverly Formation are 10 to 15 gal/min. One well in the study area had a reported specific capacity of 0.02 (gal/min)/ft of drawdown. Porosity, derived from oil-field data, ranged from 7 to 15 percent in the northern and northeastern parts of the Bighorn Basin (Libra and others, 1981, p. 42). Depth to water in six wells completed in this formation ranged from 2.6 to 60 ft.

Jurassic and Triassic rocks

Jurassic rocks in Big Horn County are the Morrison, Sundance, and Gypsum Spring Formations; the Chugwater Formation is of Triassic age (table 1, plate 1). Lithologies of Jurassic and Triassic formations are similar to Tertiary and Cretaceous formations but also include calcareous deposits and evaporites. Thickness for these four formations ranges from 1,000 to about 1,600 ft. Data for the water-yielding characteristics are limited because few wells are completed in these formations.

The Morrison Formation of Upper Jurassic age is a predominantly interbedded multicolored shale, mudstone, and silty sandstone. Freshwater marls and limestones, which are associated with lacustrine environments, and thin discontinuous lenses of conglomerate also are present (Downs, 1952, p. 28). Sandstone in the formation can yield enough water for domestic or stock supplies; most common yields are 10 to 15 gal/min.

The Sundance Formation of Upper Jurassic age can be divided into upper and lower parts (Downs, 1952, p. 28). The upper part of the Sundance consists of well-sorted sandstone with interbedded shale and occasional microcrystalline limestone. It is about 150 to 200 ft thick. The lower part of the Sundance is interbedded glauconitic sandstone, oolitic limestone, and calcareous shale. The sandstone most commonly is found near the top of the lower part of the Sundance; a persistent limestone might be found at the base (Mills, 1956, p. 16). The lower part of the Sundance is about 100 to 175 ft thick.

The Sundance Formation is developed as a water supply north of Shell along Horse Creek. In this area, near outcrops of the formation, wells yield supplies adequate for domestic and stock needs. The most commonly reported yields from wells completed in sandstone lenses in this formation are 10 to 15 gal/min. Depth to water in one well completed in the Sundance Formation was about 38 ft.

The Gypsum Spring Formation of Middle Jurassic age consists of reddish siltstone and shale, interbedded with thin dolomite and limestone, and gypsum beds. The gypsum beds might be as thick as 60 ft (Downs, 1952, p. 280). This formation can be divided into an upper sequence of shale and carbonate and a lower gypsiferous zone (Mills, 1956, p. 15).

One inventoried well completed in the Gypsum Spring Formation had a reported yield of 20 gal/min. Lowry and others (1976) stated that solution zones in the gypsum could yield large quantities of water. They deduced from water temperature and water quality of springs that, at some locations, the Gypsum Spring Formation is recharged from underlying Paleozoic aquifers. On the basis of lithology, most common well yields are in the range of 10 to 15 gal/min. Depth to water in one well completed in the Gypsum Spring Formation was 20.8 ft.

The distinctive red beds of the Chugwater Formation of Triassic age predominantly consist of fine-grained sandstone, siltstone, and shale but also contain some thin lenticular beds of limestone and gypsum. The thickness of the formation ranges from about 500 to 700 ft (Swenson and Bach 1951, p. 17; Downs, 1952, p. 27).

Oil-field data from two wells about 25 mi west of the county line indicate water production from sandstones of at least 25 gal/min (Libra and others, 1981, p. 65). On the basis of the dominantly fine-grained lithology, most common well yields are 10 to 15 gal/min. Depth to water in one well completed in the Chugwater Formation ranged from 20.8 to 24.5 ft.

Paleozoic Rocks

The major aquifers in the Paleozoic rocks, listed stratigraphically from youngest to oldest, are the Tensleep Sandstone, Madison Limestone, Bighorn Dolomite, and Flathead Sandstone (table 1, plate 1). These aquifers commonly yield large quantities of water from flowing wells. The difference in altitude between recharge areas in the mountains and well locations in the basin, in combination with aquifer confinement by impermeable beds, creates highly pressured artesian conditions in many areas. Flowing wells completed in Paleozoic rocks west of the Bighorn Mountains generally are more than 1,000 ft deep.

The overlying thick sequence of shaley Mesozoic rocks serves as an upper confining unit for all aquifers in the Paleozoic rocks. In the Paleozoic sequence of rocks, the Goose Egg Formation of Triassic and Permian age confines the Tensleep Sandstone; the Amsden Formation of Pennsylvanian and Mississippian age confines the Madison-Bighorn aquifer; and the Gallatin Limestone of Late Cambrian age and Gros Ventre Formation of Late and Middle Cambrian age confine the Flathead Sandstone. Even though the Goose Egg, Amsden, and Gros Ventre Formations are confining units for other Paleozoic rocks, these formations yield water to wells and springs in some areas of Big Horn County. The most common yields for wells completed in the Goose Egg and Amsden Formation are 10 to 15 gal/min; the Gros Ventre Formation is a potential source for small well yields.

The aquifers in the Paleozoic rocks are recharged primarily in the mountains rimming the Bighorn Basin. Precipitation and snowmelt infiltrate directly into the outcrops exposed there. Although streams commonly lose water when crossing upturned beds of Paleozoic rocks, many streams in the Trapper-Medicine Lodge area between Shell and Hyattville have been observed to lose all their flow into the karst system developed in the Madison-Bighorn aquifer (Huntoon, 1985a, 1985b). Flows as large as 50 ft^3/s have been measured in streams entering caves in the Trapper-Medicine Lodge area (Stout and others, 1987, p. 108). Data from Druse and others (1989) indicate that recharge to the aquifers in the Paleozoic rocks from streams is variable along the western flank of the Bighorn Mountains. Substantial differences exist in stream losses or gains between karst and nonkarst areas. In nonkarst areas, direct infiltration of precipitation into outcrops is probably a more substantial recharge component than that contributed by losing streams.

In the aquifers in the Paleozoic rocks, water moves from the mountains that rim the Bighorn Basin toward the Bighorn River in the basin, as potentiometric surface maps by Bredehoeft and Bennett (1972) and by Cooley (1986a) indicate. However, not all of the water that enters the aquifers in the Paleozoic rocks as recharge moves to the basin because the homocline from the Bighorn Mountain front to the Bighorn Basin is not continuous. Thrust faults and high-angle reverse faults break this continuity at intervals along the range front (pl. 1, map A). Discrete and unconnected hydrologic systems can exist on opposite sides of faults where permeable strata are faulted against impermeable rock, inhibiting basinward movement of water (Doremus, 1986, p. 12). Even where homoclines and hydrologic continuity exist, basinward decreases in permeability also can cause rejected recharge from outcrops and subcrops before it passes beneath confining beds. Bredehoeft (1964) documented basinward permeability decreases in the Tensleep Sandstone; it is likely in the other aquifers in the Paleozoic rocks.

Prior to oil-field development, the dominant points of natural discharge, inferred from the potentiometric surface of the Tensleep Sandstone from Bredehoeft and Bennett (1972), were at outcrops along the Bighorn River. Since oil-field development, springs still discharge along the Bighorn River at Sheep Mountain and Little Sheep Mountain; however, the general direction of flow in aquifers in Paleozoic rocks in the Bighorn Basin may now be to the northwest rather than north. Other points of discharge from the aquifers in Paleozoic rocks include springs along the gaining reaches of streams in the mountains and from wells. Large capacity municipal, irrigation, and water-supply wells associated with oil-field development account for most of the discharge from wells.

Tensleep Sandstone

The tan cross-bedded sandstones of the Tensleep Sandstone crop out along the eastern basin margin. The formation is dominantly a well-sorted fine- to medium-grained sandstone cemented by carbonate and silica. The upper part is considered to be eolian sand and contains cherty dolomite, and the lower part contains discontinuous marine limestone and dolomite (Moore, 1984, p. 274-275). The thickness of the formation ranges from about 50 to 200 ft and thickens to the south (Lawson and Smith, 1966, fig. 5, p. 2199). Except in outcrop areas, the Tensleep Sandstone is confined above by the Goose Egg Formation and below by the Amsden Formation. Doremus (1986, p. 8) reported that hydraulic connection between the Tensleep Sandstone and overlying rocks of the Phosphoria Formation, equivalent to the Goose Egg Formation, depends on the absence of low-permeability shales. He presented evidence of interconnection in the northern part of the county, based on similar heads in wells completed in each formation and proposed the Phosphoria-Tensleep aquifer.

The Tensleep Sandstone is developed as a water supply mostly near Hyattville where it is reached at depths less than 1,000 ft. Virtually all Tensleep Sandstone water wells in the county flow at the surface and are developed as stock or domestic water supplies. Quantities seldom are adequate for irrigation.

Yields of wells completed in the Tensleep Sandstone, which were reported at well completion, were as large as 200 gal/min. Most common yields from flowing wells in the study area ranged from about 10 to 30 gal/min. Hydraulic heads of flowing wells, converted from shut-in pressures, were as large as 115 ft above land surface (50 lb/in2). Specific capacities calculated at two flowing wells near Hyattville were 0.2 and 0.3 (gal/min)/ft of drawdown. Cooley (1986a, p. 42) reported a range of 0.4 and 2.0 (gal/min)/ft of drawdown for water wells near the town of Ten Sleep in Washakie County. Specific capacity for wells completed in this formation in the Bighorn Basin (Big Horn and adjacent counties) ranged between 0.4 and 5.0 (gal/min)/ft of drawdown, and transmissivity values in the Bighorn Basin, estimated by recovery methods, ranged from 54 to 402 ft^2/d (Libra and others, 1981, p. 44 and 55). Cooley (1986a, p. 42) estimated transmissivity values between 142 and 290 ft^2/d at three wells near Ten Sleep and Hyattville.

Porosity in the Tensleep Sandstone primarily is intergranular, but secondary fracture porosity and especially permeability also are present in folds and faults. Oil-field data indicate porosity ranges from 3 to 27 percent, averaging about 13 percent at depths less than 8,000 ft (Lawson and Smith, 1966).

Madison Limestone, Darby Formation, and Bighorn Dolomite

Three geologic units with similar lithologies--the Madison Limestone, the Darby Formation, and the Bighorn Dolomite--form the Madison-Bighorn aquifer. The Madison Limestone of Mississippian age consists predominantly of limestone and dolomite in the upper part, which may contain caves, and massive blue-gray limestone and dolomite in the lower part. Both upper and lower parts of the Madison contain thin chert beds and shale. The thickness of the formation ranges from about 500 to 800 ft and thickens to the northwest (Denson and Morrissey, 1952, fig. 6, p. 41). The formation is extensively exposed on the western flanks of the Bighorn Mountains where it dips abruptly into the Bighorn Basin.

Sando (1974, p. 133) describes Late Mississippian (pre-Darwin Sandstone) solution features in the upper 300 ft of the formation at several locations in the county. These features are enlarged joints, sinkholes, and a solution zone filled with limestone and breccia near the base of the upper part. All solution features are evident at Shell Canyon in the mountains (S1/2 sec. 9, and E1/2 sec. 17, T. 53 N., R. 90 W.), but caves are absent in outcrops in the basin. An extensive cave system has been described in the Trapper-Medicine Lodge area between Hyattville and Shell (Stout and others, 1987, p. 105; Huntoon, 1985a, 1985b). Caves also have been noted in the northeastern part of the county (Doremus, 1986, p. 13 and 14).

Joints, sinkholes, and caves are at least partially filled with sand associated with the overlying basal Darwin Sandstone Member of the Amsden Formation (Sando, 1974, p. 134). In the Trapper-Medicine Lodge area between Shell and Hyattville many of these ancient solution features are either plugged with fine sediments or are poorly connected and contribute little to aquifer permeability (Huntoon, 1985a). A more hydrologically important (post-Laramide) karst system is developing as the overlying sedimentary strata are eroded from the

Madison outcrops (Huntoon, 1985a). Evidence suggests that most water associated with caves in the Trapper-Medicine Lodge area is discharged to the surface in springs as the ability of the formation to transmit water decreases toward the basin (Huntoon, 1985a).

The Darby Formation of Upper Devonian age is predominantly an argillaceous and silty dolomitic unit. Argillaceous beds compose 50 percent or more of the formation in the Bighorn Mountains (Sandberg, 1965, p. N4). The formation thickness ranges from near zero in the southeastern part of the county to about 200 ft in the northern Bighorn Mountains and thickens to the north.

In the northern part of the county where the Jefferson Formation is thickest, it might hydraulically separate the Madison Limestone from the Bighorn Dolomite. However, the minimal formation thickness in the southeastern part of the county, and the similar lithology of the Jefferson to the Madison Limestone and the Bighorn Dolomite provide the hydraulic connection that forms the Madison-Bighorn aquifer in this area. Cooley (1986a) described the Madison-Bighorn aquifer, and this report follows his terminology.

The Bighorn Dolomite of Upper Ordovician age can be divided into two major yellow-gray dolomitic parts (Richards and Nieschmidt, 1961). The upper part consists of massive and thin-bedded dolomite and might contain dolomite breccia or conglomerate near the base. This part has a distinctive mottled appearance where it is exposed. The lower part is massive dolomite and dolomitic limestone overlaid by thinly bedded and blocky dolomite. Thin, discontinuous, cherty beds and nodules are present throughout the formation. The lower part might be underlain by a thin sandstone in the eastern part of the county, but a shaley limestone is common toward the west. The formation thickness ranges from about 350 to 450 ft.

The Madison-Bighorn aquifer is a major aquifer. Reported yields at well completion from the Madison-Bighorn aquifer ranged from 40 to 14,000 gal/min (Cooley, 1986a); the median was 508 gal/min (16 wells). Yields from flowing Madison-Bighorn wells measured during this study ranged from 10 to 1,090 gal/min. Wells yielding less than about 50 gal/min were drilled as stock or domestic wells and did not fully penetrate the aquifer. Wells successfully drilled and completed for irrigation or municipal supply fully penetrated the aquifer and produced at least 350 gal/min. Hydraulic heads, converted from measured shut-in pressures, ranged from 95 to nearly 490 ft (41 to 212 lb/in^2) above land surface. Specific capacities ranged from 0.1 to 5.2 (gal/min)/ft of drawdown in 10 flowing wells. Cooley (1986a, p. 42) reported specific capacities ranging from 0.43 to 7.6 (gal/min)/ft of drawdown in wells near the town of Ten Sleep. Libra and others (1981, p. 53) indicated similar specific capacities, ranging from 0.32 to 10.2 (gal/min)/ft of drawdown, for wells completed in the Madison-Bighorn aquifer throughout the Bighorn Basin.

Values of transmissivity, estimated from oil-field drill stem tests, ranged from 0.9 to 13.4 ft^2/d for the Madison-Bighorn aquifer. In water wells, reported values of transmissivity ranged from 134 to 4,020 ft2/d (Libra and others, 1981, p. 52). Cooley (1986a) reported values, estimated from recovery tests in the Hyattville and Ten Sleep areas, that ranged from 72 to 1,900 ft2/d. Reported porosities ranged from 10 to 21 percent at oil fields throughout the Bighorn Basin (Libra and others, 1981, p. 52).

Flathead Sandstone

The Flathead Sandstone of Cambrian age consists of arkosic and quartzitic sandstone; it is interbedded with shale in the upper part (Libra and others, 1981). The formation is absent in the northeastern part of the county, but thickens to about 170 ft in the southwest. It is confined above by the shaley sediments of the Gros Ventre Formation and the Gallatin Limestone, and below by nonporous crystalline granites. Porosity is intergranular, but secondary permeability has been created by fracturing along folds and faults.

Three wells are known to produce primarily, although not exclusively, from the Flathead Sandstone. In the basin area of Big Horn County, the formation is highly pressured and produces flowing wells. Reported yields at well completion ranged from 350 to 3,000 gal/min. Flows measured in these wells during this study ranged from 100 to 1,000 gal/min; hydraulic heads, converted from shut-in pressures, ranged from 423 to 947 ft (183 to 410 lb/in^2) above land surface. Specific capacities ranged from 1.0 to 1.4 (gal/min)/ft of drawdown in two wells that could be shut-in. Cooley (1986a, p. 42) reported specific capacities ranging from 0.52 to 3.4 (gal/min)/ft of drawdown in three wells near Hyattville and Ten Sleep in Washakie County. Values of transmissivity, estimated from recovery methods for two wells, were 250 and 320 ft2/d (Cooley, 1986a, p. 42). The Flathead Sandstone is not easily developed in the basin because it is present at great depths, and drill holes commonly cave in while drilling through the overlying Gros Ventre Formation.

Cooley (1986a, p. 16) noted decreases in shut-in pressures for wells completed in the Flathead Sandstone near Ten Sleep. His interpretation was that the decreases result from continuous discharge of water from wells that are open to the highly pressured Flathead Sandstone and the less pressured Madison-Bighorn aquifer.

Precambrian Rocks

The Precambrian crystalline basement rocks that crop out in the Bighorn Mountains and underlie the entire sedimentary section in the basin are quartzo-feldspathic gneisses and migmatites that are variably granitized (plate 1). Amphibolites, pegmatites, and quartz-diabase dikes also are present (Hoppin and Palmquist, 1965, p. 994). The general appearance is tan to pink coarse granite.

Except at shallow depths in the mountains, these rocks are not known to yield water. Although containing no inherent porosity or permeability, fractures in the granite caused by the intense freeze-thaw cycles that occur in the Bighorn Mountains create a secondary permeability. Wells in the mountains, which are completed at depths less than 100 ft, might yield small quantities of water marginally adequate for domestic or stock supplies. Yields from wells ranged from 1 to 20 gal/min (5 wells). Specific capacities ranged from 0.2 to 2.8 (gal/min)/ft of drawdown. Most common yields are 5 to 10 gal/min.

Changes in Water Levels and Hydraulic Heads

Water levels in 53 observation wells were measured quarterly beginning in May 1988 through April 1989. Measurement dates were selected to assess seasonal and irrigation effects on water levels. The irrigation season in Big Horn County is approximately mid-April through September. Water levels were measured in 26 wells completed in unconsolidated deposits and in 27 wells completed in Cenozoic and Mesozoic rocks. Water-level data are listed in table 15 (at back of the report). Well yields and shut-in pressures were measured for nearly 25 flowing wells during 1987 and 1988 to detect any long-term yield or pressure changes in the major aquifers in Paleozoic rocks.

Seasonal Water-Level Changes in Unconsolidated Deposits

The water levels measured quarterly in wells completed in unconsolidated deposits almost without exception were lower in April 1989 than at anytime measured during the previous year. All wells measured were in irrigated areas, and most of the wells were for domestic use. The changes in water level among the quarterly measurements (highest level minus lowest level) ranged from 0.4 to 3.7 ft in nine wells completed in alluvium and colluvium. In 17 wells completed in gravel, pediment, and fan deposits, the change in water levels among the quarterly measurements ranged from 0.9 to 10.6 ft.

The water-level changes are largely attributable to the effects of irrigation. Ground water in many areas along the Greybull River and Dry Creek is derived not only from precipitation but also from the infiltration of surface water applied for irrigation (Robinove and Langford, 1963, p. 35). Leakage from unlined ditches and canals also are a principal source of recharge (Cooley and Head, 1979, p. 6). This also is true for irrigated areas elsewhere in the county. After the irrigation season, water levels in wells located in irrigated areas continue to rise as the surface soils continue to drain. Maximum water levels usually are reached in December. Then, as discharge from the unconsolidated aquifers exceeds recharge, water levels begin to decline. Many landowners throughout the county reported that in the spring, water levels decline to the level where yields from pumped wells are inadequate for their intended use. This decrease in water levels usually occurs in March and April before surface water is diverted from the rivers and into the irrigation-water conveyance canals.

Seasonal Water-Level Changes in Cenozoic and Mesozoic Rocks

The magnitude of water-level changes based on quarterly measurements in nonflowing wells producing primarily from Cenozoic and Mesozoic rocks was similar to that measured in wells completed in unconsolidated deposits. The 27 wells monitored were all 245 ft deep or less. In nonirrigated areas, water-level fluctuations in six wells ranged from 0.5 to 2.7 ft throughout the year. In areas where surface water is used to irrigated, the magnitude of water-level change in 21 wells ranged from 0.8 to 58.4 ft. For example, well 50-93-27dcc01 had its highest measured water level (40.0 ft below land surface) in December 1988 and its lowest measured level (52.9 ft below land surface) in July 1988. In areas where surface water is used to irrigate, these data indicate that water-level changes in wells completed in Cenozoic and Mesozoic rocks are, at least in part, attributable to irrigation practices.

Seasonal and Daily Changes in Hydraulic Head in Flowing Wells

Withdrawals for irrigation and municipal water, which locally cause lower hydraulic heads in flowing wells, are greater in summer than at other times during the year. The differences between hydraulic head, as converted from wellhead pressures, measured at shut-in wells during irrigation and nonirrigation seasons ranged from 0 to 26 lb/in^2 (60 ft above land surface). Cooley (1986a, p.16) also observed that operating pressures in wells near Ten Sleep and Hyattville were less during late summer than earlier in the irrigation season. Variations in seasonal and daily hydraulic heads converted from operating wellhead pressures are shown for the period January 20, 1988, through May 15, 1989, at the Worland municipal well (49-91-12dba01) (fig. 12).

Long-Term Changes in Hydraulic Head and Yield of Flowing Wells

Shut-in pressures and yield measurements were collected from flowing water wells completed in the major aquifers in the Paleozoic rocks (Tensleep Sandstone, Madison-Bighorn aquifer, and Flathead Sandstone). When possible, shut-in pressure was measured before wells were activated for use during the irrigation season. Well yields usually were measured in September and October near the end of the irrigation season.

Shut-in pressures converted to hydraulic heads and well yields measured upon well completion were compared to measurements taken in September 1987 and October 1988. Interpretations of the comparisons were difficult because many reported measurements taken form driller's well-completion reports actually could be estimates; measurement methodologies were seldom stated in driller's reports.

The condition of wells also must be considered when making comparisons. Few irrigation wells in the study area can be shut-in completely because valves commonly were deteriorated; in conjunction with wellhead pressures that can reach nearly 400 lb/in^2 (924 ft above land surface), leakage was common. However, wellhead shut-in pressures were probably within a few pounds per square inch of total shut-in pressures (M.E. Cooley, consulting hydrologist, oral commun., 1987).

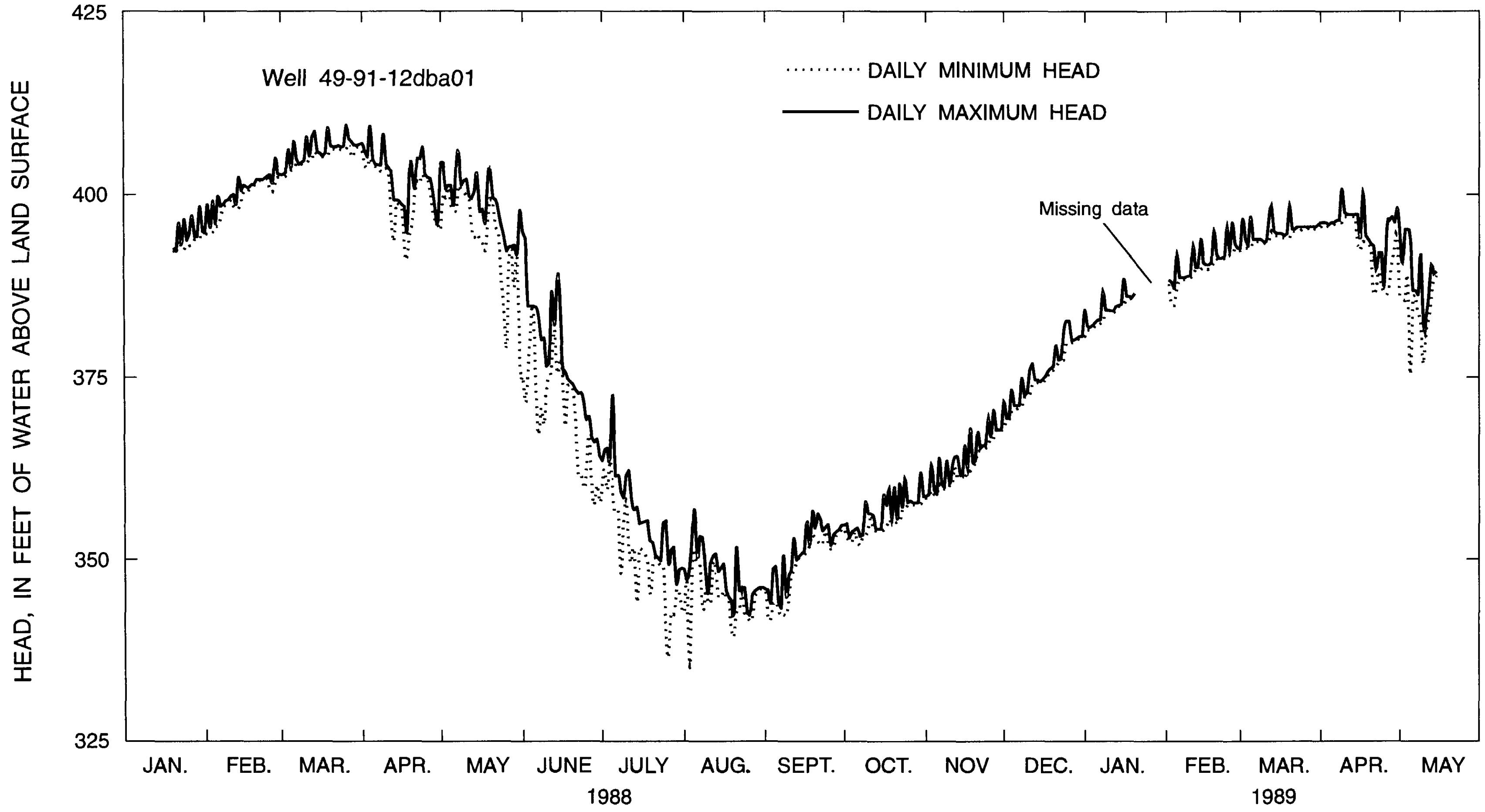


Figure 12.--Daily minimum and maximum hydraulic heads converted from wellhead pressures recorded in the Worland No. 1 municipal well completed in the Madison-Bighorn aquifer, from January 20, 1988, through May 15, 1989.

Where comparisons could be made, hydraulic heads and well yields were less for all wells measured in September 1987 and October 1988 than when the wells were completed. The smallest decline in both hydraulic head and well yield was measured for one well completed in the Tensleep Sandstone. The hydraulic head of well 49-88-16cdb01 declined from 43.2 ft above land surface in December 1982 to 34.6 ft above land surface in September 1987. The well yield changed from 13 to 11 gal/min during the same period.

Most comparisons of hydraulic heads converted from wellhead pressures were made from seven wells completed in the Madison-Bighorn aquifer. Between 1953 and 1968, when the wells were completed, the average hydraulic head was 414 ft above land surface. In October 1988, the average hydraulic head in six wells was 262 ft above land surface. The largest decline, 390 ft, was measured in the Hyattville public-supply well (49-89-06bcb01) between August 1968 and October 1988. The smallest static hydraulic-head decline, 61 ft, was measured in a stock well (49-89-29abb01) between November 1953 and October 1988.

Well-yield decreases in six wells completed between 1953 and 1968 in the Madison-Bighorn aquifer ranged from 54 to 1,410 gal/min. The median decrease was 142 gal/min. An irrigation well (49-89-05bda01) with a reported well yield in 1962 of 2,500 gal/min (Cooley, 1986a, p. 36) had the largest measured decline of 1,410 gal/min. The smallest change in yield, from 84 gal/min in 1953 to 30 gal/min in October 1988, was measured in well 49-89-28baa01.

Changes in hydraulic head and well yield were measured in one well (49-88-29dac01) completed in the Flathead Sandstone. The hydraulic head was reported at 762 ft above land surface in 1970 and decreased to 423 ft above land surface in October 1988. The well yield also decreased from 1,000 gal/min reported in 1970 to 531 gal/min measured in September 1987.

Cooley (1986a, p. 16) reported decreases of shut-in pressures for four wells completed in the Flathead Sandstone from about 60 to more than 150 lb/in^2. He suggested that decreases of pressure were, in part, because of differences between the pressure in aquifers in Paleozoic rocks. In wells completed in multiple aquifers, it is probable that the most highly pressurized aquifer is yielding water to less pressurized aquifers.

WATER USE

Seven categories of offstream use are pertinent to water use in the county, including public supply, domestic, commercial, industrial, mining, irrigation, and livestock. Definitions of these terms are given in the glossary. Each category can be divided into surface-water and ground-water use. Water-use estimates for Wyoming were most recently compiled in 1985 by the U.S. Geological Survey in cooperation with State and local agencies (C.L. Qualls, U.S. Geological Survey, oral commun., 1990). Estimates of total offstream water use in Big Horn County in 1985 are shown in table 5.

Surface water accounts for 96 percent and ground water accounts for 4 percent of total offstream water use. Irrigation is the largest offstream use of both surface and ground water. About 99 percent of offstream surface-water and 55 percent of ground-water use is for irrigation. Eighty-two percent of the water used for irrigation is consumed, which includes a 37-percent conveyance loss and 45 percent consumed by the irrigated crops. Conveyance losses include water that is lost by leakage or evaporation. Water lost to leakage might percolate to a ground-water source, thus affecting water levels, and be available for further use.

Ground water supplies 89 percent of water used for domestic purposes and about 16 percent of water used for public supplies. These statistics show that ground water is a primary domestic water supply in rural areas where public supplies are not available.

Table 5. Estimated total offstream water use in 1985 in Bighorn County, Wyoming

Offstream use	Water use, in million gallons per day: Surface water	Ground water	Total	Consumptive use
Public supply	2.12	0.40	2.52	0.78
Commercial	.10	.12	.22	.04
Domestic	.04	.32	.36	.14
Industrial	.06	.07	.13	.03
Mining	1.94	[1]9.26	[1]11.2	1.55
Livestock	.51	.13	.64	.64
Irrigation	537	12.7	550	[2]446
Totals	542	23.0	565	[2]449

[1] Includes 0.8 million gallons per day of saline ground water.

[2] Includes 202 million gallons per day conveyance losses.

Estimated water use by municipalities in Big Horn County in 1970 and 1988 is listed in table 6. Water use and population have increased in most municipalities. Increases in water use on a per capita basis were documented for some municipalities. Large per capita use in the town of Cowley (870 gallons per person per day) in part is attributable to a leaky water pipeline.

WATER QUALITY

Water quality refers to the physical properties of water and to the organic and inorganic material dissolved and suspended in water in a variety of forms. Generally, the presence of any foreign substance in water is thought to reduce water quality. However, not all materials in water are detrimental to water quality. Water quality is divided into three categories--biological, chemical, and physical. Biological quality includes organisms, both plant and animal, living in water. Little biological water-quality data have been collected from streams in Big Horn County; therefore, biological water quality is not evaluated in this report. A general discussion of the chemical quality and physical properties of ground water and surface water follows.

Inorganic materials in water are classified by the size of the particles. Dissolved materials, the smallest particles, usually are ionized and are associated with the chemical quality of water. Larger particles of insoluble suspended materials are classified as sediment. Sediments can be filtered from water; chemical substances require more sophisticated techniques for removal. Substances that will pass through a 0.45-µm membrane filter are classified as dissolved materials, and particles that will not pass through such a filter are classified as particulate materials (Hem, 1985, p. 60).

Physical properties of water commonly measured onsite during water-quality studies include water temperature, specific conductance, and pH. Temperature is an important controlling factor in many chemical processes; for example, the solubility of ions and the saturation levels of gases are affected by water temperature.

Table 6. Annual public water use and public water-user populations in Big Horn County municipalities in 1970 and 1988

[Mgal, millions of gallons; gal, gallons; --, no data]

Municipality	Water source	1970 Water use (Mgal)	1970 Water-user population[1]	1970 Water use per person per day (gal)	1988 Water use (Mgal)	1988 Water-user population[2]	1988 Water use per person per day (gal)	Remarks
Basin	Bighorn River	[3] 59	1,145	141	[3] 88	1,348	179	--
Burlington	Gravel, pediment, and fan deposits	--	--	--	[4] 9.2	144	175	--
Byron	Irrigation drain in gravel, pediment, and fan deposits	[5] 25	397	173	[3] 48	605	217	--
Cowley	Deaver Reservoir	[5] 23	366	172	--	--	--	Water supplied from Deaver Reservoir prior to 1983
	Madison-Bighorn aquifer	--	--	--	[2] 127	400	870	
Deaver	Deaver Reservoir	[5] 7.2	112	176	[3] 37	250	405	--
Frannie	Madison-Bighorn aquifer	[5] 8.9	139	175	[4] 9.9	150	181	--
Greybull	Shell Creek Madison-Bighorn aquifer	[5] 125	1,953	175	[3] 269	2,085	353	Wells completed in the Madison-Bighorn aquifer in 1984 and 1985. Water use neither includes users in Shell nor Greybull Heights
Hyattville	Madison-Bighorn aquifer	--	--	--	[4] 5.1	80	175	--

Table 6. Annual public water use and public water-user populations in Big Horn County municipalities in 1970 and 1988--Continued

Municipality	Water source	1970 Water use (Mgal)	1970 Water-user population[1]	1970 Water use per person per day (gal)	1988 Water use (Mgal)	1988 Water-user population[2]	1988 Water use per person per day (gal)	Remarks
Basin	Bighorn River	[3] 59	1,145	141	[3] 88	1,348	179	--
Lovell	Shoshone River	[2] 173	2,371	200	[2] 208	2,447	233	--
Manderson	Lance Formation	[5] 7.5	117	176	[2] 7	115	167	--
Worland[6]	Bighorn River	[3] 543	5,055	294	--	--	--	Wells drilled to Madison-Bighorn aquifer in 1979 and 1982 for water supply
	Madison-Bighorn aquifer	--	--	--	[3] 482	5,500	240	

[1] 1970 census by U.S. Department of Commerce.

[2] Estimate reported by municipality.

[3] Metered by municipality.

[4] Estimate based on estimated water use of 175 gallons per person per day.

[5] Estimate based on population reported in Lowry and others (1976).

[6] Worland is in Washakie County, but present supply is from two wells in Big Horn County.

Surface-water temperature is affected by local climatic and physical factors. Common climatic factors are solar radiation, wind, air temperature, and vapor pressure. Physical factors include shading, stream width, depth, and velocity, ground-water inflow, and proximity to reservoirs. Ground-water temperatures generally are a function of the depth of the aquifer below the surface of the earth. Deep aquifers generally have higher water temperatures than shallow aquifers.

Specific conductance is a measure of the ability of water to conduct electrical current. It is expressed in microsiemens per centimeter (μS/cm) at 25 degrees Celsius and is a function of the type and concentration of dissolved solids in the water. The concentration of dissolved solids in mg/L commonly is about 65 percent of the specific conductance. This relation varies slightly with the composition of dissolved solids.

A measure of the acidity of water is pH. The pH is defined as the negative logarithm of the hydrogen-ion concentration. This parameter is dimensionless and has a range from 0 to 14. A pH greater than 7 indicates the water is alkaline, whereas a pH less than 7 indicates an acidic water.

Chemical quality of water is related to the chemical composition of rocks and sediment with which the water has been in contact and to materials introduced into the hydrologic environment by human activities. Surface-water quality depends on the water source and the exposure of the water to soluble material between the source and the sampling site. Ground-water quality is related to the chemical composition of the rocks composing the aquifer. Water temperature, the duration of contact with the rocks, and the rate of movement of the water also will affect the chemical quality of ground water. The source and importance of common dissolved-mineral constituents and physical properties of ground water and surface water are summarized in table 7.

Water is classified into ionic types by the dominant dissolved cation (positively charged ion) and anion (negatively charged ion), which are expressed in milliequivalents per liter. The dominant dissolved ion must be greater than 50 percent of the total. Water classified as calcium sulfate type contains more than 50 percent of the cations as calcium and more than 50 percent of the anions as sulfate. If no cation or anion is dominant, the water is classified as mixed and the two most prevalent cations or anions are listed. For example, water containing 45-percent calcium, 35-percent magnesium, and 20-percent sodium and water containing 60-percent sulfate, 35-percent bicarbonate plus carbonate, and 5-percent chloride would be classified calcium magnesium sulfate type.

Composition of the surface water and ground water of Big Horn County is similar to the composition of most natural waters in that the major cations are calcium, magnesium, potassium, and sodium. The major anions are bicarbonate, carbonate, chloride, and sulfate. Minor constituents in the water of Big Horn County, which are important to residents, include boron, fluoride, iron, manganese, selenium, radionuclides, and organic pesticides. In areas of intensive agriculture, concentrations of nitrate, nitrite, and phosphate anions commonly were greater than background concentrations. Minor cations and anions commonly are collectively referred to as trace elements because they are normally present at concentrations less than a few micrograms per liter. This concentration does not minimize their importance with respect to water quality. Although many trace elements are necessary to healthy living organisms, they also may be toxic at concentrations that are not much greater than the minimum concentration required to preserve health (table 7).

Streamflow-Quality Data

Samples of dissolved materials have been collected at varying short-term frequencies at 20 streamflow-gaging stations in Big Horn County beginning in water year 1946 (table 2). The data are sparse and usually are collected in the downstream reaches of streams where the accumulation of dissolved materials is expected to be the greatest. The most extensive sampling programs in Big Horn County were conducted on the Shoshone River

Table 7.--Source or cause and importance of most common dissolved-mineral constituents and physical properties of water (Modified from Popkin, 1973)

[mg/L, milligrams per liter; μS/cm, microsiemens per centimeter at 25 degrees Celsius]

Constituent or property	Source or cause	Importance
Specific conductance (μS/cm)	Mineral content of the water.	Indicates degree of mineralization. Specific conductance is a measure of the capacity of the water to conduct an electric current. Varies with concentration and degree of ionization of the constituents.
pH	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, and phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline water also might attack metals.
Hardness as calcium carbonate ($CaCO_3$)	In most water nearly all the hardness is due to calcium and magnesium. All the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form and deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called noncarbonate hardness. Waters of hardness of 60 mg/L or less are considered soft; 61 to 120 mg/L, moderately hard; 121 to 180 mg/L, hard; more than 180 mg/L, very hard.
Calcium (Ca) and magnesium (Mg)	Dissolved from practically all soils and rocks, but especially from limestone, dolomite, and gypsum. Calcium and magnesium are detected in large quantities in some brines. Magnesium is present in large quantities in seawater.	Cause most of the hardness and scale-forming properties of water; soap consuming (see hardness). Water low in calcium and magnesium desired in electroplating, tanning, dyeing, and in textile manufacturing.

Table 7. Source or cause and importance of most common dissolved-mineral constituents and physical properties of water--Continued

Constituent or property	Source or cause	Importance
Sodium (Na) and potassium (K)	Dissolved from practically all rocks and soils; also found in ancient brines, seawater, industrial brines, and sewage.	Large concentrations, in combination with chloride, give a salty taste. Moderate concentrations have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers. Large sodium concentration may limit the use of water for irrigation.
Bicarbonate (HCO) and carbonate (CO)	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot-water facilities to form scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium, cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Commonly present in mine waters and in some industrial wastes.	Sulfate in water containing calcium forms hard scale in steam boilers. In large concentrations, sulfate in combination with other ions gives bitter taste to water. Some calcium sulfate is considered beneficial in the brewing process.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large concentrations in ancient brines, seawater, and industrial brines.	In large concentrations, in combination with sodium, gives salty taste to drinking water. In large concentrations, increases the corrosiveness of water.
Fluoride (F)	Dissolved in minute to small concentrations from most rocks and soils. Added to many waters by fluoridation of municipal supplies.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth, depending on the concentration of fluoride, the age of the child, quantity of drinking water consumed, and susceptibility of the individual.

Table 7. Source or cause and importance of most common dissolved-mineral constituents and physical properties of water--Continued

Constituent or property	Source or cause	Importance
Silica (SiO_2)	Dissolved from practically all rocks and soils, commonly less than 30 mg/L. Large concentrations, as much as 100 mg/L, generally occur in alkaline waters.	Forms hard scale in pipes and boilers. Transported in steam of high-pressure boilers to form deposits on blades of turbines. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from practically all rocks and soils. Also may be derived from iron pipes, pumps, and other equipment. More than 1 or 2 mg/L of iron in surface water generally indicates acid wastes from mine drainage or other sources.	On exposure to air, iron in ground water oxidizes to reddish-brown precipitate. More than about 0.3 mg/L stains laundry and utensils reddish-brown. Objectionable for food processing, textile processing, beverages, ice manufacture, brewing, and other processes. Larger quantities cause unpleasant taste and favor growth of iron bacteria.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils. Includes some water of crystallization.	Water containing more than 1,000 mg/L dissolved solids is unsuitable for many purposes.
Nitrate (NO_3)	Decaying organic matter, sewage, fertilizers, and nitrates in soil.	Concentration much greater than the local average may indicate contamination. Water with large nitrate concentrations has been reported to be the cause of methemoglobinemia (an often fatal disease in infants) and therefore should not be used in infant feeding. Nitrate has been shown to be helpful in reducing intercrystalline cracking of boiler steel. It encourages growth of algae and other organisms that produce undesirable tastes and odors.

and its tributaries in the Lovell area (sites 30, 31, 32, and 35) and at streamflow-gaging station Bighorn River at Kane, Wyo. (site 26). These records document water quality of streams affected by regulation for irrigation supply and by return-flow. No long-term water-quality records are available for perennial or ephemeral streams in the county.

Streamflow Quality

Specific conductance is easily measured onsite with simple to use equipment and procedures. The chemical quality of surface water can be generally indicated by measuring specific conductance and relating it to the concentration of dissolved solids.

Specific conductance of streamflow in Big Horn County varies with altitude and discharge. Streams that originate in the Bighorn Basin have larger values of specific conductance because the concentrations of dissolved solids generally are greater than 1,000 mg/L (Peterson and others, 1987). Whereas, streams that originate in the Bighorn Mountains have concentrations of dissolved solids generally less than 1,000 mg/L, which relates to smaller values of specific conductance.

Fluctuations in discharge account for much of the variability in streamflow quality. Specific conductance usually varies inversely with stream discharges, and consequently a range of specific conductance would be expected at a streamflow-gaging station having a broad range of discharges. Examples of the seasonal variations in the specific conductance of streamflow at two stations during water year 1978 are shown in figures 13 and 14.

The graphs shown in figure 13 are plots of daily mean discharge with plots of specific conductance from once-daily water samples at Bitter Creek near Garland (site 28) and Shoshone River near Lovell (site 31). Once-monthly measurements are shown with discharge for Bighorn River at Kane (site 26; fig. 14).

During low flows that generally are in the winter months, the specific conductance values are large. During high flows, the dissolved-solids concentration associated with low flows is diluted, resulting in smaller values of specific conductance.

Specific conductance values during any time of the year seem to be larger at Bitter Creek near Garland (site 28), which is affected by irrigation return-flow, than at either Shoshone River near Lovell (site 31) or Bighorn River at Kane (site 26). The Shoshone River station is downstream from the mouth of Bitter Creek and includes the discharge from Bitter Creek, but streamflow at this station has been diluted by water in the main-stream. Almost all of the larger flows in Bitter Creek are attributed to irrigation return-flow rather than snowmelt or rainfall. These irrigation return-flows contain the larger concentrations of dissolved materials.

Streamflow at several streamflow-gaging stations in Big Horn County have been sampled periodically for concentrations of major constituents. Most of these stations are in the downstream reaches of stream drainage basins and contain composite streamflows of snowmelt, rainfall runoff, reservoir storage, and irrigation return-flow. The principal dissolved constituents carried in these streams are cations (calcium, magnesium, sodium, and potassium) and anions (bicarbonate, sulfate, and chloride). Predominant ions are usually calcium or sodium and bicarbonate or sulfate. The proportions of sodium and sulfate, relative to calcium and bicarbonate, tend to become larger as the specific conductance increases.

Phosphorus is contributed to streamflow by both natural and human sources. The natural source includes soil and precipitation; human sources include sewage that might contain phosphorus from phosphate detergents and agricultural fertilizers. Phosphorus concentrations in streamflow show a seasonal pattern, with largest

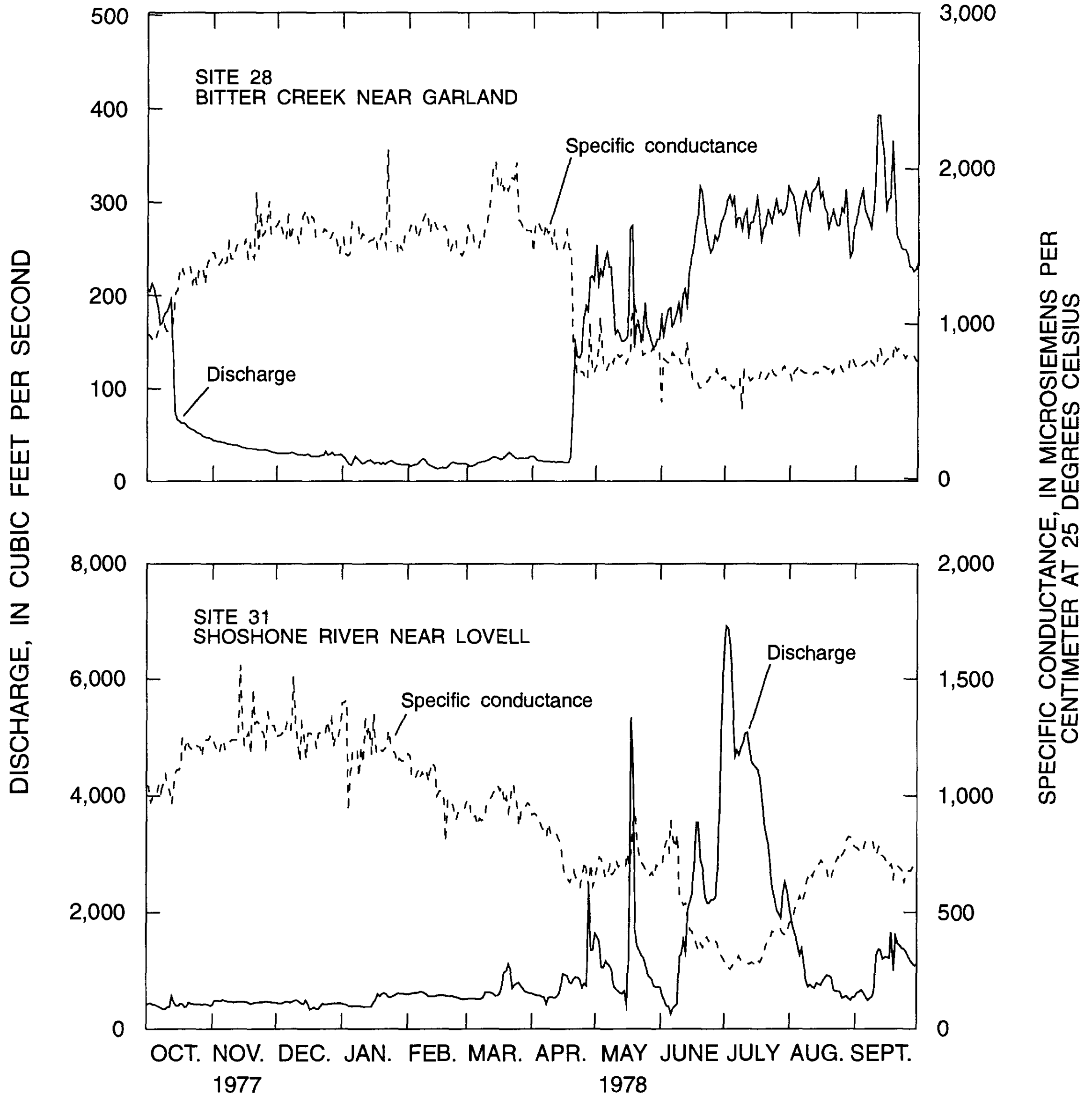


Figure 13.--Comparison of daily mean discharge and once-daily specific conductance for site 28, Bitter Creek near Garland, and site 31, Shoshone River near Lovell, water year 1978.

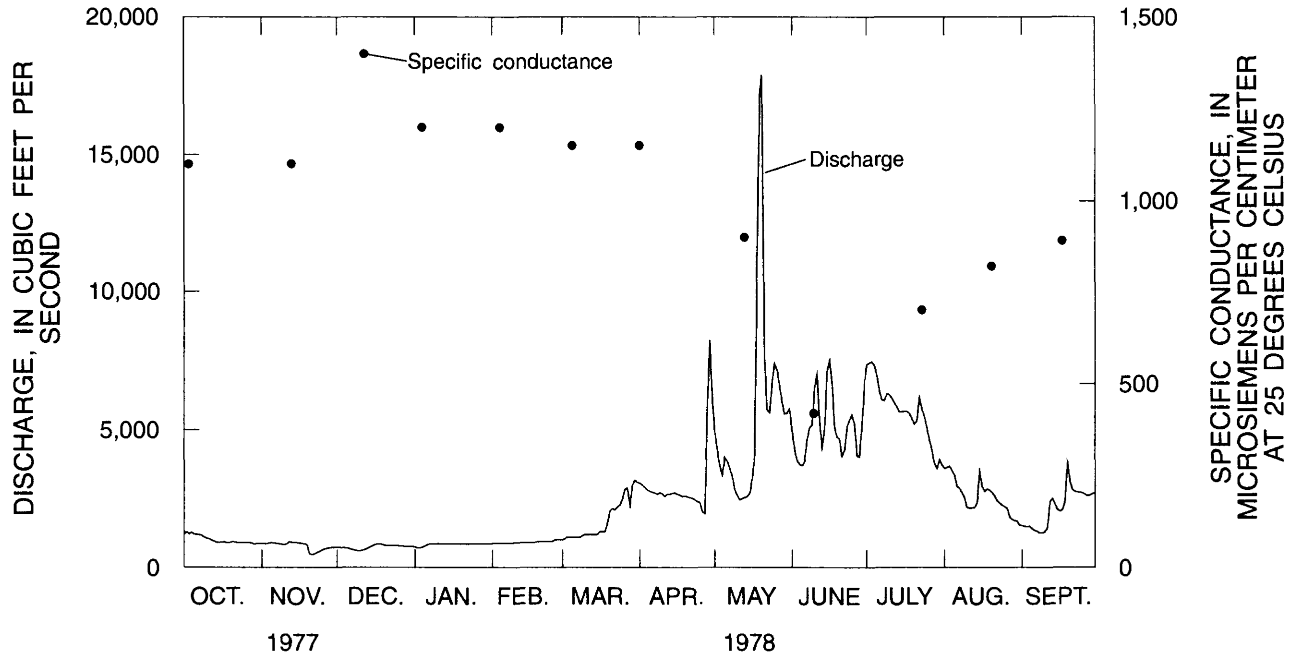


Figure 14.--Comparison of daily mean discharge and once-monthly specific conductance for site 26, Bighorn River at Kane, Wyo. for water year 1978.

concentrations usually noted during spring and summer, and smaller concentrations in the winter. The seasonal variation might be associated with runoff after the application of agricultural fertilizers (Peterson and others, 1987, p. 40).

Phosphorus and nitrogen are commonly considered to be nutrients that are essential for the growth of algae, and excess concentrations might stimulate algal growth. Algal growth regularly occurs in lowland streams and irrigation distribution canals in Big Horn County. Streamers of filamentous algae are common and normally grow attached to the substrate. Problems occur when the streamers break loose, float downstream, and clog irrigation-related structures (Peterson and others, 1987, p. 40).

Ground-Water-Quality Data

Ground-water-quality data consists of chemical analyses by aquifer for 1925-88 and are statistically summarized in table 16 (at back of report). These data were retrieved from the water-quality file of the U.S. Geological Survey's National Water-Data Storage and Retrieval System (WATSTORE). The constituents and properties in table 16 include specific conductance, pH, hardness, cations and anions, and dissolved solids.

The ground-water-quality data in this report are from existing water wells, most of which are completed in aquifers where concentrations of dissolved solids are smallest. However, wells that produce unusable water could not be sampled because they usually are plugged and abandoned. As a result, chemical data reported as representative of water quality for an aquifer are biased toward water that is suitable for use.

Ground-Water Quality and Suitability for Specific Uses

In 1980 Wyoming adopted standards to protect the ground waters of the State "for its intended use and uses for which it is suitable" (Wyoming Department of Environmental Quality, 1980, p. 4). The standards to protect water quality apply to ground water that have been classified by use and by ambient water quality. These classes include water that is suitable for domestic, agricultural, and livestock use and are shown in table 8.

Table 8. Wyoming water-quality standards for domestic, agricultural, and livestock use

[Modified from Wyoming Department of Environmental Quality, 1980. All constituent concentrations are in milligrams per liter unless otherwise indicated. --, no data; µg/L, micrograms per liter; pCi/L, picocuries per liter]

Constituent or property	Domestic use	Agricultural use	Livestock use
Boron (µg/L)	750	750	5,000
Chloride	250	100	2,000
Fluoride	1.4-2.4	--	--
Iron (µg/L)	300	5,000	--
Manganese (µg/L)	50	200	--
Nitrate as nitrogen	10	--	--
Nitrite as nitrogen	1	--	--
Nitrite plus nitrate as nitrogen	--	--	--
Selenium (µg/L)	10	20	50
Sulfate	250	200	3,000
Dissolved solids	500	2,000	5,000
pH	6.5-9.0	4.5-9.0	6.5-8.5
Sodium-adsorption ratio	--	8	--
Radium 226/228 (combined total) (pCi/L)	5	5	5
Gross alpha particle radioactivity (including radium 226 but excluding radon and uranium) (pCi/L)	15	15	15

Domestic Use

The U.S. Environmental Protection Agency (1990) has established primary and secondary drinking-water regulations and health advisories pertinent to public drinking-water supplies (table 9). These Federal regulations specify maximum contaminant levels and secondary maximum contaminant levels. The maximum contaminant levels are health related and legally enforceable. Although maximum contaminant levels apply only to public drinking-water supplies, they are useful indicators of the suitability of ground water for human consumption. The secondary maximum contaminant levels are for constituents that primarily affect the aesthetic qualities of drinking water. An example is chloride, which, at concentrations exceeding 250 mg/L, might impart a bitter taste to drinking water. Secondary maximum contaminant levels have no legally enforceable requirements. Health advisories are guidance concentrations that would not cause adverse health effects over specified short periods for most people.

Hardness, a measure of the soap-using character of water as well as the tendency to leave a crust on plumbing fixtures, is another water-quality factor important to domestic users. In this study, hardness is classified by calcium carbonate equivalent according to Durfor and Becker (1964, p. 27). The classification system of water hardness is shown in table 10. Total hardness is the hardness caused primarily by calcium and magnesium ions. The carbonate hardness is attributable to the tendency of calcium and magnesium to combine with bicarbonate and carbonate ions. In ground water of Big Horn County, the noncarbonate hardness is dominantly attributable to calcium and magnesium sulfate. Silica also can form a scale in the presence of calcium and magnesium ions that is difficult to remove. In contrast to these negative effects, hard water is considered desirable for use in irrigation because of the beneficial effects on soil structure.

The range of hardness for water samples from wells in Big Horn County was 10 to 2,600 mg/L. Although there were water samples classified with a hardness of soft, the median hardness for water samples from wells completed in most aquifers was classified as hard to very hard. Consequently, the use of water softeners in Big Horn County is common. Water softeners replace the dissolved calcium and magnesium in water with dissolved sodium.

Agricultural and Livestock Use

Wyoming has specific standards regarding appropriate drinking water for farm animals and for agricultural use (table 8). The drinking-water standards for livestock are not as stringent as for humans. Most ground water sampled in the county is suitable as drinking water for livestock. Young animals may experience gastrointestinal scours after drinking water containing large concentrations of dissolved solids.

The suitability of water for irrigation in Big Horn County was determined and classified on the basis of the sodium-adsorption ratio (SAR) using a system established by the U.S. Salinity Laboratory Staff (1954, p. 72-79). The SAR indicates the tendency of sodium to replace adsorbed calcium and magnesium. A large SAR indicates a hazard of sodium replacing calcium and magnesium (Hem, 1985, p. 161). This replacement can damage the soil and soil structure, causing deflocculation and the soil to become impermeable to water (Hem, 1985, p. 216).

A plot by aquifer of median specific conductance and SAR indicates the suitability of water for irrigation in figure 15. The salinity hazard is classified C1 (low) through C4 (very high) on the basis of the specific conductance. The sodium hazard is classified S1 (low) through S4 (very high) on the basis of the SAR. The two factors are combined to classify the suitability of water for irrigation. For example, water samples from wells completed in the Mesaverde Formation are classified C4-S2, which indicates very high salinity hazard and medium sodium hazard (fig. 15).

Table 9. Selected maximum and secondary maximum contaminant levels for public drinking-water supplies

(from U.S. Environmental Protection Agency, 1990, p. 31, 41-43)

[All values in milligrams per liter unless noted otherwise; --, no established level; pCI/L, picocuries per liter; mrem/yr, milliroentgen equivalent per year]

Constituents or property	Maximum contaminant level	Secondary maximum contaminant level
Inorganic:		
Chloride	--	250
Fluoride	4.0	2.0
Iron	--	.3
Manganese	--	.05
Nitrate (as nitrogen)	10	--
Selenium	.01	--
Sulfate	--	250
Total dissolved solids	--	500
pH	--	6.5-8.5
Organic:		
2,4-D	.1	--
Silvex	.01	--
Endrin	.0002	--
Lindane	.004	--
Methoxychlor	.1	--
Toxaphene	.005	--
Radioactivity:		
Beta particle and photon radioactivity (mrem/yr)	[1]4	--
Gross alpha particle activity (pCi/L)	15	--
Radium 226/228, total (pCi/L)	5	--

[1] Average annual concentrations assumed to produce a total body (or organ) dose of 4 mrem/yr--tritium, 20,000 pCi/L; strontium-90, 8pCi/L.

Table 10. Classification of water hardness
(From Durfor and Becker, 1964, p. 27)
[mg/L, milligrams per liter]

Hardness range (mg/L as calcium carbonate)	Description
0-60	Soft
61-120	Moderately soft
121-180	Hard
More than 180	Very hard

Plants differ widely with respect to their tolerance to dissolved minerals. The osmotic potential induced by high salinity in the soil-water solution can curtail water uptake by plants. Prolonged agricultural use of saline water is practical only where enough irrigation water can be applied to leach salts to below the root zone. Irrigation water that has large SAR tends to destroy soil structure, especially in soils containing swelling clays. The emergence of germinating seedlings can be impeded when a soil that has been greatly affected by sodium dries and forms a hard-soil crust.

Industrial Use

Water-quality requirements for industrial use differ widely. Primary criteria usually include corrosive properties, scale-forming tendencies, and the effects of any specific dissolved constituent on the manufactured product. The corrosiveness of water is related to the dissolved-solids concentration, pH, and water temperature. Scale-forming tendency in boilers and steam turbines is related to total hardness and silica concentration.

Ground-Water Quality in Unconsolidated Aquifers

Specific conductance measured in water samples from wells completed in alluvium and colluvium and in gravel, pediment, and fan deposits were made during the irrigation season (May through September) and non-irrigation season (October through April) to assess seasonal variation. All wells were in a hydrologic setting where irrigation is substantial. Specific conductance was measured quarterly; data are presented in table 15 (at the back of the report).

Most of the seasonal variations in specific conductance from water samples from wells completed in alluvium and colluvium and gravel, pediment, and fan deposits were the result of irrigation practices. Most of the water used for irrigation in Big Horn County is diverted surface water. Because surface water has a smaller specific conductance than the ground water with which it might mix, the specific conductance of ground water from alluvium and colluvium and gravel, pediment, and fan deposits tends to be smaller during the irrigation season than during the nonirrigation season.

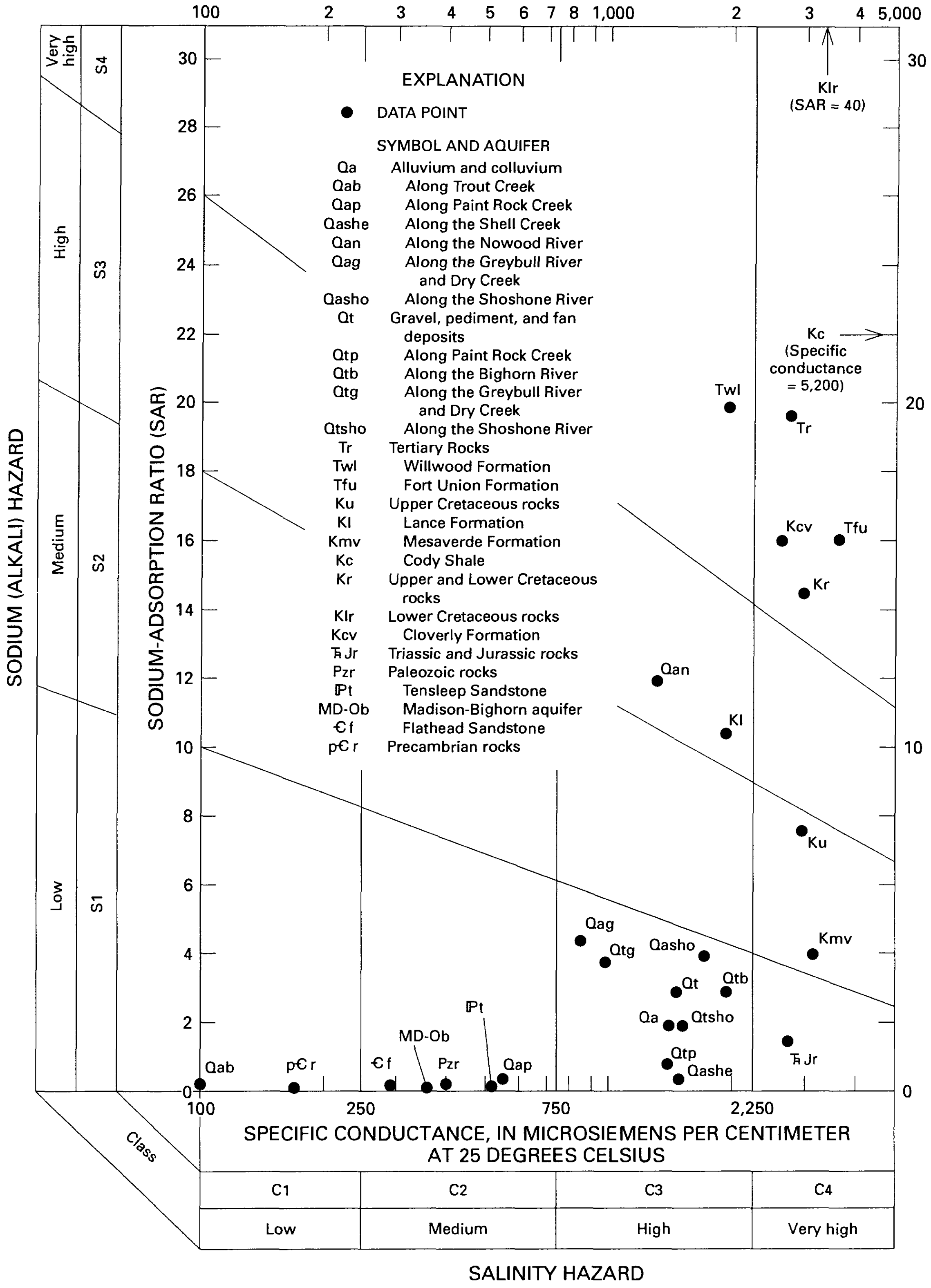


Figure 15.--Suitability of water from selected aquifers for use in irrigation based on analyses of water samples from wells. Diagram modified from U.S. Salinity Laboratory Staff (1954).

Alluvium and Colluvium

The suitability of ground water for various uses primarily is evaluated using the concentration of dissolved solids. Box plots of dissolved-solids concentrations in water samples from wells completed in alluvium and colluvium along selected streams are shown in figure 16. Water samples from wells completed in alluvium and colluvium along most of the selected streams exceeded the secondary maximum contaminant level of 500 mg/L of dissolved-solids concentration as established by the U.S. Environmental Protection Agency (1990) for public drinking-water supplies. However, concentrations of dissolved solids in water samples from wells completed in most of the alluvium and colluvium was less than 2,000 mg/L, which is the water-quality standard for agricultural use set by the Wyoming Department of Environmental Quality (1980).

A bar graph of the major cations and anions in a selected water sample from a well completed in alluvium and colluvium is shown in figure 17. The dominant cations in the alluvium and colluvium are calcium and sodium, and the dominant anion is sulfate. However, large differences in dissolved-solids concentration and chemical types of water were detected in analyses of water samples from wells completed in alluvium and colluvium (table 11).

The water quality in the alluvium and colluvium is affected by weathered material from different geologic units in the basin. Water in the alluvium and colluvium along Trout Creek and Paint Rock Creek is a calcium bicarbonate type. These two creeks primarily drain an area containing limestone, dolomite, and igneous rocks. Shell Creek drains a larger area with geologic units that contain evaporites such as the Gypsum Spring Formation. Water in alluvium and colluvium along Shell Creek is classified as calcium sulfate type. The sodium sulfate and sodium calcium sulfate water in alluvium and colluvium adjacent to the Nowood, Greybull, and Shoshone Rivers indicate that the source of these ions are from evaporites and marine or carbonaceous shales in these drainage basins.

Gravel, Pediment, and Fan Deposits

Dissolved-solids concentrations in water samples from all wells completed in gravel, pediment, and fan deposits exceeded the U.S. Environmental Protection Agency (USEPA) secondary maximum contaminant level of 500 mg/L for public drinking-water supplies except for one water sample from a well completed in the gravel, pediment, and fan deposits between the Greybull River and Dry Creek, which had a minimum dissolved-solids concentration less than 500 mg/L. Most of the water from wells completed in gravel, pediment, and fan deposits in Big Horn County is suitable for agricultural use, and all the water is suitable for livestock use (table 8).

More water from gravel, pediment, and fan deposits than from alluvium and colluvium is classified as mixed, having both calcium and sodium as dominant cations. The dominant anion is sulfate. The source of these cations is from surface water diverted from streams and used to irrigate crops on the gravel, pediment, and fan deposits. The diverted surface water is typically a calcium bicarbonate type. The water drained from these fields is typically a sodium sulfate type.

Large differences in dissolved-solids concentrations and chemical types of ground water were detected in analyses of water samples from wells completed in gravel, pediment, and fan deposits associated with different streams (table 12). Reasons for the differences in dissolved-solids concentrations generally are the same as for the measured differences in ground water produced from alluvium and colluvium. The affect of irrigation on the chemical composition of ground water is more substantial with respect to gravel, pediment, and fan deposits than alluvium and colluvium because gravel, pediment, and fan deposits are predominantly recharged by irrigation water.

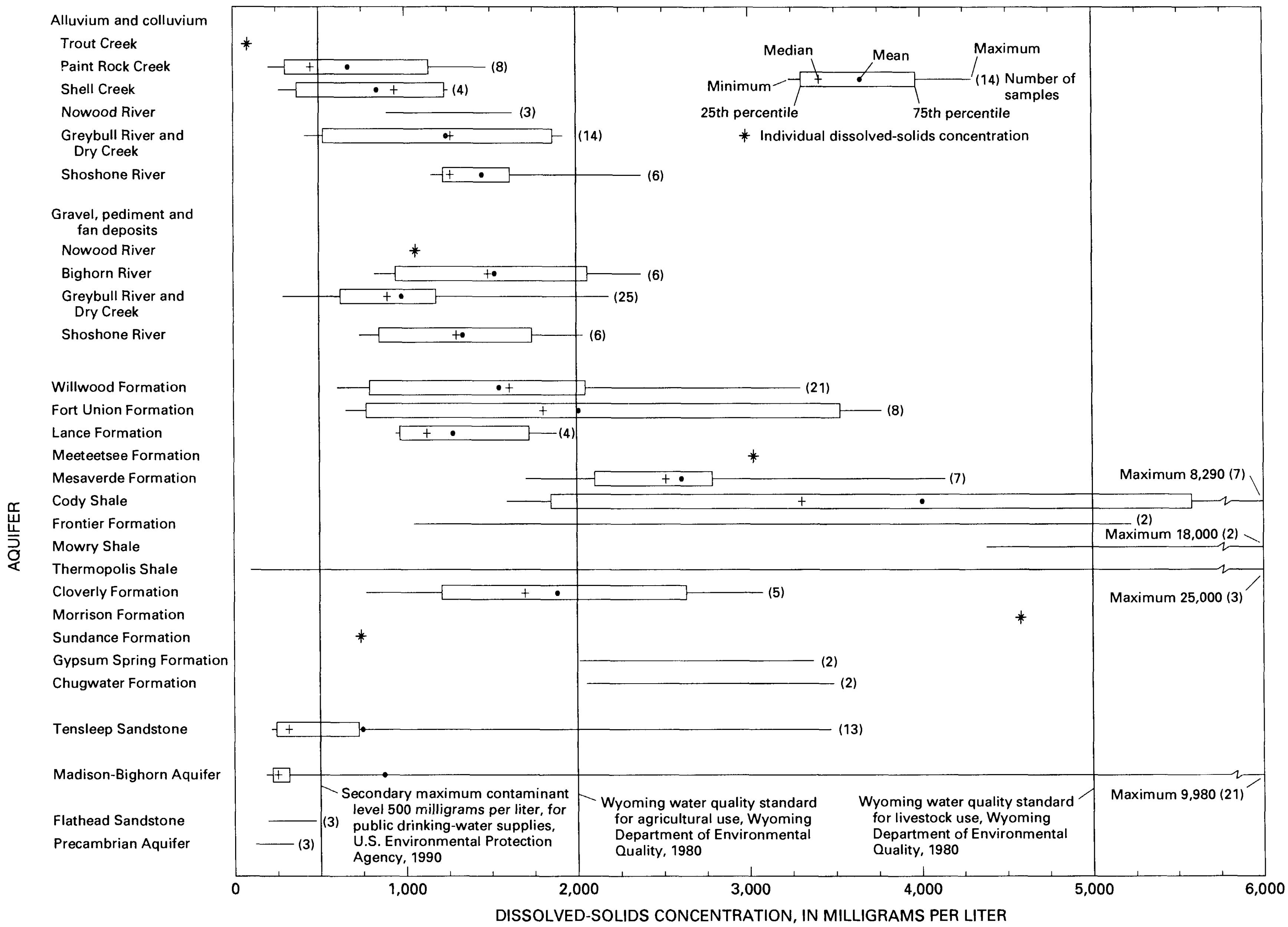


Figure 16.--Distribution of dissolved-solids concentrations in water samples from wells completed in and springs issuing from selected aquifers in Big Horn County, Wyoming.

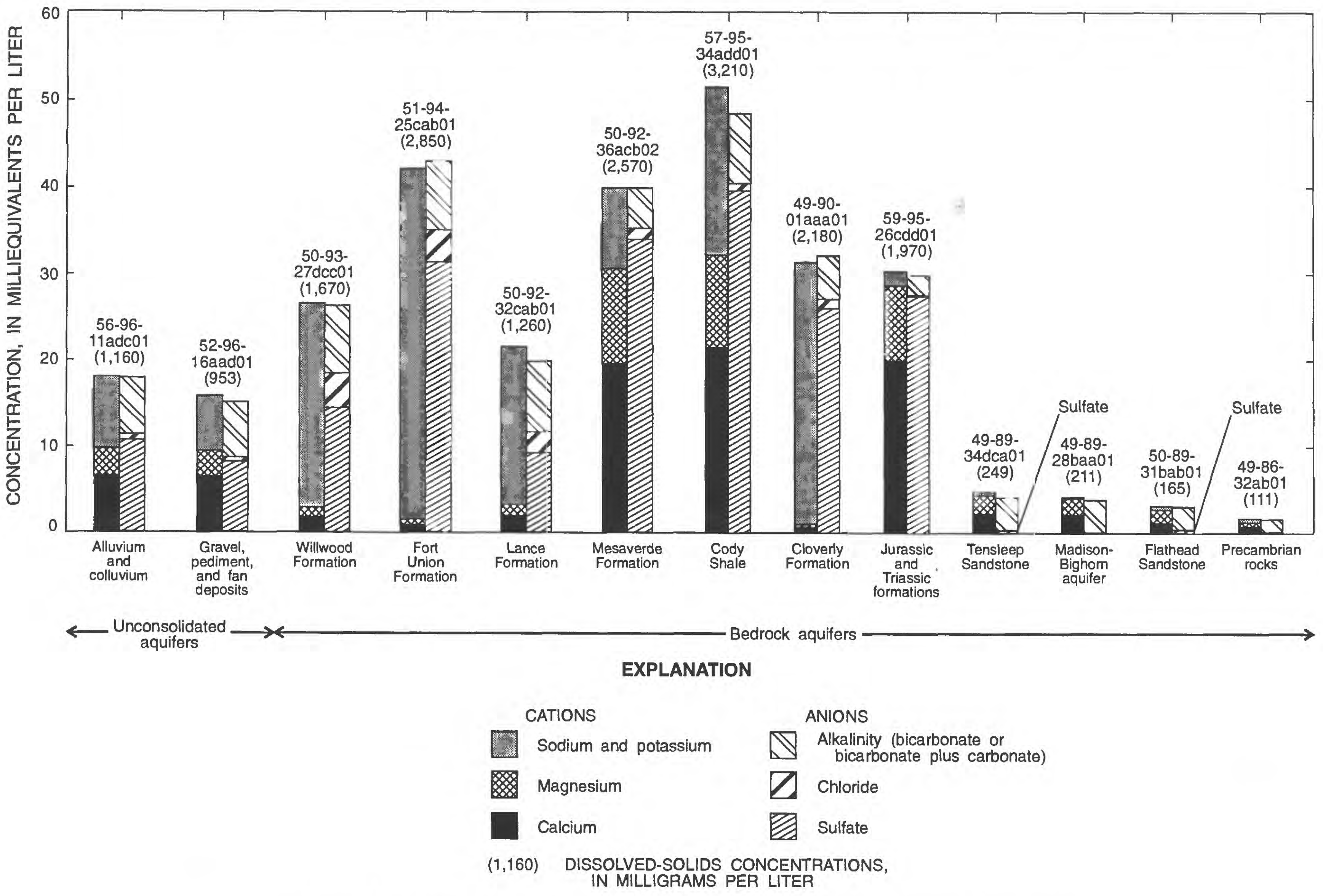


Figure 17.--Major cations and anions in selected water samples from wells completed in and springs issuing from selected unconsolidated aquifers and bedrock aquifers.

Table 11. Median dissolved-solids concentration and chemical types of ground water for water samples from wells completed in alluvium and colluvium in Big Horn County, Wyoming

[mg/L, milligrams per liter]

Location of alluvium and colluvium	Number of water samples	Median dissolved-solids concentration (mg/L)	Chemical type of ground water
Trout Creek[1]	1	[2]68	Calcium bicarbonate
Paint Rock Creek	8	457	Calcium bicarbonate
Shell Creek	4	908	Calcium sulfate
Nowood River	3	1,090	Sodium sulfate
Greybull River	14	1,240	Sodium sulfate
Shoshone River	6	1,245	Sodium calcium sulfate

[1] Trout Creek drains the Paint Rock Lakes area in the Bighorn Mountains.

[2] Individual Concentration, not a median value.

Table 12. Median dissolved-solids concentrations and chemical types of ground water for water samples from wells completed in gravel, pediment, and fan deposits in Big Horn County, Wyoming

[mg/L, milligrams per liter]

Location of gravel, pediment, and fan deposits	Number of water samples	Median dissolved-solids concentration (mg/L)	Chemical type of ground water
Paint Rock Creek	1	[1]1,030	Calcium sulfate
Bighorn River	6	1,480	Calcium sodium sulfate
Greybull River and Dry Creek	25	870	Sodium calcium sulfate bicarbonate
Shoshone River	6	1,280	Sodium calcium sulfate

[1] Individual concentration, not a median value.

Ground-Water Quality in Bedrock Aquifers

Specific conductance of water samples from 23 wells completed in bedrock was measured during the irrigation season (May through September) and nonirrigation season (October through April) to assess seasonal variation. These wells were in areas where irrigation is substantial. Specific conductance was measured quarterly; data are presented in table 15 (at the back of the report).

Specific conductance values of water samples from these wells were not affected by irrigation practices as much as were the specific conductance values of water samples from wells completed in the unconsolidated deposits. The quarterly values of specific conductance were high during the nonirrigation season almost as often as they were high during the irrigation season.

The distribution of dissolved-solids concentrations in water samples from wells completed in and springs issuing from selected bedrock aquifers is shown in figure 16. Water with the smallest median dissolved-solids concentrations (111-275 mg/L) are from Paleozoic rocks, which are composed of sandstone, limestone, and dolomite such as the Tensleep Sandstone, Madison Limestone, Darby Formation, Big Horn Dolomite, Gros Ventre Formation, and the Flathead Sandstone, as well as the granitic Precambrian deposits. Dissolved-solids concentrations increase with distance from the outcrop area in the eastern part of the county and near oil fields. Water in the Paleozoic aquifers in these areas may be too mineralized for human consumption. The dominant ions in water samples from wells completed in and springs issuing from the Paleozoic and Precambrian aquifers are calcium, magnesium, and bicarbonate. Thus, water in these aquifers is classified as calcium bicarbonate or calcium magnesium bicarbonate.

The largest median dissolved-solids concentrations (1,110-3,320 mg/L) were detected in water samples from wells completed in and springs issuing from Cenozoic and Mesozoic rocks. Dissolved-solids concentrations larger then 5,000 mg/L were detected in water samples from wells completed in or springs issuing from the Cody Shale (8,290 mg/L), the Frontier Formation (5,260 mg/L), the Mowry Shale (18,000 mg/L), and the Thermopolis Shale (25,100 mg/L). These large concentrations are typical for water samples from wells completed in or springs issuing from formations composed of evaporite, and marine or carbonaceous siltstone, mudstone, and shale. The water types for the water in Tertiary and Cretaceous rocks usually are sodium sulfate or sodium calcium sulfate; however, the dominant ions are sodium and sulfate. The water type for water in the Jurassic and Triassic rocks is classified as a calcium sulfate because of the gypsum present in the Gypsum Spring and Chugwater Formations.

Agricultural Pesticides in Water

Stream-Water Samples

From 1969 through 1988, water samples were intermittently collected at nine sites on streams in Big Horn County and analyzed for selected pesticides (herbicides and insecticides). Water samples were screened for selected compounds in the following pesticide classes: phenoxy acid herbicides (including picloram), organochlorine insecticides, and organophosphate insecticides. Locations where water samples were collected are shown in figure 18.

The pesticides most commonly detected in water samples were the phenoxy acid herbicides. The compound 2,4-D was detected in 65 percent of the samples; dicamba was detected in 58 percent of the samples, and picloram was detected in 47 percent of the samples. The herbicide 2,4,5-T was detected in 3 percent of the samples, 2, 4-DP was detected in 2 percent of the samples, and Silvex was detected in 1 percent of the samples.

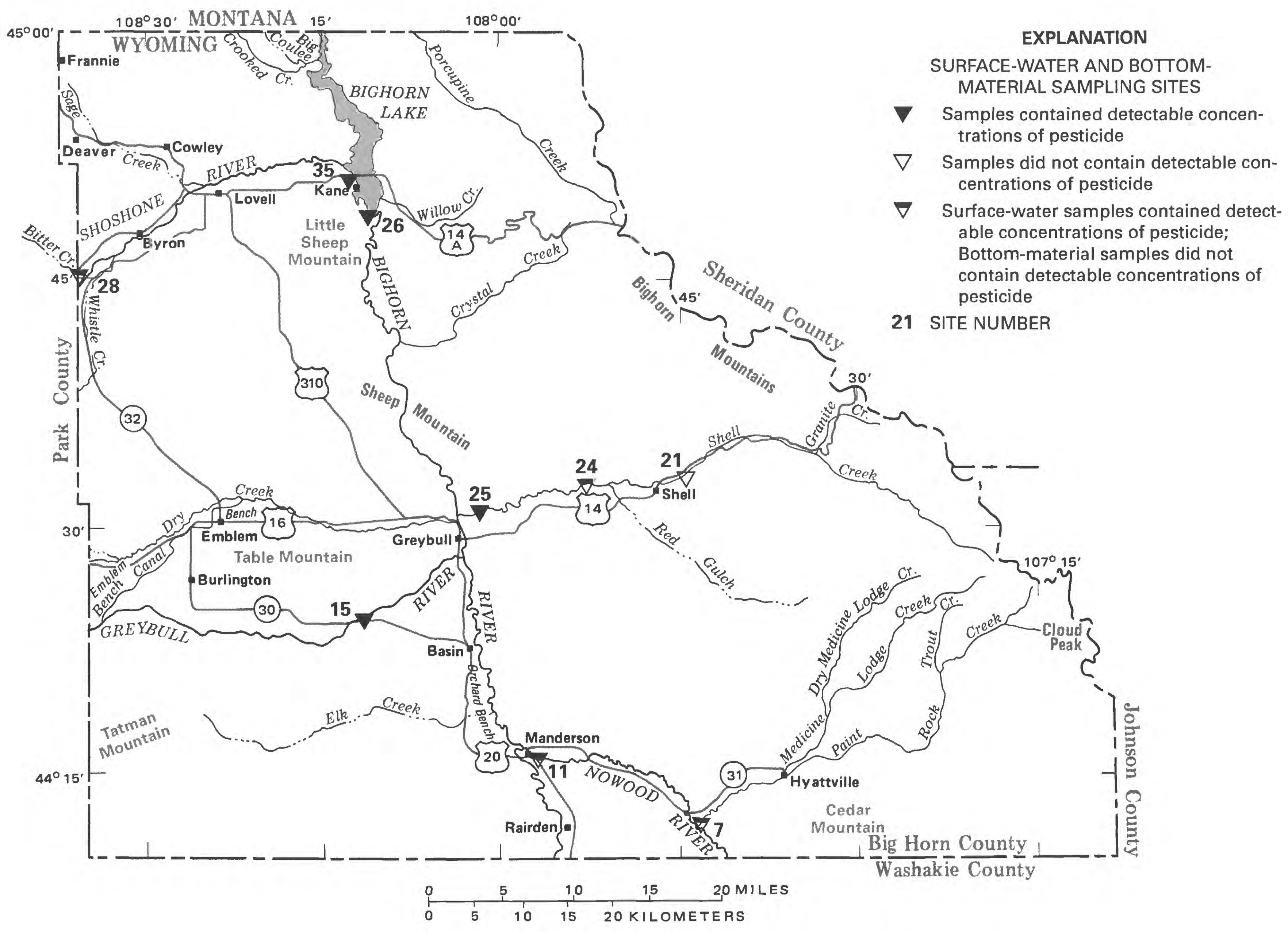


Figure18.--Location of surface-water and streambed-material sampling sites for pesticides.

Organochlorine and organophosphate insecticides were analyzed in water samples collected at the following surface-water sites: Greybull River near Basin (site 15), Bighorn River at Kane (site 26), Bitter Creek near Garland (site 28), and Shoshone River at Kane (site 35). Four percent of the 42 samples collected from these sites contained either DDE or DDT, and seven percent contained Dieldrin. Diazinon was detected in 17 percent of the 36 samples collected.

The pesticides for which the USEPA has established a maximum contaminant level are listed in table 9. The concentrations at which these pesticides were detected in Big Horn County were considerably less than their established maximum contaminant level.

Streambed-Material Samples

Streambed-material samples were collected at selected stream sites intermittently by the U.S. Geological Survey and analyzed for selected pesticides between water years 1971 and 1981. The results of these analyses are published in the U.S. Geological Survey Water-Data Reports (U.S. Geological Survey, 1971-1981). Streambed materials have not been evaluated for pesticides in the county by the USGS since 1981. Streambed materials were sampled at the same sites where surface-water samples were collected and analyzed for pesticides (fig. 18).

The pesticides detected in streambed-material samples were all in the organochlorine insecticide class, except for one pesticide in the phenoxy acid herbicide class. The detected concentrations of pesticides in the organochlorine insecticide class ranged from 0.1 to 8 μg/kg of streambed material; more than 70 percent of the concentrations ranged from 0.1 to 1.0 μg/kg. The organochlorine insecticides detected were dieldrin, chlordan, DDD, DDE, DDT, DD, and heptachlorepoxide. The organochlorine insecticides have extremely small solubilities and persist in the environment. As a result, most of these insecticides have been banned from use (Wauchope, 1978). However, the USEPA has not established maximum contaminant levels for pesticides in streambed materials. The phenoxy acid herbicide detected was dicamba.

Dieldrin, DDT, and its breakdown products DDD and DDE were detected most commonly in streambed-material samples. The percentage of samples, in which the selected pesticide was detected, is summarized as follows: Dieldrin, 58-percent; DDT, 16-percent; DDD, 23-percent; DDE, 42-percent; heptachlorepoxide, 13-percent; chlordane, 10-percent; lindane, 7-percent; and aldrin, 3-pecent.

Ground-Water Samples

Ground-water samples collected from 26 wells and drains during the summers of 1987 and 1988 were analyzed for selected pesticides. Samples were collected from eight wells or drains, or both in September 1987; additional wells and drains were sampled during June and July 1988. The wells and drains were in areas where agricultural pesticides are used commonly and are shown in figure 19. Generally, wells and drains, at which water samples were collected, were completed in unconsolidated aquifers, but, in some cases, in both unconsolidated aquifers and underlying bedrock aquifers. Water from nearly all wells, at which water samples were collected, was used primarily for domestic purposes, and, in most cases, was the owner's drinking-water supply.

Ground-water samples were analyzed to detect compounds in several different pesticide classes. Not all pesticide classes were tested for at each sampling site nor were all pesticide classes evaluated in both years. The pesticide classes, the specific compounds tested for within the class, and the test results are shown in table 13. Picloram and dicamba were detected in ground-water samples collected in September 1987. Two of eight water samples contained 0.01 μg/L picloram. One of eight water samples contained 0.03 μg/L dicamba. Organophosphate insecticides were analyzed for but not detected in water samples collected in 1987.

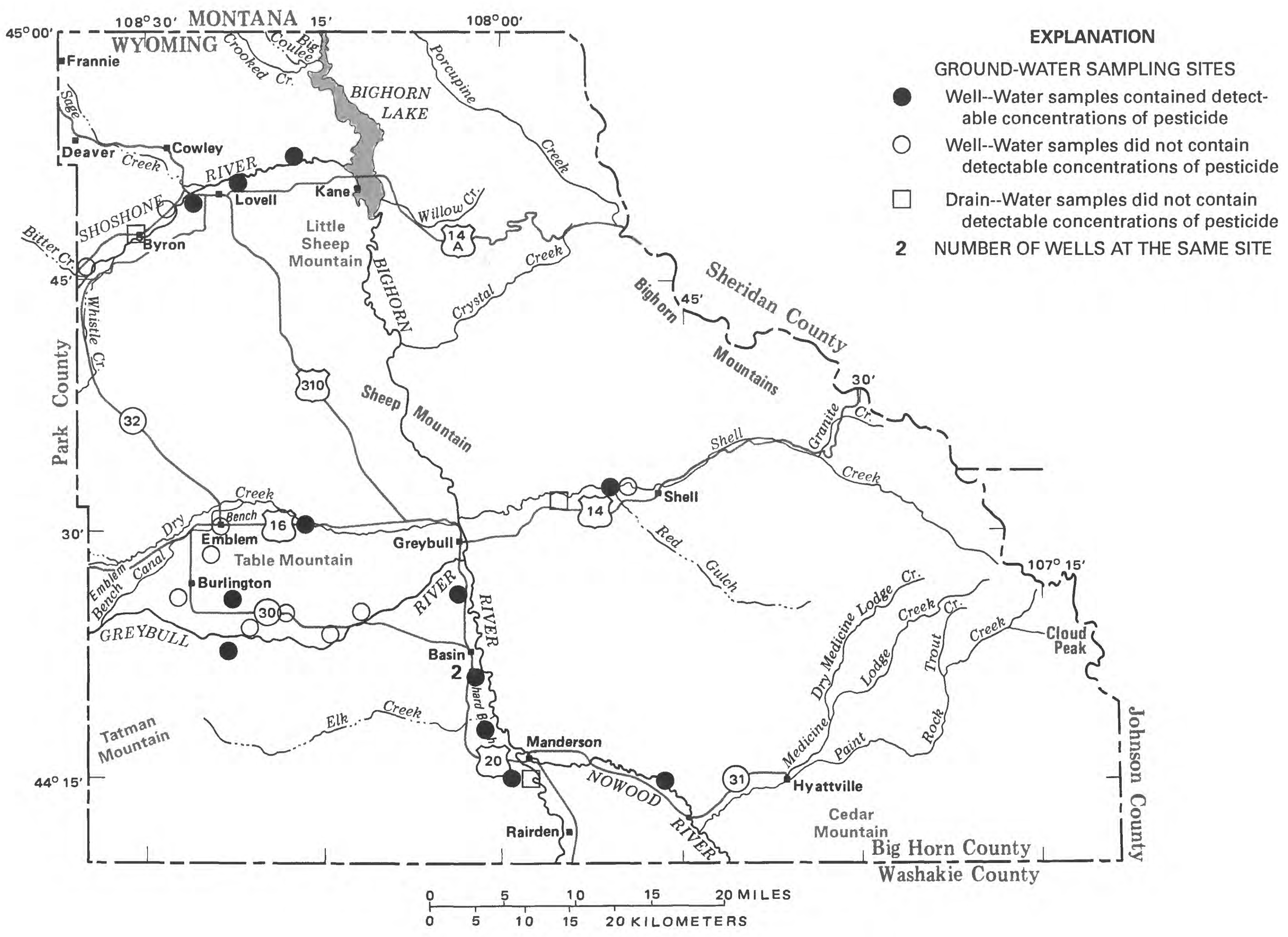


Figure 19.--Location of ground-water sampling sites for pesticides.

Table 13. Agricultural pesticides detected in water samples collected from selected wells during September 1987 and June and July 1988 in Big Horn County, Wyoming

[μg/L, micrograms per liter; --, no data]

Pesticide class	Year sampled	Number of analyses	Analyses greater than the detection limit: Number	Analyses greater than the detection limit: Percent	Pesticide detected	Maximum concentration of detected pesticide (μg/L)	Pesticides within a class analyzed for but not detected
Analide herbicides	1988	10	0	0	--	--	Alachlor and metolachlor
Carbamate herbicides	1988	14	0	0	--	--	Butylate, cycloate, EPTC, vernolate
Dinitrianaline herbicides	1988	10	0	0	--	--	Trifluralin
Phenoxy acid herbicides (including picloram)	1987	8	1	12	Dicamba	0.03	2,4-D, 2,4-DP, 2,4,5-T, silvex--all neither detected in 1987 nor in 1988
	1987	8	2	25	Picloram	.01	
	1988	22	4	18	Dicamba	.01	
	1988	22	5	23	Picloram	.05	
Triazine herbicides	1988	10	1	10	Atrazine	.40	Ametryne, cyanazine, metribuzin, prometone, prometryne, propazine, simazine, simatryne
Carbamate insecticides	1988	17	5	29	Aldicarb sulfone[1]	1.448	Aldicarb, carbaryl, carbofuran, methomyl oxyamyl, propham,

Table 13. Agricultural pesticides detected in water samples collected from selected wells during September 1987 and June and July 1988 in Big Horn County, Wyoming--Continued

Pesticide class	Year sampled	Number of analyses	Analyses greater than the detection limit: Number	Analyses greater than the detection limit: Percent	Pesticide detected	Maximum concentration of detected pesticide (μg/L)	Pesticides within a class analyzed for but not detected
Organophosphate insecticides	1987	6	0	0	--	--	Diazinon, ethion, malathion, methylparathion, methyltrithion, parathion, phorate, and trithion
	1988	10	2	20	Malathion	.02	Chloropyrifos, diazinon, disulfoton, disyston, ethion, fonofos, methylparathion, methyl-trithion, parathion, phorate, and trithion

[1] Aldicarb sulfone and aldicarb sulfoxide are breakdown products of aldicarb--the lower limit is an analytical estimate.

[2] 1-napthol is a breakdown product of carbaryl.

[3] 3-hydroxycarbofuran is a breakdown product of carbofuran.

Because the results of water sampling in 1987 indicated that pesticides were present in ground water, 23 sites were sampled in June and July 1988. Five pesticide classes not evaluated in 1987 (analide herbicides, carbamate herbicides, dinitrianaline herbicides, triazine herbicides, and carbamate insecticides) were added to the analyses in 1988. These classes were included to screen ground-water samples for pesticides commonly used in corn, sugar beet, and alfalfa production.

Water samples were collected again in 1988 at the three sites where water samples were collected with detectable concentrations of picloram or dicamba in 1987. A change in the detectable concentrations of picloram and dicamba between 1987 and 1988 in part could be because of the date of sampling and land management practices.

Dicamba was detected in 4 of 22 water samples collected from wells and picloram in 5 of 22 water samples collected from wells during 1988. Concentrations of both compounds were equal to or less than 0.05 µg/L. Analyses for triazine herbicides detected atrazine in 1 of 10 water samples at a concentration of 0.40 µg/L. Analyses for carbamate insecticides indicated that 5 of 17 water samples contained aldicarb sulfone with a maximum concentration of 1.44 µg/L. Aldicarb sulfoxide was detected in 4 of 17 water samples with a maximum concentration of 0.52 µg/L. The parent compound aldicarb, which is used extensively in sugar beet production, was not detected. Malathion, an organophosphate insecticide, was detected in water samples collected at 2 of 10 sites; maximum concentration was 0.02 µg/L.

The USEPA has not established any maximum contaminant levels for the pesticides detected in ground-water samples collected in Big Horn County. However, goals for maximum contaminant levels have been proposed for atrazine (3 µg/L), aldicarb sulfone (40 µg/L), and aldicarb sulfoxide (10 µg/L) (U.S. Environmental Protection Agency, 1990). The maximum concentrations detected for these pesticides in Big Horn County were less than the USEPA goals for maximum contaminant levels.

Radionuclides in Ground Water

In Wyoming, uranium is in rock of nearly every geologic age (Hausel and others, 1979). In Big Horn County, data are sparse and most aquifers have not been evaluated for the presence of radionuclides. Since 1979, water samples from 19 wells have been analyzed for radionuclides. Twelve of the wells are used for public-supply systems and water samples collected from the wells have been analyzed by municipalities in accordance with USEPA requirements. Most of the analyses summarized in this report were conducted by private laboratories; analytical results and laboratories that performed the analyses are given in table 14. The USEPA maximum contaminant levels for radionuclides are listed in table 9. Typically, analyses for radionuclide species (table 14) include a plus or minus counting error that generally indicates a laboratory-specified confidence level. If the counting error is large relative to the reported concentration, reliable interpretation is difficult.

The USEPA maximum contaminant level for radionuclides was exceeded in water samples collected from five wells, which included four wells used for public-supply systems and one privately owned well. The dissolved gross alpha activity in a 1986 water sample from the Manderson municipal well (50-90-32cab01) was 9.5 ± 6.5 pCi/L. The median value for the confidence interval does not exceed the USEPA maximum contaminant level of 15 pCi/L; however, the maximum value for the confidence interval is 16 pCi/L.

Water samples from other wells with dissolved gross alpha activity greater than the USEPA maximum contaminant level included a 1983 sample from well 53-92-36ada01, which produces from the Madison-Bighorn aquifer and also from the Amsden Formation. The dissolved gross alpha activity was 19 ± 11 pCi/L. Subsequent testing determined that radium-226 plus radium-228 concentrations were within acceptable limits (less than 5 pCi/L). Water samples from the municipal well at Frannie (58-97-31bac01), which was completed

Table 14. Radionuclides detected in water samples from wells completed in selected aquifers in Big Horn County, Wyoming

[pCi/L, picocuries per liter; µg/L, micrograms per liter. Geologic unit: Qa, alluvium and colluvium; Qt, gravel, pediment, and fan deposits; Twl, Willwood Formation; Kl, Lance Formation; Kmt, Thermopolis Shale; MD-Ob, Madison-Bighorn aquifer; --, no data. Analytical lab: WRRI, Water Resources Research Institute, Laramie, Wyoming; M & M, Inc., Morrison and Maierle, Incorporated, Helena, Montana; CDM, Camp, Dresser, and McKee, Wheatridge, Colorado; C & G Labs, Chemical and Geological Labs, Casper, Wyoming; Core Labs, Core Laboratories, Aurora, Colorado; USGS, U.S. Geological Survey, Arvada, Colorado; Hazen Research, Golden, Colorado; RMAL, Rocky Mountain Analytical Laboratory, Denver, Colorado; EPA, U.S. Environmental Protection Agency, Denver, Colorado]

Local well number	Primary aquifer	Date of sample	[1]Gross alpha, dissolved (pCi/L)	[1]Gross beta, dissolved (pCi/L)	[1]Radium-226, dissolved (pCi/L)	[1]Radium-228, dissolved (pCi/L as radium-228)	Uranium, natural dissolved (µg/L as uranium	Analytical lab
52-97-24aa	Qa	--	4 ± 3	0 ± 5	1.09 ± 1.24	--	2	WRRI
52-96-30ab01	Qt	08-23-86	8 ± 6	5 ± 4	--	--	--	M & M, Inc.
52-96-30ab02	Qt	08-27-86	6 ± 6	4 ± 4	--	--	--	M & M, Inc.
56-97-26bc01	Qt	09-00-79	7.4 ± 3.4	--	0 ± .4	--	--	CDM
		03-00-80	6.2 ± 4.9	--	.2 ± .4	--	--	CDM
		05-00-80	8.4 ± 3.7	--	0 ± .5	--	--	CDM
		08-00-80	13 ± 4	--	0 ± .3	--	--	CDM
		10-05-83	5 ± 6	8 ± 8	0 ± .2	0.5 ± 0.8	9	CDM
		10-16-87	31 + 12.0	16 ± 7.6	.1 ± .1	--	[2]4.5	CDM
51-96-18bc	Twl	--	0 ± 5	5 ± 8	1.19 ± .56	--	--	WRRI
56-96-18dd	Twl	--	16 ± 8	21 ± 12	.19 ± .44	--	10	WRRI
50-90-32cab01	Kl	02-19-82	3.7 ± 5.5	7.8 ± 5.7	--	--	--	C & G Labs
		04-11-86	9.5 ± 6.5	4.5 ± 5.1	.1 ± .2	--	--	Core Labs
51-92-35cbc01	Kmt	10-06-85	[3]<12	[4]<1.4	[5].04	--	< .40	USGS
49-89-05bda01	MD-Ob	07-23-84	--	--	[5].44	--	--	USGS
49-89-06bcb01	MD-Ob	04-18-79	7.7 ± 2.6	0 ± 13	.4 ± .5	--	6	CDM
		06-28-80	2.0 ± 1.5	--	--	--	--	CDM
		05-25-84	1.9 ± 2.1	10 ± 6	--	--	--	Hazen Research
		07-23-84	--	--	[5].73	--	--	USGS
		05-25-88	2.2 ± 2.5	1.6 ± 1.7	--	--	--	Core Labs

Table 14. Radionuclides detected in water samples from wells completed in selected aquifers in Big Horn County, Wyoming--Continued

Local well number	Primary aquifer	Date of sample	[1]Gross alpha, dissolved (pCi/L)	[1]Gross beta, dissolved (pCi/L)	[1]Radium-226, dissolved (pCi/L)	[1]Radium-228, dissolved (pCi/L as radium-228)	Uranium, natural dissolved (µg/L as uranium	Analytical lab
49-91-12dba01	MD-Ob	02-27-80	0.3 ± 1.1	--	--	--	--	CDM
		07-24-84	--	--	[5]0.25	--	--	USGS
49-91-26ad01	MD-Ob	07-24-84	--	--	[5].33	--	--	USGS
50-90-23cad01	MD-Ob	07-23-84	--	--	[5].22	--	--	USGS
50-90-34dca01	MD-Ob	07-23-84	--	--	[5].17	--	--	USGS
53-91-35aaa01	MD-Ob	04-30-84	0 ± 2	2 ± 3	.7 ± .6	--	3	M & M, Inc.
		07-23-84	--	--	[4]1.2	--	--	USGS
53-91-35aaa02	MD-Ob	08-27-85	0 ± 0.1	.7 ± 1.4	--	--	--	M & M, Inc.
53-92-36ada01	MD-Ob	02-17-83	19 ± 11	14 ± 16	2.0 ± 1.1	0 ± 2.2	--	RMAL
		07-23-84	--	--	4.2	--	--	USGS
58-96-34cda01	MD-Ob	09-19-83	5.7 ± 3.0	.8 ± 5.5	1.8 ± 1.3	2.7 ± 5.2	6	Hazen Research
		07-23-84	--	--	[5].79	--	--	USGS
		09-10-84	0 ± 2.7	6.2 ± 2.6	--	--	--	Core Labs
		05-00-88	2.2 ± 2.5	--	--	--	--	Core Labs
		09-21-88	3.9 ± 2.6	2.2 ± 1.9	--	--	--	Core Labs
58-97-31bac01	MD-Ob	04-22-82	40 ± 5	--	35 ± 5	--	--	CDM
		05-25-82	49 ± 6	--	45 ± 3	.5	16	CDM
		08-09-82	160	--	55 ± 1	--	11	EPA
		07-23-84	--	--	[5]51	--	--	USGS
		01-00-88	--	--	45 ± 2.4	0 ± 1.7	--	Core Labs

[1] Analyses for radionuclide species include a plus or minus counting error that generally indicates a laboratory-specified confidence level. If the counting error is large relative to the reported concentration, reliable interpretation is difficult.

[2] Uranium dissolved, measured in picocuries per liter.

[3] U.S. Geological Survey reports dissolved gross alpha in micrograms per liter as uranium.

[4] U.S. Geological Survey reports dissolved gross beta as strontium/yttrium-90.

[5] U.S. Geological Survey analyzes dissolved radium-226 by the radon method.

in the Madison-Bighorn aquifer, has consistently exceeded the USEPA maximum contaminant level for dissolved gross alpha activity and for radium-226 plus radium-228. The geologic source of the radioactivity was postulated to be the Madison Limestone (Western Water Consultants, 1986, p. 3, 4) but was not verified by results of sample analyses. Water samples from the municipal well at Byron (56-97-26bc01), which yields water from gravel, pediment, and fan deposits through a drain field, contained dissolved gross alpha radioactivity that exceeded the USEPA maximum contaminant level in 1987, but activity was less than this level during five prior tests from 1979-83.

The quantity of gross beta activity was measured in picocuries per liter; however, the USEPA maximum contaminant level is 4 mrem/yr, which is a measure of exposure. The water sample from well 56-96-18dd, which was completed in the Willwood Formation, had a dissolved gross alpha activity of 16 ± 8 pCi/L and had the largest gross beta activity of 21 ± 12 pCi/L. The radionuclide(s) producing the activity were not identified. The gross beta activity in ground-water samples collected throughout the county could be from naturally present elements such as uranium, thorium and actinium.

Results of sampling and analyses of ground water prior to 1979, for radionuclides throughout the Bighorn Basin, were summarized by Libra and others (1981, p. 105). For the water samples collected from wells completed in selected aquifers, these additional data also indicate that ground-water concentrations of radionuclides are generally acceptable in Big Horn County. The geologic units sampled by Libra, with number of water samples in parentheses, are: alluvium (6), Willwood and Fort Union Formations (6), Cloverly Formation (2), Tensleep Sandstone (3), and the Madison Limestone (1). Concentrations in only 1 of these 18 water samples exceeded the gross alpha standard of 15 pCi/L, and none exceeded 3.2 pCi/L as dissolved radium-226.

SUMMARY

Surface-water and ground-water data were compiled to describe the water resources in Big Horn County, Wyoming. Streamflow characteristics are described for two stream types, ephemeral and perennial. Ephemeral streams originate primarily in the Bighorn Basin and are characterized by long periods of no flow. Flow generally occurs as a result of rainfall or snowmelt. Perennial streams originate in the high mountains and have continuous base flows sustained by snowmelt and ground water. High streamflows are associated with spring snowmelt, and low flows occur in the winter months when the snowpack is frozen and ground-water levels are at their lowest. Both types of streams may be affected by human activities that include irrigation and reservoir storage practices. Irrigation return-flow to streams maintains perennial flow in what would otherwise be ephemeral streams. Regulation of reservoirs also are used to meet minimum streamflow and power generation requirements.

Aquifers are present in unconsolidated deposits consisting of floodplain alluvium, terraces, gravels, pediments, and alluvial fans. Along the larger streams such as the Bighorn, Greybull, Nowood, and Shoshone Rivers are the most productive and predictable sources of water supply in the county. These deposits are as much as 100 ft thick. Depth to water in wells ranged from flowing to 39 ft below land surface, and well yields generally ranged from 25 to 200 gal/min; however, yields of 1,600 gal/min are reported from wells completed in the gravel, pediment, and fan deposits.

Bedrock aquifers that yield the most abundant water supplies in the county are those in the Tensleep Sandstone, Madison Limestone, Bighorn Dolomite, and Flathead Sandstone. The aquifers with the most potential for development as a water supply are those in the sandstone deposits of the Lance, Mesaverde, and Frontier Formations.

Reported yields from the Lance Formation ranged from 20 to 65 gal/min. Depth to water in wells ranged from 4.9 to 202 ft. Yields from wells completed in the Mesaverde Formation ranged from 10 to 35 gal/min and depth to water in the wells ranged from 2.4 to 176 ft. Reported well yields from the Frontier Formation ranged from 5 to 16 gal/min and depth to water in wells ranged from 8.1 to 120 ft.

The most commonly reported yields of flowing wells completed in the Tensleep Sandstone ranged from 10 to 30 gal/min with one well yielding 200 gal/min. Flowing wells had shut-in pressures as large as 50 lb/in^2 (115 ft above land surface). Depths of wells near Hyattville are less than 1,000 ft.

The Madison Limestone, the Darby Formation, and the Bighorn Dolomite form the Madison-Bighorn aquifer. Reported well yields from this aquifer ranged from 40 to 14,000 gal/min. Flowing wells had shut-in pressures ranging from 41 to 212 lb/in^2 (95 to 490 ft above land surface).

Reported yields from wells completed in the Flathead Sandstone ranged from 350 to 3,000 gal/min. Flowing wells had shut-in pressures ranging from 183 to 410 lb/in^2 (423 to 947 ft above land surface).

Several other aquifers in bedrock yield sufficient quantities of water for domestic and livestock supplies. These aquifers are in the White River, Tatman, Willwood, Fort Union, Meeteetse Formations; the Cody and Thermopolis Shales; and the Cloverly, Morrison, Sundance, Gypsum Springs, Chugwater, and Goose Egg Formations; and igneous and metamorphic rocks in the mountain area.

Seasonal water-level changes in unconsolidated deposits ranged from less than 1 to 10.6 ft. These changes are largely attributable to the effects of irrigation. Water levels in wells located in irrigated areas continue to rise as surface soils continue to drain. Water levels in wells are lowest in spring when yields from some wells become inadequate for their intended use.

Shut-in pressures from flowing wells in bedrock aquifers showed declines from the time the well was completed to 1988, as much as 390 ft. Flows also decreased over time.

Surface water accounts for 96 percent and ground water accounts for 4 percent of total offstream water use in Big Horn County. Irrigation is the largest offstream use of both surface and ground water. About 99 percent of offstream surface water and 55 percent of ground water is used for irrigation. Eighty-two percent of the water used for irrigation is consumed, which includes a 37-percent conveyance loss and 45 percent consumed by the irrigated crops. Ground water supplies 89 percent of water used for domestic purposes, primarily in rural areas where public supplies are not available, and about 16 percent of water used for public supplies.

Streams that originate in the Bighorn Basin have specific conductance values generally greater than 1,000 mg/L; streams that originate in the Bighorn Mountains have specific conductance values generally less than 1,000 mg/L. Specific conductance usually varies inversely with stream discharge. The dissolved constituents in the water are predominantly calcium or sodium and bicarbonate or sulfate.

Water from wells completed in alluvium and colluvium and in gravel, pediment, and fan deposits has concentrations of dissolved solids less than 2,000 mg/L. Water samples from wells completed in alluvium and colluvium along Shell Creek were classified as a calcium sulfate type; while water samples from alluvium and colluvium along the Nowood, Greybull, and Shoshone Rivers were classified as sodium sulfate and sodium-calcium sulfate types. More water samples from gravel, pediment, and fan deposits than alluvium and colluvium were classified as mixed, having both calcium and sodium as dominant cations. The dominant anion was sulfate. Water samples with the smallest median concentrations of dissolved solids were from wells completed in aquifers in Paleozoic and Precambrian rocks (111-275 mg/L). The dominant ions in these aquifers were calcium, magnesium, and bicarbonate. The largest median dissolved-solids concentrations were from wells completed in Tertiary and Cretaceous rocks (1,107-3,320 mg/L). The water types for these aquifers were usually sodium sulfate or mixed; however, the dominant ions were sodium and sulfate.

The concentrations of pesticides detected in surface-water samples collected in Big Horn County were considerably less than the U.S. Environmental Protection Agency (USEPA) maximum contaminant levels. Water samples collected from 26 wells and drains during the summers of 1987 and 1988 were analyzed for selected pesticides. Dicamba was detected in 4 of 22 water samples collected from wells and picloram in 5 of 22 water samples collected from wells in 1988. Concentration of both compounds are equal to or less than 0.05 μg/L. Analyses for triazine herbicides detected atrazine in 1 of 10 water samples at a concentration of 0.40 μg/L. Analyses for carbamate insecticides indicated that 5 of 17 water samples contained aldicarb sulfone with a maximum concentration of 1.44 μg/L. Aldicarb sulfoxide was detected in 4 of 17 water samples with a maximum concentration of 0.52 μg/L. Malathion, an organophosphate insecticide, was detected in water samples collected at 2 of 10 sites; maximum concentration was 0.02 μg/L. The USEPA has not established any maximum contaminant levels for the pesticides detected in ground-water samples collected in Big Horn County. The pesticides detected in streambed-material samples were all in the organochlorine insecticide class, except for one pesticide in the phenoxy acid herbicide class. The detected concentrations of pesticides in the organochlorine insecticide class ranged from 0.1 to 8.0 μg/kg of streambed material; more than 70 percent of the concentrations ranged from 0.1 to 1.0 μg/kg. However, the USEPA has not established maximum contaminant levels for streambed materials.

Analysis of ground-water samples for radionuclides indicated that concentrations in the water from four municipal wells exceeded the maximum contaminant level established by the USEPA. Radionuclide concentrations in water samples from the municipal well at Frannie consistently exceeded the USEPA maximum contaminant level for dissolved gross alpha activity (15 pCi/L) and for radium-226 plus radium-228 (5 pCi/L). The source of the radioactivity was postulated to be the Madison Limestone.

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GLOSSARY

AQUIFER--A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield usable quantities of water to wells and springs.

ARTESIAN AQUIFER--Synonymous with confined aquifer.

ARTESIAN WELL--A well deriving its water from an artesian or confined aquifer.

COMMERCIAL USE--water for motels, hotels, restaurants, office buildings, and other commercial facilities, and institutions, both civilian and military. The water may be obtained from a public supply or may be self-supplied.

CONFINED AQUIFER--an aquifer bounded above and below by impermeable beds or by beds of distinctly lower permeability than that of the aquifer itself; an aquifer containing confined ground water.

CONFINING UNIT--A body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers.

CONSUMPTIVE USE--That part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment. Also referred to as water consumed and water depletion.

CONVEYANCE LOSS--Water that is lost in transit from a pipe, canal, conduit, or ditch by leakage or evaporation. Generally, the water is not available for further use; however, leakage from an irrigation ditch, for example, may percolate to a ground-water source and be available for further use.

DOMESTIC WATER USE--Water for household purposes, such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and watering lawns and gardens. Also called residential water use. The water may be obtained from a public supply and self-supplied water.

UNCONFINED GROUND WATER--Water in an aquifer that has a water table.

CONFINED GROUND WATER--Ground-water under pressure substantially greater than atmospheric throughout and whose upper limit is the bottom of a bed having distinctly lower hydraulic conductivity than that of the material in which the confined water occurs.

HEAD--The height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point.

INDUSTRIAL USE--Water used for industrial purposes such as fabrication, processing, washing, and cooling, and includes such industries as steel, chemical and allied products, paper and allied products, mining, and petroleum refining. The water may be obtained from a public supply or may be self-supplied.

IRRIGATION RETURN-FLOW--The part of artificially applied water that is not consumed by evapotranspiration and that migrates to an aquifer or surface-water body.

IRRIGATION WATER USE--Artificial application of water on lands to assist in the growing of crops and pastures or to maintain vegetative growth in recreational lands, such as parks and golf courses.

LIVESTOCK WATER USE--Water for stock watering, feed lots, dairy operations, fish farming, and other on-farm needs.

MINING USE--Water used for the extraction of minerals occurring naturally including solids, such as coal and ores; liquids, such as crude petroleum; and gases, such as natural gas. Also includes uses associated with quarrying, well operations (dewatering), milling (crushing, screening, washing, and flotation), and other preparations customarily done at the mine site or as part of a mining activity.

OFFSTREAM USE--Water withdrawn or diverted from a ground- or surface-water source for public-water supply, industry, irrigation, livestock, thermoelectric power generation, and other uses. Sometimes called off-channel use or withdrawal use.

pH--A measure of the acidity or basicity of water. It is defined as the negative logarithm of the hydrogen ion concentration. This parameter is dimensionless and has a range from 0.0 to 14.0, with a pH of 7.0 representing pure water. A pH of greater than 7.0 indicates the water is basic while a pH value of less than 7.0 indicates an acidic water.

PERMEABILITY--A measure of the ability of a porous medium to transmit fluids under a hydraulic gradient.

POROSITY--The volume percentage of the total bulk not occupied by solid particles.

PUBLIC SUPPLY--Water withdrawn by public and private water suppliers and delivered to groups of users. Public suppliers provide water for a variety of uses, such as domestic, commercial thermoelectric power, industrial, and public water use.

SECONDARY PERMEABILITY--The porosity developed in a rock after its deposition or emplacement, through such processes as solution or fracturing.

SODIUM-ADSORPTION RATIO (SAR)--A measure of irrigation-water sodium hazard. It is the ratio of sodium to calcium plus magnesium adjusted for valence. The SAR value of water is considered along with specific conductance in determining suitability for irrigation.

SPECIFIC CAPACITY--The rate of discharge of water from the well divided by the drawdown of the water level within the well.

SPECIFIC CONDUCTANCE--A measure of water's ability to conduct an electrical current. Specific conductance is expressed in microsiemens per centimeter (μS/cm) at 25 degrees Celsius (25°C). For water containing between 100 and 5,000 mg/L of dissolved solids, specific conductance in μS/cm (at 25°C) multiplied by a factor between 0.55 and 0.71 will approximate the dissolved-solids concentration in mg/L. For most water, reasonable estimates can be obtained multiplying by 0.64.

UNCONFINED AQUIFER--An aquifer that has a water table.

WATER TABLE--The water table is that surface in an unconfined water body at which the pressure is atmospheric. It is defined by the levels at which water stands in wells that penetrate the water body just far enough to hold standing water. In wells penetrating to greater depths, the water level will stand above or below the water table if an upward or downward component of ground-water flow exists.

SUPPLEMENTAL DATA

Table 15. Records of selected wells, springs, drains,

[**Local number:** see text describing well-numbering system in the section titled Ground-Water Data. **Type of site:** W, well; S, spring; D, drain; includes perforated, screened, and open hole. **Diameter of casing above first open interval:** *, well constructed with multiple casing sizes. Fort Union Formation; Kl, Lance Formation; Km, Meeteetse Formation; Kmv, Mesaverde Formation; Kc, Cody Shale; Kf, Frontier Gypsum Spring Formation; ₸c , Chugwater Formation; Pzu, Paleozoic rocks undifferentiated; ₸Pg, Goose Egg Formation; IPt, Flathead Sandstone; p€r, Precambrian rocks. **Primary use of water:** C, commercial; D, de-water; H, domestic; I, irrigation; calculated by multiplying the shut-in pressure in pounds

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
49-86-04cb 01	W	1984	50	33-43	6.0	Qg	P
49-86-20bd 01	W	1980	50	35-45	6.0	Qg	P
49-86-32ab 01	W	1985	67	47-65	6.0	p€r	P
49-88-16cdb01	W	1982	415**R**	--	5.5*	IPt	S
		NA	NA	NA	NA	NA	NA
49-88-29caa01	S	NA	Spring	NA	NA	₸Pg	--
49-88-29daa01	W	--	--	--	8.0	₸Pg	S
		NA	NA	NA	NA	NA	NA
49-88-29dac01	W	1966	2,745**R**	610-1,600	8.62*	€f	Q
		NA	NA	2,530-2,745	NA	NA	NA
49-89-05bda01	W	1963	2,210**R**	2,050-2,210	8.0	MD-Ob	I
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
49-89-06bcb01	W	1968	2,890**R**	2,630-2,890	5.5*	MD-Ob	P
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
49-89-18dbb01	W	--	8,080**R**	--	--	Pzu	U
49-89-21bd 01	W	1946	431**R**	300-431	6.0	IPt	S
49-89-24dcb01	W	1936	1,480**R**	--	6.0	MD-Ob	S
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
49-89-28baa01	W	1953	944**R**	692-944	4.5*	MD-Ob	S
		NA	NA	NA	NA	NA	NA
49-89-29abb01	W	1951	960**R**	--	8.0	MD-Ob	S
		NA	NA	NA	NA	NA	NA
49-89-29daa01	W	--	--	--	--	IPt	S
49-89-34dca01	W	--	300**R**	--	6.0	IPt	S
49-89-35bb 01	W	--	--	--	--	MD-Ob	I
49-89-35bcb01	W	1949	694**R**	--	8.0	MD-Ob	S
49-90-01aaa01	W	1940	140	--	6.0	Kcv	S
49-90-01acd01	W	--	50	--	--	Qa	--

and collection galleries, in Big Horn County, Wyoming

C, collection gallery. **Depth of well:** well depths are given in feet below land surface datum (R, reported; no letter, measured). **Open interval:**
Primary aquifer: Qa, alluvium and colluvium; Qt, gravel, pediment, and fan deposits; Qg, glacial deposits; Twl, Willwood Formation; Tfu,
Formation; Kmr, Mowry Shale; Kt, Thermopolis Shale; Kcv, Cloverly Formation; Jm, Morrison Formation; Js, Sundance Formation; Jgs,
Tensleep Sandstone; TPMa, Amsden Formation; MD, Madison Limestone; Ob, Bighorn Dolomite; Ꞓgv, Gros Ventre Formation; Ꞓf ,
N, industrial; P, public supply; Q, aquiculture; S, stock; T, institutional; U, not used. Water level or hydraulic head (hydraulic head
per square inch by 2.31): Na, not applicable; --, no data]

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface (feet)	Water level below or hydraulic head above (+) land surface (date)	Water temperature and specific conductance (degrees Celsius)	Water temperature and specific conductance (microsiemens per centimeter at 25 degrees Celsius)	Water temperature and specific conductance (data)	Discharge (gallons per minute)	Discharge (date)
8,905	--	--	4	101	10-28-88	7	8-07-84
8,570	--	--	6	134	10-28-88	5	--
8,250	25	9-16-85	4	160	10-28-88	8	9-16-85
5,405	+43.2	12-23-82	--	--	--	13	12-23-82
NA	+34.6	9-28-87	--	--	--	11	9-28-87
--	NA	NA	--	--	--	--	--
5,030	--	--	10	570	8-30-88	35	- -53
NA	--	--	--	--	--	8	8-30-88
5,035	+762	- -70	19	308	8-30-88	1,000	- -70
NA	+423	10-11-88	--	--	--	531	9-29-87
4,642	393	5-11-62	17	325	8-31-88	2,500	- -62
NA	--	--	--	--	--	970	9-26-87
NA	+326	10-13-88	--	--	--	1,090	10-06-88
4,470	+485	8- -68	18	460	8-31-88	130	8-22-68
NA	+94.7	10-09-88	--	--	--	--	--
NA	--	--	--	--	--	25	10-05-88
--	--	--	20	--	9- -47	50	--
--	20.0	- -47	--	--	--	30	--
4,960	+119	5-12-62	10	--	11- -53	200	- -36
NA	--	--	12	--	5-14-75	46	- -60
NA	--	--	13	500	8-30-88	10	9-25-87
NA	--	--	--	--	--	21	8-28-88
4,795	293	11-04-53	--	--	--	84	11-04-53
NA	+94.7	10-09-88	14	350	8-29-88	30	10-09-88
4,710	+247	11-05-53	--	--	--	108	- -53
NA	+186	10-09-88	13	350	8-30-88	12	4-28-88
4,590	--	--	--	--	--	--	--
4,590	--	--	11	1,130	8-30-88	--	--
--	--	--	11	--	11- -53	84	--
4,680	20.0	5- -55	13	415	8-30-88	15	8-30-88
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
49-90-01ccc01	W	1937	12	--	8.0	Qa	H
49-90-01dbd01	S	NA	spring	NA	NA	Qa	--
49-90-03aaa01	W	1938	40	--	5.0	Jm	S
49-90-14daa01	W	--	100	--	--	Qa	--
49-90-17acd01	W	--	20	--	--	Qa	--
49-90-20ccb01	W	--	2,800**R**	--	8.0	MD-Ob	S
49-90-30dda01	W	--	29	--	--	Qt	H
49-90-32abd01	W	--	--	--	--	Kmr	--
49-91-01cbc01	W	1982	2,334	2,200-2,334	13.4*	MD-Ob	P
49-91-03cbb01	W	1980	40	12-40	4.5	Qa	H
		NA	NA	NA	NA	NA	NA
49-91-04acb01	W	1953	38	30-38	7.0	Kc	--
49-91-05daa01	W	--	55	--	5.0	Kc	S
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
49-91-06aab01	W	--	80	40-80	6.0	Kc	S
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
49-91-12dba01	W	1979	2,730**R**	2,120-2,130	9.62*	MD-Ob	P
		NA	NA	2,180-2,200	NA	NA	NA
		NA	NA	2,350-2,370	NA	NA	NA
		NA	NA	2,410-2,430	NA	NA	NA
		NA	NA	2,460-2,480	NA	NA	NA
		NA	NA	2,480-2,500	NA	NA	NA
49-91-14daa01	W	1973	100	55-60	7.0	Kc	S
		NA	NA	85-90	NA	NA	NA
49-91-14ddd01	W	--	62	--	5.5	Kc	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
49-91-26ad 01	W	--	--	--	--	MD-Ob	--
49-92-06	D	--	--	--	--	Qt	H
49-92-07bc 01	W	1980	50	10-40	4.0	Qa	H
49-92-28ad 01	W	--	200	27-200	6.0	Twl	H
49-92-32ba 01	W	1988	420**R**	110-120	8.75	Twl	H
		NA	NA	175-380	NA	NA	NA
49-92-32ca 01	W	1949	80	--	--	Twl	H

and collection galleries, in Big Horn County, Wyoming--Continued

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface		Water temperature and specific conductance			Discharge	
	(feet)	(date)	(degrees Celsius)	(microsiemens per centimeter at 25 degrees Celsius)	(data)	(gallons per minute)	(date)
--	--	--	--	--	--	--	--
--	NA	NA	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
4,290	--	--	--	--	--	--	--
--	--	--	--	--	--	12	--
--	--	--	--	--	--	--	--
4,362	+422	9-01-88	26	355	9-01-88	--	--
4,048	8.4	7-21-88	12	1,570	9-29-87	--	--
NA	--	--	12	1,570	7-21-88	--	--
4,031	--	--	--	--	--	--	--
4,030	6.5	8-03-88	18	8,800	8-03-88	--	--
NA	6.4	9-02-88	17	9,500	9-02-88	--	--
NA	5.9	9-26-88	17	9,800	9-26-88	--	--
NA	6.4	11-02-88	17	11,000	11-02-88	--	--
NA	6.6	12-19-88	8	10,500	12-19-88	--	--
NA	6.7	4-15-89	10	10,500	4-15-89	--	--
4,408	12.8	9-26-88	10	5,980	9-26-88	--	--
NA	13.0	12-19-88	8	5,200	12-19-88	--	--
NA	15.3	4-16-89	10	5,250	4-16-89	--	--
4,422	+416	4-28-87	24	353	9-01-88	--	--
NA	NA	NA	NA	NA	NA	NA	NA
NA	NA	NA	NA	NA	NA	NA	NA
NA	NA	NA	NA	NA	NA	NA	NA
NA	NA	NA	NA	NA	NA	NA	NA
NA	NA	NA	NA	NA	NA	NA	NA
4,100	--	--	--	--	--	--	--
NA	NA	NA	NA	NA	NA	NA	NA
4,115	12.3	8-03-88	13	2,720	8-03-88	--	--
NA	7.3	9-26-88	12	2,420	9-26-88	--	--
NA	10.4	12-19-88	9	2,450	12-19-88	--	--
NA	24.1	4-15-89	11	2,550	4-15-89	--	--
--	--	--	--	--	--	--	--
3,974	8.2	9-21-87	14	1,450	9-21-87	--	--
3,983	10.8	7-31-88	16	2,050	7-31-88	--	--
3,945	44.5	7-30-88	18	2,400	7-30-88	--	--
4,018	--	--	17	3,500	9-02-88	--	--
NA	NA	NA	NA	NA	NA	NA	NA
4,010	18.1	7-31-88	15	2,370	7-31-88	--	--

Table 15. Records of selected wells, springs, drains,

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
49-92-34bca01	W	--	30	--	6.0	Qa	S
49-92-34cba01	W	--	113	--	--	Twl	H
49-93-01acd01	W	1977	35	30-35	7.0	Qt	H
49-93-29dbc01	W	1967	350**R**	315-350	7.0	Twl	S
49-94-11dda01	W	1968	305**R**	65-283	7.0	Twl	S
49-94-15abb01	W	1966	--	--	7.0	Twl	S
50-86-33cad01	W	1980	100**R**	20-100	6.0	Qg	P
50-88-02dba01	S	NA	Spring	NA	NA	MD-Ob	U
50-88-11bbc01	S	NA	Spring	NA	NA	MD-Ob	S
50-89-05dcb01	W	1943	440**R**	--	5.0*	ℙt	U
50-89-21aaa01	W	--	50	--	6.0	ℙt	H
50-89-26cac01	W	--	160	--	6.0	ℙt	H
50-89-26cac02	W	--	30	--	6.0	ℙt	U
50-89-27cdc01	W	--	40	--	5.0	Qa	H
50-89-28cbc01	W	1943	25	--	6.0	Qa	H
50-89-31bab01	W	1967	3,990**R**	3,100-3,990	4.5*	Ꞓf	I
50-89-32dbb01	W	--	20	--	--	Qa	--
50-89-33acb01	W	1987	990**R**	852-990	7.0	ℙt	H
50-89-33bdb01	W	1975	1,120**R**	800-1,120	8.62*	ℙt	H
50-90-01ccd01	W	1984	2,090**R**	--	5.5*	MD-Ob	S
50-90-14bbd01	W	1949	1,620**R**	1,590-1,620	5.5*	ℙt	H
50-90-14bdb01	W	1980	2,800**R**	1,970-2,530	7.0*	MD-Ob	I
50-90-14cac01	W	1953	2,000**R**	1,600-1,620	6.0	ℙt	S
50-90-23cad01	W	1956	2,500**R**	--	10	MD-Ob	I
		NA	NA	NA	NA	NA	NA
50-90-34dca01	W	1963	2,980**R**	--	6.0	MD-Ob	H
50-92-31bba02	W	--	104	--	5.0	Tfu	H
50-92-32abc01	W	1909	22	--	6.0	Qa	S

and collection galleries, in Big Horn County, Wyoming--Continued

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface		Water temperature and specific conductance			Discharge	
	(feet)	(date)	(degrees Celsius)	(microsiemens per centimeter at 25 degrees Celsius)	(data)	(gallons per minute)	(date)
3,962	7.6	7-30-88	12	3,600	7-30-88	--	--
3,970	66.0	9-02-88	22	1,330	7-30-88	--	--
4,000	12.3	6-29-88	13	900	6-29-88	--	--
NA	11.1	9-26-88	11	1,240	9-26-88	--	--
NA	12.6	12-19-88	8	1,210	12-19-88	--	--
NA	14.2	4-13-89	10	1,380	4-13-89	--	--
4,200	70.0	1-01-67	--	--	--	5	--
4,430	80.0	4-04-68	--	--	--	6	--
NA	--	--	--	--	--	6	4-12-68
4,350	35.0	8-01-70	--	--	--	--	--
9,080	--	--	4	94	10-28-88	4	6-19-80
8,570	NA	NA	8	63	10-29-88	--	--
8,170	NA	NA	8	207	10-29-88	--	--
5,280	328	10-29-88	--	--	--	8	--
4,790	16.0	5-12-76	--	--	--	--	--
4,965	15.5	5-12-76	11	325	10-29-88	--	--
NA	26.7	10-29-88	--	--	--	--	--
4,980	8.0	9-09-47	--	--	--	--	--
4,815	12.0	- -76	--	--	--	--	--
4,642	--	--	--	--	--	--	--
4,685	+922	10-09-88	25	280	8-31-88	1,020	10-11-88
--	--	--	--	--	--	--	--
4,730	+95.9	8-29-88	11	510	8-29-88	15	8-29-88
4,720	+115	10-10-88	13	940	8-29-88	32	5-01-75
4,765	+257.3	4-29-88	11	335	9-26-87	37	9-26-87
NA	+254.0	8-31-88	14	347	4-29-88	37	4-29-88
NA	--	--	12	325	8-31-88	38	4-29-88
4,700	+106	9-01-88	14	730	9-01-88	200	--
4,690	+326	9-01-88	14	330	9-01-88	--	--
4,620	+215	9-01-88	10	342	9-01-88	--	--
4,550	808	- -56	--	--	--	--	--
NA	+476	10-10-88	14	318	9-01-88	2,880	2-14-56
4,530	+554	- -65	20	--	9-01-88	1,500	- -65
NA	+397	10-08-88	--	330	9-01-88	1,500	5-22-65
NA	--	--	--	--	--	1,040	10-08-88
3,894	--	--	--	--	--	--	--
3,908	7.0	8-02-88	12	3,800	8-02-88	--	--

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
50-92-32cab01	W	1984	780**R**	519-559	8.0*	Kl	P
		NA	NA	629-659	NA	NA	NA
		NA	NA	760-780	NA	NA	NA
50-92-33baa01	W	--	40	--	--	Qa	--
50-92-35aca01	W	1937	76	--	5.0	Kmv	S
50-92-35bbb01	W	--	40	--	--	Qa	--
50-92-36acb01	W	--	90	--	--	Kmv	I
50-92-36acb02	W	1943	122	--	4.0	Kmv	H
50-93-03aba01	W	1980	120	60-120	4.0*	Kl	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
50-93-03abc02	W	1981	100	40-95	6.0	Kl	H
50-93-03cbc01	W	1981	120	60-120	4.0*	Tfu	U
50-93-03dca01	W	1973	50	--	6.0	Qt	H
50-93-04aaa01	W	1975	45	30-40	4.0	Tfu	H
50-93-09ada01	W	1975	180**R**	20-160	6.0	Tfu	H
50-93-10bab01	W	1987	25	--	5.0	Qt	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
50-93-10cbc01	W	1954	55	--	6.0	Tfu	H
50-93-15ccb01	W	1981	21	13-18	6.0	Qt	H
50-93-22abb01	W	1986	83	--	6.0	Tfu	H
50-93-22bbc01	W	1977	27	22-27	6.0	Qt	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
50-93-22cdd01	W	1977	26	21-26	6.0	Qt	H
50-93-22dab01	W	1971	90	75-90	6.0	Tfu	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
50-93-22ddd01	D	--	--	--	--	Qt	H
50-93-22ddd02	W	--	25	--	6.0	Qt	U
50-93-26cbc01	W	1960	22	16-22	8.0	Qt	H

and collection galleries, in Big Horn County, Wyoming--Continued

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface (feet)	(date)	Water temperature and specific conductance (degrees Celsius)	(microsiemens per centimeter at 25 degrees Celsius)	(data)	Discharge (gallons per minute)	(date)
4,040	202.0	2-18-84	13	1,960	9-01-88	--	--
NA	NA	NA	NA	NA	NA	NA	NA
NA	NA	NA	NA	NA	NA	NA	NA
--	--	--	--	--	--	--	--
3,962	8.3	9-04-47	--	--	--	--	--
--	--	--	--	--	--	--	--
3,995	10.0	11-06-88	14	3,100	11-06-88	--	--
3,990	9.0	9-01-47	--	--	--	--	--
3,902	18.8	7-21-88	19	1,680	7-21-88	--	--
NA	17.1	9-27-88	17	1,380	9-27-88	--	--
NA	21.8	12-17-88	8	1,360	12-17-88	--	--
NA	27.7	4-14-89	8	1,400	4-14-89	--	--
3,900	--	--	16	1,620	7-18-88	--	--
3,940	20.0	- -81	--	--	--	20	- -81
3,878	5.7	7-18-88	17	1,940	7-18-88	--	--
3,944	5.7	7-18-88	--	2,230	7-18-88	--	--
3,937	15.0	7-19-88	--	3,850	7-19-88	--	--
3,925	5.6	7-18-88	16	2,500	7-18-88	--	--
NA	5.0	9-28-88	14	2,300	9-28-88	--	--
NA	8.5	12-20-88	8	2,600	12-20-88	--	--
NA	8.3	4-14-89	8	2,780	4-14-89	--	--
3,935	--	--	--	2,700	7-19-88	--	--
3,944	4.4	7-19-88	--	1,820	7-19-88	--	--
3,946	3.4	7-29-88	--	2,360	7-21-88	--	--
3,957	3.5	7-19-88	--	3,000	7-19-88	30	4-18-77
NA	4.9	9-27-88	14	2,720	9-27-88	--	--
NA	8.0	12-20-88	--	--	--	--	--
NA	8.9	4-14-89	--	--	--	--	--
3,960	2.2	7-21-88	--	2,500	7-21-88	--	--
3,945	11.8	6-29-88	12	5,100	9-21-87	--	--
NA	30.6	7-22-88	14	4,800	6-29-88	--	--
NA	26.2	9-26-88	12	4,900	7-22-88	--	--
NA	6.4	12-21-88	12	4,120	9-26-88	--	--
NA	12.0	4-14-89	10	4,120	12-21-88	--	--
NA	--	--	11	4,410	4-14-89	--	--
3,950	--	--	--	1,630	7-19-88	--	--
3,950	14.7	7-19-88	--	--	--	--	--
3,960	6.8	7-16-88	13	1,550	7-19-88	--	--

Table 15. Records of selected wells, springs, drains,

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
50-93-27bca01	W	1976	40	10-15	9.0	Tfu	H
		NA	NA	10-40	6.0	NA	NA
50-93-27dbc01	D	--	--	--	--	Qt	H
50-93-27dcc01	W	1976	140	64-140	6.0	Twl	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
50-93-28aaa01	W	1968	40	--	--	Tfu	H
50-93-28aba01	W	1982	295**R**	175-295	6.0	Twl	H
50-93-34aca01	W	1968	200**R**	--	--	Twl	H
50-93-35cba01	W	--	35	--	--	Qt	H
50-93-36adb01	W	1976	245**R**	155-245	6.0	Tfu	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
51-87-07cca01	W	1986	56	37-55	6.0	Qa	P
51-88-12ddd01	W	1986	53	42-52	6.0	Qa	P
51-88-13add01	W	1986	66	51-66	6.0	Qa	P
51-92-35cbc01	W	--	1,530**R**	--	--	Kt	--
51-93-08ca 01	W	1917	125	--	--	Kl	H
51-93-17daa01	W	1975	58	40-58	6.0	Qt	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
51-93-17ddc01	W	1977	120	100-120	4.0	Kmv	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
51-93-17ddc02	W	1977	160	140-160	6.0	Kmv	H
51-93-24cc 01	W	1969	3,910**R**	--	--	MD-Ob	N
51-93-28dad01	W	1984	110	90-105	4.0*	Tfu	H
51-93-28dbc01	W	1972	53	40-53	6.0	Kl	I
51-93-28ddd01	W	1979	118	78-118	6.0	Kl	H
51-93-33aaa01	W	1971	116	--	6.0	Kl	H
51-93-33add01	W	--	45	36-45	6.0	Qt	H
51-93-33bad01	W	1978	60	40-60	7.0	Tfu	I
51-93-33dda01	W	1985	65	35-55	4.0*	Tfu	H

and collection galleries, in Big Horn County, Wyoming--Continued

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface (feet)	(date)	Water temperature and specific conductance (degrees Celsius)	(microsiemens per centimeter at 25 degrees Celsius)	(data)	Discharge (gallons per minute)	(date)
3,994	--	--	--	4,130	7-19-88	--	--
NA	NA	NA	NA	NA	NA	NA	NA
3,970	--	--	--	2,030	7-19-88	--	--
4,000	52.9	7-19-88	14	3,200	7-19-88	10	7- -76
NA	41.9	9-26-88	14	2,820	9-26-88	--	--
NA	40.0	12-21-88	11	2,920	12-21-88	--	--
NA	48.0	4-15-89	10	3,200	4-15-89	--	--
3,996	--	--	16	3,500	7-19-88	--	--
4,040	--	--	17	2,400	9-02-88	--	--
4,012	--	--	--	6,800	7-19-88	--	--
4,002	--	--	--	1,560	7-19-88	--	--
3,962	81.8	9-02-88	24	1,040	9-02-88	--	--
NA	103.1	9-26-88	16	1,030	9-26-88	--	--
NA	138.5	12-19-88	9	980	12-19-88	--	--
NA	140.2	4-15-89	4	1,310	4-15-89	--	--
9,170	--	--	4	98	11-02-88	38	8-14-86
9,270	--	--	5	73	11-02-88	17	7-26-86
9,365	--	--	4	64	11-02-88	5	8-15-86
4,240	--	--	--	--	--	--	--
3,930	30.0	- -17	19	2,070	7-20-88	--	--
3,895	6.4	7-16-88	23	1,610	7-16-88	25	10-09-75
NA	7.9	9-27-88	--	1,430	9-27-88	--	--
NA	11.6	12-17-88	12	1,540	12-17-88	--	--
NA	17.0	4-14-89	11	1,800	4-14-89	--	--
3,970	25.9	7-16-88	22	2,810	7-16-88	--	--
NA	24.8	9-27-88	14	2,560	9-27-88	--	--
NA	29.4	12-17-88	10	2,180	12-17-88	--	--
NA	34.6	4-14-89	11	2,380	4-14-89	--	--
3,970	26.2	7-20-88	--	5,780	7-20-88	--	--
--	--	--	--	--	--	--	--
3,883	100.0	5-15-84	16	1,680	7-21-88	--	--
3,925	13.1	9-02-88	18	1,550	9-02-88	--	--
3,905	18.6	7-21-88	--	4,400	7-21-88	--	--
3,920	24.8	7-18-88	19	1,780	7-18-88	--	--
3,930	4.9	7-18-88	17	1,550	7-18-88	--	--
3,920	15.4	9-02-88	18	1,850	9-02-88	--	--
3,935	4.2	6-29-88	16	3,400	6-29-88	--	--

Table 15. Records of selected wells, springs, drains,

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
51-93-34bbb01	W	1977	54	40-50	6.0	Kl	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
51-93-34bdc01	W	1982	38	20-38	6.0	Kl	H
51-93-34ccc01	W	1976	38	20-38	4.0*	Tfu	H
51-93-34ccc02	W	1978	80	--	6.0	Qt	H
51-93-34dcd01	W	1977	140	--	4.5*	Kl	H
51-94-02bbd01	W	--	15	--	--	Qa	S
51-94-02dba01	W	1984	48	20-40	6.0	Twl	H
51-94-03dcd01	W	1984	390**R**	320-390	4.0*	Twl	H
51-94-05bdd01	W	1938	42	--	8.0	Qa	H
51-94-05bdd02	W	1938	106	40-106	6.0	Twl	H
51-94-07adc01	W	--	--	--	--	Qt	--
51-94-08 01	W	--	50	--	8.0	Qt	H
51-94-08ba 01	W	1988	38	--	--	Qt	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
51-94-08dbb01	W	--	40	--	9.0	Twl	H
51-94-08dbb03	W	--	40	--	--	Twl	H
51-94-11baa01	W	1963	70	48-70	--	Twl	H
51-94-11bb 01	W	1960	18	--	36.0	Qt	H
51-95-05cca01	W	1987	82	15-80	5.0	Twl	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
51-95-06cdb01	W	--	--	--	--	Twl	--
51-95-12dbc01	W	--	100	--	--	Twl	--
51-95-14a 01	W	--	--	--	--	Twl	H
51-95-15ccb01	W	--	24	--	8.0	Qa	I
51-95-15ccb02	W	1950	124	115-120	6.0	Twl	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
51-95-15ddc01	W	--	130	--	--	Twl	--
51-95-21aca01	W	--	10	--	--	Qa	--

and collection galleries, in Big Horn County, Wyoming--Continued

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface		Water temperature and specific conductance			Discharge	
	(feet)	(date)	(degrees Celsius)	(microsiemens per centimeter at 25 degrees Celsius)	(data)	(gallons per minute)	(date)
3,905	9.9	7-21-88	13	2,630	7-21-88	20	4-20-77
NA	6.0	9-27-88	14	2,480	9-27-88	20	4-20-77
NA	11.2	12-17-88	9	3,600	12-17-88	--	--
NA	15.9	4-14-89	11	3,490	4-14-89	--	--
3,905	4.9	7-18-88	14	3,480	7-18-88	50	4-10-82
3,940	6.8	7-21-88	--	2,720	7-21-88	--	--
3,939	5.8	7-18-88	14	2,020	7-18-88	--	--
3,900	35.4	7-19-88	15	2,690	7-19-88	--	--
--	--	--	--	--	--	--	--
3,940	8.0	7-20-88	--	4,100	7-20-88	--	--
3,983	40.0	7-20-88	--	2,000	7-20-88	--	--
4,030	28.6	8-31-88	22	--	8-31-88	--	--
4,030	--	--	22	2,250	8-31-88	--	--
--	--	--	--	--	--	--	--
4,035	--	--	--	1,060	7-20-88	--	--
3,995	11.2	6-26-88	10	1,620	6-26-88	--	--
NA	10.6	9-27-88	12	1,720	9-27-88	--	--
NA	12.6	12-17-88	11	1,770	12-17-88	--	--
NA	13.5	4-14-89	10	1,780	4-14-89	--	--
--	6.5	8-10-57	--	--	--	--	--
4,028	6.5	8-10-57	--	1,220	8-10-57	--	--
3,972	56.0	7-20-88	--	2,150	7-20-88	10	4- -63
3,965	9.8	7-20-88	--	2,260	7-20-88	3	- -60
4,233	17.2	6-26-88	14	4,350	6-26-88	--	--
NA	18.0	9-27-88	13	3,900	9-27-88	--	--
NA	18.8	12-17-88	10	4,180	12-17-88	--	--
NA	20.7	4-11-89	--	4,300	4-11-89	--	--
NA	--	--	10	--	4-11-89	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
4,082	21.7	9-21-87	12	3,800	9-21-87	--	--
4,130	7.0	8-04-56	--	--	--	141	--
4,130	5.8	8-04-56	14	2,830	10-08-88	--	--
NA	5.3	8-10-56	--	--	--	--	--
NA	9.8	10-08-88	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--

Table 15. Records of selected wells, springs, drains,

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
51-96-03cda01	W	--	25	--	--	Qt	H
51-96-05dbd01	W	--	56	--	--	Qt	--
51-96-07dda01	W	--	12	--	--	Qa	H
51-96-08cba01	W	--	39	--	--	Qa	S
51-96-10dbd01	W	1982	7	--	--	Qa	H
51-96-22bab01	W	1970	51	--	--	Qa	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
51-96-22bab02	W	--	200	--	--	Twl	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
51-96-24bab01	W	--	25	--	--	Qa	--
51-96-24bab02	W	--	25	--	--	Qa	--
51-97-02bdd01	W	--	20	--	24.0	Qa	--
51-97-12abc02	W	--	16	--	--	Qa	H
52-91-20bcd01	W	1983	1,550**R**	170-1,550	8.62	IPt	S
52-92-04aaa01	W	1981	106	84-100	7.0	Kcv	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
52-93-09dbc01	W	1982	109	60-106	6.0	Kf	H
52-93-19bda01	W	--	32	--	6.0	Qa	H
52-93-19cbc01	W	1981	85	51-80	6.0	Kmv	H
52-93-19cbd01	W	--	--	--	--	Kmv	--
52-93-19dad01	W	1976	150	60-150	6.0	Kc	H
52-93-20abc01	W	--	12	--	12.0	Qa	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
52-93-28cba01	W	--	350**R**	--	--	Kc	I
52-93-29aab01	W	--	18	--	3.0	Qt	H
52-93-29aab02	W	1982	80	5-23	66.0	Kc	U
52-93-30abb01	W	--	20	--	--	Kc	S
52-93-32ddc01	W	1984	27	15-27	4.0	Qt	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA

and collection galleries, in Big Horn County, Wyoming--Continued

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface (feet)	(date)	Water temperature and specific conductance (degrees Celsius)	(microsiemens per centimeter at 25 degrees Celsius)	(data)	Discharge (gallons per minute)	(date)
4,325	7.0	7-01-56	12	--	8- -57	--	--
4,381	--	--	--	--	--	--	--
4,398	4.9	7-26-56	--	--	--	--	--
4,400	3.3	7-26-56	--	--	--	--	--
4,305	4.4	6-25-88	12	820	6-25-88	--	--
4,308	12.5	6-27-88	12	1,500	6-27-88	--	--
NA	12.7	9-27-88	13	1,460	9-27-88	--	--
NA	14.7	12-17-88	9	1,510	12-17-88	--	--
NA	16.2	4-11-89	10	1,670	4-11-89	--	--
4,308	56.0	6-27-88	--	1,130	6-27-88	--	--
NA	64.0	9-27-88	17	1,060	9-27-88	--	--
NA	80.8	12-17-88	9	1,040	12-17-88	--	--
NA	56.8	4-11-89	12	1,050	4-11-89	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
4,508	--	--	--	--	--	--	--
4,460	4.3	7-26-56	--	--	--	--	--
4,556	--	--	--	1,650	6-28-88	--	--
4,080	43.9	8-31-88	18	3,650	8-31-88	--	--
NA	33.2	9-29-88	16	3,700	9-29-88	--	--
NA	32.5	12-20-88	9	3,920	12-20-88	--	--
NA	34.2	4-13-89	10	4,180	4-13-89	--	--
3,901	12.7	9- 1-88	16	1,280	9-01-88	15	12- 6-82
4,475	--	--	--	--	--	--	--
3,880	39.9	8-31-88	16	3,100	8-31-88	--	--
3,855	--	--	--	--	--	--	--
3,835	--	--	16	2,480	7-22-88	--	--
3,801	5.2	9-17-56	16	2,350	9-01-88	--	--
NA	7.7	12-01-56	--	--	--	--	--
NA	4.6	9-01-88	--	--	--	--	--
3,862	--	--	17	5,200	9-01-88	--	--
3,862	5.5	7-16-88	19	1,480	7-16-88	--	--
3,862	6.3	7-16-88	--	--	--	--	--
3,838	3.7	6-16-88	--	4,780	6-16-88	--	--
3,885	3.8	7-21-88	17	2,680	7-21-88	--	--
NA	5.6	9-27-88	17	3,180	9-27-88	--	--
NA	7.6	12-17-88	11	3,100	12-17-88	--	--
NA	7.8	4-14-89	6	2,570	4-14-89	--	--

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
52-94-01bda01	W	1961	70	--	8.0	Km	S
		NA	NA	NA	NA	NA	NA
52-94-01dbb01	W	1981	85	25-40	6.0	Kmv	S
		NA	NA	65-85	NA	NA	NA
52-94-03 01	W	--	30	--	4.0	Tfu	I
52-94-24dda01	W	--	8	--	8.0	Qa	S
52-94-25acc01	W	--	--	--	--	Tfu	--
52-94-25bcd01	W	--	125	--	8.0	Tfu	U
52-94-25caa01	W	--	--	--	--	Tfu	-
52-94-25caa02	W	1975	110	--	10.0	Tfu	S
52-94-25cab01	W	1976	300	160-220	8.0	Tfu	S
				280-300			
52-95-04cdb01	W	1950	25	5-20	5.0	Qt	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
52-95-04dcb01	W	1972	15	6-15	12.0	Qt	H
52-95-05cba01	W	--	9	--	--	Qt	H
52-95-05cbc01	W	1976	40	--	--	Qt	H
52-95-05cdb01	W	1977	30	0-30	--	Qt	H
52-95-05dcb01	W	1983	30	--	--	Qt	H
52-95-06ada01	W	1975	55	10-55	6.0	Twl	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
52-95-06ccb01	W	1978	20	--	--	Qt	D
52-95-06dda01	W	1980	35	15-35	7.0*	Qt	H
52-95-07bbc01	W	1959	33	--	12.0	Qt	I
52-95-07bcc01	W	1988	130	100-128	6.0	Twl	H
52-95-07caa01	W	1988	120	80-120	4.0*	Twl	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA

and collection galleries, in Big Horn County, Wyoming--Continued

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface (feet)	Water level (date)	Water temperature (degrees Celsius)	Specific conductance (microsiemens per centimeter at 25 degrees Celsius)	(data)	Discharge (gallons per minute)	Discharge (date)
3,945	35.0	10-01-61	16	3,700	9-09-70	500	--
NA	--	--	--	--	--	500	10- 1-61
3,943	--	--	13	4,350	11-05-88	10	10-24-81
NA	NA	NA	NA	NA	NA	NA	NA
4,000	13.3	11-05-88	11	3,800	11-05-88	--	--
--	3.0	9-01-56	16	--	8- -57	--	--
--	--	--	--	--	--	--	--
3,922	38.7	8-31-88	--	--	--	--	--
--	--	--	--	--	--	--	--
3,885	80.5	8-31-88	23	2,050	8-31-88	--	--
3,900	60.1	8-31-88	21	3,920	8-31-88	--	--
4,246	8.4	8-09-56	13	1,520	9-13-87	--	--
NA	6.7	9-13-87	--	1,380	5-27-88	--	--
NA	6.7	9-23-87	14	1,470	6-27-88	--	--
NA	6.5	5-27-88	13	1,470	9-28-88	--	--
NA	6.3	6-27-88	12	1,340	11-05-88	--	--
NA	6.6	9-28-88	9	1,520	12-15-88	--	--
NA	6.2	11-05-88	8	1,670	4-10-89	--	--
NA	7.0	12-15-88	--	--	--	--	--
NA	7.1	4-10-89	--	--	--	--	--
4,238	5.9	5-27-88	--	2,630	5-27-88	--	--
--	5.3	8-10-56	13	--	8-10-56	--	--
4,294	5.3	5-24-88	10	1,150	5-24-88	--	--
4,332	--	--	10	1,120	5-26-88	10	9- -77
4,273	5.2	5-27-88	--	1,750	5-27-88	--	--
4,281	6.8	8-12-87	--	3,630	5-24-88	10	4-15-75
NA	6.7	5-24-88	15	3,500	9-28-88	--	--
NA	6.7	9-28-88	8	3,600	12-16-88	--	--
NA	10.4	12-16-88	9	4,000	4-10-89	--	--
NA	13.3	4-10-89	--	--	--	--	--
4,318	3.3	5-23-88	--	1,120	5-23-88	--	--
4,300	5.3	5-24-88	--	995	5-24-88	--	--
4,334	8.1	5-24-88	--	1,120	5-23-88	420	6- -59
4,398	38.9	5-29-88	--	1,000	5-29-88	--	--
4,378	16.6	5-23-88	--	918	5-29-88	--	--
NA	40.8	9-27-88	13	825	9-27-88	--	--
NA	46.1	12-16-88	14	920	12-16-88	--	--
NA	70.3	4-10-89	12	965	4-10-89	--	--

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
52-95-07cab01	W	--	90	--	--	Twl	S
52-95-07cbb01	W	--	165	--	--	Twl	H
52-95-08cbb01	W	--	108	--	--	Twl	D
52-95-08cbb02	W	--	147	--	4.0	Twl	H
52-95-09cad01	W	1960	27	--	--	Qt	H
52-95-09dbd01	W	1960	22	--	5.0	Qt	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
52-95-10cba01	W	1959	45	--	--	Qt	I
52-95-10dbd01	W	1982	56	25-50	4.5	Twl	I
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
52-95-10dbd02	W	--	27	--	--	Qt	H
52-95-10ddb01	D	1975	14	--	36.0	Qt	I
52-95-15ada01	W	1987	70	--	--	Twl	S
52-96-01cda01	W	1958	25	--	--	Qt	H
52-96-02add01	W	1974	35	--	7.0	Qt	H
52-96-02bcb01	W	1961	25	--	24.0	Qt	I
52-96-02cbd01	W	1937	20	--	8.0	Qt	H
		NA	NA	NA	NA	NA	NA
52-96-02dda01	W	--	19	--	6.0	Qt	H
52-96-03acc01	W	1979	40	25-40	4.0*	Qt	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
52-96-03cbb02	W	1927	27	18-27	8.0	Qt	U
52-96-03cbc01	W	1955	36	15-25	48.0	Qt	I
		NA	NA	28-30	NA	NA	NA
52-96-03dbc01	W	1961	28	--	36.0	Qt	I
52-96-03dca01	W	1988	33	--	--	Qt	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
52-96-03dda01	W	1935	26	--	8.0	Qt	I

and collection galleries, in Big Horn County, Wyoming--Continued

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface (feet)	Water level below or hydraulic head above (+) land surface (date)	Water temperature and specific conductance (degrees Celsius)	Water temperature and specific conductance (microsiemens per centimeter at 25 degrees Celsius)	Water temperature and specific conductance (data)	Discharge (gallons per minute)	Discharge (date)
4,380	22.2	5-23-88	--	2,960	5-23-88	--	--
4,410	--	--	--	1,280	5-23-88	--	--
4,340	52.3	5-24-88	12	1,530	5-24-88	--	--
4,340	33.3	8-08-57	--	--	--	--	--
4,235	--	--	10	1,690	5-24-88	--	--
4,245	7.7	5-12-87	--	1,630	5-24-88	--	--
NA	9.6	5-24-88	14	1,480	9-28-88	--	--
NA	10.7	9-28-88	9	1,510	12-16-88	--	--
NA	12.9	12-16-88	10	1,680	4-10-89	--	--
NA	14.7	4-10-89	--	--	--	--	--
4,220	4.8	5-24-88	--	--	--	--	--
4,208	4.8	8-12-87	--	1,400	5-23-88	17	7-20-82
NA	8.7	5-23-88	20	1,800	9-29-88	--	--
NA	8.7	9-29-88	9	1,440	12-16-88	--	--
NA	9.3	12-16-88	8	1,400	4-10-89	--	--
NA	9.4	4-10-89	--	--	--	--	--
4,200	--	--	13	--	8- 8-57	--	--
4,198	5.7	12-16-88	8	1,720	12-16-88	1,350	7-31-75
4,208	11.4	5-23-88	--	--	--	--	--
4,347	7.6	5-23-88	--	1,440	5-23-88	--	--
4,365	10.6	5-23-88	11	915	5-23-88	--	--
4,402	9.8	5-23-88	--	948	5-23-88	1,600	- -79
4,398	5.9	8-10-56	--	960	5-23-88	17	4-15-37
NA	6.1	5-23-88	--	--	--	--	--
--	5.4	8-10-56	16	--	8-10-56	--	--
4,421	7.9	5-22-88	12	900	5-22-88	--	--
NA	9.3	9-29-88	16	820	9-29-88	--	--
NA	11.5	12-15-88	8	865	12-15-88	--	--
NA	12.9	4-10-89	9	910	4-10-89	--	--
4,440	8.0	6-05-27	--	--	--	200	5-28-27
4,443	18.5	6-23-55	--	1,020	5-23-88	900	--
NA	8.3	9-18-56	--	--	--	900	6-23-55
4,427	8.1	5-22-88	--	--	--	1,000	3-07-61
4,421	8.7	5-23-88	14	995	5-23-88	--	--
NA	4.2	6-27-88	15	1,040	6-27-88	--	--
NA	8.3	9-29-88	16	980	9-29-88	--	--
NA	13.3	12-15-88	3	1,040	12-15-88	--	--
NA	14.4	4-10-89	3	1,110	4-10-89	--	--
4,412	5.6	8-10-56	10	--	8-10-56	300	--

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
52-96-04ccc01	W	1935	24	12-24	8.0	Qt	H
52-96-04cda01	W	1981	40	10-40	6.0*	Qt	H
52-96-04daa01	W	1984	70	35-70	6.0	Qt	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
52-96-08bbc01	W	--	31	--	8.0	Qt	H
52-96-08cbc01	W	1955	50	--	20.0	Qt	I
		NA	NA	NA	NA	NA	NA
52-96-08dbc01	W	1961	24	16-24	12.0	Qt	I
52-96-08dbd01	W	--	17	--	--	Qt	I
		NA	NA	NA	NA	NA	NA
52-96-09ada02	W	--	16	--	36.0	Qt	U
52-96-09ada03	W	--	16	--	--	Qt	H
52-96-09ccb01	W	1979	30	10-30	7.0*	Qt	H
52-96-10bcb01	W	1946	80	--	6.0*	Twl	H
52-96-10cda01	W	1936	44	--	6.0	Qt	H
52-96-10dcd01	W	1934	57	--	15.0	Qt	I
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
52-96-11cad01	W	1960	65	--	12.0	Qt	I
52-96-11cbd01	W	1982	45	--	6.0	Qt	H
		NA	NA	NA	NA	NA	NA
52-96-15bbc01	W	1981	52	40-50	7.0	Twl	I
52-96-16aad01	W	--	44	22-42	12.0	Qt	I
52-96-16abb01	W	--	27	--	6.0	Qt	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
52-96-16dac01	W	1955	114	--	10.0	Twl	U
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
52-96-17bbc01	W	--	14	--	--	Qt	H
52-96-18ada01	W	1940	18	10-18	1.25	Qt	H

and collection galleries, in Big Horn County, Wyoming--Continued

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface (feet)	(date)	Water temperature and specific conductance (degrees Celsius)	(microsiemens per centimeter at 25 degrees Celsius)	(data)	Discharge (gallons per minute)	(date)
4,483	11.9	5-25-88	12	1,270	5-25-88	--	--
4,464	10.5	5-23-88	12	975	5-23-88	--	--
4,443	8.1	5-22-88	10	950	5-22-88	15	9-01-84
NA	9.6	9-29-88	15	850	9-29-88	--	--
NA	11.8	12-15-88	8	990	12-15-88	--	--
NA	14.1	4-10-89	10	975	4-10-89	--	--
4,515	11.8	5-27-88	11	1,060	5-27-88	--	--
4,530	5.8	8-06-56	--	--	--	750	8-06-56
NA	--	--	--	--	--	900	4-10-61
4,512	9	4-10-61	--	--	--	900	4-10-61
4,508	5.8	8-06-56	--	1,200	5-27-88	--	--
NA	5.9	5-27-88	--	--	--	--	--
4,455	--	--	--	--	--	--	--
4,462	4.0	5-22-88	--	550	5-22-88	--	--
4,480	5.2	5-22-88	12	955	5-25-88	15	9-04-79
4,445	--	--	--	3,600	5-19-88	--	--
4,455	24.0	8- -56	12	770	5-18-88	--	--
4,470	39.3	8-02-56	--	--	--	450	--
NA	28.1	5-18-88	--	--	--	200	9-12-34
NA	--	--	--	--	--	200	- -56
4,440	--	--	--	--	--	300	7-31-60
4,438	19.0	12-16-88	10	1,180	12-16-88	25	1-10-82
NA	--	--	--	--	--	25	1-19-82
4,474	20.2	5-19-88	--	--	--	50	9-20-81
4,475	22.9	8-07-56	--	--	--	226	--
4,465	6.0	8-07-56	14	1,830	6-27-88	--	--
NA	7.6	6-27-88	19	1,600	9-29-88	--	--
NA	6.1	9-29-88	12	1,620	12-16-88	--	--
NA	7.8	12-16-88	10	2,810	4-12-89	--	--
NA	10.9	4-12-89	--	--	--	--	--
4,490	43.5	5-18-88	--	--	--	120	- -56
NA	42.5	9-28-88	--	--	--	--	--
NA	43.7	12-17-88	--	--	--	--	--
NA	44.6	4-10-89	--	--	--	--	--
4,540	5.8	5-27-88	12	925	5-27-88	--	--
4,544	--	--	13	935	5-27-88	--	--

Table 15. Records of selected wells, springs, drains,

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
52-96-18cbc01	W	--	14	--	20.0	Qt	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
52-96-20bbc01	W	1910	20	15-20	8.0	Twl	H
52-96-20bbc02	W	1978	40	7-20	--	Twl	I
52-96-28cbc01	W	--	70	--	--	Twl	U
52-96-29bba01	W	--	90	--	--	Twl	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
52-96-29cca01	W	1977	100	70-100	4.0*	Twl	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
52-96-30dab01	W	1986	42	21-31	8.0*	Qt	P
52-96-30dab02	W	1986	41	21-31	8.62*	Qt	P
52-96-30dad01	W	1930	90	--	5.0	Twl	H
52-96-31bcb01	W	1966	19	15-19	4.0	Qt	H
		NA	NA	NA	NA	NA	NA
52-96-31cda01	W	1988	35	25-35	--	Qt	P
		NA	NA	NA	NA	NA	NA
52-96-32cbc01	W	--	27	--	--	Qt	I
52-96-32ccb01	W	--	30	--	6.0	Qt	H
52-96-32ccb02	W	1961	40	20-40	36.0	Qt	I
52-96-32ccc01	W	--	26	--	--	Qt	-
52-96-32ccc02	W	1961	39	33-39	30.0	Qt	I
52-96-32dc 01	W	1962	37	--	26.0	Qt	I
52-96-32dcb01	W	1951	132	125-132	6.0	Twl	H
52-96-33dcb02	W	--	22	--	1.5	Qt	H
52-96-34bbb01	W	1969	24	--	--	Qa	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
52-97-13bad01	W	1944	20	--	24.0	Qt	H
52-97-13ddbO1	W	1930	15	--	18.0	Qt	H
52-97-25dbc01	W	1951	19	--	6.0	Qt	H
52-97-25dbc02	W	--	19	--	6.0	Qt	-
52-97-26cad01	W	--	180	--	8.0	Twl	H

and collection galleries, in Big Horn County, Wyoming--Continued

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface (feet)	(date)	Water temperature and specific conductance (degrees Celsius)	(microsiemens per centimeter at 25 degrees Celsius)	(data)	Discharge (gallons per minute)	(date)
4,581	3.5	5-26-88	--	725	5-26-88	--	--
NA	6.6	9-28-88	14	470	9-28-88	--	--
NA	8.3	12-17-88	10	520	12-17-88	--	--
NA	10.4	4-10-89	6	541	4-10-89	--	--
4,531	--	--	--	2,220	5-25-88	--	--
4,527	6.5	5-23-88	--	--	--	--	--
4,395	--	--	--	--	--	--	--
4,432	41.7	5-25-88	--	3,180	5-25-88	--	--
NA	11.7	12-21-88	--	2,950	9-28-88	--	--
NA	29.4	4-11-89	--	2,900	12-21-88	--	--
NA	--	--	12	2,850	4-11-89	--	--
4,424	12.4	6-27-88	13	770	6-27-88	--	--
NA	13.2	9-28-88	13	650	9-28-88	--	--
NA	14.5	12-17-88	--	--	--	--	--
NA	18.6	4-11-89	--	--	--	--	--
4,445	11.1	8-26-86	--	790	8-23-86	127	--
4,445	10.5	8-20-86	--	730	8-27-86	123	--
4,437	14.2	6-24-88	--	1,920	6-24-88	--	--
4,451	--	--	14	870	9-23-87	--	--
NA	--	--	10	922	6-25-88	--	--
4,432	--	--	--	764	8-26-88	100	--
NA	--	--	--	--	--	100	8-10-88
4,416	5.2	6-25-88	--	--	--	--	--
4,418	2.0	8-03-56	--	--	--	--	--
--	7.0	9-10-70	10	--	9-10-70	1,500	--
4,420	--	--	--	--	--	--	--
4,420	--	--	16	810	6-15-88	600	4-29-61
4,396	6.0	6-30-62	--	--	--	600	- -62
4,397	--	--	10	2,100	9-12-70	--	--
4,363	5.5	8-01-56	14	--	8-09-57	--	--
4,355	7.3	6-26-88	13	1,530	6-26-88	--	--
NA	7.5	9-28-88	14	1,300	9-28-88	--	--
NA	9.0	12-17-88	10	1,520	12-17-88	--	--
NA	8.3	4-11-89	8	1,430	4-11-89	--	--
4,586	9.7	8-06-56	--	2,100	5-26-88	--	--
4,588	3.1	2-08-56	--	672	5-25-88	--	--
4,471	4.0	8-02-56	10	--	8- -52	--	--
4,472	--	--	--	--	--	--	--
4,530	19.0	8-01-56	13	--	8-09-57	--	--

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
52-97-26dba01	W	--	16	--	36.0	Qt	H
53-88-19d 01	S	NA	Spring	NA	NA	€gv	-
53-88-19dcd01	W	1985	60	38-58	6.0	Qg	P
53-89-14cac01	W	1983	65	45-55	6.0	p€r	P
53-89-14dbb01	W	1983	60	50-60	6.0	p€r	P
53-90-19ccd01	W	1958	6	--	60.0	Qa	T
53-91-02cac01	S	NA	Spring	NA	NA	Js	H
53-91-14bcb01	S	NA	Spring	NA	NA	Js	H
53-91-21bbb01	W	--	50	--	6.0	Kcv	S
53-91-21cdd01	W	1979	200	60-180	6.0*	Kcv	H
53-91-22ddb01	S	NA	Spring	NA	NA	Jm	H
53-91-23bbc01	W	--	60	50-60	8.0	Js	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
53-91-24ddd01	W	1980	8	--	--	Qa	H
53-91-25bcb01	W	1978	50	20-40	4.0	Qa	H
		NA	NA	42-50	NA	NA	NA
53-91-25bcc01	W	--	8	--	--	Qa	S
53-91-26aaa01	W	1965	1,300**R**	1,230-1,300	2.5	IPt	S
53-91-26bda01	C	1974	10	7-10	30	Qa	H
53-91-26dad01	S	NA	Spring	NA	NA	Js	H
53-91-27bca01	W	1961	30	25-30	--	Kcv	S
53-91-29adc01	W	1986	41	32-40	5.0	Qa	H
53-91-29cbc01	W	--	20	--	--	Qa	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
53-91-29daa01	W	1984	34	35-45	5.0	Qa	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
53-91-35aaa01	W	1984	3,500**R**	1,850-2,420	10.7*	MD-Ob	P
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
53-91-35aaa02	W	1985	3,380**R**	1,810-3,380	9.62*	MD-Ob	P
53-91-36cad01	S	NA	Spring	NA	NA	Qa	U

and collection galleries, in Big Horn County, Wyoming--Continued

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface (feet)	Water level (date)	Water temperature (degrees Celsius)	Specific conductance (microsiemens per centimeter at 25 degrees Celsius)	(data)	Discharge (gallons per minute)	Discharge (date)
4,520	5.7	8-01-56	--	--	--	--	--
--	NA	NA	--	--	--	--	--
7,665	--	--	7	72	10-31-88	5	12-04-85
7,580	--	--	7	495	10-31-88	20	8-22-83
7,615	--	--	9	435	10-31-88	20	8-18-83
4,290	3.5	8-30-88	--	--	--	70	--
4,860	NA	NA	17	415	8-30-88	--	--
4,500	NA	NA	19	870	8-30-88	--	--
4,228	8.6	6-28-88	14	3,250	6-28-88	--	--
4,200	60	11-15-79	--	2,850	8-03-82	--	--
4,320	NA	NA	19	1,550	8-30-88	--	--
4,410	36.6	8-30-88	17	1,020	8-30-88	--	--
NA	38.1	9-29-88	12	1,020	9-29-88	--	--
NA	37.9	12-20-88	9	825	12-20-88	--	--
NA	37.8	4-13-89	10	1,010	4-13-89	--	--
4,275	4.2	8-27-88	21	640	8-27-88	25	6-28-80
4,250	20	6-25-78	--	1,600	8-28-88	--	--
NA	NA	NA	NA	NA	NA	NA	NA
4,238	3.3	8-27-88	18	950	8-27-88	--	--
4,310	+92.4	10-05-88	17	2,260	8-30-88	10	10-05-88
4,215	2.9	8-27-88	22	2,050	8-27-88	--	--
4,250	NA	NA	18	720	8-28-88	--	--
--	21.0	1-01-61	10	--	7- -70	--	--
4,130	18.1	9-16-87	12	1,420	9-16-87	--	--
4,086	6.9	6-28-88	13	1,600	9-22-87	--	--
NA	7.3	9-30-88	10	1,620	6-28-88	--	--
NA	7.6	12-20-88	15	1,490	9-30-88	--	--
NA	8.1	4-13-89	9	1,510	12-20-88	--	--
NA	--	--	7	1,440	4-13-89	--	--
4,125	17.1	6-28-88	13	1,530	6-28-88	25	4-24-84
NA	18.5	9-29-88	12	1,300	9-29-88	--	--
NA	19.8	12-20-88	9	1,400	12-20-88	--	--
NA	20.1	4-13-89	8	1,490	4-13-89	--	--
4,398	+293	10-13-88	18	460	8-29-88	224	4-16-84
NA	--	--	--	--	--	367	12-10-84
NA	--	--	--	--	--	340	10-13-88
4,360	+371	9-09-85	19	450	8-29-88	--	--
4,308	NA	NA	20	950	8-28-88	--	--

Table 15. Records of selected wells, springs, drains,

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
53-92-29ddb01	S	NA	Spring	NA	NA	Kt	-
53-92-32abb01	W	1940	100	--	8.0	Kt	S
53-92-32adc01	W	1955	100	--	8.0	Kt	H
53-92-34dbb01	D	--	--	--	--	Qa	U
53-92-36ada01	W	1983	3,250**R**	2,440-3,250	24.0	MD-Ob	U
54-88-30dba01	S	NA	Spring	NA	NA	€f	U
54-88-31cba01	S	NA	Spring	NA	NA	Ob	P
54-91-05cba01	W	1983	250**R**	210-250	4.0	Kcv	H
54-93-01bdd01	W	--	--	--	--	Kmr	U
54-94-02dad01	W	1964	70	55-70	8.0	Jgs	H
54-96-10bac01	W	1982	86	60-80	4.0	Tfu	U
55-91-33bcb01	S	NA	Spring	NA	NA	Js	I
55-92-33cda01	W	1969	4,850**R**	4,460-4,500	5.0*	€f	I
		NA	NA	4,800-4,850	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
55-93-23cca01	S	NA	Spring	NA	NA	Kt	U
55-93-28dad01	S	NA	Spring	NA	NA	Qt	U
55-94-21dad01	W	1980	91	17-91	6.0		S
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
55-95-03dac01	W	1968	560**R**	535-555	6.62	IPt	S
55-95-13dad01	W	1970	600**R**	320-400 515-600	6.62	TPMa	S
55-96-04bcd01	W	--	28	24-28	3.0	Kmv	H
55-96-20abc01	W	1942	66	61-66	5.0	Tfu	U
55-96-21dcd01	W	1941	235**R**	--	8.0	Tfu	U
55-97-04da 01	W	--	18	12-18	6.0	Qa	H
55-97-04dc 01	W	1963	79	--	--	Kmv	H
55-97-04dd 01	W	1982	180	160-180	6.0	Kc	H
55-97-07cba01	W	--	20	12-20	6.0	Qa	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
55-97-07cbc01	W	1949	48	--	6.0	Qa	H
55-97-07cbc02	W	1973	55	30-55	6.0	Kl	H

and collection galleries, in Big Horn County, Wyoming--Continued

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface		Water temperature and specific conductance			Discharge	
	(feet)	(date)	(degrees Celsius)	(microsiemens per centimeter at 25 degrees Celsius)	(data)	(gallons per minute)	(date)
3,975	NA	NA	--	--	--	--	--
3,930	--	--	--	3,250	6-27-88	--	--
3,925	--	--	--	1,880	6-27-88	--	--
3,972	--	--	15	1,720	6-28-88	--	--
4,183	--	--	18	2,550	8-30-88	--	--
8,915	NA	NA	4	237	11-02-88	--	--
8,600	NA	NA	5	253	11-02-88	--	--
5,480	23.2	8-29-88	17	1,300	8-29-88	--	--
4,800	--	--	--	--	--	--	--
3,725	20.8	7-15-88	18	4,250	7-15-88	20	3-31-64
4,320	71.2	11-03-88	--	--	--	5	7-10-82
5,900	NA	NA	22	750	8-29-88	--	--
5,180	1,390	1-16-70	20	--	7- -70	350	--
NA	--	--	32	690	8-29-88	350	1-16-70
NA	--	--	--	--	--	115	9-14-87
NA	--	--	--	--	--	105	10-05-88
4,360	NA	NA	--	2,100	7-29-88	--	--
4,160	NA	NA	--	960	7-29-88	--	--
3,748	20.9	7-15-88	19	3,650	7-15-88	--	--
NA	20.8	9-30-88	16	4,200	7-28-88	--	--
NA	24.5	12-18-88	15	3,600	9-30-88	--	--
NA	24.0	4-13-89	9	3,600	12-18-88	--	--
NA	--	--	9	3,700	4-13-89	--	--
4,390	252	9-01-70	18	--	9- -68	10	--
4,070	295	11-02-88	17	3,650	11-02-88	--	--
4,090	17.1	7-11-88	20	2,800	7-11-88	--	--
4,138	33.3	11-03-88	--	--	--	30	5-06-42
4,205	96.9	11-03-88	--	--	--	--	--
4,020	14.8	6-16-88	21	1,500	6-16-88	--	--
4,082	47.9	6-16-88	24	1,220	6-16-88	--	--
4,060	38.7	6-16-88	31	3,600	6-16-88	--	--
4,095	10.9	6-20-88	16	1,210	6-20-88	--	--
NA	11.1	9-30-88	11	1,600	9-30-88	--	--
NA	11.0	12-14-88	11	1,540	12-14-88	--	--
NA	11.5	4-13-89	10	1,690	4-13-89	--	--
4,098	10.0	7-14-70	35	--	7-14-70	--	--
4,098	--	--	21	1,450	6-17-88	25	12-02-73

Table 15. Records of selected wells, springs, drains,

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
55-97-09ba 01	W	1980	110	90-110	6.0	Kmv	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
55-97-25baa01	W	1941	111	--	8.0	Tfu	U
		NA	NA	NA	NA	NA	--
		NA	NA	NA	NA	NA	NA
55-97-31cdd01	W	1942	90	--	6.0	Tfu	I
56-91-18bdd01	W	1987	60	50-60	6.0	p€r	P
56-91-30bbd01	W	1987	80	70-80	6.0	p€r	P
56-91-30bdb01	S	NA	Spring	NA	NA	p€r	U
56-92-17add01	S	NA	Spring	NA	NA	Ob	S
		NA	NA	NA	NA	NA	NA
56-92-20cad01	S	NA	Spring	NA	NA	€gv	P
56-92-31bbb01	S	NA	Spring	NA	NA	IPt	--
56-93-19dcb01	S	NA	Spring	NA	NA	Qa	U
56-93-34aba01	S	NA	Spring	NA	NA	Kt	S
56-94-06c 01	W	1981	1,230**R**	1,170-1,220	--	Kcv	N
56-95-01c 01	W	1948	25	21-25	4.0	Qt	I
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
56-95-02cc 01	S	NA	Spring	NA	NA	Qt	H
56-95-08dc 01	W	--	14	10-14	3.0	Qt	S
56-95-09dcb01	W	--	19	15-19	3.0	Qt	I
56-95-12b 01	W	--	13	9-13	4.0	Qt	I
56-96-08dc 01	W	1973	52	30-52	7.0	Kc	U
56-96-11adc01	W	--	18	14-18	3.0	Qa	I
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
56-96-12aa 01	W	--	965**R**	--	4.0	Kcv	--
56-96-12dc 01	W	1940	35	30-35	3.0	Qa	H
56-96-14ad 01	W	1975	20	9-18	3.0	Qt	S
56-96-14bb 01	W	1978	35	17-19	4.0	Kc	I
56-96-14da 01	W	1964	32	--	6.0	Qt	H
56-96-15bd 01	W	--	19	16-19	3.0	Qa	I

and collection galleries, in Big Horn County, Wyoming--Continued

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface (feet)	(date)	Water temperature and specific conductance (degrees Celsius)	(microsiemens per centimeter at 25 degrees Celsius)	(data)	Discharge (gallons per minute)	(date)
4,085	52.4	6-16-88	21	3,150	6-16-88	--	--
NA	52.4	7-26-88	--	3,400	7-26-88	--	--
NA	52.3	9-29-88	15	3,000	9-29-88	--	--
NA	62.2	12-15-88	10	4,070	12-15-88	--	--
NA	67.1	4-13-89	14	3,450	4-13-89	--	--
4,175	49.3	11-03-88	--	--	--	--	--
--	49.6	12-17-88	--	--	--	--	--
NA	49.8	4-13-89	--	--	--	--	--
4,215	--	--	--	1,470	11-05-88	--	--
8,780	26	8-17-87	6	212	7-28-88	6	8-17-87
9,080	16	8-18-87	7	255	7-28-88	1	8-18-87
9,120	NA	NA	10	225	7-28-88	--	--
9,010	NA	NA	10	--	7-28-88	1	--
NA	--	--	--	355	7-29-88	--	--
7,940	NA	NA	12	890	7-29-88	3	7-29-88
--	NA	NA	10	--	8- -70	--	--
4,150	NA	NA	12	2,050	7-29-88	--	--
4,842	NA	NA	16	520	7-29-88	3	--
3,825	--	--	--	5,800	7-28-88	20	8-24-81
3,741	7.5	7-14-88	16	1,200	7-14-88	--	--
NA	8.7	9-30-88	17	1,100	9-30-88	--	--
NA	11.7	12-14-88	9	1,130	12-14-88	--	--
NA	12.2	4-13-89	10	1,220	4-13-89	--	--
3,746	NA	NA	20	1,650	7-14-88	--	--
3,815	5.5	7-14-88	24	2,500	7-14-88	--	--
3,813	7.2	7-14-88	21	2,450	7-14-88	--	--
3,750	7.9	7-14-88	14	2,700	7-14-88	--	--
3,905	7.1	7-09-88	--	--	--	20	- -73
3,797	8.8	7-13-88	15	2,050	7-13-88	--	--
NA	8.7	9-30-88	17	1,660	9-30-88	--	--
NA	9.0	12-14-88	--	--	--	--	--
NA	9.1	4-13-89	--	--	--	--	--
3,790	2.6	7-14-88	18	2,000	7-14-88	--	--
3,810	7.9	7-14-88	16	2,100	7-14-88	--	--
3,872	7.2	7-13-88	20	1,010	7-13-88	--	--
3,830	13.1	7-08-88	16	3,200	7-08-88	--	--
3,875	5.0	6-08-67	--	--	--	--	--
3,845	11.3	7-11-88	17	2,600	7-11-88	--	--

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
56-96-15dd 01	W	--	25	15-25	6.0	Kc	H
56-96-16bb 01	W	--	16	14-16	3.0	Qa	I
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
56-96-16cd 01	W	--	18	15-18	3.0	Qa	I
56-96-16dd 01	S	NA	Spring	NA	NA	Qt	H
56-96-17ad 01	W	--	42	--	4.0	Kc	H
56-96-18cd 01	W	1972	38	30-38	6.0	Qt	H
56-96-19bd 01	W	1982	72	--	7.0	Kmv	H
56-96-20ad 01	W	1975	135	20-135	6.0	Qt	H
56-96-20ca 01	S	NA	Spring	NA	NA	Qt	H
56-96-20dd 01	W	1981	75	30-75	8.0	Kmv	H
56-96-21cc 01	W	--	18	--	6.0	Qt	H
56-96-22dd 01	W	1950	17	--	--	Qt	H
56-96-23aa 01	W	1961	20	16-20	3.0	Qt	S
56-96-23dc 01	W	1976	40	5-40	6.0	Kc	S
56-96-24bda01	W	--	22	18-22	3.0	Qt	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
56-96-26db 01	W	--	50	--	6.0	Kc	H
56-96-28dd 01	W	--	35	--	6.0	Kmv	H
56-96-29acd01	W	--	30	15-30	3.5	Qt	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
56-96-29bcd01	W	1980	18	10-18	3.0	Qt	H
56-96-30adc01	W	1940	40	--	7.0	Qt	H
56-96-32aab01	W	1984	91	45-80	6.0	Kmv	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
56-96-32bac01	W	1936	25	--	8.0	Qt	H
56-96-33bac01	W	--	24	20-24	6.0	Qt	C
56-96-33bca01	W	1988	60	0-60	5.5	Kmv	I

and collection galleries, in Big Horn County, Wyoming--Continued

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface (feet)	(date)	Water temperature and specific conductance (degrees Celsius)	(microsiemens per centimeter at 25 degrees Celsius)	(data)	Discharge (gallons per minute)	(date)
3,901	6.7	6-19-88	14	3,400	6-19-88	--	--
3,856	9.8	7-09-88	13	1,720	7-09-88	--	--
NA	10.4	9-30-88	13	1,780	9-30-88	--	--
NA	10.1	12-14-88	9	1,850	4-13-89	--	--
NA	9.0	4-13-89	--	--	--	--	--
3,885	7.2	7-09-88	16	1,450	7-09-88	--	--
3,904	NA	NA	15	1,420	6-19-88	--	--
3,863	7.0	6-20-88	12	3,350	6-20-88	--	--
3,970	12.3	6-20-88	25	1,700	6-20-88	--	--
3,923	17.1	6-20-88	13	1,600	6-20-88	--	--
3,940	14.5	7-09-88	17	840	7-09-88	--	--
3,895	NA	NA	14	1,100	7-09-88	--	--
3,953	10.0	7-11-88	13	4,000	7-11-88	--	--
3,960	6.6	7-09-88	20	2,150	7-09-88	--	--
3,912	6.1	7-11-88	17	980	7-11-88	--	--
3,881	5.6	7-13-88	16	3,450	7-13-88	--	--
3,903	5.5	6-19-88	13	3,600	6-19-88	--	--
3,878	5.6	7-13-88	22	1,320	7-26-88	--	--
NA	10.4	9-30-88	20	1,500	9-30-88	--	--
NA	12.2	12-14-88	8	1,990	12-14-88	--	--
NA	12.6	4-13-89	--	--	--	--	--
3,910	17.1	7-11-88	12	6,500	7-11-88	--	--
4,050	6.8	6-18-88	15	1,250	6-18-88	--	--
3,960	4.9	6-18-88	16	1,350	6-18-88	--	--
NA	5.4	9-30-88	25	1,100	7-26-88	--	--
NA	10.3	12-14-88	14	1,080	9-30-88	--	--
NA	8.0	4-13-89	12	1,050	12-14-88	--	--
NA	--	--	14	1,170	4-13-89	--	--
3,972	3.3	7-09-88	14	1,300	7-09-88	--	--
3,980	10.2	7-11-88	14	1,430	7-11-88	--	--
3,982	11.0	7-11-88	17	4,000	7-11-88	--	--
NA	11.0	7-27-88	13	3,950	9-30-88	--	--
NA	7.9	9-30-88	8	4,000	12-14-88	--	--
NA	9.9	12-14-88	11	4,620	4-13-89	--	--
NA	11.0	4-13-89	--	--	--	--	--
4,015	8.4	6-18-88	14	1,100	6-18-88	--	--
4,000	5.0	6-19-88	19	1,650	6-19-88	--	--
4,000	2.4	6-18-88	14	--	6-18-88	--	--

Table 15. Records of selected wells, springs, drains,

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
56-97-05bbb01	W	--	92	78-92	8.0	Kc	H
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
		NA	NA	NA	NA	NA	NA
56-97-22dbd01	W	1982	815**R**	204-276	8.0	Kmv	N
		NA	NA	338-358	NA	NA	NA
		NA	NA	590-610	NA	NA	NA
		NA	NA	674-694	NA	NA	NA
		NA	NA	746-800	NA	NA	NA
56-97-24bd 01	W	--	35	--	5.0	Kmv	H
56-97-26bb 01	W	1930	40	--	5.5	Qt	H
56-97-26bc 01	D	1918	13	--	--	Qt	P
57-94-08bcb01	W	1966	370**R**	330-370	1.25	MD-Ob	U
57-95-10cbb01	W	1968	250**R**	197-240	6.0	Kf	U
57-95-34add01	W	1961	31	27-31	3.0	Kc	H
57-95-34cbb01	W	1979	78	--	--	Kf	U
57-96-31dc 01	W	--	43	10-43	12.0	Kc	S
57-97-04abb01	W	--	13	1-13	24.0	Qt	S

and collection galleries, in Big Horn County, Wyoming--Continued

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface (feet)	(date)	Water temperature and specific conductance (degrees Celsius)	(microsiemens per centimeter at 25 degrees Celsius)	(data)	Discharge (gallons per minute)	(date)
4,090	9.2	6-14-88	19	6,800	6-14-88	--	--
NA	9.9	9-30-88	17	6,100	7-26-88	--	--
NA	11.9	12-15-88	12	6,600	9-30-88	--	--
NA	11.7	4-13-89	8	6,900	12-15-88	--	--
NA	--	--	9	6,800	4-13-89	--	--
4,173	176	10-13-82	--	--	--	35	10-13-82
NA	--	--	--	--	--	13	10-13-82
NA	NA	NA	NA	NA	NA	NA	NA
NA	NA	NA	NA	NA	NA	NA	NA
NA	NA	NA	NA	NA	NA	NA	NA
3,990	10.6	6-17-88	15	3,000	6-17-88	--	--
4,030	10.2	7-09-88	13	1,500	7-09-88	--	--
4,434	10.0	1-01-88	14	1,580	9-23-87	--	--
	8.5	9-30-88	17	1,600	7-27-88	--	--
3,659	77.6	2-16-66	--	--	--	--	--
NA	77.6	2-18-66	--	--	--	--	--
NA	77.7	3-08-66	--	--	--	--	--
NA	77.6	3-18-66	--	--	--	--	--
NA	78.0	3-28-66	--	--	--	--	--
NA	67.0	2-16-67	--	--	--	--	--
NA	66.4	3-01-67	--	--	--	--	--
NA	64.9	3-22-67	--	--	--	--	--
NA	57.6	4-28-67	--	--	--	--	--
NA	58.2	5-26-67	--	--	--	--	--
NA	34.4	11-21-67	--	--	--	--	--
3,910	120	1-01-68	--	--	--	16	8-13-68
NA	8.1	9-05-80	--	--	--	--	--
NA	8.8	11-01-88	--	--	--	--	--
3,740	19.6	6-19-88	17	5,400	6-19-88	--	--
NA	22.1	9-30-88	16	3,800	9-30-88	--	--
NA	23.7	12-14-88	16	4,000	12-14-88	--	--
NA	23.6	4-13-89	12	4,030	4-13-89	--	--
3,777	44.5	7-14-88	--	--	--	5	12-11-79
NA	44.1	9-30-88	--	--	--	--	--
NA	44.5	12-14-88	--	--	--	--	--
NA	44.8	4-13-89	--	--	--	--	--
3,960	17.8	6-15-88	21	1,700	6-15-88	--	--
4,263	4.6	6-13-88	15	2,400	6-13-88	--	--
NA	7.2	9-30-88	22	2,500	7-27-88	--	--
NA	9.4	12-15-88	16	2,620	9-30-88	--	--
NA	11.9	4-13-89	7	2,340	4-13-89	--	--

Table 15. Records of selected wells, springs, drains,

Local number	Type of site	Year drilled	Depth of well (feet)	Open interval (feet)	Diameter of casing above first open interval (inches)	Primary aquifer	Primary use of water
57-97-05aaa01	W	1979	63	50-55	6.0	Kc	U
57-97-26dad01	C	--	12	0-12	24.0	Qa	I
57-97-32cad01	W	1971	30	20-30	5.5	Kc	I
57-97-33cca01	W	1971	77	47-77	6.0	Kc	H
57-97-36ddd01	W	1981	125	115-125	6.0	Kmv	U
58-94-31bdc01	W	1966	281	239-281	1.25	MD-Ob	U
58-95-19bab01	W	--	20	--	--	Qa	H
58-95-19bac01	S	NA	Spring	NA	NA	Qa	S
58-95-20bca01	W	1986	70	50-70	6.0	TRc	S
58-95-20bcb01	S	NA	Spring	NA	NA	TRc	S
58-95-26cdd01	S	NA	Spring	NA	NA	Jgs	--
58-95-29dca01	W	--	28	24-28	3.0	Qa	H
		NA	NA	NA	NA	NA	NA
58-95-33dad01	W	--	38	--	7.0	Qa	H
58-95-36bad01	W	1966	364**R**	212-364	1.25	MD-Ob	U
58-95-36bdd01	W	1966	526**R**	428-526	1.25	MD-Ob	U
58-95-36dcb01	W	1966	462**R**	330-462	1.25	MD-Ob	U
58-96-22bcb01	W	1973	1,850**R**	1,420-1,850	7.0*	MD-Ob	I
58-96-34cda01	W	1983	2,300**R**	1,970-2,300	7.0*	MD-Ob	P
58-97-29cca01	C	1978	23	--	24.0	Qa	H
58-97-30bbb01	W	--	16	--	6.0	Qa	H
58-97-31bac01	W	1955	4,500**R**	--	12.0*	MD-Ob	P
		NA	NA	NA	NA	NA	NA
58-97-31daa01	W	1974	55	--	6.0	Kc	H
58-97-31dab01	W	--	12	--	6.0	Qa	I

and collection galleries, in Big Horn County, Wyoming--Continued

Land surface altitude above sea level (feet)	Water level below or hydraulic head above (+) land surface (feet)	(date)	Water temperature and specific conductance (degrees Celsius)	(microsiemens per centimeter at 25 degrees Celsius)	(data)	Discharge (gallons per minute)	(date)
4,230	19.8	6-13-88	--	--	--	12	5-29-79
NA	19.0	9-30-88	--	--	--	--	--
NA	18.9	12-15-88	--	--	--	--	--
NA	20.1	4-13-89	--	--	--	--	--
4,028	3.5	6-15-88	20	2,700	6-15-88	--	--
NA	4.1	9-30-88	--	--	--	--	--
NA	5.3	12-15-88	--	--	--	--	--
NA	5.4	4-13-89	--	--	--	--	--
4,166	9.1	6-14-88	21	2,150	6-14-88	25	10-30-71
4,120	12.4	6-14-88	--	--	--	--	--
4,020	38.3	6-15-88	--	--	--	25	4-29-81
3,717	170	4-18-66	--	--	--	--	--
4,128	1.2	7-08-88	16	560	7-08-88	--	--
4,125	NA	NA	11	510	7-08-88	--	--
4,140	--	--	19	2,450	7-26-88	--	--
4,137	NA	NA	14	2,920	7-07-88	--	--
3,885	NA	NA	10	--	7- -70	50	--
3,920	16.5	7-07-88	14	2,000	7-07-88	--	--
NA	--	--	16	1,480	7-26-88	--	--
3,827	5.0	7-07-88	17	1,920	7-07-88	--	--
3,647	80.1	9-01-66	--	--	--	--	--
3,799	237	9-12-66	--	--	--	--	--
3,656	79.8	10-03-66	--	--	--	--	--
4,558	--	--	16	550	7-08-88	--	--
4,222	+378	10-04-88	18	406	9-02-88	850	8-31-88
4,230	8.7	6-13-88	12	1,550	6-13-88	--	--
4,240	6.9	6-13-88	14	3,800	6-13-88	--	--
4,200	--	--	32	1,500	6-13-88	1,650	--
NA	--	--	--	--	--	1,660	4-11-55
4,190	5.0	6-13-88	18	6,500	6-13-88	--	--
4,180	3.4	6-13-88	14	1,870	6-13-88	--	--
NA	3.2	9-30-88	19	2,900	7-27-88	--	--
NA	6.8	12-15-88	18	1,310	9-30-88	--	--
NA	6.6	4-13-89	4	1,730	4-13-89	--	--

Table 16. Statistical summary of chemical analyses by aquifer based on water samples collected from wells and springs, 1925-88 in Big Horn County, Wyoming

[Analytical results in milligrams per liter except as indicated; S/cm, microsiemens per centimeter at 25 degrees Celsius; g/L, micrograms per liter; --, statistic not computed]

Constituent or property	Descriptive statistics: Number of analyses	Maximum	Minimum	Mean	Percentage of analyses in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Alluvium and Colluvium									
Specific conductance (S/cm)	21	2,800	104	1,220	2,690	1,600	1,410	718	130
pH	21	9.1	7.3	7.7	9.0	7.8	7.6	7.5	7.3
Hardness as $CaCO_3$	36	1,300	12	480	1,000	730	440	260	43
Calcium, dissolved	37	320	3.2	130	260	200	120	72	13
Magnesium, dissolved	36	110	0.9	39	100	52	33	20	2.9
Sodium, dissolved	36	530	2.3	160	520	290	110	29	2.4
Sodium-adsorption ratio	36	37	0.1	4.4	17	5.8	2.0	0.6	0.1
Potassium, dissolved	38	62	0.7	4.4	8.1	3.5	2.8	2.2	0.8
Bicarbonate as HCO_3	24	710	220	410	700	520	400	270	220
Carbonate as CO_3	24	6	0	0	4	0	0	0	0
Alkalinity, total as $CaCO_3$	14	480	46	300	480	380	320	230	46
Sulfate, dissolved	38	1,400	3.7	480	1,000	800	510	120	8.0
Chloride, dissolved	38	36	0	11	31	18	5.8	1.8	0.1
Fluoride, dissolved	38	1.4	0.1	0.6	1.3	0.8	0.6	0.4	0.2
Dissolved solids, sum of constituents	36	2,380	68	1,050	2,000	1,440	1,150	495	175
Nitrite plus nitrate, dissolved as nitrogen	14	9.8	0.12	3.9	9.8	7.3	1.9	0.76	0.12
Phosphorous, total	27	0.63	0.01	0.07	0.60	0.03	0.02	0.01	0.01
Boron, dissolved (g/L)	13	630	30	210	630	260	180	90	30
Manganese, dissolved (g/L)	1	5	5	--	--	--	--	--	--
Selenium, dissolved (g/L)	9	26	1	7	--	--	4	--	--

Table 16. Statistical summary of chemical analyses by aquifer based on water samples collected from wells and springs, 1925-88 in Big Horn County, Wyoming--Continued

Constituent or property	Descriptive statistics: Number of analyses	Maximum	Minimum	Mean	Percentage of analyses in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Gravel, pediment, and fan deposits									
Specific conductance (S/cm)	18	2,640	833	1,550	2,640	1,980	1,460	1,010	833
pH	18	9.0	7.3	7.7	9.0	7.8	7.6	7.5	7.3
Hardness as $CaCO_3$	38	1,400	130	500	1,300	550	440	310	160
Calcium, dissolved	38	410	0.8	120	380	140	100	79	33
Magnesium, dissolved	38	230	11	45	140	54	36	25	13
Sodium, dissolved	38	550	35	170	360	240	140	100	54
Sodium-adsorption ratio	38	12	0.9	3.6	8.2	4.2	3.0	2.0	1.0
Potassium, dissolved	37	10	1.5	3.6	6.8	4.8	3.2	2.5	1.6
Bicarbonate as HCO_3	22	610	160	380	600	430	380	320	170
Carbonate as CO_3	22	0	0	0	0	0	0	0	0
Alkalinity, total as $CaCO_3$	16	500	200	330	500	360	320	290	200
Sulfate, dissolved	38	1,400	80	520	1,300	700	420	230	130
Chloride, dissolved	38	31	0	12	30	18	10	5.4	1.9
Fluoride, dissolved	37	4.2	0.2	1.3	3.2	2.0	0.9	0.6	0.4
Dissolved solids, sum of constituents	38	2,380	260	1,100	2,190	1,380	992	666	494
Nitrite plus nitrate, dissolved as nitrogen	16	9.8	0.72	4.4	9.8	6.2	4.4	2.0	0.72
Phosphorous, total	17	0.27	0.01	0.04	0.27	0.03	0.02	0.02	0.01
Boron, dissolved (g/L)	30	560	10	200	450	240	180	130	30
Manganese, dissolved (g/L)	1	83	83	--	--	--	--	--	--
Selenium, dissolved (g/L)	12	27	2	7	27	8	6	3	2

Table 16. Statistical summary of chemical analyses by aquifer based on water samples collected from wells and springs, 1925-88 in Big Horn County, Wyoming--Continued

Constituent or property	Number of analyses	Descriptive statistics: Maximum	Minimum	Mean	Percentage of analyses in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Willwood Formation									
Specific conductance (S/cm)	12	3,990	873	2,160	3,990	3,270	1,990	1,180	873
pH	12	8.6	7.6	8.0	8.6	8.3	8.0	7.8	7.6
Hardness as $CaCO_3$	21	1,100	10	240	1,100	380	130	46	10
Calcium, dissolved	21	290	3.2	64	280	95	33	13	3.3
Magnesium, dissolved	21	95	0	19	91	24	10	3.2	0.1
Sodium, dissolved	21	950	89	430	930	640	450	240	91
Sodium-adsorption ratio	21	36	2.0	19	36	30	20	8.5	2.0
Potassium, dissolved	21	7.1	1.1	3.5	7.1	4.1	3.3	2.3	1.1
Bicarbonate as HCO_3	13	490	230	350	490	470	320	260	230
Carbonate as CO_3	13	20	0	3	20	4	0	0	0
Alkalinity, total as $CaCO_3$	8	410	120	300	--	--	370	--	--
Sulfate, dissolved	21	1,800	22	720	1,800	1,200	690	200	25
Chloride, dissolved	21	320	3.2	93	320	140	60	16	3.7
Fluoride, dissolved	21	4.3	0.2	1.7	4.2	2.4	1.4	1.0	0.2
Dissolved solids, sum of constituents	21	3,320	573	1,540	3,300	2,040	1,590	758	578
Nitrite plus nitrate, dissolved as nitrogen	8	30	0.10	5.3	--	--	0.45	--	--
Phosphorous, total	11	0.03	0.01	0.01	0.03	0.02	0.01	0.01	0.01
Boron, dissolved (g/L)	13	440	80	190	440	210	180	140	80
Manganese, dissolved (g/L)	1	1	1	--	--	--	--	--	--
Selenium, dissolved (g/L)	7	350	1	96	--	--	7	--	--

Table 16. Statistical summary of chemical analyses by aquifer based on water samples collected from wells and springs, 1925-88 in Big Horn County, Wyoming--Continued

Constituent or property	Number of analyses	Descriptive statistics: Maximum	Minimum	Mean	Percentage of analyses in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Fort Union Formation									
Specific conductance (S/cm)	7	4,720	1,100	2,850	--	--	3,070	--	--
pH	7	8.2	7.5	7.8	--	--	7.7	--	--
Hardness as $CaCO_3$	8	1,200	12	500	--	--	390	--	--
Calcium, dissolved	8	310	2.9	130	--	--	110	--	--
Magnesium, dissolved	8	99	1.1	42	--	--	30	--	--
Sodium, dissolved	8	1,000	110	490	--	--	340	--	--
Sodium-adsorption ratio	8	48	2.0	20	--	--	13	--	--
Potassium, dissolved	8	10	1.9	5.6	--	--	5.4	--	--
Bicarbonate as HCO_3	3	960	400	670	--	--	640	--	--
Carbonate as CO_3	3	3	0	1	--	--	0	--	--
Alkalinity, total as $CaCO_3$	5	420	280	340	--	--	300	--	--
Sulfate, dissolved	8	2,300	4.2	960	--	--	960	--	--
Chloride, dissolved	8	410	6.7	120	--	--	100	--	--
Fluoride, dissolved	8	3.6	0.4	1.6	--	--	1.2	--	--
Dissolved solids, sum of constituents	8	3,790	623	2,010	--	--	1,790	--	--
Nitrite plus nitrate, dissolved as nitrogen	5	5.7	0.10	3.1	--	--	2.3	--	--
Phosphorous, total	5	0.01	0.01	0.01	--	--	0.01	--	--
Boron, dissolved (g/L)	6	390	130	220	--	--	210	--	--
Manganese, dissolved (g/L)	1	2	2	--	--	--	--	--	--
Selenium, dissolved (g/L)	5	36	1	18	--	--	21	--	--

Table 16. Statistical summary of chemical analyses by aquifer based on water samples collected from wells and springs, 1925-88 in Big Horn County, Wyoming--Continued

Constituent or property	Descriptive statistics: Number of analyses	Maximum	Minimum	Mean	Percentage of analyses in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Lance Formation									
Specific conductance (S/cm)	3	2,450	1,410	1,920	--	--	1,900	--	--
pH	3	8.3	7.0	7.6	--	--	7.6	--	--
Hardness as $CaCO_3$	4	630	10	310	--	--	300	--	--
Calcium, dissolved	4	170	2.9	77	--	--	68	--	--
Magnesium, dissolved	4	51	0.6	29	--	--	32	--	--
Sodium, dissolved	4	420	140	310	--	--	340	--	--
Sodium-adsorption ratio	4	51	3.0	19	--	--	10	--	--
Potassium, dissolved	4	9.7	1.3	4.2	--	--	2.8	--	--
Bicarbonate as HCO_3	1	510	510	--	--	--	--	--	--
Carbonate as CO_3	1	4	4	--	--	--	--	--	--
Alkalinity, total as $CaCO_3$	3	410	280	320	--	--	290	--	--
Sulfate, dissolved	4	1,100	220	560	--	--	450	--	--
Chloride, dissolved	4	86	19	52	--	--	52	--	--
Fluoride, dissolved	4	4.0	0.3	1.9	--	--	1.7	--	--
Dissolved solids, sum of constituents	4	1,860	931	1,250	--	--	1,110	--	--
Nitrite plus nitrate, dissolved as nitrogen	3	0.80	0.10	0.41	--	--	0.32	--	--
Phosphorous, total	3	0.04	0.01	0.02	--	--	0.01	--	--
Boron, dissolved (g/L)	4	280	130	220	--	--	240	--	--
Manganese, dissolved (g/L)	0	--	--	--	--	--	--	--	--
Selenium, dissolved (g/L)	3	2	1	1	--	--	1	--	--

Table 16. Statistical summary of chemical analyses by aquifer based on water samples collected from wells and springs, 1925-88 in Big Horn County, Wyoming--Continued

Constituent or property	Number of analyses	Descriptive statistics: Maximum	Minimum	Mean	Percentage of analyses in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Mesaverde Formation									
Specific conductance (S/cm)	5	4,410	2,100	3,320	--	--	3,160	--	--
pH	5	8.1	7.3	7.7	--	--	7.8	--	--
Hardness as $CaCO_3$	7	2,200	28	1,100	--	--	1,500	--	--
Calcium, dissolved	7	450	9.3	270	--	--	370	--	--
Magnesium, dissolved	7	270	1.1	110	--	--	110	--	--
Sodium, dissolved	7	970	36	400	--	--	320	--	--
Sodium-adsorption ratio	7	84	0.4	16	--	--	4.0	--	--
Potassium, dissolved	7	13	2.4	7.0	--	--	5.0	--	--
Bicarbonate as HCO_3	3	630	280	410	--	--	320	--	--
Carbonate as CO_3	3	0	0	0	--	--	0	--	--
Alkalinity, total as $CaCO_3$	4	610	260	380	--	--	320	--	--
Sulfate, dissolved	7	2,800	790	1,500	--	--	1,400	--	--
Chloride, dissolved	7	44	12	26	--	--	26	--	--
Fluoride, dissolved	7	0.9	0	0.5	--	--	0.4	--	--
Dissolved solids, sum of constituents	7	4,150	1,690	2,600	--	--	2,510	--	--
Nitrite plus nitrate, dissolved as nitrogen	4	10	0.10	3.9	--	--	2.8	--	--
Phosphorous, total	5	0.02	0.01	0.01	--	--	0.01	--	--
Boron, dissolved (g/L)	6	550	120	280	--	--	240	--	--
Manganese, dissolved (g/L)	1	20	20	--	--	--	--	--	--
Selenium, dissolved (g/L)	4	9	1	4	--	--	3	--	--

Table 16. Statistical summary of chemical analyses by aquifer based on water samples collected from wells and springs, 1925-88 in Big Horn County, Wyoming--Continued

Constituent or property	Number of analyses	Descriptive statistics: Maximum	Minimum	Mean	Percentage of analyses in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Cody Shale									
Specific conductance (S/cm)	6	9,730	1,800	5,210	--	--	5,100	--	--
pH	6	8.0	7.2	7.6	--	--	7.5	--	--
Hardness as $CaCO_3$	7	2,000	26	1,100	--	--	1,500	--	--
Calcium, dissolved	7	430	8.2	240	--	--	310	--	--
Magnesium, dissolved	7	280	1.1	120	--	--	130	--	--
Sodium, dissolved	7	2,000	110	890	--	--	720	--	--
Sodium-adsorption ratio	7	120	2.0	31	--	--	9.0	--	--
Potassium, dissolved	7	10	1.4	4.9	--	--	5.2	--	--
Bicarbonate as HCO_3	2	450	240	340	--	--	340	--	--
Carbonate as CO_3	2	0	0	0	--	--	0	--	--
Alkalinity, total as $CaCO_3$	5	2,070	330	740	--	--	400	--	--
Sulfate, dissolved	7	5,200	5.6	2,200	--	--	1,900	--	--
Chloride, dissolved	7	640	3.8	150	--	--	66	--	--
Fluoride, dissolved	7	3.4	0.1	0.9	--	--	0.5	--	--
Dissolved solids, sum of constituents	7	8,290	1,470	4,010	--	--	3,320	--	--
Nitrite plus nitrate, dissolved as nitrogen	5	14	0.10	3.2	--	--	0.74	--	--
Phosphorous, total	6	0.06	0.01	0.03	--	--	0.02	--	--
Boron, dissolved (g/L)	5	4,900	400	1,500	--	--	650	--	--
Manganese, dissolved (g/L)	1	440	440	--	--	--	--	--	--
Selenium, dissolved (g/L)	5	27	1	8	--	--	1	--	--

Table 16. Statistical summary of chemical analyses by aquifer based on water samples collected from wells and springs, 1925-88 in Big Horn County, Wyoming--Continued

Constituent or property	Descriptive statistics: Number of analyses	Maximum	Minimum	Mean	Percentage of analyses in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Cloverly Formation									
Specific conductance (S/cm)	2	3,840	1,190	2,520	--	--	2,520	--	--
pH	2	8.2	7.0	7.6	--	--	7.6	--	--
Hardness as $CaCO_3$	5	810	28	280	--	--	62	--	--
Calcium, dissolved	5	210	3.5	64	--	--	14	--	--
Magnesium, dissolved	5	70	4.6	29	--	--	6.6	--	--
Sodium, dissolved	4	700	280	500	--	--	500	--	--
Sodium-adsorption ratio	5	47	8.0	25	--	--	16	--	--
Potassium, dissolved	4	6.0	2.5	4.3	--	--	4.4	--	--
Bicarbonate as HCO_3	3	770	260	430	--	--	270	--	--
Carbonate as CO_3	3	43	0	20	--	--	17	--	--
Alkalinity, total as $CaCO_3$	2	280	260	270	--	--	270	--	--
Sulfate, dissolved	5	2,000	330	1,000	--	--	1,000	--	--
Chloride, dissolved	5	37	3.8	18	--	--	9.8	--	--
Fluoride, dissolved	4	1.6	0.4	0.9	--	--	0.8	--	--
Dissolved solids, sum of constituents	5	3,080	814	1,860	--	--	1,680	--	--
Nitrite plus nitrate, dissolved as nitrogen	2	0.10	0.10	0.10	--	--	0.10	--	--
Phosphorous, total	2	0.01	0.01	0.01	--	--	0.01	--	--
Boron, dissolved (g/L)	4	1,600	460	930	--	--	830	--	--
Manganese, dissolved (g/L)	0	--	--	--	--	--	--	--	--
Selenium, dissolved (g/L)	2	1	1	1	--	--	1	--	--

Table 16. Statistical summary of chemical analyses by aquifer based on water samples collected from wells and springs, 1925-88 in Big Horn County, Wyoming--Continued

Constituent or property	Number of analyses	Descriptive statistics: Maximum	Minimum	Mean	Percentage of analyses in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Jurassic and Triassic formations									
Specific conductance (S/cm)	4	4,090	1,110	2,680	--	--	2,760	--	--
pH	4	7.4	7.1	7.3	--	--	7.4	--	--
Hardness as $CaCO_3$	6	1,700	550	1,300	--	--	1,400	--	--
Calcium, dissolved	6	440	110	340	--	--	390	--	--
Magnesium, dissolved	6	150	66	100	--	--	96	--	--
Sodium, dissolved	6	790	21	240	--	--	110	--	--
Sodium-adsorption ratio	6	9.0	0.3	3.1	--	--	1.4	--	--
Potassium, dissolved	6	14	1.3	4.5	--	--	2.3	--	--
Bicarbonate as HCO_3	2	330	140	240	--	--	240	--	--
Carbonate as CO_3	2	0	0	0	--	--	0	--	--
Alkalinity, total as $CaCO_3$	4	360	130	260	--	--	270	--	--
Sulfate, dissolved	6	3,000	270	1,700	--	--	1,600	--	--
Chloride, dissolved	6	37	0.9	12	--	--	8.4	--	--
Fluoride, dissolved	6	1.4	0.2	0.8	--	--	0.8	--	--
Dissolved solids, sum of constituents	6	4,590	708	2,570	--	--	2,400	--	--
Nitrite plus nitrate, dissolved as nitrogen	4	19	0.39	5.6	--	--	1.5	--	--
Phosphorous, total	4	0.01	0.01	0.01	--	--	0.01	--	--
Boron, dissolved (g/L)	6	750	130	430	--	--	400	--	--
Manganese, dissolved (g/L)	0	--	--	--	--	--	--	--	--
Selenium, dissolved (g/L)	4	29	2	11	--	--	6	--	--

Table 16. Statistical summary of chemical analyses by aquifer based on water samples collected from wells and springs, 1925-88 in Big Horn County, Wyoming--Continued

	Descriptive statistics				Percentage of analyses in which values were less than or equal to those shown				
Constituent or property	Number of analyses	Maximum	Minimum	Mean	95	75	50 (Median)	25	5
Tensleep Sandstone									
Specific conductance (S/cm)	10	2,240	315	732	2,240	920	520	345	315
pH	10	8.5	7.7	8.1	8.5	8.1	8.1	8.0	7.7
Hardness as $CaCO_3$	13	2,600	170	570	2,600	500	260	180	170
Calcium, dissolved	13	590	29	130	590	110	54	44	29
Magnesium, dissolved	13	280	15	59	280	56	31	18	15
Sodium, dissolved	13	88	2.2	16	88	23	5.4	3.2	2.2
Sodium-adsorption ratio	13	0.8	0.1	0.2	0.8	0.3	0.1	0.1	0.1
Potassium, dissolved	13	9.8	0.7	3.0	9.8	3.0	1.9	1.4	0.7
Bicarbonate as HCO_3	5	300	210	240	--	--	230	--	--
Carbonate as CO_3	5	0	0	0	--	--	0	--	--
Alkalinity, total as $CaCO_3$	8	240	87	170	--	--	180	--	--
Sulfate, dissolved	13	2,300	4.5	370	2,300	340	39	13	4.5
Chloride, dissolved	13	10	0.6	3.4	10	5.7	2.0	1.2	0.6
Fluoride, dissolved	13	2.8	0.1	0.8	2.8	1.2	0.5	0.2	0.1
Dissolved solids, sum of constituents	13	3,480	175	708	3,480	682	275	196	175
Nitrite plus nitrate, dissolved as nitrogen	8	2.4	0.11	1.0	--	--	0.85	--	--
Phosphorous, total	2	0.01	<0.01	0.01	--	--	<0.01	--	--
Boron, dissolved (g/L)	3	360	30	150	--	--	60	--	--
Manganese, dissolved (g/L)	0	--	--	--	--	--	--	--	--
Selenium, dissolved (g/L)	0	--	--	--	--	--	--	--	--

Table 16. Statistical summary of chemical analyses by aquifer based on water samples collected from wells and springs, 1925-88 in Big Horn County, Wyoming--Continued

Constituent or property	Descriptive statistics: Number of analyses	Maximum	Minimum	Mean	Percentage of analyses in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Madison-Bighorn aquifer									
Specific conductance (S/cm)	17	2,530	323	567	2,530	446	362	340	323
pH	17	8.5	6.9	8.1	8.5	8.4	8.2	8.0	6.9
Hardness as $CaCO_3$	21	2,100	130	400	2,100	240	200	180	130
Calcium, dissolved	21	460	20	86	450	53	42	38	21
Magnesium, dissolved	21	270	2.6	43	260	28	23	22	4.2
Sodium, dissolved	21	2,300	0.4	120	2,100	3.6	2.6	2.0	0.5
Sodium-adsorption ratio	21	23	<0.1	1.5	21	0.1	0.1	0.1	<0.1
Potassium, dissolved	21	14	0.8	2.2	13	1.8	1.1	1.0	0.8
Bicarbonate as HCO_3	4	440	79	230	--	--	210	--	--
Carbonate as CO_3	4	17	0	4	--	--	0	--	--
Alkalinity, total as $CaCO_3$	17	210	10	170	210	190	180	170	10
Sulfate, dissolved	21	6,900	0.4	470	6,400	58	13	7.2	0.8
Chloride, dissolved	21	70	0.5	4.7	64	1.7	0.9	0.8	0.5
Fluoride, dissolved	21	4.3	0	0.7	4.1	0.7	0.3	0.2	0
Dissolved solids, sum of constituents	21	9,980	143	844	9,230	282	211	186	147
Nitrite plus nitrate, dissolved as nitrogen	17	1.3	0.10	0.48	1.3	0.53	0.44	0.31	0.10
Phosphorous, total	6	0.02	0.01	0.01	--	--	0.01	--	--
Boron, dissolved (g/L)	4	230	30	80	--	--	40	--	--
Manganese, dissolved (g/L)	0	--	--	--	--	--	--	--	--
Selenium, dissolved (g/L)	1	2	2	--	--	--	--	--	--

Table 16. Statistical summary of chemical analyses by aquifer based on water samples collected from wells and springs, 1925-88 in Big Horn County, Wyoming--Continued

Constituent or property	Descriptive statistics: Number of analyses	Maximum	Minimum	Mean	Percentage of analyses in which values were less than or equal to those shown: 95	75	50 (Median)	25	5
					Flathead Sandstone				
Specific conductance (S/cm)	3	706	288	431	--	--	298	--	--
pH	3	8.5	8.4	8.5	--	--	8.5	--	--
Hardness as $CaCO_3$	3	160	23	110	--	--	140	--	--
Calcium, dissolved	3	32	7.6	21	--	--	24	--	--
Magnesium, dissolved	3	19	0.9	13	--	--	19	--	--
Sodium, dissolved	3	150	2.9	53	--	--	6.0	--	--
Sodium-adsorption ratio	3	14	0.1	4.8	--	--	0.2	--	--
Potassium, dissolved	3	5.1	1.9	3.4	--	--	3.3	--	--
Bicarbonate as HCO_3	0	--	--	--	--	--	--	--	--
Carbonate as CO_3	0	--	--	--	--	--	--	--	--
Alkalinity, total as $CaCO_3$	3	150	130	140	--	--	140	--	--
Sulfate, dissolved	3	160	9.9	63	--	--	20	--	--
Chloride, dissolved	3	20	0.5	7.2	--	--	1.0	--	--
Fluoride, dissolved	3	1.9	0.2	0.8	--	--	0.2	--	--
Dissolved solids, sum of constituents	3	443	165	258	--	--	166	--	--
Nitrite plus nitrate, dissolved as nitrogen	3	0.31	0.10	0.18	--	--	0.12	--	--
Phosphorous, total	1	0.01	0.01	--	--	--	--	--	--
Boron, dissolved (g/L)	0	--	--	--	--	--	--	--	--
Manganese, dissolved (g/L)	0	--	--	--	--	--	--	--	--
Selenium, dissolved (g/L)	0	--	--	--	--	--	--	--	--

Table 16. Statistical summary of chemical analyses by aquifer based on water samples collected from wells and springs, 1925-88 in Big Horn County, Wyoming--Continued

Constituent or property	Descriptive statistics				Percentage of analyses in which values were less than or equal to those shown				
	Number of analyses	Maximum	Minimum	Mean	95	75	50 (Median)	25	5
Precambrian rocks									
Specific conductance (S/cm)	3	456	138	254	--	--	169	--	--
pH	3	8.1	7.8	8.0	--	--	8.1	--	--
Hardness as $CaCO_3$	3	270	50	130	--	--	65	--	--
Calcium, dissolved	3	69	17	34	--	--	17	--	--
Magnesium, dissolved	3	23	1.8	10	--	--	5.5	--	--
Sodium, dissolved	3	8.8	1.9	5.1	--	--	4.5	--	--
Sodium-adsorption ratio	3	0.5	0.1	0.2	--	--	0.1	--	--
Potassium, dissolved	3	4.6	0.4	2.4	--	--	2.1	--	--
Bicarbonate as HCO_3	0	--	--	--	--	--	--	--	--
Carbonate as CO_3	0	--	--	--	--	--	--	--	--
Alkalinity, total as $CaCO_3$	3	230	69	130	--	--	75	--	--
Sulfate, dissolved	3	34	2.6	14	--	--	5.2	--	--
Chloride, dissolved	3	2.2	0.4	1.4	--	--	1.6	--	--
Fluoride, dissolved	3	0.2	0.1	0.2	--	--	0.2	--	--
Dissolved solids, sum of constituents	3	284	75	157	--	--	111	--	--
Nitrite plus nitrate, dissolved as nitrogen	3	0.72	0.11	0.40	--	--	0.40	--	--
Phosphorous, total	3	0.04	0.01	0.02	--	--	0.02	--	--
Boron, dissolved (g/L)	1	10	10	--	--	--	--	--	--
Manganese, dissolved (g/L)	2	60	6	33	--	--	33	--	--
Selenium, dissolved (g/L)	1	1	1	--	--	--	--	--	--

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