WATER RESOURCES OF HOT SPRINGS COUNTY, WYOMING

By Maria Plafcan and Kathy Muller Ogle

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To obtain
acre	4,047	square meter
acre	0.4047	hectare
acre-foot per year (acre-ft/yr)	1,233	cubic meter
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer
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 kilometer
foot (ft)	0.3048	meter
foot squared per day (ft^2/d)	0.0929	meter squared per day
gallon per minute (gal/min)	0.06309	liter per second
gallon per day per square foot [(gal/min)/ft]	0.041	meter per day
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
square mile (mi^2)	2.590	square kilometer

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

$$°F = 9/5\ (°C) + 32$$

$$°C = 5/9\ (°F - 32)$$

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:

mg/L	milligram per liter
µg/L	microgram per liter
µm	micrometer
µS/cm	microsiemens per centimeter at 25 degrees Celsius

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ABSTRACT

The wells and springs inventoried in Hot Springs County most commonly had been completed in or issued from the Quaternary alluvium, Quaternary terrace deposits, Fort Union and Mesaverde Formations, Cody Shale, and the Frontier and Chugwater Formations. The largest discharges measured were from the Quaternary terrace deposits (400 gallons per minute) and the Phosphoria Formation (1,000 gallons per minute). Discharges from all other geologic units varied, but most wells and springs yielded 50 gallons per minute or less.

Water-quality samples collected from springs that issued from the Absaroka Volcanic Supergroup, the Bighorn Dolomite, and the Flathead Sandstone had the lowest dissolved-solids concentrations, which ranged from 58 to 265 milligrams per liter, and the least variable water types. Water from the volcanic rocks was a sodium bicarbonate type; whereas, water from the Flathead Sandstone was a calcium bicarbonate type. Water types for all the other aquifers varied from sampling site to sampling site; however, water samples from the Fort Union Formation and the Cody Shale were consistently of the sodium sulfate type.

The effect of oil- and gas-development at Hamilton Dome on thermal spring discharges at Hot Springs State Park near Thermopolis was studied. The estimated drawdown from 1918, when the Hamilton Dome oil field was discovered, to 1988 was made using drill-stem data from previous studies. Drawdown at Big Spring in the Park was estimated to be less than 3 feet on the basis of recent oil- and water-production data, previous modeling studies, and the estimated water-level drawdown of 330 feet in wells at the Hamilton Dome oil field.

Streams originating in the Plains region of the county, such as Middle Fork Owl Creek, are ephemeral or intermittent; whereas, streams originating in the mountains, such as Gooseberry Creek, are perennial. Average annual runoff across the county ranges from 0.26 inches at a representative streamflow-gaging station near Worland in the plains region to 5.4 inches in the Owl Creek Mountains and southeastern Absaroka Range.

INTRODUCTION

Hot Springs County in north-central Wyoming (fig. 1) has an area of about 2,022 mi^2. The topography in the county is varied, ranging from the high rugged terrain of the Absaroka Range and the Owl Creek and Bridger Mountains in the western and southern parts of the county to rolling plains in the northern part. Land-surface altitudes ranged from 12,495 ft above sea level at Washakie Needles to 4,220 ft along the Bighorn River north of Thermopolis.

The county population in 1980 was 5,710 (Wyoming Department of Administration and Fiscal Control, 1989, p. 213). About three-fourths of the residents lived in Thermopolis, which is the county seat. Thermopolis obtains its water from the Bighorn River. Most of the remaining population lived in rural areas primarily along Owl Creek (fig.1), where the availability of water suitable for domestic use is a problem for residents.

To obtain the kinds of information that are needed to plan for and manage the increased demands for water in Hot Springs 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

This report describes the water resources in Hot Springs County. The information is presented for possible use in future management of the resources, including planning and designing new water supplies and related economic development. Streamflow is described first, but the emphasis of this report is ground water. The relation of ground water to geology is described, as well as ground-water recharge, movement, and discharge, water-level changes, and hydrothermal resources.

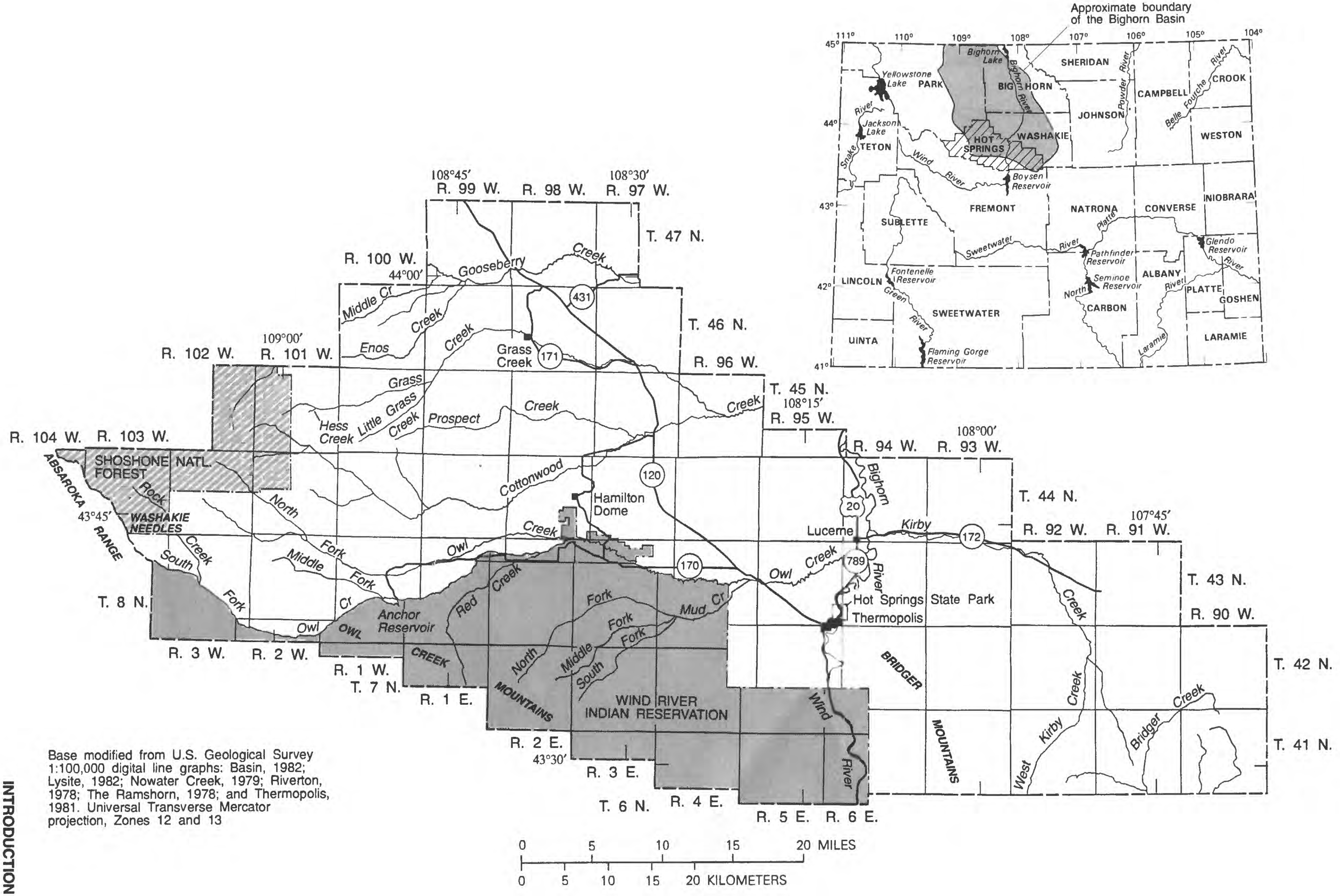
Data type and availability are described for both streamflow and ground water. Additional streamflow and ground-water sites were inventoried and sampled during this study (1989-90) to improve data coverage in the county. During 1990, discharge measurements and water-quality samples were collected from 13 streamflow sites on Grass Creek and its tributaries. During 1989 and 1990, water-quality samples were collected from 69 wells and springs and analyzed for major ions and trace elements.

Climate

Climate in Hot Springs County is varied and is related to altitude. Because of the range of altitudes in the county, temperature and precipitation vary greatly (Mora, 1987, p. 6). For example, mean monthly air temperature (fig. 2) for all months is cooler at the dam at Anchor Reservoir in the Owl Creek Mountains than at Thermopolis, which is 2,060 ft lower in altitude.

Temperature in the county also varies as a result of changing seasons, as well as vertical temperature inversions and movement of air masses. At the dam at Anchor Reservoir, the mean monthly air temperature ranges from 19.4 °F in January to 65.3 °F in July. The mean monthly air temperature at Thermopolis ranges from 20.1 °F in January to 71.8 °F in July. All temperature data cited here are from Martner (1986, p. 288, 415).

Mean annual precipitation increases with altitude in the Bridger and Owl Creek Mountains and southeastern Absaroka Range (fig. 3, modified from Martner, 1986, fig. 6.1, p. 79). The plains of the Bighorn Basin in the northern part of the county are less influenced by the proximity of mountains and receive more precipitation than at higher altitudes farther south (Mora, 1987, p. 6). The mean annual precipitation for 1951-80 along the northeastern edge of the county is less than 10 in., which Martner (1986, p. 3) classified as desert. In the Absaroka Range in the western part of the county, the mean annual precipitation for 1951-80 is greater than 40 in.



Base modified from U.S. Geological Survey 1:100,000 digital line graphs: Basin, 1982; Lysite, 1982; Nowater Creek, 1979; Riverton, 1978; The Ramshorn, 1978; and Thermopolis, 1981. Universal Transverse Mercator projection, Zones 12 and 13

Figure 1.--Hot Springs County.

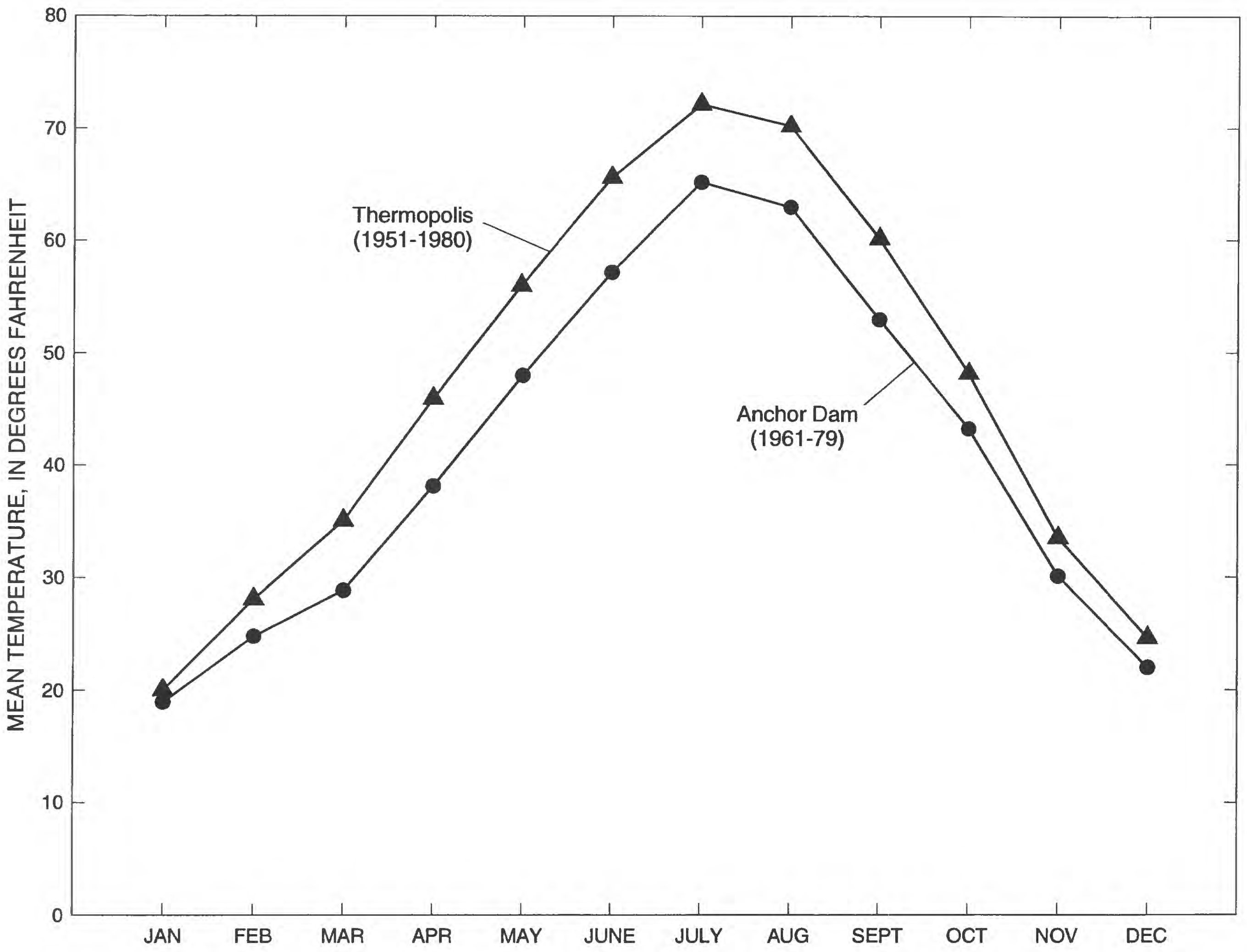


Figure 2.--Mean monthly air temperatures at Thermopolis and Anchor Dam.

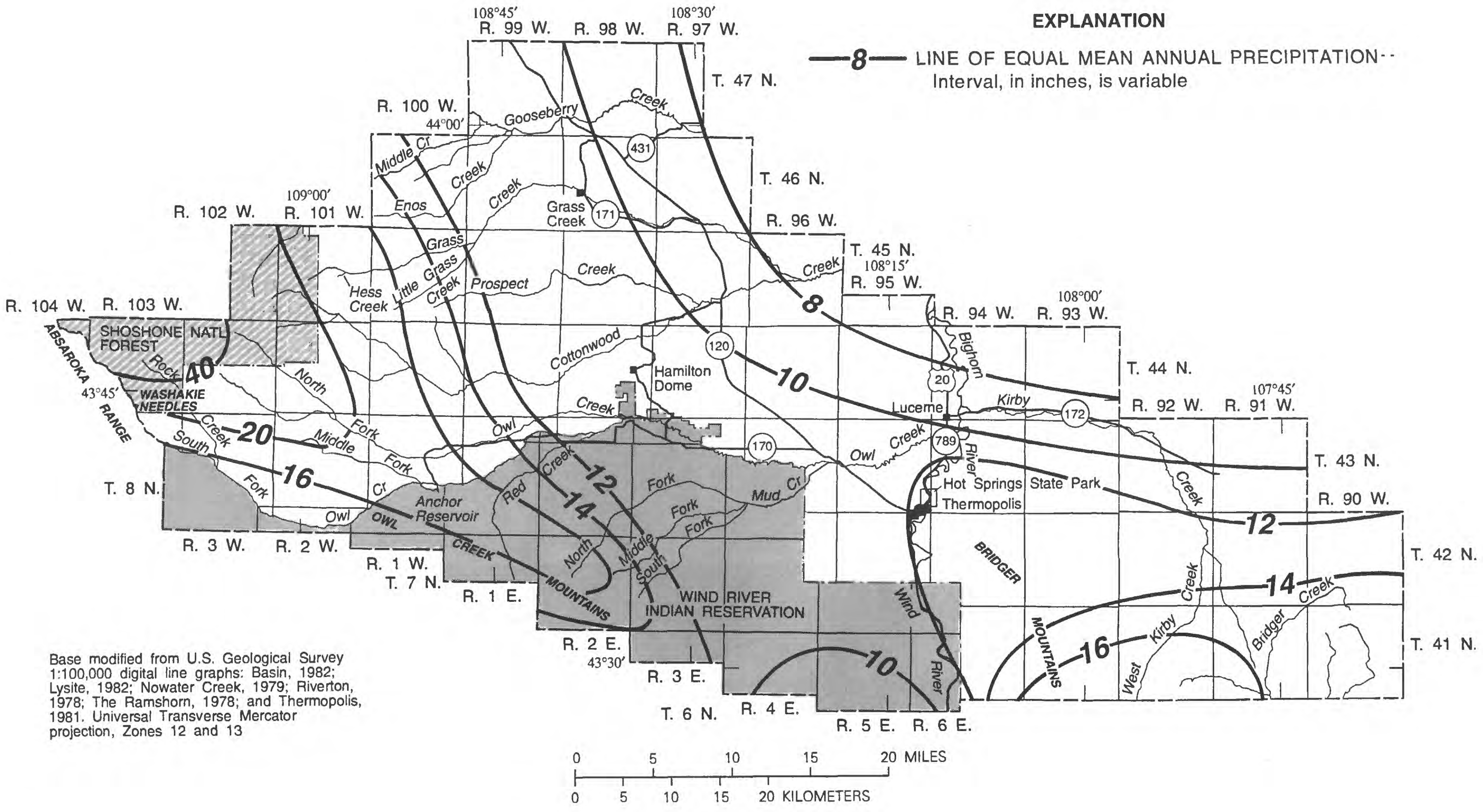


Figure 3.--Mean and annual precipitation in Hot Springs County, 1951-1980. (modified from Martner, 1986, Figure 6.1).

Geology

Hot Springs County is located in the southern part of the Bighorn Basin, which is a Rocky Mountain synclinal sedimentary basin that formed as a result of structural movements during the Laramide orogeny about 65 million years ago (Lageson, and Spearing, 1988, p. 165). The southern boundary of the county roughly coincides with the upper ridgeline of the Bridger and Owl Creek Mountains. These mountains also form the southern boundary of the Bighorn Basin. The southeastern Absaroka Range bounds the county to the west (fig.1, pl.2). Geologic units are described later in this report in table 5.

The oldest rocks exposed in the county are plutonic and metamorphic rocks of Precambrian age that include granite, metasedimentary, and metavolcanic rocks (Love and Christiansen, 1985) and are found in the upper parts of the Owl Creek Mountains (pl. 1 and pl. 2). Bedrock of the southeastern Absaroka Range consists of intrusive and volcanic rocks of Eocene age. The intrusive rocks include both felsic and mafic types. The volcanic rocks include three formations of the Absaroka Volcanic Supergroup: The Wiggins Formation, a light-gray volcanic conglomerate and white tuff, containing clasts of igneous rocks, the Tepee Trail Formation, a green and olive-drab hard and generally well-bedded andesitic conglomerate, sandstone, and claystone, and the Aycross Formation, a brightly variegated bentonitic claystone and tuffaceous sandstone, grading laterally into greenish-gray sandstone and claystone (Love and Christiansen, 1985).

The remainder of the county in the southern Bighorn Basin is underlain by sedimentary rocks that range in age from Cambrian to Ordovician and Devonian to Quaternary. Thicknesses up to 33,000 ft have been measured in the Big Horn Basin (Libra and others, 1981, p. 15); however, the thickness of sedimentary rocks in the county probably are less than 33,000 ft, because the thickness of sedimentary rocks tends to become thinner toward the basin edge.

During the Paleozoic Era, the primary rock types in the southern Bighorn Basin—marine limestone and shale—were deposited by transgressive and regressive seas; less dominant rock types—sandstone and shale—were deposited in beach and near shore environments (Libra and others, 1981, p. 15). Sandstone, which was deposited by shallow seas, was the primary rock type deposited during the early Mesozoic Era.

Depositional environments changed from terrestrial during the middle of the Mesozoic Era to shallow marine and deltaic environments during the later part of the Mesozoic Era (Libra and others, 1981, p. 15-18). The primary rock types deposited during the middle of the Mesozoic Era were sandstone and shale; thick sequences of interbedded sandstone and shale were deposited during the later part of the Mesozoic Era.

The Laramide orogeny began during the Late Cretaceous Epoch and continued into the Tertiary period. The Bridger and Owl Creek Mountains and the Absaroka Range were the sources of Tertiary sediments that were deposited in fan, fluvial, or lacustrine environments. During the mid-Tertiary Period, several thousand feet of volcanic rocks were deposited in the western part of the Bighorn Basin. General upwarping of the Bighorn Basin during the late Tertiary Period resulted in erosion of portions of many Tertiary deposits (Libra and others, 1981, p. 18).

Quaternary landslide, terrace, and alluvial deposits are the youngest units in the Bighorn Basin. These deposits are unconsolidated, localized, and of variable thickness.

Faults and folds of Laramide age are common on the flanks of the Bighorn Basin. Several structural features in the county can be observed in the Owl Creek Mountains (pl. l). Many faulted anticlines have been developed extensively for oil and gas reserves and are important structural features affecting ground-water circulation patterns in deeper aquifers (Blackstone and Huntoon, 1984, p. 2).

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.

Acknowledgments

The authors gratefully acknowledge the generous assistance of the ranchers and landowners in the county who provided access to their property, wells, and springs.

STREAMFLOW

The principal stream in Hot Springs County and the Bighorn Basin is the Bighorn River. The upper reach of this stream is named the Wind River. The name changes to the Bighorn River a few miles south of Thermopolis at the mouth of the Wind River Canyon at a point called the "Wedding of the Waters" (pl. 2; Mora, 1987, p. 4). The Bighorn River flows north from the Wedding of the Waters through the east-central part of the county. Streams that drain the western two-thirds of the county include Owl, Cottonwood, Grass, and Gooseberry Creeks. The stream draining the eastern part of the county is Kirby Creek (fig.1).

Streamflow Data

Streamflow data often are needed when planning, designing, or managing water uses and developments associated with streams. To obtain these data, streamflow-gaging or sampling stations commonly are installed and operated on the principal streams. At these stations, data are collected continuously or on a periodic basis. Streamflow-gaging and sampling stations are operated for a variety of purposes in the county, but the main purpose is for planning and managing irrigation-water supplies.

Streamflow data generally are collected at continuous-record gaging stations, where water-level sensing equipment and a recorder are housed in a streamside shelter. Using discharge measurements of the streamflow, a relation known as a rating is developed between stage (water level) and measured discharge at the gaging station (fig. 4). This rating is used with the continuous record of stage from the gaging-station recorder to develop a continuous record of stream discharge. This record can be compiled to express average daily, monthly, or yearly rates or volumes of discharge. Instantaneous peak flows and total runoff for a particular period also can be determined from the records. The location of streamflow-gaging stations where substantial amounts of data have been collected for streamflow and water quality in the county are shown in figure 5, and specific information concerning these stations is listed in table 1. A summary of streamflow characteristics at selected sites in the county is listed in table 2.

Streamflow and water-quality data are sometimes required at locations where streamflow-gaging or sampling stations are not operated. For example, to determine water loss or gain from seepage in a particular stream reach may require measurements of discharge at several locations along the stream reach. Likewise, to define water-quality changes within a stream reach may require that water samples be collected (periodically or routinely) at several locations to account for the effects of inflows from seeps and tributaries. Locations where only one or a few measurements or samples have been obtained are known as miscellaneous streamflow sites. Locations of miscellaneous streamflow sites used for this study are shown in figure 6, and specific information concerning these sites is listed in table 3.

Additional information about the streamflow-gaging stations and miscellaneous streamflow sites in the county can be obtained from the computer files and published reports of the U.S. Geological Survey. Inquiries should be directed to the District Chief, U.S. Geological Survey, WRD, 2617 E. Lincolnway, Suite B, Cheyenne, Wyoming 82001-5662.

Streamflow Characteristics

Streams in the county can be classified as the following types: ephemeral, intermittent, or perennial. Assigning a stream type can be somewhat arbitrary because it depends on which reach of the stream is being considered and the length of time the stream has been observed (Lowham, 1985, p. 32).

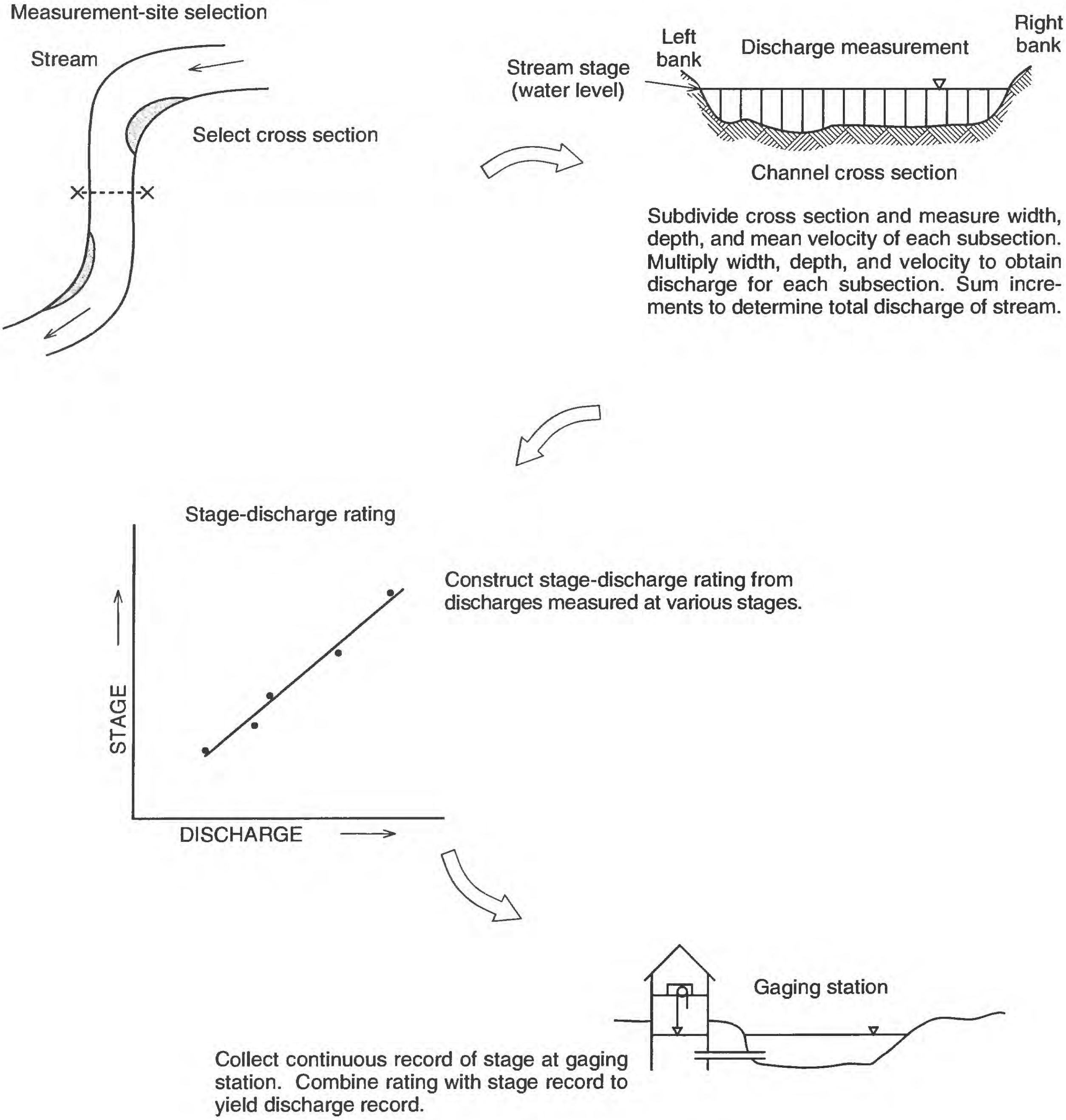


Figure 4.--Procedure for collection of streamflow data at a gaging station (from Lowham, 1988, p.13).

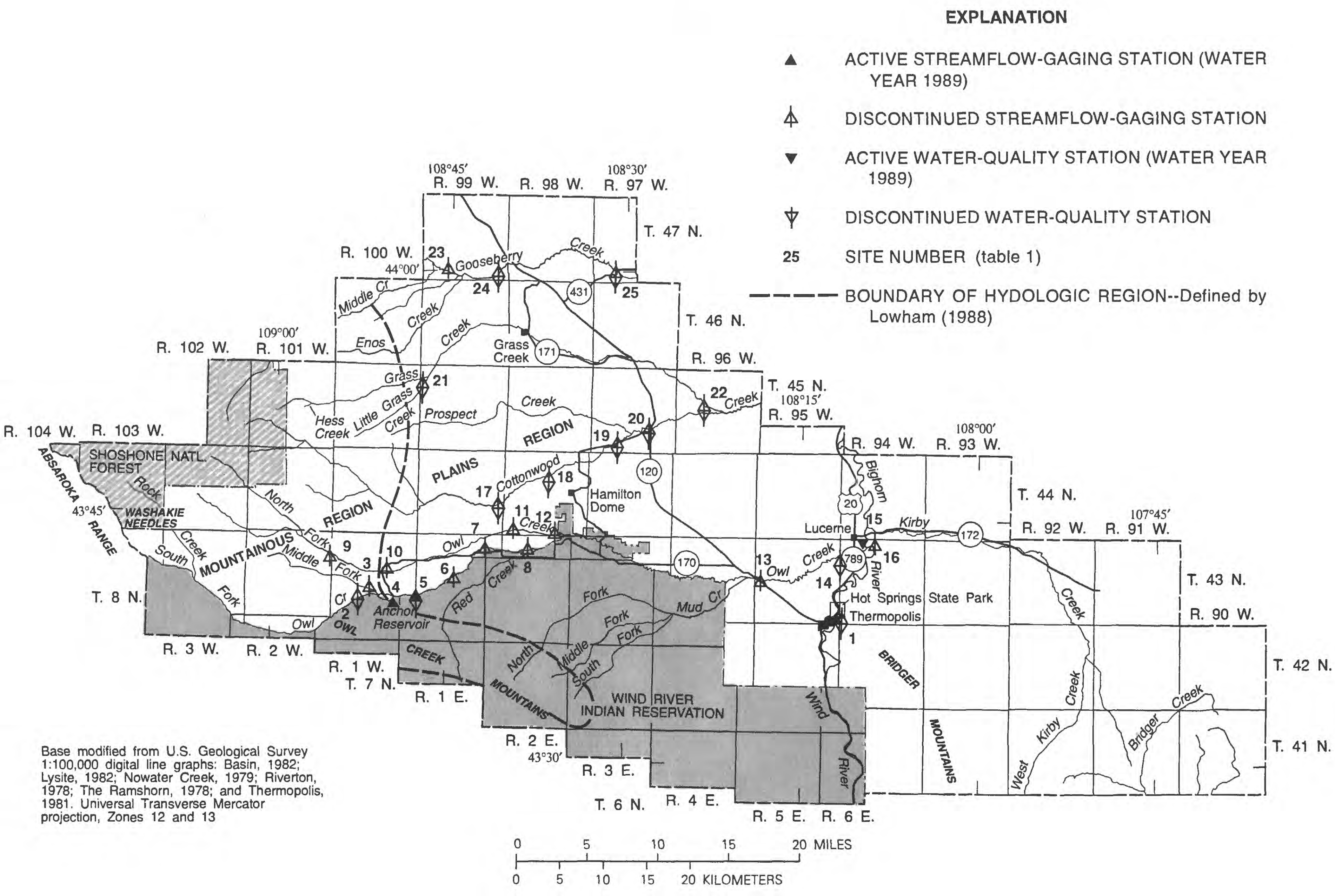


Figure 5.--Location of streamflow-gaging stations in Hot Springs County.

Table 1. *Selected streamflow-gaging stations in Hot Springs County*

[Site number: Simplified site number used in this report to identify location of streamflow-gaging stations. Station number: Assigned by U.S. Geological Survey to locations where streams are measured or sampled on a regular basis. The first two digits identify the major basin in which the station is located (Missouri River Basin is 06). The remaining six digits identify the relative location. mi^2, square miles; NC, not computed; --, no data]

Site number (fig. 5)	Station number	Station name	Drainage-basin area (mi^2)	Period of record in calendar year: Discharge	Quality: Chemical	Quality: Sediment
1	06259500	Bighorn River at Thermopolis	8,020	1900-05	1947-54	1947-53
				1910-53	1970	--
2	06260000	South Fork Owl Creek near Anchor	85.5	1932	1974-85	--
				1939-43	--	--
				1959-85	--	--
3	06260200	Middle Fork Owl Creek above Anchor Reservoir	33.6	1959-65	--	--
4	06260300	Anchor Reservoir	131	[1]1960-89	--	--
5	06260400	South Fork Owl Creek below Anchor Reservoir	131	[1]1959-89	1974-86	--
6	06260500	South Fork Owl Creek above Curtis Ranch, near Thermopolis	144	1943-59	--	--
7	06261000	South Fork Owl Creek at Curtis Ranch, near Thermopolis	149	1931-32	--	--
				1938-43	--	--
8	06261500	South Fork Owl Creek near Thermopolis	180	1921-22	--	--
				1929-32	--	--
9	06262000	North Fork Owl Creek near Anchor	54.8	1941-62	--	--
10	06262300	North Fork Owl Creek above Basin Ranch, near Anchor	61.0	1962-75	--	--
11	06262500	North Fork Owl Creek at Crann Ranch, near Thermopolis	94.2	1938-39	--	--
12	06263000	North Fork Owl Creek near Thermopolis	102	1930-32	--	--
13	06264000	Owl Creek near Thermopolis	478	1910-17	--	--
				1931-32	--	--
				1938-69	--	--
14	06264500	Owl Creek near Lucerne	509	1932-33	--	1947
				1938-53	--	--
15	06264700	Bighorn River at Lucerne	NC	--	[1]1965-89	--
16	06265000	Kirby Creek near Lucerne	199	1941-45	--	--
17	06265337	Cottonwood Creek at county bridge, near Hamilton Dome	NC	1977-78	1977-78	1977-78
18	06265350	Cottonwood Creek above Hamilton Dome	NC	1970	1970	--
19	06265400	Cottonwood Creek below Hamilton Dome	NC	1970	1970	--
20	06265410	Cottonwood Creek at State Highway 120, near Hamilton Dome	NC	1977-78	1977-78	1977-78
21	06265435	Grass Creek above Little Grass Creek, near Grass Creek	NC	1977-78	1977-78	1977-78
22	06265492	Grass Creek near mouth, near Hamilton Dome	NC	1977-78	1977-78	1977-78
23	06265800	Gooseberry Creek at Dickie	95.0	1957-78	--	--
24	06266000	Gooseberry Creek near Grass Creek	142	1945-57	1951	--
25	06266450	Gooseberry Creek at State Highway 431, near Grass Creek	NC	1977-78	1977-78	1977-78

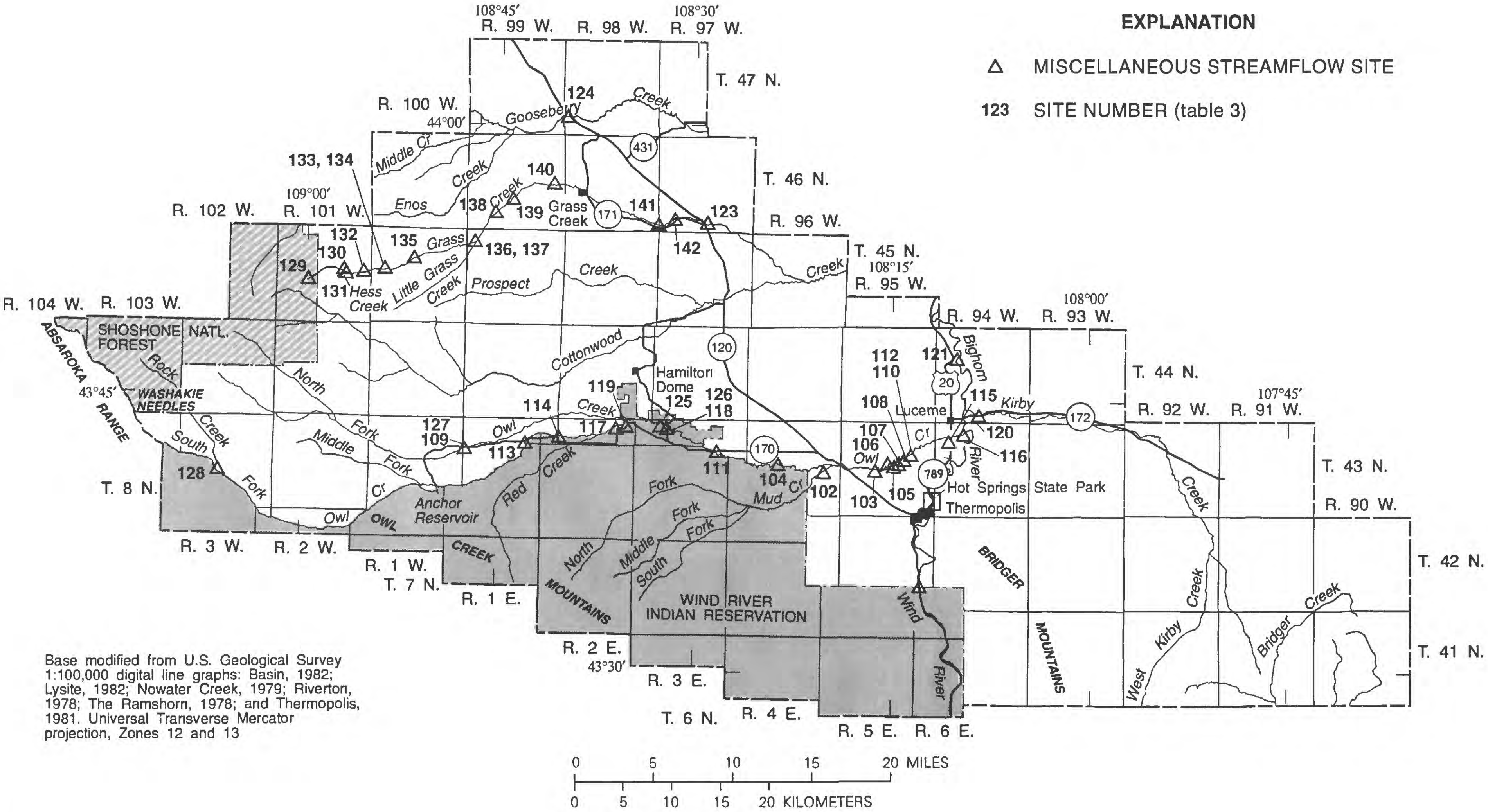
[1] Currently in operation (1989).

Table 2. *Streamflow characteristics at selected streamflow-gaging stations in Hot Springs County*

[Site number: Simplified site number used in this report to identify location of streamflow-gaging stations. mi^2, square miles; Q_a, average annual flow, in cubic feet per second, number in parentheses is average annual runoff, in inches[1]; P_t, annual peak flow, in cubic feet per second, with subscript designating the average recurrence interval in years. The peak flows listed are estimates based on a Pearson Type III probability distribution of gaged discharges; NC, not computed. See figure 5 for location of streamflow-gaging stations]

Site number (fig. 5)	Station name	Drainage-basin area (mi^2)	Q_a	P_2	P_5	P_{10}	P_{25}	P_{50}	P_{100}	Factors affecting natural flow
1	Bighorn River at Thermopolis	8,020	1,850	NC	NC	NC	NC	NC	NC	Diversions for irrigation of about 141,000 acres above station. Flow completely regulated by Boysen Reservoir.
2	South Fork Owl Creek near Anchor	85.5	34 (5.4)	483	785	1,030	1,380	1,690	2,030	No diversions above station.
5	South Fork Owl Creek below Anchor Reservoir	131	22	NC	NC	NC	NC	NC	NC	Flow regulated by Anchor Dam. No diversions above station.
6	South Fork Owl Creek above Curtis Ranch, near Thermopolis	144	27 (2.5)	592	950	1,220	1,580	1,880	2,190	Two diversions for irrigation of about 400 acres above station.
9	North Fork Owl Creek near Anchor	54.8	14 (3.5)	336	823	1,340	2,300	3,290	4,570	One small diversion for irrigation of hay meadows above station.
10	North Fork Owl Creek above Basin Ranch, near Anchor	61	14	475	790	1,030	1,380	1,660	1,960	Several small reservoirs above station used for storage of stock and irrigation water. Diversion above station into Basin Ranch ditch for irrigation of about 820 acres below station.
13	Owl Creek near Thermopolis	478	27	NC	NC	NC	NC	NC	NC	Some regulation by Anchor Dam since Nov. 1960. Diversions for irrigation of about 14,000 acres above station.
14	Owl Creek near Lucerne	509	23	NC	NC	NC	NC	NC	NC	Diversions above station for irrigation of about 18,000 acres.
23	Gooseberry Creek at Dickie	95	14 (2.0)	247	437	597	838	1,050	1,290	No diversions above station.
24	Gooseberry Creek near Grass Creek	142	14	281	431	535	670	774	878	Diversions for irrigation of about 800 acres above station.

[1] Average annual runoff represents average water depth, in inches, over the entire drainage basin.



Base modified from U.S. Geological Survey 1:100,000 digital line graphs: Basin, 1982; Lysite, 1982; Nowater Creek, 1979; Riverton, 1978; The Ramshorn, 1978; and Thermopolis, 1981. Universal Transverse Mercator projection, Zones 12 and 13

Figure 6.--Location of miscellaneous streamflow sites in Hot Springs County.

Table 3. *Miscellaneous streamflow sites in Hot Springs County*

[Site number: Simplified site number used in this report to identify miscellaneous streamflow sites. Miscellaneous streamflow site number: Assigned by the U.S. Geological Survey to locations where only one or a few measurements or samples have been obtained. The first six digits designate latitude of the site, the next seven digits designate longitude, and the last two digits are sequence numbers to distinguish between several sites that may be in close proximity of one another]

Site number (fig. 6)	Miscellaneous streamflow site number	Location (degrees, minutes, seconds)		Site name
		Latitude	Longitude	
101	433452108124500	43 34 52	108 12 45	Bighorn River at Wedding of the Waters
102	434104108200500	43 41 04	108 20 05	Mud Creek at mouth, near Thermopolis
103	434112108160800	43 41 12	108 16 08	Owl Creek 0.5 mile below Eagle Draw, near Thermopolis
104	434128108233400	43 41 28	108 23 34	Owl Creek near Thompson Reservoir No. 1, near Thermopolis
105	434129108145400	43 41 29	108 14 54	Owl Creek 1.7 miles above Meeteetse Draw, near Thermopolis
106	434134108150400	43 41 34	108 15 04	Owl Creek 3.1 miles below Eagle Draw, near Thermopolis
107	434137108143500	43 41 37	108 14 35	Owl Creek 1.0 mile above Meeteetse Draw, near Thermopolis
108	434152108141100	43 41 52	108 14 11	Owl Creek below Meeteetse Draw, near Thermopolis
109	434204108473200	43 42 04	108 47 32	North Fork Owl Creek above Rattlesnake Creek, near Anchor Dam
110	434206108133500	43 42 06	108 13 35	Owl Creek above Sunnyside Lane, near Thermopolis
111	434207108281700	43 42 07	108 28 17	Owl Creek at Middleton School
112	434208108133000	43 42 08	108 13 30	Owl Creek at Sunnyside Lane, near Thermopolis
113	434229108425500	43 42 29	108 42 55	South Fork Owl Creek near Ember Ranch
114	434250108401900	43 42 50	108 40 19	South Fork Owl Creek at Ember Ranch
115	434255108103200	43 42 55	108 10 32	Owl Creek at U.S. Highway 20, near Lucerne
116	434319108093100	43 43 19	108 09 31	Owl Creek at mouth, near Lucerne
117	434326108355900	43 43 26	108 35 59	South Fork Owl Creek near mouth, near Arapahoe Ranch
118	434327108320500	43 43 27	108 32 05	Owl Creek at Arapahoe Ranch
119	434336108352800	43 43 36	108 35 28	South Fork Owl Creek at mouth, near Arapahoe Ranch
120	434419108081900	43 44 19	108 08 19	Kirby Creek at Black Mountain Road, near Lucerne
121	434730108102600	43 47 30	108 10 26	Coal Draw at mouth, at Kirby
122	435030108275300	43 50 30	108 27 53	Cottonwood Creek above Grass Creek, near Hamilton Dome
123	435445108291500	43 54 45	108 29 15	Grass Creek near mouth, near Grass Creek
124	440033108395600	44 00 33	108 39 56	Gooseberry Creek at State Highway 120, near Dickie
125	434331108321601	43 43 31	108 32 16	Owl Creek at Arapahoe Ranch, near Thermopolis

Table 3. *Miscellaneous streamflow sites in Hot Springs County--Continued*

Site number (fig. 6)	Miscellaneous streamflow site number	Location (degrees, minutes, seconds)		Site name
		Latitude	Longitude	
126	434326108320201	43 43 26	108 32 02	Owl Creek near Hamilton Dome
127	434204108472901	43 42 04	108 47 29	North Fork Owl Creek near Anchor Reservoir
128	434035109062101	43 40 35	109 06 21	South Fork Owl Creek above Rock Creek, near Anchor Reservoir
129	435115108593901	43 51 15	108 59 39	Grass Creek near Anderson Saw Mill, near Grass Creek
130	435145108570201	43 51 45	108 57 02	Grass Creek above Hess Creek, near Grass Creek
131	435135108570201	43 51 35	108 57 02	Hess Creek Draw near Anderson Saw Mill, near Grass Creek
132	435141108553201	43 51 41	108 55 32	Carmichael Draw near LU Cow Camp, near Grass Creek
133	435156108535601	43 51 56	108 53 56	Sanford Draw near LU Cow Camp, near Grass Creek
134	435155108535501	43 51 55	108 53 55	Grass Creek near LU Cow Camp, near Grass Creek
135	435236108514301	43 52 36	108 51 43	Grass Creek below LU Cow Camp, near Grass Creek
136	435329108470601	43 53 29	108 47 06	Little Grass Creek at mouth, near LU Cow Camp, near Grass Creek
137	435330108470801	43 53 30	108 47 08	Grass Creek above Little Grass Creek, near Grass Creek
138	435510108452501	43 55 10	108 45 25	Grass Creek at LU Ranch House, near Grass Creek
139	435610108440301	43 56 10	108 44 03	Grass Creek above Gary Kellogg Ranch, near Grass Creek
140	435649108410001	43 56 49	108 41 00	Grass Creek near Grass Creek
141	435439108330201	43 54 39	108 33 02	Grass Creek at site 12, near Grass Creek
142	435459108314601	43 54 59	108 31 46	Grass Creek at site 13, near Grass Creek

Streams originating in the Plains region of the county (fig. 5) usually are classified as ephemeral or intermittent. These types of streams flow only periodically and often have extended periods of no flow. Intermittent streams may receive some ground-water inflows in addition to direct surface runoff; however, the ground-water inflows are insufficient to sustain flow throughout the year (Lowham, 1985, p. 32). A hydrograph for the Middle Fork Owl Creek above Anchor Reservoir (site 3) illustrates the streamflow of an ephemeral stream (fig. 7).

In the Plains region, streams originating in the mountains usually are classified as perennial. Perennial (year-round) streamflow results from greater precipitation, lower evapotranspiration, and greater water-storage capacity than occurs with streams originating in the Plains region of the county. Water stored as ground water and in snowfields in the mountains is released slowly, maintaining streamflows throughout the year. An example of a perennial stream is Gooseberry Creek at Dickie (site 23); a hydrograph is shown in figure 7. In addition to responses to individual rainfall events, this hydrograph shows the characteristic period of snowmelt runoff from April to June followed by sustained flow throughout the year.

Average Annual Runoff

Surface-water runoff in Hot Springs County varies greatly, from the mountains in the western and southwestern parts of the county to the lower plains areas in the central and eastern part of the county. In a comprehensive study of streamflows in Wyoming, Lowham (1988) showed the existence of distinct runoff characteristics for different regions of the state. On the basis of climatic, topographic, and geologic conditions, the State was divided into three regions: Mountainous, Plains, and High Desert. Most of the county falls in the area defined by Lowham (1988, p. 18, pl. 1) as the Plains region, but the Owl Creek Mountains and the southeast Absaroka Range fall in the Mountainous region (fig. 5). The average annual runoff for four streamflow-gaging stations that measure runoff mostly from the Mountainous region of the county ranges from 2.0 to 5.4 in. (table 2). The runoff at most of these streamflow-gaging stations is from the Owl Creek Mountains. The runoff at Gooseberry Creek at Dickie (site 23) was from the southeast Absaroka Range. None of the streamflow-gaging stations in the Plains region (fig. 5) that are listed in table 2 met the requirements for computing average annual runoff (minimum period of record of 5 years and streamflow has not been significantly affected by artificial diversions, storage, or other works of man in or on the stream channels). Fifteen Mile Creek near Worland (station 06268500, located 33 mi north of Thermopolis in Washakie County) is a representative streamflow-gaging station in the Plains region. Fifteen Mile Creek originates in the Plains region and has an average annual runoff of 0.26 in. at the streamflow-gaging station near Worland. However, the flow at this station was affected by extensive irrigation systems on some of the tributaries above the station.

Average annual runoff from the Owl Creek Mountains and the Absaroka Range is a function of climatic factors and physical characteristics of the drainage basins. Important climatic variables are precipitation, temperature, wind, evaporation, and solar radiation. Climatic conditions of an intermontane drainage basin like the Bighorn Basin are related to the basin altitude and to the relative topographic position of the basin in the mountain range. Drainage-basin size is the most important physical characteristic. Water storage in lakes, ponds, and aquifers has some effect on total runoff, but to a lesser degree than the climatic conditions and drainage-basin size (Rankl, 1987, p. 30).

Average annual runoff of streams originating in the Plains region of the county is a function of quantity and intensity of precipitation, drainage-basin area, evapotranspiration, and infiltration rate of the surficial material. Rainstorm intensities or snowmelt rates that exceed the infiltration rate of moisture into the surficial material produce runoff. The contribution of ground-water inflows to streams originating in the Plains region of the county is minor. Irrigation storage, drainage structures, and stock ponds decrease the total runoff from a drainage basin because they increase evapotranspiration and other consumptive uses.

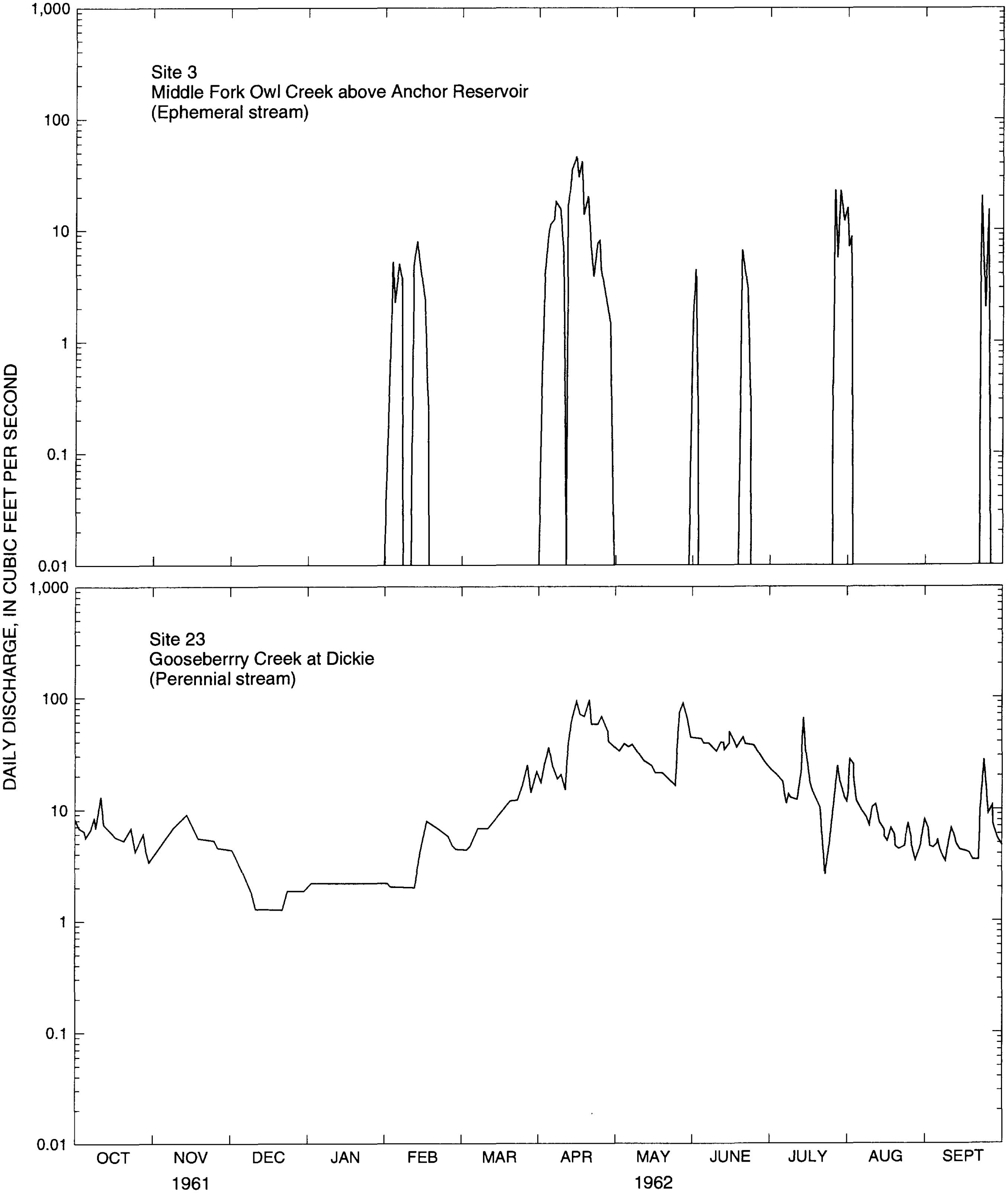


Figure 7.--Daily mean discharge for an ephemeral stream and a perennial stream for water year 1962.

Flow Duration

The flow-duration curve is a cumulative frequency curve of daily mean discharges that shows the percentage of time 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 its range of discharge. Flow-duration characteristics presented here and the methods used to develop the curves are in Peterson (1988, p. 2). The flow-duration curve applies only to the period of record for which it was developed. Streamflow data for complete years of record were used for the flow-duration curves. Although the years need not be consecutive, the records used represent periods when human influences such as reservoir storage and irrigation diversions remain unchanged.

Streamflow duration is dependent on the following drainage-basin characteristics: climate, physiography, geology, and land use. Drainage basins where these conditions are similar can have similar streamflow durations. The duration of high flows is controlled largely by climate, physiography, and land use of the basin. The duration of low flows is controlled mainly by the geology of the basin. Streamflow duration is the result of variable precipitation and the drainage-basin characteristics previously mentioned. The effects of precipitation are reduced by storage, either on the surface or in the ground (Searcy, 1959, p. 30).

Flow-duration curves can be used to evaluate the variability of streamflow in the county (fig. 8). Hydrologic and geologic characteristics of a drainage basin are the major factors that determine the shape of the flow-duration curve. Flow-duration curves (fig. 8) for site 9, North Fork Owl Creek near Anchor, and site 23, Gooseberry Creek at Dickie, illustrate streamflow variability. The steep slope at the low-flow end of the flow-duration curve for site 9 indicates highly variable streamflows dependent primarily on direct runoff. Whereas, the flatter slope in the middle- and high-flow sections of both curves indicates that there is storage in the basin, probably in seasonal snowpack and alluvial deposits. The slope remains relatively flat at the low-flow end of the curve for site 23, indicating continuous ground-water inflow to the stream.

Low Flow

Frequency analysis of low-flow data provides information about water-supply conditions related to municipal, industrial, and irrigation uses, instream fisheries, and waste disposal. Indices generally used to describe low-flow characteristics of streams are the lowest mean discharges averaged over a period of 7 consecutive days and having recurrence intervals of 2 and 10 years. For simplicity, these indices are referred to as the 7-day Q_2 ($7Q_2$) and 7-day Q_{10} ($7Q_{10}$) discharges. Seven-day low-flow discharges of selected streams are listed in table 4. The $7Q_2$ and $7Q_{10}$ discharges per mi^2 also are listed in table 4 for comparison purposes. However, it should be noted that extrapolation of the $7Q_2$ and $7Q_{10}$ discharges in table 4 to other reaches on the same stream or to other streams in the drainage basin should not be attempted without knowledge of the drainage-basin characteristics and without knowledge of the effects of human activities. Low-flow frequency values for the different stations are not to be compared directly because the values are based on different periods of record.

The hydrographs in figure 7 illustrate the differences in the occurrence of low flow between ephemeral and perennial streams. In ephemeral streams low flow is zero flow. Most ephemeral streams are dry most of the time. Low flows in perennial streams occur in the winter months and are predominantly from ground-water inflows.

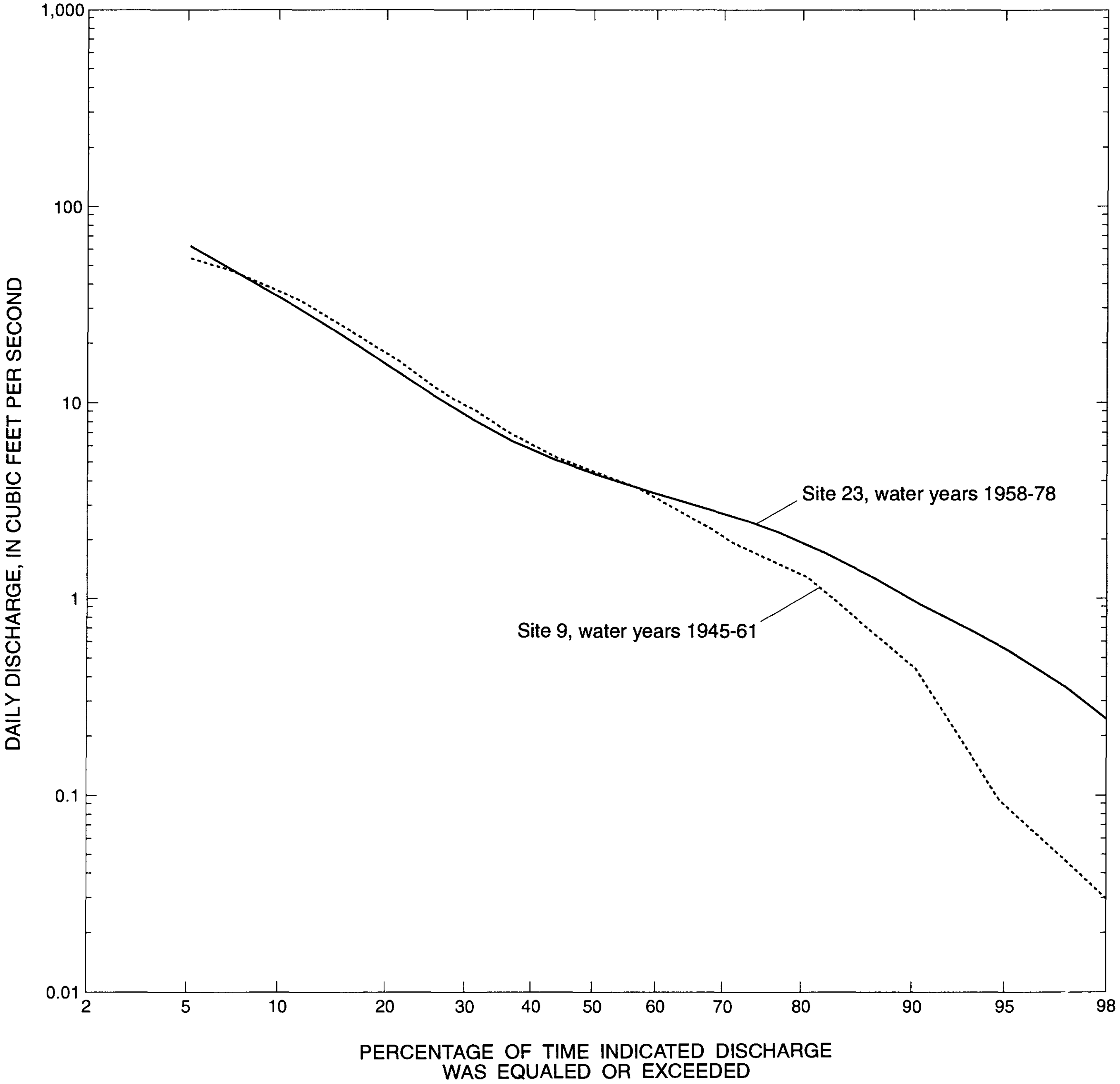


Figure 8.--Duration of daily mean discharge for site 9, North Fork Owl Creek near Anchor and site 23, Gooseberry Creek at Dickie.

Table 4. *Seven-day low-flow discharges for selected streamflow-gaging stations in Hot Springs County*

[Site number: Simplified site number used in this report to identify location of streamflow-gaging stations; mi^2, square miles; ft^3/s, cubic feet per second; $(ft^3/s)/mi^2$, cubic feet per second per square mile of drainage-basin area; --, no value computed]

Site number (fig. 5)	Station name	Drainage-basin area (mi^2)	Length of record (years)	Seven-day low-flow discharge for indicated recurrence interval			
				2 years		10 years	
				Discharge (ft^3/s)	Yield [$(ft^3/s)/mi^2$]	Discharge (ft^3/s)	Yield [$(ft^3/s)/mi^2$]
1	Bighorn River at Thermopolis	8,020	35	421	0.0525	308	0.0384
2	South Fork Owl Creek near Anchor	85.5	24	1.6	.019	0.08	.0009
5	South Fork Owl Creek below Anchor Reservoir	131	29	0	0	0	0
6	South Fork Owl Creek above Curtis Ranch, near Thermopolis	144	15	0	0	0	0
9	North Fork Owl Creek near Anchor	54.8	16	0	0	0	0
10	North Fork Owl Creek above Basin Ranch, near Anchor	61	10	0	0	--	--
13	Owl Creek near Thermopolis	478	30	0.90	.0019	0	0
14	Owl Creek near Lucerne	509	12	0.53	.0010	0	0
23	Gooseberry Creek at Dickie	95	20	0.36	.0038	0	0
24	Gooseberry Creek near Grass Creek	142	11	0	0	--	--

High Flow

High-flow characteristics of streams in the county vary with stream type. High flows in ephemeral streams are the result of lowland snowmelt or rainfall runoff during a winter or spring thaw or from summer thunderstorms. Snowmelt runoff usually is smaller in magnitude and longer in duration than rainfall runoff. Runoff from intense thunderstorms can be extremely large and of short duration. Magnitudes and durations of rainfall runoff depend on drainage-basin characteristics and on the distribution and intensity of precipitation. Peak flows in most ephemeral streams are reached quickly from rainfall runoff, and are followed by an equally rapid decrease in flows, with a gradual return to no-flow conditions. Perennial streams generally have a period of high flow in May and June as mountain snowpacks melt. Diurnal fluctuations in flow are typical during snowmelt periods with successive daily flows increasing as daylight hours lengthen and temperatures increase. This diurnal pattern, if uninterrupted by changing weather conditions, continues until peak flows occur. However, weather conditions have a substantial effect on snowmelt runoff, making it difficult to predict peak flows.

The design of bridges and culverts for road crossings, dams, diversions, and other structures on or near streams requires information about expected peak-flow conditions (floods). If the stream has been gaged in the vicinity of the planned structure, statistical analysis of the annual maximum instantaneous flows for the period of record can be used to determine the magnitude and frequency of floods. If peak-flow records are not available, then an estimate generally is made using one of several other techniques that are available (Lowham, 1985, p. 34). For example, if a bridge, when built, was planned to be used for 20 or more years, the bridge was designed for the 100-year peak flow. The 100-year peak flow, or 100-year flood, for selected streamflow-gaging stations in the county is listed in table 2. A 100-year flood is defined as the annual maximum instantaneous (peak) discharge that will be equaled or exceeded once in 100 years, on the average. Alternately, the 100-year flood is the discharge that has a 1-percent chance of being equaled or exceeded during any particular year. Also listed in table 2 are the instantaneous peak flows with recurrence intervals of 2, 5, 10, 25, and 50 years. The magnitude of these flows is listed for stations where the natural flow is not substantially affected by regulation, diversion, or irrigation. The method used to compute the instantaneous peak flows listed in table 2 is described in Peterson (1988, p. 3).

GROUND WATER

The quantity and quality of ground water in Hot Springs County differ in and between geologic units and are related to the lithology and the physical and geochemical properties of the rocks. Porosity, a measure of the void space in a rock, and permeability, a measure of the ability of a porous medium to transmit fluids, are important physical properties that affect the ability of a geologic unit to store water and to yield water to wells. A description of the lithology and water-yielding characteristics of the geologic units that crop out in the county are given in table 5. The distribution of these units is shown on plates 1 and 2. Water-quality analyses of samples collected from wells completed in and springs that issue from different geologic units in the county are described in the water-quality section of this report.

Ground-Water Data

The ground-water data collected consist of water levels, well or spring discharges, and water quality. Data from selected wells and springs throughout the county are compiled in table 6. The compilation consists of the local number, type of site, primary use of water, and discharge. The locations of selected wells and springs are shown on plate 2.

Wells and springs are identified in this report by location, according to the Federal township-range system of land subdivision and assigned a local number. An example of a local number used in this report is 46-100-22daa01 (fig. 9). The first number (46) denotes the township, the second number (100) denotes the range, and the third number (22) denotes 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 counter-clockwise direction, beginning in the northeast quarter. The last two characters in the local number are a sequence number indicating the order of inventory. For example, in figure 9, well 46-100-22daa01 is the first well inventoried in the northeast quarter of the northeast quarter of the southeast quarter of section 22, T. 46 N., R. 100 W. All wells in the county have ranges west of the Sixth Principal Meridian and townships north of the baseline.

In the Wind River Indian Reservation, the township-range system is based on the Wind River Meridian and Baseline system. Townships are denoted as north or south of the baseline and ranges are denoted as east or west of the meridian (for example, 8N-4E-15add01).

Relation of Ground Water to Geology

The lithology and water-yielding characteristics of geologic units in the county are summarized in table 5, and the surface distribution of these geologic units is shown in plate 1. Included in table 5 are range of thickness of and range of most common water yields from these geologic units. Most common water yields did not necessarily reflect potential well yields from a geologic unit. Well yields were a function of the diameter of the hole and pump capacity and efficiency, as well as the saturated interval penetrated and the permeability of that interval.

Table 5. *Lithologic and water-yielding characteristics of geologic units in Hot Springs County*

(Table modified from Libra and others, 1981 and Lowry and others, 1976; geologic age and geologic unit from Love and Christiansen, 1985 and Love, Christiansen, and Ver Ploeg, 1992; unless otherwise indicated, ranges and descriptions are for the Bighorn Basin)

[ft, feet; gal/min, gallons per minute; >, greater than; <, less than; --, no data; Ma, millions of years]

Erathem	System	Series	Geologic unit	Range of thickness (ft)	Lithology	Water-yielding characteristics	Range of most common water yields (gal/min)
Cenozoic	Quaternary	Sequence in table does not indicate age relative to other Quaternary entries	Alluvium and colluvium	0-100	Unconsolidated clay, silt, sand, and gravel in floodplains, fans, and terraces. Deposits associated with mountain streams are generally coarser.	Might yield large quantities (>200 gal/min) of water to wells (Libra and others, 1981, p. 41); permeability dependent upon sorting and size of grains and clasts.	<50
Cenozoic	Quaternary	Sequence in table does not indicate age relative to other Quaternary entries	Gravel, pediment, and fan deposits	--	Mostly locally derived clasts (Love and Christiansen, 1985). Terrace deposits.	Maximum water yield in the county was estimated at 400 gal/min from well 43-096-17bbb03.	--
Cenozoic	Quaternary	Sequence in table does not indicate age relative to other Quaternary entries	Landslide deposits	--	Aggregate of poorly sorted parent material (Lowry and others, 1976).	Composed of material of low permeability and are not favorable sites for wells (Lowry and others, 1976).	--
Cenozoic	Tertiary	Eocene	Intrusive rocks	--	Felsic and mafic igneous bodies; larger bodies are mainly felsic (Love and Christiansen, 1985).	Shallow permeability due to weathering or fracture might yield water to wells and springs.	--
Cenozoic	Tertiary	Eocene	Wagon Bed Formation	--	Green and gray tuffaceous claystone, sandstone, and conglomerate. Some marlstone and bentonitic claystone. Local oil shale (Love and Christiansen, 1985).	Water-bearing properties vary greatly due to diverse lithologies (Lowry and others, 1976).	--
Cenozoic	Tertiary	Eocene	Wiggins Formation[1]	--	Light-gray volcanic conglomerate and white tuff, containing clasts of igneous rocks (Love and Christiansen, 1985).	Water-bearing properties vary greatly due to diverse lithologies (Lowry and others, 1976).	--

Table 5. *Lithologic and water-yielding characteristics of geologic units in Hot Springs County--Continued*

Erathem	System	Series	Geologic unit	Range of thickness (ft)	Lithology	Water-yielding characteristics	Range of most common water yields (gal/min)
Cenozoic	Tertiary	Eocene	Tepee Trail Formation[1]	--	Green and olive-drab hard and generally well-bedded andesitic conglomerate, sandstone, and claystone (Love and Christiansen, 1985).	Water-bearing properties vary greatly due to diverse lithologies (Lowry and others, 1976).	--
Cenozoic	Tertiary	Eocene	Aycross Formation[1]	--	Brightly variegated bentonitic claystone and tuffaceous sandstone, grading laterally into greenish-gray sandstone and claystone (Love and Christiansen, 1985).	Localized water yield primarily a function of sandstone content. Sandstone presence highly variable both vertically and laterally.	--
Cenozoic	Tertiary	Eocene	Wind River Formation	--	Interbedded siltstone, sandstone, and conglomerate containing some carbonaceous shale and thin coal seams (Whitcomb and Lowry, 1968).	Unknown.	--
Cenozoic	Tertiary	Eocene	Tatman Formation	375-725	Interbedded claystone, shale, mudstone, marl, sandstone, with minor coal (Lowry and others, 1976). Occurs only in northernmost portion of the county; of limited extent.	Not considered to be a potential aquifer because of its small areal extent.	--
Cenozoic	Tertiary	Eocene	Willwood Formation	1,300-2,300	Variegated, interbedded claystone and channel sandstone. Averages about 25 percent sandstone (Lowry and others, 1976).	Might yield enough water from sandstones for domestic or stock use. Some development in adjacent counties. Libra and others (1981, p. 41) reported that water yields were generally between 5-20 gal/min throughout the central Bighorn Basin.	--
Cenozoic	Tertiary	Paleocene	Fort Union Formation	600-3,500	Claystone, siltstone, and sandstone with some carbonaceous material. Cliff-forming sandstone near the base. Averages about 25 percent sandstone (Lowry and others, 1976).	Might yield enough water from sandstones for domestic or stock use. Water yields as large as 12 gal/min were observed in well 47-097-31cbb01 and well 47-098-28aaa01.	<20

Table 5. *Lithologic and water-yielding characteristics of geologic units in Hot Springs County--Continued*

Erathem	System	Series	Geologic unit	Range of thickness (ft)	Lithology	Water-yielding characteristics	Range of most common water yields (gal/min)
Mesozoic	Cretaceous	Upper Cretaceous	Lance Formation	800-1,800	Massive sandstone overlain by interbedded claystone, siltstone, shale, and minor coal seams. Forms resistant ledges (Libra and others, 1981, p. 41).	Not extensively developed (Libra and others, 1981, p. 41). Might yield enough water from sandstones for domestic or stock use.	--
Mesozoic	Cretaceous	Upper Cretaceous	Meeteetse Formation	650-1,200	Lenticular, poorly indurated fine-grained clayey to silty sandstone interbedded with siltstone, claystone, shale, bentonite, and minor thin coal beds (Libra and others, 1981, p. 42).	Sandstones might yield enough water for domestic or stock use. Yields as large as 10 gal/min were observed from well 46-099-34dcb01.	<15
Mesozoic	Cretaceous	Upper Cretaceous	Mesaverde Formation	1,100-1,800	Light-colored massive to thin-bedded sandstone, gray sandy shale, and coal beds (Love and Christiansen, 1985).	Yields as large as 50 gal/min were observed from well 45-097-26bcd01.	5-10
Mesozoic	Cretaceous	Upper Cretaceous	Cody Shale	2,100-3,000	Lower part dominantly consists of dark gray marine shale, glauconitic sandstone, and thin bentonite beds; whereas, the upper part is interbedded gray, sandy shale and sandstone (Libra and others, 1981, p. 42).	Thin sandstones might yield enough water locally for domestic or stock use. In fractured areas and where encountering confined sandstone beds, yields up to 20 gal/min might be obtained (Libra and others, 1981, p. 42).	--
Mesozoic	Cretaceous	Upper Cretaceous	Frontier Formation	450-700	Lenticular fine- to medium-grained sandstone and conglomeratic sandstone beds alternating with shale and lesser amounts of bentonite (Libra and others, 1981, p. 42).	Artesian conditions exist in the area along Kirby Creek. Yields as large as 38 gal/min were observed from spring 41-090-04baa01.	2-10
Mesozoic	Cretaceous	Lower Cretaceous	Mowry Shale	300-400	Siliceous brittle shale with thin beds; sandstone and bentonite beds in the upper part (Libra and others, 1981, p. 42).	Brittle shales and thin sandstones might yield very limited quantities of water to wells where fractured. Yields as large as 5 gal/min were observed from well 42-092-34bab01.	--

Table 5. *Lithologic and water-yielding characteristics of geologic units in Hot Springs County--Continued*

Erathem	System	Series	Geologic unit	Range of thickness (ft)	Lithology	Water-yielding characteristics	Range of most common water yields (gal/min)
Mesozoic	Cretaceous	Lower Cretaceous	Thermopolis Shale	400-600	Soft shale with bentonite beds and sandy and silty zones. The Muddy Sandstone Member, which is about 40 ft thick, occurs about 200 ft above the base (Libra and others, 1981, p. 42).	Yields of 5 gal/min were observed from well 41-092-11abd01 and spring 41-092-11adb01. Wells developed in the Muddy Sandstone Member were observed to yield up to 8 gal/min (well 43-091-36bca01).	--
Mesozoic	Cretaceous	Lower Cretaceous	Cloverly Formation	85-470	Composed of three units; an upper sandstone, a middle shale, and a lower lenticular conglomeratic sandstone (Libra and others, 1981, p. 42).	Sandstones might yield enough water for domestic or stock use. Yields as large as 21 gal/min were observed from well 43-094-13add01.	--
Mesozoic	Jurassic	Upper Jurassic	Morrison Formation	75-300	Variegated sandy shale and mudstone with lenses of fine-grained sandstone, conglomerate, and limestone.	Sandstones might yield enough water for domestic or stock use.	--
Mesozoic	Jurassic	Upper and Middle Jurassic	Sundance Formation	200-300	Greenish-gray glauconitic sandstone and shale, underlain by red and gray nonglauconitic sandstone and shale (Love and Christiansen, 1985).	Sandstones might yield enough water for domestic or stock use.	--
Mesozoic	Jurassic	Middle Jurassic	Gypsum Spring Formation	80-215	Red siltstone and shale with gray to brown limestone beds and massive gypsum beds (Libra and others, 1981, p. 43).	Solution zones in gypsum beds yield small amounts of water (Libra and others, 1981, p. 43). Yields as large as 28 gal/min were observed from spring 41-091-23ddd01.	--
Mesozoic	Jurassic(?)-Triassic(?)		Nugget Sandstone	--	Gray to dull-red massive to coarsely crossbedded quartz sandstone (Love and Christiansen, 1985).	Unknown.	--
Mesozoic	Triassic	Upper and Lower Triassic	Chugwater Formation	450-1,000	Red very fine-grained sandstone, siltstone, shale, and one thin limestone (Alcova Limestone Member) in the southern part of the Bighorn Basin (Lowry and others, 1976).	Yields as large as 50 gal/min were observed from spring 41-091-27dbc01.	2-10
Mesozoic	Triassic	Lower Triassic	Dinwoody Formation	0-100	Yellowish siltstone interbedded with gypsum and shales (Lowry and others, 1976).	Unknown.	--

Table 5. *Lithologic and water-yielding characteristics of geologic units in Hot Springs County--Continued*

Erathem	System	Series	Geologic unit	Range of thickness (ft)	Lithology	Water-yielding characteristics	Range of most common water yields (gal/min)
Paleozoic	Permian		Phosphoria Formation and related rocks	100-300	Brown sandstone and dolomite, cherty phosphatic and glauconitic dolomite, phosphatic sandstone and dolomite, greenish-gray to black shale (Love and Christiansen, 1985).	Yields as large as 1,000 gal/min were observed from spring 42-095-25bca01.	--
Paleozoic	Pennsylvanian	Upper and Middle Pennsylvanian	Tensleep Sandstone	50-375	Tan to white massive, crossbedded sandstone. Lower part more dolomite with interbedded carbonate beds (Libra and others, 1981, p. 44).	Flowing wells yield large and dependable supplies of potable water in adjacent counties. Development of secondary permeability in addition to primary permeability increases the water-yielding ability (Lowry and others, 1976). Yields as large as 25 gal/min were observed from spring 41-094-21cda01.	50-200
Paleozoic	Pennsylvanian and Mississippian	Middle and Lower Pennsylvanian and Upper Mississippian	Amsden Formation	120-300	Red shale and dolomite with chert and occasional gypsum. Darwin Sandstone Member at base ranges in thickness from 0 to 90 ft (Libra and others, 1981, p. 44).	Darwin Sandstone Member yields water under pressure (Libra and others, 1981, p. 44).	--
Paleozoic	Mississippian	Upper and Lower Mississippian	Madison Limestone	300-880	Massive crystalline limestone and dolomite with siltstone and shale zones, cherty in places (Libra and others, 1981, p. 44).	Secondary porosity due to solution along joints and fractures. Yields as large as 3,000 gal/min, but usually less (Libra and others, 1981, p. 44). In hydrologic connection with the underlying Bighorn Dolomite forming the Madison-Bighorn aquifer. One well (46-098-28bcc01) had a water yield of 284 gal/min.	--
Paleozoic	Devonian	Upper Devonian	Darby Formation	--	Yellow and greenish-gray shale and dolomitic siltstone underlain by fetid brown dolomite and limestone (Love and Christiansen, 1985).	May hydrologically separate the overlying Madison Limestone from the underlying Bighorn Dolomite.	--

Table 5. *Lithologic and water-yielding characteristics of geologic units in Hot Springs County--Continued*

Erathem	System	Series	Geologic unit	Range of thickness (ft)	Lithology	Water-yielding characteristics	Range of most common water yields (gal/min)
Paleozoic	Ordovician	Upper Ordovician	Bighorn Dolomite	350-450	Massive to thin-bedded dolomite and dolomite limestone. Fine-grained massive sandstone at base. Contains cavernous zones near outcrop areas (Libra and others, 1981, p. 44).	In combination with the Darby Formation and the Madison Limestone, forms the Madison-Bighorn aquifer, which produces large and dependable supplies of potable water in adjacent counties. Porosity primarily due to fracturing and solution (Libra and others, 1981, p. 44). Yields as large as 323 gal/min were observed from well 46-098-18cbb01.	--
Paleozoic	Cambrian	Upper Cambrian and Lower Ordovician	Gallatin Limestone	400-500	Gray-green calcareous shale and flat-pebble conglomerate (Lowry and others, 1976).	In combination with the underlying Gros Ventre Formation, forms a confining layer for the Flathead Sandstone.	--
Paleozoic	Cambrian	Upper and Middle Cambrian	Gros Ventre Formation	400-500	Greenish-gray thin-bedded limestone and limestone-pebble conglomerate (Lowry and others, 1976).	Thin sandstone beds indicate potential for small yields. However, one well (43-093-28ccd01) yielded 110 gal/min.	--
Paleozoic	Cambrian	Middle Cambrian	Flathead Sandstone	0-170	Arkosic and quartzitic sandstone with interbedded shale in upper part (Libra and others, 1981, p. 45).	Libra and others (1981, p. 45) reported water yields over 2,000 gal/min. Yields as large as 15 gal/min were observed from spring 41-092-33daa01 and spring 41-093-31dcd01.	--
Precambrian			Igneous and metamorphic rocks	--	Metasedimentary and metavolcanic rocks, and granitic rocks of 2,600-Ma age group (Love and Christiansen, 1985).	Dominantly not an aquifer, but in the mountains intensively weathered or fractured rocks within 100 feet of the surface might yield enough water for domestic or stock use.	--

[1] Part of the Absaroka Volcanic Supergroup (Love and Christiansen, 1985).

Table 6. *Records of selected wells and springs in Hot Springs County*

[Local number: See text describing well-numbering system in the section titled Ground-Water Data. Site type: S, spring; W, well. Primary use of water: H, domestic; I, irrigation; N, industrial; P, public supply; S, stock; U, unused. Altitude of land surface, in feet above sea level. Static water level: F, flowing; ft, feet; gal/min, gallons per minute; --, no data; <, less than]

Local number	Type of site	Depth of well (ft)	Year drilled	Primary use of water	Altitude of land surface (ft)	Static water level: [ft above (+) or below land surface]	Static water level: Date	Discharge: (gal/min)	Discharge: Date
				Geologic unit unknown					
42-094-27cab01	W	190	--	S	4,880	146.6	07-27-89	2.0	07-27-89
42-095-21cac01	W	350	1962	S	4,550	153.6	10-13-70	4.0	10-13-70
43-091-26cba01	W	--	--	--	5,160	--	--	5.0	--
43-094-07bcb01	W	36	--	H	4,349	6.05	04-22-46	--	--
43-094-08acc01	W	78	--	H	4,307	26.26	04-29-46	--	--
43-094-18caa01	W	90	1966	--	4,400	--	--	--	--
43-095-12acc01	W	60	--	H	4,370	7.00	04-22-46	--	--
43-095-20bab01	W	53	--	H	4,550	25.76	05-02-46	--	--
43-095-21bab01	W	84	--	H	4,508	20.62	04-17-46	--	--
43-096-09bbc01	W	155	--	S	4,915	53.39	04-19-46	--	--
43-096-14cdd01	W	60	--	H	4,670	9.55	04-23-46	--	--
43-096-23adb01	W	69	--	H	4,673	30.28	04-18-46	--	--
43-097-02cba01	W	--	--	S	5,140	7.58	03-08-89	--	--
43-097-11abc01	W	25	--	S	5,021	6.59	04-23-46	--	--
43-097-12aad01	W	122	--	S	4,973	29.97	04-23-46	--	--
43-097-12cdd01	W	140	--	U	4,952	9.03	04-20-46	--	--
43-097-12ddc01	W	30	--	S	4,932	9.69	04-20-46	--	--
43-098-07bbb01	W	--	--	U	5,618	4.67	05-22-46	--	--
43-098-07bbc01	W	86	--	H	5,603	4.34	04-26-46	--	--
43-099-09dbb01	W	80	--	H	5,870	6.12	05-03-46	--	--
43-099-18bbb01	W	--	--	U	6,093	4.00	05-03-46	--	--
43-100-13abd01	W	35	--	S	6,130	5.50	05-03-46	--	--
44-093-33cad01	W	--	--	S	4,397	F	07-27-90	7.1	07-27-90
44-094-20bcc01	W	140	--	S	4,396	66.74	05-28-46	--	--
44-094-31dda01	W	75	--	S	4,310	17.18	05-28-46	--	--
45-096-16cbb01	W	34	--	I	4,770	20.97	05-20-55	--	--
7N-3E-12ddd01	S	--	--	U	5,980	--	--	--	--
8N-3E-01bcc01	W	--	--	U	5,000	4.51	03-08-89	--	--
8N-3E-02bac01	W	--	--	H	5,060	30.41	03-08-89	--	--
8N-3E-02dcb01	W	--	--	U	5,040	8.83	03-07-89	--	--
8N-3E-02dda01	S	--	--	S	5,010	--	--	--	--
8N-3E-06ddc01	S	--	--	S	5,390	--	--	--	--
8N-4E-10ccb01	W	61	--	H	4,799	9.68	04-19-46	40	04-19-46
8N-4E-10ccc01	W	22	1948	I	4,794	10.25	03-18-49	--	--
8N-4E-16aca01	W	250	--	S	4,850	14.30	04-19-46	--	--

Table 6. *Records of selected wells and springs in Hot Springs County--Continued*

Local number	Type of site	Depth of well (ft)	Year drilled	Primary use of water	Altitude of land surface (ft)	Static water level [ft above (+) or below land surface]	Static water level Date	Discharge (gal/min)	Discharge Date
				Geologic unit unknown--Continued					
9N-1E-36daa01	W	88	--	H	5,695	9.32	04-26-46	--	--
9N-2E-34cbb01	W	--	--	H	5,497	14.91	04-25-46	--	--
9N-2E-34cbb02	W	--	--	U	5,497	4.89	05-22-46	--	--
9N-2E-35bdb01	S	--	--	H	5,410	--	--	9.3	01-06-89
				Quaternary alluvium					
43-094-07ada01	W	32	--	H	4,314	2.95	04-29-46	--	--
43-095-11cdd01	W	12	--	H	4,403	5.23	04-17-46	--	--
43-095-15ccc02	W	13	--	U	4,480	4.61	04-17-46	--	--
43-095-16ddc01	W	42	--	S	4,486	14.84	04-22-46	--	--
43-095-19abc01	W	--	--	U	4,580	11.07	08-11-45	--	--
43-097-05bca01	W	12	--	S	5,179	7.94	04-24-46	--	--
						7.51	03-07-89	--	--
43-097-11ccc01	W	68	--	H	5,005	20.98	04-19-46	--	--
43-097-11cdc01	W	48	--	U	4,989	5.34	05-13-46	--	--
43-097-14bab01	W	50	--	H	5,000	36.96	03-07-89	3.0	03-07-89
43-099-08cda01	W	60	--	U	5,973	5.95	08-10-45	--	--
44-094-08ba 01	W	15	1916	P	4,225	7.00	10-12-70	--	--
44-094-20ccc01	W	42	--	S	4,306	27.59	05-28-46	--	--
44-094-20dcd01	W	--	--	U	4,271	6.56	05-27-46	--	--
44-094-29cac01	W	24	--	U	4,294	15.99	05-28-46	--	--
44-094-30aaa01	W	59	--	U	4,323	39.26	05-28-46	--	--
44-094-32cdb01	W	38	--	H	4,295	15.36	05-28-46	--	--
44-094-33ccb01	W	15	--	H	4,265	--	--	--	--
44-099-02aad01	W	19	--	U	5,673	11.55	07-25-90	--	--
44-099-20cba01	W	26	--	U	6,020	13.37	07-24-90	--	--
44-101-02dad01	W	--	--	H	7,240	--	--	--	--
45-097-20dca01	W	34	--	U	5,086	22.12	07-26-90	--	--
45-099-23cab01	S	--	--	S	5,897	--	--	1.0	07-25-90
45-100-17acd01	W	84	--	U	6,750	65.39	06-21-90	2.0	06-21-90
8N-3E-01bcb01	W	73	--	H	5,000	15.93	04-26-46	--	--
8N-3E-01cca01	W	--	--	--	5,000	11.79	03-08-89	--	--
8N-3E-01cda01	W	40	--	S	4,982	15.35	08-11-45	--	--
8N-3E-02aac01	W	--	--	--	5,013	11.86	03-07-89	--	--
8N-3E-02ada01	W	--	--	U	5,013	11.21	04-19-46	--	--
8N-3E-02bca01	W	--	--	H	5,065	26.32	03-08-89	--	--
8N-3E-02bca02	W	73	--	H	5,060	25.43	04-19-46	--	--
8N-3E-02dca01	W	60	1960	H	5,020	21.49	03-07-89	2.0	08- -88
8N-3E-03aab01	W	69	--	U	5,079	19.75	04-20-46	--	--

Table 6. *Records of selected wells and springs in Hot Springs County--Continued*

Local number	Type of site	Depth of well (ft)	Year drilled	Primary use of water	Altitude of land surface (ft)	Static water level [ft above (+) or below land surface]	Static water level Date	Discharge (gal/min)	Discharge Date
				Quaternary alluvium--Continued					
8N-4E-15bab01	W	--	--	S	4,786	3.99	05-14-46	--	--
8N-4E-16aaa01	W	50	--	H	4,797	7.25	05-14-46	--	--
8N-4E-16aab01	W	24	--	I	4,808	7.96	05-14-46	--	--
8N-4E-16aad01	W	48	--	H	4,802	11.60	05-14-46	--	--
8N-4E-16aba01	W	72	--	U	4,808	7.51	04-19-46	--	--
9N-1E-36ccc01	W	21	--	I	5,765	7.40	04-26-46	--	--
9N-2E-33cdd01	W	42	1954	I	5,536	21.52	05-20-55	140	05-20-55
9N-2E-33dcc01	W	90	--	H	5,532	13.70	04-25-46	--	--
9N-2E-35aaa01	W	47	--	S	5,372	10.15	08-10-45	--	--
9N-2E-35aab01	W	13	1951	U	5,385	9.62	04-06-51	--	--
9N-3E-29cad01	W	12	--	H	5,210	7.00	01-05-89	--	--
9N-3E-29dac01	W	--	--	U	5,200	7.48	01-05-89	--	--
9N-3E-29dda01	W	--	--	H	5,190	22.00	08-10-45	--	--
9N-3E-33adb01	W	28	--	H	5,129	12.50	04-20-46	--	--
9N-3E-33adb02	W	28	--	H	5,129	12.55	04-20-46	--	--
				Quaternary terrace deposits					
43-094-08ccc01	W	36	--	S	4,325	22.07	04-29-46	--	--
43-096-07dbc01	W	40	1937	I	4,901	9.67	08-11-45	--	--
43-096-14bda01	W	44	--	U	4,699	26.83	04-23-46	--	--
43-096-17bbb03	W	42	1954	I	4,865	18.24 5.22	06-21-55 05-21-60	400 --	08-23-65 --
43-096-18aba01	W	64	--	H	4,885	26.72 9.21	04-18-46 04-23-46	-- --	-- --
43-097-03ccd01	W	--	--	U	5,105	16.20	04-24-46	--	--
43-097-11acc01	W	40	1962	S	5,022	3.06	06-22-70	16	06-22-70
43-098-03caa01	W	31	1955	I	5,395	4.58	06-03-55	--	--
43-099-07cdd01	W	12	--	H	6,060	7.06	05-03-46	--	--
43-099-08ccb01	W	--	--	H	6,020	14.06	05-03-46	--	--
43-099-09cab01	W	18	--	U	5,902	8.65	05-03-46	--	--
43-099-09cab02	W	5	--	I	5,900	1.85	05-03-46	--	--
46-098-28bbb01	W	28	--	H	5,500	13.14	06-20-90	5.0	06-20-90
8N-4E-15bab02	W	21	--	I	4,786	14.17	05-23-55	--	--
				Absaroka Volcanic Supergroup					
43-100-04aad01	S	--	--	S	6,800	--	--	.5	07-24-90
43-102-15daa01	S	--	--	U	8,950	--	--	1.2	10-18-89
45-099-08bdc01	S	--	--	S	6,920	--	--	1.0	06-21-90
8N-3W-16add01	S	--	--	S	8,600	--	--	1.5	10-19-89

Table 6. *Records of selected wells and springs in Hot Springs County--Continued*

Local number	Type of site	Depth of well (ft)	Year drilled	Primary use of water	Altitude of land surface (ft)	Static water level [ft above (+) or below land surface]	Static water level Date	Discharge (gal/min)	Discharge Date
				Fort Union Formation					
45-096-15dda01	W	100	--	H	4,682	26.80	09-13-90	5.0	09-13-90
45-097-05cdc01	S	--	--	U	5,390	--	--	--	--
45-097-17acc01	S	--	--	S	5,353	--	--	2.0	07-26-90
45-098-05cbb01	W	37	--	U	5,715	30.31	06-21-90	--	--
45-099-01cba01	W	76	--	S	5,922	62.96	06-21-90	--	--
46-097-21caa01	W	320	1982	S	5,250	78.14	06-20-90	--	--
46-098-12aab01	W	375	1969	S	5,327	68.09	06-20-90	--	--
47-097-31cbb01	W	247	1968	S	5,297	129.1	07-29-70	12	07-29-70
47-098-28aaa01	W	200	1955	H	5,341	50.00	06-18-90	12	06-18-90
47-098-34cad01	W	320	1966	S	5,540	--	--	--	--
				Lance Formation					
45-097-06bdd01	W	110	--	S	5,425	70.36	06-21-90	--	--
45-098-13cdc01	W	266	--	U	5,291	73.99	07-26-90	--	--
				Meeteetse Formation					
45-099-09ada01	W	320	--	S	6,280	141.1	06-21-90	--	--
46-097-31aaa01	W	160	--	H	5,185	--	--	--	--
46-099-34dcb01	W	310	--	S	6,203	263.0	06-21-90	10	06-21-90
46-100-15bcd01	S	--	--	S	6,440	--	--	5.0	06-22-90
46-100-22daa01	W	100	--	S	6,580	F	06-22-90	3.5	06-22-90
47-098-32aba01	W	101	1985	H	5,390	7.58	06-19-90	10	06-19-90
47-099-33cad01	W	135	--	S	5,680	30.00	06-19-90	10	06-19-90
				Mesaverde Formation					
44-095-17bba01	W	293	1967	S	4,590	--	--	--	--
44-097-25cdc01	W	--	--	S	5,210	--	--	--	--
44-098-17abc01	W	203	1987	H	5,525	17.96	07-23-90	15	07-23-90
44-098-18dca01	W	--	--	H	5,645	80.5	07-23-90	10	07-23-90
45-097-15cbd01	W	260	--	S	5,117	9.19	07-26-90	5.0	07-26-90
45-097-26bcd01	W	156	--	N	4,975	31.08	07-24-90	50	07-24-90
45-097-28dad01	W	150	--	H	4,025	38.61	07-23-90	5.0	07-23-90
45-099-25ccd01	S	--	--	S	5,673	--	--	9.5	07-25-90
45-099-28aba01	W	120	1942	S	6,095	74.73	07-25-90	5.0	07-25-90
46-098-10bba01	W	350	1967	S	5,480	--	--	--	--
46-099-22cbc01	S	--	--	H	5,900	--	--	8.0	06-20-90
47-099-04dab01	W	215	1982	S	5,630	41.07	06-20-90	20	06-20-90
47-099-14abc02	W	1,180	1956	S	5,550	F	09-16-70	--	--
47-099-16ccc01	W	150	--	S	5,815	25.84	06-20-90	10	06-20-90

Table 6. *Records of selected wells and springs in Hot Springs County--Continued*

Local number	Type of site	Depth of well (ft)	Year drilled	Primary use of water	Altitude of land surface (ft)	Static water level [ft above (+) or below land surface]	Static water level Date	Discharge (gal/min)	Discharge Date
				Cody Shale					
42-091-15bab01	W	120	--	U	5,108	3.46	09-13-90	--	--
43-092-24adb01	W	123	--	S	4,735	66.90	08-21-90	4.0	08-21-90
43-094-05dad01	W	30	1947	H	4,280	9.00	01-10-47	--	--
43-094-06abd01	W	108	--	H	4,365	57.84	04-15-46	--	--
43-094-06daa01	W	76	--	S	4,361	26.64	05-02-46	--	--
43-094-07ada02	W	200	--	--	4,325	12.55	01-10-47	--	--
43-094-07caa01	W	100	--	H	4,349	26.80	04-22-46	--	--
43-094-07cda01	W	63	--	H	4,353	20.45	04-29-46	--	--
43-094-07ddd01	W	42	--	S	4,336	31.71	04-29-46	--	--
43-094-18aad01	W	--	--	S	4,349	51.92	05-27-46	--	--
43-095-01dca01	W	50	--	S	4,360	8.33	04-15-46	--	--
43-095-12acd01	W	52	1946	H	4,366	8.84	04-29-46	--	--
43-095-12bcc02	W	53	--	H	4,389	19.55	04-17-46	--	--
43-097-05bca02	W	98	--	H	5,176	20.67	04-24-46	--	--
43-098-03aca01	W	125	--	H	5,390	44.16	04-25-46	--	--
43-098-03aca02	W	--	--	S	5,390	33.74	04-25-46	--	--
43-098-03acd01	W	60	1946	H	5,371	11.44	04-25-46	--	--
						12.26	06-22-89	--	--
44-094-31adb01	W	42	--	S	4,329	27.98	05-28-46	--	--
44-094-32bbb01	W	--	--	H	4,308	41.69	05-28-46	--	--
46-098-27dcc01	W	80	1952	S	5,435	--	--	--	--
8N-3E-14bdd01	W	130	--	H	5,000	--	--	--	--
9N-2E-32cbb02	W	80	--	H	5,623	5.91	04-26-46	--	--
9N-2E-34adc01	W	120	--	H	5,447	8.67	05-20-46	--	--
9N-2E-34cab01	W	90	--	H	5,481	13.24	04-25-46	--	--
9N-2E-35bcc01	W	53	1945	H	5,438	9.27	04-25-46	--	--
9N-3E-30cba02	W	--	--	S	5,290	13.10	04-25-46	--	--
				Frontier Formation					
41-090-04baa01	S	--	--	S	6,538	--	--	38	09-14-90
42-091-35acc01	S	--	--	S	6,280	--	--	9.0	09-14-90
42-092-02cbb01	W	600	1964	S	4,950	F	07-09-70	2.0	07-09-70
						F	08-22-90	2.2	08-22-90
42-092-08ddd01	W	254	--	S	4,990	F	07-25-89	1.0	07-25-89
42-092-12cda01	W	381	1985	H	4,890	F	08-22-90	4.0	08-22-90
43-092-04bda01	W	--	1968	S	4,610	F	08-21-90	7.0	07-31-69
						--	--	8.5	08-22-90
43-092-22cdb01	W	--	--	S	4,635	F	08-22-90	9.0	08-22-90
43-096-23abc01	W	75	--	H	4,679	26.72	04-18-46	--	--

Table 6. *Records of selected wells and springs in Hot Springs County--Continued*

Local number	Type of site	Depth of well (ft)	Year drilled	Primary use of water	Altitude of land surface (ft)	Static water level [ft above (+) or below land surface]	Static water level Date	Discharge (gal/min)	Discharge Date
Frontier Formation--Continued									
44-093-33dac01	W	1,490	--	S	4,405	F	08-23-90	1.2	08-23-90
44-093-34dcc01	W	1,390	1951	H	4,435	F	08-23-90	2.7	08-23-90
44-098-23ada01	W	2,910	1958	H	5,590	--	--	--	--
8N-2E-11bac01	S	--	--	S	5,780	--	--	.6	06-22-89
8N-2E-12bcc01	S	--	--	S	5,740	--	--	1.2	06-21-89
8N-3E-03bda01	W	130	1983	H	5,120	25.11	01-05-89	4.0	09-13-83
8N-3E-04aab01	W	95	--	S	5,171	31.93	04-19-46	--	--
8N-4E-07cab02	W	440	--	S	4,964	+5.06	05-02-46	--	--
8N-4E-07cba01	W	--	--	U	4,949	17.15	08-11-45	--	--
8N-4E-14bbb01	W	40	--	S	4,773	21.65	08-11-45	--	--
8N-4E-15acc01	W	--	--	S	4,840	24.42	05-15-46	--	--
8N-4E-15add01	W	175	--	H	4,853	54.40	05-14-46	--	--
8N-4E-15bcd01	W	86	--	S	4,849	17.80	05-13-46	--	--
8N-4E-15bcd02	W	80	--	U	4,862	26.92	05-15-46	--	--
9N-3E-32ddd01	W	--	--	S	5,300	47.40	03-07-89	--	--
9N-3E-33ccc01	W	--	--	H	5,260	--	--	--	--
Mowry Shale									
41-091-09cca01	S	--	--	H	5,885	--	--	1.5	08-23-90
42-092-29abc01	S	--	--	S	5,575	--	--	--	--
42-092-34bab01	W	150	--	S	5,400	F	08-11-89	5.0	08-11-89
42-093-07cdc01	S	--	--	S	5,430	--	--	<.1	07-25-89
42-094-12cdc01	S	--	--	S	5,335	--	--	<.1	07-25-89
Thermopolis Shale									
41-092-11abd01	W	80	--	H	5,510	26.65	07-27-89	5.0	07-27-89
41-092-11adb01	S	--	--	U	5,510	--	--	5.0	07-27-89
43-096-13bcd01	W	129	--	H	4,674	60.55	04-23-46	--	--
Muddy Sandstone Member of the Thermopolis Shale									
43-091-19daa02	W	1,240	--	S	4,965	F	07-13-70	1.0	07-13-70
43-091-36bca01	W	683	--	N	5,630	300.0	08-15-47	8.0	08-15-47
Mowry and Thermopolis Shales									
8N-2E-13aba01	S	--	--	S	5,860	--	--	.2	06-21-89
8N-3E-30bca01	S	--	--	S	5,840	--	--	16	06-21-89
8N-3E-32abc01	S	--	--	S	5,940	--	--	4.0	06-21-89
Cloverly Formation									
42-094-07bac01	W	75	1955	S	4,670	--	--	--	--
42-095-03aac01	W	183	1988	S	4,615	F	07-27-90	8.0	07-27-90
43-094-13add01	W	559	1967	--	4,750	35.87	07-15-70	21	07-15-70

Table 6. *Records of selected wells and springs in Hot Springs County--Continued*

Local number	Type of site	Depth of well (ft)	Year drilled	Primary use of water	Altitude of land surface (ft)	Static water level [ft above (+) or below land surface]	Static water level Date	Discharge (gal/min)	Discharge Date
				Sundance Formation					
41-091-13cdc01	S	--	--	S	6,390	--	--	6.0	09-11-89
				Gypsum Spring Formation					
41-091-23ddd01	S	--	--	S	6,180	--	--	28	09-13-89
41-091-32aac01	S	--	--	S	5,870	--	--	5.0	09-13-89
42-092-18caa01	S	--	--	S	5,450	--	--	8.0	09-15-89
42-094-15dad01	S	--	--	S	5,010	--	--	4.0	09-12-89
				Chugwater Formation					
41-091-27dbc01	S	--	--	S	5,800	--	--	50	09-14-89
41-091-27dcc01	S	--	--	S	5,780	--	--	25	09-13-89
41-091-32cad01	W	68	--	H	6,030	13.00	09-13-89	2.0	09-13-89
41-092-04bcb01	W	210	--	S	6,150	169.0	09-15-89	6.0	09-15-89
42-093-14ccb01	W	127	--	S	5,108	111.5	07-26-89	10	07-26-89
42-093-20caa01	W	127	--	S	5,015	100.5	07-26-89	1.0	07-26-89
42-093-21acc01	W	183	--	S	5,043	165.0	07-26-89	10	07-26-89
42-093-22bbc01	W	287	--	S	5,082	163.1	07-26-89	--	--
42-094-17ddc01	S	--	--	H	4,635	--	--	1.0	07-26-89
42-094-19adc01	W	54	--	S	4,400	30.30	07-27-89	--	--
42-094-25aad01	W	112	--	S	4,910	91.20	07-26-89	--	--
42-094-25bdb01	W	260	--	S	4,970	128.7	07-25-89	5.0	07-25-89
43-099-10dba01	W	400	--	U	5,782	11.25	08-10-45	--	--
6N-5E-04dcd01	S	--	--	H	5,950	--	--	2.0	07-28-89
6N-5E-09adb01	S	--	--	S	5,840	--	--	8.0	07-28-89
7N-5E-31cda01	S	--	--	S	5,315	--	--	6.0	07-28-89
				Phosphoria Formation					
41-090-29dbc01	S	--	--	S	6,440	--	--	102	09-14-89
42-093-29bdb01	W	627	--	S	5,041	--	--	.5	07-26-89
42-095-25bca01	S	--	--	I	4,380	--	--	1,000	07-07-70
						--	--	280	07-24-89
42-095-26aad01	W	20	--	S	4,390	8.73	07-28-89	5.0	07-28-89
43-095-25cdc01	W	228	--	U	4,700	114.1	07-15-83	--	--
46-100-24cca01	W	6,200	1966	--	6,560	--	--	--	--
				Tensleep Sandstone					
41-093-08bbc01	W	600	--	U	5,970	498.5	08-08-89	--	--
41-093-08cba01	W	230	1962	U	6,028	199.1	07-26-89	--	--
41-094-21cda01	S	--	--	S	6,180	--	--	25	08-08-89
41-094-27aaa01	S	--	--	S	6,480	--	--	5.0	08-08-89
42-094-26cac01	W	550	--	H	4,850	289.1	07-25-89	2.0	07-25-89

Table 6. *Records of selected wells and springs in Hot Springs County--Continued*

Local number	Type of site	Depth of well (ft)	Year drilled	Primary use of water	Altitude of land surface (ft)	Static water level [ft above (+) or below land surface]	Static water level Date	Discharge (gal/min)	Discharge Date
				Tensleep Sandstone--Continued					
42-095-13dca01	W	1,140	1952	S	4,370	--	--	5.0	06-25-70
43-095-18cab01	W	354	--	U	4,700	248.8	09-15-84	--	--
42-096-12ccd01	W	1,160	1966	--	5,240	--	--	--	--
				Madison Limestone					
46-098-28bcc01	W	6,000	1956	--	5,510	--	--	284	06-07-67
				Bighorn Dolomite					
41-092-17ddd01	S	--	--	S	6,700	--	--	6.0	09-15-89
41-092-27dac01	S	--	--	S	6,710	--	--	5.0	08-10-89
41-092-28aaa01	S	--	--	H	7,180	--	--	1.0	09-15-89
41-093-21bcd01	S	--	--	S	6,270	--	--	5.0	08-08-89
41-093-21dcb01	S	--	--	S	6,310	--	--	22	08-08-89
41-093-23aad01	S	--	--	S	6,720	--	--	1.0	07-26-89
46-098-18cbb01	W	5,800	1964	--	5,710	1,220	09-17-70	323	09-17-70
				Gallatin Limestone					
6N-6E-15cca01	W	90	--	H	4,580	64.00	09-12-89	8.0	09-12-89
				Gros Ventre Formation					
41-093-32aab01	S	--	--	S	6,670	--	--	3.0	08-09-89
43-093-28ccd01	W	2,960	1964	U	5,355	--	--	110	02-06-70
				Flathead Sandstone					
41-092-33daa01	S	--	--	S	6,940	--	--	15	08-10-89
41-093-25cac01	S	--	--	S	7,050	--	--	7.5	09-14-89
41-093-31dcd01	S	--	--	S	6,685	--	--	15	08-09-89

Most of the geologic units listed in table 5 will yield water for local stock and domestic purposes. However, fewer than 12 geologic units are developed as water sources regionally (Libra and others, 1981, p. 40). Records of selected wells completed in and springs that issued from 23 geologic units are listed in table 6. Wells and springs located in Quaternary deposits were identified in the field as being completed in alluvium or terrace deposits. Only Quaternary alluvium, Quaternary terrace deposits, Fort Union Formation, Mesaverde Formation, Cody Shale, Frontier Formation, and Chugwater Formation have 10 or more inventoried wells and springs.

Libra and others (1981, p. 21) grouped geologic units in the Bighorn Basin into aquifer systems according to their areal extent, hydrologic properties, and recharge/discharge mechanisms. A similar grouping has been used in this report to organize the following discussions and the water-quality analysis and discussion. The geologic units were grouped as Quaternary unconsolidated deposits, Tertiary rocks, Upper Cretaceous rocks, Mesozoic rocks, and Paleozoic rocks.

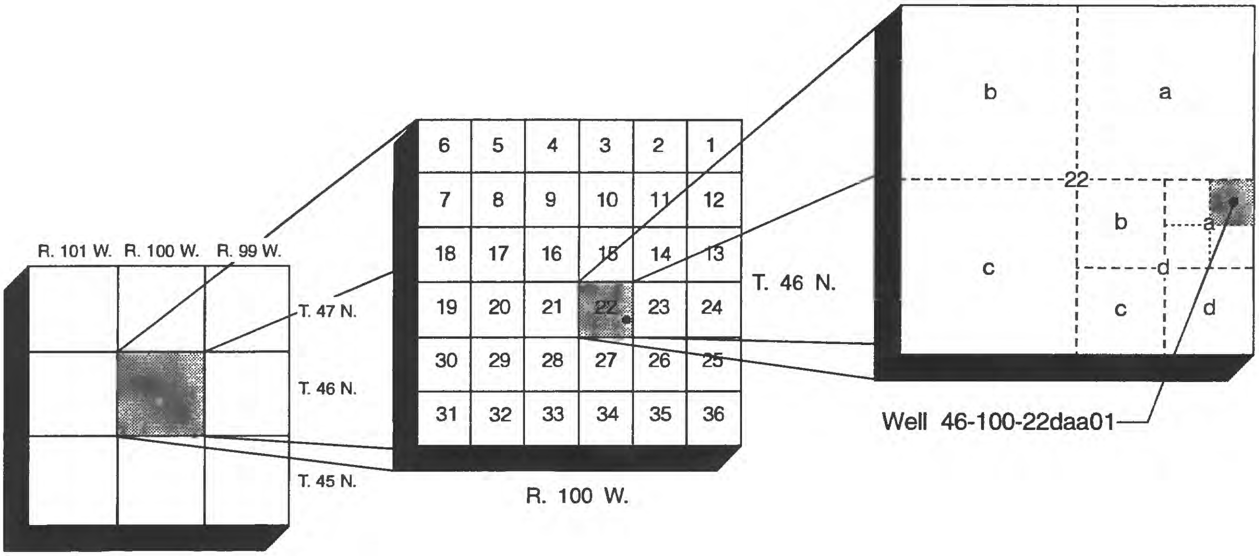


Figure 9.--System for numbering wells and springs.

Quaternary Unconsolidated Deposits

Quaternary unconsolidated deposits include alluvium and colluvium, gravel, pediment, and fan deposits, and landslide deposits. Wells and one spring completed in and issuing from the Quaternary alluvium are listed in table 6. Wells completed in Quaternary terrace deposits also are listed in table 6. The distinction was not made whether the well was completed in terrace deposits of the Quaternary alluvium and colluvium or Quaternary gravel, pediment, and fan deposits. Discharge points from Quaternary landslide deposits were not inventoried. Lithologic and water-yielding characteristics of the gravel, pediment, and fan deposits, and landslide deposits are described in table 5.

Quaternary alluvium and colluvium is composed of unconsolidated clay, silt, sand, and gravel and terrace deposits. The terrace deposits are similar in lithologic composition to that of the alluvium (table 5). Quaternary alluvium and colluvium in the county primarily are found along the Wind/Bighorn River, and Owl, Cottonwood, Grass, and Gooseberry Creeks (pl. 1 and pl. 2). The range of thickness of the alluvium and colluvium in the Bighorn Basin is 0 to 100 ft (Libra and others, 1981, p. 41).

Depth to water in wells completed in alluvium ranged from less than 3 ft to about 65 ft below land surface; median depth to water was 12 ft below land surface (table 6). Depth to water was measured in fewer wells completed in terrace deposits than in wells in the alluvium. Depth to water in these wells ranged from less than 2 ft to about 27 ft below land surface; median depth to water was 11 ft below land surface.

Most common water yields from alluvium and colluvium were reported to be less than 50 gal/min (Libra and others, 1981, p. 41). During this study, discharges measured from four wells completed in alluvium and colluvium were less than 5 gal/min (table 6). A discharge of 140 gal/min was reported in 1955 from a well (9N-2E-33cdd01) completed in the alluvium along Owl Creek. The maximum discharge in the county from a well (43-096-17bbb03) completed in terrace deposits along Owl Creek was an estimated 400 gal/min in 1965. The measured discharge in 1970 from a well (43-097-11acc01) completed in terrace deposits in the same general area was only 16 gal/min.

Tertiary Rocks

Tertiary rocks in the county include intrusive rocks, the Wagon Bed Formation, the Absaroka Volcanic Supergroup, and the Tatman, Willwood, and Fort Union Formations. Little is known about the water-yielding characteristics of most of the Tertiary rocks. Favorable water yields are not expected from most of the Tertiary rocks because of their crystalline or fine-grained texture; therefore, few wells are completed in the Tertiary rocks. Sandstone units that occur in most of the Tertiary rocks might yield enough water for stock or domestic purposes. In Tertiary intrusive rocks, permeability produced by weathering and fracturing might yield water to shallow wells and springs. No wells or springs that were completed in or issued from Tertiary intrusive rocks were found during this study. The Tatman Formation is not considered a potential aquifer because of its small areal extent in the northern part of the county.

Of the Tertiary rocks, the only sites inventoried in the county during this study were wells completed in and springs that issued from the Absaroka Volcanic Supergroup and the Fort Union Formation. The Absaroka Volcanic Supergroup, composed of the Wiggins, Tepee Trail, and Aycross Formations, represents a potential, but currently undeveloped, ground-water source (Libra and others, 1981, p. 23) in the western part of the county. The Fort Union Formation is exposed at the surface in two synclinal areas in the northern part of the county and in a band near the county boundary from the north to the northeast (pl. 1). In that outcrop band, the Fort Union Formation dips to the northeast toward the center of the Bighorn Basin. The Fort Union Formation might yield enough water from sandstones for domestic or stock purposes.

Ground water from the Absaroka Volcanic Supergroup and the Fort Union Formation is used mostly for stock purposes. Four springs that issued from the Absaroka Volcanic Supergroup were inventoried in 1989 and 1990 (table 6). All of the springs discharged water at a rate less than 2 gal/min. Eight wells completed in and two springs that issued from the Fort Union Formation are listed in table 6. Depth to water in seven wells completed in the Fort Union Formation ranged from less than 27 ft to 129 ft below land surface (table 6). The median depth to water was 63 ft below land surface. The maximum discharge measured from three wells was 12 gal/min. Most common water yields from the Fort Union Formation in the Bighorn Basin were reported to be less than 20 gal/min (Libra and others, 1981, p. 41).

Upper Cretaceous Rocks

Upper Cretaceous rocks in the county are the Lance, Meeteetse, and Mesaverde Formations and the Cody Shale. Libra and others (1981, p. 23) considered the Cody Shale a regional confining bed separating the overlying Upper Cretaceous and Tertiary aquifer systems from the underlying Mesozoic and Paleozoic aquifer systems. However, 26 wells completed in the Cody Shale were inventoried during this study. Because of its significance in the county as a water supply for stock and domestic purposes, the Cody Shale was included with the Upper Cretaceous rocks in this report. These rocks crop out in a band from northwest to southeast across the northern part of the county and dip generally to the northeast towards the center of the Bighorn Basin (pl. 1). Ground water from all the Upper Cretaceous rocks is used mostly for stock and domestic purposes.

Generally, the Lance, Meeteetse, and Mesaverde Formations consist of lenticular, interfingering beds of claystone, siltstone, shale, and sandstone (Libra and others, 1981, p. 67). Thin coal beds are found in all three formations, and massive sandstone deposits are found in the Lance and Mesaverde Formations. The Cody Shale is composed of a thick (2,100 to 3,000 ft) sequence of marine shale (Libra and others, 1981, p. 23).

The massive sandstone at the base of the Lance Formation might be a potential source of water for domestic and stock use. However, little is known about the depth to water or the water-yielding characteristics of the Lance Formation in the county. Only two wells completed in the Lance Formation were inventoried during this study. One well is 110 ft deep, and depth to water was 70 ft; the other is 266 ft deep, and depth to water was 74 ft (table 6).

During this study, six wells completed in and one spring that issued from the Meeteetse Formation were inventoried. Well depths ranged from 100 to 320 ft. Depth to water in four of these wells ranged from 8 to 263 ft, and one well (46-100-22daa01) was flowing when inventoried in June, 1990. Discharge from four wells and one spring ranged from 3.5 to 10 gal/min.

Sandstone layers in the upper and lower parts of the Mesaverde Formation are the most likely sources of water in that formation. Depths of wells completed in the Mesaverde typically varied from 120 to 350 ft (table 6), although one well was 1,179 ft deep. The median depth to water in 8 wells was 50 ft below land surface; the range was 9 to 80 ft below land surface. Most common water yields from the Mesaverde Formation ranged from 5 to 10 gal/min (Libra and others, 1981, p. 42). Discharge from 8 wells completed in and 2 springs that issue from the Mesaverde Formation and were inventoried during this study ranged from 5 to 50 gal/min (table 6).

Twenty-six inventoried wells completed in the Cody Shale ranged from 30 to 200 ft deep. The median depth to water was 20 ft below land surface and ranged from less than 4 to almost 67 ft below land surface. Information is limited about the water-yielding characteristics of wells completed in the Cody Shale.

Mesozoic Rocks

The Mesozoic rocks consist of sandstone and shale from the Upper Cretaceous Frontier Formation through the Triassic Dinwoody Formation. These geologic units, folded into synclines and anticlines, crop out from east to west across the central and southern parts of the county (pl.1).

Fine-grained units in this sequence may act as confining layers on a regional scale, but enhanced permeabilities in fractured zones, along bedding planes, and within coarser clastic beds (Berry and Littleton, 1961, p. 19) may produce small water yields locally. In the Mesozoic rocks, most wells and springs inventoried in table 6 were completed in and issued from the Frontier and Chugwater Formations. Other Mesozoic rocks inventoried included the Mowry and Thermopolis Shales (including the Muddy Sandstone Member of the Thermopolis Shale), the Cloverly, Sundance, and Gypsum Spring Formations.

Water in the Frontier Formation occurs under artesian conditions at some places in the county and under water-table conditions at other places. The Cody Shale in the Kirby Creek area acts as a confining bed for the underlying Frontier Formation. During this study, shut-in pressures were not measured in seven wells that flowed at the surface; therefore, potentiometric heads could not be computed. However, in 1946 a potentiometric head of 5 feet above land surface was measured in well 8N-4E-07cab02 (table 6). Depth to water in most of the other wells completed in the Frontier Formation varied from 17 to 54 ft below land surface.

Discharge from most wells completed in and springs that issued from the Frontier Formation was less than 10 gal/min. The maximum discharge (38 gal/min) was measured in 1990 from a spring in the eastern part of the county (table 6).

Ground water in the Chugwater Formation is used mostly for stock water (table 6). The maximum well depth inventoried from wells completed in the Chugwater Formation was 400 ft; the minimum was 54 ft. Depth to water ranged from 11 to 169 ft below land surface; the median depth to water was 106 ft below land surface. The discharge for most wells and springs was 10 gal/min or less. The maximum discharge (50 gal/min) was measured in 1989 from a spring in the eastern part of the county.

Paleozoic Rocks

Paleozoic rocks from the Phosphoria Formation through the Flathead Sandstone are composed mostly of sandstone, limestone, and dolomite. These rocks are exposed along the flanks of the Owl Creek and Bridger Mountains. Most ground-water development is in the outcrop area. Because of the steep dip of these beds toward the center of the Bighorn Basin, the Paleozoic rocks beyond the outcrop area presently are too deep to drill economically for domestic or stock use. Generally, private landowners have not drilled wells for domestic or stock use completed in Paleozoic rock deeper than 1,000 ft.

Inventoried wells completed in and springs that issue from the Paleozoic rocks include the Phosphoria Formation, Tensleep Sandstone, Madison Limestone, Bighorn Dolomite, Gallatin Limestone, Gros Ventre Formation, and the Flathead Sandstone (table 6). Wells completed in these units may be as shallow as 20 ft or as deep as 6,200 ft. Water levels also were variable, ranging from about 9 to 1,220 ft below land surface. Discharge from wells and springs ranged from 0.5 to 1,000 gal/min.

Recharge, Movement, and Discharge

Aquifers in geologic units of unconsolidated and consolidated deposits are recharged by precipitation, streamflow leakage, irrigation, and subsurface inflow from other aquifers. Quaternary unconsolidated deposits in the county usually are recharged by leakage from streams, by precipitation, and, in agricultural areas, by seepage from irrigation and irrigated lands (Berry and Littleton, 1961, p. 27). Individual geologic units might be recharged by leakage from overlying saturated alluvium or terrace deposits or through fractured zones along anticlinal structures (Lowry and others, 1976). For example, in the Owl Creek drainage basin, the water in the Cody Shale and Frontier and Cloverly Formations is recharged locally by leakage from overlying saturated alluvium or terrace deposits (Berry and Littleton, 1961, p. 24). The potential for additional recharge to overlying geologic units along anticlinal structures is created by fractured zones and artesian conditions between the Phosphoria Formation, Tensleep Sandstone, Madison Limestone, and Bighorn Dolomite.

Ground-water movement is controlled by the location of recharge and discharge areas and by the thickness and permeability of the geologic unit. Primary permeability is a function of the grain size, sorting, and cementation between grains. Secondary permeability created by fracturing and dissolution also is an important factor controlling ground-water movement. Fractures along anticlines can provide important conduits for vertical and horizontal ground-water flow.

Ground-water movement in alluvium usually is toward local streams. Ground-water movement in the terrace deposits and alluvium along Owl Creek generally follows the same direction as the creek and toward the Bighorn River (Berry and Littleton, 1961, p. 26). Conditions that can affect movement include losing streams that recharge alluvium, pumping wells, and topographic variations in the bedrock. Water in the Tertiary, Upper Cretaceous, Mesozoic, and Paleozoic rocks generally flows to the north toward the center of the Bighorn Basin. Ground-water movement in the Tensleep Sandstone was mapped by Bredehoeft and Bennett (1971), and is from the south and west part of the county toward the center of the Bighorn Basin to the north and east. Ground-water movement in other Paleozoic rocks is assumed similar to that in the Tensleep Sandstone (Lowry and others, 1976).

Ground water is discharged through pumped wells and is naturally discharged by springs and seeps, by evapotranspiration, and by discharge to streams and other geologic units. Springs and seeps occur when the water table intersects the land surface. This is the result of changes in lithology within a geologic unit or between geologic units, faults and fractures, and topography. Evaporation from soils and transpiration by plants can be important processes for the removal of water from geologic units. Ground water also is discharged by evaporation and transpiration when the water table is close to the land surface, which is most likely to be the case in the alluvium near streams. Discharges to streams from geologic units, including the alluvium, occurs when the water-surface gradient in the geologic unit is above and sloping toward the stream.

Water-Level Changes

Ground-water levels fluctuate in response to changes in recharge and discharge. For example, infiltration of precipitation can result in water-level rises. Conversely, recharge can decrease or cease completely during droughts, resulting in water-level declines. A comparison of precipitation at the Thermopolis weather station and water-level changes in four wells that were completed in Quaternary alluvium and terrace deposits, the Cody Shale, and the Frontier Formation along Owl Creek indicates that water levels in all four wells fluctuate in response to changes in precipitation (fig. 10). The variation in precipitation at Thermopolis between 1946 and 1952 generally was parallel to the water-level changes in all four wells during the same time period. The water levels shown in figure 10 were used by Berry and Littleton (1961) in the study of the Owl Creek drainage-basin area. They estimated 1 inch or less of recharge in the Owl Creek area from a normal annual precipitation of 13 inches (Berry and Littleton, 1961, p. 27). However, in irrigated areas of Owl Creek, they considered leakage from irrigation canals, laterals, and irrigated fields a more important source of recharge.

Water-level changes in response to precipitation are affected by the hydraulic properties of the geologic unit in which the well is completed. Permeabilities in Quaternary unconsolidated deposits as high as 4,400 gal/d/ft^2 were reported by Libra and others, 1981, p. 41. Water levels in wells 9N-1E-36ccc01 and 43-096-14bda01 (fig. 10) respond shortly after precipitation occurs. Water levels in well 8N-4E-14bbb01, completed in the Frontier Formation, show a delayed and subdued response to precipi-tation because this consolidated geologic unit is composed of lenticular fine- to medium-grained sandstone. Thus, the Frontier Formation's ability to transmit water (maximum permeability 1.4 gal/d/ft^2, Libra and others, 1981, p. 42) is several orders of magnitude less than that of the Quaternary unconsolidated deposits. Well 9N-2E-34cbb02, completed in both the Cody Shale and the Quaternary alluvium deposits, reflects a better water-level response to precipitation than if the well were completed only in the Cody Shale (fig. 10).

Graphs of water-level changes in two wells completed in Paleozoic rocks, and monthly and annual precipitation at Thermopolis from 1983 to 1987, are shown in figure 11. Well 43-095-25cdc01 is completed in the Phosphoria Formation, and well 43-095-18cab01 is completed in the Tensleep Sandstone. Automatic digital recorders were used to measure the maximum daily water level in each well. Maximum monthly water levels for each well from 1983 to 1987 are shown in figure 11.

Water-level changes in response to monthly precipitation are not evident in wells completed in the Phosphoria Formation and the Tensleep Sandstone. However, water-level changes compared to changes in annual precipitation showed about a one-year delay. Water levels in wells in both formations declined in 1985 after annual precipitation decreased in 1984 (fig. 11). Water levels began to rise in 1986 following the increased

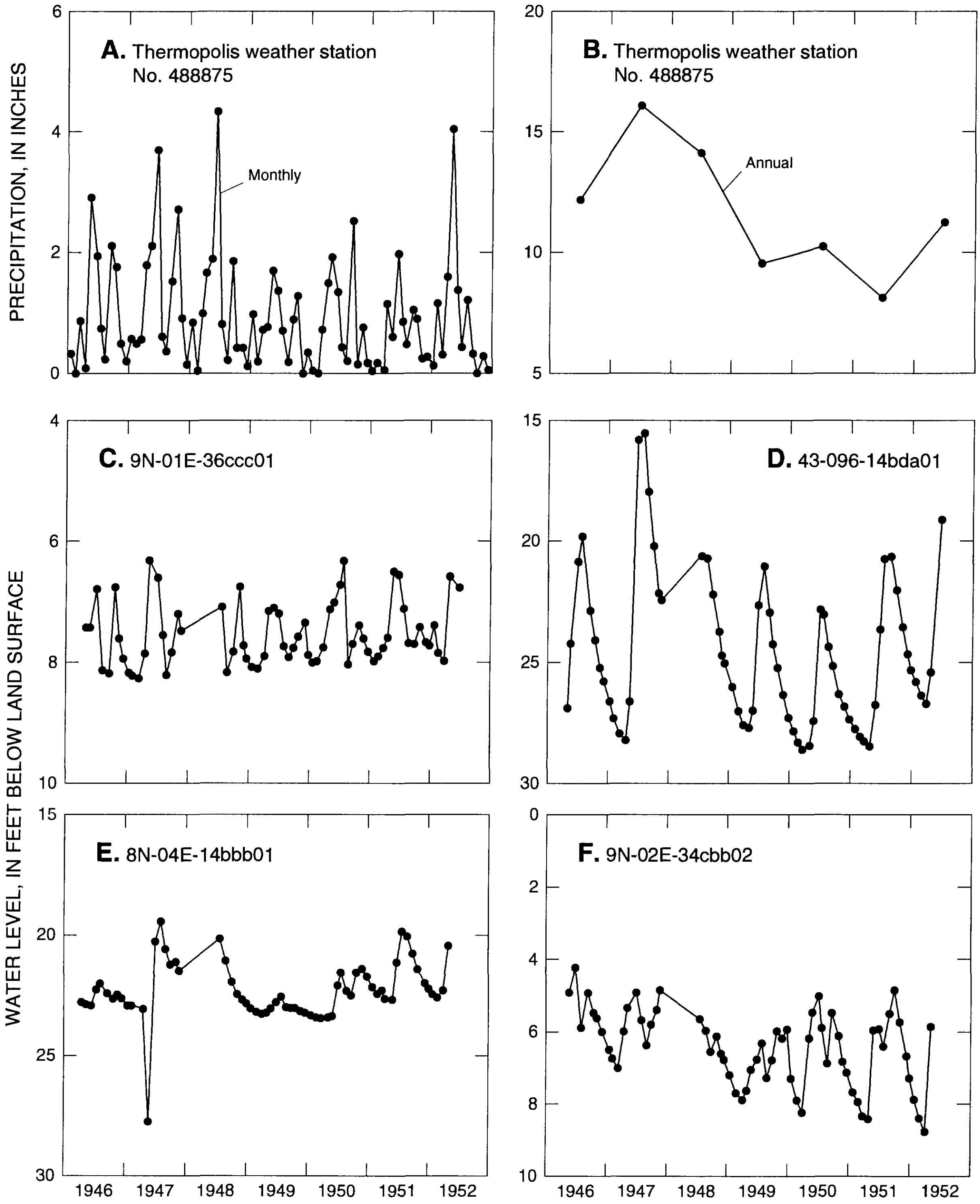


Figure 10.--**A**, Monthly precipitation: **B**, annual precipitation, and instantaneous water levels in wells completed in **C**, Quaternary alluvium; **D**, Quaternary terrace deposits; **E**, Frontier Formation; **F**, Cody Shale and Quaternary alluvium, 1946-52. Source: Ringen (1973).

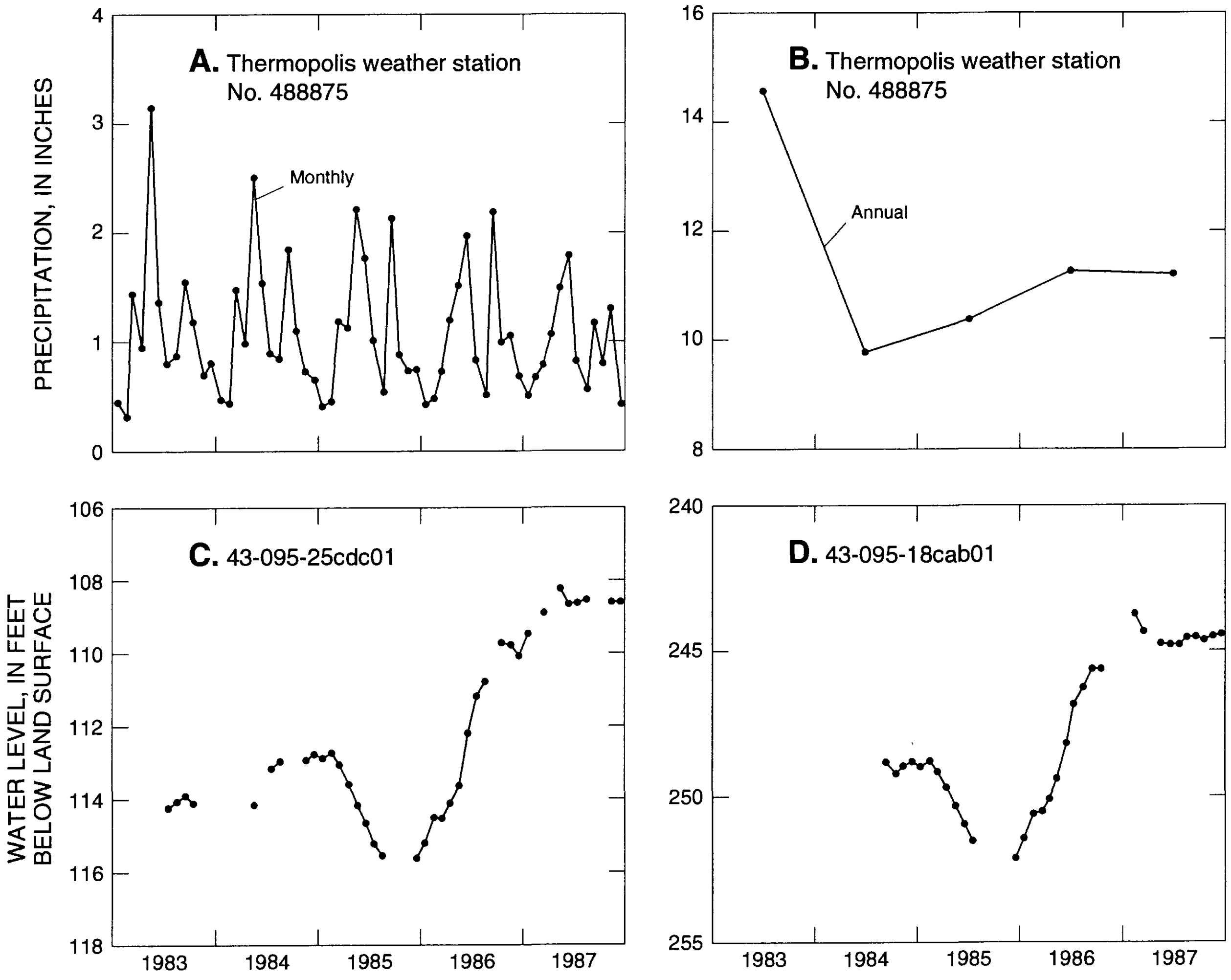


Figure 11.--**A**, Monthly precipitation: **B**, annual precipitation, and maximum monthly water levels in wells completed in **C**, Phosphoria Formation and **D**, Tensleep Sandstone, 1983-87.

precipitation in 1985. The similar response to changes in precipitation in both wells indicates that the Phosphoria Formation and the Tensleep Sandstone might be hydraulically connected in the area of these two wells.

Hydrothermal Resources

Thermal springs are present at Hot Springs State Park near Thermopolis (fig. 12). Numerous thermal springs and wells in the park and vicinity produce about 4,900 gal/min of water from the Chugwater Formation at temperatures of 115 to 132°F (46 to 56°C) (Hinckley and others, 1982, p. 5). However, Hinckley and others (1982, p. 24-34) reported interformational flow from the underlying Paleozoic rocks, such as the Phosphoria Formation, Tensleep Sandstone, and the Madison Limestone, to be the source of the water. In the park, water from the largest thermal spring, Big Spring, supplies nearby pools at public and private facilities. The travertine terraces formed by the thermal springs, variously colored by algae and bacteria that inhabit the terraces, provide an additional tourist attraction to the area. Several Thermopolis area residences and facilities near the park are heated by geothermal water from wells less than 1,000 ft deep (Hinckley and others, 1982, p. 2).

Many studies have been conducted in the area by the U.S. Geological Survey, the Wyoming State Engineer's office, consultants, graduate students, and other State and Federal agencies in an attempt to better understand the Thermopolis hydrothermal system. A concern to State, County, and local managers has been the effect of oil- and gas-development at Hamilton Dome, which produces water from the Phosphoria Formation, Tensleep Sandstone, and the Madison Limestone and hydrothermal well development near Thermopolis on thermal spring discharges at Hot Springs State Park. This section focuses on the effect of oil- and gas-development at Hamilton Dome on the water resources.

Bredehoeft and Bennett (1971) constructed a map of the potentiometric surface of the Tensleep Sandstone before oil field development in the Bighorn Basin. Contours of the potentiometric surface presented in their report indicate the presence of a ground-water ridge separating the Hamilton Dome oil field from the Thermopolis hydrothermal system (fig. 13). Hydraulic head data measured in the 1940s and 1950s in wells in the Hamilton Dome oil field were used by Bredehoeft and Bennett (1971) to calculate potentiometric head. In this report, an estimate of the pre-oil-field development (1918) potentiometric head at Hamilton Dome oil field was made using drill-stem data from Bredehoeft and Bennett (1971) and Spencer (1986b) for wells that tested the Tensleep Sandstone during the period 1945 to 1984. The estimated 1918 head data generally support the general regional direction of ground-water flow indicated by Bredehoeft and Bennett (1971). The estimated drawdown from 1918, when the Hamilton Dome oil field was discovered, to 1988 is 330 ft. This estimated drawdown for the Hamilton Dome oil field is less than the drawdowns referenced by Spencer (1986a, p. 63) for other selected oil fields in the southwestern part of the Big Horn Basin.

Oil production from Hamilton Dome oil field for the period 1918 to 1988 was about 230 million barrels (Wyoming Oil and Gas Conservation Commission, 1988, p. 35). Discharge and specific conductance measurements made on Cottonwood Creek upstream and downstream of Hamilton Dome in 1977 and 1978 were evaluated. The difference in discharge between the upstream (site 17, table 1) and downstream (site 20, table 1) sites showed an increase in discharge of 5.3 ft^3/s at the downstream site in June, 1977 (U.S. Geological Survey, 1978 and 1980). On the basis of specific conductance of the water at the downstream site and the resistivity of the production water, the increase in streamflow is attributed to discharge of oil-field production water and amounts to 3,800 acre-ft/yr or 2,400 gal/min, which is less than the discharges used by Spencer (1986a, p. 96) in her numerical ground-water-flow model of the Thermopolis hydrothermal system. Spencer's model predicted a water-level decline of 3 ft at Thermopolis, near Big Spring, using a constant discharge of 5,000 gal/min from the Hamilton Dome oil field and variable transmissivities, both horizontally and vertically.

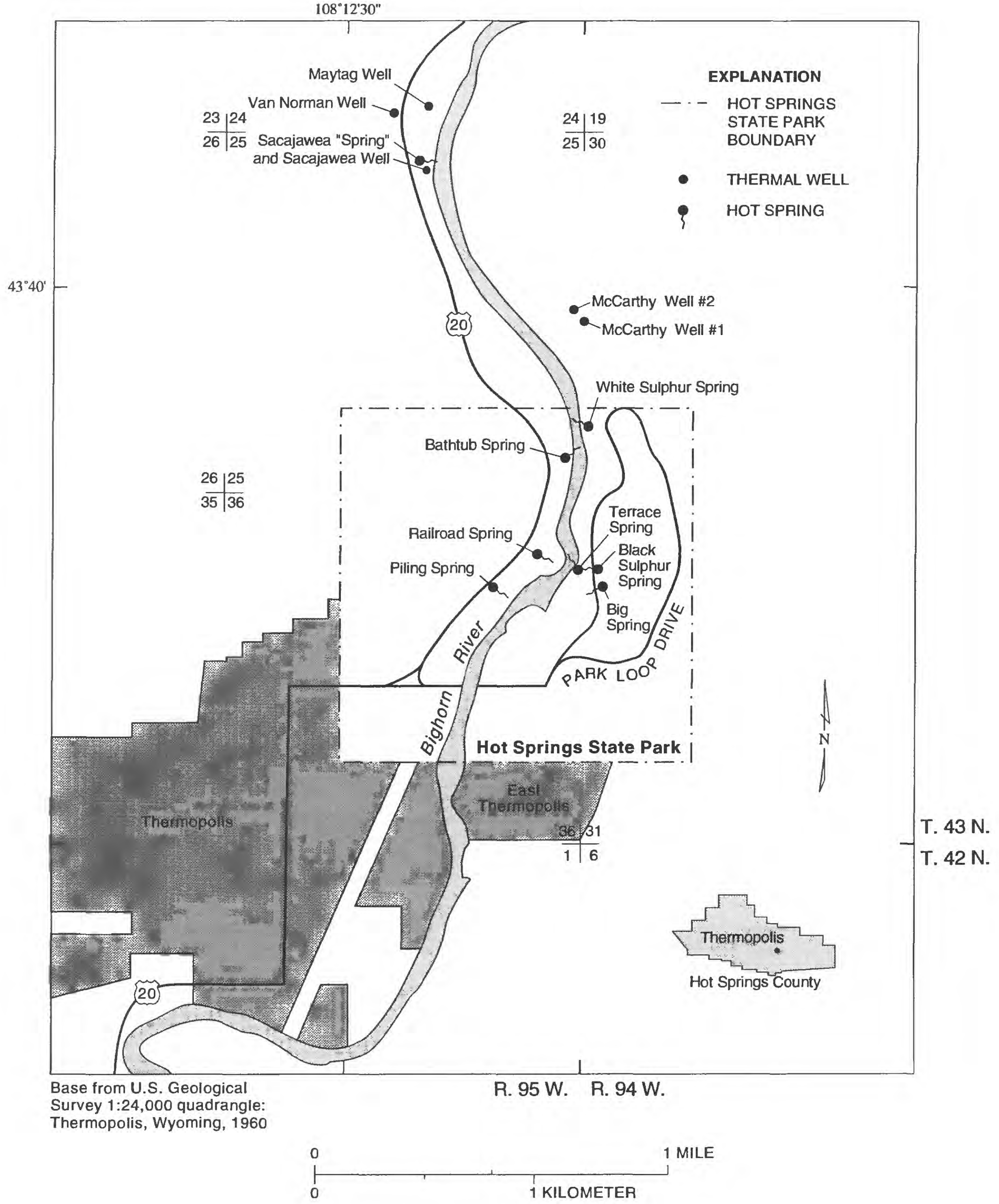
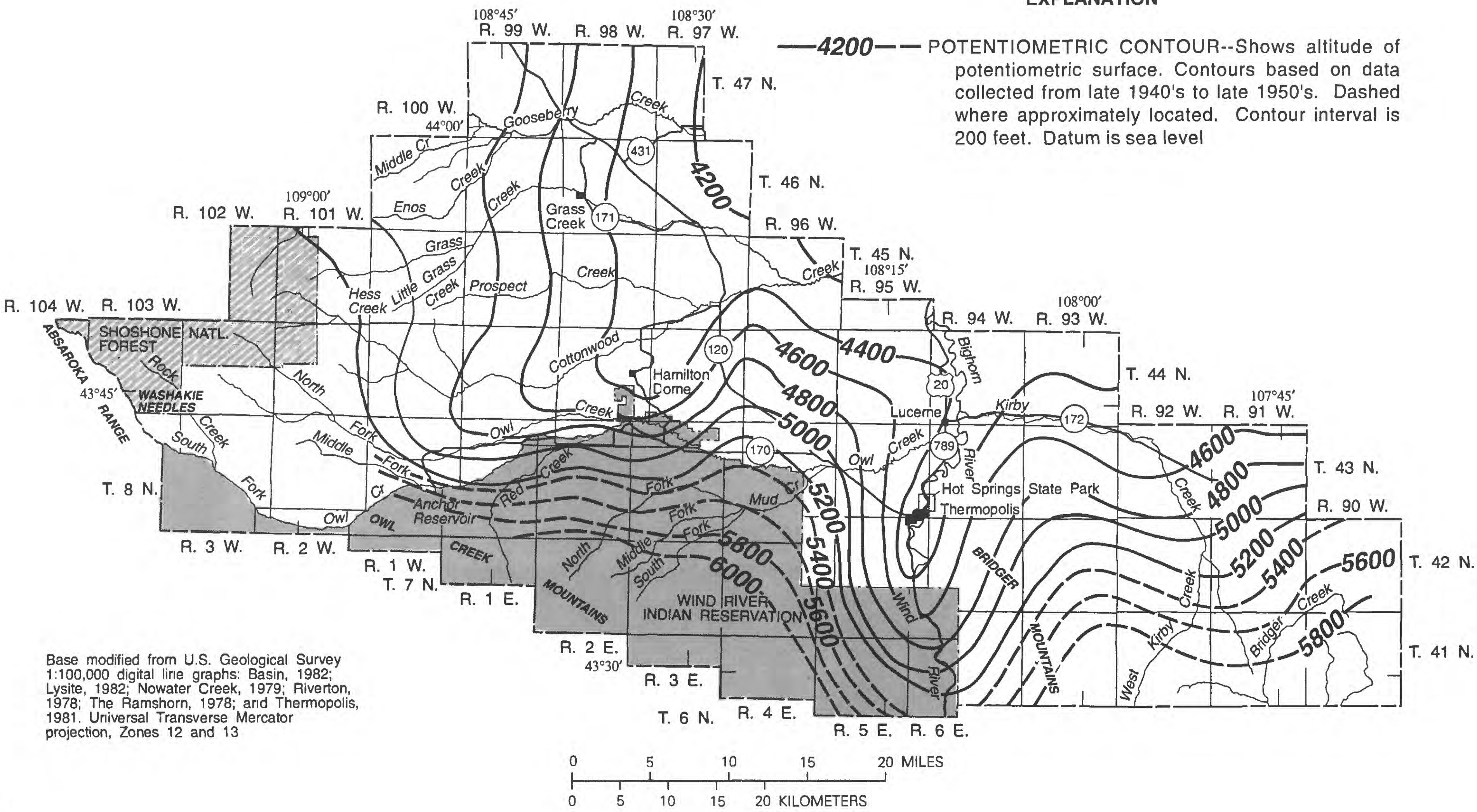


Figure 12.--Location of hydrothermal wells and springs in Hot Springs State Park and vicinity (modified from Spencer, 1986a, p. 66).

EXPLANATION

—4200— — POTENTIOMETRIC CONTOUR--Shows altitude of potentiometric surface. Contours based on data collected from late 1940's to late 1950's. Dashed where approximately located. Contour interval is 200 feet. Datum is sea level



Base modified from U.S. Geological Survey 1:100,000 digital line graphs: Basin, 1982; Lysite, 1982; Nowater Creek, 1979; Riverton, 1978; The Ramshorn, 1978; and Thermopolis, 1981. Universal Transverse Mercator projection, Zones 12 and 13

Figure 13.--Potentiometric surface of the Tensleep Sandstone (modified from Bredehoeft and Bennett, 1971).

The drawdown at the Hamilton Dome oil field was 500 ft. Therefore, if the estimated drawdown of 330 ft and a discharge of 2,400 gal/min at the Hamilton Dome oil field were used in Spencer's (1986a) model, the expected water-level decline at Thermopolis near Big Spring would be less than 3 ft.

Drill-stem-test data near the Hamilton Dome oil field, where only water was recovered during the tests, suggested that the Phosphoria Formation, Tensleep Sandstone, and Madison Limestone may be interconnected vertically as a result of fracturing and may be acting as a single aquifer. The vertical movement of water in the Hamilton Dome oil field would tend to reduce the areal effect of drawdown on the regional potentiometric surface. Long-term enhanced oil recovery also must be considered. The Phosphoria Formation producing unit produced 13,137,557 barrels of oil and water from 1973 to 1989 (U.S. Bureau of Land Management, written commun., 1990) and water injection was 168,410,501 barrels. An average of 1,200 acre-ft/yr of water was injected back into the aquifer system in excess of oil and water produced. An increase in enhanced oil recovery operation in the coming years, where more water is injected than oil and water produced, could reduce or stabilize drawdown of the regional potentiometric surface.

Total discharge of water from the Thermopolis hydrothermal system is about 4,900 gal/min (Hinckley and others, 1982, p. 5) or 7,900 acre-ft/yr. Thus, on the average, the Thermopolis hydrothermal system produces some 4,100 acre-ft/yr of water more than the average 3,800 acre-ft/yr of oil and water being produced from Hamilton Dome oil field. Drill-stem-test and production data presented in this report and the potentiometric surface of Bredehoeft and Bennett (1971) suggest that oil and gas development at Hamilton Dome oil field does not directly affect the Thermopolis hydrothermal system. In addition, Jarvis (1986, p. 107) reported a decrease in dissolved-solids concentration for Big Spring from 2,238 mg/L in 1958 to 1,920 mg/L in 1982. Because the wells in figure 11 are completed in the same Paleozoic rocks as Big Spring, the spring should show a similar response to precipitation. Therefore, the decrease in dissolved-solids concentration may have resulted from increased recharge at times when monthly precipitation was above normal between 1958 and 1982.

WATER USE

Water-use estimates for Wyoming for 1985 were compiled by the U.S. Geological Survey in cooperation with State and local agencies (Solley and others, 1988). Estimates of total offstream water use for Hot Springs County in 1985 are presented in table 7. Seven categories of offstream use are listed and each category is divided by surface- and ground-water sources. Most of the water use in the county was surface water (table 7).

Table 7. *Estimated total offstream water use in Hot Springs County in 1985*

[NA, not applicable]

	Units in million gallons per day				
Offstream use	Surface water	Ground water	Public supplied	Total	Consumptive use
Public supply	0.91	0.30	NA	1.21	0.21
Commercial	.05	.06	0.10	.21	.02
Domestic	.02	.14	.85	1.01	.40
Industrial	.03	.03	.05	.11	.01
Mining	1.21	5.79	0	7.00	.97
Livestock	.37	.09	0	.46	.46
Irrigation	112	2.12	0	114.12	80.5
Totals	114.59	8.53	1.00	124.12	[1]82.57

[1] Includes estimated 41.9 million gallons per day conveyance losses.

Water for public supply is withdrawn by public and private suppliers and delivered to groups of users. Most of the water in this category is used for domestic purposes, with small quantities delivered to commercial and industrial users. Commercial use includes water for motels, hotels, restaurants, office buildings, other commercial facilities, and institutions. Industrial use is water used for fabrication, processing, washing, and cooling, and includes such industries as steel, chemical and allied products, paper and allied products, mining, and petroleum refining.

Surface water supplies about 92 percent of the total offstream use in the county. Irrigation is the largest offstream use of surface water. Only 7 percent of the total offstream use in the county is supplied by ground water. The largest use of ground water is for mining. However, ground water supplied 88 percent of the domestic use in the county that was not public supplied. This statistic shows that ground water is a primary domestic water supply in rural areas where public supplies are not available.

WATER QUALITY

Water quality refers to organic and inorganic material dissolved and suspended in water in a variety of forms and includes the physical properties of water. Generally, the presence of any foreign substance in water is considered 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 water quality includes organisms, both plant and animal, living in water and generally restricted to surface water. Only limited biological water-quality data have been collected from streams in the county; therefore, biological water quality is not described here. A general discussion of the chemical quality and physical properties of ground water and surface water follows. For a more thorough discussion of water quality the reader is referred to Hem (1985) or Freeze and Cherry (1979).

Based on the amount of specific ions present in a water sample, the water can be classified into types by the dominant dissolved cations (positive ion) and anions (negative ion). The dominant ions are the anion and cation with the largest concentration in milliequivalents. For example, in a sodium sulfate type water, sodium has the largest concentration of the cations present, and sulfate has the largest concentration of the anions present. If a water sample does not contain a dominant cation and anion, the water is classified as a mixture of the cations and anions with the largest concentrations.

All chemical-quality data from water samples used in this report had a chemical-balance check value between plus or minus 5 percent, except for three samples. A chemical-balance check value is based on the percent difference between the sums, in milliequivalents per liter, of the cations and anions. Those three samples, for sites Km5 (Meeteetse Formation), Kmv4 (Mesaverde Formation), and Pp1 (Phosphoria Formation), had a chemical-balance check value of 11 percent or less.

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-micrometer (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. Surface-water temperature is affected by local climatic and physical factors. Common climatic factors are solar radiation, wind, air temperature, and vapor pressure. Physical conditions include shading, stream width, depth, velocity, ground-water inflow, and proximity to reservoirs. Ground-water temperatures generally are a function of the depth of the geologic unit below the surface of the earth. Water in deeper geologic units generally has higher temperatures than water in shallow geologic units.

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 (^{o}C) and is a function of the type and concentration of dissolved solids in the water. The concentration of dissolved solids, in mg/L, ranges from 55 to 75 percent of the specific conductance in μS/cm (Hem, 1985, p. 67). This relation varies with the composition and concentration of dissolved ions.

A measure of the acidity of water is pH and is defined as the negative logarithm of the hydrogen-ion concentration. This parameter is dimensionless and has a range from 0 to 14. At 25^{o}C, a pH greater than 7 indicates that the water is alkaline; whereas, a pH less than 7 indicates that the water is acidic.

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 geologic units. It also may be affected by human activities. 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 or cause and significance of common dissolved-mineral constituents and physical properties of ground water and surface water are summarized in table 8.

The chemical characteristics and physical properties of the water aid in evaluating its suitability for various uses. Water-quality standards for chemical constituents or parameters that were adopted by the State of Wyoming and used for evaluating ground-water quality for domestic, agricultural, and livestock use are listed in table 9. Because of the variability of water quality at different sampling points and the limited number of samples analyzed from the county, samples from surface waters or ground waters reported here are not classified as suitable for specific uses. However, individual samples listed in tables in this report can be compared to the water-quality standards given in table 9.

The U.S. Environmental Protection Agency (1991a, b, and c) has established primary and secondary drinking-water regulations and health advisories pertinent to public drinking-water supplies (table 10). 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 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.

Streamflow Quality

Data on the water quality of a stream are determined by collecting samples of water on a systematic basis. The quality of water in streams changes with the seasons and also with the magnitude of the streamflow. A single sample defines the type and concentration of material in the streamflow only for the time and conditions of the sampling.

Table 8. *Source or cause and significance of 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	Significance
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 may also attack metals.
Hardness as calcium carbonate ($CaCO_3$)	In most waters 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 bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called noncarbonate hardness. Water with hardness of 60 mg/L or less is 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 is desired in electroplating, tanning, dyeing, and in textile manufacturing.
Sodium (Na) and potassium (K)	Dissolved from practically all rocks and soils; also 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. A large sodium concentration may limit the use of water for irrigation.
Bicarbonate (HCO_3) and carbonate (CO_3)	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.

Table 8. *Source or cause and significance of dissolved-mineral constituents and physical properties of water--Continued*

Constituent or property	Source or cause	Significance
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.
Silica ($Si0_2$)	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 manufacturing, 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.

Table 9. *Wyoming ground-water quality standards for domestic, agricultural, and livestock use*

(Modified from Wyoming Department of Environmental Quality, 1980, p. 9)

[All constituent concentrations are in milligrams per liter unless otherwise indicated. --, no data; µg/L, micrograms per liter]

Constituent or property	Domestic use	Agricultural use	Livestock use
Aluminum (µg/L)	--	5,000	5,000
Arsenic (µg/L)	50	100	200
Barium (µg/L)	1,000	--	--
Boron (µg/L)	750	750	5,000
Cadmium (µg/L)	10	10	50
Chloride	250	100	2,000
Chromium (µg/L)	50	100	50
Copper (µg/L)	1,000	200	500
Fluoride	[1](1.4-2.4)	--	--
Iron (µg/L)	300	5,000	--
Lead (µg/L)	50	5,000	100
Manganese (µg/L)	50	200	--
Mercury (µg/L)	2	--	.05
Nitrite, nitrate + nitrite, as nitrogen	--	--	100
Selenium (µg/L)	10	20	50
Silver (µg/L)	50	--	--
Sulfate	250	200	3,000
Dissolved solids	500	2,000	5,000
pH, standard units	(6.5-9.0)	(4.5-9.0)	(6.5-8.5)
Sodium-adsorption ratio	--	8	--

[1] Dependent on the annual average of the maximum daily air temperature: 1.4 mg/L corresponds with a temperature range of 26.3 to 32.5°C and 2.4 mg/L corresponds with a temperature of 12.0°C and below.

Streamflow quality was examined in three drainage-basin areas or streams in the county: (1) Grass Creek in the northern part of the county, (2) Owl Creek drainage basin in the south-central part, and (3) the Bighorn River in the central part. Each drainage-basin area or stream is discussed below.

Grass Creek and its tributaries were sampled at 13 sites during a 3-day period from September 11-13, 1990. The sampling sites ranged from the Shoshone National Forest boundary in the headwaters area of Grass Creek to just east of R. 97 W. (fig. 6). Samples were collected during a low-flow period, and Grass Creek was dry in the reach crossing R. 99 W. Dissolved-solids concentration increased in a downstream direction. The headwater sample (site 129; fig. 6) had a dissolved-solids concentration of 135 mg/L. The farthest downstream sample (site 142), about 2 miles west of where Grass Creek is crossed by Highway 120, had a dissolved-solids concentration of 2,120 mg/L (table 11). The water throughout the stream reach sampled was dominated by the sodium cation. However, the dominant anion in Grass Creek changed from bicarbonate in the upstream reaches to sulfate in the downstream reaches. Water samples collected at these sites also were analyzed for selected trace elements. Barium and boron increased downstream, whereas iron and aluminum decreased downstream. Concentrations of selected chemical constituents for individual samples from Grass Creek and its tributaries are listed in tables 11 and 12.

Table 10. *Selected maximum and secondary maximum contaminant levels for public drinking-water supplies*

(from U.S. Environmental Protection Agency, 1991a, p. 585-587; 1991b, p. 672-673;and 1991c, p. 759)

[All values in milligrams per liter unless noted otherwise; --, no established level]

Constituent or property	Maximum contaminant level	Secondary maximum contaminant level
Inorganic:		
Arsenic (µg/L)	[1]50	--
Barium (µg/L)	[1]1,000	--
Cadmium (µg/L)	[2]5	--
Chloride	--	[3]250
Chromium (µg/L)	[2]100	--
Copper (µg/L)	--	[3]1,000
Fluoride	[2]4.0	[3]2.0
Iron (µg/L)	--	[3]300
Lead (µg/L)	[1]50	--
Manganese (µg/L)	--	[3]50
Mercury (µg/L)	[2]2	--
Nitrate, as nitrogen	[1]10	--
Selenium (µg/L)	[2]50	--
Silver (µg/L)	--	[3]100
Sulfate	--	[3]250
Zinc (µg/L)	--	[3]5,000
Dissolved solids	--	[3]500
pH, standard units	--	[3]6.5-8.5
Organic:		
2,4-D	[2].07	--
Silvex	[2].05	--
Endrin	[1].0002	--
Lindane	[2].0002	--
Methoxychlor	[2].04	--
Toxaphene	[2].003	--

[1] U.S. Environmental Protection Agency, 1991a, p. 585-587.
[2] U.S. Environmental Protection Agency, 1991b, p. 672-673.
[3] U.S. Environmental Protection Agency, 1991c, p. 759.

Water quality in the major streams in the Owl Creek drainage basin was evaluated in a previous study of that area (Ogle, 1992, p. 9-29). Ogle found the water quality in the drainage basin separated into three distinct segments. Water samples from each segment have a distinct water type, dissolved-solids concentration, and dissolved-solids concentration to specific conductance ratio. Water samples from the upper segment have a sodium calcium bicarbonate water type, an average dissolved-solids concentration of 171 mg/L, and a dissolved-solids concentration to specific conductance ratio of 0.742 that was developed from paired data. Water samples from the middle segment have a calcium sulfate water type, an average dissolved-solids concentration of 566 mg/L, and a dissolved-solids concentration to specific conductance ratio of 0.810 that was developed from paired data. Water samples from the lower segment have a sodium sulfate water type, an average dissolved-solids concentration of 2,340 mg/L, and a dissolved-solids concentration to specific conductance ratio of 1.03 that was developed from paired data.

Water quality in the section of the Bighorn River that flows through the county was summarized by Peterson (1987, p. 38-41). He found the water quality at two streamflow stations, the Bighorn River at Thermopolis (site 1) and the Bighorn River at Lucerne (site 15), to have an average dissolved-solids concentration of less than 500 mg/L (Peterson, 1987, p. 39). A water sample that was collected on September 18, 1968 from the Bighorn River at Lucerne had a calcium sodium sulfate water type and a dissolved-solids concentration of 464 mg/L.

Ground-Water Quality

Data on the water quality of geologic units are obtained by collecting samples of water from wells completed in a specific geologic unit or from springs that issue from that geologic unit. Water-quality data in this report consisted of both analyses of water-quality samples collected as part of this study of the county and historic data in the U.S. Geological Survey's ground-water data base. Information in the data base was collected by the U.S. Geological Survey as part of previous studies in the area. Analyses of water-quality samples from wells completed in and springs that issued from Quaternary unconsolidated deposits and the Tertiary, Upper Cretaceous, Mesozoic, and Paleozoic rocks are covered in this report. Because of water-quality variability, individual geologic units are discussed in each section.

Quaternary Unconsolidated Deposits

Twenty-three water-quality samples were collected from wells completed in and springs that issue from Quaternary unconsolidated deposits. These water-quality samples consisted of 15 from the alluvium and of 8 from the terrace deposits. The chemical-quality characteristics of the water-quality samples are described next.

Fifteen water-quality samples were collected from the alluvium—two in 1990 as part of this study, five in 1989, one in 1988, two in 1976, one in 1970, one in 1967, and three in 1946 for previous studies. The samples are from wells completed in the alluvium and located in three areas: along Owl Creek, along the Bighorn River in the central part of the county, and in the alluvium in the northwestern part. One spring (Qa7) in the northwestern part of the county issues from the alluvium and was sampled (fig. 14). Dissolved-solids concentration of the water samples from the alluvium ranged from 181 to 5,710 mg/L (table 13). Water types of the samples from the alluvium, based on modified Stiff diagrams, varied from sampling site to sampling site. Selected constituents, for each water sample listed in table 13, also reflected that variability. Dissolved boron was analyzed in four samples and found to range from 20 to 190 μg/L (table 14). Dissolved concentrations of selected trace elements were analyzed for sites Qa7 and Qa8. These individual dissolved concentrations are listed in table 14. Well Qa11 was analyzed for selected pesticides: picloram; 2,4-D; 2,4,5-T; 2,4,5-TP; dicamba; 2,4-DP. No concentrations were reported above the detection limit of 0.01 μg/L.

Table 11. Chemical *analysis and physical properties of water samples*

[Site number: Simplified site number used in this report to identify miscellaneous microsiemens per centimeter at 25 degrees Celsius; --,,

Site number	Site name	Date	Specific conduct-ance (µS/cm)	pH	Water tempera-ture (°C)	Hardness ($CaCO_3$)	Calcium, dissolved (Ca)	Magne-sium, dissolved (Mg)
129	Grass Creek near Anderson Saw Mill, near Grass Creek	09-11-90	202	8.2	6.5	27	5.9	2.9
130	Grass Creek above Hess Creek, near Grass Creek	09-11-90	279	9.0	20.5	44	12	3.3
131	Hess Creek Draw near Anderson Saw Mill, near Grass Creek	09-11-90	310	8.5	19.0	35	9.4	2.7
133	Sanford Draw near LU Cow Camp, near Grass Creek	09-11-90	421	8.7	19.5	46	13	3.2
134	Grass Creek near LU Cow Camp, near Grass Creek	09-11-90	338	9.6	19.0	49	13	3.9
135	Grass Creek below LU Cow Camp, near Grass Creek	09-12-90	360	8.8	12.0	61	17	4.6
136	Little Grass Creek at mouth, near LU Cow Camp, near Grass Creek	09-12-90	1,050	8.2	13.0	420	89	47
137	Grass Creek above Little Grass Creek, near Grass Creek	09-12-90	524	8.8	15.5	150	33	17
138	Grass Creek at LU Ranch House, near Grass Creek	09-12-90	598	8.8	20.0	170	27	25
139	Grass Creek above Gary Kellogg Ranch, near Grass Creek	09-12-90	752	8.5	19.0	230	38	32
140	Grass Creek near Grass Creek	09-12-90	1,320	8.7	17.5	310	37	52
141	Grass Creek at site 12, near Grass Creek	09-13-90	3,050	8.6	12.5	610	45	120
142	Grass Creek at site 13, near Grass Creek	09-13-90	3,050	8.7	13.5	680	57	130

Eight water-quality samples were collected from the terrace deposits—one in 1990 as part of this study, and one in 1968, one in 1965, one in 1949, and four in 1946 for previous studies. One water-quality sample is from a well in the northern part of the county, and seven samples are from wells in the central part. All wells were completed in the terrace deposits (fig. 14). Dissolved-solids concentrations of these water samples ranged from 1,310 to 11,100 mg/L (table 13). Modified Stiff diagrams (fig. 14), which by their shapes indicate the type of water present in the samples, were produced for samples at sites Qt2, Qt4, and Qt7, collected between 1965 and 1990. The modified Stiff diagrams show that the water types varied from sampling site to sampling site. The variability of selected constituents for individual water samples listed in table 13 also reflected the variability of water type. The water sample from well Qt7 collected in 1990 was analyzed for dissolved concentrations of selected trace elements; dissolved concentrations are listed in table 14.

Tertiary Rocks

Nine water-quality samples were collected from wells completed in and springs that issue from Tertiary rocks. Four samples are from the Absaroka Volcanic Supergroup and five from the Fort Union Formation. The chemical-quality characteristics of the water samples from each geologic unit are described next.

collected at selected streamflow sites of Grass Creek and its tributaries

streamflow sites. Analytical results in milligrams per liter as indicated; µS/cm, no data; <, less than; °C, degrees Celsius]

Sodium, dissolved (Na)	Sodium adsorption ratio	Potassium, dissolved (K)	Alkalinity, total as ($CaCO_3$)	Sulfate, dissolved (SO_4)	Chloride, dissolved (Cl)	Fluoride, dissolved (F)	Silica, dissolved (SiO_2)	Dissolved solids, sum of constituents	Nitrogen, NO_2+NO_3 dissolved	Phosphorous, total (P)
36	3	0.6	86	9.3	1.8	<0.1	25	135	<0.100	0.31
51	3	.8	130	20	4.2	.7	15	184	<.100	.15
56	4	1.9	150	17	3.2	.6	14	196	.200	.18
85	5	2.1	200	27	3.3	.9	4.8	258	<.100	.10
58	4	1.5	150	24	4.6	.8	9.6	206	<.100	.14
58	3	1.6	170	25	4.9	.8	5.9	218	<.100	.07
86	2	3.6	270	280	10	.9	12	692	<.100	.01
64	2	1.4	220	64	5.0	.7	7.4	323	<.100	<.01
68	2	2.4	220	94	5.6	.9	5.7	359	<.100	.01
77	2	3.2	310	110	6.7	.8	8.3	460	<.100	.02
190	5	6.7	510	230	11	.8	7.8	839	<.100	.04
440	8	8.3	470	980	130	.8	1.0	2,010	<.100	.01
480	8	9.7	520	1,000	130	.7	2.4	2,120	<.100	.02

Four water-quality samples were collected from the Absaroka Volcanic Supergroup—two in 1990 as part of this study and two in 1989 for a previous study. These water-quality samples all are from springs in the western part of the county and issued from the Absaroka Volcanic Supergroup (fig. 15). Dissolved-solids concentrations of water samples from these springs ranged from 125 to 265 mg/L (table 13). Modified Stiff diagrams (fig. 15), which by their shapes indicate the type of water present in the samples, show the water to be of the sodium bicarbonate type with little variability between samples. Selected constituents for these four water samples listed in table 13 also reflect the consistency between the samples. Water samples from springs Tav1 and Tav3 were analyzed for selected trace elements. The dissolved concentrations are listed in table 14.

Five water-quality samples were collected from the Fort Union Formation—three in 1990 as part of this study, one in 1968, and one in 1966 for previous studies. Four of the samples are from wells located in the northern part of the county and were completed in the Fort Union Formation. One sample is from a spring (Tfu2) that issues from the Fort Union Formation located in that same area (fig. 15). Dissolved-solids concentrations of water samples from these wells and spring ranged from 1,730 to 3,420 mg/L (table 13). Modified Stiff diagrams (fig. 15), which by their shapes indicate the type of water present in the samples, show the water from the four wells to be sodium sulfate type. The water sample from the spring was a magnesium sulfate type. Selected constituents for individual water samples are listed in table 13. Selected wells and the spring were analyzed for specific trace elements and those concentrations are reported in table 14.

Table 12. *Concentrations of selected trace elements of water samples collected*

[Site number: Simplified site number used in this report to identify miscellaneous streamflow sites.

Site number	Site name	Date	Aluminum, dissolved (A1)	Arsenic, dissolved (As)	Barium, dissolved (Ba)	Boron, dissolved (B)
129	Grass Creek near Anderson Saw Mill, near Grass Creek	09-11-90	800	2	28	30
130	Grass Creek above Hess Creek, near Grass Creek	09-11-90	100	2	16	50
131	Hess Creek Draw near Anderson Saw Mill, near Grass Creek	09-11-90	--	--	--	40
133	Sanford Draw near LU Cow Camp, near Grass Creek	09-11-90	80	2	26	60
134	Grass Creek near LU Cow Camp, near Grass Creek	09-11-90	100	2	22	50
135	Grass Creek below LU Cow Camp, near Grass Creek	09-12-90	--	--	--	50
136	Little Grass Creek at mouth, near LU Cow Camp, near Grass Creek	09-12-90	<10	<1	52	100
137	Grass Creek above Little Grass Creek, near Grass Creek	09-12-90	<10	<1	36	60
138	Grass Creek at LU Ranch House, near Grass Creek	09-12-90	--	--	--	70
139	Grass Creek above Gary Kellogg Ranch, near Grass Creek	09-12-90	--	--	--	90
140	Grass Creek near Grass Creek	09-12-90	--	--	--	160
141	Grass Creek at site 12, near Grass Creek	09-13-90	<10	<1	100	720
142	Grass Creek at site 13, near Grass Creek	09-13-90	--	--	--	680

Upper Cretaceous Rocks

Twenty water-quality samples were collected from wells completed in and springs that issued from Upper Cretaceous rocks. These water-quality samples consist of 5 from the Meeteetse Formation, 12 from the Mesaverde Formation, and 3 from the Cody Shale. The water-quality sample results are discussed next, by source unit.

Five water-quality samples were collected from the Meeteetse Formation—four in 1990 as part of this study and one in 1967 for a previous study. These water-quality samples are from wells in the northern part of the county that were completed in the Meeteetse Formation (fig. 16). Dissolved-solids concentrations of water samples from these wells ranged from 936 to 1,400 mg/L (table 13). Modified Stiff diagrams (fig. 16), which by their shapes indicate the type of water present in the samples, show the water to be dominated by the sodium plus potassium cation in three wells and by the magnesium cation in the other two wells. Three of the water-quality samples from these wells were dominated by the bicarbonate plus carbonate anion, and two were dominated by the sulfate anion. Selected constituents for these water samples listed in table 13 also reflected the variability from sampling site to sampling site. Selected wells and springs were analyzed for specific trace elements; concentrations are summarized in table 14.

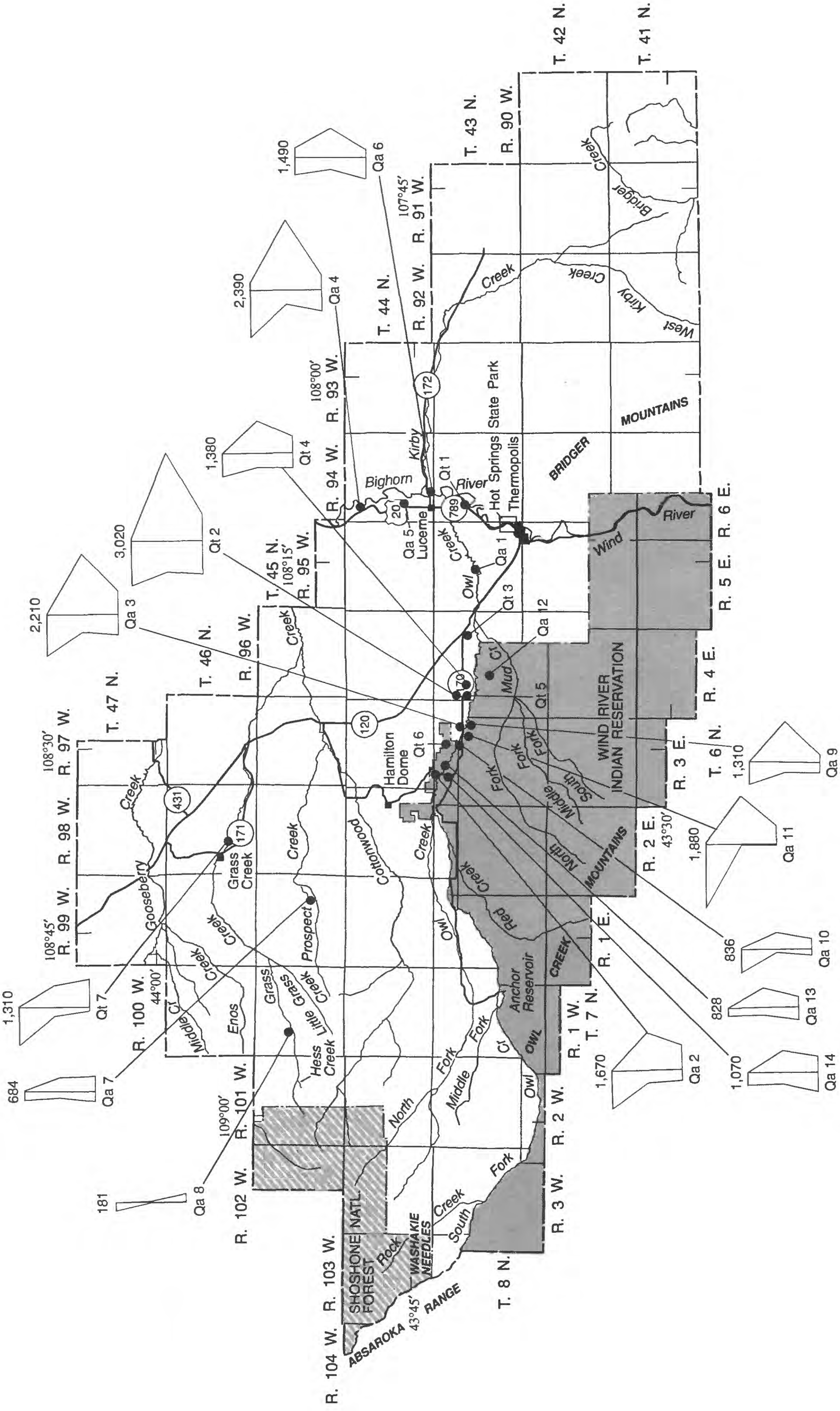
at selected streamflow sites of Grass Creek and its tributaries

Dissolved concentrations in micrograms per liter; --, no data; <, less than]

Cadmium, dissolved (Cd)	Chromium, dissolved (Cr)	Copper, dissolved (Cu)	Iron, dissolved (Fe)	Lead, dissolved (Pb)	Manganese, dissolved (Mn)	Mercury, dissolved (Hg)	Selenium, dissolved (Se)	Silver, dissolved (Ag)	Zinc, dissolved (Zn)
<1.0	1	5	740	1	19	0.1	<1	<1	5
<1.0	<1	3	70	<1	2	<.1	<1	<1	<3
--	--	--	100	--	6	--	6	--	--
<1.0	<1	4	140	9	6	.1	<1	<1	4
<1.0	<1	4	200	<1	6	.1	<1	<1	<3
--	--	--	80	--	3	--	<1	--	--
<1.0	1	1	8	<1	6	<.1	2	2	5
<1.0	<1	1	50	<1	4	<.1	<1	<1	<3
--	--	--	30	--	3	--	<1	--	--
--	--	--	20	--	18	--	<1	--	--
--	--	--	20	--	14	--	<1	--	--
<1.0	<1	2	20	<1	<10	.2	2	<1	<10
--	--	--	60	--	10	--	6	--	--

Twelve water-quality samples were collected from the Mesaverde Formation—eight in 1990 as part of this study, three in 1970, and one in 1967 for a previous study. Ten water-quality samples are from wells completed in the Mesaverde Formation and are located in the northern and central parts of the county; two samples are from springs that issue from the Mesaverde Formation and are located in that same area (fig. 16). Dissolved-solids concentrations of water samples from these wells and springs ranged from 688 to 5,510 mg/L (table 13). Modified Stiff diagrams (fig. 16), which by their shapes indicate the type of water present in the samples, show that the water varied in type between sampling sites. The variability of selected constituents for individual water samples listed in table 13 also reflected that variability of water type. Selected wells and springs were analyzed for specific trace elements; concentrations are summarized in table 14.

Three water-quality samples were collected from the Cody Shale—one in 1989 as part of this study, one in 1970, and another in 1946 for a previous study. These water-quality samples are all from wells—one in the northern part, and two in the central part of the county and were completed in the Cody Shale (fig. 16). Dissolved-solids concentrations of water samples from these wells ranged from 711 to 2,720 mg/L (table 13). Modified Stiff diagrams (fig. 16), which by their shapes indicate the type of water present in the samples, show the water to be of the sodium sulfate type. There are differences between the three sampling sites. Well Kc2 has a low concentration of chloride and a concentration of alkalinity almost as great as the sulfate concentration. Well Kc3, although dominated by the sulfate ion, has substantial concentrations of chloride and bicarbonate. Selected additional constituents for these two water samples are listed in table 13. The water sample from well Kc3 had a dissolved-boron concentration of 1,000 µg/L (table 14).



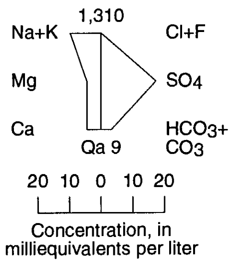
T. 42 N.
T. 41 N.
T. 43 N.
R. 90 W.
T. 44 N.
R. 91 W.
R. 92 W.
R. 93 W.
R. 94 W.
T. 45 N.
R. 95 W.
T. 46 N.
R. 96 W.
T. 47 N.
R. 97 W.
R. 98 W.
R. 99 W.
R. 100 W.
R. 101 W.
R. 102 W.
R. 103 W.
R. 104 W.
R. 1 W.
T. 7 N.
R. 2 W.
R. 3 W.
T. 8 N.
R. 1 E.
R. 2 E.
R. 3 E.
T. 6 N.
R. 4 E.
R. 5 E.
R. 6 E.
107°45′
108°00′
108°15′
108°30′
108°45′
44°00′
109°00′
43°45′
43°30′
Bridger Creek
West Kirby Creek
Creek
Bighorn River
Kirby
Hot Springs State Park
Thermopolis
Lucerne
Owl Creek
Mud Ct
Wind River
BRIDGER MOUNTAINS
WIND RIVER INDIAN RESERVATION
South Fork
Middle Fork
North Fork
Red Creek
OWL CREEK MOUNTAINS
Anchor Reservoir
Hamilton Dome
Cottonwood Creek
Grass Creek
Gooseberry Creek
Enos Creek
Middle Ct
Little Grass Creek
Prospect Creek
Hess Creek
North Fork
Middle Fork
South Fork
Owl Ct
SHOSHONE NATL FOREST
Rock Creek
WASHAKIE NEEDLES
ABSAROKA RANGE
172
789
20
170
120
431
171
Qa 6
1,490
Qa 4
2,390
Qt 4
1,380
Qt 1
Qa 5
Qa 1
Qt 2
3,020
Qt 3
Qa 12
Qa 3
2,210
Qt 5
Qt 6
Qt 7
1,310
Qa 7
684
Qa 8
181
Qa 9
1,310
Qa 11
1,880
Qa 10
836
Qa 13
828
Qa 2
1,670
Qa 14
1,070

Base modified from U.S. Geological Survey 1:100,000 digital line graphs: Basin, 1982; Lysite, 1982; Nowater Creek, 1979; Riverton, 1978; The Ramshorn, 1978; and Thermopolis, 1981. Universal Traverse Mercator projection, Zones 12 and 13.

0 5 10 15 20 MILES

0 5 10 15 20 KILOMETERS

EXPLANATION



MODIFIED STIFF DIAGRAM WITH CONCENTRATIONS OF MAJOR IONS IN MILLIEQUIVALENTS--Number above the diagram denotes the dissolved-solids concentration in milligrams per liter for the same water sample. Number below the diagram indicates sampling site number (correlates to tables 13 and 14). Letter in the sampling site number indicates the geologic unit in which the well is completed or from which the spring issues

Qa	ALLUVIUM AND COLLUVIUM
Qt	TERRACE DEPOSITS
●	WELL
●~	SPRING

Figure 14.--Location, modified Stiff diagrams, and dissolved-solids concentrations for wells completed in and springs that issue from Quaternary unconsolidated deposits.

Table 13. *Chemical analyses and physical properties of water samples*

[Site number: Simplified site number used in this report to identify well and spring sampling
Water. Analytical results in milligrams per liter except as indicated; ft, feet; µS/cm, micro-

Site number (figs. 14-18)	Local number	Date	Well depth (ft)	Specific conductance (µS/cm)	pH	Water temperature (°C)	Hardness ($CaCO_3$)	Calcium, dissolved (Ca)	Magnesium, dissolved (Mg)	Sodium, dissolved (Na)
										Quaternary
Qa1	43-095-16ddc01	07-23-46	42	2,540	7.5	--	980	250	88	--
Qa2	43-097-05bca01	08-19-88	12	2,630	--	13.0	630	120	80	430
		03-07-89		1,250	7.7	8.5	460	82	62	380
Qa3	43-097-14bab01	03-07-89	50	2,780	7.4	9.5	820	180	90	390
Qa4	44-094-08ba 01	10-12-70	15	3,150	8.2	--	800	190	76	450
Qa5	44-094-20ccc01	07-23-46	42	5,760	7.8	--	2,500	450	340	--
Qa6	44-094-33ccb01	06-07-67	15	2,080	7.8	11.0	760	200	65	160
Qa7	45-099-23cab01	07-25-90	Spring	1,060	7.6	13.0	390	92	38	90
Qa8	45-100-17acd01	06-21-90	84	331	9.2	7.0	33	6.7	3.9	60
Qa9	8N-3E-01cda01	09-17-76	40	--	--	--	490	100	58	230
Qa10	8N-3E-02bca01	03-08-89	--	1,250	8.0	8.5	140	36	11	230
Qa11	8N-3E-02dca01	03-07-89	60	2,710	8.3	12.0	38	9.7	3.3	620
Qa12	8N-4E-16aaa01	07-23-46	50	2,440	8.0	--	450	110	41	--
Qa13	9N-3E-33adb01	06-23-89	28	1,200	6.9	10.5	450	110	43	89
Qa14	9N-3E-33adb02	09-14-76	28	--	--	--	600	150	55	120
										Quaternary
Qt1	43-094-08ccc01	07-22-46	36	3,230	8.0	--	1,300	280	150	--
Qt2	43-096-07dbc01	10-28-49	40	3,620	7.4	9.0	1,400	350	130	460
		09-03-68		3,720	7.7	--	1,400	300	170	420
Qt3	43-096-14bda01	07-25-46	44	11,300	7.9	--	2,000	210	350	--
Qt4	43-096-17bbb03	08-23-65	42	1,890	8.2	9.5	600	120	70	230
Qt5	43-096-18aba01	07-22-46	64	2,460	8.0	--	1,000	240	110	--
Qt6	43-097-03ccd01	07-22-46	--	2,200	7.9	--	790	180	81	--
Qt7	46-098-28bbb01	06-20-90	28	1,920	7.9	10.0	240	28	42	360
										Absaroka Volcanic
Tav1	43-100-04aad01	07-24-90	Spring	378	7.5	9.0	29	7.5	2.4	76
Tav2	43-102-15daa01	10-18-89	Spring	202	7.9	7.0	29	7.6	2.4	37
Tav3	45-099-08bdc01	06-21-90	Spring	412	8.0	15.0	93	30	4.5	57
Tav4	8N-3W-16add01	10-19-89	Spring	180	7.5	3.0	28	9.6	1.0	30
										Fort Union
Tfu1	45-096-15dda01	09-13-90	100	4,750	7.1	16.5	1,300	270	160	610
Tfu2	45-097-17acc01	07-26-90	Spring	2,450	7.5	14.0	1,300	140	220	91
Tfu3	47-097-31cbb01	02-16-68	247	4,320	8.4	--	720	100	110	850
Tfu4	47-098-28aaa01	06-18-90	200	3,700	8.0	22.0	620	99	90	680
Tfu5	47-098-34cad01	04-12-66	320	2,350	8.1	--	500	93	65	380

collected from selected wells and springs in Hot Springs County

sites. Local number: See text describing well-numbering system in the section titled Ground-
siemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; --, no data; <, less than]

Sodium adsorption ratio	Potassium, dissolved (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity, total (as $CaCO_3$)	Sulfate, dissolved (SO_4)	Chloride, dissolved (Cl)	Fluoride, dissolved (F)	Silica, dissolved (SiO_2)	Dissolved solids, sum of constituents	Nitrogen, NO_2+NO_3, dissolved	Phosphorous, total (P)
alluvium											
4	--	280	0	--	1,300	28	0.4	--	2,070	--	--
7	5.9	--	--	490	920	28	.6	50	1,930	<0.100	0.04
8	7.2	--	--	510	760	16	.7	50	1,670	.16	.22
6	5.8	--	--	480	1,200	24	.5	38	2,210	<.100	.33
7	8.1	310	0	--	1,400	90	.2	18	2,390	--	--
8	--	450	0	--	3,700	87	.8	--	5,710	--	--
2	9.4	160	0	--	5,800	40	.6	20	1,490	--	--
2	4.3	--	--	290	260	9.8	1.3	13	684	.40	.01
5	.8	--	--	140	24	.6	.3	1.8	181	<.100	<.01
5	3.7	180	0	--	810	15	.6	4.0	1,310	--	<.01
9	2.4	--	--	260	380	9.4	.4	8.2	836	.12	<.01
44	2.0	--	--	380	990	15	1.5	9.6	1,880	<.100	.03
9	--	330	0	--	1,100	30	.8	--	1,860	--	--
2	1.1	--	--	240	380	5.9	.7	33	828	5.3	.03
2	1.4	470	0	--	470	12	1.0	32	1,070	--	.03
terrace deposits											
5	--	470	0	--	1,700	26	1.0	--	2,840	--	--
5	5.6	440	0	--	1,900	37	1.2	32	3,120	--	--
5	5.6	610	0	--	1,800	15	2.4	41	3,020	--	--
28	--	500	0	--	7,300	90	1.3	--	11,100	--	--
4	5.0	450	0	--	680	12	1.4	39	1,380	--	--
4	--	440	0	--	1,100	42	1.3	--	2,020	--	--
4	--	570	0	--	800	44	1.1	--	1,720	--	--
10	2.7	--	--	610	460	24	1.8	17	1,310	.50	<.01
Supergroup											
6	0.4	--	--	150	36	2.9	0.3	18	236	0.20	0.40
3	.7	--	--	93	13	.8	.2	27	143	.31	.18
3	.6	--	--	140	77	3.7	.2	7.7	265	.50	<.01
2	.3	--	--	73	17	.8	.2	22	125	.25	.10
Formation											
7	6.5	--	--	460	1,700	70	.7	16	3,420	2.5	<.01
1	14	--	--	610	870	21	.7	11	1,730	.10	<.01
14	9.0	790	8	--	1,800	35	1.7	8.3	3,340	--	--
12	7.9	--	--	590	1,300	29	.7	8.6	2,570	<.100	<.01
7	13	540	0	--	900	12	.8	7.8	1,730	--	--

Table 13. *Chemical analysis and physical properties of water samples*

Site number (figs. 14-18)	Local number	Date	Well depth (ft)	Specific conductance (μS/cm)	pH	Water temperature (°C)	Hardness ($CaCO_3$)	Calcium, dissolved (Ca)	Magnesium, dissolved (Mg)	Sodium, dissolved (Na)
										Meeteetse
Km1	46-097-31aaa01	06-07-67	160	1,690	8.4	11.0	430	39	81	230
Km2	46-099-34dcb01	06-21-90	310	1,460	7.3	9.5	790	120	120	43
Km3	46-100-22daa01	06-22-90	100	1,400	7.3	8.0	580	100	81	100
Km4	47-098-32aba01	06-19-90	101	1,840	7.7	11.0	550	80	86	200
Km5	47-099-33cad01	06-19-90	135	2,000	8.1	16.0	380	35	70	310
										Mesaverde
Kmv1	44-095-17bba01	07-16-70	293	3,260	7.9	13.0	1,900	170	360	160
Kmv2	44-097-25cdc01	06-23-70	--	2,330	7.9	14.5	1,400	250	190	67
Kmv3	44-098-17abc01	07-23-90	203	1,350	7.8	12.5	110	28	9.8	290
Kmv4	45-097-15cbd01	07-26-90	260	1,550	7.8	12.0	50	12	4.9	300
Kmv5	45-097-26bcd01	07-24-90	156	6,800	7.4	10.5	2,100	380	280	930
Kmv6	45-097-28dad01	07-23-90	150	2,590	7.6	12.5	650	140	72	350
Kmv7	45-099-25ccd01	07-25-90	Spring	1,760	8.0	9.5	360	66	47	280
Kmv8	45-099-28aba01	07-25-90	120	1,020	7.7	12.0	370	96	31	98
Kmv9	46-098-10bba01	02-06-67	350	2,650	7.0	--	1,200	390	50	250
Kmv10	46-099-22cbc01	06-20-90	Spring	1,210	7.6	9.5	430	80	56	98
Kmv11	47-099-04dab01	06-20-90	215	3,790	8.7	10.0	45	11	4.3	920
Kmv12	47-099-14abc02	09-16-70	1,180	2,260	8.5	16.0	9	2.0	1.0	600
										Cody
Kc1	43-095-12bcc02	07-22-46	53	2,960	7.8	7.0	99	23	10	--
Kc2	43-098-03acd01	06-22-89	60	1,080	7.2	9.5	92	25	7.1	210
Kc3	46-098-27dcc01	09-17-70	80	4,010	7.5	--	1,200	200	170	520
										Frontier
Kf1	41-090-04baa01	09-14-90	Spring	435	8.2	6.0	230	56	21	5.0
Kf2	42-091-35acc01	09-14-90	Spring	2,350	7.4	7.0	1,000	200	130	150
Kf3	42-092-02cbb01	07-09-70	600	1,580	8.7	15.0	3	.60	.30	410
		08-22-90		1,580	9.0	14.5	4	1.1	.21	370
Kf4	42-092-08ddd01	07-25-89	254	1,580	9.2	14.5	4	1.4	.12	340
Kf5	42-092-12cda01	08-22-90	381	1,750	8.5	13.0	9	2.8	.45	380
Kf6	43-092-04bda01	08-22-90	--	1,630	9.2	18.0	2	.83	.06	460
Kf7	43-092-22cdb01	08-22-90	--	1,170	9.2	16.0	3	1.1	.07	270
Kf8	44-093-33dac01	08-23-90	1,490	10,300	8.3	15.5	57	10	7.7	3,400
Kf9	44-093-34dcc01	08-23-90	1,390	1,850	9.3	19.5	3	1.1	.16	400
Kf10	8N-2E-11bac01	06-22-89	Spring	2,340	7.3	15.0	740	180	70	270
Kf11	8N-2E-12bcc01	06-21-89	Spring	2,350	7.5	11.5	730	180	69	290

collected from selected wells and springs in Hot Springs County--Continued

Sodium adsorption ratio	Potassium, dissolved (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity, total (as $CaCO_3$)	Sulfate, dissolved (SO_4)	Chloride, dissolved (Cl)	Fluoride, dissolved (F)	Silica, dissolved (SiO_2)	Dissolved solids, sum of constituents	Nitrogen, NO_2+NO_3, dissolved	Phosphorous, total (P)
Formation											
5	5.1	370	12	--	560	25	1.4	11	1,150	--	--
.7	6.8	--	--	710	200	9.9	.5	11	938	<.100	<.01
2	11	--	--	550	250	43	.1	6.7	936	3.0	<.01
4	4.0	--	--	440	530	16	.5	14	1,200	<.100	<.01
7	7.0	--	--	810	470	13	.9	9.7	1,400	<.100	<.01
Formation											
2	21	800	0	--	1,500	30	.5	5.9	2,620	--	--
.8	9.6	810	0	--	840	11	.4	9.8	1,770	--	--
12	2.0	--	--	530	180	17	1.1	20	867	<.100	.01
18	2.5	--	--	550	240	5.9	.2	9.7	907	.40	<.01
9	11	--	--	450	3,200	420	1.1	12	5,510	<.100	<.01
6	6.7	--	--	360	1,100	42	1.0	9.8	1,940	<.100	<.01
6	8.7	--	--	460	540	7.3	.9	10	1,230	<.100	<.01
2	3.2	--	--	230	190	120	.8	9.9	688	.50	<.01
3	15	770	0	--	1,000	21	.7	8.2	2,160	--	--
2	4.2	--	--	480	190	7.8	.4	14	741	.30	<.01
60	4.8	--	--	820	1,000	22	.7	5.8	2,460	<.100	<.01
86	2.5	1,340	22	--	100	36	3.4	7.4	1,430	--	--
Shale											
30	--	400	0	--	1,100	46	0.6	--	2,080	--	--
10	1.8	--	--	260	290	6.5	.3	9.6	711	0.59	0.01
7	6.8	680	0	--	970	510	.6	14	2,720	--	--
Formation											
.1	2.9	--	--	190	65	3.1	.8	18	284	<.100	.03
2	1.7	--	--	330	1,000	4.6	1.1	31	1,720	<.100	<.01
110	.8	770	26	--	150	15	3.1	10	998	--	--
85	.8	--	--	660	170	18	2.9	10	971	.30	.25
74	.7	--	--	520	240	11	1.2	8.9	921	.56	.02
56	.9	--	--	320	510	2.1	.6	18	1,110	<.100	.19
130	.8	--	--	690	280	14	2.8	14	1,190	<.100	.08
67	.6	--	--	250	320	2.9	.3	14	758	<.100	.08
200	7.4	--	--	570	5,900	280	<.1	11	9,960	<.100	.05
94	.7	--	--	400	450	14	.8	16	1,120	.30	.06
4	7.9	--	--	180	1,200	3.2	1.5	15	1,860	<.100	.07
5	11	--	--	310	1,100	6.3	1.7	18	1,860	<.100	.18

Table 13. *Chemical analysis and physical properties of water samples*

Site number (figs. 14-18)	Local number	Date	Well depth (ft)	Specific conductance (µS/cm)	pH	Water temperature (°C)	Hardness ($CaCO_3$)	Calcium, dissolved (Ca)	Magnesium, dissolved (Mg)	Sodium, dissolved (Na)
										Mowry
Kmr1	41-091-09cca01	08-23-90	Spring	565	7.9	9.5	75	17	8.0	89
Kmr2	42-092-34bab01	08-11-89	150	1,750	7.2	10.5	400	110	30	220
Kmr3	42-093-07cdc01	07-25-89	Spring	815	7.6	27.0	160	39	16	110
							Thermopolis Shale and Muddy Sandstone			
Kt1	41-092-11abd01	07-27-89	80	965	7.4	15.0	230	57	21	120
Kt2	41-092-11adb01	07-27-89	Spring	1,010	7.4	12.0	250	62	22	120
Kt3	43-091-19daa02	07-13-70	1,240	1,750	9.1	14.0	4	.60	.70	450
Kt4	43-091-36bca01	07-13-70	683	1,100	9.0	17.0	2	.60	.10	250
										Mowry and
Kmt1	8N-2E-13aba01	06-21-89	Spring	1,750	6.8	12.5	480	120	43	91
Kmt2	8N-3E-30bca01	06-21-89	Spring	795	6.5	9.5	380	89	39	17
Kmt3	8N-3E-32abc01	06-21-89	Spring	1,070	6.6	10.0	560	130	56	24
										Cloverly
Kcv1	42-094-07bac01	06-25-70	75	2,960	7.8	10.5	1,700	490	130	140
Kcv2	42-095-03aac01	07-27-90	183	2,240	7.5	12.0	740	170	76	190
										Sundance
Js1	41-091-13cdc01	09-11-89	Spring	590	8.0	9.0	300	75	27	3.2
									Gypsum Spring	
Jgs1	41-091-23ddd01	09-13-89	Spring	500	7.9	8.5	250	58	25	5.5
Jgs2	41-091-32aac01	09-13-89	Spring	610	7.9	10.0	140	35	12	87
Jgs3	42-092-18caa01	09-15-89	Spring	2,000	8.0	10.5	940	270	64	84
Jgs4	42-094-15dad01	09-12-89	Spring	2,900	7.3	14.0	1,800	540	110	100
										Chugwater
TRc1	41-091-27dbc01	09-14-89	Spring	880	7.4	9.0	370	89	35	30
TRc2	41-091-27dcc01	09-13-89	Spring	730	7.4	8.5	330	79	32	11
TRc3	41-091-32cad01	09-13-89	68	535	7.7	8.0	220	52	21	39
TRc4	41-092-04bcb01	09-15-89	210	1,300	7.5	10.0	450	84	59	20
TRc5	42-093-14ccb01	07-26-89	127	1,790	7.2	14.0	1,000	320	53	30
TRc6	42-093-21acc01	07-26-89	183	2,680	7.1	14.0	1,700	570	71	24
TRc7	42-094-17ddc01	07-26-89	Spring	2,880	7.3	21.0	1,500	430	95	170
TRc8	42-094-25bdb01	07-25-89	260	3,120	7.1	14.0	1,900	530	130	110
TRc9	43-099-10dba01	07-22-46	400	3,950	8.0	--	160	38	15	--
TRc10	6N-5E-04dcd01	07-28-89	Spring	420	7.8	13.0	200	41	24	13
TRc11	6N-5E-09adb01	07-28-89	Spring	2,430	7.3	15.5	1,600	570	43	11
TRc12	7N-5E-31cda01	07-28-89	Spring	960	7.4	16.0	480	120	44	18

collected from selected wells and springs in Hot Springs County--Continued

Sodium adsorption ratio	Potassium, dissolved (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity, total (as $CaCO_3$)	Sulfate, dissolved (SO_4)	Chloride, dissolved (Cl)	Fluoride, dissolved (F)	Silica, dissolved (SiO_2)	Dissolved solids, sum of constitutents	Nitrogen, NO_2+NO_3, dissolved	Phosphorous, total (P)
Shale											
4	.6	--	--	170	120	2.3	.5	24	362	.10	.14
5	4.3	--	--	300	590	4.6	.7	11	1,150	<.100	<.01
4	3.3	--	--	180	240	5.1	.7	12	537	1.20	.02
Member of the Thermopolis Shale											
3	3.1	--	--	260	220	3.6	.9	13	599	<.100	.09
3	4.4	--	--	280	240	5.7	.4	14	638	.32	.02
93	.8	750	79	--	180	9.2	2.3	12	1,100	--	--
78	.4	280	31	--	250	1.3	.4	11	683	--	--
Thermopolis Shales											
2	6.2	--	--	280	400	3.0	1.0	17	847	<.100	.02
.4	5.4	--	--	110	310	4.3	.9	12	542	<.100	<.01
.4	6.2	--	--	170	440	4.6	1.0	16	779	.24	.04
Formation											
1	4.9	120	0	--	1,900	8.6	2.0	20	2,750	--	--
3	5.2	--	--	140	990	12	.5	11	1,540	<.100	<.01
Formation											
.1	2.6	--	--	180	1,000	.8	.4	14	331	.50	.02
Formation											
.2	2.6	--	--	190	66	1.2	.3	12	287	.30	<.01
3	1.3	--	--	230	87	2.2	.3	18	383	.19	<.01
1	4.8	--	--	120	970	3.1	.8	19	1,490	.58	<.01
1	5.4	--	--	130	1,800	2.6	.7	16	2,650	.80	<.01
Formation											
.7	1.7	--	--	230	200	1.4	.3	18	514	.50	.06
.3	2.7	--	--	170	140	2.6	.3	15	388	.74	<.01
1	6.2	--	--	290	12	6.3	.3	9.0	321	<.100	<.01
.4	7.0	--	--	210	240	9.6	.9	11	569	2.5	<.01
.4	3.0	--	--	240	870	2.5	.3	15	1,450	3.4	<.01
.3	4.4	--	--	180	1,500	2.8	.5	11	2,320	7.1	.02
2	5.5	--	--	130	1,800	3.3	.6	16	2,600	.63	<.01
1	6.9	--	--	140	1,900	6.5	.4	11	2,790	2.5	<.01
32	--	230	0	--	1,800	26	1.3	--	2,940	--	<.01
.4	1.0	--	--	200	24	4.5	.4	21	251	1.2	.02
.1	1.3	--	--	160	1,500	1.8	.6	11	2,240	.14	<.01
.4	2.1	--	--	190	320	6.5	.4	19	648	.84	<.01

Table 13. *Chemical analysis and physical properties of water samples*

Site number (figs. 14-18)	Local number	Date	Well depth (ft)	Specific conductance (μS/cm)	pH	Water temperature (°C)	Hardness ($CaCO_3$)	Calcium, dissolved (Ca)	Magnesium, dissolved (Mg)	Sodium, dissolved (Na)
										Phosphoria
Pp1	41-090-29dbc01	09-14-89	Spring	560	7.5	7.0	250	70	19	4.4
Pp2	42-093-29bdb01	07-26-89	627	1,080	7.3	17.0	580	130	62	16
Pp3	42-095-25bca01	07-07-70	Spring	1,150	8.0	21.5	570	150	50	41
Pp4	42-095-26aad01	07-28-89	20	1,240	6.9	21.0	630	160	55	46
Pp5	46-100-24cca01	09-16-70	6,200	4,730	6.7	--	2,000	530	150	420
										Tensleep
Pt1	41-094-21cda01	08-08-89	Spring	370	7.8	9.0	160	36	16	1.9
Pt2	41-094-27aaa01	08-08-89	Spring	390	8.0	11.0	190	42	21	2.0
Pt3	42-094-26cac01	10-12-70	550	730	8.2	--	400	92	41	10
Pt4	42-095-13dca01	06-25-70	1,140	2,200	7.8	19.5	1,100	280	86	110
										Madison
MDm1	46-098-28bcc01	06-07-67	6,000	4,150	7.1	--	1,800	520	130	300
										Bighorn
Ob1	41-092-17ddd01	09-15-89	Spring	370	9.0	9.5	210	35	30	1.5
Ob2	41-092-27dac01	08-10-89	Spring	480	7.8	9.0	220	35	32	1.8
Ob3	41-092-28aaa01	09-15-89	Spring	530	7.7	7.5	240	36	36	2.0
Ob4	41-093-21dcb01	08-08-89	Spring	450	7.4	10.0	200	49	19	3.9
Ob5	41-093-23aad01	07-26-89	Spring	440	7.4	12.0	240	41	34	2.1
Ob6	46-098-18cbb01	09-17-70	5,800	4,210	6.8	14.0	2,000	610	120	280
										Gallatin
Cg1	6N-6E-15cca01	09-12-89	90	520	7.8	11.0	270	48	36	8.0
										Flathead
Cf1	41-092-33daa01	08-10-89	Spring	155	7.4	12.0	60	18	3	2.5
Cf2	41-093-25cac01	09-14-89	Spring	70	7.8	8.0	35	9.7	2	2.5
Cf3	41-093-31dcd01	08-09-89	Spring	150	6.7	12.0	61	18	4	2.6

collected from selected wells and springs in Hot Springs County--Continued

Sodium adsorption ratio	Potassium, dissolved (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity, total (as $CaCO_3$)	Sulfate, dissolved (SO_4)	Chloride, dissolved (Cl)	Fluoride, dissolved (F)	Silica, dissolved (SiO_2)	Dissolved solids, sum of constitutents	Nitrogen, NO_2+NO_3, dissolved	Phosphorous, total (P)
Formation											
.1	2.6	--	--	160	62	1.1	.3	11	268	.28	<.01
.3	3.7	--	--	180	450	4.4	1.5	9.7	787	.49	.02
.7	7.4	380	0	--	280	39	1.2	13	759	--	--
.8	8.1	--	--	290	330	43	1.2	14	832	<.100	<.01
4	160	1,330	0	--	1,300	370	4.1	39	3,680	--	--
Sandstone											
.1	.6	--	--	150	8	.7	.1	13	171	.73	.01
.1	.6	--	--	190	9	.6	.1	13	204	.97	.04
.2	1.6	300	0	--	170	3.1	2.2	12	478	--	--
2	22	710	0	--	540	120	2.2	13	1,530	--	--
Limestone											
3	170	990	0	--	1,500	280	3.8	30	3,390	--	--
Dolomite											
.0	1.4	--	--	190	7	.6	.1	7.4	196	.260	<.01
.0	1.4	--	--	220	10	1.3	.1	7.2	222	.770	<.01
.1	.8	--	--	240	6	1.3	.2	9.4	237	.500	<.01
.1	2.2	--	--	200	18	1.2	.2	9.8	223	.570	.01
.1	1.9	--	--	230	16	1.1	.2	8.8	247	.620	<.01
3	160	1,210	0	--	1,400	270	3.4	30	3,440	--	--
Limestone											
.2	2.9	--	--	240	46	1.7	.2	9.7	296	.470	<.01
Sandstone											
.1	.8	--	--	50	9	1.3	.2	14	85	.81	.03
.2	.7	--	--	20	5	3.7	.1	11	58	1.90	<.01
.1	.5	--	--	60	6	.9	.1	15	85	.88	.02

Table 14. *Concentrations of selected trace elements*

[Site number: Simplified site number used in this report to identify numbering system in the section titled Ground-Water Data.

Site number (tab. 13)	Local number	Date	Aluminum, dissolved (A1)	Arsenic, dissolved (As)	Barium, dissolved (Ba)	Boron, dissolved (Ba)	Cadmium, dissolved (Cd)
							Quaternary alluvium
Qa4	44-094-08ba 01	10-12-70	--	--	--	190	--
Qa6	44-094-33ccb01	06-07-67	--	--	--	20	--
Qa7	45-099-23cab01	07-25-90	--	--	--	130	--
Qa8	45-100-17acd01	06-21-90	<10	<1	18	40	1
							Quaternary terrace
Qt2	43-096-07dbc01	10-28-49	--	--	--	530	--
		09-03-68	--	--	--	610	--
Qt4	43-096-17bbb03	08-23-65	--	--	--	300	--
Qt7	46-098-28bbb01	06-20-90	10	<1	11	610	<1.0
							Absaroka Volcanic
Tav1	43-100-04aad01	07-24-90	200	8	12	70	2
Tav3	45-099-08bdc01	06-21-90	10	2	19	70	<1.0
							Fort Union
Tfu1	45-096-15dda01	09-13-90	<10	<1	100	920	<1.0
Tfu2	45-097-17acc01	07-26-90	10	<1	<100	110	<1.0
Tfu3	47-097-31cbb01	02-16-68	--	--	--	250	--
Tfu4	47-098-28aaa01	06-18-90	20	<1	<100	170	<1.0
Tfu5	47-098-34cad01	04-12-66	--	--	--	160	--
							Meeteetse
Km1	46-097-31aaa01	06-07-67	--	--	--	130	--
Km2	46-099-34dcb01	06-21-90	10	<1	30	60	<1.0
Km3	46-100-22daa01	06-22-90	<10	<1	19	100	<1.0
Km4	47-098-32aba01	06-19-90	10	<1	19	110	<1.0
Km5	47-099-33cad01	06-19-90	<10	<1	18	130	<1.0
							Mesaverde
Kmv1	44-095-17bba01	07-16-70	--	--	--	1,300	--
Kmv2	44-097-25cdc01	06-23-70	--	--	--	160	--
Kmv3	44-098-17abc01	07-23-90	--	--	--	250	--
Kmv4	45-097-15cbd01	07-26-90	10	<1	12	170	1
Kmv5	45-097-26bcd01	07-24-90	10	<1	<100	960	<1.0
Kmv6	45-097-28dad01	07-23-90	10	6	<100	290	<1.0
Kmv7	45-099-25ccd01	07-25-90	--	--	--	260	--
Kmv8	45-099-28aba01	07-25-90	--	--	--	120	--
Kmv9	46-098-10bba01	02-06-67	--	--	--	350	--
Kmv10	46-099-22cbc01	06-20-90	10	<1	24	80	<1.0
Kmv11	47-099-04dab01	06-20-90	10	<1	<100	210	<1.0
Kmv12	47-099-14abc02	09-16-70	--	--	--	290	--

for selected wells and springs in Hot Springs County

well and spring sampling sites. Local number: See text describing well-
Analytical results in micrograms per liter; --no data; <, less than]

Chromium, dissolved (Cr)	Copper, dissolved (Cu)	Iron, dissolved (Fe)	Lead, dissolved (Pb)	Manganese, dissolved (Mn)	Mercury, dissolved (Hg)	Selenium, dissolved (Se)	Silver, dissolved (Ag)	Zinc, dissolved (Zn)
deposits								
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
--	--	9	--	25	--	3	--	--
<1	2	30	<1	7	<0.1	<1	1	30
deposits								
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
2	260	20	<1	3	< .1	8	<1.0	80
Supergroup								
1	4	250	1	17	.2	7	1	3
<1	<1	10	<1	16	< .1	2	2	6
Formation								
2	16	80	<1	20	< .1	6	<1.0	140
2	2	10	1	<10	.2	<2	<1.0	<10
--	--	--	--	--	--	--	--	--
3	1	20	<1	20	< .1	<1	<1.0	<10
--	--	--	--	--	--	--	--	--
Formation								
--	--	--	--	--	--	--	--	--
<1	1	100	1	200	< .1	1	2	150
1	10	610	<1	16	< .1	<1	2	30
2	1	40	1	130	< .1	<1	1	40
2	4	10	<1	45	< .1	<1	<1.0	100
Formation								
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
--	--	40	--	600	--	<2	--	--
2	1	190	<1	13	0.2	<2	<1.0	6
2	1	60	<1	180	.3	6	<1.0	20
<1	1	1,900	<1	120	.2	<2	<1.0	10
--	--	20	--	86	--	<2	--	--
--	--	1,100	--	39	--	3	--	--
--	--	--	--	--	--	--	--	--
<1	10	7	<1	<1	< .1	2	<1.0	50
1	<1	30	<1	50	< .1	<1	<1.0	<10
--	--	--	--	--	--	--	--	--

Table 14. *Concentrations of selected trace elements*

Site number (tab. 13)	Local number	Date	Aluminum, dissolved (A1)	Arsenic, dissolved (As)	Barium, dissolved (Ba)	Boron, dissolved (Ba)	Cadmium, dissolved (Cd)
							Cody
Kc3	46-098-27dcc01	09-17-70	--	--	--	1,000	--
							Frontier
Kf1	41-090-04baa01	09-14-90	--	--	--	20	--
Kf2	42-091-35acc01	09-14-90	<10	<1	<100	70	<1.0
Kf3	42-092-02cbb01	07-09-70	--	--	--	1,400	--
		08-22-90	20	<1	17	1,300	<1.0
Kf4	42-092-08ddd01	07-25-89	--	--	--	160	--
Kf5	42-092-12cda01	08-22-90	<10	<1	12	80	<1.0
Kf6	43-092-04bda01	08-22-90	--	--	--	1,000	--
Kf7	43-092-22cdb01	08-22-90	--	--	--	30	--
Kf8	44-093-33dac01	08-23-90	--	--	--	2,400	--
Kf9	44-093-34dcc01	08-23-90	20	<1	35	180	<1.0
							Mowry
Kmr1	41-091-09cca01	08-23-90	30	1	23	20	<1.0
Kmr2	42-092-34bab01	08-11-89	--	--	--	370	--
Kmr3	42-093-07cdc01	07-25-89	--	--	--	140	--
							Thermopolis Shale and Muddy Sandstone
Kt1	41-092-11abd01	07-27-89	--	--	--	240	--
Kt2	41-092-11adb01	07-27-89	--	--	--	80	--
Kt3	43-091-19daa02	07-13-70	--	--	--	1,000	--
Kt4	43-091-36bca01	07-13-70	--	--	--	80	--
							Cloverly
Kcv1	42-094-07bac01	06-25-70	--	--	--	500	--
Kcv2	42-095-03aac01	07-27-90	20	1	<100	370	<1.0
							Sundance
Js1	41-091-13cdc01	09-11-89	--	--	--	380	--
							Gypsum Spring
Jgs1	41-091-23ddd01	09-13-89	--	--	--	30	--
Jgs2	41-091-32aac01	09-13-89	--	--	--	60	--
Jgs3	42-092-18caa01	09-15-89	--	--	--	210	--
Jgs4	42-094-15dad01	09-12-89	--	--	--	50	--
							Chugwater
TRc1	41-091-27dbc01	09-14-89	--	--	--	50	--
TRc2	41-091-27dcc01	09-13-89	--	--	--	20	--
TRc3	41-091-32cad01	09-13-89	--	--	--	40	--
TRc4	41-092-04bcb01	09-15-89	--	--	--	100	--
TRc5	42-093-14ccb01	07-26-89	--	--	--	110	--

for selected wells and springs in Hot Springs County--Continued

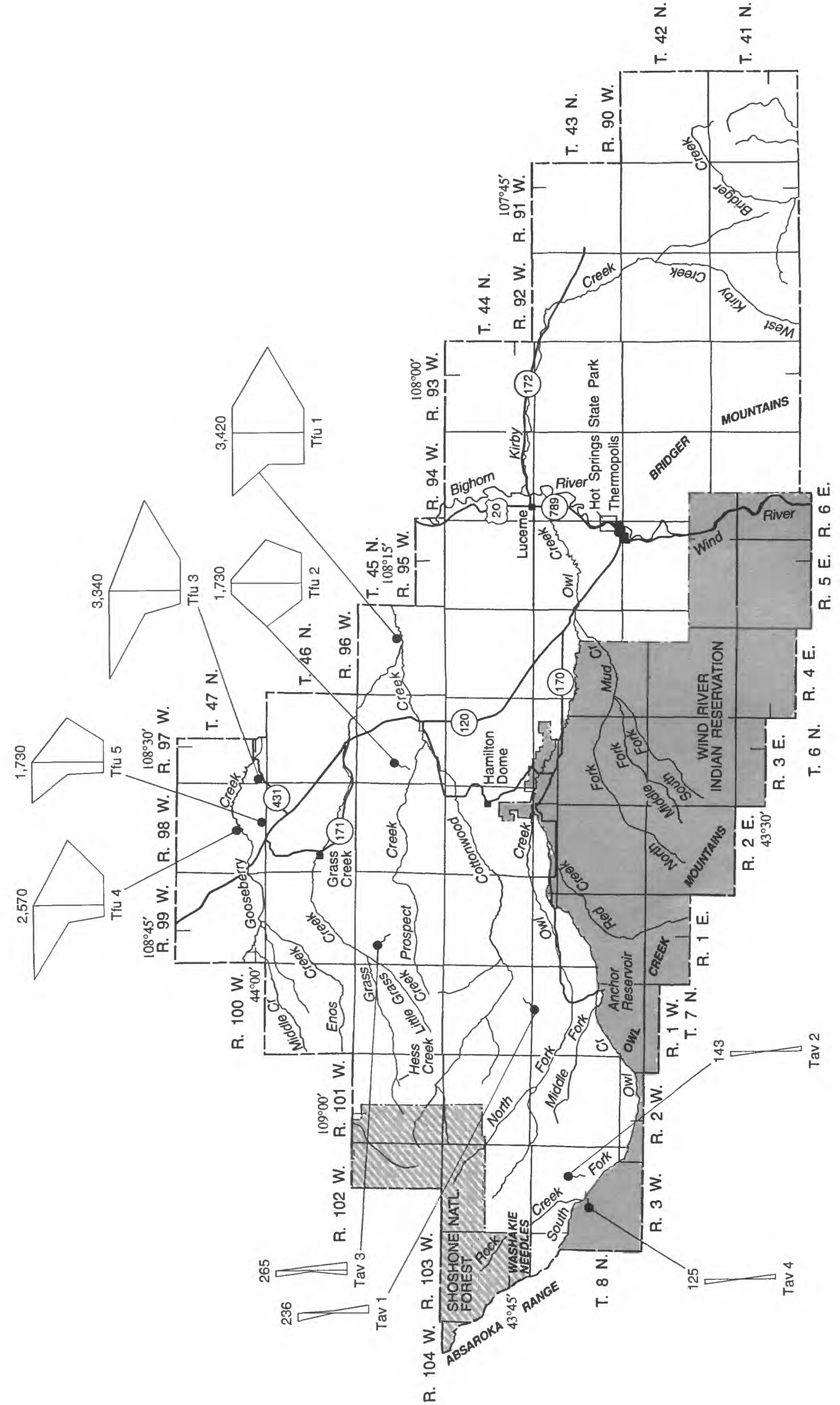
Chromium, dissolved (Cr)	Copper, dissolved (Cu)	Iron, dissolved (Fe)	Lead, dissolved (Pb)	Manganese, dissolved (Mn)	Mercury, dissolved (Hg)	Selenium, dissolved (Se)	Silver, dissolved (Ag)	Zinc, dissolved (Zn)
Shale								
--	--	--	--	--	--	--	--	--
Formation								
--	--	<3	--	5	--	<1	--	--
<1	<1	850	<1	190	.2	<1	<1.0	<10
--	--	--	--	--	--	--	--	--
1	1	30	<1	6	< .1	<1	<1.0	<3
--	--	100	--	5	--	<1	--	--
1	3	40	<1	21	.1	<1	<1.0	<3
--	--	50	--	4	--	<1	--	--
--	--	20	--	9	--	--	--	--
--	--	50	--	120	--	<1	--	--
1	<1	40	<1	9	.6	<1	<1.0	<3
Shale								
<1	1	20	1	5	< .1	<1	<1.0	<3
--	--	310	--	96	--	<1	--	--
--	--	110	--	4	--	4	--	--
Member of the Thermopolis Shale								
--	--	520	--	910	--	<1	--	--
--	--	4	--	4	--	--	--	--
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
Formation								
--	--	--	--	--	--	--	--	--
3	2	1,700	1	170	0.2	<1	<1.0	40
Formation								
--	--	8	--	11	--	5	--	--
Formation								
--	--	20	--	12	--	3	--	--
--	--	8	--	<1	--	<1	--	--
--	--	20	--	2	--	3	--	--
--	--	40	--	10	--	4	--	--
Formation								
--	--	10	--	<1	--	2	--	--
--	--	7	--	<1	--	8	--	--
--	--	160	--	53	--	<1	--	--
--	--	10	--	9	--	5	--	--
--	--	10	--	2	--	--	--	--

Table 14. *Concentrations of selected trace elements*

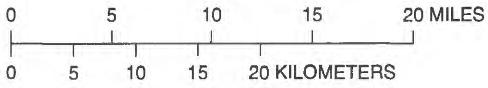
Site number (tab. 13)	Local number	Date	Aluminum, dissolved (A1)	Arsenic, dissolved (As)	Barium, dissolved (Ba)	Boron, dissolved (Ba)	Cadmium, dissolved (Cd)
							Chugwater
TRc6	42-093-21acc01	07-26-89	--	--	--	220	--
TRc7	42-094-17ddc01	07-26-89	--	--	--	540	--
TRc8	42-094-25bdb01	07-25-89	--	--	--	550	--
TRc10	6N-5E-04dcd01	07-28-89	--	--	--	50	--
TRc11	6N-5E-09adb01	07-28-89	--	--	--	60	--
TRc12	7N-5E-31cda01	07-28-89	--	--	--	90	--
							Phosphoria
Pp1	41-090-29dbc01	09-14-89	--	--	--	10	--
Pp2	42-093-29bdb01	07-26-89	--	--	--	60	--
Pp3	42-095-25bca01	07-07-70	--	--	--	120	--
Pp4	42-095-26aad01	07-28-89	--	--	--	160	--
Pp5	46-100-24cca01	09-16-70	--	--	--	1,100	--
							Tensleep
Pt1	41-094-21cda01	08-08-89	--	--	--	<10	--
Pt2	41-094-27aaa01	08-08-89	--	--	--	<10	--
Pt3	42-094-26cac01	10-12-70	--	--	--	0	--
Pt4	42-095-13dca01	06-25-70	--	--	--	410	--
							Madison
MDm1	46-098-28bcc01	06-07-67	--	--	--	10	--
							Bighorn
Ob1	41-092-17ddd01	09-15-89	--	--	--	10	--
Ob2	41-092-27dac01	08-10-89	--	--	--	<10	--
Ob3	41-092-28aaa01	09-15-89	--	--	--	10	--
Ob4	41-093-21dcb01	08-08-89	--	--	--	20	--
Ob5	41-093-23aad01	07-26-89	--	--	--	20	--
Ob6	46-098-18cbb01	09-17-70	--	--	--	1,500	--
							Gallatin
Cg1	6N-6E-15cca01	09-12-89	--	--	--	120	--
							Flathead
Cf1	41-092-33daa01	08-10-89	--	--	--	10	--
Cf2	41-093-25cac01	09-14-89	--	--	--	<10	--
Cf3	41-093-31dcd01	08-09-89	--	--	--	30	--

for selected wells and springs in Hot Springs County--Continued

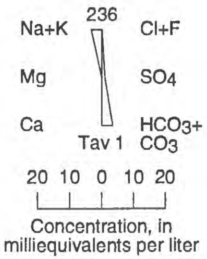
Chromium, dissolved (Cr)	Copper, dissolved (Cu)	Iron, dissolved (Fe)	Lead, dissolved (Pb)	Manganese, dissolved (Mn)	Mercury, dissolved (Hg)	Selenium, dissolved (Se)	Silver, dissolved (Ag)	Zinc, dissolved (Zn)
Formation								
--	--	70	--	20	--	--	--	--
--	--	8	--	2	--	--	--	--
--	--	140	--	20	--	--	--	--
--	--	6	--	<1	--	--	--	--
--	--	50	--	20	--	--	--	--
--	--	5	--	2	--	--	--	--
Formation								
--	--	9	--	<1	--	2	--	--
--	--	1,100	--	18	--	--	--	--
--	--	--	--	--	--	--	--	--
--	--	20	--	6	--	--	--	--
--	--	--	--	--	--	--	--	--
Sandstone								
--	--	10	--	<1	--	<1	--	--
--	--	10	--	2	--	--	--	--
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
Limestone								
--	--	--	--	--	--	--	--	--
Dolomite								
--	--	40	--	7	--	<1	--	--
--	--	10	--	<1	--	--	--	--
--	--	8	--	<1	--	<1	--	--
--	--	10	--	<1	--	--	--	--
--	--	40	--	2	--	--	--	--
--	--	--	--	--	--	--	--	--
Limestone								
--	--	10	--	<1	--	<1	--	--
Sandstone								
--	--	10	--	<1	--	--	--	--
--	--	30	--	<1	--	<1	--	--
--	--	20	--	1	--	--	--	--


T. 42 N.
T. 41 N.
T. 43 N.
R. 90 W.
107°45'
R. 91 W.
T. 44 N.
R. 92 W.
108°00'
R. 93 W.
R. 94 W.
T. 45 N.
108°15'
R. 95 W.
T. 46 N.
R. 96 W.
T. 47 N.
108°30'
R. 97 W.
R. 98 W.
108°45'
R. 99 W.
R. 100 W.
44°00'
109°00'
R. 101 W.
R. 102 W.
R. 103 W.
R. 104 W.
T. 8 N.
T. 7 N.
R. 1 W.
R. 2 W.
R. 3 W.
R. 1 E.
R. 2 E.
43°30'
R. 3 E.
T. 6 N.
R. 4 E.
R. 5 E.
R. 6 E.
43°45'
Bridger Creek
Kirby Creek
West Kirby Creek
Creek
Hot Springs State Park
Thermopolis
BRIDGER
MOUNTAINS
Bighorn
River
Kirby
Lucerne
Owl Creek
Wind River
WIND RIVER INDIAN RESERVATION
Mud Cr.
Fork
South Fork
Middle Fork
North Fork
MOUNTAINS
Red Creek
Hamilton Dome
Cottonwood Creek
Grass Creek
Prospect Creek
Gooseberry Creek
Enos Creek
Middle Cr.
Grass Creek
Little Grass Creek
Hess Creek
Owl Creek
Anchor Reservoir
OWL CREEK
Owl Cr.
North Fork
Middle Fork
South Fork Creek
SHOSHONE NATL FOREST
Rock
WASHAKIE NEEDLES
ABSAROKA RANGE
172
20
789
170
120
431
171
3,420
Tfu 1
3,340
Tfu 3
1,730
Tfu 2
1,730
Tfu 5
2,570
Tfu 4
143
Tav 2
125
Tav 4
265
Tav 3
236
Tav 1

Base modified from U.S. Geological Survey 1:100,000 digital line graphs: Basin, 1982; Lysite, 1982; Nowater Creek, 1979; Riverton, 1978; The Ramshorn, 1978; and Thermopolis, 1981. Universal Traverse Mercator projection, Zones 12 and 13.



EXPLANATION



MODIFIED STIFF DIAGRAM WITH CONCENTRATIONS OF MAJOR IONS IN MILLIEQUIVALENTS--Number above the diagram denotes the dissolved-solids concentration in milligrams per liter for the same water sample. Number below the diagram indicates sampling site number (correlates to tables 13 and 14). Letter in the sampling site number indicates the geologic unit in which the well is completed or from which the spring issues

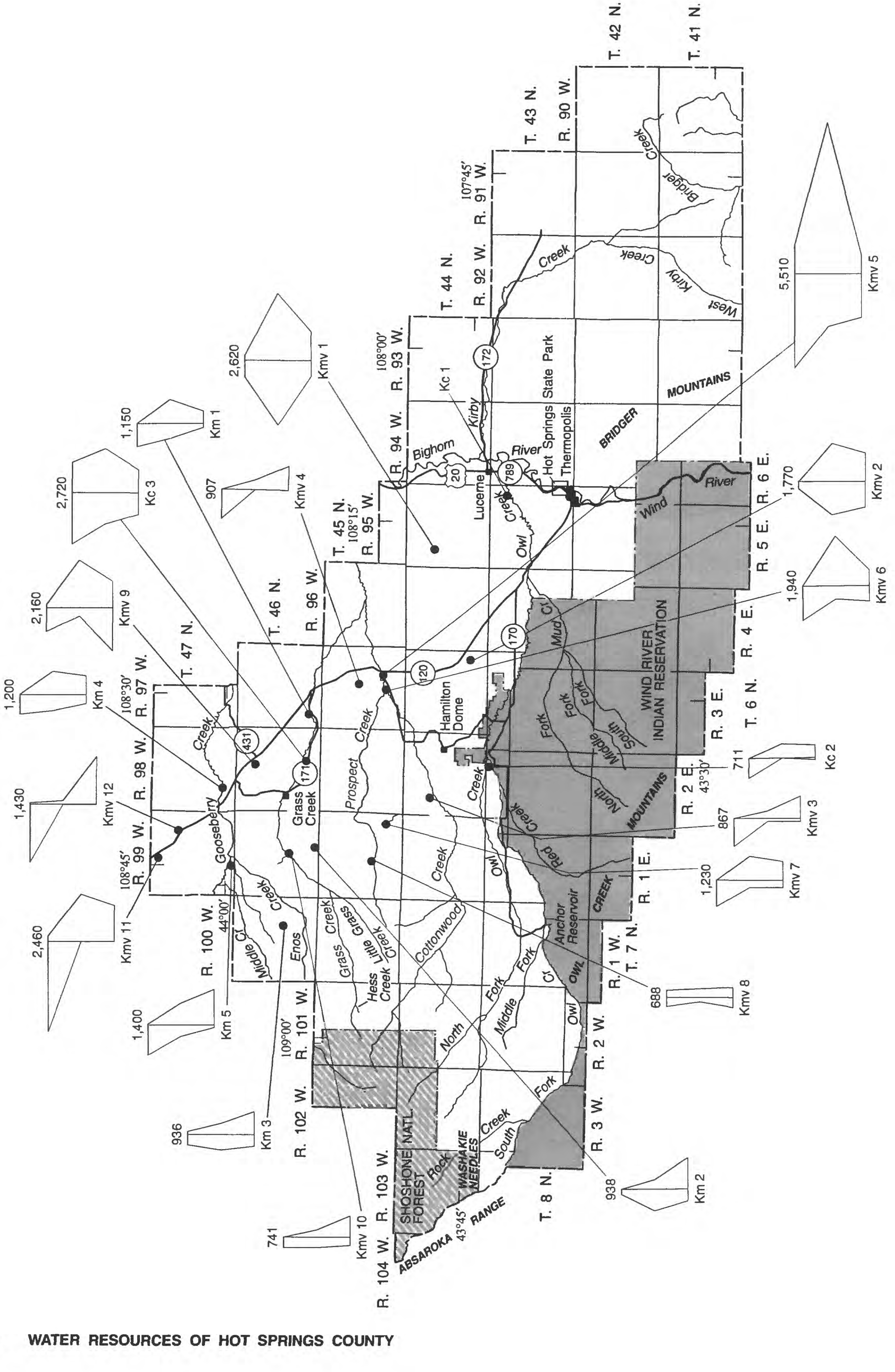
Tav ABSAROKA VOLCANIC SUPERGROUP

Tfu FORT UNION FORMATION

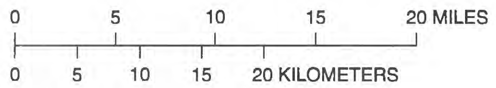
● WELL

●~ SPRING

Figure 15.--Location, modified Stiff diagrams, and dissolved-solids concentrations for wells completed in and springs that issue from Tertiary rocks.


WIND RIVER INDIAN RESERVATION
SHOSHONE NATL. FOREST
BRIDGER MOUNTAINS
OWL CREEK MOUNTAINS
ABSAROKA RANGE
WASHAKIE NEEDLES
Hot Springs State Park
Thermopolis
Lucerne
Hamilton Dome
Grass Creek
Anchor Reservoir
Bighorn River
Wind River
Kmv 1
Kmv 2
Kmv 3
Kmv 4
Kmv 5
Kmv 6
Kmv 7
Kmv 8
Kmv 9
Kmv 10
Kmv 11
Kmv 12
Km 1
Km 2
Km 3
Km 4
Km 5
Kc 1
Kc 2
Kc 3
2,620
1,150
2,720
907
2,160
1,200
1,430
2,460
1,400
936
741
5,510
1,770
1,940
711
867
1,230
688
938

Base modified from U.S. Geological Survey 1:100,000 digital line graphs: Basin, 1982; Lysite, 1982; Nowater Creek, 1979; Riverton, 1978; The Ramshorn, 1978; and Thermopolis, 1981. Universal Traverse Mercator projection, Zones 12 and 13.



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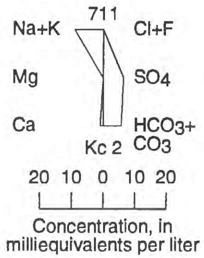


MODIFIED STIFF DIAGRAM WITH CONCENTRATIONS OF MAJOR IONS IN MILLIEQUIVALENTS--Number above the diagram denotes the dissolved-solids concentration in milligrams per liter for the same water sample. Number below the diagram indicates sampling site number (correlates to tables 13 and 14). Letter in the sampling site number indicates the geologic unit in which the well is completed or from which the spring issues

Km MEETEETSE FORMATION

Kmv MESAVERDE FORMATION

Kc CODY SHALE

● WELL

●~ SPRING

Figure 16.--Location, modified Stiff diagrams, and dissolved-solids concentrations for wells completed in and springs that issue from Upper Cretaceous rocks.

Mesozoic Rocks

Forty-one water-quality samples have been collected from wells completed in and springs that issued from Mesozoic rocks. These water-quality samples consisted of twelve from the Frontier Formation, three from the Mowry Shale, three from the Mowry Shale and Thermopolis Shale (undifferentiated), four from the Thermopolis Shale, two from the Cloverly Formation, one from the Sundance Formation, four from the Gypsum Spring Formation, and twelve from the Chugwater Formation. The chemical-quality characteristics of the water samples from each geologic unit are discussed next.

Twelve water-quality samples were collected from the Frontier Formation—nine in 1989-90 as part of this study, two in 1989, and one in 1970 for previous studies. These water-quality samples are from seven wells completed in and four springs that issue from the Frontier Formation and located in two areas of the county--the southeastern part along Kirby Creek, and the south-central part in the Owl Creek Mountains (fig. 17). The dissolved-solids concentrations of water samples from these wells and springs ranged from 284 to 9,960 mg/L (table 13). Modified Stiff diagrams (fig. 17), which by their shapes indicate the type of water present in the samples, show that the water type varied from site to site. Samples from the springs in the Owl Creek Mountains were of the sodium and calcium sulfate type. In the area along the middle section of Kirby Creek, the water samples were dominated by the sodium cation and the anion was either sulfate or bicarbonate. Selected constituents for individual water samples listed in table 13 also reflected the significant differences between samples. Selected wells and springs were analyzed for specific trace elements; concentrations are listed in table 14. Dissolved concentrations of boron and iron in water samples from selected wells and springs ranged from 20 to 2,400 μg/L for boron and from less than 3 to 850 μg/L for iron.

Three water-quality samples were collected from the Mowry Shale in 1989-90 for this study. The three samples are from two springs that issue from the Mowry Shale and one well completed in the formation (fig. 17). All three water-quality sampling sites are in the southeastern part of the county. Dissolved-solids concentrations of water samples from this well and these springs ranged from 362 to 1,150 mg/L (table 13). Modified Stiff diagrams (fig. 17), which by their shapes indicate the type of water present in the samples, show the water to be dominated by the sodium and calcium cations and the bicarbonate and sulfate anions. The sample from well Kmr2 has a larger sulfate than bicarbonate concentration, in milliequivalents per liter, whereas samples from the springs have about equal concentrations, in milliequivalents per liter, of these two anions (fig. 17). The concentrations of selected constituents for individual water samples are listed in table 13. Water samples from all three sites in the Mowry Shale were analyzed for dissolved concentrations of boron, iron, manganese, and selenium. These dissolved concentrations are listed in table 14. All the high values, except the dissolved-selenium value, were associated with the water sample from well Kmr2.

Three water-quality samples were collected from the Mowry Shale and Thermopolis Shale (undifferentiated unit) in 1989 for this study. These three samples were collected at springs that issued from this unit in the central part of the county (fig. 17). Dissolved-solids concentrations of water samples from these springs ranged from 542 to 847 mg/L (table 13). Modified Stiff diagrams (fig. 17), which by their shapes indicate the type of water present in the samples, show the water to be of the calcium sulfate type. The individual water samples listed in table 13 also reflected similar water types.

Four water-quality samples were collected from the Thermopolis Shale—two in 1989 as part of this study, and two in 1970 for a previous study. Well Kt1 in the southeastern part of the county is completed in the Thermopolis Shale. Spring Kt2, also located in the southeastern part of the county, issues from the Thermopolis Shale (fig. 17). Wells Kt3 and Kt4 are completed in the Muddy Sandstone Member of the Thermopolis Shale. Dissolved-solids concentrations of the water samples from the Thermopolis Shale ranged from 599 to 1,100 mg/L (table 13). The two samples from the Thermopolis Shale, based on modified Stiff diagrams, show the water to be sodium bicarbonate type. Water samples from the Muddy Sandstone Member of the

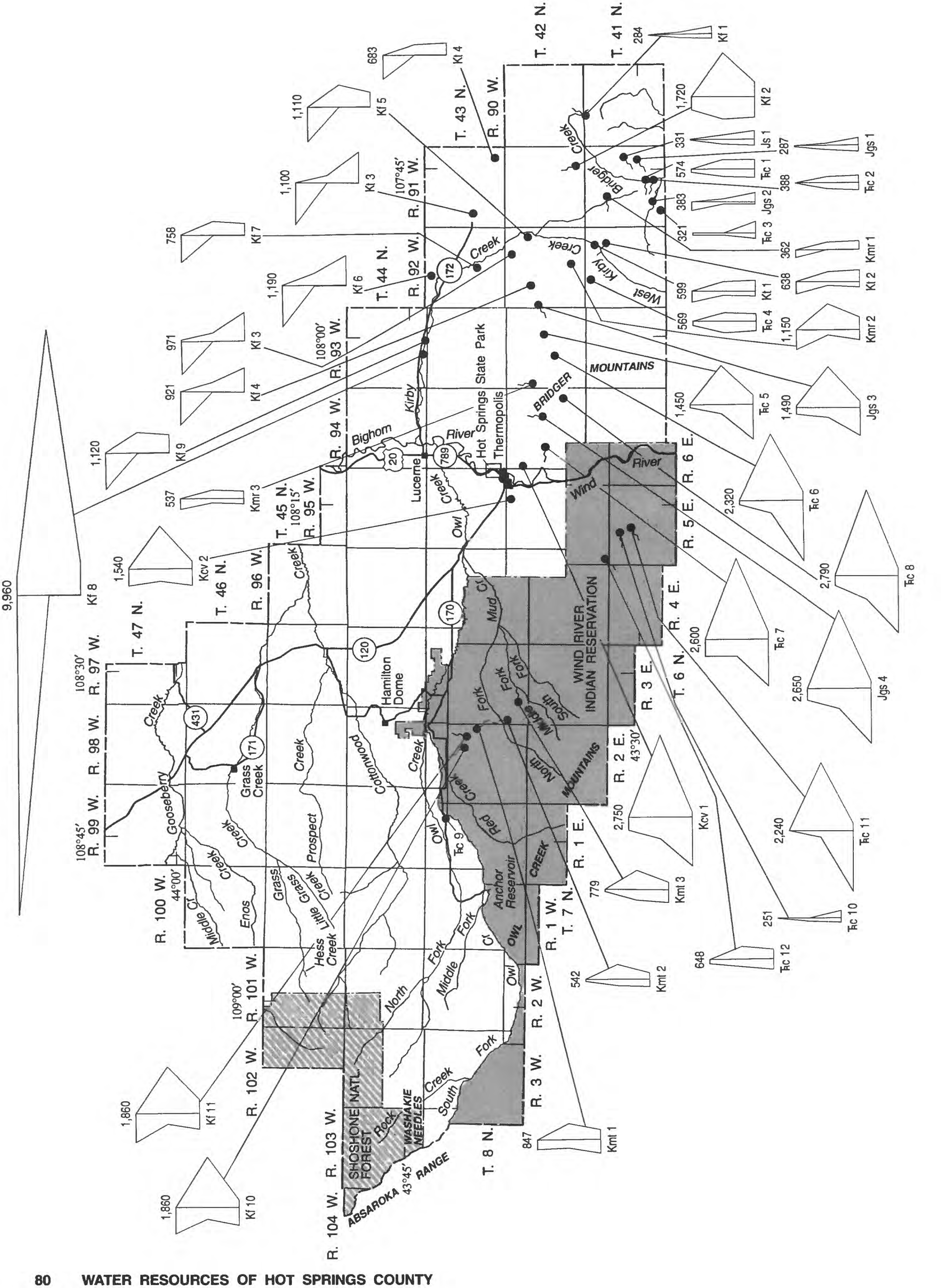
Thermopolis Shale are the same type, but are even more dominated by sodium and bicarbonate. The concentrations of selected constituents for the water samples are listed in table 13. Dissolved concentrations of selected trace elements are listed in table 14.

Two water-quality samples were collected from the Cloverly Formation—one in 1990 as part of this study, and one in 1970 for a previous study. Both water-quality samples are from wells (Kcv1 and Kcv2) in the central part of the county (fig. 17). The dissolved-solids concentrations of water samples from both wells were 2,750 and 1,540 mg/L (table 13). Modified Stiff diagrams (fig. 17), which by their shapes indicate the type of water present in the samples, show calcium to be the dominant cation in Kcv1 and in Kcv2. Sulfate was the dominant anion in both water samples. Concentrations of constituents for the individual water samples listed in table 13 reflected the consistency of water type between the samples. Dissolved concentrations of selected trace elements in samples from well Kcv1 and well Kcv2 are listed in table 14.

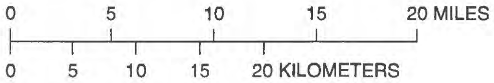
One water-quality sample was collected from the Sundance Formation in 1989 as part of this study. This water-quality sample (site Js1) was from a spring in the southeastern part of the county. The dissolved-solids concentration of the water sample from this spring was 331 mg/L (table 13). A modified Stiff diagram (fig. 17), which by its shape indicates the type of water present in the sample, show the water to be of the calcium bicarbonate type. The shape and size of the modified Stiff diagram was similar to spring Jgs1, that issued from the underlying Gypsum Spring Formation slightly to the southwest. Selected constituents for the water sample are listed in table 13. Dissolved boron, iron, manganese, and selenium concentrations for sample Js1 are listed in table 14.

Four water-quality samples were collected from the Gypsum Spring Formation in 1989 as part of this study. All four of these water-quality samples are from springs in the southeastern part of the county issuing from the Gypsum Spring Formation (fig. 17). Dissolved-solids concentrations of water samples from these springs ranged from 287 to 2,650 mg/L (table 13). Modified Stiff diagrams (fig. 17), which by their shapes indicate the type of water present in the samples, show that the water varied between sampling points. Springs Jgs3 and Jgs4 were both of the calcium sulfate type, as would be expected in this gypsiferous formation. Selected constituents from individual samples are listed in table 13. Water samples from all four sites were analyzed for dissolved concentrations of boron, iron, manganese, and selenium (table 14).

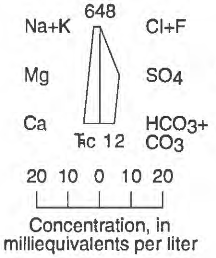
Twelve water-quality samples were collected from the Chugwater Formation—11 in 1989 as part of this study, and one in 1946 for a previous study. Six water-quality samples are from wells in the south and southeastern part of the county and were completed in the Chugwater Formation, while an additional six samples were from springs in that same area that issue from that formation (fig. 17). Dissolved-solids concentrations of water samples from these wells and springs ranged from 251 to 2,940 mg/L (table 13). Modified Stiff diagrams (fig. 17), which by their shapes indicate the type of water present in the samples, show the water to be primarily calcium sulfate type. However, there was variability in water type between sampling points. The variability of selected constituents for individual water samples listed in table 13 also reflected the variability of water type. Water from all samples collected in 1989 was analyzed for dissolved-boron, dissolved-iron, and dissolved-manganese concentrations. Dissolved-boron and dissolved-iron concentrations were found to be highly variable; dissolved-boron ranged from 20 µg/L at spring Ꞧc2 to 550 µg/L at well Ꞧc8 and dissolved-iron ranged from 5 µg/L at spring Ꞧc12 to 160 µg/L at well Ꞧc3. Dissolved-manganese concentrations ranged from less than the detection limit of 1 µg/L at three sites (Ꞧc1, Ꞧc2, Ꞧc10) to 53 mg/L at well Ꞧc3. Springs Ꞧc10 and Ꞧc11 lie in close proximity but their dissolved-solids concentrations differ by an order of magnitude (or factor of 10), their dissolved-calcium concentrations differ by an order of magnitude, and their dissolved-sulfate concentrations differ by two orders of magnitude. There was great variability of concentrations and water types between sampling sites in the Chugwater Formation. Dissolved-selenium concentrations in samples from four sites are listed in table 14.


T. 42 N.
T. 41 N.
T. 43 N.
R. 90 W.
R. 91 W.
107°45'
T. 44 N.
R. 92 W.
R. 93 W.
108°00'
R. 94 W.
T. 45 N.
108°15'
R. 95 W.
T. 46 N.
R. 96 W.
T. 47 N.
108°30'
R. 97 W.
R. 98 W.
R. 99 W.
108°45'
R. 100 W.
44°00'
R. 101 W.
109°00'
R. 102 W.
R. 103 W.
R. 104 W.
T. 8 N.
R. 3 W.
R. 2 W.
R. 1 W.
T. 7 N.
R. 1 E.
R. 2 E.
43°30'
R. 3 E.
T. 6 N.
R. 4 E.
R. 5 E.
R. 6 E.
43°45'
Hot Springs State Park
Thermopolis
Lucerne
Hamilton Dome
Grass Creek
Bighorn
River
Wind
Kirby
Creek
West
Bridger
BRIDGER
MOUNTAINS
WIND RIVER INDIAN RESERVATION
OWL CREEK MOUNTAINS
Anchor Reservoir
Owl
Mud
Ct
North
Middle
South
Fork
Red
Cottonwood
Prospect
Little
Grass
Enos
Hess Creek
Gooseberry
SHOSHONE NATL. FOREST
WASHAKIE NEEDLES
Rock
ABSAROKA RANGE
20
789
172
170
120
431
171
9,960
Kf 8
1,120
Kf 9
537
Kmr 3
921
Kf 4
971
Kf 3
1,190
Kf 6
758
Kf 7
1,100
Kf 3
1,110
Kf 5
683
Kf 4
284
Kf 1
1,720
Kf 2
331
Js 1
287
Jgs 1
574
Ћc 1
388
Ћc 2
383
Jgs 2
321
Ћc 3
362
Kmr 1
599
Kt 1
638
Kt 2
569
Ћc 4
1,150
Kmr 2
1,450
Ћc 5
1,490
Jgs 3
2,320
Ћc 6
2,790
Ћc 8
2,600
Ћc 7
2,650
Jgs 4
2,750
Kcv 1
2,240
Ћc 11
779
Kmt 3
251
Ћc 10
648
Ћc 12
542
Kmt 2
847
Kmt 1
1,540
Kcv 2
1,860
Kf 11
1,860
Kf 10
Ћc 9

Base modified from U.S. Geological Survey 1:100,000 digital line graphs: Basin, 1982; Lysite, 1982; Nowater Creek, 1979; Riverton, 1978; The Ramshorn, 1978; and Thermopolis, 1981. Universal Traverse Mercator projection, Zones 12 and 13.



EXPLANATION



MODIFIED STIFF DIAGRAM WITH CONCENTRATIONS OF MAJOR IONS IN MILLIEQUIVALENTS--Number above the diagram denotes the dissolved-solids concentration in milligrams per liter for the same water sample. Number below the diagram indicates sampling site number (correlates to tables 13 and 14). Letter in the sampling site number indicates the geologic unit in which the well is completed or from which the spring issues

Kf	FRONTIER FORMATION
Kmr	MOWERY SHALE
Kmt	MOWERY AND THERMOPOLIS SHALES
Kt	THERMOPOLIS SHALE AND MUDDY SANDSTONE MEMBER OF THE THERMOPOLIS SHALE
Kcv	CLOVERLY FORMATION
Js	SUNDANCE FORMATION
Jgs	GYPSUM SPRING FORMATION
TRc	CHUGWATER FORMATION
●	WELL
●~	SPRING

Figure 17.--Location, modified Stiff diagrams, and dissolved-solids concentrations for wells completed in and springs that issue from Mesozoic rocks.

Paleozoic Rocks

Twenty water-quality samples were collected from wells completed in and springs that issue from units in Paleozoic rocks. These water-quality samples consist of five from the Phosphoria Formation, four from the Tensleep Sandstone, one from the Madison Limestone, six from the Bighorn Dolomite, one from the Gallatin Limestone, and three from the Flathead Sandstone. The water-quality samples from each unit are discussed below.

Five water-quality samples were collected from the Phosphoria Formation—three in 1989 as part of this study, and two in 1970 for another study. Three water-quality samples, sites Pp2, Pp4, and Pp5, are from wells in the northwestern and southern part of the county, and were completed in the Phosphoria Formation, whereas sites Pp1 and Pp3 were from springs in the southern part of the county that issue from the Phosphoria Formation (fig. 18). Dissolved-solids concentrations of water samples from these wells and springs ranged from 268 to 3,680 mg/L (table 13). Modified Stiff diagrams (fig. 18), which indicate the water types by their shapes, show that the water varied in type between sampling points. The variability of additional selected constituents for individual water samples listed in table 13 also reflected the variability of water type. Water samples from spring Pp1 and wells Pp2 and Pp4 were analyzed for dissolved-iron concentrations. Those concentrations also were found to be highly variable (table 14).

Four water-quality samples were collected from the Tensleep Sandstone—two in 1989 as part of this study, and two in 1970 from a previous study. Two water-quality samples are from wells (Pt3 and Pt4) in the south-central part of the county that were completed in the Tensleep Sandstone, whereas two samples are from springs (Pt1 and Pt2) in the south-central part that issue from the Tensleep Sandstone (fig. 18). Dissolved-solids concentrations in samples from the two springs were about 200 mg/L, whereas dissolved-solids concentrations were as much as 1,530 mg/L in the samples from the wells (table 13). Modified Stiff diagrams (fig. 18), which indicate the water types by their shapes, show the water to be dominated by calcium and bicarbonate. Well Pt3 showed a larger sulfate concentration than Pt1 and Pt2, and in well Pt4 it was almost as dominant as the bicarbonate ion. The concentrations of selected constituents for individual water samples are listed in table 13. Water samples from all four sites were analyzed for concentrations of dissolved boron (table 14).

One water-quality sample was collected from the Madison Limestone in 1967 for a previous study. This water-quality sample is from a well (site MDm1) in the northern part of the county and was completed in the Madison Limestone. Dissolved-solids concentration was 3,390 mg/L (table 13). A modified Stiff diagram (fig. 18), which indicates the water type by its shape, shows the water to be of the calcium sulfate type. Selected additional constituents for well MDm1 are listed in tables 13 and 14.

Six water-quality samples were collected from the Bighorn Dolomite—five in 1989 as part of this study, and one in 1970 for a previous study. One water-quality sample is from a well (Ob6) in the northern part of the county, that was completed in the Bighorn Dolomite, while five samples were from springs (Ob1 through Ob5) in the southern part of the county that issue from the Bighorn Dolomite (fig. 18). Concentrations of total dissolved solids for samples from the springs in the southern part of the county were under 250 mg/L, but the concentration of total dissolved solids for the sample from the deep well in the northern part of the county was 3,440 mg/L (table 13). Modified Stiff diagrams (fig. 18), which indicate the water type by their shapes, show the water that issued from the springs to be of the magnesium bicarbonate type with the calcium ion almost as significant as the magnesium ion. Well Ob6 is a calcium sulfate type water with large concentrations of sodium and potassium. Selected constituents for individual water samples listed in table 13 reflected the consistency between the spring samples and showed that they differ significantly from well Ob6. Dissolved concentrations of selected trace elements are listed in table 14.

One water-quality sample was collected from the Gallatin Limestone in 1989 as part of this study. It is from well Cg1 completed in the Gallatin Limestone in the south-central part of the county (fig. 18). The dissolved-solids concentration of the water sample from this relatively shallow well was 296 mg/L (table 13). A modified Stiff diagram (fig. 18), which indicates the water type by its shape, shows the water to be of the magnesium bicarbonate type. Based on the modified Stiff diagram, the water type was similar to that of water issuing from springs in the Bighorn Dolomite. The concentrations of selected additional constituents for the water sample are listed in tables 13 and 14.

Three water-quality samples were collected from the Flathead Sandstone in 1989 as part of this study. These water-quality samples were all from springs in the southern part of the county that issue from the Flathead Sandstone (fig. 18). Dissolved-solids concentrations of water samples from these springs were quite low, varying from 58 to 85 mg/L (table 13). The springs that issue from the Flathead Sandstone have calcium bicarbonate type waters (fig. 18). There was only a small amount of variability of selected ions for individual water samples from these springs (table 13). Dissolved concentrations of selected trace elements are listed in table 14.

SUMMARY

Surface-water and ground-water data were compiled to describe and evaluate the water resources of Hot Springs County, Wyoming. Ephemeral, perennial, and intermittent streams in the county are described. Ephemeral and intermittent streams, which originate in the plains region of the county, are characterized by extended periods of no flow. Perennial streams, which originate in the mountains, have sustained streamflow as a result of precipitation, low evapotranspiration, ground-water storage, and water stored as snowpack.

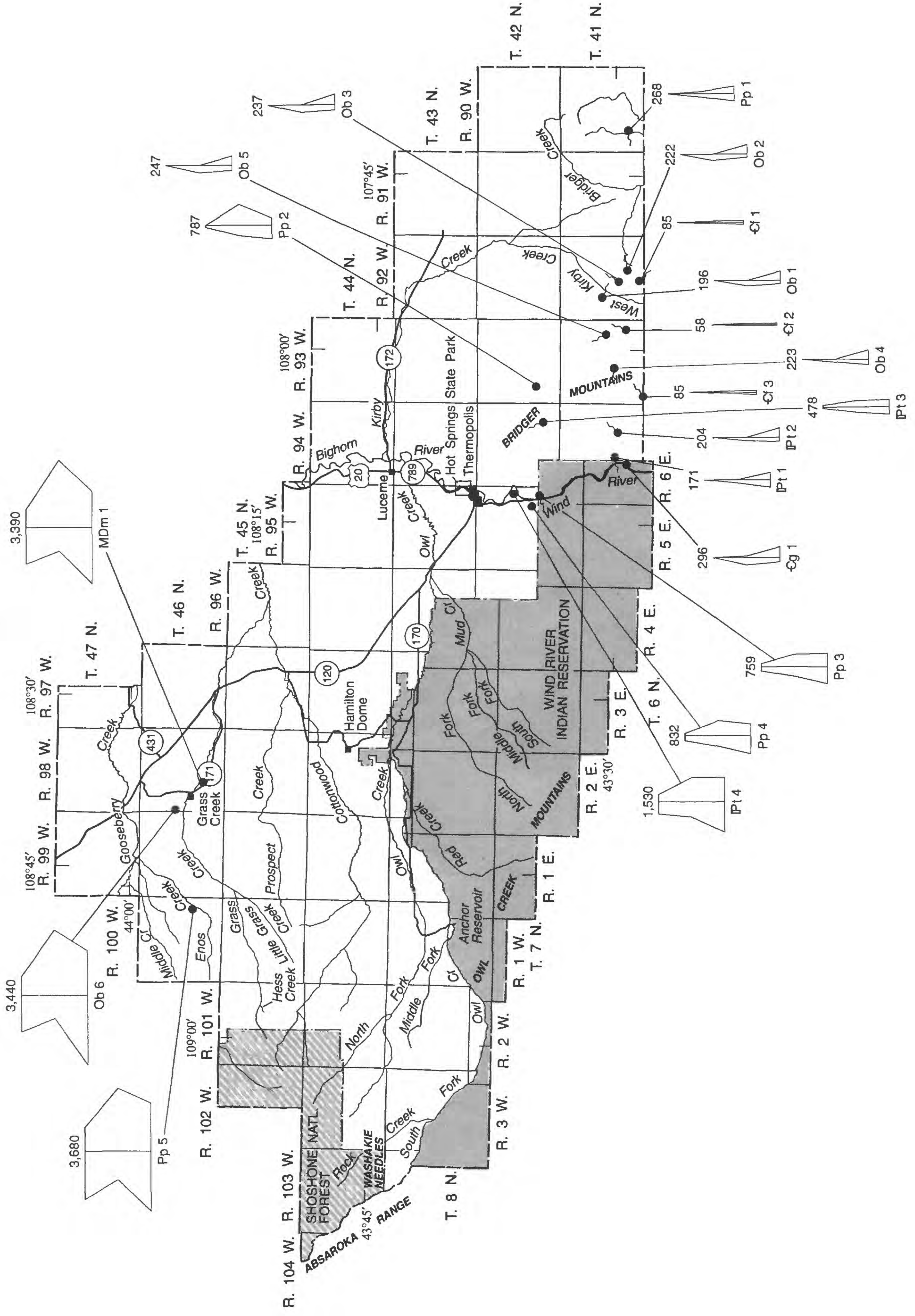
The average annual runoff varies across the county. In the mountainous region, average annual runoff ranges from 2.0 to 5.4 inches. In the plains region, available streamflow data are insufficient for computing average annual runoff.

Geologic units were grouped according to their areal extent, hydrologic properties, and recharge/discharge mechanisms. Groupings include geologic units in the Quaternary unconsolidated deposits and the Tertiary, Upper Cretaceous, Mesozoic, and Paleozoic rocks. Inventoried wells and springs most commonly completed in or issue from the Quaternary alluvium, Quaternary terrace deposits, Fort Union and Mesaverde Formations, Cody Shale, and the Frontier and Chugwater Formations. The largest discharges were measured from the Quaternary terrace deposits (400 gal/min) and the Phosphoria Formation (1,000 gal/min). Discharges from all other geologic units were variable, but most wells and springs yielded 50 gal/min or less.

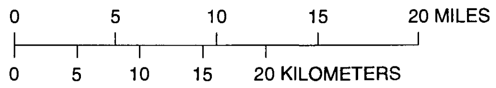
Water levels in four wells completed in the Quaternary alluvium and terrace deposits, the Cody Shale, and the Frontier Formation along Owl Creek fluctuate in response to changes in precipitation. However, previous investigators considered leakage from irrigation canals, laterals, and irrigated fields a more important source of recharge in the Owl Creek area.

The effect of oil and gas development at the Hamilton Dome oil field on thermal spring discharges at Hot Springs State Park near Thermopolis has been a concern to State, county, and local managers. Drawdown at Big Spring in the Park was estimated to be less than 3 ft, based on recent oil- and water-production data, previous modeling studies, and an estimated water-level drawdown of 330 ft in wells at the Hamilton Dome oil field.

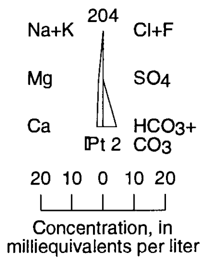
Surface-water supplies about 92 percent of the total offstream use in Hot Springs County. Irrigation is the largest offstream use of surface water in the county. Only 7 percent of the total offstream use in the county is supplied by ground water. The largest use of ground water in the county is for mining.


T. 42 N.
T. 41 N.
T. 43 N.
R. 90 W.
R. 91 W.
107°45′
T. 44 N.
R. 92 W.
108°00′
R. 93 W.
R. 94 W.
T. 45 N.
108°15′
R. 95 W.
T. 46 N.
R. 96 W.
T. 47 N.
108°30′
R. 97 W.
R. 98 W.
108°45′
R. 99 W.
R. 100 W.
44°00′
109°00′
R. 101 W.
R. 102 W.
R. 103 W.
R. 104 W.
R. 6 E.
R. 5 E.
R. 4 E.
R. 3 E.
T. 6 N.
R. 2 E.
43°30′
R. 1 E.
R. 1 W.
T. 7 N.
R. 2 W.
R. 3 W.
T. 8 N.
43°45′
Hot Springs State Park
Thermopolis
Lucerne
Hamilton Dome
Grass Creek
Bighorn
River
Wind
Kirby
Creek
West Kirby Creek
Bridger Creek
Owl Creek
Mud Cr.
Red Creek
Anchor Reservoir
Cottonwood Creek
Prospect Creek
Grass Creek
Little Grass Creek
Hess Creek
Enos Creek
Middle Cr.
Gooseberry Creek
North Fork
Middle Fork
South Fork
Rock Creek
North Fork
Middle Fork
South Fork
BRIDGER MOUNTAINS
OWL CREEK MOUNTAINS
WIND RIVER INDIAN RESERVATION
SHOSHONE NATL. FOREST
WASHAKIE NEEDLES
ABSAROKA RANGE
20
789
172
120
170
431
171
237
Ob 3
247
Ob 5
787
Pp 2
268
Pp 1
222
Ob 2
85
Ꞓf 1
196
Ob 1
58
Ꞓf 2
223
Ob 4
85
Ꞓf 3
478
IPt 3
204
IPt 2
171
IPt 1
296
Ꞓg 1
759
Pp 3
832
Pp 4
1,530
IPt 4
3,390
MDm 1
3,440
Ob 6
3,680
Pp 5

Base modified from U.S. Geological Survey 1:100,000 digital line graphs: Basin, 1982; Lysite, 1982; Nowater Creek, 1979; Riverton, 1978; The Ramshorn, 1978; and Thermopolis, 1981. Universal Traverse Mercator projection, Zones 12 and 13.



EXPLANATION



MODIFIED STIFF DIAGRAM WITH CONCENTRATIONS OF MAJOR IONS IN MILLIEQUIVALENTS--Number above the diagram denotes the dissolved-solids concentration in milligrams per liter for the same water sample. Number below the diagram indicates sampling site number (correlates to tables 13 and 14). Letter in the sampling site number indicates the geologic unit in which the well is completed or from which the spring issues

Pp	PHOSPHORIA FORMATION
Pt	TENSLEEP FORMATION
MDm	MADISON FORMATION
Ob	BIGHORN DOLOMITE
Ꞓg	GALLATIN FORMATION
Ꞓf	FLATHEAD SANDSTONE
●	WELL
●~	SPRING

Figure 18.--Location, modified Stiff diagrams, and dissolved-solids concentrations for wells completed in and springs that issue from Paleozoic rocks.

The Bighorn River at Thermopolis has a calcium sodium sulfate water type and an average dissolved-solids concentration less than 500 mg/L. Water-quality samples, collected during a low-flow period at 13 miscellaneous streamflow sites in Grass Creek in September 1990, showed that dissolved-solids concentrations increase downstream and ranged from 135 to 2,120 mg/L. The water throughout the stream was a sodium type with a bicarbonate type in the upstream reach to a sulfate type in the downstream reach. Results from an earlier study showed that dissolved-solids concentrations increased downstream in the Owl Creek drainage basin, but the basin can be separated into three distinct segments with different average dissolved-solids concentrations. Water from the upper segment is a sodium calcium bicarbonate type with an average dissolved-solids concentration of 171 mg/L. Water from the middle segment is a calcium sulfate type with an average dissolved-solids concentration of 566 mg/L. Water from the lower segment is a sodium sulfate type with an average dissolved-solids concentration of 2,340 mg/L.

Water-quality samples from wells completed in and springs that issue from the Absaroka Volcanic Supergroup, the Bighorn Dolomite, and the Flathead Sandstone contained the lowest dissolved-solids concentrations of all the water-quality samples. Dissolved-solids concentrations from all three geologic units ranged from 58 to 265 mg/L. For all other geologic units, dissolved-solids concentrations of water samples varied greatly.

Water samples collected from springs that issue from the Absaroka Volcanic Supergroup and the Flathead Sandstone also had the least variable water types. Water from the volcanic rocks was a sodium bicarbonate type; whereas, water from the Flathead Sandstone was a calcium bicarbonate type. Water types for all the other aquifers varied between sampling sites; however, water samples from the Fort Union Formation and the Cody Shale were of the sodium sulfate type.

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GLOSSARY

AQUIFER. A body of rock that contains sufficient saturated permeable material to yield significant 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 in which the water level stands above the top of the 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 BED. 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 or self-supplied water.

GROUND WATER, CONFINED. Confined ground water is under pressure substantially greater than atmospheric throughout, and its upper limit is the bottom of a bed of distinctly lower permeability than that of the material in which the confined water occurs.

GROUND WATER, UNCONFINED. Unconfined ground water is water in an aquifer that has a water table.

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 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 alkalinity of water. It is defined as the negative logarithm of the hydrogen-ion concentration. This parameter is dimensionless and generally has a range from 0.0 to 14.0, with a pH of 7.0 representing neutral water. A pH of greater than 7.0 indicates the water is alkaline while a pH value of less than 7.0 indicates an acidic water.

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

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.

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