DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
WYOMING STATE ENGINEER

HYDROLOGIC INVESTIGATIONS
ATLAS HA-539 (SHEET 1 OF 3)

PHYSICAL SETTING AND GROUND-WATER HYDROLOGY

INTRODUCTION

This report describes the results of one of a series of water-resources reconnaissance studies of large areas in Wyoming by the U.S. Geological Survey in cooperation with the Wyoming State Engineer. The purposes of the study are to obtain a general knowledge of the occurrence, availability, and quality of ground water and to summarize flow characteristics and chemical quality of water in major streams in the thrust belt of western Wyoming.

The water resources of parts of the area have been studied previously; however, little hydrologic work of a detailed nature has been done in the thrust belt. Meinzer (1939) briefly discussed "The Geyser," an ebbing and flowing spring near Afton, in his summary of ground water in the United States. Gordon and others (1960) presented very general information on the occurrence and quality of water in part of the Green River basin and adjacent thrust belt. Ground-water resources of the Bear River valley and upper Star Valley were studied by Robinove and Berry (1963) and Walker (1965), respectively, but the reports included little quantitative information. Waddell and Price (1972) summarized the quality of surface water in the Bear River basin in Utah, Wyoming, and Idaho.

GEOGRAPHIC SETTING

The thrust belt of western Wyoming is an elongate, nearly rectangular area of about 5,300 square miles in the Middle Rocky Mountain physiographic province. The study area is bounded on the north by the Teton and the Gros Ventre Ranges, on the east by the Green River and Hoback structural basins, and on the south and west by the Wyoming State line. The area, which is divided about equally between the Snake, Bear, and Green River drainage basins, includes parts of Lincoln, Sublette, Teton, and Uinta Counties, Wyoming. A small area of less than 10 square miles in the extreme southwest corner of Wyoming is in the Weber River drainage basin.

The thrust belt is mountainous. Several peaks in the Salt River and Wyoming Ranges are at altitudes above 10,000 feet. The lowest altitude in the area, about 5,600 feet, is along the Snake River at the Wyoming-Idaho State line. Mountains in the northern part of the area are typically forested, whereas vegetation in the southern part of the area is typically sage brush and grass. Approximately 40 percent of the area is in national forests.

Average annual precipitation ranges from about 9 inches at Kemmerer and at Sage to more than 40 inches in the mountain ranges in the northern part of the area. Most of the precipitation in the mountains falls as snow, and the area has a heavy snow cover during winter. Monthly precipitation at Evanston and at Sage is shown with hydrographs of water levels in observation wells.

WATER USE

By far the largest use of water in the area is for irrigation of alfalfa, grass hay, and pasture to complement livestock grazing on the vastly larger areas of forest and range land. In that part of the Bear River basin that is in Wyoming, an estimated 58,700 acres were irrigated in 1970 (Hunter and others, 1971, p. 12); only about 2,000 acres of this total was irrigated with water from wells. In Star Valley an estimated 56,300 acres were irrigated (Hunter and others, 1971, p. 12); only about 400 acres of this total were irrigated with water from wells. In that part of the Snake River valley in the study area, an estimated 2,300 acres were irrigated in 1970 (Water Planning Program Office of Wyoming State Engineer, oral commun., 3-1-72) with diverted surface water. Small isolated areas were irrigated with surface water along Hams Fork, and Fontenelle, La Barge, North Piney, and Horse Creeks in 1970. The estimated total area of these isolated localities is about 6,700 acres in that part of the Green River basin in the study area (Water Planning Program Office of Wyoming State Engineer, oral commun., 12-7-71).

Average annual irrigation requirements (consumptive use less effective precipitation) in the Bear River valley are about 1.85 acre-feet of water per acre of alfalfa and 1.45 acre-feet per acre of grass hay and pasture (Water Resources Work Group, 1971, p. 24). Using these irrigation requirements as a guide, in 1970 about 200,000 acre feet of surface water and about 4,000 acre-feet of water from wells was consumptively used for irrigation in the study area. Approximately two to three times this amount is diverted from streams for irrigation, but most of the water returns to the streams or recharges the ground-water system.

Industrial water use in 1970 is estimated at 6 mgd (million gallons per day) with about 80 percent of the water derived from surface-water sources. The largest industrial user is Naughton Power Plant near Elkol with an estimated use in 1970 of 4.8 mgd (Utah Power and Light Company, oral commun., 9-7-71). Water for the power plant is taken from Hams Fork. Stauffer Chemical Company near Sage and Star Valley Swiss Cheese Company at Thayne are major industrial users that utilize ground water.

Approximately two-thirds of the estimated 18,000 people that lived in the study area in 1970 were served by municipal water supplies in Afton, Cokeville, Evanston, Kemmerer, Jackson, and Thayne. Estimated use in 1970 by these municipal supplies was 5.4 mgd as shown in the table with chemical analyses of untreated waters. Per capita use is very high because water from the public supplies is also used by small industries and for some livestock watering. Per capita use appears high also because the population figures in the table do not include the large number of tourists that visit the area during summer months. About 55 percent of the water used in Jackson during a year is in the 4-month period of May through August.

The remaining one-third of the residents in the study area either have private water supplies or are served by cooperative supplies at unincorporated communities such as Bedford, Etna, Grover, Smoot, and Turnerville. These private and cooperative supplies utilize wells and springs almost exclusively. Water use from these sources in 1970 is estimated at 3 mgd.

GEOLOGIC SETTING

An understanding of the hydrology of the area is impossible without an understanding of the complex geology of the thrust belt. It is beyond the scope of this report to present all the geologic information and ideas that have emerged in recent years. This report should be supplemented with reports for other studies, some of which are cited. The structure sections that accompany the hydrogeologic map on sheet 2 are usually most complex and intricate where data are most abundant and simplest where data are sparse. Thus, smooth uninterrupted lines in the structure sections may reflect more a lack of data rather than simple structure. The stratigraphic positions of geologic formations and their lithologies are summarized in the adjacent table.

Igneous and metamorphic rocks of Precambrian age comprise the basement complex. Overlying the basement complex, sedimentary rocks deposited during Paleozoic and Mesozoic time have an aggregate thickness of about 55,000 feet in the thrust belt. This entire thickness of sedimentary rocks was not deposited at any one place, but the sites of maximum deposition changed with time as shown in the thickness maps. During Paleozoic time, thick accumulations of marine strata, predominantly limestone and sandstone, were deposited in a transitional area between a miogeosyncline to the west, in what is now eastern Idaho and Utah, and a continental shelf to the east. Beginning in Mississippian time, the miogeosyncline—the sites of maximum deposition—shifted eastward. Except for a reversal in this trend during Permian time, the eastward shift continued into the Mesozoic.

With passage of time in the Mesozoic, increasingly larger proportions of continental strata (predominantly shale and sandstone) were deposited in the area; finally, to the exclusion of marine sediments. In late Mesozoic time, basins developed on what had been the stable continental shelf and the miogeosyncline to the west disappeared. This was accompanied by folding and eastward movement on thrust faults along the eastern flank of the ancient miogeosyncline.

The thrust faults dip gently to the west and, unlike many faults, the rocks involved are unmetamorphosed. No major fault breccia or gorge is present. Stratigraphic displacements on the larger thrust faults range from 20,000 to 40,000 feet; horizontal displacements are probably tens of miles. (See structure sections on sheet 2.) Thrusting started in the western part of the area during Late Jurassic time and ended in the eastern part during early Eocene time. In general, the upper plate of each successively more eastward thrust fault contains younger strata.

The aggregate thickness of continental sedimentary rocks deposited during Tertiary time is about 35,000 feet. Again the entire thickness was not deposited at any one place, and the sites of maximum deposition changed with time. Sites of major deposition were in the Hoback structural basin where about 16,000 feet of sedimentary rocks in the Hoback Formation were deposited and in the Fossil Syncline and Green River structural basin. The Green River Formation was deposited in a lacustrine and subtropical to tropical environment. Fluctuations in lake sizes are recorded in the intertonguing of lake beds of the Green River Formation and fluviatile beds of the Wasatch and Bridger Formations. Cretaceous rocks that underlie Oyster Ridge, a prominent topographic feature, formed a barrier between the Fossil Syncline and Green River structural basin during deposition of most of the Tertiary sediments. The Green River Formation in the Fossil Syncline contains few evaporite deposits, indicating that ancient "Fossil Lake" did not undergo as great a saline cycle as did ancient "Lake Gosiute" in the Green River structural basin.

The latest stage in the tectonic development of the thrust belt, normal faulting, began during Eocene time and has continued to the present as indicated by faulted alluvial fans. Both north-trending and east-trending sets of normal faults are recognized. The normal faults have steep dips (70° to 90°). Stratigraphic displacement on many normal faults is less than 200 feet, but on others may be as much as 5,000 feet. The controlling mechanisms for normal faulting are unknown. If normal faulting is controlled by stress in basement rocks, thrust sheets are offset and the normal faults extend to great depth. If normal faulting is related to a reversal in the direction of movement along thrust faults during a relaxation stage, the normal faults probably do not extend beneath the thrust plate in which they lie. Some downthrown blocks of normal faults became areas of considerable sedimentation of conglomerates and accumulation areas of windblown volcanic ash as in the Salt Lake and Camp Davis Formations.

GROUND-WATER HYDROLOGY

Few generalizations can be made regarding the ground-water hydrology that will hold true for the whole area because of the complex geology of the thrust belt; however, the following discussion summarizes the most common conditions in which water recharges aquifers, moves through them, and is discharged.

RECHARGE, MOVEMENT, AND DISCHARGE

Limestone and dolomite aquifers in the Madison Limestone, Darby Formation, and Bighorn Dolomite receive most of their recharge in outcrop areas by direct penetration of rainfall and snowmelt. In some areas, they also drain overlying aquifers and aquifers that are butted against them along faults. Most of the water discharged from the limestones is through a few large springs. In these natural discharge areas, flow is concentrated in the larger openings and thus the major conduits are selectively enlarged by solution. Water that recharges these aquifers in one surface drainage basin may eventually be discharged by springs in adjacent basins. A block diagram on sheet 2 illustrates the movement of ground water in part of the Salt River Range.

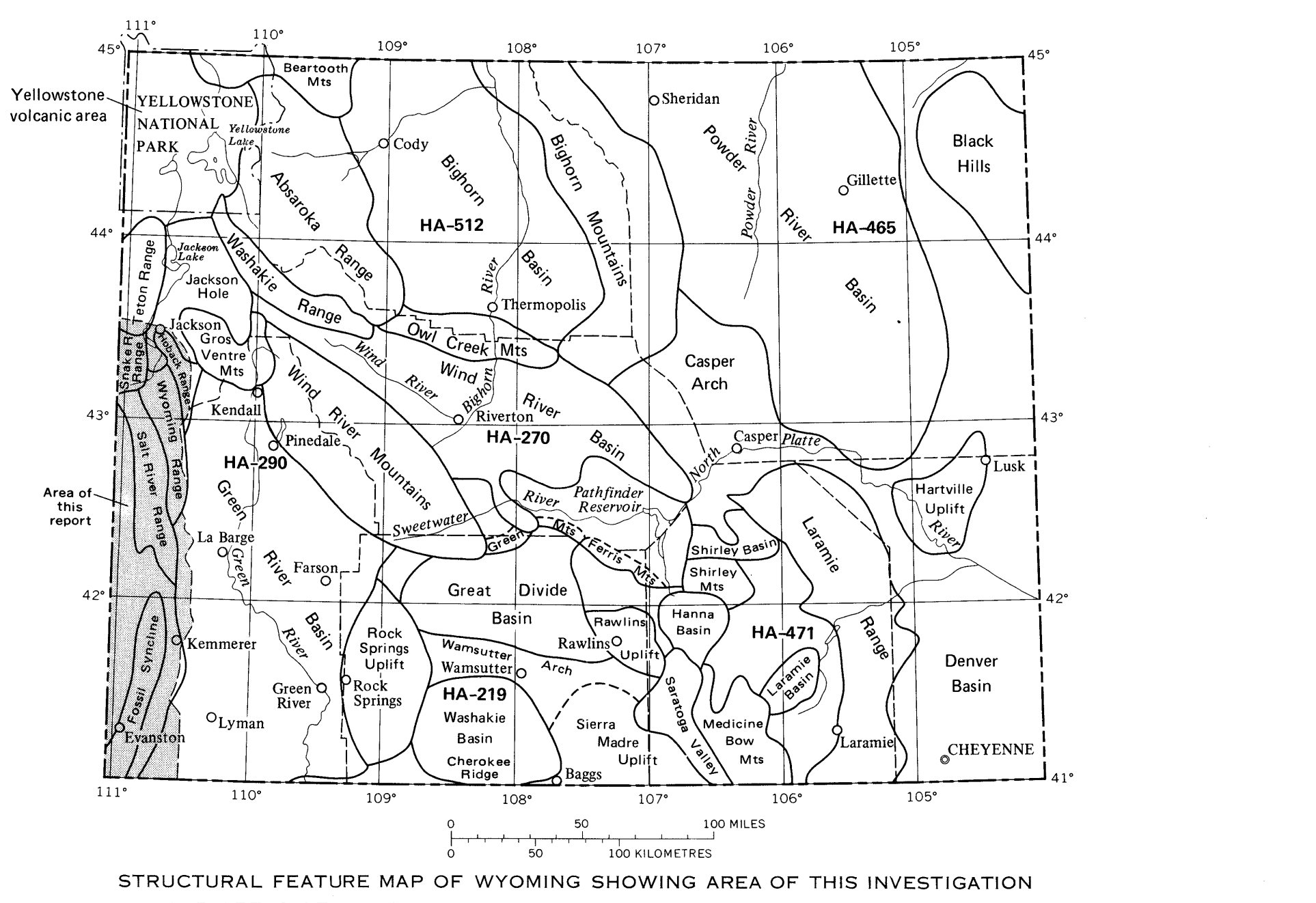
Interbasin movement of ground water is a cause for the high runoff observed at a gaging station on Swift Creek near Afton (13025000). A large ebbing and flowing spring, "The Geyser" (32-118-25b1 on well- and spring-data map) issues from limestone in the Amsden Formation. Although the spring issues from the Amsden, most of the water is probably derived from limestone and dolomite aquifers in the Madison, Darby, and Bighorn. Some water may also be derived from the overlying sandstone in the Wells Formation. Water from the spring flows into Swift Creek about 4 miles above the gaging station. "The Geyser" is unusual because of its very large discharge and intermittent flow. The spring reportedly flows at a steady rate of about 90 cfs (cubic feet per second) during the period of snowmelt in May and June; however, the average discharge for the entire year is probably 40 to 50 cfs. On September 14, 1971, the flow of the spring varied from about 10 to 60 cfs in cycles of 30 minutes, and it supplied about one-half of the water observed at the gaging station. In some periods during dry years, the low discharge in the cycle is zero. The effects of "The Geyser" upon streamflow at the gaging station during late summer are shown on an adjacent hydrograph. (See Meinzer, 1939, p. 192–194.) Above the spring in the Swift Creek drainage basin, the outcrop area of the Wells, Amsden, Madison, Darby, and Bighorn is about 5 square miles; more than 100 inches per year of ground-water recharge would be needed in this area to supply the water discharged by the spring. Annual precipitation is about 40 inches in the upper part of the Swift Creek basin, and therefore most of the water discharged by the spring originates as recharge to the ground-water system in adjacent drainage basins. The Swift Creek basin is similar to other limestone terrain throughout the Salt River, Snake River, and Wyoming Ranges in that the stream is fed by a few large springs rather than receiving ground-water discharge from many small springs throughout its reach.

Mesozoic sandstone and limestone aquifers (as in the Frontier and Bear River Formations and the Twin Creek and Thaynes Limestones) are commonly interbedded with relatively impermeable shale or siltstone. (See stratigraphic table.) These aquifers are recharged almost exclusively by rainfall and snowmelt percolating downward from land surface in outcrop areas. The direction of water movement through these aquifers is commonly similar to that of the surface drainage. The configuration of land-surface and surface-drainage patterns are commonly indicative of geologic structure that influences the movement of ground water. Horizontal movement of water is impeded at faults where the sandstone or limestone aquifers are offset against less permeable rock. However, most of the larger springs that issue from these Mesozoic aquifers occur along faults where fractures permit the vertical movement of water through otherwise confining beds. Zones of perched water occur in these rocks in outcrop areas, and the perched water is discharged through many small gravity springs and seeps at the contact between an aquifer and underlying less permeable rock.

Sandstone aquifers in the Wasatch and Green River Formations are recharged in their outcrop areas by direct penetration of rainfall and snowmelt. Nearly impermeable mudstone and siltstone predominate in these formations in the northern part of the Fossil Syncline, and vertical movement of water is small in these relatively flat-lying rocks. A large part of the water that recharges these sandstone aquifers is eventually discharged through gravity springs and seeps that are characterized by small swampy depressions on hillsides. Most of the water from these springs is consumed by evapotranspiration and very little reaches streams. Increased pumpage from these sandstone aquifers would probably have very little effect on the flow of streams. Annual water-level fluctuations in sandstone aquifers in the Wasatch Formation are 2 to 16 feet. (See hydrographs of water levels in observation wells 15-118-24bc1 and 16-121-11ac1.)

Alluvium in the Bear, Salt, and Snake River valleys is recharged predominantly by irrigation water and by direct penetration of rainfall and snowmelt. The alluvium is also recharged with water from streams that percolates into the heads of alluvial fans along the margins of the valleys. Although there are local highs and lows in the water table caused by local conditions of recharge and withdrawals, the direction of movement of water through alluvium is probably similar to surface drainage patterns—toward the center of the valleys and in a downstream direction. Annual fluctuations of the water table in alluvium are 2 to 15 feet. (See hydrographs of water levels in observation wells 22-119-5cda1, 23-119-18bb1, 23-119-32bda2, and 24-119-28acb1.) Long-term declines of the water table in alluvium, caused by pumpage, have not occurred in the area to date (1973).

Three areas of thermal-water discharge are known in the area. In all of these areas the hot water issues from springs that are along faults. West of Jackson, spring 41-117-36caa1 issues from Cambrian rocks and reportedly has a flow of 90 gpm; the water temperature is reportedly 31°C (Celsius) or 88°F (Fahrenheit). Along the Snake River, spring 39-116-32daal has a flow of about 350 gallons per minute and the water temperature is 39°C (102°F). The water is a calcium sodium sulfate type and contains 1,160 mg/l dissolved solids. The spring issues from Madison Limestone. Water from a nearby well (39-116-32dbdl) is similar in chemical character and has a temperature of 25°C (77°F). The third area is along the northwest side of Star Valley just south of "The Narrows." Springs 33-119-23acl and 33-119-26adl have flows of 38 gpm and 5 gpm, respectively; water temperatures are 55°C (131°F) and 56°C (133°F), respectively. Water from spring 33-119-23acl is a sodium chloride type and contains 5,690 mg/l dissolved solids.



STRUCTURAL FEATURE MAP OF WYOMING SHOWING AREA OF THIS INVESTIGATION AND AREAS OF OTHER REPORTS IN THE HYDROGEOLOGIC ATLAS SERIES

HYDROGEOLOGIC DIVISIONS

Geologic formations with somewhat similar origins, lithologies, and water-bearing properties are grouped into eight hydrogeologic divisions to facilitate discussion of availability and quality of ground water. The dominant rock types in the eight hydrogeologic divisions are as follows: Division 1, igneous and metamorphic rocks; division 2, Paleozoic limestones and sandstones; division 3, Triassic and Permian siltstones and limestones; division 4, Jurassic and Cretaceous sandstones and limestones; division 5, Cretaceous shales and sandstones; division 6, Tertiary siltstones and sandstones; division 7, Tertiary conglomerates and tuffs; and division 8, Quaternary sand and gravel. The areal distribution of formations in these hydrogeologic divisions is shown on the hydrogeologic map (sheet 2). The chemical character of waters from aquifers in the eight hydrogeologic divisions is shown in the adjacent diamond-field diagrams. The stratigraphic positions and lithologies of formations and the availability and chemical quality of water from aquifers are summarized in the adjacent table. Terms like "moderate quantities of water" are used in the table to describe well yield. For this report, the terms are defined as follows: Very small, less than 25 gpm; small, 25-100 gpm; moderate, 101-500 gpm; and large, more than 500 gpm.

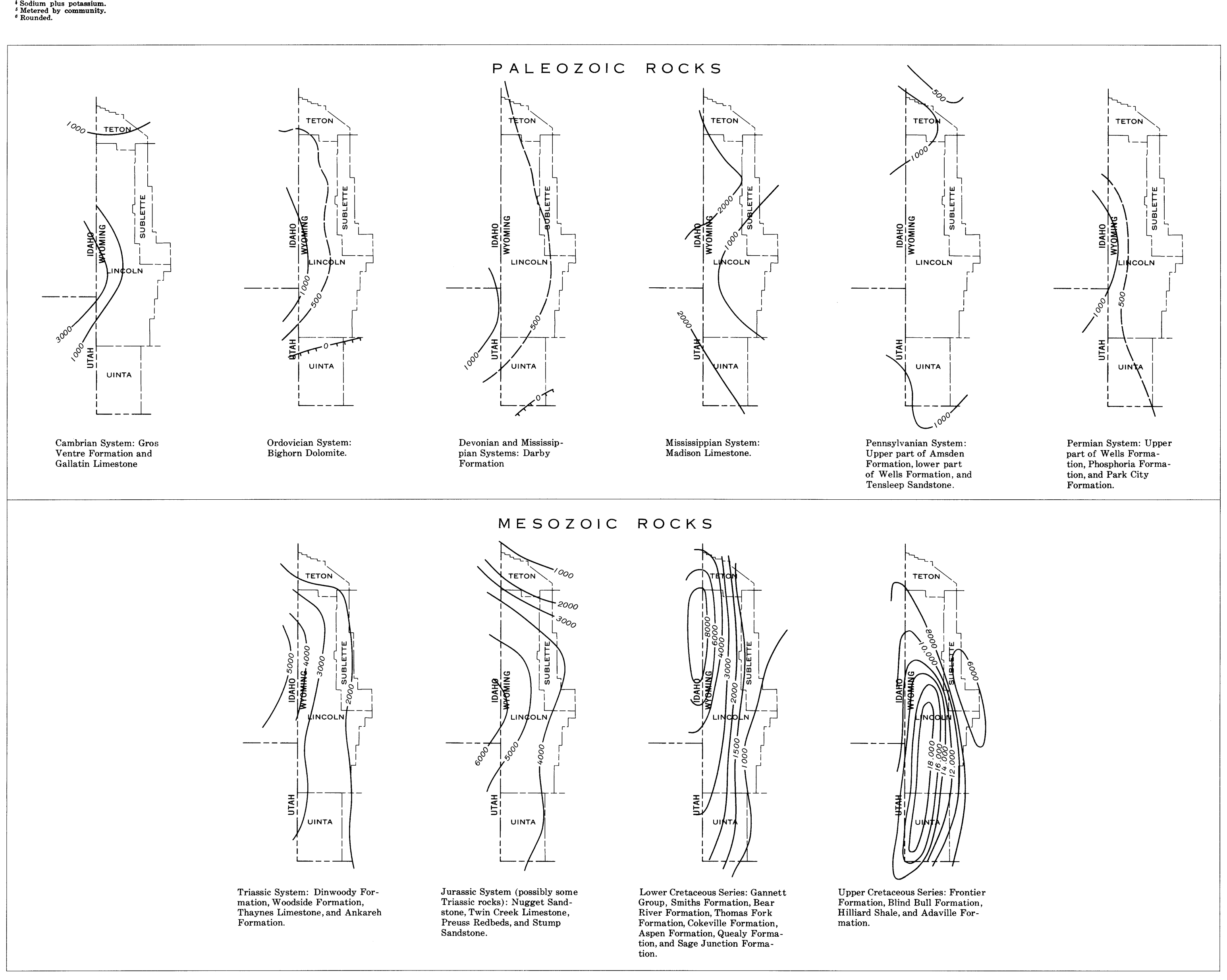
Because of the varied hydrologic settings in the thrust belt, it is desirable to describe the availability and quality of ground water in smaller subareas. Eight geographic subareas are shown on the well- and spring-data map on sheet 2, and the availability and quality of ground water in each subarea are summarized.

CHEMICAL ANALYSIS OF UNTREATED WATER USED BY MUNICIPAL WATER SUPPLIES AND THE QUANTITY USED IN 1970

[Analytical results in miligrams per liter or micrograms per liter (μg/l) except as indicated. Analyses by U.S. Geological Survey]

Community	Population served[1]	Water use (in gallons per day)	Source of water	Date of collection	Temperature (°C)	Silica (SiO2)	Iron (Fe) (μg/l)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO3)	Carbonate (CO3)	Sulfate (SO4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO3)	Boron (B) (μg/l)	Dissolved solids		Hardness as CaCO3		Sodium-adsorption ratio	Specific conductance (micromhos at 25°C)	pH (units)	Remarks
																			Residue on evaporation at 180°C	Sum	Calcium, magnesium	Noncarbonate				
Afton	1,300	[2]500,000	Madison Limestone	9-14-71	4.0	4.3	60	29	5.0	0.0	0.7	101	0	9.9	1.0	0.5	0.8	0	102	100	93	10	0.0	186	8.2	Spring 32-118-25bl.
Cokeville	440	[3]180,000	Alluvium	9-17-71	7.0	14	20	91	21	7.6	1.4	213	0	130	4.3	.2	.8	30	----	378	310	140	.2	587	7.5	Spring 24-119-2bdbl.
Evanston	4,500	[3]1,200,000	Bear River	7-22-68	22.0	5.7	----	33	7.7	2.0	.8	141	0	4.5	1.4	1.7	.4	3	----	126	114	0	.1	217	7.5	Station 10014100 Bear River above Sulphur Creek, near Evanston.
			Alluvium	7-11-68	10.0	12	----	73	23	30	1.7	352	5	26	9.7	.3	6.6	130	356	360	276	0	.8	618	8.3	Well 15-120-21cbdl.
			Wasatch Formation	9-12-72	11.0	6.4	440	30	26	24	5.3	251	0	12	11	1.9	.3	60	----	242	180	0	.8	432	7.6	Well 15-120-20abl.
Kemmerer (includes (Diamondville and Frontier)	[3]3,000	[3]2,000,000	Hams Fork	8-4-58	----	2.5	----	56	19	[4]6.5	---	149	0	101	3.5	---	.0	----	263	262	218	96	---	430	7.9	Station 09223500 Hams Fork near Frontier.
Jackson	2,100	[5]1,400,000	Alluvium	9-9-71	7.0	15	420	53	22	2.2	1.8	171	0	83	1.7	.4	.6	40	276	264	222	83	.1	435	7.8	Well 41-116-27dbbl.
Thayne	200	[3]80,000	Salt Lake Formation	9-10-71	8.0	10	40	53	18	1.0	.7	207	0	30	2.1	.3	4.4	30	232	222	207	37	.0	394	8.0	Spring 34-119-24ddcl.
Totals	11,740	[6]5,400,000																								

[1] Based on 1970 census by U.S. Department of Commerce.
[2] Based on reported number of services.
[3] Reported by community.
[4] Sodium plus potassium.
[5] Metered by community.
[6] Rounded.



Cambrian System: Gros Ventre Formation and Gallatin Limestone

Ordovician System: Bighorn Dolomite.

Devonian and Mississippian System: Darby Formation

Mississippian System: Madison Limestone.

Pennsylvanian System: Upper part of Amsden Formation, lower part of Wells Formation, and Tensleep Sandstone.

Permian System: Upper part of Wells Formation, Phosphoria Formation, and Park City Formation.

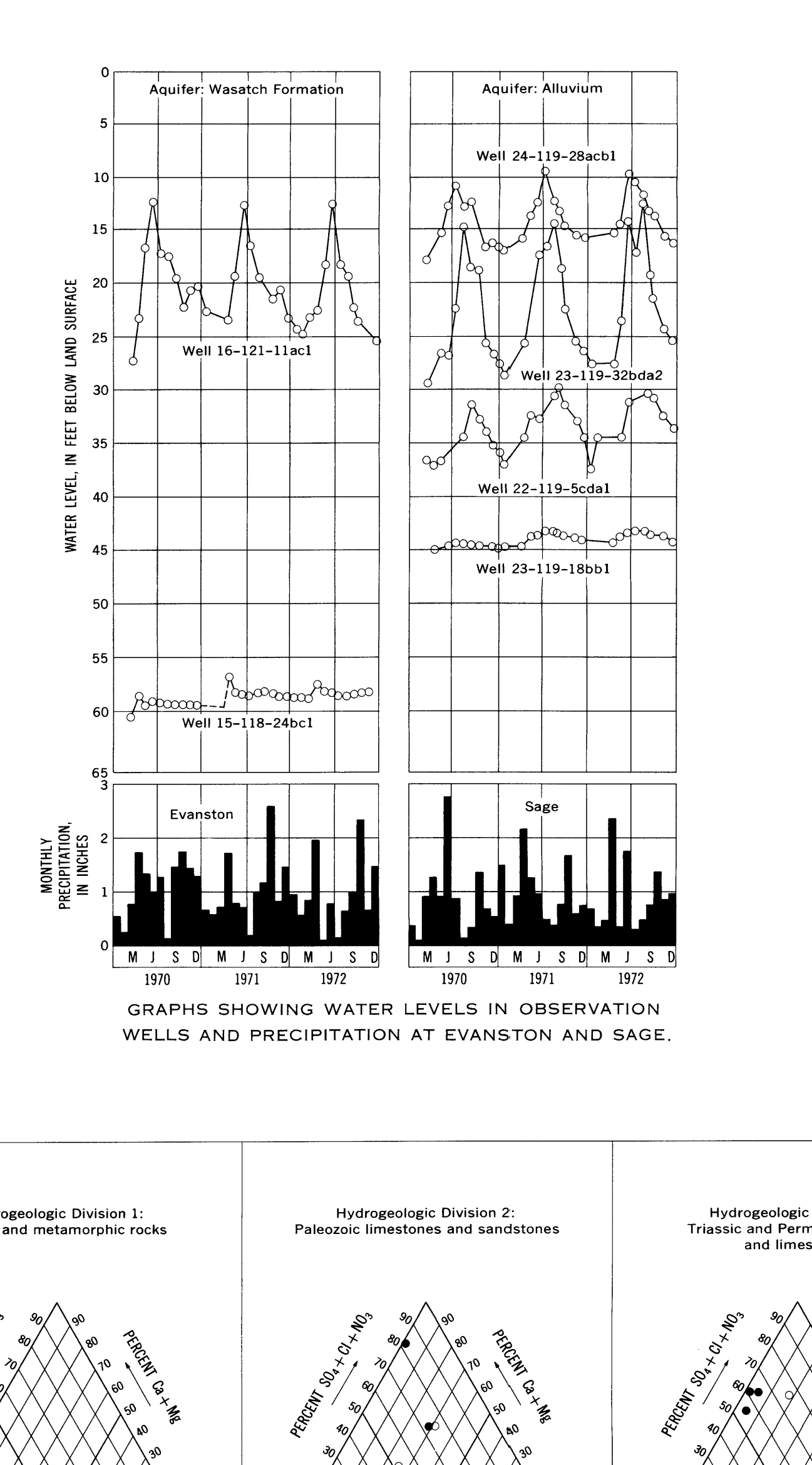
Triassic System: Dinwoody Formation, Woodside Formation, Thaynes Limestone, and Ankareh Formation.

Jurassic System (possibly some Triassic rocks): Nugget Sandstone, Twin Creek Limestone, Preuss Redbeds, and Stump Sandstone.

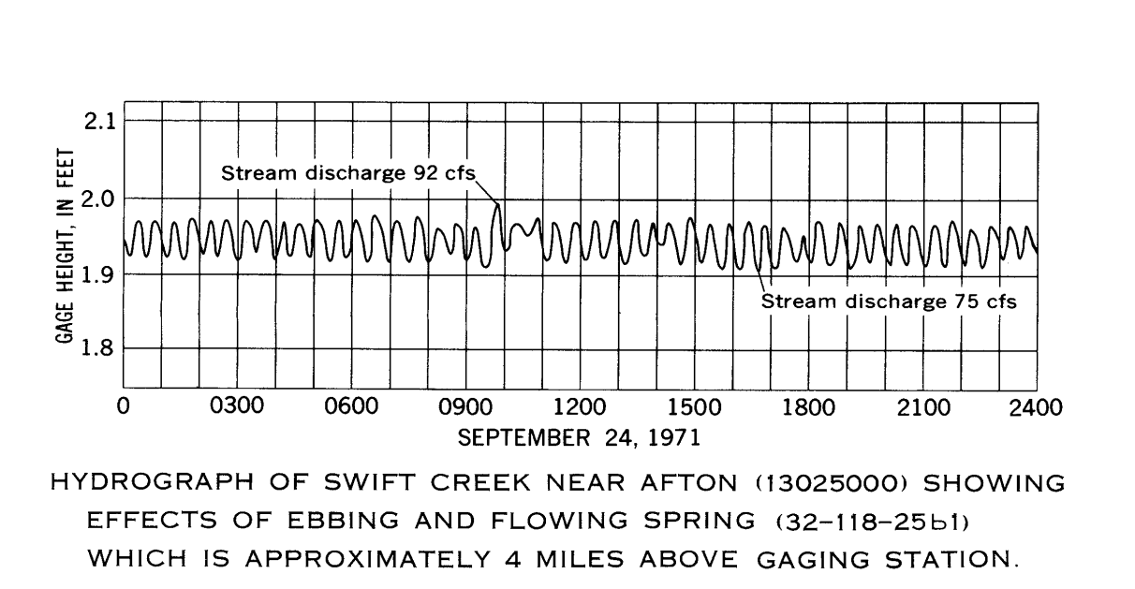
Lower Cretaceous Series: Gannett Group, Smiths Formation, Bear River Formation, Thomas Fork Formation, Cokeville Formation, Aspen Formation, Quealy Formation, and Sage Junction Formation.

Upper Cretaceous Series: Frontier Formation, Blind Bull Formation, Hilliard Shale, and Adaville Formation.

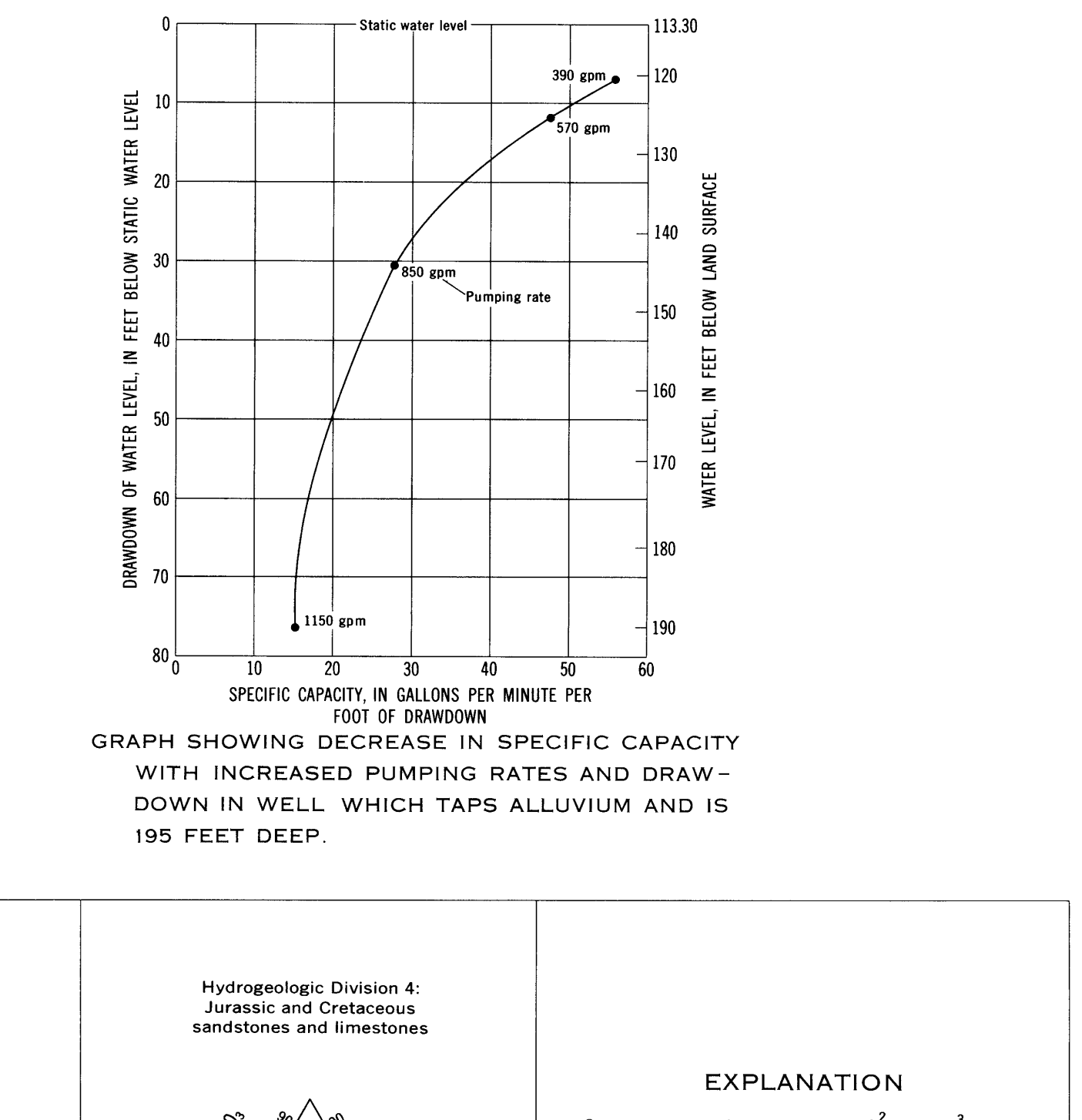
GENERALIZED THICKNESS MAPS OF PALEOZOIC AND MESOZOIC ROCKS IN THE THRUST BELT OF WESTERN WYOMING. LINES SHOW APPROXIMATE THICKNESS IN FEET. BECAUSE OF THRUSTING, ROCK THICKNESS MAY BE REPEATED A NUMBER OF TIMES IN A VERTICAL SECTION. (ADAPTED FROM ARMSTRONG AND ORIEL, 1965).



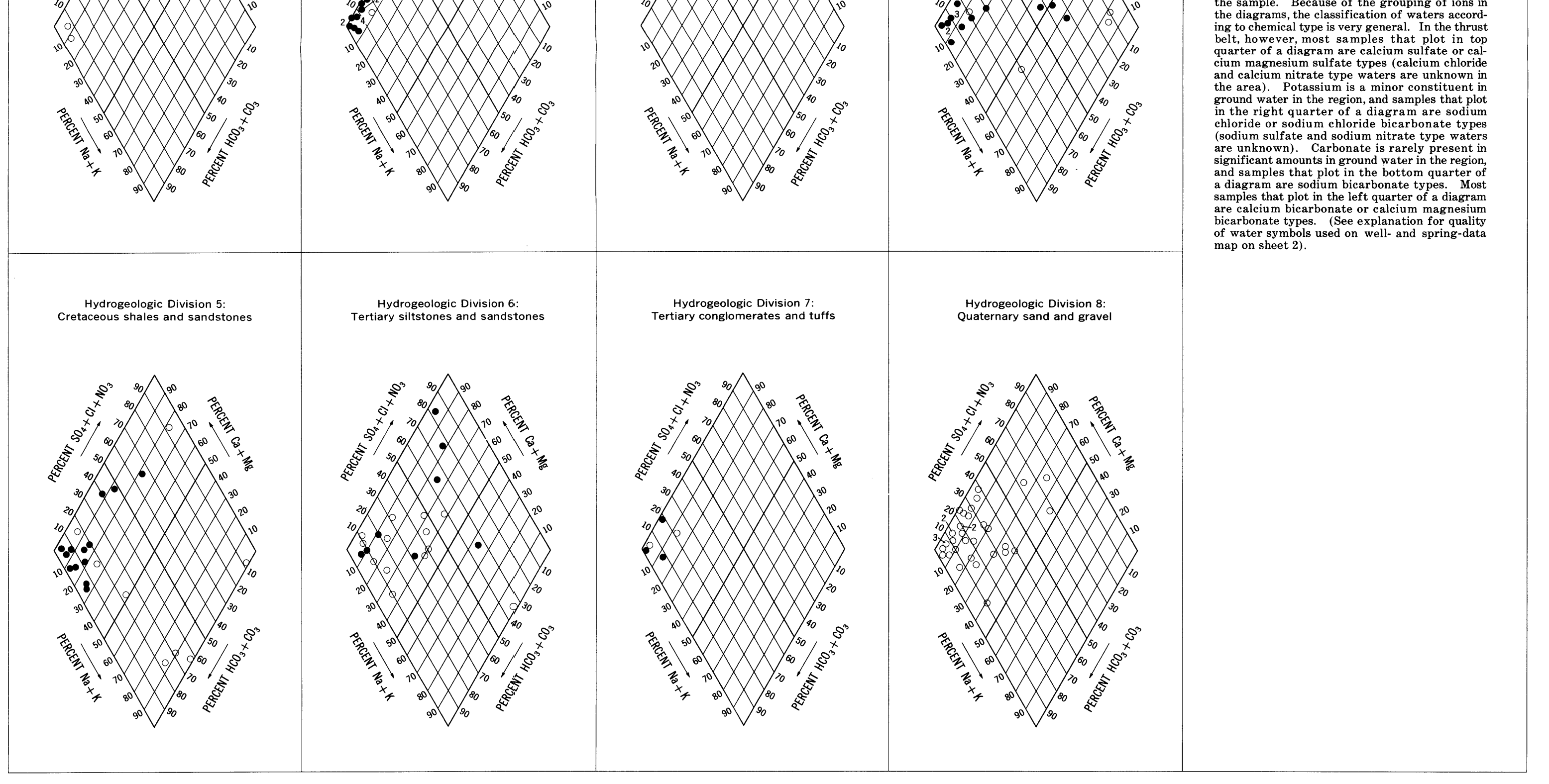
GRAPHS SHOWING WATER LEVELS IN OBSERVATION WELLS AND PRECIPITATION AT EVANSTON AND SAGE.



HYDROGRAPH OF SWIFT CREEK NEAR AFTON (13025000) SHOWING EFFECTS OF EBBING AND FLOWING SPRING (32-118-25b1) WHICH IS APPROXIMATELY 4 MILES ABOVE GAGING STATION.



GRAPH SHOWING DECREASE IN SPECIFIC CAPACITY WITH INCREASED PUMPING RATES AND DRAW-DOWN IN WELL WHICH TAPS ALLUVIUM AND IS 195 FEET DEEP.



EXPLANATION

○ Well
● Spring
Numerals indicate the number of samples that plot at a point.

Each point on a diamond-field diagram represents an analysis of a sample of ground water from a well or spring, and the position of the point indicates the chemical character of the water. The points are plotted on the basis of percentages of milliequivalents per liter of cations and anions in the sample. Because of the grouping of ions in the diagram, the classification of waters according to chemical type is very general. In the thrust belt, however, most samples that plot in top quarter of a diagram are calcium sulfate or calcium magnesium sulfate types (calcium chloride and calcium nitrate type waters are unknown in the area). Potassium is a minor constituent in ground water in the region, and samples that plot in the right quarter of a diagram are sodium chloride or sodium sulfate types (sodium nitrate type waters are unknown). Carbonate is rarely present in significant amounts in ground water in the region, and samples that plot in the bottom quarter of a diagram are sodium bicarbonate types. Most samples that plot in the left quarter of a diagram are calcium bicarbonate or calcium magnesium bicarbonate types. (See explanation for the chemical character of water samples used in well- and spring-data map on sheet 2.)

DIAGRAMS SHOWING CHEMICAL CHARACTER OF GROUND WATER IN THE EIGHT HYDROGEOLOGIC DIVISIONS.

SUMMARY OF STRATIGRAPHY AND AVAILABILITY AND QUALITY OF GROUND WATER

ERA	SYSTEM	SERIES	Geologic unit and symbol Sedimentary rocks		Lithology and thickness	Availability and chemical quality of ground water	Hydrogeologic division number
			West side of thrust belt	East side of thrust belt			
CENOZOIC	QUATERNARY	Holocene (order may not reflect relative age)	Alluvium (Qal) (includes flood-plain deposits and alluvial fans)		Unconsolidated sand and gravel interbedded with silt and clay. The maximum thickness of alluvium in the Bear, Salt, and Snake River valleys is unknown; however, wells that are 200 feet deep have not penetrated the full thickness in these areas. It is at least 410 feet thick in Bear River valley near Border. The maximum thickness in smaller stream valleys such as along the Smiths, Thomas, and Hams Forks, and the Greys and Hoback Rivers is probably about 100 feet. Rocks overlying Sublette Flat east of Cokeville are Quaternary and Tertiary in age (Rubey, written commun., 1973); because of their similarity to alluvial fan material, they are shown on the hydrogeologic map as alluvium.	Sand and gravel in alluvium is the most utilized aquifer in the thrust belt. Irrigation and municipal wells in the Bear, Salt, and Snake River valleys yield 1,000 to 2,000 gpm. Yields of wells that tap alluvium are dependent on the thickness, the sorting of the saturated sand and gravel, and the well construction. Most municipal and irrigation wells that tap alluvium have 12- to 18-inch, slotted, gravel-packed casing in at least 40 feet of saturated sand and gravel. Specific capacities of such wells generally range from 20 to 80. Domestic wells usually have 6-inch casing, and the well finish is either open-end or 5 to 10 feet of perforated casing. Specific capacities of domestic wells are rarely greater than 10. The efficiency of an alluvium well decreases rapidly when the water level in a pumping well is drawn down more than about one-third of the thickness of the aquifer. Terrace and glacial deposits yield small quantities of water to wells. Availability of water from these aquifers is limited because of poorly sorted material and small saturated thicknesses. Some domestic wells that tap terrace deposits in the southern Bear River valley fail during relatively dry years because of the small saturated thickness. Rock debris is not a potential source of water because of its poorly sorted material and small saturated thickness. Water in aquifers of this hydrogeologic division in the more humid northern part of the area is usually a calcium bicarbonate type and contains 150 to 300 mg/l dissolved solids. In the more arid southern part of the area, many different chemical types are present, and dissolved solids commonly range from 500 to 1,000 mg/l.	8
			Terrace deposits (Qt)		Poorly to moderately well sorted gravel, sand, and silt. The terraces are most extensive along the Bear River and probably have a maximum thickness of about 50 feet.		
			Rock debris (Qd) (includes landslides material slopewash, and talus)		Locally derived rock fragments. Generally less than 50 feet thick, but several landslides in the northern part of the area are several hundred feet thick.		
		Pleistocene	Glacial deposits (Qg)		Poorly sorted silt, sand, gravel, and boulders as much as 40 feet in diameter. The maximum thickness of the deposits is unknown, but it may be greater than 300 feet thick in the vicinity of Wilson in Teton County.		
	TERTIARY	Pliocene	Salt Lake Formaton (Tsl)	Camp Davis Formation (Tcd)	Salt Lake Formation—Pale-reddish gray conglomerate, grit, sandstone, siltstone, clay, and white volcanic ash (Rubey, 1973). The formation is most extensive in Star Valley, where it has a maximum thickness of about 1,000 feet. Camp Davis Formation—Red conglomerate in the upper part, brown claystone in the middle, freshwater limestone and tuffaceous claystone in the lower part, and gray conglomerate at the base (Love, 1960). Thickness 2,250 feet along the Hoback River (Ross and St. John, 1960, p. 51) but at least 5,200 feet thick along Horse Creek in Teton County (Schroeder, 1971).	Few wells tap conglomerate aquifers in this hydrogeologic division, but small quantities are available. The availability of water from these aquifers is limited because the conglomerates are usually well indurated, poorly sorted, and have little primary permeability. Outcrops of conglomerate are usually topographically high and well drained, and water levels are probably 100 to 200 feet below land surface on topographic highs. Many springs issue from the conglomerates on side hills, but their flows are rarely greater than 20 gpm. One exception is spring 34-119-24ddc1, which issues from fractured conglomerate of the Salt Lake Formation and has an estimated flow of 8,000 gpm. Fracture permeability, however, is not widespread in these conglomerates. Water in aquifers of this hydrogeologic division is usually a calcium bicarbonate type and contains 200 to 400 mg/l dissolved solids.	7
		Eocene (?) or Pliocene (?)	Fowkes Formation (Tf): Gooseberry Member	Browns Park Formation (Tbp) (Miocene) Bishop Conglomerate (Tbi) (Miocene ?)	The Fowkes Formation is subdivided into the following units, in ascending order: The Sillem Member (100 to 400 feet thick), which consists predominantly of conglomerate at the base and mudstone and claystone interbedded with sandstone and algal limestone; the Bulldog Hollow Member (200 to 2,000 feet thick), which consists predominantly of green and white tuffaceous mudstone and green to buff and brown tuffaceous calcareous sandstone; and the Gooseberry Member (more than 200 feet thick and incompletely represented), which consists predominantly of light-gray to white conglomerate and calcareous rhyolitic ash (Oriel and Tracey, 1970, p. 34-36). These subdivisions of the Fowkes are not distinguished on the hydrogeologic map, but their stratigraphic positions are shown in this table. Browns Park Formation—White to light-gray tuffaceous sandstone, mudstone, and quartzite in upper part and conglomerate in lower part. Maximum thickness of about 1,200 feet (Bradley, 1964, p. 56). Bishop Conglomerate—Conglomerate made up of well-rounded cobbles and boulders of quartzite, limestone, and metamorphic rocks (Bradley, 1964, p. 55). Maximum thickness of at least 200 feet.		
		Eocene	Fowkes Formation (Tf): Bulldog Hollow Member Sillem Member	Bridger Formation (Tb)	Bridger Formation—Gray to pink mudstone and sandstone interbedded with white tuff and cherty limestone layers; conglomeratic in the extreme southern part of the area. Maximum thickness unknown; however, it is about 2,300 feet thick, in T. 13 N., R. 113 W. (Bradley, 1964, p. 53).	Availability of water from sandstone and conglomerate aquifers in this hydrogeologic division is dependent on their sorting, saturated thicknesses, continuity of bedding, and the degree of fracturing in the much larger thickness of interbedded shale and mudstone. Rocks in this hydrogeologic division have some fracture permeability, but they generally have less fracture permeability than older rocks in the thrust belt that are more extensively faulted and folded. Conglomeratic sandstones and conglomerates in the Wasatch and Evanston Formations are capable of yielding moderate to large quantities of water to wells. Well 15-120-20 ab1 taps conglomeratic sandstone in the Wasatch and has been pumped at a rate of 1,300 gpm with 92 feet of drawdown (specific capacity = 14). This well is 620 feet deep, and 158 feet of its casing is perforated at intervals between the depths of 104 and 523 feet. Spring 22-116-6 ab1 issues from conglomerate in the Evanston Formation and has an estimated flow of 1,000 gpm. Small to moderate quantities of water are available from finer grained sandstones in the Wasatch, Green River, and Evanston Formations, but well yields are greatly dependent on the thickness of saturated sandstone that is tapped. Tuffaceous sandstone in the Fowkes is probably capable of yielding small quantities of water to wells. Spring 19-121-25 aad1 issues from the Fowkes and has an estimated flow of 125 gpm. The Bridger Formation usually crops out on topographic highs and is well drained as indicated by the many small springs that issue from it on hillsides. Small quantities of water may be available from the Bridger along the northern flank of the Uinta Mountains in the extreme southeastern part of the area, where the formation is conglomeratic. Few hydrologic data are available for the Hoback Formation, but, because of its large thicknesses of sandstone and conglomerate, it is a potential source of water. Water in aquifers of this hydrogeologic division is usually a calcium bicarbonate type and rarely contains more than 500 mg/l dissolved solids in the southern and central parts of the Fossil Syncline and southwestern part of the Green River structural basin. Farther to the north in the Fossil Syncline and along the west side of Green River basin, water in these aquifers contains 300 to 2,000 mg/l dissolved solids and larger concentrations of sodium, sulfate, and chloride.	6
			Wasatch Formation (Tw): Bullpen Member; Green River Formation (Tgr): Angelo Member, Mudstone tongue, Fossil Butte Member, Sandstone tongue; Tunp Member; Main body; Lower member; Conglomerate member	Green River Formation (Tgr): Upper tongue, Upper tongue, Middle tongue, New Fork Tongue, Fontenelle Tongue Wasatch Formation (Tw) conglomerate member; La Barge Member; Wasatch Formation (Tw) Chappo Member Hoback Formation (Th)	The Green River Formation in the Fossil Syncline is subdivided into the Fossil Butte Member (200 to 270 feet thick), which consists of light-gray and buff laminated limestone and marlstone in the lower part and laminated marlstone, limestone, oil shale, and ash in the upper part; and the Angelo Member (as much as 200 feet thick), which consists predominantly of laminated marlstone and limestone (Oriel and Tracey, 1970, p. 30-32, 38). In the western part of the Green River structural basin, the Green River Formation is subdivided into three units: The Fontenelle Tongue (as much as 150 feet thick), which has a similar lithology as the lower part of the Fossil Butte Member; a middle tongue (as much as 295 feet thick), which has a similar lithology to the upper part of the Fossil Butte Member; and an upper tongue (180 to 250 feet thick), which has a similar lithology to the Angelo Member (Oriel, 1969, p. 19-21; Oriel and Tracey, 1970, p. 38). These subdivisions of the Green River Formation are not distinguished on the hydrogeologic map, but their stratigraphic positions are shown in this table. The Wasatch Formation in the Fossil Syncline is subdivided into seven units: A basal conglomerate member (a few feet to several hundred feet thick), which consists of lenticular conglomerate of sandstone pebbles and cobbles; a lower member (as much as 300 feet thick), which consists predominantly of drab-colored mudstone and sandstone; the main body of the Wasatch (1,500 to 2,000 feet thick), which consists predominantly of red, purple, and tan mudstone; a sandstone tongue (40 to 50 feet thick), which consists of brown sandstone and green mudstone; a mudstone tongue (as much as 50 feet thick), which consists of gray-green and pink mudstone; the Bullpen Member (400 feet thick), which consists predominantly of red and salmon-colored mudstone and gray and brown sandstone; and the Tunp Member (200 to 500 feet thick), which consists of conglomeratic mudstone and diamictite (Oriel and Tracey, 1970, p. 17-24). In the western part of the Green River structural basin, the Wasatch is subdivided into five units: The Chappo Member (1,200 to 2,000 feet thick), which consists predominantly of boulder conglomerate, multicolored mudstone, and pisolitic limestone; the La Barge Member (as much as 1,500 feet thick), which consists of red, purple, and yellow mudstone and sandstone; the New Fork Tongue (200 to 250 feet thick), which has a similar lithology to the sandstone tongue; an upper tongue (about 200 feet thick), which has a similar lithology to the mudstone tongue; and a conglomerate member (several thousand feet thick in places), which consists of red diamictite, poorly sorted to well-sorted conglomerate, sandstone, and mudstone (Oriel and Tracy, 1970, p. 38; Oriel, 1969, p. 15-18). These subdivisions of the Wasatch are not distinguished on the hydrogeologic map, but their stratigraphic positions are shown in this table. Hoback Formation—Gray and brown sandstone, conglomerate, shale, siltstone, and shaley limestone. The Hoback has a maximum thickness of about 16,000 feet, but it thins southward in its outcrop area to 8,000 feet (Spearing, 1969, fig. 4).		
		Paleocene	Evanston Formation (TKe): Main body; Hams Fork Conglomerate Member; Lower member		The Evanston Formation is subdivided into the following units: A lower member (as much as 500 feet thick), which consists of gray mudstone, siltstone, claystone, and carbonaceous sandstone; the Hams Fork Conglomerate Member (450 to 1,000 feet thick), which consists of cobbles and boulders that are heterogeneous in composition, size, and rounding in a matrix ranging from coarse crossbedded sand to clayey fine sand; and the main body of the Evanston (400 to 1,400 feet thick), which consists of gray carbonaceous sandy to clayey siltstone interbedded with yellow to brown to gray sandstone and conglomerate (Oriel and Tracey, 1970, p. 5-10). These subdivisions of the Evanston are not distinguished on the hydrogeologic map, but their stratigraphic positions are shown in this table.		
MESOZOIC	CRETACEOUS	Upper	Adaville Formation (Kav)		Brown and buff fine- to medium-grained calcareous sandstone, gray carbonaceous mudstone, and numerous coal beds. The proportions of sandstone to mudstone are about equal (Oriel, 1969, p. M-14). Thickness varies because of the irregularity of the unconformity that separates the Adaville and overlying Tertiary rocks. About 1,400 feet thick in the eastern part of the area (Schultz, 1914, p. 29) and a maximum thickness between 4,000 and 5,000 feet in the southern part (Veatch, 1907, p. 73).	Sandstone aquifers in the Frontier Formation are capable of yielding moderate quantities of water and are the best aquifers in this hydrogeologic division. Shipp and Dunnewald (1962, p. 279) report that the average permeability of Frontier sandstones is about 1 md (millidarcy) or about $1 \times 10^{-3}(\mu m)^2$(square micrometres) in the Big Piney-La Barge gas field; however, permeabilities are as high as $1.1\ (\mu m)^2$(about 1,100 md) in the coarsest sandstones. Small quantities of water are available from sandstone in the Bear River Formation and probably from the Lazeart Sandstone Member (not shown) at the base of the Adaville Formation and from the Blind Bull Formation. Very small quantities of water are available from shale in the Aspen Formation and Hilliard Shale. Few hydrologic data are available for the Smiths, Thomas Fork, Cokeville, Quealy, and Sage Junction Formations. Based on lithologies, small quantities of water are probably available from sandstone aquifers in all these formations, except the Quealy Formation. Water from springs that issue from aquifers in this hydrogeologic division is usually a calcium bicarbonate type and contains 150 to 400 mg/l dissolved solids. However, water from springs is probably only indicative of the quality of water at shallow depths. The quality of water from wells that tap these aquifers varies considerably because of the many lithologies within formations. Water from sandstones and limestones in this hydrogeologic division, however, is most commonly a calcium bicarbonate or sodium bicarbonate type; water from siltstones and shales is most commonly a calcium sulfate or sodium chloride type. Thus, water from a well that taps the Frontier Formation could be one of many different chemical types, depending upon the lithologies contributing water to the well and the degrees of mixing. Well 18-116-6dda1 taps sandstone in the Frontier Formation, and the water is a sodium bicarbonate type and contains 1,467 mg/l dissolved solids. Well 19-116-32ca1 taps shale in the Aspen, and the water is a sodium chloride type and contains 5,570 mg/l dissolved solids. Well 19-116-18bd1 taps shale in the Hilliard, and the water is a calcium sulfate type and contains 3,340 mg/l that dossilved solids. Along the Snake River in T. 39 N., some domestic wells that tap the Aspen and Bear River Formations have been abandoned because of hydrogen sulfide gas.	5
			Hilliard Shale (Kh)	Blind Bull Formation (Kbb)	Hilliard Shale—Dark-gray sandy shale, mudstone, and shaly sandstone. Generally 5,500 to 6,800 feet thick in the southern part of the area (Veatch, 1907, p. 70) and about 5,000 feet thick in the eastern part (Schultz, 1914, p. 64). Blind Bull Formation—Fine-grained to conglomeratic sandstone, siltstone, and shale with some beds of bentonite and coal. About 5,100 feet thick along the divide between Horse Creek and Hoback River (W.W. Rubey, written commun., 1973).		
			Frontier Formation (Kf)		Frontier Formation—Gray, fine- to medium-grained sandstone, and gray mudstone, claystone, and siltstone with some beds of coal. The Oyster Ridge Sandstone Member is near the top of the formation and it contains numerous oyster shells. The Frontier has a maximum thickness of about 3,000 feet in the south-central part of the area (Armstrong and Oriel, 1965, fig. 12).		
		Lower	Sage Junction Formation (Ksj)	Aspen Formation (Ka)	Sage Junction Formation—Gray and tan sandy siltstone and shale, tan sandstone and quartzite, porcelanite, fossiliferous limestone, and a few coal beds in lower part. About 2,270 feet thick at Sage Junction but incompletely represented (W. W. Rubey, written commun., 1973). Aspen Formation—Light-gray to black shale, gray fine-grained sandstone, and white to gray porcelanite. Ranges in thickness from 1,600 to 2,200 feet in the southern part of the area (Veatch, 1907, p. 65) and from 1,200 to 1,800 feet in the eastern part (Schultz, 1914, p. 59).		
			Quealy Formation (Kq)		Quealy Formation—Red and variegated mudstone and siltstone. About 1,200 feet thick near Quealy Reservoir but thins southward and absent south of Cokeville (W.W. Rubey, written commun., 1973).		
			Cokeville Formation (Kc)	Bear River Formation (Kbr)	Cokeville Formation—Gray and tan sandstone, siltstone, gray shale, highly fossiliferous limestone, porcelanite, bentonite, and a few coal beds in upper part. About 1,600 feet thick near Cokeville and as much as 2,500 feet thick near Sage Junction (W.W. Rubey, written commun., 1973). Bear River Formation—Mainly gray to black fissile shale with interbeds of gray sandstone. Thickness generally ranges from 800 to 1,500 feet.		
			Thomas Fork Formation (Ktf)		Thomas Fork Formation—Red and variegated mudstone and sandstone with calcareous nodules. About 2,000 feet thick (W.W. Rubey, written commun., 1973).		
			Smiths Formation (Ks)		Smiths Formation—Interbedded tan quartzitic sandstone and black ferruginous shale. About 755 feet thick along Smiths Fork but thins southward (W.W. Rubey, written commun., 1973).		
			Gannett Group (Kg): Red bed unit; Draney Limestone; Bechler Conglomerate; Peterson Limestone; Ephraim Conglomerate		The Gannett Group is subdivided into the following units, in ascending order: The Ephraim Conglomerate, which consists of brick-red and maroon siltstone and claystone, red to brown calcareous to quartzitic sandstone, red to brown conglomerate, and gray to tan nodular limestone; the Peterson Limestone, which consists of gray finely crystalline limestone; the Bechler Conglomerate, which consists of red sandstone and conglomerate, and purplish- to reddish-gray siltstone and mudstone with thin limestone interbeds; the Draney Limestone, which consists of gray finely crystalline limestone and gray calcareous siltstone; and an unnamed red bed unit, which consists of red siltstone and mudstone (Rubey, 1973). All these subdivisions of the Gannett may not be recognizable at any one locality. The Gannett Group is about 800 feet thick in the eastern part of the area (Oriel, 1969, p. M-11) but may be 5,000 feet thick in the northwestern part (Armstrong and Oriel, 1965, fig. 11).	The Nugget Sandstone is the best aquifer in this hydrogeologic division. Where its outcrop or recharge areas are large, where bedding is continuous and not offset by faults, and in topographic lows where a large thickness of sandstone is saturated, the Nugget is capable of yielding moderate to large quantities of water. No wells in the area tap the Nugget for water, but many springs issue from the Nugget and flows greater than 1,000 gpm are common. (See 30-116-9bb1, and 36-116-8bc1.) Michael (1960, p. 212) reports that sandstone in the upper 50 feet of the Nugget in Tps. 26-29 N., Rs. 113-114 W. has permeabilities that range from 10 to 200 millidarcies (1×10^{-2} to 0.2 square micrometres). The Nugget in this area is several thousand feet below land surface, and sandstone permeabilities, therefore, are probably much less than those in or near outcrop areas. Rocks in the Gannett Group, Stump Sandstone, Preuss Redbeds, and upper part of the Twin Creek Limestone are relatively impermeable and in most areas they are capable of yielding only small quantities of water. However, conglomerate aquifers in the Gannett are capable of yielding moderate quantities of water where the rock is extensively fractured. Well 14-121-14dcc1 taps fractured Gannett conglomerate along a fault, and the well has been pumped at a rate of 200 gpm. No wells tap the lower part of the Twin Creek Limestone, but the limestone is brecciated and honeycombed and is probably capable of yielding moderate quantities of water. Few springs issue from the lower part of the Twin Creek because it is probably in hydraulic connection with, and drains into, the underlying sandstone in the Nugget. Water from aquifers in this hydrogeologic division at shallow depths is usually a calcium bicarbonate type and contains 150 to 300 mg/l dissolved solids. However, water from springs that issue from the Preuss Redbeds in the Gannett Hills is commonly a sodium chloride or sodium chloride bicarbonate type and contains 500 to 1,000 mg/l dissolved solids. (See 28-119-27bad1 and 29-119-26bbc1.) Well 27-114-9ad1 taps the Nugget at a depth of 11,550 feet, and the water is a sodium chloride type and contains 82,560 mg/l dissolved solids.	4
	JURASSIC	Upper	Stump Sandstone (Js)		Green to greenish-gray glauconitic sandstone, siltstone, and limestone. About 90 feet thick in the eastern part of the area (Oriel, 1969, p. M-10) and about 120 feet thick in the northern part (Ross and St. John, 1960, p. 50).		
			Preuss Redbeds (Jp)		Red, maroon, brown, and orange calcareous siltstone, mudstone, and sandstone, and some beds of rock salt in the west-central part of the area. About 340 feet thick in the eastern part of the area (Oriel, 1969, p. M-10) and about 180 feet thick in the northern part (Ross and St. John, 1960, p. 49).		
		Middle	Twin Creek Limestone (Jtc)		Light-gray to black limestone and shale in the upper part, and red, brown, and orange claystone and gray mainly brecciated but partly honeycombed limestone in the lower part (Oriel, 1969, p. M-10). Thickness 800 feet near Jackson (Imlay, 1950, p. 46) but 3,800 feet thick in southern Lincoln County (Veatch, 1907, p. 56).		
		Lower					
	JURASSIC (?) and TRIASSIC (?)		Nugget Sandstone (JTRn)		Varicolored (generally pink to salmon) crossbedded fine- to medium-grained well-sorted quartzitic sandstone, and a few beds of maroon, red, and brown mudstone in the lower part. About 750 feet thick in the northern part of the area (Ross and St. John, 1960, p. 49) and about 1,300 feet thick in southern Lincoln County (Veatch, 1907, p. 56).		
	TRIASSIC	Upper	Ankareh Formation (TRa)		Red to brown shale, siltstone, and fine-grained sandstone, and, locally, greenish-gray limestone in about the middle part. About 200 feet thick in the northern part of Lincoln County (Ross and St. John, 1960, p. 49) and about 600 feet thick in the southern part (Veatch, 1907, p. 56).	Limestone in the Thaynes is the best aquifer in this hydrogeologic division. Where the Thaynes has secondary permeability in the form of fractures and (or) solution openings, the limestone will yield moderate quantities of water to wells. Well 22-118-20baa1 taps the Thaynes and flows at a rate of 150 gpm. Springs 31-116-21a1 and 27-115-22b1 issue from the Thaynes and have flows of 700 and 900 gpm, respectively. Rocks in the Ankareh, Woodside, Dinwoody, and Phosphoria Formations are relatively impermeable and in most areas they are probably capable of yielding only small quantities of water. However, the Phosphoria is capable of yielding moderate quantities of water when the rock is extensively fractured. (See wells 22-118-29aab1 and 22-118-20ad1.) Water in aquifers of this hydrogeologic division is usually a calcium bicarbonate or calcium sulfate type, and the dissolved solids range from 150 to 3,000 mg/l. The chemical type and dissolved solids are largely dependent on the amount of soluble anhydrite ($CaSO_4$) in the rock.	3
		Lower	Thaynes Limestone (TRt)		Mainly buff to dark-gray silty limestone, and red to tan siltstone and shale predominantly in the upper part. About 1,100 feet thick in the northern part of Lincoln County (Ross and St. John, 1960, p. 49) and 2,400 to 2,600 feet thick in the southern part (Veatch, 1907, table opposite p. 50).		
			Woodside Formation (TRw)		Mainly red and orange partly anhydritic siltstone and mudstone, and some orange fine-grained sandstone. About 350 feet thick in the northern part of the area (Ross and St. John, 1960, p. 49) and about 500 feet thick in the east-central part (Oriel, 1969, p. M-9).		
			Dinwoody Formation (TRd)		Gray to brown siltstone and shale, gray to tan dolomite, and thin beds of anhydrite in the upper part. About 250 feet thick in the northern (Ross and St. John, 1960, p. 49) and eastern (Oriel, 1969, p. M-9) parts of the area, and 650 to 700 feet thick in the west-central part (Newell and Kummel, 1942, p. 937).		
PALEOZOIC	PERMIAN		Phosphoria and Park City Formations undifferentiated (Pp)		Phosphoria Formation—Mainly phosphatic, carbonaceous, and cherty shale and sandstone. Park City Formation—Predominantly carbonate rocks and subordinate sandstone (McKelvey and others, 1959, p. 9). The two formations intertongue in the area; however, the extreme southern part of the area is predominantly Park City and the northern part is predominantly Phosphoria (Sheldon, 1963, fig. 9). The total thickness of the two formations generally ranges from about 200 feet in the northern part of the area to more than 400 feet in the southwestern part (McKelvey and others, 1959, fig. 2).		
	PENNSYLVANIAN	Upper Middle	Wells Formation (PℙW)	Tensleep Sandstone (ℙt)	Wells Formation—Gray thick-bedded quartzite, calcareous sandstone, and limestone mainly in the upper part. About 450 feet thick in the subsurface in the eastern part of the area (Oriel, 1969, p. M-8) and about 1,000 feet thick in the western part (Richardson, 1941, p. 24-25). Tensleep Sandstone—White to pink well-sorted fine-grained sandstone and quartzite, and thin layers of white siliceous, dolomitic limestone. About 400 feet (Schroeder, 1969) to 700 feet thick (Ross and St. John, 1960, p. 48) in the northern part of the area.	The availability of water from limestone and dolomite aquifers of the Madison Limestone, Darby Formation, Bighorn Dolomite, and Gallatin Limestone is dependent on the secondary permeability in the form of solution openings and fractures. A favorable environment for solution is in outcrop areas or near land surface where water containing carbon dioxide can be readily recharged to the aquifers and discharged from them. In the Wyoming, Salt River, and Snake River Ranges most of the water discharged from these aquifers is through a few large springs where there has been selective enlargement of solution openings and a concentration of flow in a few of the larger openings. There are large volumes of poorly permeable rock. Outcrops on topographic highs are probably drained to depths of several hundred feet. Wells that penetrate water-bearing solution channels will yield many times more water than wells that do not penetrate the major conduits. Unlike other limestones in this hydrogeologic division, outcrops of Madison Limestone have ancient solution openings that probably developed before and during deposition of the overlying Amsden Formation. Thus, solution permeability in the Madison is probably present at great depths below the present land surface. Five of the largest springs that issue from the Madison, Darby, and Bighorn have flows of 900, 1,100, 3,200, 4,000, and 40,000 gpm (38-115-3bca1, 38-115-3bcb1, 34-118-26aad1, 26-114-1bac1, and 30-118-25c1 on well- and spring-data map.) The water in Paleozoic limestones at shallow depths is usually a calcium bicarbonate type and contains 100 to 250 mg/l dissolved solids. However, water from springs that issue from these rocks along major faults is commonly a calcium sulfate or calcium sodium sulfate type and contains greater than 1,000 mg/l dissolved solids. Water from these springs may be indicative of the quality of water in these limestone aquifers at great depths. Sandstone aquifers in the Wells Formation and Tensleep Sandstone are capable of yielding moderate to large quantities of water. Availability is dependent upon local conditions of recharge, continuity of beds, and development of fracture permeability. These sandstones on topographic highs may be drained, especially if underlying limestones have extensive solution development. Wells 21-120-10db1 and 21-120-10da1 tap the Wells Formation and have reported yields of 700 and 300 gpm, respectively. Well 41-117-25ddb1 taps the Tensleep and has been pumped at a rate of 210 gpm. Three of the largest springs in the area that issue from the Tensleep and Wells have flows of 1,500, 1,600 and 2,200 gpm (33-116-12b1, 26-117½-13bad1, 30-117-35c1 on well- and spring-data map). Water in these sandstone aquifers at shallow depth is usually a calcium bicarbonate type and contains 200 to 500 mg/l dissolved solids. Few hydrologic data are available for the Amsden and Gros Ventre Formations and the Flathead Quartzite. Based on lithology, the Flathead is probably a potential source of water; the Gros Ventre Formation consists predominantly of poorly permeable rock and is probably not an important aquifer. Small quantities of water may be available from cherty limestone in the Amsden Formation, but, on topographic highs, the Amsden is probably well drained, especially if underlying limestones have extensive solution development. Well 41-116-32acc1 penetrates the Amsden and has a reported yield of 8 gpm. The water from this well is a calcium bicarbonate type and contains less than 250 mg/l dissolved solids.	2
		Lower	Amsden Formation (ℙMa)		Varicolored mudstone, siltstone, and sandstone, and gray cherty limestone. Thickness 600 to 700 feet in the northern part of the area (Ross and St. John, 1960, p. 48) and about 400 feet thick in the subsurface in the east-central part (Oriel, 1969, p. M-8).		
	MISSISSIPPIAN	Upper Lower	Madison Limestone (Mm)		Gray, brown, and tan thin-bedded to massive partly cherty and brecciated limestone and gray to tan thick-bedded to massive dolomite. About 1,300 feet thick in the northern part of the area (Schroeder, 1969) and about 2,100 feet thick along the Wyoming-Utah border southwest of Sage (Richardson, 1941, pl. 6). (See generalized thickness map.)		
	DEVONIAN	Upper	Darby Formation (MDd) (Jefferson Limestone and Three Forks Formation included in some of the area)		Gray to brown thin-bedded to massive dolomite and limestone, and black, yellow, and red siltstone. Thickness 400 to 450 feet in the northern part of the area (Schroeder, 1969) and about 1,000 feet thick along the Wyoming-Utah border southwest of Sage. (See generalized thickness map.)		
		Lower and middle					
	SILURIAN						
	ORDOVICIAN	Upper Middle Lower	Bighorn Dolomite (Ob)		Gray fine- to medium-grained massive dolomite and dolomitic limestone that has rough pitted surfaces upon weathering. Thickness 400 to 450 feet in the northern (Schroeder, 1969) and eastern (Oriel, 1969, p. M-7) parts of the area but more than 1,000 feet thick in the west-central part. (See generalized thickness map.)		
	CAMBRIAN	Upper	Gallatin Limestone (Єg)		Dark-gray brown-mottled thin-bedded limestone and gray partly dolomitic limestone with some beds of conglomerate (Oriel, 1969, p. M-7). Generally ranges in thickness from 125 to 200 feet in the northern and eastern parts of the area but is much thicker in the west-central part. (See thickness map for Gallatin Limestone and Gros Ventre Formation.)		
			Gros Ventre Formation (Єgv)		Gray and green shale with some conglomerate in the upper part, blue to gray rusty mottled limestone in the middle part, and green and red hematitic shale in the lower part. About 725 feet thick in the northern part of the area but much thicker in the subsurface in the west-central part. (See thickness map for Gallatin Limestone and Gros Ventre Formation.)		
		Lower	Flathead Quartzite (Єf)		White to pink fine-grained quartzite and some lenses of coarse-grained sandstone. The upper part contains some green silty shale interbeds, and the basal part is conglomeratic. Thickness 175 to 200 feet in the northern part of the area (Schroeder, 1969).		
			Igneous and metamorphic rocks				
	QUATERNARY (?) and TERTIARY		Igenous intrusive and extrusive rocks, undivided (QTi)		Rhyolite, dacite, andesite, and basalt. Their exposure is confined to small outcrops in the northern part of the area. Maximum thickness is unknown because the rocks are usually covered by alluvium and glacial deposits.	Igneous and metamorphic rocks have little primary permeability, but fractures may contain water. The optimum drilling depth is probably less than 200 feet because the size and number of fractures decrease with depth. Maximum expectable well yield is a few tens of gallons per minute. Well 41-117-24bd1 (120 feet deep) taps fractured andesite and has a reported yield of 50 gpm. Water from this well is a calcium bicarbonate type and contains 323 mg/l dissolved solids.	1
	PRECAMBRIAN		Metamorphic and igneous rocks, undivided (pЄr)		Mainly coarse grained granite gneiss with some schist, granite, and pegmatite (Schroeder, 1969). The rocks are exposed only in a small area west of Wilson in Teton County.		

Interior—Geological Survey, Reston, Va.—1975

WATER RESOURCES OF THE THRUST BELT OF WESTERN WYOMING

By
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1975

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