Artesian Pressures and Water Quality in Paleozoic Aquifers in the Ten Sleep Area of the Bighorn Basin, North-Central Wyoming

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Prepared in cooperation with the
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CONTENTS

PLATES [Plates are in pocket]

FIGURES

TABLES [Tables are at back of report]

Artesian Pressures and Water Quality in Paleozoic Aquifers in the Ten Sleep Area of the Bighorn Basin, North-Central Wyoming

By Maurice E. Cooley

Abstract

The major Paleozoic artesian aquifers, the aquifers most favorable for continued development, in the Ten Sleep area of the Bighorn Basin of Wyoming are the Tensleep Sandstone, the Madison Limestone and Bighorn Dolomite (Madison-Bighorn aquifer), and the Flathead Sandstone. The minor aquifers include the Goose Egg and Park City Formations (considered in the Ten Sleep area to be the lateral equivalent of the Phosphoria Formation) and the Amsden Formation. Most wells completed in the major and minor aquifers flow at the land surface. Wellhead pressures generally are less than 50 pounds per square inch for the Tensleep Sandstone, 150–250 pounds per square inch for the Madison-Bighorn aquifer, and more than 400 pounds per square inch for the Flathead Sandstone. Flowing wells completed in the Madison-Bighorn aquifer and the Flathead Sandstone yield more than 1,000 gallons per minute. The initial test of one well completed in the Madison-Bighorn aquifer indicated a flow rate of 14,000 gallons per minute. Transmissivities range from 500 to 1,900 feet squared per day for the Madison-Bighorn aquifer and from about 90 to 325 feet squared per day for the Tensleep and Flathead Sandstones.

Significant secondary permeability from fracturing in the Paleozoic aquifers allows local upward interformational movement of water, and this affects the altitude of the potentiometric surfaces of the Tensleep Sandstone and the Madison–Bighorn aquifer. Water moves upward from the Tensleep and other formations, through the Goose Egg Formation, to discharge at the land surface as springs. Much of the spring flow is diverted for irrigation or is used for rearing fish.

Decreases from original well pressures were not apparent in wells completed in the Tensleep Sandstone or in the Madison-Bighorn aquifer in the study area except for a few wells in or near the town of Ten Sleep. Most wells completed in the Flathead Sandstone, which also are open to the Madison-Bighorn aquifer, show a decrease of pressure from the time of completion to 1978. The decrease of pressure is partly the result of water moving from the Flathead Sandstone into the Madison-Bighorn aquifer, which has a lower potentiometric surface than does the Flathead Sandstone, even during the time the wells are not in operation. Pressure in some small-capacity wells completed in the Goose Egg Formation also has decreased near Ten Sleep. Most of the wells, particularly the irrigation wells, show a progressive decrease in pressure during the irrigation season but recover during periods of nonuse. Measurements of the pressure were made principally in 1953, 1962, 1970, and 1975–78.

Well water from the Paleozoic aquifers generally contains minimal concentrations of dissolved solids and individual constituents but excessive hardness. Dissolved-solids concentrations of water are less than 300 milligrams per liter in the Tensleep Sandstone and the Madison-Bighorn aquifer, less than 200 milligrams per liter in the Flathead Sandstone, and as much as 450 milligrams per liter in the Goose Egg Formation. Bicarbonate is the major constituent, followed by calcium and magnesium. Relatively large concentrations of sulfate, as much as 490 milligrams per liter, were found, mainly in water from the Goose Egg Formation. The water has low sodium (alkali) and medium salinity; therefore, the water is satisfactory for irrigation and most other uses, if excessive hardness is not a detrimental factor.

Wellhead temperatures range from 11° to 27.5° Celsius (51° to 81.5° Fahrenheit) within a range in depth of approximately 250 to 4,000 feet. This gives a geothermal gradient of about 0.44° Celsius per 100 feet (0.79° Fahrenheit per 100 feet).

INTRODUCTION

In the Bighorn Basin of north-central Wyoming, there is an increasing need for additional water for irrigation, municipal, and industrial use. The deeply buried Paleozoic rocks near Ten Sleep in the eastern part of the basin are among the more promising sources of additional water. The Ten Sleep area includes part of the cattle-range country adjoining the southwestern flank of the Bighorn Mountains. Crops—mainly hay and alfalfa, associated with the raising of cattle—are irrigated by diverting water from streams or from flowing wells.

In 1974 the U.S. Geological Survey, in cooperation with the Wyoming State Engineer, began an investigation of the hydrology of the Paleozoic aquifers in the Ten Sleep area. This report describes the results of that investigation.

The area investigated extends from T. 42 N. to T. 50 N. and parts or all of R. 86 W. to R. 90 W. in Washakie and Big Horn Counties (fig. 1, pl. 1) near Ten Sleep and Hyattville in southeastern Bighorn Basin. The

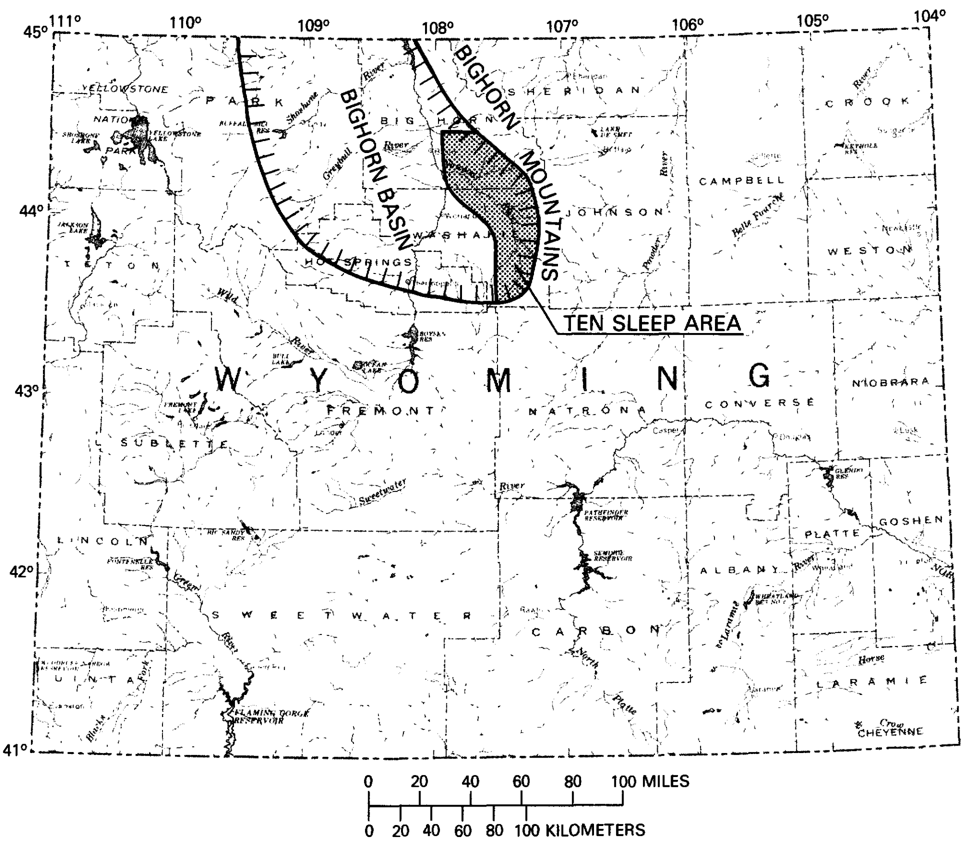

Figure 1. Location of the Ten Sleep area of the Bighorn Basin, Wyo.

investigative effort was concentrated in T. 44 N. to T. 50 N.; only a geohydrologic reconnaissance was made of the area south of T. 44 N.

Purpose and Scope

The purposes of the study were to define the potentiometric surfaces, to determine changes of artesian pressure, to describe water quality, and to describe the principal aquifers most favorable for continued development.

Geologic investigation was limited to mapping the main fold structures and principal fracture systems that seem to affect the artesian aquifers. Aerial photographs, 7½-minute quadrangle maps (scale 1:24,000; contour interval 20 and 40 ft), and Landsat imagery were used to do the mapping. In addition, areas containing solution-collapse features were outlined; many of the springs and spring-sustained ponds are associated with these features.

All water wells completed in the Paleozoic aquifers before 1978 were inventoried on-site. A few springs were inventoried, principally in valleys adjoining the western boundary of the Bighorn Mountains. No attempt was made to visit all springs in the Ten Sleep area or the numerous springs in the canyons in the Bighorn Mountains adjoining the eastern border of the area.

Measurement of artesian pressures in wells completed in the Paleozoic aquifers was given particular attention. Measurements of the static wellhead pressures were made each spring during 1975–78 before the start of the irrigation season. Other pressure measurements were made, mainly during 1975, during the irrigation season when the wells were in operation. In addition, recovery or drawdown tests were made on eight wells.

Water samples for chemical analysis were collected from most wells in 1975 before irrigation began; many of the wells were resampled near the end of the irrigation season. Other chemical analyses or measurements of specific conductance were obtained from springs, spring-sustained streams, and ponds.

Previous Investigations

Previous geologic and hydrologic investigations include a structure study by Rogers and others (1948), a water-resources study of the Manderson-Hyattville area by Swenson and Bach (1951), an unpublished inventory by H.M. Babcock and R.R. Bennett, U.S. Geological Survey, in 1953 of the flowing wells, including pressure measurements of 12 of the wells completed in the Paleozoic aquifers, a study of the artesian pressures of the Paleozoic artesian aquifers by Lowry (1962), and a hydrogeologic study of the valleys of the Nowood River and Tensleep and Paint Rock Creeks by Cooley and Head (1979).

Other investigations that include all of the Bighorn Basin concern the structure (Zapp, 1956), the permeability and the potentiometric surface of the Tensleep Sandstone (Bredehoeft, 1964; Bredehoeft and Bennett, 1972), and a hydrologic reconnaissance (Lowry and others, 1976).

Acknowledgments

The author gratefully acknowledges all the ranchers, officials of the towns of Ten Sleep and Hyattville, and others who assisted with the testing of their wells. Particular appreciation is extended to Gene Anderson, Mark Carter, L.J. Davis, Boyd Mills, R.C. Mills, Harold Misomelius, Bill Renner, Homer Renner, and Bud Shirron. Special thanks also are extended to Donald Peterson of the Wyoming Game and Fish Department for providing information concerning the water supplies at the Wigwam Fish Rearing Station. Well-log data and well-yield information were obtained from the files of the Wyoming State Engineer, Cheyenne. Chemical analysis of water samples from wells, springs, and streams collected during 1975–76 was done by the Wyoming Department of Agriculture, Laramie.

Well-Numbering System

Wells are identified by three numbers followed by one or more lower case letters (e.g., 47–90–29cab). The numbering system is based on the Federal system of land subdivision. The first number denotes the township, the second number the range, and the third number the section. The letters following the section number denote the location within the section. The section is divided into quarters (160 acres), which are lettered a, b, c, and d in a counterclockwise direction, beginning in the northeast quarter. Similarly, each quarter may be further divided into quarters (40 acres) and again into 10-acre tracts and lettered as before. The first letter following the section number denotes the quarter section, the second letter, if shown, the quarter-quarter section, and the third letter the quarter-quarter-quarter section, or 10-acre tract. For example, in figure 2 well 47–90–29cab is in the NW1/4 of the NE1/4 of the SW1/4 of section 29, T. 47 N., R. 90 W.

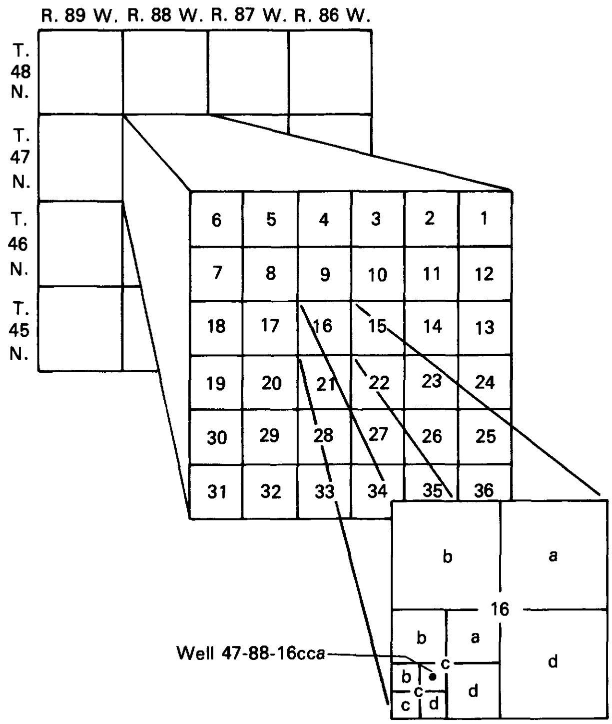

Figure 2. Well-numbering system.

GEOHYDROLOGIC SETTING

The Paleozoic aquifers discussed in this report are located in the Ten Sleep area of north-central Wyoming. The Ten Sleep area, between 4,000 and 6,000 ft above sea level, is in the southeastern Bighorn Basin, the large structural depression that borders the western flank of the Bighorn Mountains (pl. 1). The outcrops of sedimentary rocks outline a structural slope that extends from the summit of the Bighorn Mountains to the central area of the basin. Erosion of the sedimentary rocks has formed terrain characterized by rolling foothills dominated by cuesta ridges and strike valleys. Grassland and open stands of pinon and juniper occupy ridges and uplands and provide rangeland for cattle; generally well-watered meadows and cultivated fields occupy the bottom lands along the main drainages. Most fields are irrigated because mean annual precipitation, about 10 to 12 in, is insufficient for growing most crops. Irrigation water comes from wells completed in the Paleozoic aquifers (large sprinkler systems are used) or from diversions from the Nowood River and its main tributaries—Paint Rock, Tensleep, Spring, Otter, and Little Canyon Creeks—which derive their flow from precipitation falling on the Bighorn Mountains. Storage reservoirs are not present along these streams.

The Paleozoic strata, lying between the Triassic Chugwater Formation and the Precambrian basement rocks, comprise a series of major and minor artesian aquifers or confining layers throughout the Ten Sleep area (table 1) (all tables are at back of report). The major aquifers, in descending stratigraphic order, are: (1) the Tensleep Sandstone (Permian and Pennsylvanian); (2) the Madison Limestone (Mississippian and Devonian) and the Bighorn Dolomite (Ordovician), which together form the Madison-Bighorn aquifer; and (3) the Flathead Sandstone (Cambrian), which rests on Precambrian basement rocks. The minor aquifers include the Goose Egg Formation (Permian) and the Park

City Formation (Permian)—equivalent formations of the Phosphoria Formation (Permian) elsewhere—and the Amsden Formation (Pennsylvanian and Mississippian). The Gallatin and Gros Ventre Formations (Cambrian) are the only Paleozoic strata not known to yield water to wells in the Ten Sleep area.

Major Aquifers

The major aquifers are defined in this report as those that yield more than 300 gal/min to wells. All the large-capacity irrigation and public-supply wells and wells providing water for the rearing of fish are completed in the major aquifers (pl. 1).

Tensleep Sandstone

The conspicuously cross-stratified Tensleep Sandstone is classified as a major aquifer because at places it yields more than 300 gal/min to wells. It consists of well-sorted fine- to medium-grained particles cemented by carbonate and siliceous materials. The cross strata are large-scale and generally dip southwesterly at steep to slight angles. The sandstone is relatively free of readily soluble minerals such as gypsum that is present in the overlying Goose Egg Formation. The sandstone is exposed along the eastern margin of the area (pl. 1) and on Zeisman dome and Brokenback anticline. The sandstone generally occurs at depths of less than 600 ft except near Hyattville, where it is at depths of more than 1,000 ft. Water in the Tensleep is under artesian pressure, except near the outcrops. Most wells completed in the Tensleep are located downdip from its outcrops, and therefore most of the wells flow at the land surface. Most of the small-capacity stock and domestic wells (yielding less than about 50 gal/min) in the study area are completed in the Tensleep Sandstone. Only locally are well yields from the Tensleep Sandstone more than 300 gal/min.

Madison-Bighorn Aquifer

The Madison Limestone and Bighorn Dolomite, which make up the Madison-Bighorn aquifer, are thick-bedded carbonate rocks that include few detrital minerals but considerable chert. The formations are exposed in massive cliffs in canyons along the lower western flank of the Bighorn Mountains, but in the area investigated the top of the Madison occurs at depths between 500 and 2,000 ft. Most irrigation wells completed in the Madison-Bighorn aquifer penetrate the Madison Limestone only partly and do not penetrate the underlying Bighorn Dolomite. The Madison-Bighorn aquifer provides most of the water used for irrigation, by the communities of Ten Sleep and Hyattville, and in the rearing of fish.

In most exposures the strata of the Madison-Bighorn aquifer are transected by many large vertical fractures, which occur singly or in groups. In places the fractured rocks make drilling difficult and cause the loss of circulation of drilling mud. Well 50–90–34dca is reported to obtain its main flow from a cavity in the Bighorn Dolomite or possibly from along the contact between the Madison Limestone and Bighorn Dolomite. Difficulties in drilling and well construction, possibly resulting from the fractures in combination with the karst zone at the top of the Madison, were encountered in wells 47–88–12bca and 49–89–6bcb.

The occurrence of water in the Madison-Bighorn aquifer is controlled principally by secondary permeability resulting from dissolution along fractures. Thus, yields of wells penetrating fractured, cavernous parts of the formations are much greater than yields obtained from the less extensively fractured parts. At least one well, 47–88–16aba, drilled to the underlying Flathead Sandstone, penetrated no permeable intervals (reported by the driller as "no water") in the Madison-Bighorn aquifer. However, many wells completed in the Madison-Bighorn aquifer yield more than 1,000 gal/min and provide dependable supplies for irrigation. Abrupt fluctuations in wellhead pressure during a recovery test of well 49–89–6bcb are interpreted to have been caused partly by the cavernous nature of the Madison, which is present at a depth of more than 2,000 ft below the land surface. In upper Medicine Lodge Creek drainage, cavities in the Madison Limestone intercept the flow of the creek, causing reaches of the stream to be dry (Barbara Tomes, student, University of Wyoming, oral commun., 1975). The quantity of flow intercepted is a few cubic feet per second.

Flathead Sandstone

The Flathead Sandstone is composed of fine- to medium-grained, partly arkosic, quartz sand. In outcrops outside the Ten Sleep area, the sandstone generally is well cemented by silica, with lesser quantities of calcium carbonate, and ranges from a quartzitic sandstone to a quartzite. Water movement in the sandstone seems to be controlled principally by fracturing, judging from the general tightness of the unfractured part of the sandstone where exposed. However, the degree of cementation of the sandstone, at least at places in the subsurface, is much less. During the drilling of wells 48–89–25ada and 49–88–29dac, the drillers reported the Flathead Sandstone "soft" and easy to drill. Throughout the area, the Flathead is deeply buried; water wells completed in the unit range in depth from 2,287 to 3,995 ft. As far as can be ascertained, yields ranging from 500 to more than 1,000 gal/min were obtained from the Flathead in all of the wells that develop irrigation water from this formation. Only wells 47–87–33bdb2 and 48–89–25ada are known to have been drilled through the sandstone into the underlying granitic basement rocks.

Drilling for water supplies from the Flathead Sandstone is a comparatively recent development; seven of the eight wells that penetrate the unit were drilled after 1964.

Water in the Flathead is under very high artesian pressure, causing wellhead pressures as much as 472 lb/in^2 (highest pressure measured during 1975–78). As far as can be ascertained, mainly on the basis of pressures, only wells 47–87–33bdb2, 47–88–16aba, 48–89–25ada, 49–88–29dac, and 50–89–31bab withdraw water mainly from the Flathead Sandstone. The other three wells also withdraw substantial quantities of water from the Madison-Bighorn aquifer.

Minor Aquifers

The three minor aquifers in the area, the Goose Egg, Park City, and Amsden Formations (table 1), provide water to a few wells in different parts of the Ten Sleep area. Most of the wells completed in the minor aquifers flow at the land surface. Many springs discharge water from the minor aquifers.

Goose Egg Formation

The Goose Egg Formation is exposed in the eastern part of the project area in lowlands along the lower western slopes of the Bighorn Mountains. The formation consists of redbeds composed of shale, siltstone, and generally fine-grained sandstone, and in places, considerable gypsum. Dissolution of the gypsum has formed many collapse features, which are distributed throughout the lowlands (pl. 2). This dissolution has been aided by fractures, which has allowed water from the underlying Tensleep Sandstone to move upward and be in contact with the gypsum. Much of the spring flow that discharges from the Goose Egg Formation probably is derived from the Tensleep Sandstone. Most of the wells completed in the Goose Egg Formation are in the valley of Tensleep Creek near Ten Sleep. Generally, these wells flow at rates of only a few gallons per minute, with pressures of less than 20 lb/in^2 at the land surface.

Park City Formation

Limestone and dolomite making up the Park City Formation are present only in the area south of Big Trails. The formation is exposed on slopes bordering the lowlands occupied by the Goose Egg Formation. Only two stock and domestic wells are known to withdraw small quantities of water from the formation in combination with the Tensleep Sandstone. Both wells flow at the land surface with pressures of less than 10 lb/in^2. These wells are equipped with booster pumps because of insufficient pressure and quantity of the flows.

Amsden Formation

The Amsden Formation is present in the subsurface throughout the study area but is exposed only near the Wigwam Fish Rearing Station in Tensleep Canyon and in the canyon of the Nowood River south of Big Trails. The upper part of the formation consists of redbeds composed mainly of shale and siltstone, with some fine-grained sandstone. Springs at the Wigwam Fish Rearing Station issue from the redbeds, but their flow, aggregating a few hundred gallons per minute, probably is water that has moved upward along fractures from the lower part of the Amsden Formation and from the Madison-Bighorn aquifer. The lower part consists of a reddish-brown cross-stratified sandstone that is not as conspicuously cross stratified as the Tensleep Sandstone. The sandstone is mainly fine to medium grained. It yields some water to a few wells, including 46–87–10acb, 47–88–16cca, and 49–89–6bcb, in combination with the Madison-Bighorn aquifer.

Confining Layers

The major and minor aquifers are separated by generally fine-grained units that act mainly as confining layers (table 1), as indicated by large differences in pressure, particularly between the major aquifers. The main confining layer that separates the hydrologic systems of the Paleozoic aquifers from those in the overlying rocks is formed by the thick Chugwater Formation (Triassic) in combination with the Goose Egg Formation. Extensive fracturing and dissolution of gypsum beds has locally developed a secondary permeability in the Goose Egg Formation, so that this formation is a discontinuous confining layer. The upper, shaly part of the Amsden Formation is the confining layer between the Tensleep Sandstone and the Madison-Bighorn aquifer (including the lower sandstone of the Amsden), and the shaly Gallatin and Gros Ventre Formations make up a thick confining layer between the Madison-Bighorn aquifer and the Flathead Sandstone.

Fractures allow some vertical movement of water through the confining layers. This water movement is especially apparent in some of the oil fields in the Bighorn Basin, where there is easy movement of fluids between formations (Lawson and Smith, 1966; Stone, 1967, p. 2069–2077). There is some indication of vertical water movement through the upper part of the Amsden Formation from the Madison-Bighorn aquifer to the Tensleep Sandstone near Ten Sleep and Big Trails, where there are analomous small differences between their potentiometric surfaces (pls. 3, 4). The potentiometric contours of the Madison-Bighorn aquifer indicate a slight hydraulic mound near Zeisman dome, and this indicates that there may be some upward movement of water through the Gallatin and Gros Ventre Formations from the Flathead Sandstone along fractures associated with the doming.

Geologic Structures

The sedimentary rocks in the Ten Sleep area of the Bighorn Basin outline part of a structural slope that generally dips southwestward toward the axis of the basin (figs.

3, 4). In much of the area the regional dip of the Paleozoic rocks, as shown by structure contours of the top of the Tensleep Sandstone (Zapp, 1956), flattens slightly and forms a platform-like feature (pl. 5) that extends northwestward from Big Trails to Zeisman dome. The platform-like feature contains a series of northwest-trending anticlines and synclines. Some of the anticlines and the Tensleep fault are shown in figure 4. This platform-like feature is bounded on the north by a monocline that forms part of the north flank of Zeisman dome. The southwestern boundary is along a sharply flexed monocline between Big Trails and Ten Sleep and by monoclines near Hidden dome and along the southwest side of the Bonanza oil field. At Ten Sleep, the platform-like feature is transected by the east-trending Tensleep fault and an associated monocline (pl. 5). A large downwarped area crossed also by a series of northwest-trending anticlines is in the vicinity of Hyattville to the north of Zeisman dome.

The Tensleep Sandstone is exposed on Zeisman dome and at places along the crest of Brokenback anticline. These structural highs significantly affect the local movement of water in the Tensleep Sandstone and the Goose Egg Formation. Elsewhere, the folds seem to have only a minor effect on water movement.

Linear Features

The pattern of linear features in the Ten Sleep area was studied from aerial photographs (scale 1:62,500) and Landsat imagery (scale 1:1,000,000). The linear features obtained from the aerial photographs are conspicuous joints, most of which are easily seen from on-site inspection. The linear features determined from the Landsat imagery are not identified as to type or origin; those shown on plate 5 probably represent fractures or fracture zones. Most of these linear features are believed to be surface expressions of fractures or fracture zones that extend upward from zones of structural weakness in the Precambrian basement rocks. The

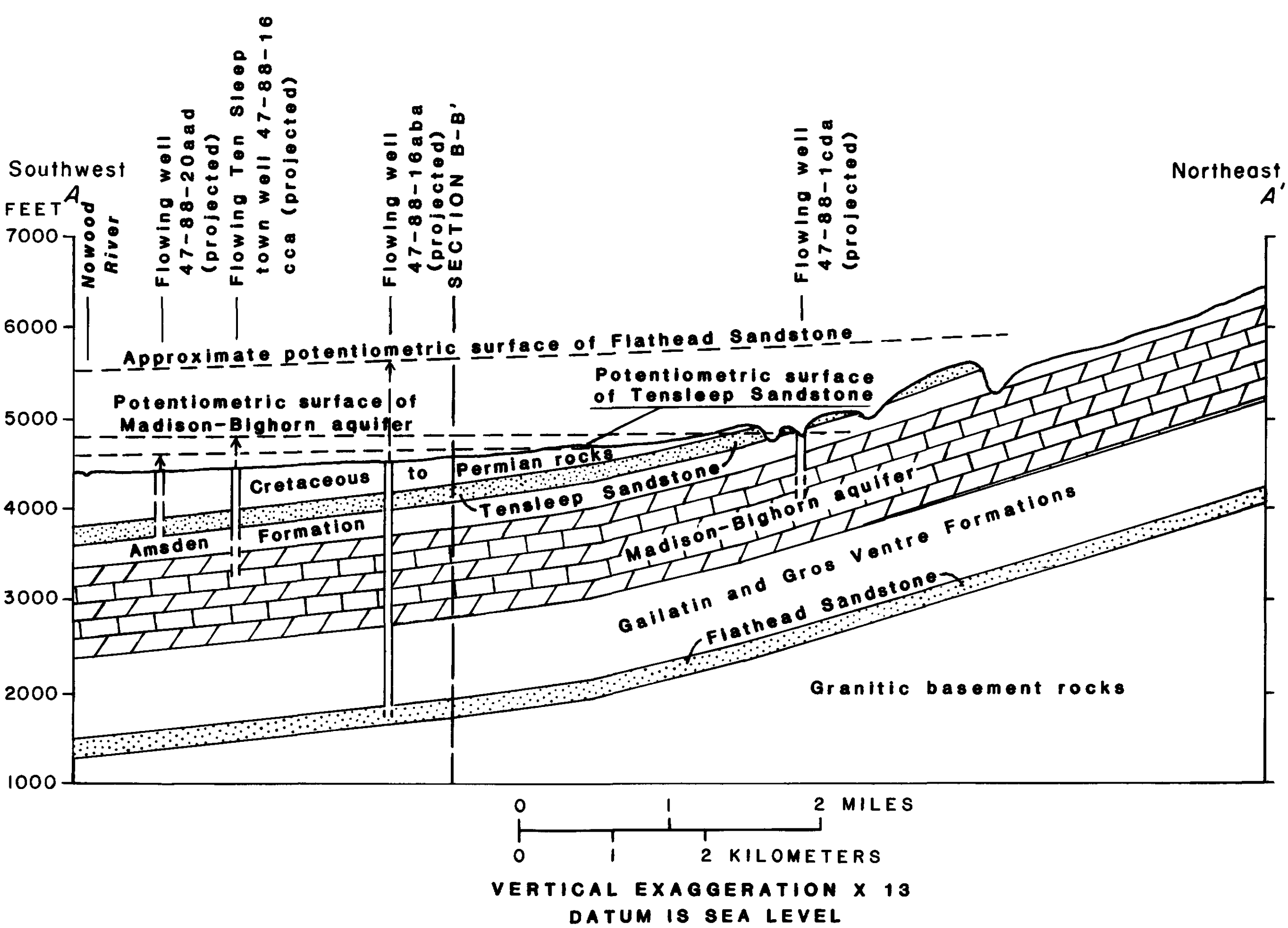

Figure 3. Generalized southwest-northeast section showing geologic structure and the 1978 potentiometric surfaces. Location of section is shown on plate 1.

principal objectives of the study of linear features were (1) to determine areas where secondary permeability resulting from fracturing may have increased the transmissivity of the sedimentary rocks, and (2) to determine relations of the linear features to anticlines, monoclines, and the Tensleep fault.

The pattern of linear features determined from Landsat imagery gives an overview of structural trends that affect the location and orientation of fold and fault structures. In general, linear features trend northwest, north to north-northeast, northeast, and east to east-southeast (pl. 5). The northwest-trending linear features are the dominant linear features recognized in the Ten Sleep area and in most of Wyoming. The northwest trend also is the trend of most axes of the numerous anticlines in the Bighorn Basin and the trend in the study area of the margins of the Bighorn Mountains and Bighorn Basin. In contrast, many monoclines and faults, including the conspicuous Tensleep fault, are aligned with north- to northeast-trending linear features.

The linear features observed on aerial photographs include many north–northwest- to north- and east- to east–2 northeast-trending fracture traces that are not well shown on the Landsat imagery, although these trend directions are easily seen on imagery of adjoining regions of Wyoming (Cooley, 1984). Many of these fracture traces form acute angles with faults and axes of folds. Generally, the fractures and their points of intersection are more conspicuous and numerous northeast of the Nowood River than in the area southwest of the river, except near the Bonanza and Nowood oil fields.

Fractures associated with linear features may give the sedimentary rocks a significant secondary permeability. Studies have indicated that wells drilled along and near linear features, particularly in carbonate rocks, generally have larger yields than wells drilled between linear features (Lueder and Simons, 1962; Moore, 1976). A fracture analysis revealed that a concentration of fractures coincided with the location of the hot springs at Thermopolis in the southern part of the Bighorn Basin (Cooley and Head, 1982, p.18). Crist (1980, p. 10, figs. 8 and 9) reported that in Laramie County in southeastern Wyoming there is some correlation between the orientation of the linear features obtained from Landsat imagery and the direction of ground-water movement.

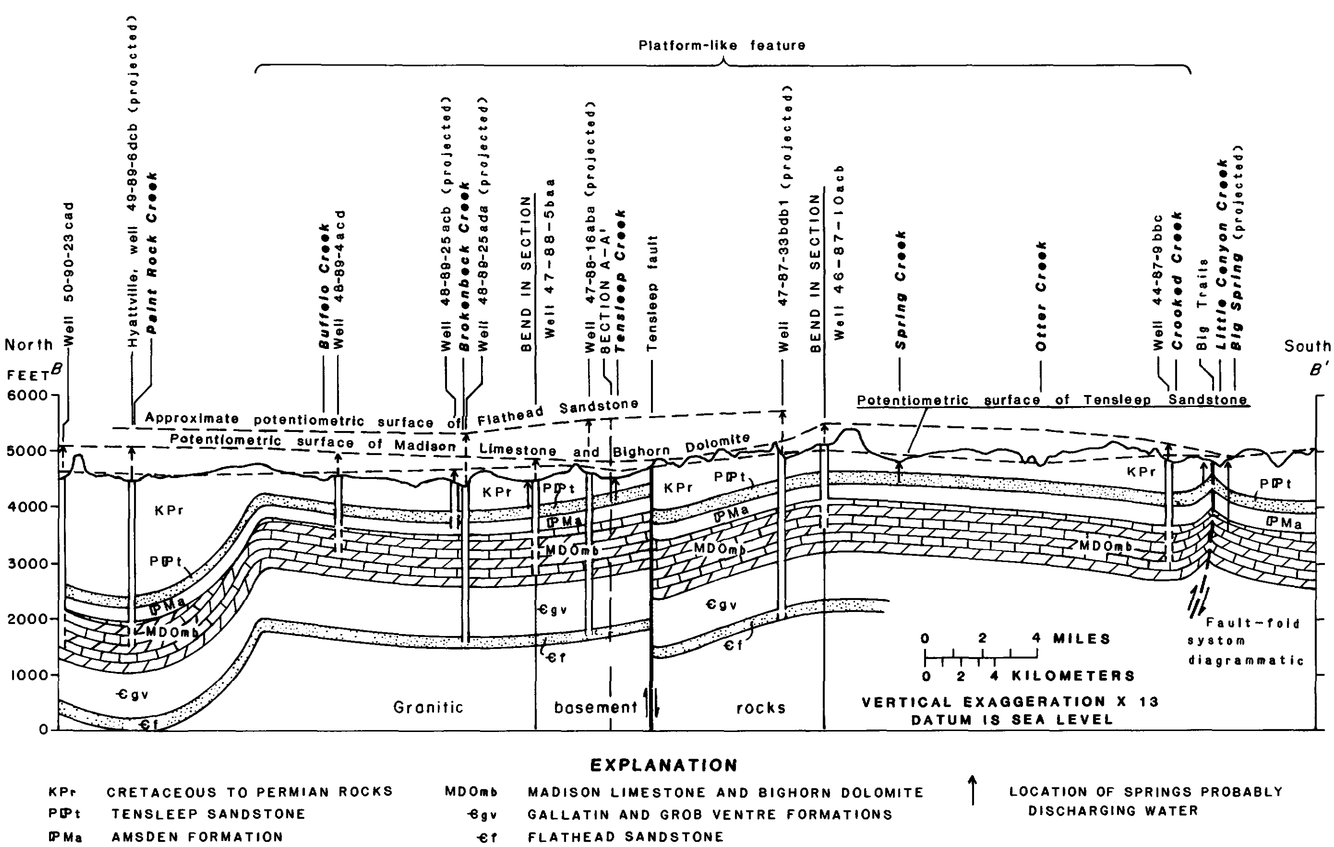

Figure 4. Generalized north-south section showing geologic structure and the 1978 potentiometric surfaces. Location of section is shown on plate 1.

Fracturing is known to exert significant local control on the movement of fluids and on the gradients of potentiometric surfaces at places in the Bighorn Basin. During secondary-recovery operations at the Cottonwood Creek oil field near the western edge of the Ten Sleep area, movement of the injected gas and water fronts was more rapid in the densely fractured part of the field than in the less fractured part (McCaleb and Willingham, 1967, p. 2125–2126, fig. 6). Because fracturing allows easy movement of fluids between formations, the common oil–water contact is at a constant altitude across different oil-producing formations that are folded along anticlines in several oil fields of the basin (Lawson and Smith, 1966, fig. 26; Stone, 1967, p. 2069–2077).

Fracture permeability (secondary permeability) is an important control on water movement in the aquifers, particularly in the Madison-Bighorn aquifer. It allows some vertical movement of water through the confining layers and, at places, affects the gradients of the potentiometric surfaces. In addition, fracture permeability allows upward-moving water to discharge as springs, particularly from the Goose Egg Formation and from the upper part of the Amsden Formation at the Wigwam Fish Rearing Station. Fracture permeability also must have aided significantly in the dissolution of gypsum in the Goose Egg Formation.

GROUND-WATER HYDROLOGY

Recharge

The ground-water hydrology of the Ten Sleep area is controlled by the configuration of the Bighorn Basin and the adjacent western slope of the Bighorn Mountains. Most of the water that is recharged to the Paleozoic aquifers along the western flank of the Bighorn Mountains generally moves westward through the Ten Sleep area and toward the axis of the Bighorn Basin. Only a small quantity of water is discharged naturally in the Ten Sleep area; most of the water that is discharged is from flowing wells.

The principal recharge areas of the formations occurring stratigraphically below the Tensleep Sandstone are east of the study area, along the broad west-dipping flank of the Bighorn Mountains. Large accumulations of snow during the winter months make this area favorable for recharge. The rates of recharge are not known, but owing to extensive fracturing they may be quite rapid locally, particularly for the Madison Limestone and Bighorn Dolomite. The Tensleep Sandstone is recharged mainly along the eastern border of the study area. Some recharge to the Tensleep occurs on Zeisman dome and along Brokenback anticline. The Goose Egg and Park City Formations are locally recharged in the study area. However, most of the water in the Goose Egg Formation probably is derived from upward leakage from the Tensleep Sandstone.

The only information concerning recharge obtained during this study involves well 47–88–1cda and East Spring at the Wigwam Fish Rearing Station. At times, the combined flow of the well and the spring seems to be affected by recharge resulting from precipitation falling on outcrops of the Madison-Bighorn aquifer which are present within a mile to the east of the station. The combined flow of the well and the spring at the station decreased from 1972 to 1974 but increased considerably during the early part of 1975 (fig. 5). Although flow during 1975 was less than that of 1972, it was substantially greater than the flow at any other time during 1973–78. This increase in flow probably resulted from recharge to the Madison-Bighorn aquifer that was obtained from greater than average precipitation and snowpack in the Bighorn Mountains during the winter and spring of 1975 (fig. 5).

The potential for recharge from the melting of the snowpack is great because of the high flows of streams draining the Bighorn Mountains. Streamflow records for gaging stations on Clear Creek and Nowood River (fig. 5) and approximate measurements made in 1975 of the stage of Tensleep Creek, which drains the area where recharge occurs to the aquifer near the Wigwam Fish Rearing Station, indicate the magnitude of annual snowfall. Although Clear Creek is on the east flank of the Bighorn Mountains, it shares a common divide with Tensleep Creek on the broad summit of the mountains. Precipitation on the summit probably affects Clear Creek and Tensleep Creek similarly, as evidenced by high flows along both creeks during May and June 1972 (U.S. Geological Survey, 1972, p. 47, 88) and again during June and early July 1975.

Potentiometric Surfaces and Water Movement

The Paleozoic aquifers in the Ten Sleep area characteristically have high artesian pressures, but there are large differences in hydraulic head among the three major aquifer systems. The potentiometric surface of the Tensleep Sandstone is the lowest and that of the Flathead Sandstone is the highest (figs. 3, 4). The potentiometric surface of the Madison-Bighorn aquifer is as much as 450 ft higher than that of the Tensleep Sandstone, but the potentiometric surfaces of these two aquifers are only about 100 ft apart in the northern part of T. 47 N., R. 88 W. and R. 89 W. near Ten Sleep and are at approximately the same altitude in a small area west of the anticline-fault structure near Big Trails (pls. 3, 4). The potentiometric surface of the Flathead Sandstone is as much as 800 ft higher than that of the Madison-Bighorn aquifer.

The potentiometric surfaces of the Tensleep Sandstone (pl. 3) and the Madison-Bighorn aquifer (pl. 4) are shown on maps that also show the main fold and fault structures that affect the artesian systems. Distribution and altitude of the outcrops where water discharges from the

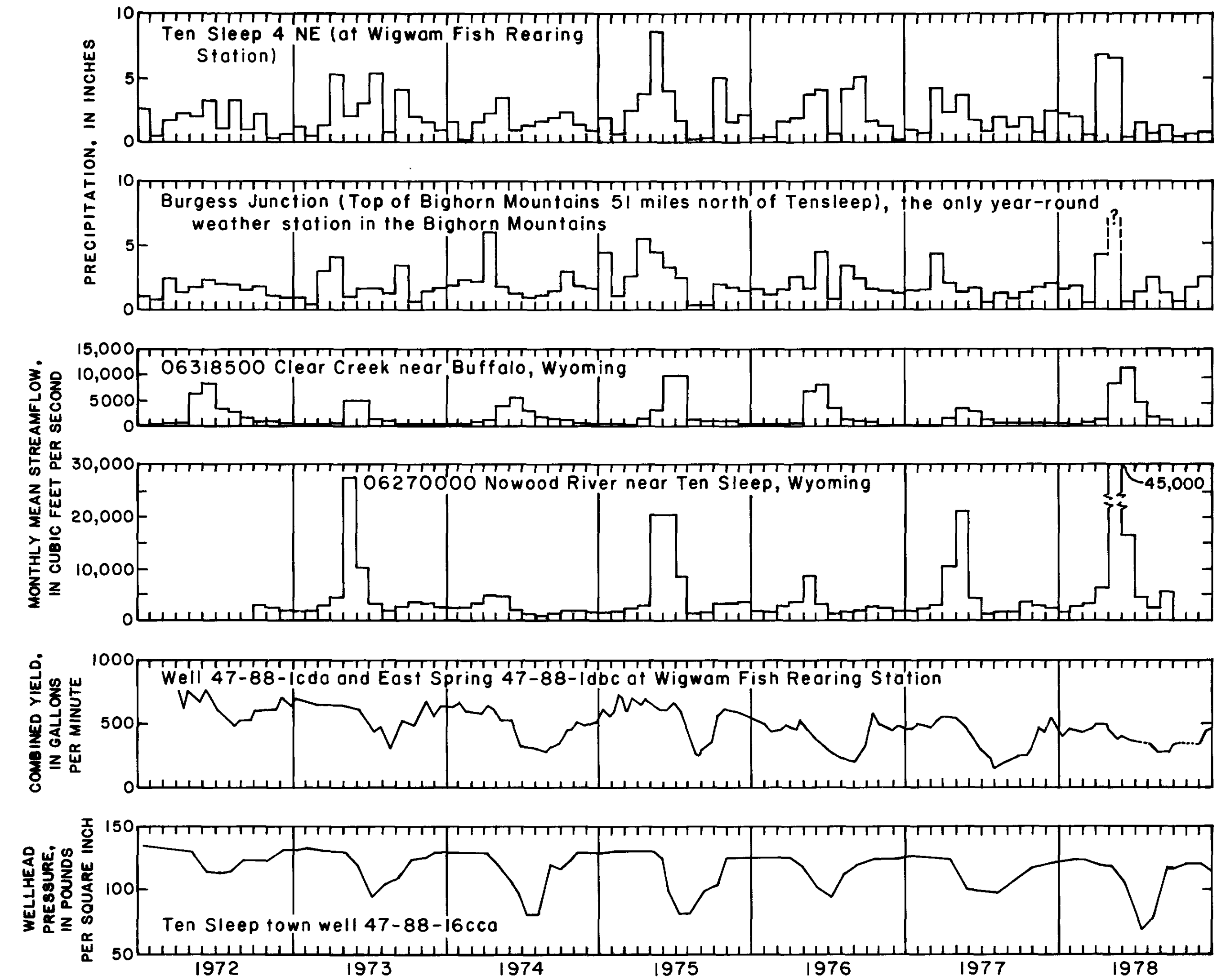

Figure 5. Precipitation, streamflow, yield of well 47–88–1cda and spring 47–88–1dbc, and pressure of Ten Sleep town well 47–88–16cca, 1972–78.

Tensleep Sandstone and Madison Limestone aided in determining the potentiometric surfaces. Insufficient pressure data precluded preparation of maps showing the potentiometric surface of the Flathead Sandstone or of the minor Paleozoic aquifers. All available pressure data are listed in table 2.

Pressures in the Tensleep Sandstone and the Madison-Bighorn aquifer along the western edge of the Ten Sleep area are affected by activities in nearby oil fields. Seven pressure measurements obtained from drill-stem tests of oil wells used by Bredehoeft and Bennett (1972) were included in preparation of the potentiometric surfaces shown on plates 3 and 4, even though the effects of withdrawal or injection of fluids from oil-field activities were not studied comprehensively during this investigation. In the Bonanza and other nearby oil fields, withdrawal of oil, gas, and water since the initial oil-field pressures were recorded probably has substantially decreased pressures in the Tensleep Sandstone and Madison-Bighorn aquifer. In contrast, several injection wells in the northwestern part of T. 47 N., R. 90 W. force water obtained from oil production back into the formations and increase artesian pressure in the Cottonwood Creek oil field (McCaleb and Willingham, 1967). However, south of Ten Sleep the oil-test data generally may be representative of current hydrologic conditions because only widely separated oil wells have been drilled.

The gradient of the potentiometric surfaces, indicating the direction of water movement in the Paleozoic aquifers, generally is westward across the area and ranges from less than 50 to about 200 ft/mi, with the steeper gradients adjacent to the Bighorn Mountains. The gradient in the Madison-Bighorn aquifer is steeper than the gradient in the

Tensleep Sandstone, except near Hyattville. West of the Ten Sleep area in the broad, central part of Bighorn Basin the potentiometric gradient in the Tensleep Sandstone is less than 20 ft/mi (Bredehoeft and Bennett, 1972).

Large troughs, or lows, are outlined by the potentiometric surfaces of the Tensleep Sandstone and the Madison-Bighorn aquifer near Big Trails, Ten Sleep, and Hyattville (pls. 3, 4). The troughs are associated with points of ground-water discharge from the Paleozoic aquifers, either to the surface or to shallower aquifers. The intervening highs on the potentiometric surfaces are broad features and are not as well defined as are the troughs.

In the southern part of the area the troughs outlined by both potentiometric surfaces (pls. 3, 4) approximately correspond with the structural configuration of the Bighorn Basin. The troughs are sharply accentuated along a fractured fold and fault structure near Big Trails where considerable spring flow occurs. The spring flow is mainly from Big Spring and from the location where Little Canyon Creek crosses outcrops of the Tensleep Sandstone and the Park City Formation. The Madison Limestone and older strata are not exposed near Big Trails. Big Spring issues from the Goose Egg Formation near a small normal fault. The flow (about 1,000 gal/min) seems to be too great to be derived from only the Tensleep, the Goose Egg, or the Park City. Therefore, part or most of the spring flow may be from the Madison Limestone. Partial confirmation that the Madison may be hydraulically connected with the Tensleep in this area is from similar wellhead pressures of water in both formations reported by the owner (C.E. Lewtons, oral commun., 1976) of well 44–87–17ccb. The potentiometric surfaces at this well are approximately the altitude of Big Spring.

A generally southwestward-plunging trough is shown on the potentiometric surfaces of the Madison-Bighorn aquifer and the Tensleep Sandstone near Tensleep Creek. Near the Wigwam Fish Rearing Station, where Tensleep Creek crosses the Paleozoic formations, water discharges from these formations to the creek. Also, near the Wigwam Fish Rearing Station, the flow aggregates to several hundred gallons per minute—principally from the Madison Limestone and subordinately from the Amsden Formation—from wells 47–88–1cda and 47–88–12bca and from springs at the station. A considerable but unknown quantity of water from the Tensleep Sandstone and possibly also from the underlying formations is discharged to Tensleep Creek near Ten Sleep (Cooley and Head, 1979, p. 28). Closed lows on the potentiometric surfaces may occur in the southwestward-plunging trough near Ten Sleep (pl. 3) and near the Wigwam Fish Rearing Station (pl. 4). These closed lows are not shown on the maps owing to sparse pressure data.

Another trough is present in the area of the mouth of Medicine Lodge Creek, a tributary to Paint Rock Creek. Ground water is discharged to these creeks where they cross the relatively low-altitude outcrops of the Tensleep Sandstone and the Madison-Bighorn aquifer along the western flank of the Bighorn Mountains. Possibly, some ground water also is discharged to these creeks downstream of the Tensleep outcrop in an area that may contain solution-collapse features 3 to 5 mi northeast of Hyattville (pl. 2).

The Tensleep Sandstone and the Madison-Bighorn aquifer are below their respective potentiometric surfaces along the anticlines west of the Bighorn Mountains, except near Zeisman dome in the northern part of the study area. Water in the Tensleep Sandstone, therefore, is locally under water-table (unconfined) conditions along the flanks of Zeisman dome (fig. 6) and also along the Brokenback anticline southeast of the dome. Near the crest of Zeisman dome, the Tensleep has been sufficiently elevated that it is entirely above the water table. Along both structures the shaly upper part of the Amsden Formation forms a barrier to westward movement of water in the Tensleep Sandstone. Flow is instead diverted northerly and southerly around the folds, with some discharge occurring along Buffalo Creek and along branches of Brokenback Creek where these streams cross outcrops of the Tensleep Sandstone.

Beneath the crest of Zeisman dome, the uppermost 100 to 200 ft of the Madison-Bighorn aquifer is above its potentiometric surface (fig. 6), and locally this aquifer is under water-table conditions. Presumably, the water table in the intervening Amsden Formation is in transition between the lower level in the Tensleep beneath the flanks of the dome and the higher level in the Madison-Bighorn beneath the crest, creating a probable water-table mound. If actually present, however, the mound probably represents only the adjustment between the two potentiometric surfaces to vertical leakage rather than evidence of significant recharge. The potentiometric contours for the Madison-Bighorn aquifer (pl. 4) do indicate a hydraulic mound in the vicinity of Zeisman dome, probably owing to upward movement of water from the Flathead Sandstone along fractures resulting from the doming.

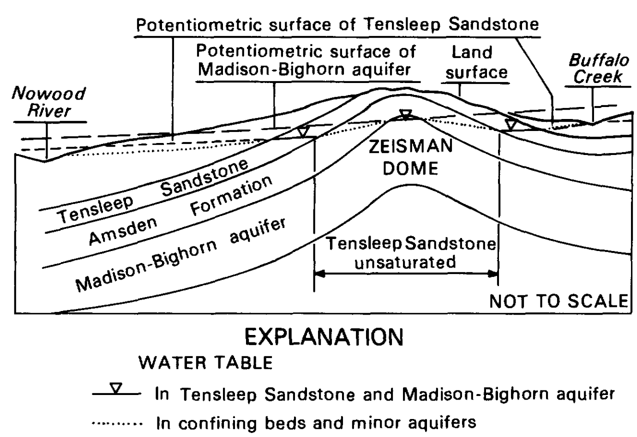

Figure 6. Schematic section showing hydrologic conditions at Zeisman dome.

Anomalously greater pressures occur at places in the Tensleep Sandstone. Wellhead pressures for wells 47–89–1cac and 47–89–13aab indicate that the potentiometric surface at these locations is about 100 ft higher than the potentiometric levels of the nearest wells completed in the Tensleep to the north and to the south (pl. 3) and the altitudes of the closest exposures of the Tensleep Sandstone along Brokenback and Tensleep Creeks. The potentiometric surface of the Tensleep Sandstone, which is at or above the land surface, precludes the possibility of local recharge to the Tensleep from precipitation close to the wells. Near these wells, the potentiometric surface of the Madison-Bighorn aquifer is only slightly above the potentiometric surface of the Tensleep Sandstone (pls. 3, 4). Along the western border of the Ten Sleep area, seemingly greater pressures were reported for the Tensleep Sandstone in some of the oil-test wells (Bredehoeft and Bennett, 1972). The anomalously greater pressures in the Tensleep Sandstone (with the corresponding decrease in the separation between the potentiometric surfaces in the Tensleep and in the Madison-Bighorn aquifer) may indicate a hydraulic connection between the Tensleep and the Madison-Bighorn aquifer—possibly by means of fractures, which are common in the area.

Hydraulic Characteristics of Aquifers

Several large-capacity wells were tested during 1975–76 to determine some of the main hydraulic characteristics of the major aquifers (table 3). The wells tested are used for irrigation, except for the municipal well 49–89–6bcb at Hyattville. Previously, seven tests were made of wells completed mainly in the Tensleep Sandstone. In all tests, only the discharging well was examined, as no observation wells are nearby.

Transmissivities, in feet squared per day, were obtained from pressure-recovery tests of wells 47–88–5baa and 48–89–4acd completed in the Madison Limestone and of wells 48–89–25ada and 49–88–29dac completed mainly in the Flathead Sandstone; these tests are believed to provide representative characteristics of wells completed in these formations. The test of well 48–89–4acd continued for approximately 10 days (fig. 7) and of well 49–88–29dac (fig. 8) for 13 days. These two wells had been flowing for several months prior to the tests. In wells completed in the Madison Limestone much of the recovery occurred during the first hour. However, in the wells completed mainly in the Flathead Sandstone, the recovery was steady and much slower. The test of well 49–88–29dac showed that the pressure was still increasing after 13 days. Because this well also is open to the Madison-Bighorn aquifer, the slow recovery was partly due to the continuous movement of water in the well from the Flathead Sandstone to the Madison-Bighorn aquifer, which has a lower potentiometric surface than the Flathead Sandstone. The recovery, therefore, is a composite one for the two aquifers, and a unique calculation of the transmissivity of the Flathead Sandstone cannot be made. The value shown (250 ft^2/d) in figure 8 is a maximum value. In wells completed in the Tensleep Sandstone, the recovery was steady but rather rapid, as represented by the test of well 47–89–13aab (fig. 9), which recovered to the static pressure in 1 hour 40 minutes.

Transmissivities of the Madison-Bighorn aquifer range from about 300 to 1,900 ft^2/d as determined in tests of properly constructed large-capacity wells. Transmissivities of about 90 to 325 ft^2/d were calculated from tests of the Tensleep Sandstone and the Flathead Sandstone. Maximum yields of wells in the Madison-Bighorn aquifer and the Flathead Sandstone may be more than 1,000 gal/min. However, yields of 500 gal/min or less were reported for the Madison-Bighorn aquifer in three wells that also are completed in the Flathead Sandstone.

Large fluctuations of pressure during the test of well 49–89–6bcb (completed in the Madison Limestone and Amsden Formation) precluded calculation of an accurate value of transmissivity (fig. 10). This well supplies Hyattville and flows continuously at a rate of about 100 gal/min. Abrupt fluctuations, as much as 9 lb/in^2, of pressure

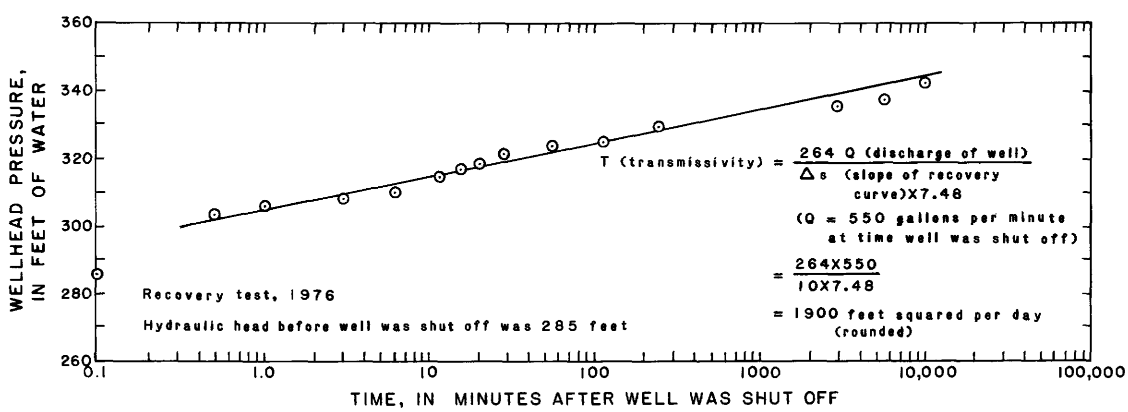

Figure 7. Recovery curve for well 48–89–4acd completed in the Madison Limestone.

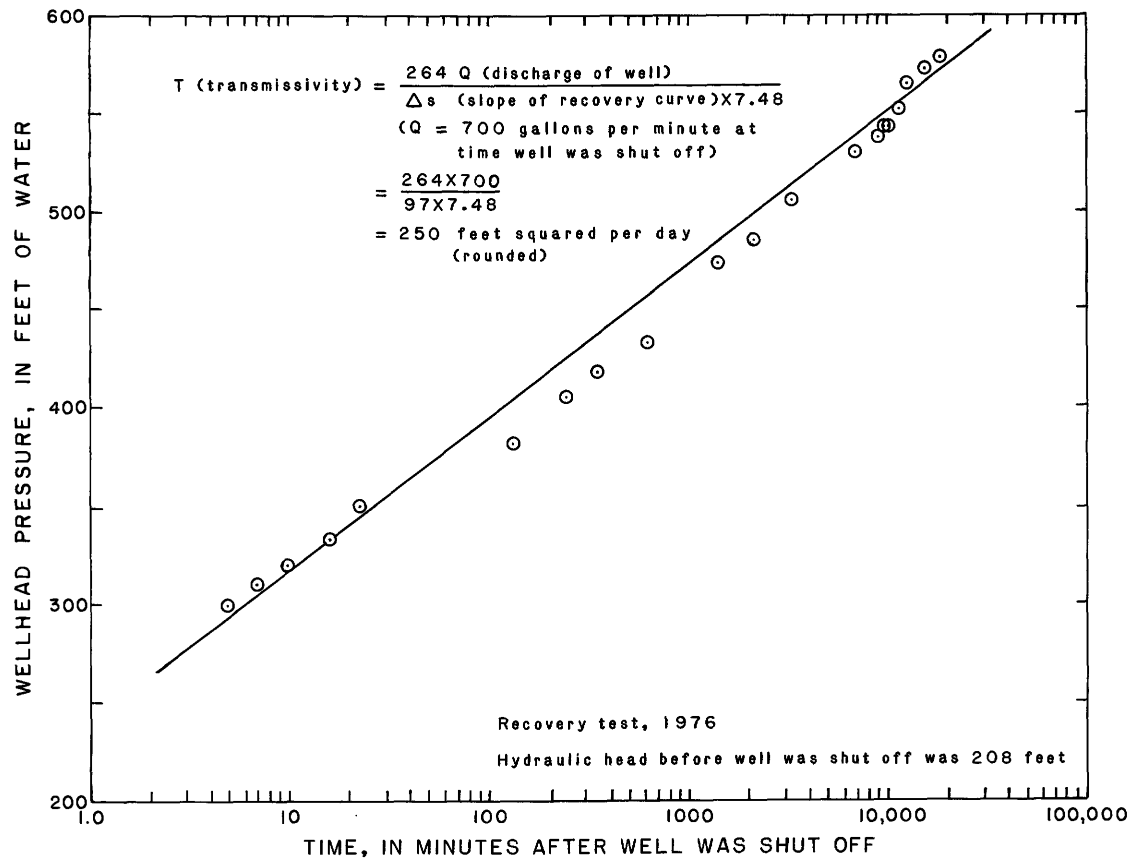

Figure 8. Recovery curve for well 49–88–29dac completed mainly in the Flathead Sandstone.

began 5 to 9 minutes after the well was shut off and had a duration of about 6 to 10 minutes (fig. 10). After an abrupt initial increase in pressure, the pressure increased steadily before and after the period of fluctuation.

The information available from the test is insufficient to allow detailed analysis, but the early (8 min) part of the recovery curve indicates a transmissivity of about 140 ft^2/d. The average slope of the curve in the interval from about 8 to 15 min indicates that the expanding cone of recovery reached a boundary with a major decrease in permeability. Such a boundary might produce reflections to cause the oscillations observed at the well. The fractured nature of this aquifer is consistent with such a radical lateral change in hydraulic properties.

Discharge

Accurate accounting of ground-water discharge in the Ten Sleep area is beyond the scope of this investigation. However, significant quantities of water from the Paleozoic aquifers are discharged to numerous springs and from at least 75 wells. A substantial but unknown quantity of ground water is discharged to the Nowood River, to Paint Rock, Tensleep, and Spring Creeks, and to other streams where these streams cross outcrops of the Goose Egg Formation, the Park City Formation, the Tensleep Sandstone, the Amsden Formation, and the Madison-Bighorn aquifer.

Springs

The numerous small springs and few large springs in the Ten Sleep area, except for the springs at the Wigwam Fish Rearing Station, are distributed in lowlands that have much of the farmland east of the Nowood River. The lowlands, underlain by the Goose Egg and Chugwater Formations, at places contain solution-collapse features (pl. 2). The dissolution and collapse, aided by fractures, allow for upward movement of water from the Tensleep Sandstone and underlying formations to discharge at the land surface from the Goose Egg and Chugwater Formations. Principal evidence of this upward water movement is the large flows of a few springs such as Big Spring and spring 42–88–30ad, flows that are in fact larger than the yield of wells completed in the Tensleep Sandstone. Therefore, part of the large spring flows also must include water that has moved upward from the Madison-Bighorn aquifer.

Springs and seeps distributed throughout the length of the lowlands (pl. 2) help maintain perennial flows in several small streams, such as Alkali Creek near Hyattville, Alkali

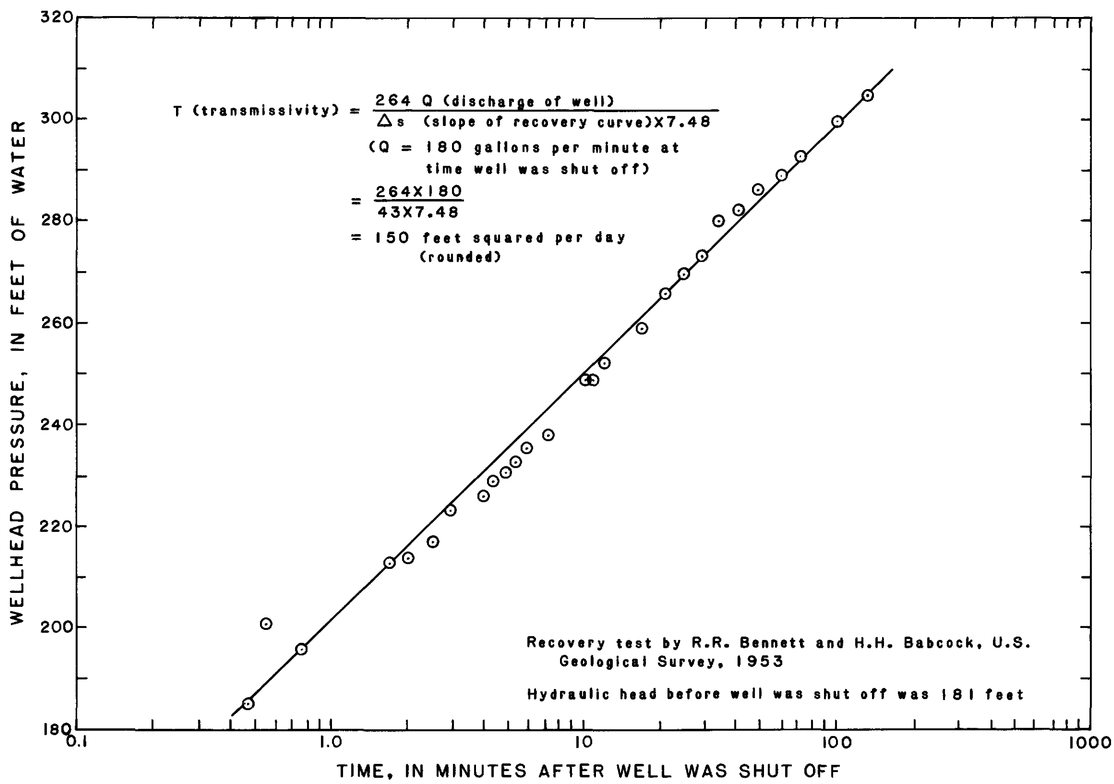

Figure 9. Recovery curve for well 47–89–13aab completed in the Tensleep Sandstone.

Creek near Ten Sleep, Spring Creek and Crooked Creek near Big Trails, and Redbank Creek south of Big Trails. Many of the springs are along conspicuous linear features (pl. 5) or near their intersections, indicating that fractures along the linear features may be a principal control on the spring locations. For example, a concentration of springs occurs near Spring Creek in the area of intersection of several linear features 1 to 2.5 mi west of a monocline. Other springs and permanent seep areas are present on the lower part of the Chugwater Formation in section 1, T. 47 N., R. 89 W. (Mark Carter, rancher, oral commun., 1975) and in the southern part of section 9, T. 44 N., R. 87 W. A large seep area is present in the valley along the steeply dipping northeast limb of Brokenback anticline (Homer Renner, rancher, oral commun., 1976). The Renner Reservoir and an unnamed reservoir were built in the valley to take advantage of the seepage, as well as to impound runoff. The largest springs in the lowlands are Alkali Spring, which maintains the perennial flow of Alkali Creek north of Hyattville, Big Spring near Big Trails, which discharges about 1,000 gal/min near a fault, and spring 42–88–30ad, which yields about 4,500 gal/min (S.J. Rucker, IV, U.S. Geological Survey, oral commun., 1977) in the southern part of the area.

Springs at the Wigwam Fish Rearing Station have a combined flow of a few hundred gallons per minute. The two main springs, East and West Springs, and the flow from well 47–88–1cda maintain the ponds at the station. These springs issue from shaly redbeds that make up the upper part of the Amsden Formation. Their flow, however, probably is derived from sandstone beds in the lower part of the Amsden and from the underlying Madison Limestone.

Wells

A substantial quantity of water is discharged from the Paleozoic aquifers through flowing wells, although intensive use of this water source has been comparatively recent. Artesian water (probably flow at the land surface) was first known in 1888 when an oil-test well drilled in section 14, T. 49 N., R. 91 W. along the Bonanza anticline "***encountered a little artesian water but no oil or gas***" (Hewett and Lupton, 1917, p. 53). Because the Tensleep Sandstone is a major oil-producing zone of the basin, this formation was known early in the 20th century to yield rather large quantities of water through flowing wells. However, wells to develop this artesian water were not drilled until the early 1940's, when at least eight wells were completed near Ten Sleep and in the area south of the town. During 1953, probably only one irrigation well (47–89–13aab) withdrawing water from the Tensleep Sandstone was in operation (L.J. Davis, well owner, oral commun., 1974). Except for coverted oil-test wells, the flowing wells drilled before 1953 are less than 1,000 ft deep and were completed

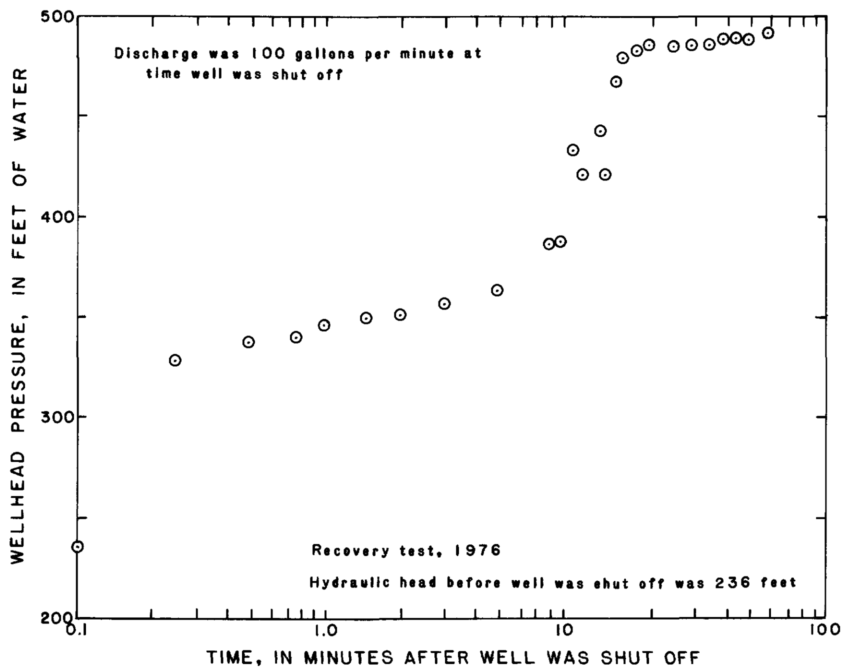

Figure 10. Recovery curve for the Hyattville town well 49–89–6bcb completed in the Madison Limestone and the Amsden Formation.

in the Tensleep Sandstone or in the overlying Goose Egg Formation.

Beginning in the middle 1950's, as the need for water for irrigation and for the communities of Ten Sleep and Hyattville increased, some old wells were deepened and new wells were drilled below the Tensleep Sandstone. Some of these wells reached depths of more than 2,500 ft to obtain larger quantities of water and to take advantage of the greater pressures available in the underlying Madison-Bighorn aquifer and the Flathead Sandstone.

By 1978, at least 70 flowing wells and 5 nonflowing artesian wells were obtaining water from the Paleozoic aquifers (pl. 1, table 2). Twenty-five of these wells are large-capacity wells (flowing or yielding more than 300 gal/min) that are used for irrigation, for public supply at Ten Sleep and Hyattville, or for rearing fish. Twenty-two of the 25 wells obtain large flows from the Madison-Bighorn aquifer or the Flathead Sandstone and three, from the Tensleep Sandstone. The remaining 50 wells are small-capacity wells (flowing or yielding less than 300 gal/min) that are completed in the Tensleep Sandstone and the Goose Egg or Park City Formations. They are used primarily for stock and domestic purposes, including the watering of gardens and small pastures.

Yields of water from wells in the Paleozoic aquifers are large but varied. Maximum yields of large-capacity flowing wells at the time of their completion, when the wells were allowed to flow freely, are reported to have been as much as 3,000 gal/min for the irrigation wells. The largest yields reported in the area investigated are along an anticline in the northeastern part of T. 49 N., R. 91 W., where the average flows during 24-hour tests were 5,000 gal/min for an abandoned oil-test well in section 2 and 14,000 gal/min for the Worland municipal well completed in the Madison Limestone in section 12 (Vern Nelson, consulting hydrologist, oral commun., 1982). The Worland well yields the largest reported flow of any well in Wyoming.[1]

Well flows are substantially less during sustained periods of operation and at the pressures at which the wells are operated. Unfortunately, measuring yields of operating wells is difficult, in contrast to measuring pressure at the wellhead, which is relatively easy. The irrigation wells are connected to a sprinkler systems and the quantity of flow cannot be measured directly. As a result, yields of operating wells were estimated from the number of sprinkler heads and their rated discharges at given pressures. In general, the operational yields of the irrigation wells completed in the Madison-Bighorn aquifer or the Flathead Sandstone range from 300 to 1,500 gal/min, whereas maximum yields from wells completed in the Tensleep Sandstone are about 300 gal/min.

[1]The Worland well was completed after data collection for this study was completed. It is mentioned here because of the unusually large yield. Detailed information about the well is not included in this report.

On the basis of an irrigation season of slightly more than 5 months, an approximation of the quantity of water withdrawn from the Paleozoic aquifers during 1975–76 is 13,000 acre-ft/yr. The approximate quantities withdrawn annually from the major aquifers are shown below.

Tensleep Sandstone	Madison-Bighorn aquifer	Flathead Sandstone (includes discharge from wells also open to the Madison-Bighorn aquifer)
Less than 500 acre-ft	7,000 acre-ft	6,000 acre-ft

Use of ground water has increased markedly since 1953, when the quantity of ground water withdrawn by wells is estimated to have been about 5 percent of the quantity used during 1975 or 1976.

CHANGES IN ARTESIAN PRESSURE OR YIELD

During this investigation, artesian pressure was measured in order to assess changes since earlier measurements were made. The artesian pressures of the flowing wells were first measured in 1953, when pressures in 12 wells were obtained. When these wells were revisited in 1975, the pressures of only 6 of the 12 could be measured. Other measurements were made in 1962 (Lowry, 1962, table 1) and 1970. Artesian pressures were measured at 23 flowing wells during 1975–78; pressures at about two-thirds of these wells were measured annually during this period. The measurements were obtained during early May, before the beginning of the irrigation season, except for the 1953 pressure measurements, which were made at the end of the irrigation season (table 2). The static pressures of about one-half of the large-capacity wells, including all the wells open to the Flathead Sandstone, were measured for the first time in 1975. The pre-1975 measurements are principally of the small-capacity stock and domestic wells.

The operative conditions of the wells need to be considered in comparing pressure measurements. Because of great pressures at the wellheads, nearly all the valves leak and are replaced periodically. Few wells can be shut off completely and a true shut-in pressure measured. When wells are not in full operation between irrigation seasons, lines may be left open to allow a small flow of water so that water in the wellhead will not freeze during the winter. Under these conditions, the wellhead pressures in most wells may be a few pounds per square inch less than the true static pressure.

Goose Egg Formation

Long-term decrease of artesian pressures has taken place in shallow small-capacity wells that derive their flow from the Goose Egg Formation near Ten Sleep in the west-central part of T. 47 N., R. 88 W. Specific information concerning long-term decreases of pressure is known for two of these wells. Well 47–88–16daa had a pressure of about 45 lb/in^2 during the 1940's (G.C. Anderson, well owner, oral commun., 1974), but in 1978 its static pressure was only 6 lb/in^2. Similarly, the static pressure in well 47–88–16cdc2 was 51 lb/in^2 in 1953, 32 lb/in^2 (5-min recovery test) in 1962, and 21 to 23.5 lb/in^2 during 1975–78.

Tensleep Sandstone

Slight fluctuations in pressure have occurred since 1953 in the small-capacity wells and in the irrigation wells completed in the Tensleep Sandstone. The quantity of water withdrawn from the sandstone has not been large enough to show any long-term decline in hydraulic head as indicated by the pressure measurements, except at Ten Sleep, where the outer casing of well 47–88–16cca (completed in the Tensleep Sandstone) shows a slight decrease of pressure in measurements made between 1962 and 1970.

Madison–Bighorn Aquifer

A comparison of the 1975–78 pressure data with previous pressure measurements (table 2) indicates (1) little or no difference in pressure in the irrigation wells drilled into the Madison-Bighorn aquifer (excluding the wells in combination with the Flathead Sandstone) since the wells were drilled, and (2) some decrease of pressure or yield in the well at the Wigwam Fish Rearing Station (47–88–1cda) and in the Ten Sleep town well (47–88–16cca). About one-third of the wells completed in the Madison-Bighorn aquifer are within 5 mi of the town of Ten Sleep, principally north of Tensleep Creek (pl. 1). Ten Sleep is the only locality in the area that has gained population during the past several years.

Records of the yield of well 47–88–1cda at the Wigwam Fish Rearing Station and of the pressure of well 47–88–16cca at Ten Sleep are available only since 1972, although these wellls have been in continuous operation since they were drilled. The operating pressure of the Ten Sleep town well is recorded each month, but information concerning the yield is not available. Only the record of the yield of well 47–88–1cda is available; pressure cannot be measured owing to the well design. The flow of this well is measured weekly and jointly with the flow of East Spring, 47–88–1dbc, which also flows principally from the Madison-Bighorn aquifer.

Between 1972 and 1975 the pressure in the Ten Sleep town well recovered each winter—during the time of minimum water use—to between 130 and 135 lb/in^2. However, from 1975 to 1978 there was a decrease to 123 lb/in^2 in the maximum pressure during the winter recovery (fig. 5).

Also during 1972–77, there has been a persistent but intermittent decrease in the average combined flow from well 47–88–1cda and East Spring at the Wigwam Fish Rearing Station, as shown by the following tabulation:

Year	Average flow (gallons per minute)	Remarks
1972	622	Includes only flow from April to December.
1973	576	
1974	495	
1975	549	
1976	418	
1977	399	

The maximum flow recorded each year decreased from about 750 gal/min in early 1972 to 500 gal/min in 1978.

The decrease of the maximum pressure of the Ten Sleep town well and of the maximum yield of the well and East Spring at the Wigwam Fish Rearing Station from 1972 to 1978 appear to be at relatively uniform rates (fig. 5). The uniform rates of decrease indicate that some interference occurs between the ground-water developments at these locations. At the time of maximum pressures or yields, the other large-capacity irrigation wells are not in operation. A simple relation between the decreases of the pressure and yield is shown as follows:

Year	Ten Sleep town well 47–88–16cca	Well 47–88–1cda and East Spring at Wigwam Fish Rearing Station	
	Maximum pressure (pounds per (square inch)	Approximate maximum yield (gallons per minute)	Approximate decrease in maximum yield since 1972 (gallons per minute)
1972	135	750	---
1973	135	650	100
1974	130	650	100
1975	132	600	150
1976	128	600	150
1977	127	550	200
1978	123	500	250

A decrease of 1 lb/in^2 in the Ten Sleep town well indicates an approximate decrease of about 20 gal/min in flow of the well and East Spring at the fish rearing station.

Changes in pressure (or yield) of wells near Ten Sleep are assumed to indicate that some interference occurs between wells. During the summer, pressure in the Ten Sleep town well decreases 30 to 50 lb/in^2 and yield from the well and spring at the Wigwam Fish Rearing Station decreases more than 300 gal/min (fig. 5). Generally, in early May the town uses more water and operation of all irrigation wells begins. The minimum flow at the fish rearing station occurs about 4 to 5 weeks later than the time when minimum pressure occurs in the Ten Sleep town well. The time difference indicates that the minimum flow at the fish rearing station may be caused jointly by interference from the town well and the nearby irrigation wells, especially the wells completed in the Madison-Bighorn aquifer within 5 mi of the station. The fish rearing station is about 5 mi from all these large-capacity wells, so 4 to 5 weeks seems a reasonable time lag before the town well (and the other wells) begin to interfere with the flow of well 47–88–1cda and East Spring at the Wigwam Fish Rearing Station.

The only other information about well interference concerns three wells near Ten Sleep. In 1975 and 1976 there were slight indications of interference between wells 47–88–8dab and 47–88–5baa. In 1975, static pressures in well 47–88–8dab decreased 2 lb/in^2 from May 14 to June 12. Well 47–88–5baa, 1.6 mi north of well 47–88–8dab, was operated during May 22–June 12, possibly causing the pressure decrease in well 47–88–8dab. Also, beginning in May, the flow of the Ten Sleep town well 47–88–16cca, 1.3 mi south of well 47–88–8dab, was increased to supply water for the spring and summer growing season. Similarly, between May 3 and May 14, 1976, the static pressure in well 47–88–8dab decreased nearly 2 lb/in^2. Well 47–88–5baa began operation on May 4; on May 10 well 47–88–16aba, located 1.1 mi southeast of well 47–88–8dab, also began operation.

Flathead Sandstone

Little information is available concerning pressure changes in wells completed in the Flathead Sandstone, because pressures of these wells were not measured before 1975. During 1975–78, the pressures of well 50–89–31bab and probably well 47–88–8dab, which is open also to the Madison-Bighorn aquifer, remained relatively steady. However, a pressure decrease of about 60 lb/in^2 occurred in well 48–89–25ada. The small apparent decrease of about 5 lb/in^2 indicated in table 2 for well 47–88–16aba probably is due to the inability to shut off the well completely, to obtain a true static-pressure measurement.

The 1975–78 pressures are substantially less than the original static pressures reported for at least four wells in the Flathead, wells for which the original pressures are known. Decreases in pressure range from about 60 to more than 150 lb/in^2 (table 4). For comparison, of five wells completed in the Madison-Bighorn aquifer for which the initial pressure is known, only in well 50–90–23cad was the reported initial static pressure substantially greater than the 1975 static pressure. The decrease of pressure of the wells penetrating the Flathead Sandstone may be caused mainly by the continuous discharge of water from the wells that are open to both the Flathead and the Madison-Bighorn aquifer, even during the time the wells are not in operation. When the wells are shut in, the water from the Flathead continues to move through the well into the Madison-Bighorn aquifer, which as a lower potentiometric surface than does the Flathead Sandstone.

Seasonal Fluctuation

Many ranchers report that wellhead pressures decrease progressively and are substantially less in late summer than in the spring. Measurements made in four irrigation wells operating during the summers of 1975 and 1976 showed decreases of pressure (table 5). For example, well

48–89–4acd, flowing at a rate of 1,000 gal/min, had pressures of 105 lb/in^2 on July 8 and 92 lb/in^2 on September 8. Similarly, the pressure of well 48–89–25ada, flowing at a rate of 900 gal/min, was 80 lb/in^2 on July 8 and 57 lb/in^2 on October 21. The pressures in some of the stock and domestic wells, as indicated by 5-min recovery tests, decreased between 1 and 3 lb/in^2 during the summers of 1975 and 1976 (table 2).

Static pressure tests were made to try to determine if seasonal use of water in Ten Sleep (mainly of well 47–88–16cca completed in the Madison-Bighorn aquifer and the Amsden Formation) affected the pressure in well 47–88–16cdc2, probably completed in the Goose Egg Formation, which is used intermittently for watering lawns. The static pressure of this well was measured during recovery periods ranging from 24 to 68 hours in June, July, September, and October 1975. Only slight changes in the pressure were indicated by the measurements (table 2). The pressure recovered to the original static pressure that was measured in May, except for the test during June. The June decrease of pressure was only about 1 lb/in^2, but it occurred during the time of maximum use of water, as indicated by the minimum pressure of well 47–88–16cca during 1975.

CHEMICAL QUALITY OF WATER

The chemical quality of ground water from springs in the Ten Sleep area is variable, but the quality of water from wells generally is suitable for most uses. Concentrations of dissolved solids range from 156 to 2,230 mg/L (milligrams per liter) for springs and generally are less than 300 mg/L in water from the flowing wells. The largest concentrations of dissolved solids are in water derived from the Goose Egg Formation.

Springs, Spring-Sustained Streams, Ponds, and Reservoirs

Chemical analyses of water from springs and spring-sustained streams, ponds, and reservoirs in the lowlands are shown in tables 6 and 7. The maximum concentrations of dissolved solids shown by these analyses are as much as 2,230 mg/L for springs, 2,210 mg/L for spring-sustained streams, and 3,120 mg/L for ponds and reservoirs. The smallest concentrations of dissolved solids, 156 to 169 mg/L, are from the spring flows (springs 47–88–1cad, 1cdb, and 1dbc) at the Wigwam Fish Rearing Station. In most analyses, calcium, sulfate, and sometimes magnesium concentrations are excessive, indicating that water probably has been in contact with gypsum in the Goose Egg Formation.

In addition, specific conductance, which gives an indication of the concentration of dissolved solids in water (to obtain approximate dissolved-solids concentration, in milligrams per liter, from specific conductance, multiply specific conductance by 0.6), was measured in streams where part of their flow is from ground-water discharge from the Paleozoic aquifers (pl. 2). These streams generally show a progressive downstream increase in specific conductance, partly owing to return flows of irrigation water from fields. The increase of specific conductance of Tensleep Creek at Ten Sleep, however, also is attributed to water that has moved upward from the Tensleep Sandstone, through the Goose Egg Formation and the adjacent flood-plain alluvium, into the creek (Cooley and Head, 1979, p. 28).

Wells

Water in the Paleozoic aquifers obtained from wells generally is suitable for most uses (tables 8 and 9). Water in the Tensleep Sandstone and the Madison-Bighorn aquifer contained less than 300 mg/L of dissolved solids, and water in the Flathead Sandstone had less than 200 mg/L of dissolved solids. Water containing as much as about 400 mg/L of dissolved solids generally was present in the Goose Egg Formation. Only one operating irrigation well, 47–87–33dbd2, discharged water having more than 450 mg/L of dissolved solids. Bicarbonate, ranging from 149 to 300 mg/L, was the chief constituent, followed by calcium, magnesium, and sulfate.

Sulfate concentrations are relatively large in water from the Paleozoic aquifers, particularly in the younger units. The greatest concentrations were in samples from the Goose Egg Formation and in the upper part of the Amsden Formation. Water from wells completed in the Goose Egg Formation, or in the Goose Egg in combination with the Tensleep Sandstone, contained as much as 490 mg/L of sulfate, and water from wells completed in the Tensleep Sandstone and upper part of the Amsden Formation contained as much as 230 mg/L of sulfate. The sulfate is derived from water that is in contact with gypsum beds in the Goose Egg Formation and from possibly gypsiferous deposits in the redbeds that make up the upper part of the Amsden Formation. Concentrations of sulfate generally were less than 40 mg/L in water obtained from the lower part of the Amsden Formation and the Tensleep Sandstone, the Madison-Bighorn aquifer, and the Flathead Sandstone.

Dissolved fluoride and chloride concentrations generally are minimal in the waters of the Paleozoic aquifers. Only two wells contained water with fluoride concentrations exceeding 1.5 mg/L, the upper limit recommended by the U.S. Environmental Protection Agency (1976) to avoid mottling of teeth. Two analyses of the water in well 47–87–33bdb2 indicated 1.7 and 2.2 mg/L of fluoride, and a single analysis of well 50–89–21aaa indicated a fluoride concentration of 1.6 mg/L. The concentration of dissolved fluoride was 1.1 mg/L or less from the other wells, and much of the well water contained less than 0.4 mg/L of fluoride. In most water samples, chloride concentrations were less than

5 mg/L. Only well 47–87–33bdb2 produced water having a relatively large chloride concentration—84 mg/L.

The hardness calculated as calcium carbonate ranges from 110 to more than 350 mg/L in wells (table 8). Hardness of water from the Flathead Sandstone was generally less than 140 mg/L, the least reported for water from any of the Paleozoic aquifers.

Ratios based on milliequivalents per liter of selected constituents were plotted in order to indicate some differences in the chemical composition of water in the Paleozoic aquifers; only those of calcium to sulfate, calcium to sodium, magnesium to sulfate, and sulfate to chloride are presented (fig. 11). Very slight differences of other ratios such as calcium to magnesium, sulfate to bicarbonate, calcium to bicarbonate, and magnesium to bicarbonate between the different aquifers are indicated. Water from wells completed mainly in the Flathead Sandstone has the least values for these four ratios. The ratios are also small for the water in wells completed in the Tensleep Sandstone or (except for the ratio of sulfate to chloride) the Tensleep Sandstone in combination with the Goose Egg Formation. Owing to the presence of gypsum, the ratio of sulfate to chloride is greatest in water obtained from the Goose Egg Formation. As expected, a large ratio of calcium to sodium is indicated for the limy and dolomitic Madison-Bighorn aquifer.

Water in the Paleozoic aquifers is satisfactory for irrigation and for other uses where hardness is not a detrimental factor. According to the system for classification of irrigation waters (U.S. Salinity Laboratory Staff, 1954, fig. 25), these waters have a low sodium hazard (sodium-adsorption ratio less than 6 when the specific conductance is less than 750 mS/cm) and a medium salinity hazard (specific conductance between 250 and 750 mS/cm). All samples from wells completed in the Paleozoic aquifers are in the low-sodium range and medium-salinity range (fig. 12).

Water from irrigation wells was sampled in early May and in September 1975 (at the beginning and near the end of the growing season) to determine if any chemical changes in the well water had occurred. Except for some change in the temperature, significant differences in the quality of the water were not noted (table 9).

Geothermal Gradient

Wellhead temperatures of the operating flowing wells ranged from 11° to 27.5°C (51.8°F to 81.5°F). A comparison of wellhead temperatures with well depths is shown in figure 13. All temperatures shown in figure 13 were measured in wells that had been operating for most of the irriga-

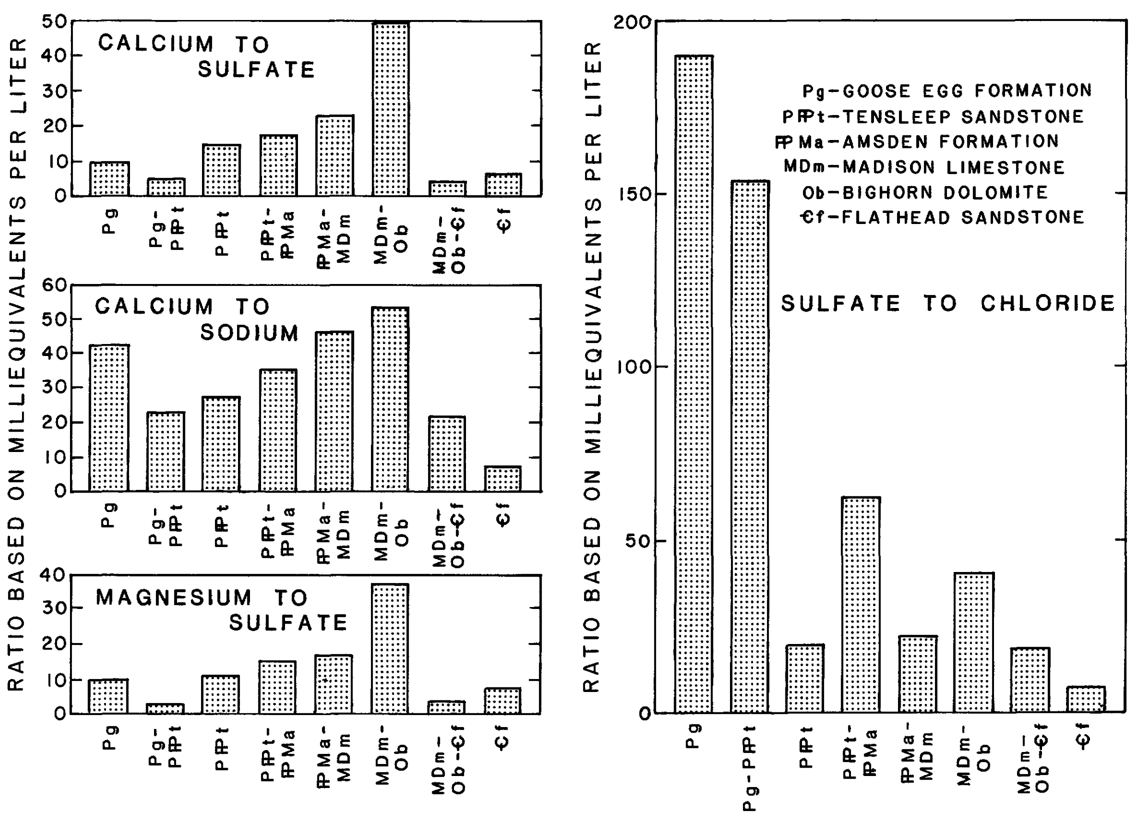

Figure 11. Ratios of calcium to sulfate, calcium to sodium, magnesium to sulfate, and sulfate to chloride in water from the Paleozoic artesian aquifers.

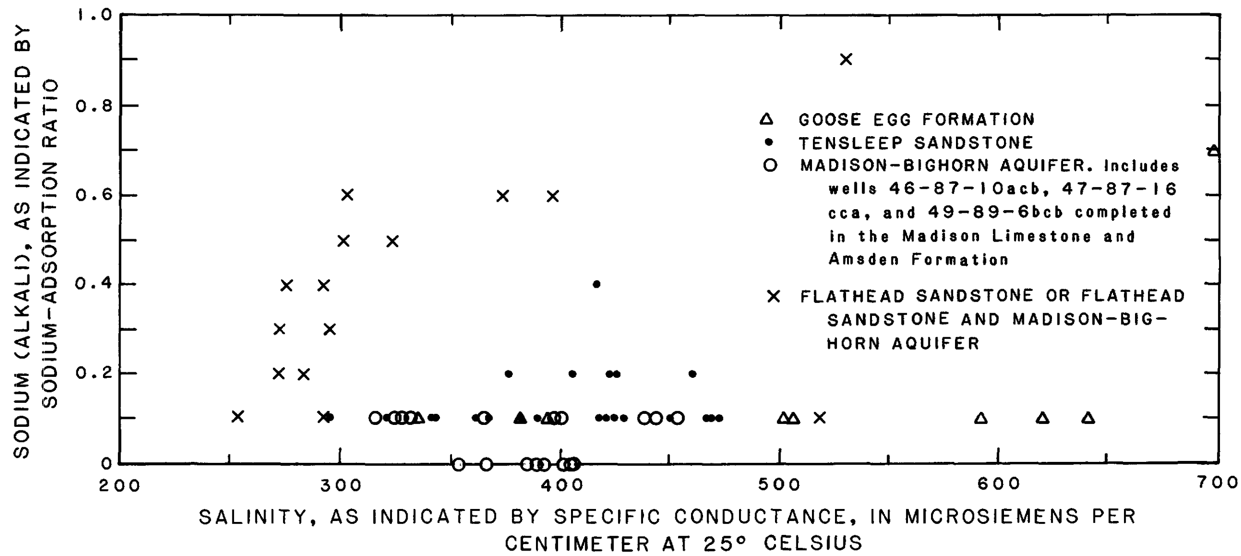

Figure 12. Comparison of sodium (alkali), as indicated by sodium-adsorption ratio, with salinity, as indicated by specific conductance of water from the Paleozoic aquifers.

tion season or that had been issuing substantial quantities of water for relatively long times. When flowing wells are shut in or are issuing only small quantities of water, temperatures of the water at the wellhead are modified by the atmospheric temperature. The plotted data indicate that the temperature (geothermal) gradient is about 0.44°C per 100 ft (0.79°F per 100 ft). For wells completed only in the Madison-Bighorn aquifer or the Madison-Bighorn aquifer and the Amsden Formation, the temperature gradient is approximately 0.36°C per 100 ft (0.65°F per 100 ft).

AQUIFERS MOST FAVORABLE FOR CONTINUED DEVELOPMENT

The major aquifers—the Tensleep Sandstone, the Madison-Bighorn aquifer, and the Flathead Sandstone—are

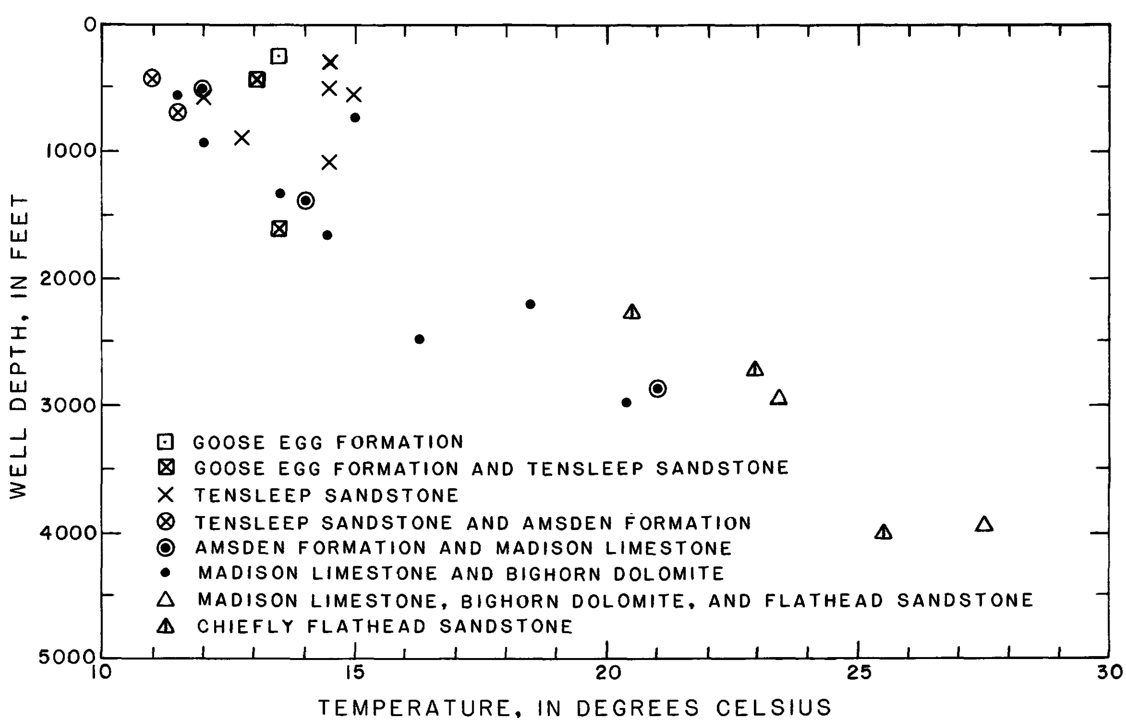

Figure 13. Well depths and wellhead temperatures.

by far the aquifers most suitable for continued development. All three yield water to wells at sufficiently high pressures and pumping systems are not required.

Large yields are obtained more consistently from the Madison-Bighorn aquifer than from the two sandstone aquifers. The Madison-Bighorn aquifer yields the largest quantities of water (more than 1,000 gal/min for the irrigation wells and 14,000 gal/min for the Worland municipal well). Near Ten Sleep there has been a measurable decrease of pressure or yield in two wells—the well at Wigwam Fish Rearing Station and the Ten Sleep municipal well—owing to current water use. Additional development of this aquifer is possible in areas not previously developed.

The Flathead Sandstone also yields substantial quantities of water, with some wells flowing at rates of more than 1,000 gal/min. Pressure has decreased in most wells completed in this unit since the wells were drilled. Additional development of the Flathead Sandstone is possible in areas not previously developed.

The Tensleep Sandstone yields moderate quantities of water (as much as 300 gal/min) in only two known areas near Ten Sleep and near Big Trails. This limited yield restricts its use for irrigation and for other purposes that would require greater quantities of water. Current development has not resulted in a measurable decrease of pressure in the Tensleep Sandstone, except at Ten Sleep. The Tensleep Sandstone supplies many domestic and stock wells. Additional drilling of domestic and stock wells would not cause overdevelopment. Although some additional irrigation water could be obtained from the Tensleep in places where the unit yields maximum quantities of water, any new irrigation development could easily cause interference between the wells and also a marked decrease in pressure.

SUMMARY

The large-capacity irrigation and public-supply wells of the Ten Sleep area are completed in the major Paleozoic aquifers—in descending order, the Tensleep Sandstone, the Madison-Bighorn aquifer, and the Flathead Sandstone. In places, wells completed in the Madison-Bighorn aquifer and the Flathead Sandstone flow at rates of more than 1,000 gal/min (maximum flow of 14,000 gal/min for the Worland municipal well), whereas wells completed in the Tensleep Sandstone flow at a maximum rate of about 300 gal/min. Large yields are more consistently obtained from the Madison-Bighorn aquifer than from the other two major aquifers. The minor aquifers, the Goose Egg and Park City Formations, yield water only locally to wells used mainly for domestic and stock purposes. The Amsden Formation, in combination with the Madison-Bighorn aquifer, yields some water to at least three wells.

A few large springs in the area flow at between 200 and 4,500 gal/min. These springs issue from the Goose Egg Formation, except for the springs at the Wigwam Fish Rearing Station, which issue from the Amsden Formation. This spring flow from both formations is believed to be principally water that moves upward along fractures from the underlying major aquifers.

Wells have significant artesian pressures; all of the 25 large-capacity wells and all but 5 of the small-capacity wells flow at the land surface. Wellhead pressures of some of the large-capacity wells exceed 200 lb/in^2; the greatest pressure measured was 472 lb/in^2. Wellhead pressures of most of the small-capacity wells are less than 40 lb/in^2. The potentiometric surface of the Flathead Sandstone is as much as 800 ft higher than the potentiometric surface of the Madison-Bighorn aquifer and as much as 1,000 ft higher than that of the Tensleep Sandstone.

Decreases in pressure were not apparent in wells completed in the Tensleep Sandstone (except at Ten Sleep) or in most irrigation wells completed in the Madison-Bighorn aquifer. However, a decrease of pressure in the Madison-Bighorn aquifer near Ten Sleep is indicated, mainly by a decrease in yield of the well and East Spring at the Wigwam Fish Rearing Station and by a corresponding decrease in pressure in the Ten Sleep town well. Most of the wells completed in the Flathead Sandstone show a decrease of pressure from the time of completion of the well to 1975–78. A few wells completed in the Goose Egg Formation near Ten Sleep also have had decreases of pressure.

Most wells, particularly the irrigation wells, show a progressive decrease of pressure during the irrigation season. This seasonal fluctuation in pressure is most apparent in wells completed in the Flathead Sandstone; it is least noticeable in the small-capacity wells completed in the minor aquifers.

During 1975–76, the annual withdrawal of water was estimated to be less than 500 acre-ft from the Tensleep Sandstone and 7,000 acre-ft from the Madison-Bighorn aquifer. About 6,000 acre-ft of water was withdrawn from wells completed mainly in the Flathead Sandstone or the Flathead in combination with the Madison-Bighorn aquifer. Most of the water withdrawn was used for irrigation, but considerable quantities also were used by Ten Sleep and Hyattville and for the rearing of fish.

Transmissivities determined from recovery tests commonly range from 300 to 1,900 ft^2/d in wells completed in the Madison-Bighorn aquifer, and from 90 to about 325 ft^2/d in wells completed in the Tensleep and Flathead Sandstones. In wells completed in the Madison-Bighorn aquifer, much of the recovery during tests occurred during the first hour after the wells had been shut off. Recovery was steady and very slow for wells completed mainly in the Flathead Sandstone; the pressure had not recovered to the original reported static pressure after 13 days during one recovery test. One test of a well completed in the Tensleep Sandstone indicated that recovery was steady and that the pressure had recovered to the static pressure in 1 hour 40 min.

The water in the Paleozoic artesian aquifers generally contains minimal concentrations of dissolved solids and of individual constituents, and excessive hardness. The dissolved-solids concentration of the water was less than 300 mg/L in the Tensleep Sandstone and the Madison-Bighorn aquifer, less than 200 mg/L in the Flathead Sandstone, and as much as 450 mg/L in the Goose Egg Formation. Bicarbonate was the chief constituent, followed by calcium and magnesium. Relatively large concentrations of sulfate were found only in water from the Goose Egg Formation and the upper part of the Amsden Formation. Generally, fluoride, chloride, and sodium concentrations were minimal. The water had a low sodium (alkali) hazard and a medium salinity hazard. Therefore, the water in the major aquifers—the Tensleep Sandstone, the Madison-Bighorn aquifer, and the Flathead Sandstone—is satisfactory for irrigation and other uses for which excessive hardness is not a detrimental factor.

The major aquifers—the Tensleep Sandstone, the Madison-Bighorn aquifer, and the Flathead Sandstone—are by far the aquifers most suitable for development. All three yield water to wells at sufficiently high pressures that pumping systems are not required. Large yields are obtained more consistently from the Madison-Bighorn aquifer than from the two sandstone aquifers.

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TABLES 1–9

Table 1. Summary of geohydrology of formations in the Ten Sleep area

System	Formation and geologic symbol	Major or minor aquifer or confining layer	Yield of wells (gallons per minute)	Pressure (pounds per square inch)	Remarks
Triassic	Chugwater Formation (ℜc)	Generally does not yield water; a confining layer.	----------	----------	Thickness--700-800 feet; consists mainly of siltstone and silty sandstone.
Permian	Goose Egg Formation[1] (Pg)	Minor aquifer; locally, mainly a confining layer.	Generally <50	<30±	Thickness--160 feet; consists of siltstone to silty sandstone and gypsum; sandstone beds yield small quantities of water to wells; many springs discharge from the unit in areas containing solution-collapse features; silty part of formation in combination with the overlying Chugwater Formation forms upper confining bed of Tensleep Sandstone.
Permian	Park City Formation[1] (Pp)	Minor aquifer.	<3	<15	Thickness--100± feet; consists mainly of limestone and dolomite. Present only in the southern part of the area as a thin wedge-like unit between the Goose Egg Formation above and the Tensleep Sandstone below.
Permian and Pennsylvanian	Tensleep Sandstone (PIPt)	Major aquifer.	Generally <50, few wells >100	Generally <50, as much as 150	Thickness--130-300 feet; thickens from northwest to southeast; consists of well-sorted fine- to medium-grained very cross-stratified sandstone; pressure of most wells rather constant throughout the year; unit maintains flow of many springs and small spring-sustained perennial streams.
Pennsylvanian and Mississippian	Amsden Formation (IPMa)	Upper part forms a confining layer; lower part is a minor aquifer.	----------	----------	Thickness--300± feet; upper part consists of an upper thin-bedded red shale; the lower part consists of a cross-stratified sandstone; the sandstone yields small quantities of water to a few wells and springs; in places red beds fill cavities in the karst zone at the top of the Madison Limestone.

Mississippian, Devonian, and Ordovician	Madison Limestone (MDm) and Bighorn Dolomite (Ob) (Madison-Bighorn aquifer)	Major aquifer.	50->2,000	Generally 150-250	Thickness of Madison--500-700 feet, thickness of Bighorn--300 feet; consists of thick-bedded cliff-forming limestone and dolomite; interval also includes Three Forks and Jefferson Formations (Devonian) where present; Madison Limestone is main water-yielding unit; significant fracturing and formation of karst and caves, with 62 caves noted in Tensleep Canyon 1 to 8 miles upstream of the Wigwam Fish Rearing Station; unit maintains flows of many springs and small spring-sustained perennial streams along west side of Bighorn Mountains.
Cambrian	Gallatin (Єg) and Gros Ventre (Єgv) Formations	Generally does not yield water; a confining layer.	----------	----------	Thickness--900 feet; consists mainly of thin-bedded grayish green shale; formations are not known to yield water in the Ten Sleep area.
Cambrian	Flathead Sandstone (Єf)	Major aquifer.	Generally 500-800	±200->400	Thickness--100-200 feet; consists of thin- to thick-bedded fine- to medium-grained sandstone; unit is quartzite or quartzitic sandstone in outcrops but in at least two wells the drillers reported the Flathead Sandstone interval to be easy to drill.
Precambrian	Granitic basement rocks	Generally does not yield water.	----------	----------	Forms basal confining unit of the hydrologic systems of the Bighorn Basin.

[1] Equivalent units of the Phosphoria Formation

Table 2. Records of wells completed in the Paleozoic artesian aquifers

[Flow rate: E, estimated; M, measured; R, reported (date of yield information in parentheses); F, well flows but no information about yield; NF, not flowing. stone; Ob, Bighorn Dolomite; Ꞓf, Flathead Sandstone. Use of water: D, domestic, F, fish-rearing activity; I, irrigation, N, none; P, public supply; S, stock. apparently stabilized within a 5-min period. For large-capacity wells (wells flowing more than 300 gal/min), 5 min are insufficient for the pressure to recover

Well location number	Owner or tenant	Year drilled	Depth of well (ft)	Diameter of casing (in.)	Flow rate of well at completion or at a later date (gal/min)	Water-yielding unit	Use of water	Land surface altitude above sea level (ft)
42-88-3adc	Orchard Ranch	1965	400	6-5/8	---	Pp,PPt	D,S	5,095
21bbd	-----do-----	1952	590	10-3/4	F	PPt	D,S	5,355
21bcb	-----do-----	1965	595	5-1/2	F	PPt	D,S	5,365
31bcc	-----do-----	1942	585	6-5/8	NF	PPt	D,S	5,720
43-87-11ddb	George Woods	Before 1953	443	6	17.3 M (1953)	Pp,PPt	D,S	5,340
20ccc	Helm Ranch	1943(?)	----	4	F	Pg,PPt(?)	D,S	4,955
21bcb	Dexter Bush	1950	500	8	35 (1950)	PPt	D,S,I	5,050
44-87-8dcd	R. C. Mills	1974(?)	----	12	F	PPt	I	4,830
8ddc	B. H. Ainsworth	1952	1,040	-----	462 M (1953)	PPt(?),MDm	N	4,795
9bbc	Greet Bros.	1961	1,820	6-5/8	260 M (1962)	MDm,Ob, others	S,I	4,860
9cbd	Daniels	1975(?)	----	-----	---	PPt	S,I	4,795
17ccb	C. E. Lewtons	1976	----	-----	---	MDm	I	4,790

Water-yielding unit: Pg, Goose Egg Formation; Pp, Park City Formation; IPt, Tensleep Sandstone; IPMa, Amsden Formation; MDm, Madison Lime-
Wellhead pressure: R, reported. After 5-min recovery: For small-capacity wells (wells flowing less than 300 gal/min) the well pressure recovered and
to the original preirrigation static level. Units: ft, feet; in, inch; gal/min, gallons per minute; lb/in^2, pounds per square inch; <, less than; >, greater than]

Water level and wellhead pressure: Static: Water level above land surface (ft)	Static: Wellhead pressure (lb/in^2)	After 5-minute recovery test: Water level above land surface (ft)	After 5-minute recovery test: Wellhead pressure (lb/in^2)	Date of measurement	Remarks
----	----	----	----	--------	<5 lb/in^2 reported by owner. Equipped with submersible pump. Bail-tested at 35 gal/min with 75 ft of drawdown.
----	----	----	----	--------	Barely flows. Static pressure has remained nearly the same since drilled. Depth of pumping level about 30 ft equipped with small submersible pump.
----	----	----	----	--------	Flows ¼-in. stream (reported by owner), <5 lb/in^2. Equipped with submersible pump. Bail-tested at 20 gal/min with 50 ft of drawdown.
----	----	----	----	--------	Lone Tree Well. Reported depth to water 105 ft. Equipped with submersible pump.
14	6	----	----	11-12-53	Booster pump maintains pressure-tank system.
16	7 R	----	----	1961	
		17	7.5	5- 5-70	
143	62	----	----	11-12-53	
155	67	----	----	5-14-62	
36	15.5	----	----	11-12-53	Deepened from 485 to 500 ft in 1972, 35 lb/in^2 reported at completion of deepening.
24	10.5	----	----	5- 7-62	
65	28 R	----	----	1972-74	
54	23.5	----	----	5- 6-75	
55	24	----	----	6-10-75	
----	----	54	23.5	7- 8-75	
----	----	54	23.5	8- 5-75	
----	----	55	24	9- 8-75	
58	25	----	----	10- 7-75	
----	----	58	25	10-20-75	
----	----	58	25	11- 5-75	
----	----	59	25.5	5- 4-76	
----	----	61	26	6-22-76	
22	9	----	----	9- 9-76	Well casing deteriorated.
2.3	1	----	----	4-26-77	Do.
6.9	3	----	----	5-15-78	Do.
153	67	----	----	10-21-75	Well not completely shut off.
157	69	----	----	11- 5-75	Do.
164	71	----	----	5-13-76	
109	47	----	----	9- 9-76	Well shut off 28± hours before measurement
113	49	----	----	9-10-76	Well shut off 36± hours before measurement.
150	65	----	----	11- 5-76	Small flow, well winterized.
160	70	----	----	4-26-77	
167	73	----	----	5-15-78	
166	72	----	----	11-11-53	41.5 lb/in^2 in 1964 with small leaks in casing.
173	75	----	----	5-14-62	
	42	----	----	5-11-64	Water leaking around casing in 1964. Casing rusted out; could not measure pressure in 1975. Drilled as oil test.
266	115	----	----	5- 9-62	Well not completely shut off. Dual-completion well. Pressure same for both wells; 50 gal/min reported from Tensleep Sandstone.
----	----	----	----	--------	Flow reported to be insufficient for irrigation.
81	35	----	----	1976	Pressure reported by owner; 35 lb/in^2 for the Tensleep Sandstone also reported by the owner.

Table 2. Records of wells completed in the Paleozoic artesian aquifers—Continued

Well location number	Owner or tenant	Year drilled	Depth of well (ft)	Diameter of casing (in.)	Flow rate of well at completion or at a later date (gal/min)	Water-yielding unit	Use of water	Land surface altitude above sea level (ft)
44-87-17ddc	R. C. Mills	1942	475	-----	250 (1942?)	PPt	D,S,I	4,810
46-87-10acb	Taylor Bros.	-----	1,410	5	380 M (1962)	PMa,MDm	I	5,070±
21acd	Robert Taylor	Before 1953	1,100(?)	6	9.7 M (1953)	PPt	D,S,I	4,780
47-87-28bbc	------------	-----	----	-----	---	Pg(?)	D	4,980
33bdb1	L. G. Craft	1959(?)	2,708	7	1,800 R (1960?)	Chiefly Єf (also MDm,Ob)	I	4,975
33bdb2	-----do-----	-----	----	-----	F	PPt, PMa(?)	D,S	4,990
47-88-1cda	Wyoming Wigwam Fish Rearing Station	1965	1,070	8	700 (1966)	MDm,Ob	F	4,770
2bcd	L. J. Davis	1941	540	6	F	PPt, PMa(?)	D,S,I	4,755

Water level and wellhead pressure					
Static		After 5-minute recovery test			
Water level above land surface (ft)	Well-head pres-sure (lb/in^2)	Water level above land surface (ft)	Well-head pres-sure (lb/in^2)	Date of measure-ment	Remarks
58	25	----	----	11-12-53	
----	----	55	23.5	5- 9-62	
----	----	63	27.5	5- 5-70	
55	24	----	----	5- 6-75	
58	23	----	----	6-11-75	
49	23	----	----	10- 9-75	Well turned off about 6 hours before measurement.
61	28	----	----	10-20-75	
61	28	----	----	11- 5-75	
56	26	----	----	5- 4-76	
58	25	----	----	11- 5-76	
49.6	23	----	----	4-26-77	
51.9	24	----	----	5-15-78	
393	170 R	----	----	5- 9-62	Deepened from 400 to 1,410 ft during 1958. During drilling of Tensleep Sandstone, depth to water about 50 ft. Possibly 20 gal/min and >150 lb/in^2 of flow encountered during drilling Amsden Formation. In Madison Limestone, flow tests at 1,010 ft, 125 gal/min, 140 lb/in^2; at 1,030 ft, 150 gal/min, 170 lb/in^2; at 1,250 ft, 330 gal/min.
416	180 R	----	----	1974	
104	45	----	----	10-31-53	Deepened from 912 to 1,100(?) ft during 1960.
----	----	162	70	5- 9-62	
----	----	155	67	5- 6-70	
176	76	----	----	5-22-75	
----	----	----	----	--------	Well depth reported as 34 or 62 ft. Well doesn't flow.
767	332	----	----	5-14-75	Several small leaks at wellhead. Very significant pressure which has to be decreased for sprinkler system. Since 1970, because of pressure decrease during late part of irrigation season a booster pump is used to maintain pressure. Drilled to granite. At 1,400 ft (Madison Limestone and Bighorn Dolomite) 800 gal/min with 90 lb/in^2. Pressure so great in 1961-62 that it broke two valves rated at 500 lb/in^2.
89	43	----	----	5-14-75	
----	----	86	41.5	6-10-75	
89	42.5	----	----	7- 8-75	
----	----	85	41	8- 5-75	
----	----	86	41.5	9- 8-75	
88	42.5	----	----	10- 9-75	
89	43	----	----	10-21-75	
89	43	----	----	11- 5-75	
89	43	----	----	5- 4-76	
89	43	----	----	6-22-76	
----	----	87	42	9- 9-76	
----	----	83	40.5	11- 5-76	
----	----	78	38	4-27-77	
----	----	78	38	5-15-78	
12	5	----	----	5-16-66	Supplies part of water for Wigwam Fish Rearing Station. Well yield is in combination with flow of East Spring (47-88-1dbc); yield varies seasonally. Minimum yield was 200 gal/min and maximum yield was 803 gal/min during 1972-78. Well is in continuous operation.
28	12 R	----	----	1968	Deepened to 540 ft in 1953 or 1954.

Table 2. Records of wells completed in the Paleozoic artesian aquifers—Continued

Well location number	Owner or tenant	Year drilled	Depth of well (ft)	Diameter of casing (in.)	Flow rate of well at completion or at a later date (gal/min)	Water-yielding unit	Use of water	Land surface altitude above sea level (ft)
47-88-5baa	Mark Carter	1970	1,682	13	1,500 (1974)	MDm,Ob	I	4,465
8dab	-----do-----	1970	2,960	13	650 (1974)	MDm,Ob,Ꞓf	I	4,470
10cbb	Mark Carter	1950±	700	-----	50+ R (1950±)	Pg(?),PPt	S	4,595
10dbd	-----do-----	1950±	500	4	F	Pg(?)	S	4,590
12bca	Walter Patch	1972	597	-----	275-300 (1972-74)	MDm	D,F,I	4,725
15caa	Lyman Ranch Co.	-----	----	8	F	Pg(?)	S,D	4,490
16aba	Anderson Ranch	1970	2,700	-----	800 (1970?)	Chiefly Ꞓf (also MDm,Ob)	I	4,550
16cca	Town of Ten Sleep	1955	1,050	5	1,100 R (1964)	PMa,MDm	P	4,455

Water level and wellhead pressure					
Static		After 5-minute recovery test			
Water level above land surface (ft)	Well-head pres-sure (lb/in^2)	Water level above land surface (ft)	Well-head pres-sure (lb/in^2)	Date of measure-ment	Remarks
370	160 R	----	----	1970(?)	Pressure reported by owner to have been steady since drilled.
368	158	----	----	5-14-75	
366	157	----	----	5- 4-76	
----	----	312	135	5-14-76	
----	----	338	146.5	5-14-76	Measurement made 67 minutes after well was shut off.
----	----	345	148	4-27-77	5-minute test(?).
----	----	319(?)	138(?)	5-16-78	Do.
457	198	----	----	5-14-75	Drilled to base of Flathead Sandstone. Reported yield of 1,500 gal/min at completion of well.
453	196	----	----	6-12-75	Pressure probably affected by operation of well 47-88-5baa.
405	174	----	----	10- 8-75	Well shut off about 5 hours before measurement. Small flow, well winterized.
407	175	----	----	10- 9-75	
412	177	----	----	10-20-75	Small flow, well winterized.
419	180	----	----	10-31-75	Do.
419	180	----	----	11- 6-75	Do.
457	198	----	----	5- 3-76	No irrigation wells in operation.
453	196	----	----	5-14-76	Well 47-88-5baa turned on 5-4-76 and well 47-88-16aba turned on 5-10-76.
414	178	----	----	11- 5-76	Small flow, well winterized.
437	188	----	----	4-27-77	Do.
411(?)	178(?)			5-16-78	Do.
----	----	----	----	--------	
----	----	----	----	--------	Estimated flow 2 gal/min 10-31-53. Deepened from 300 to 500 ft in 1972. Owner estimates pressure to be about 50 lb/in^2 and flow fills a 2-in. discharge pipe.
----	----	----	----	--------	During drilling, depth to water obtained from Amsden(?) Formation was 4 ft. Owner reports yield has been constant since drilled.
15	6.5	----	----	11- 5-75	Flows continuously. Well not completely shut off.
----	----	12.5	5	5- 4-76	Do.
----	----	14.5	6	6-22-76	Do.
----	----	14.5	6	9- 9-76	Do.
----	----	9.5	4	11- 5-76	Do.
----	----	9.5	4	4-27-77	Do.
1,058	458	----	----	5-15-75	Well not completely shut off. Driller reported no flow from Madison Limestone.
1,091	472	----	----	6-10-75	Well not completely shut off.
580	250	----	----	9- 8-75	Ten minutes after well was shut off.
869	375	----	----	10-21-75	Well not completely shut off.
869	375	----	----	11- 6-75	Do.
1,041	451	----	----	5-10-76	Do.
1,037	450	----	----	11- 5-76	Do.
1,048	453	----	----	4-26-77	Do.
----	----	----	----	--------	Dual completion well. Inner casing is completed in Amsden Formation and Madison Limestone. Flow of inner casing supplies the town of Ten Sleep. During 1977-78, flow pressure of inner casing ranged seasonally according to the amount of use. (See fig. 5.) Outer casing is completed in Tensleep Sandstone. Flow pressure of outer casing was 80 lb/in^2 on 5-10-62, 79 lb/in^2 on 5-11-64, and 78 lb/in^2 on 5-6-70.

Table 2. Records of wells completed in the Paleozoic artesian aquifers—Continued

Well location number	Owner or tenant	Year drilled	Depth of well (ft)	Diameter of casing (in.)	Flow rate of well at completion or at a later date (gal/min)	Water-yielding unit	Use of water	Land surface altitude above sea level (ft)
47-88-16cbb	Anderson Ranch	-----	----	8	F	-------	N	4,465
16cdb	-----do-----	-----	200+	6	F	Pg	S	4,430
16cdc1	-----do-----	-----	----	8	F	Pg(?)	N	4,430
16cdc2	Flagstaff Motel	Before 1953	505	4	F	Pg(?)	I	4,430
16daa	Anderson Ranch	1942	227	6-1/2	150 R (Before 1962)	Pg	D	4,465
16dba	-----do-----	1945	230±	6	F	Pg	N	4,450
17dad	Town of Ten Sleep	1978	1,100	8	3,000	MDm	P	4,465
20aad	Sweet	1952	758	5	5 R (1953)	Pg(?),PPt	N	4,405
21aba	Hawkins	1969	280	5-1/2	5 R (1975)	Pg(?)	D	4,435
47-89-1cac	Mark Carter	1957	755	8	100 R (1974)	PPt	S,I	4,410
6abc	Bureau of Land Management (Lloyd Bader)	1964(?)	2,848	5	F	MDm	S	4,770

Water level and wellhead pressure					
Static		After 5-minute recovery test			
Water level above land surface (ft)	Well-head pres-sure (lb/in²)	Water level above land surface (ft)	Well-head pres-sure (lb/in²)	Date of measure-ment	Remarks
----	----	----	----	--------	
----	----	----	----	--------	Well drilled originally for town of Ten Sleep.
----	----	----	----	--------	Owner reported insufficient flow for intended use.
118	51 R	----	----	1953	Well used for watering lawn.
----	----	74	32	5-14-62	
55	24	----	----	5- 6-70	
54	23.5	----	----	5- 7-75	
----	----	51	22.5	6-10-75	Well used intermittently before measurement.
51	22.5	----	----	6-11-75	Well shut off for 24 hours.
53	23	----	----	6-11-75	Well shut off for 31 hours.
51	22.5	----	----	6-12-75	Well shut off for 48 hours.
51	22.5	----	----	6-13-75	Well shut off for 72 hours.
53	23	----	----	7- 8-75	
54	23.5	----	----	7-14-75	Well shut off for 6 hours.
54	23.5	----	----	7-15-75	Well shut off for 24 hours.
54	23.5	----	----	8- 5-75	Well used intermittently before measurement.
53	23	----	----	9- 7-75	Well shut off for 24 hours.
54	23.5	----	----	9- 8-75	Well shut off for 36 hours.
54	23.5	----	----	10- 7-75	Well shut off for 12 hours.
54	23.5	----	----	10- 9-75	Well shut off for 68 hours.
54	23.5	----	----	10-22-75	
51	22	----	----	5- 4-76	Well used intermittently before measurement.
51	22	----	----	5-11-76	Well used intermittently before measurement.
53	23	----	----	6-22-76	
53	23	----	----	9- 9-76	
49	21	----	----	4-26-77	
51	22	----	----	5-15-78	
104±	45± R	----	----	1940's	Well equipped with small pump.
18.5	7.5	----	----	5- 6-75	
20.5	8.5	----	----	6-10-75	
20	8.2	----	----	7-11-75	
20.5	8.5			10- 8-75	
----	----	19.5	8	10- 9-75	Well flowing continuously from 10-9-75 to 11-6-75.
----	----	19.5	8	10-21-75	
----	----	19.5	8	10-31-75	
----	----	18.5	7.5	11- 6-75	
17.5	7	----	----	5- 3-76	Well shut off after flowing continuously all winter.
19.5	8	----	----	6-22-76	
----	----	20.5	8.5	9- 9-76	
----	----	17.5	7	11- 5-76	Well flowing continuously.
----	----	16.5	6.5	4-27-77	
----	----	15.4	6.0	5-15-78	
----	----	----	----	-------	Well drilled originally for town of Ten Sleep.
296	128	----	----	9----78	Original yield 3,900 gal/min. Yield of 3,050 gal/min after a 24-hour test. Estimated 40 to 50 gal/min from Tensleep Sandstone. Top of Madison Limestone at 848 ft. Estimated yield of only 200 gal/min above 860 ft.
81	35	----	----	1942	Well unused since about 1955.
----	----	----	----	--------	Owner reports 5 to 8 lb/in². Well equipped with small pump. Reported tested at 60 gal/min.
323	140 R	----	----	Before 1969	Owner reported a yield of 250 gal/min in 1957(?) and 100 gal/min in 1974.
85	37 R	----	----	(?)	Drilled originally as oil test. Well plugged below 2,835 ft.

Table 2. Records of wells completed in the Paleozoic artesian aquifers—Continued

Well location number	Owner or tenant	Year drilled	Depth of well (ft)	Diameter of casing (in.)	Flow rate of well at completion or at a later date (gal/min)	Water-yielding unit	Use of water	Land surface altitude above sea level (ft)
47-89-13aab	L. J. Davis	1940's	901	6	181 M (1953)	PPt	D,I	4,405
47-90-8db	Pan American	-----	6,660	-----	500 R	MDm,Ob	---	4,500±
48-88-9acb	Vernon Rice	1951	-----	-----	F	PPt,MDm	S	5,020
28ccb	------------	1969(?)	545(?)	7	250 R	PMa,MDm	S,I	4,725
28ccc1	------------	Before 1953	-----	-----	100 E	PMa,MDm	---	4,640
28ccc2	------------	Probably during 1962-70	725(?)	13	250 R (1972)	MDm	S,I	4,660
29baa	Boyd Mills	Before 1953(?)	450	8	15 E (1974)	PPt,PMa	S	4,610
48-89-4abb	Homer Renner	1950	470	6	50 R (Before 1953)	Pg,PPt	S	4,510
4acd	-----do-----	1959	1,362	7	2,500 (1959?)	MDm	I	4,546
6dcb	Tanner	1974	3,933	13	2,300 R	MDm,Ob,Ꞓf	I	4,430
8dbc	-----do-----	1971	3,987	13	2,200 R	MDm,Ob,Ꞓf	I	4,490
10acc	Homer Renner	Before 1953	460	6	20 R (Before 1953?)	PPt	N	4,550

Water level and wellhead pressure: Static: Water level above land surface (ft)	Static: Wellhead pressure (lb/in^2)	After 5-minute recovery test: Water level above land surface (ft)	After 5-minute recovery test: Wellhead pressure (lb/in^2)	Date of measurement	Remarks
330	143	----	----	10-30-53	Owner reports this is first flowing well used for
344	149	----	----	5-22-75	irrigation in the area. Repaired break in casing
					during the 1960's.
254	110 R	----	----	(?)	Drilled originally as oil test. Well probably used
					as an oil-field injection well.
----	----	----	----	--------	Dual-completion well. Outside casing finished in
					Tensleep Sandstone. Inside casing finished in
					Madison Limestone. Casing rusted and contains
					many leaks.
----	----	----	----	--------	Reported 94.7 gal/min at 25 lb/in^2.
----	----	----	----	--------	Old well drilled before 1953.
208	90	----	----	1972(?)	
----	----	----	----	--------	Old well. Flows into small reservoir. Owner
					reports yield of 300 gal/min many years ago.
----	----	----	----	--------	
393	170 R	----	----	About 1960	105 lb/in^2 with well flowing at 1,000± gal/min
----	----	312	135	5-10-62	on 5-10-62.
----	----	277	120	5- 6-70	
384	165	----	----	5-14-75	Shut off except for small flow left on for
					winterizing well.
----	----	299	128	6-10-75	Well flowing at about 1,450 gal/min; well in
					continuous operation from about 6-10-75 to
					10-31-75.
----	----	299	128	7- 8-75	Well flowing about 1,000 gal/min.
----	----	280	120	8- 5-75	Well flowing about 1,250 gal/min.
----	----	278	119	9- 8-75	Well flowing about 1,000 gal/min.
----	----	285	122	10- 7-75	Well flowing about 800 gal/min.
----	----	310	133	10-31-75	Well flowing about 550 gal/min. Well shut down
					and winterized with small flow estimated at
					50 gal/min 10-13-75.
324	139	----	----	10-31-75	Measurement made 55 minutes after well was shut
					down and winterized.
343	147	----	----	11- 7-75	Measurement made 165 hours after well was shut
					down and winterized.
377	162	----	----	5- 5-76	Well winterized and flowing at about 50 gal/min.
383	164.5	----	----	5- 6-76	Well shut off 5-5-76.
347	149	----	----	11- 5-76	Well winterized with small flow estimated at
					40 to 50 gal/min 10-23-76 after operating
					continuously all summer.
373	160	----	----	4-27-77	Well winterized with small flow.
647	280 R	----	----	1974	
577	250	----	----	5-23-75	Drilled to granite.
647	280 R	----	----	1971	
504	240±	----	----	5-15-75	
102	44	----	----	11- 3-53	U.S. Bureau of Land Management well. Decrease in
2	1	----	----	12-17-74	pressure may be due to deterioration of well casing.

Table 2. Records of wells completed in the Paleozoic artesian aquifers—Continued

Well location number	Owner or tenant	Year drilled	Depth of well (ft)	Diameter of casing (in.)	Flow rate of well at completion or at a later date (gal/min)	Water-yielding unit	Use of water	Land surface altitude above sea level (ft)
48-89-25acb	Boyd Mills	Before 1953	400	-----	F	Pℙt,ℙMa	D,S	4,540
25ada	-----do-----	1965	2,287	6	2,000 R (1965)	Chiefly Ꞓf, (also MDm,Ob)	I	4,575
49-88-29daa	Homer Renner	-----	----	8	35 (Before 1953)	Pℙt,Pg	N,S	5,030
29dac	-----do-----	1966(?)	2,287	10	1,100	Chiefly Ꞓf, (also MDm,Ob)	S,I	5,035
49-89-5bda	R. S. Neeley	1962	2,214	-----	2,500 R (1962)	MDm	I	4,642
6bcb	Hyattville	1968	2,895	10	130 (1968)	ℙMa,MDm	P	4,470

Water level and wellhead pressure					
Static		After 5-minute recovery test			
Water level above land surface (ft)	Well-head pressure (lb/in^2)	Water level above land surface (ft)	Well-head pressure (lb/in^2)	Date of measurement	Remarks
65	28	----	----	11-10-53	Deepened to 600 ft after 1962. Repaired hole in casing in 1974.
74	32	----	----	5-14-62	
87	37.5	----	----	5-22-75	
88	38	----	----	6-10-75	
----	-----	82	35.5	7- 8-75	
----	-----	82	35.5	8- 5-75	
----	-----	82	35.5	9- 9-75	
----	-----	83	36	10- 7-75	
----	-----	89	38.5	10-31-75	
----	-----	83	36	5-11-76	
----	-----	83	36	9-10-76	
----	-----	85	37	11- 5-76	
1,155	500	----	----	1965	Maximum pressure reported at completion of well; 500 gal/min at 100 lbf/in^2 from Madison Limestone and Bighorn Dolomite.
924	400 R	----	----	5----75	Reported by owner to be original static pressure for 1975.
832	360	----	----	5-22-75	Well not completely shut off. Small flow left on to keep air out of sprinkler lines.
587	253	----	----	10-31-75	Well shut off 10-27-75 after continuous operation during the irrigation season.
650	280	----	----	11- 2-75	Well shut off for 7 days.
659	284	----	----	11- 3-75	Well shut off for 8 days.
661	285	----	----	11- 4-75	Well shut off for 9 days.
671	289	----	----	11- 6-75	Well shut off for 11 days.
671	289	----	----	11- 7-75	Well shut off for 12 days.
783	338	----	----	5- 6-76	Well shut off during winter months.
812	350	----	----	4-27-77	
785	340	----	----	4----78	Pressure measurement by owner.
----	----	----	----	--------	Wooden plug in casing.
762	330 R	----	----	1970	Small flow was reported from Tensleep Sandstone and 200 to 250 gal/min from the Madison Limestone and Bighorn Dolomite; 32 lb/in^2 at 1,000 gal/min in 5-13-70; 238 lb/in^2 at 100 gal/min in 6-10-75.
----	----	232	100	5- 5-76	During recovery test after well flowed continuously since September 1975 at 700 gal/min; 90 lb/in^2 on 5-5-76 before start of recovery test.
575	248	----	----	5-18-76	End of recovery test. Pressure still increasing.
568	244	----	----	6-22-76	Well flowing 75 to 100 gal/min.
552	239	----	----	10-10-79	Well flowing 5 gal/min. Pressure of 20 lb/in^2 when well was flowing about 1,050 gal/min. Measured by Anderson and Kelly, consulting hydrologists.
393	170	----	----	5-11-62	Measurement by Lowry (1962) at completion of well and before well was used.
----	----	323	140	4-20-65	
300	130	----	----	5- 6-70	Well probably not completely shut off.
485	210 R	----	----	8----68	Two static pressure measurements of 188 and 210 lb/in^2 are reported for this well in 1968. At times water has slight red tint from clay particles in suspension.
----	----	362	155	11- 6-76	During recovery test after well flowed continuously at about 100 gal/min for several months.
484	208	----	----	11- 6-76	Thirty minutes after well was shut off.
489	210	----	----	11- 6-76	Sixty minutes after well was shut off.

Table 2. Records of wells completed in the Paleozoic artesian aquifers—Continued

Well location number	Owner or tenant	Year drilled	Depth of well (ft)	Diameter of casing (in.)	Flow rate of well at completion or at a later date (gal/min)	Water-yielding unit	Use of water	Land surface altitude above sea level (ft)
49-89-21bda	Bureau of Land Management	1946	431	6	NF	Pg(?),PPt	N	4,820
24dcb	Homer Renner	1936 1960	570 1,480	6 -----	200 R 46	PPt,PMa, MDm,Ob(?)	S	4,920
28baa	-----do-----	Before 1953	944	4	84 M (1953)	MDm	S	4,795
29abb	D. W. Straight	1951	960	8	108 M (1953)	MDm, others	S	4,710
34dad	Homer Renner	Before 1953	240	10	3 (1953)	PPt	S	4,625
34dca	-----do-----	-----	300±	-----	F	PPt	D,I	4,590
34dca	Homer Renner	Before 1953	360	6	45 R (Before 1953)	PPt	S	4,555
35bcb	-----do-----	Before 1953	----	-----	84 M (1953)	MDm	N	4,680
49-91-2bb	Bureau of Land Management	-----	2,851	7	400	MDm,Ob	N	4,200±
50-89-5dcc	-----do-----	1943	440	6	NF	PPt(?)	N	5,274
21aaa	Wyo.Recreation Comm.	-----	50	6	NF	PPt	D	4,790
26cac1	Hyatt Ranch	1950±	160	6	NF	PPt	D	4,970
26cac2	-----do-----	Before 1947	30	-----	NF	PPt	N	4,980±

Water level and wellhead pressure: Static: Water level above land surface (ft)	Static: Wellhead pressure (lb/in^2)	After 5-minute recovery test: Water level above land surface (ft)	After 5-minute recovery test: Wellhead pressure (lb/in^2)	Date of measurement	Remarks
----	----	----	----	--------	Tested by bailer at 30 gal/min with 60 ft of drawdown. Depth to water was 19.5 ft in 1947 and 82.7 ft on 6-10-75. Difference in the depth to water may be due to deterioration of well casing since the well is not now used.
----	----	----	----	--------	
119	51.5	97	42	5-12-62	Well was deepened to the Flathead Sandstone and a large flow was obtained. Subsequently, the well caved which caused the loss of most of the flow. After well was shut off for 1/2 hour, pressure was 49 lb/in^2; measured in 1979 by Anderson and Kelley, consulting hydrologists.
293	127	----	----	11- 4-53	Drilled originally as an oil test. U.S. Bureau of Land Management well. Flows continuously at 21 gal/min. Pressure in 1979 was 36.5 lb/in^2 after well was shut off for 16 hours.
247	107	----	----	11- 5-53	
277	120	----	----	5-14-62	
293	127	----	----	5-15-75	
297	128	----	----	5- 7-76	
293	127	----	----	5- 9-76	
286	123	----	----	4-27-77	Water very rust-colored.
274	118	----	----	5-16-78	Do.
----	----	----	----	--------	Flow a trickle in December 1974. Well in outcrop of Tensleep Sandstone. No flow visible 11-5-76.
32	16	----	----	6-10-75	
----	----	27	14	7- 8-75	
30	15.5	----	----	8- 5-75	
32	16	----	----	9- 9-75	
32	16	----	----	10- 7-75	
32	16	----	----	10-21-75	
32	16	----	----	10-28-75	
32	16	----	----	11- 7-75	
30	15	----	----	5- 7-76	
30	15	----	----	6-22-76	
26	13.5	----	----	9-10-76	
27	14	----	----	11- 5-76	
37	18	----	----	4-27-77	
32	16	----	----	5-16-78	
----	----	----	----	--------	Casing rusted out.
----	----	----	----	--------	Well dynamited. Well in outcrop of Tensleep Sandstone. Well flows continuously at about 19 gal/min.
----	----	----	----	--------	Reported wellhead pressure of 350 to 450 lb/in^2.
----	----	----	----	--------	Well near outcrop of Tensleep Sandstone. Depth to water was 321 ft on 5-11-76, 314 ft on 4-28-77, and 320 ft on 5-16-78.
----	----	----	----	--------	Depth to water 16 ft.
----	----	----	----	--------	Depth to water 22 ft on 5-12-76.
----	----	----	----	--------	At abandoned fish hatchery.

Table 2. Records of wells completed in the Paleozoic artesian aquifers—Continued

Well location number	Owner or tenant	Year drilled	Depth of well (ft)	Diameter of casing (in.)	Flow rate of well at completion or at a later date (gal/min)	Water-yielding unit	Use of water	Land surface altitude above sea level (ft)
50-89-31bab	Paintrock Ranch	1967	3,995	7	3,000± (1967?)	Chiefly Ꞓf (also MDm,Ob)	1	4,695
50-90-14bbd	Hamilton Ranch	Before 1953	1,625	5-1/2	200 R	Pg(?),PPt	S	4,700
14cac	-----do-----	1953	2,000(?)	6	49 M (1953?)	PPt,PMa MDm	S	4,620
23cad	-----do-----	1956	2,500	5-1/2	2,880 (1962)	MDm,Ob	S,I	4,555
34dca	Chester Mercer	1964	2,985	6	1,500 (1965)	MDm,Ob	D,S,I	4,530

Water level and wellhead pressure					
Static		After 5-minute recovery test			
Water level above land surface (ft)	Well-head pressure (lb/in^2)	Water level above land surface (ft)	Well-head pressure (lb/in^2)	Date of measurement	Remarks
912	395	----	----	5-19-75	
878	380	----	----	7- 8-75	Well shut off 10 days before measurement.
868	375	----	----	10- 7-75	Flow 15 gal/min, well winterized. Well shut off for about 3 days before measurement.
873	377	----	----	10-21-75	Flow 15 gal/min.
901	385	----	----	10-31-75	Do.
922	398	----	----	5- 4-76	Do.
920	397	----	----	5- 7-76	Do.
922	398	----	----	5-10-76	Do.
929	403	----	----	11- 7-76	Small flow.
----	----	----	----	---------	Drilled originally as an oil test. Water in Sundance, Chugwater, and Goose Egg Formations sealed out; 14.5 lb/in^2 at 28.6 gal/min.
----	----	150	65	11- 7-53	
----	----	189	82	5-12-62	
----	----	189	82	5-12-70	
808	350 R	----	----	1956	Well yields 1,000 gal/min at 15 lb/in^2 and 750 gal/min at 120 lb/in^2.
----	----	531	230	5-14-62	
531	230	----	----	5- 6-70	
540	233	----	----	5-14-75	
538	232	----	----	10- 7-75	
543	234	----	----	5- 4-76	
545	235	----	----	4-28-77	
545	235	----	----	5-16-78	
554	240 R	----	----	1965	Small flow reported from Tensleep Sandstone.
518	225	----	----	5- 8-75	Well not completely shut off; valves leak.
538	232	----	----	5- 4-76	Do.
522	225	----	----	4-28-77	Do.
603	260	----	----	5-16-78	Do.

Table 3. Yield, specific capacity, and transmissivity of wells completed in the Paleozoic artesian aquifers

[Geologic source: Pg, Goose Egg Formation; Pp, Park City Formation; ℙPt, Tensleep Sandstone; ℙMa, Amsden Formation; MDm, Madison Limestone, Ob, Bighorn Dolomite; Ꞓf, Flathead Sandstone. Units: ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot; ft^2/d, feet squared per day; lb/in^2, pounds per square inch]

Well location number	Geologic source	Amount of drawdown or recovery (ft)	Yield before or during test (gal/min)	Specific capacity [(gal/min)/ft]	Transmissivity (ft^2/d)	Remarks
42-88-3adc	Pp,ℙPt	80±	35	0.4±	---	
21bcb	ℙPt	55±	20	.4±	---	12-hour test.
44-87-8dcd	ℙPt	85	150±	2.0±	[1] 290±	
8ddc	ℙPt(?), MDm	---	---	---	[2] 402	
46-87-10acb	MDm	347	150	.43	---	Specific capacity calculated from a static level of 416 ft (180 lb/in^2) above land surface.
	MDm	289	125	.43	---	
47-88-5baa	MDm,Ob	317	1,500±	4.7±	670	Recovery test.
16aba	Chiefly Ꞓf	859	450	.52	---	
47-89-13aab	ℙPt	182	180±	1.0±	[2] 164	Drawdown test.
					[2] 148	Recovery test.
48-89-4acd	MDm	132	1,000	7.6	1,900	Recovery test lasted about 10 days.
25ada	Chiefly Ꞓf	539	900	1.67	94	Recovery test.
49-88-29dac	Chiefly Ꞓf	635±	1,730	2.7±	250	Recovery test lasted about 13 days.
		577±	1,610	2.8±		Specific capacity calculated from estimated static level of 693 ft (300 lb/in^2) above land surface.
		520±	1,500	2.9±		
		442±	1,380	3.1±		
		346±	1,095	3.2±		
		231±	775	3.4±		
49-89-6bcb	ℙMa,MDm	254	100±	.4±	---	
24dcb	MDm	---	---	---	720	Test made before well was deepened to Flathead Sandstone. (See table 2.)
28baa	MDm	---	---	---	[2] 72	Well originally drilled as an oil test.
29abb	MDm, others	---	---	---	[2] 119	Well originally drilled as an oil test.
50-89-31bab	Chiefly Ꞓf	145	300±	2.0±	[1] 320±	
		598	1,200±	2.0±	---	
50-90-14bbd	Pg(?),ℙPt	---	---	---	[2] 142	Well originally drilled as an oil test.
14cac	ℙPt,ℙMa, MDm	---	---	---	[2] 60	Well originally drilled as an oil test.
23cad	MDm,Ob	486	1,000	2.1	[1] 320	Specific capacity calculated from static level of 521 ft (231 lb/in^2) above land surface.
		405	960	2.4		
		371	910	2.5		
		336	860	2.6		
		290	805	2.8		
		244	750	3.1	[1] 510	

[1] Transmissivity estimated from specific capacity by method used by Walton (1962, p. 62-63, fig. 2).

[2] Transmissivity from Lowry (1962, table 1); low transmissivity may be due to type of well construction.

Table 4. Comparison of the reported original static pressures with the 1975–78 static pressures of wells penetrating the Flathead Sandstone

Well location number	Reported static pressure at time of completion of well		Static pressure after well was in operation	
	Pressure (pounds per square inch)	Date	Pressure (pounds per square inch)	Date
47-87-33dbd1	[1] >500(?)	1961-62	332	5-14-75
47-88-8dab	280	1970	198	5-14-75
			198	5-03-76
48-89-6dcb	[2] 350	1974	250	5-23-75
8dbc	280	1971	[3] 218	5-15-75
25ada	500	1966	400	May 1975
			338	5-06-76
			350	4-27-77
			340	April 1978
49-89-29dac	>330	1966	[4] 248	5-18-76

[1] Original pressure reported to have broken two valves rated at 500 pounds per square inch

[2] Estimated, method of estimating not known

[3] Approximate, pressure probably an additional 20 pounds per square inch

[4] End of 13-day recovery test, pressure was still increasing. Projection of recovery curve indicates that it would take approximately 1,300 days for the pressure to recover to the approximate initial static pressure of 330 pounds per square inch.

Table 5. Comparison of preseason static pressures with operating pressures of four irrigation wells during the irrigation season

[Geologic source: IPPt, Tensleep Sandstone; MDm, Madison Limestone; Єf, Flathead Sandstone]

Well location number	Geologic source	Preseason static level			Well in operation during irrigation season			
		Water level above land surface (feet)	Wellhead pressure (pounds per square inch)	Date	Water level above land surface (feet)	Wellhead pressure (pounds per square inch)	Approximate yield (gallons per minute)	Date
44-87-8dcd	IPPt	164	71	5-13-76	62	27	150	6-22-76
					51	22	150	9-12-76
47-88-16aba	Mainly Єf	1,093	472	6-10-75	130	55	450	7-10-75
					95	40	450	9-08-75
48-89-4acd	MDm	384	165	5-14-75	246	105	1,000	7-08-75
					216	92	1,000	9-08-75
25ada	Mainly Єf	924±	400±	5- -75	465	200	450	6-13-75
					188	80	900	7-08-75
					199	72	900	8-05-75
					292	125	450	9-09-75
					158	67	900	10-07-75
					135	57	900	10-21-75
		783	338	5-06-76	350	150	450	6-22-76
					124	52	900	9-10-76

Table 6. Chemical analyses of water from springs

[Analytical results in milligrams per liter except as indicated; °C, degrees Celsius; µS/cm at 25°C, microsiemens per centimeter at 25 degrees Celsius. Analyses by Wyoming Department of Agriculture and by U.S. Geological Survey. Water-yielding unit: Pg, Goose Egg Formation; Pp, Park City Formation; ℙMa, Amsden Formation; MDm, Madison Limestone]

Location number	Water-yielding unit	Date of collection	Temperature (°C)	Dissolved silica (SiO_2)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)
42-88-21b	Pp(?)	6-25-65	10	20	187	40	6.5
30ad	Pp(?)	6-25-65	10.5	26	506	77	75
44-87-21bdd	----	11-07-76	----	9.1	53	24	2.9
46-87-22add	----	9-12-76	12.0	20	420	67	11
22daa	----	9-12-76	----	24	350	75	11
23acd	Pg	9-13-76	----	11	59	30	1.2
26dbd	Pg	9-15-76	----	11	53	27	2.9
47-88- 1cad	ℙMa, MDm(?)	9-15-76	----	9.4	33	19	2.3
1cdb	ℙMa, MDm(?)	10-30-53	11.5	9.9	37	17	1.8
1cdb	ℙMa, MDm(?)	9-08-75	9.0	9.9	34	16	1.8
1dbc	ℙMa, MDm(?)	10-30-53	11.5	9.5	38	16	1.9

Location number	Dissolved potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Dissolved fluoride (F)	Dissolved nitrate (NO_3)	Dissolved solids (sum of constituents)
42-88-21b	2.2	214	0	449	2.0	0.8	2.2	815
30ad	4.9	228	0	1,420	6.5	.7	3.6	2,230
44-87-21bdd	1.4	210	0	48	10	.4	1.6	252
46-87-22add	2.3	230	0	1,100	2.2	.8	5.2	1,770
22daa	2.1	240	0	970	2.2	.9	6.1	1,560
23acd	.9	260	0	61	.5	.3	2.9	295
26dbd	1.2	270	0	20	1.8	.3	3.2	254
47-88- 1cad	.7	190	0	4.9	3.6	.2	2.3	169
1cdb	.8	194	0	1.0	1.5	0	2.4	167
1cdb	1.6	170	0	4.8	1.1	.1	1.7	156
1dbc	.7	197	0	1.0	1.5	0	2.4	168

Table 6. Chemical analyses of water from springs—Continued

Location number	Hardness (Ca, Mg)	Sodium-adsorption ratio (units)	Specific conductance (μS/cm at 25°C)	pH (units)	Remarks
42-88-21b	630	0.1	1,060	7.8	
30ad	1,580	.8	2,380	7.8	Flows 4,500 gallons per minute.
44-87-21bdd	230	.1	413	7.7	Big Spring. Orifice in Goose Egg Formation near fault. Flow derived from Tensleep Sandstone or underlying formations.
46-87-22add	1,300	.1	1,930	8.0	Orifice in flood-plain alluvium, flow probably from Goose Egg Formation.
22daa	1,200	.1	1,870	7.7	Do.
23acd	270	0	501	7.9	
26dbd	240	.1	444	8.0	
47-88- 1cad	160	.1	300	8.2	North spring, Wigwam Fish Rearing Station.
1cdb	162	.1	307	7.6	West spring, Wigwam Fish Rearing Station.
1cdb	150	.1	274	8.1	Do.
1dbc	162	.1	308	7.5	East spring, Wigwam Fish Rearing Station.

Table 7. Chemical analyses of water from selected spring-sustained streams, ponds, and reservoirs

[Analytical results in milligrams per liter except as indicated; µS/cm at 25°C, microsiemens per centimeter at 25 degrees Celsius. Analyses by Wyoming Department of Agriculture and U.S. Geological Survey]

Site name	Site number (pl. 2)	Approximate stage or flow	Date of collection	Dissolved silica (SiO_2)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)
SPRING-SUSTAINED STREAMS								
Spring Creek	S1	low	9-15-76	11	47	23	1.2	0.9
Alkali Creek near Ten Sleep	S2	----	9-12-76	16	350	130	130	11
Tributary of Brokenback Creek	S3	low	11- 5-76	9.6	39	28	4.1	1.6
Brokenback Creek	S4	low	9-10-76	11	54	31	1.8	1.2
PONDS AND RESERVOIRS								
Unnamed ephemeral pond near Spring Creek NE¼ sec. 34, T. 46 N., R. 87 W.	P1	low	9-12-76	36	71	13	5.9	23
Oxbow lake in abandoned meander of Tensleep Creek SE¼ sec. 16, T. 47 N., R. 88 W.	P2	high	9- 9-76	28	490	110	20	9.1
Small reservoir below spring, NE¼ sec. 1, T. 47 N., R. 89 W.	P3	high	9-10-76	21	410	120	85	3.7
Carothers Lake, Brokenback Creek drainage area	P4	high	9-10-76	26	90	47	5.3	2.3
Unnamed reservoir, Buffalo Creek drainage area	P5	medium low	9-10-76	.7	490	250	77	1.4
Renner Reservoir, Buffalo Creek	P6	high	9-10-76	16	540	160	120	11

Site name	Site number (pl. 2)	Bicar-bonate (HCO_3)	Carbonate (CO_3)	Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Dissolved fluoride (F)	Dissolved nitrate (NO_3)	Dissolved solids (sum of constituents)
SPRING-SUSTAINED STREAMS								
Spring Creek	S1	240	6	8.2	1.8	0.2	3.0	218
Alkali Creek near Ten Sleep	S2	160	0	1,500	25	1.3	0	2,210
Tributary of Brokenback Creek	S3	260	0	4.1	1.5	.3	2.4	217
Brokenback Creek	S4	280	6	17	.9	.3	1.7	262
PONDS AND RESERVOIRS								
Unnamed ephemeral pond near Spring Creek NE¼ sec. 34, T. 46 N., R. 87 W.	P1	120	0	150	12	.4	2.3	372
Oxbow lake in abandoned meander of Tensleep Creek SE¼ sec. 16, T. 47 N., R. 88 W.	P2	240	0	1,500	2.7	1.0	2.5	2,310
Small reservoir below spring, NE¼ sec. 1, T. 47 N., R. 89 W.	P3	45	0	1,500	38	1.4	.5	2,240
Carothers Lake, Brokenback Creek drainage area	P4	95	0	340	1.9	.6	.9	563
Unnamed reservoir, Buffalo Creek drainage area	P5	92	0	2,200	15	1.4	.1	3,120
Renner Reservoir, Buffalo Creek	P6	69	0	2,200	16	1.2	1.9	3,090

Table 7. Chemical analyses of water from selected spring-sustained streams, ponds, and reservoirs—Continued

Site name	Site number (pl. 2)	Hardness (Ca, Mg)	Sodium-adsorption ratio	Specific conductance (µS/cm at 25°C)	pH (units)	Remarks
SPRING-SUSTAINED STREAMS						
Spring Creek	S1	210	---	382	8.5	Location SW¼ sec. 26, T. 46 N., R. 87 W.
Alkali Creek near Ten Sleep	S2	1,400	1.5	2,270	7.9	Thin white alkali encrustations along creek.
Tributary of Brokenback Creek	S3	210	.1	404	8.0	Location in Salt Trough, NE¼ sec. 9, T. 48 N., R. 88 W.
Brokenback Creek	S4	260	0	456	8.4	Location SE¼ sec. 20, T. 48 N., R. 88 W.
PONDS AND RESERVOIRS						
Unnamed ephemeral pond near Spring Creek NE¼ sec. 34, T. 46 N., R. 87 W.	P1	230	4.0	535	7.1	Pond occupied small area in internally drained depression.
Oxbow lake in abandoned meander of Tensleep Creek SE¼ sec. 16, T. 47 N., R. 88 W.	P2	1,700	.2	2,360	7.8	
Small reservoir below spring, NE¼ sec. 1, T. 47 N., R. 89 W.	P3	1,500	.9	2,410	8.4	Sampled at spillway.
Carothers Lake, Brokenback Creek drainage area	P4	420	.1	779	7.6	Sampled on east shore, NW¼ sec. 16, T. 48 N., R. 88 W. Flow of stream in Salt Trough diverted into lake.
Unnamed reservoir, Buffalo Creek drainage area	P5	2,300	.7	3,070	8.1	Sampled at dam, SE¼ sec. 1, T. 48 N., R. 89 W.
Renner Reservoir, Buffalo Creek	P6	2,000	1.2	3,010	7.4	Sampled at dam in east-central sec. 35, T. 49 N., R. 89 W.

Table 8. Summary of selected chemical constituents, dissolved solids, and hardness of water in the Paleozoic artesian aquifers

[Analytical results in milligrams per liter. Analyses by Wyoming Department of Agriculture and U.S. Geological Survey]

Aquifer	Range of					
	Dissolved calcium	Dissolved magnesium	Dissolved sodium	Dissolved sulfate	Dissolved solids	Hardness as $CaCO_3$
Goose Egg Formation	50-96	18-42	1.6-4.8	9.1-200	184-440	170-370
Goose Egg Formation and Tensleep Sandstone[1]	50-81	21-37	2.6-12	25-210	229-448	212-360
Tensleep Sandstone	42-59	14-29	2.0-12	2.0-60	164-272	150-259
Amsden Formation and Tensleep Sandstone[2]	47-93	15-41	1.6-9.1	6.7-150	220-414	200-380
Amsden Formation and Madison-Bighorn aquifer	44-59	22-28	1.1-4.8	4.9-74	214-274	210-238
Madison-Bighorn aquifer	18-51	19-27	.5-5.0	2.0-48	176-237	170-240
Madison-Bighorn aquifer and Flathead Sandstone	20-66	12-31	3.5-16	18-64	158-324	110-290
Chiefly Flathead Sandstone	21-26	15-20	3.7-9.9	8.2-18	142-175	120-140

[1]Ranges do not include analysis of water from well 48-89-4abb that contained excessive concentrations of sodium (19 milligrams per liter), sulfate (490 milligrams per liter), and dissolved solids (881 milligrams per liter).

[2]Ranges do not include analysis of water from well 47-87-33bdb2 that contained excessive concentrations of sodium (120 milligrams per liter), sulfate (230 milligrams per liter), and dissolved solids (607 milligrams per liter).

Table 9. Chemical analyses of water from wells completed in the Paleozoic artesian aquifers

[Analytical results in milligrams per liter except as indicated; ft, feet; °C, degrees Celsius; µS/cm at 25°C, microsiemens per centimeter at 25 degrees Celsius. Tensleep Sandstone; PMa, Amsden Formation; MDm, Madison Limestone; Ob, Bighorn Dolomite; Ꞓf, Flathead Sandstone]

Location number	Depth of well (ft)	Water-yielding unit	Date of collection	Temperature (°C)	Dissolved silica (SiO_2)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)
42-88-21bcb	595	PPt	6-21-65	12	11	43	24	3.5	1.4	212	0
21bcb	595	PPt	5-13-75	----	10	44	23	4.3	1.2	220	0
31bcc	585	PPt	6-10-75	----	11	42	18	4.3	4.0	200	0
43-87-11ddb	443	Pp,PPt	11-12-53	----	11	43	22	1.4	1.8	228	0
11ddb	443	Pp,PPt	5-23-75	----	10	36	24	1.6	1.2	220	0
20ccc	-----	Pg,PPt(?)	5-22-75	----	9.3	80	31	6.4	2.1	260	0
21bcb	485	PPt	11-12-53	----	9.4	59	27	2.6	1.0	258	0
21bcb	500	PPt	5-06-75	----	8.4	50	27	2.1	2.8	250	0
21bcb	500	PPt	9-08-75	11.5	9.7	54	24	2.3	1.4	250	0
44-87- 8dcd	-----	PPt	7-15-75	----	9.2	42	16	2.9	1.2	170	0
8ddc	1,040	PPt(?),MDm	11-11-53	14.5	8.0	43	16	1.3	1.2	166	0
9bbc	1,820	MDm,Ob,and others	5-13-75	15.5	9.5	46	23	3.2	1.2	230	0
9cbd	-----	PPt	5-09-76	13.0	9.3	37	14	2.3	.9	160	0
17ddc	575	PPt	11-12-53	13.5	9.6	45	21	12	1.2	192	0
17ddc	575	PPt	5-06-75	13	10	42	22	2.7	1.2	200	0
17ddc	575	PPt	9-08-75	15	10	50	20	2.3	1.4	200	0
46-87-10acb	1,410	PMa,MDm	6-11-75	----	9.2	44	24	1.1	2.3	230	0
10acb	1,410	PMa,MDm	9-08-75	14	9.8	46	23	1.2	.7	230	0
21acd	912	PPt	10-31-53	14.5	9.6	58	28	3.0	1.4	289	0
21acd	912	PPt	7-28-59	14.5	9.9	53	29	2.8	1.3	289	0
21acd	1,100(?)	PPt	5-13-75	----	10	54	26	2.7	.9	280	0
47-87-33bdb1	2,708	Mainly Ꞓf	5-14-75	----	9.8	62	31	4.8	1.6	300	0
33bdb1	2,708	Mainly Ꞓf	9-08-75	25.0	10	66	31	3.5	1.6	290	0
33bdb2	-----	PPt,PMa(?)	5-14-75	14	9.0	54	15	110	12	150	0
33bdb2	-----	PPt,PMa(?)	9-08-75	15.5	11	54	17	120	12	150	0
47-88- 1cda	1,070	MDm,Ob	12-20-65	----	----	---	20	4.0	1.0	---	---
1cda and 1dbc	-----	PMa,MDm(?)	5-06-75	10.5	11	40	22	2.7	.5	230	0
1cda and 1dbc	-----	PMa,MDm(?)	9-08-75	10.5	10	38	20	1.8	.9	220	0
47-88- 2bcb	540	PPt,PMa(?)	7-19-68	----	9.6	47	24	2.4	1.1	256	0
2bcb	540	PPt,PMa(?)	6-11-75	----	9.5	49	26	1.6	3.0	260	0
5baa	1,682	MDm,Ob	5-14-75	----	9.5	43	27	1.6	.7	270	0
5baa	1,682	MDM,Ob	9-09-75	14.5	10	47	26	1.2	.9	260	0
8dab	2,960	MDm,Ob,Ꞓf	5-14-75	----	10	20	16	16	5.6	160	0
8dab	2,960	MDM,Ob,Ꞓf	9-09-75	23.5	11	20	14	15	5.4	140	0
10dbd	500	Pg(?)	5-22-75	----	9.6	50	18	1.6	.9	230	0
12bca	597	MDm	1973	----	----	39	19	2.1	.9	207	0
12bca	597	MDm	5-06-75	----	9.7	32	22	2.7	1.2	210	0
12bca	597	MDm	9-08-75	11.5	9.8	37	19	1.8	.7	210	0
15caa	-----	Pg(?)	11-05-75	----	9.7	36	20	2.9	.7	200	0
47-88-16aba	2,700	Mainly Ꞓf	5-15-75	20.5	11	21	15	8.0	4.7	160	0
16aba	2,700	Mainly Ꞓf	9-08-75	23.0	11	25	15	9.9	5.1	160	0
16cca	1,050	PMa,MDm	5-10-62	----	11	44	28	2.9	2.0	250	0
16cca	1,050	PMa,MDm	6-13-75	----	8.9	49	24	3.2	4.2	260	0
16cdb	200+	Pg	5-15-75	----	11	96	33	3.2	1.4	220	---
16cdc1	-----	Pg(?)	5-15-75	9	7.4	64	26	4.8	3.5	220	0
16cdc2	505	Pg(?)	9-09-75	14.5	8.2	48	22	6.4	3.7	230	0
16daa	227	Pg	5-15-75	13	11	88	35	4.3	1.6	200	0
16daa	227	Pg	9-08-75	14	11	85	32	2.3	1.2	200	0
16dba	230±	Pg	5-15-75	13.5	12	43	23	2.7	1.6	220	0
20aad	758	Pg(?),PPt	10-31-53	----	7.3	50	21	12	3.6	217	0
21aba	280	Pg(?)	11-06-75	----	9.7	61	27	3.5	1.2	220	0
47-89- 1cac	755	PPt	6-11-75	----	6.4	93	29	5.4	4.0	250	0
6abc	2,848	MDm	7-23-70	16	9.4	45	25	2.0	1.2	249	0

Analyses by Wyoming Department of Agriculture and U.S. Geological Survey. Water-yielding unit: Pg, Goose Egg Formation; Pp, Park City Formation; PIPt,

Dis-solved sulfate (SO_4)	Dis-solved chloride (Cl)	Dis-solved fluo-ride (F)	Dis-solved nitrate (NO_3)	Dissolved solids (sum of consti-tuents	Hardness (Ca, Mg)	Sodium-adsorp-tion ratio	Specific conduct-ance (µS/cm at 25°C)	pH (units)	Remarks
32	1.2	0.4	0.9	221	205	0.1	381	7.7	
27	1.8	.3	2.3	221	200	.1	391	7.9	
24	3.6	.3	.6	204	180	.1	342	7.8	
9.0	1.0	.2	1.0	202	200	0	365	7.5	
6.6	0	.2	.8	188	190	.1	352	7.8	
130	1.8	.3	0	382	330	.2	618	7.9	
44	1.0	.3	0	272	256	.1	470	7.4	
33	1.8	.3	0	248	240	.1	430	8.0	Deepened from 485 to 500 feet in 1972. Specific conductance 460 µS/cm at 25°C on 5-7-62.
32	1.4	.3	.5	248	230	.1	425	8.1	
35	1.8	.3	.2	193	170	.1	321	8.2	
34	1.0	.6	0	187	173	0	329	7.5	
34	1.8	.3	0	231	210	.1	400	7.9	Multiple completion well.
20	0	.1	.1	164	150	.1	293	8.3	
60	2.0	.2	.3	247	200	.4	414	7.5	
34	0	.3	.3	209	190	.1	368	8.0	
49	1.8	.2	.7	231	210	.1	389	8.1	
23	1.8	.2	0	218	210	0	390	8.2	
19	.0	.2	.5	214	210	0	385	8.1	
24	2.0	.2	0	271	259	.1	474	7.6	
21	1.2	.3	0	264	253	.1	467	7.7	
21	1.8	.2	.6	257	240	.1	444	7.8	Deepened in 1960 to 1,100 feet.
41	1.8	.2	.1	297	280	.1	518	8.0	Drilled to granite.
64	2.5	.2	1.0	324	290	.9	529	7.8	Do.
220	84	1.7	0	583	200	3.5	957	8.2	
230	84	2.2	.5	607	210	3.6	961	8.2	
48	1.5	---	---	226	---	---	---	---	At completion of well.
8.2	1.8	.2	2.6	200	190	.1	345	7.9	
5.8	0	.2	2.5	185	170	.1	314	8.0	
7.7	.4	.2	1.6	220	215	.1	395	8.1	
6.7	16	.2	2.4	243	230	0	403	7.7	
2.5	0	.3	2.2	217	220	0	406	7.7	
3.3	0	.2	2.2	220	220	0	400	7.9	
18	0	.4	0	165	110	.6	295	8.1	
19	2.2	.4	.5	158	110	.6	273	8.1	
9.1	1.8	.2	.2	205	200	.1	381	7.6	Deepened from 300 to 500 feet in 1972.
12	1.7	.2	1.5	184	170	.1	317	7.8	
4.1	1.8	.2	1.1	176	170	.1	324	7.8	
4.9	0	.2	1.6	176	170	.1	318	7.9	
13	2.1	.3	1.1	184	170	.1	336	8.1	
8.2	1.8	.3	.5	149	120	.3	272	8.0	
14	1.8	.3	.7	163	120	.4	276	8.2	
17	1.0	.4	.9	230	224	.1	445	7.5	Ten Sleep town well.
19	1.8	.3	.3	237	220	.1	411	7.6	Do.
190	1.8	.4	.6	445	370	.7	696	7.7	
90	0	.6	0	306	270	.1	515	7.8	
32	2.2	.4	.4	235	210	.2	405	7.9	
200	0	.3	1.0	440	360	.1	640	7.8	
180	.7	.3	1.1	410	340	.1	620	7.7	
25	1.8	.3	.9	220	200	.1	392	8.0	
56	3.0	.6	0	262	212	.4	444	7.7	
97	1.8	.4	0	309	260	.1	507	7.9	
150	1.8	1.0	0	414	350	.1	640	7.8	
9.6	.8	.3	1.6	217	215	.1	395	7.8	Field pH; converted oil-test well.

Table 9. Chemical analyses of water from wells completed in the Paleozoic artesian aquifers—Continued

Location number	Depth of well (ft)	Water-yielding unit	Date of collection	Temperature (°C)	Dissolved silica (SiO_2)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)
47-89- 6abc	2,848	MDm	6-11-75	----	8.1	45	25	1.6	3.0	250	0
13aab	901	PPt	10-30-53	13.5	8.3	49	25	2.4	2.1	256	0
13aab	901	PPt	9-21-54	13	8.7	46	27	3.2	3.2	260	0
13aab	901	PPt	5-22-75	----	8.7	49	28	7.0	2.1	270	0
13aab	901	PPt	9-08-75	13.0	9.2	49	26	2.9	1.9	260	0
47-90- 8db	6,660	MDm,Ob	7-22-70	25	9.4	46	25	2.0	1.1	250	0
8db	6,660	MDm,Ob	10-21-71	----	---	46	26	5.0	---	258	---
48-88- 9acb	-----	PPt	11-09-53	10	8.9	56	24	2.0	1.4	290	0
9acb	-----	PMa,MDm	5-19-75	10	10	46	25	1.6	.5	270	0
28ccb	545(?)	PMa,MDm	6-12-75	12	9.2	45	25	1.6	2.6	270	0
28ccc2	725(?)	MDm	6-12-75	15	8.9	48	26	1.6	3.0	270	0
29baa	450	Pg,PPt	5-23-75	11	8.6	83	41	9.1	2.8	290	0
48-89- 4abb	470	Pg,PPt	5-15-75	13	8.6	200	40	19	4.4	230	0
4acd	1,362	MDm	5-14-75	----	8.6	47	24	.5	.9	240	0
4acd	1,362	MDm	9-09-75	13.5	9.4	44	23	2.3	.9	240	0
6dcb	3,933	MDm,Ob,Ꞓf	5-23-75	----	11	29	12	12	8.6	160	0
6dcb	3,933	MDm,Ob,Ꞓf	5-17-76	----	11	27	12	14	7.0	160	0
8dbc	3,987	MDm,Ob,Ꞓf	5-15-75	27.5	11	24	12	13	7.0	150	0
25acb	600	PPt,PMa	5-22-75	11.5	8.0	49	33	7.0	3.0	240	0
25acb	600	PPt,PMa	9-09-75	11.5	8.5	56	34	8.2	3.3	230	0
25ada	2,287	Mainly Ꞓf	5-22-75	----	9.2	23	20	8.6	4.9	180	0
25ada	2,287	Mainly Ꞓf	9-09-75	20.5	9.4	26	16	9.9	5.4	160	3
49-88-29daa	40	Pg(?),PPt	6-10-75	10.5	9.1	68	32	4.8	3.7	260	0
29dac	2,287	Mainly Ꞓf	5-13-70	20.5	9.5	24	15	3.8	3.0	149	0
29dac	2,287	Mainly Ꞓf	5-14-75	----	11	24	16	3.7	2.3	150	0
29dac	2,287	Mainly Ꞓf	10-07-75	----	10	32	17	3.5	1.9	170	0
49-89- 5bda	2,214	MDm	5-14-75	----	9.5	43	22	2.7	.7	230	0
5bda	2,214	MDm	9-09-75	18.5	10	39	21	2.3	1.2	210	0
6bcb	2,895	PMa,MDm	8-05-70	21	11	59	22	3.8	1.9	200	0
6bcb	2,895	PMa,MDm	6-12-75	----	9.8	50	25	4.8	2.3	230	0
21bda	431	Pg(?),PPt	11-10-53	----	9.6	52	21	2.6	1.6	229	0
24dcb	570	PPt,PMa, MDm,Ob(?)	11-03-53	10.5	9.9	80	33	7.2	2.2	259	0
24dcb	<1,480	PPt,PMa, MDm,Ob(?)	5-14-75	11.5	10	65	30	3.7	1.2	260	0
28baa	944	MDm	11-04-53	12	9.4	41	21	1.5	1.0	225	0
28baa	944	MDm	5-15-75	----	9.4	43	23	2.7	1.2	230	0
49-89-29abb	960	MDm,others	10-05-53	12	8.5	51	19	1.9	1.3	224	0
29abb	960	MDm,others	5-15-75	----	7.1	84	23	7.5	1.2	200	0
34dca	300±	PPt	6-10-75	----	7.0	46	26	5.4	4.9	230	0
34dca	300±	PPt	9-09-75	14.5	8.3	46	25	5.9	3.0	230	0
35bcb	-----	MDm	11-02-53	11	9.1	47	23	1.3	1.4	250	0
35bcb	-----	MDm	5-14-75	12	8.6	51	27	1.1	2.1	260	0
50-89-21aaa	50	PPt	5-12-76	----	8.3	45	15	3.5	.7	210	0
26cac1	160	PPt	9-11-47	----	18	52	25	5.5	4.0	262	0
26cac2	160	PPt	5-12-76	----	10	44	18	2.9	1.6	230	0
31bab	3,995	Mainly Ꞓf	5-14-75	20	11	25	19	5.9	4.7	170	0
31bab	3,995	Mainly Ꞓf	9-10-75	25.5	11	25	17	6.4	4.7	150	0
50-90-14bbd	1,625	Pg(?),PPt	11-07-53	13.5	8.2	59	32	8.9	1.7	199	0
14bbd	1,625	Pg(?),PPt	6-11-75	----	7.9	81	37	8.0	4.2	200	0
14cac	2,000(?)	PPt,PMa,MDm	11-05-53	14	7.9	89	47	12	3.0	176	0
14cac	2,000(?)	PPt,PMa,MDm	6-12-75	----	7.8	75	39	9.1	4.4	180	0
23cad	2,500	MDm,Ob	5-14-75	16.5	9.0	41	21	2.7	.7	220	0
23cad	2,500	MDm,Ob	9-10-75	15	9.4	39	19	2.9	.9	210	0
34dca	2,985	MDm,Ob	5-08-75	19	9.7	42	21	2.7	.7	220	0
34dca	2,985	MDm,Ob	9-10-75	20.5	9.7	39	20	3.5	.9	210	0

Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Dissolved fluoride (F)	Dissolved nitrate (NO_3)	Dissolved solids (sum of constituents	Hardness (Ca, Mg)	Sodium-adsorption ratio	Specific conductance (μS/cm at 25°C)	pH (units)	Remarks
19	1.8	0.3	1.3	229	220	0	394	7.7	
15	2.0	.4	.5	231	225	.1	421	7.3	
18	1.0	.3	.5	236	226	.1	421	7.7	Additional constituents in analysis.
29	3.6	.5	2.5	261	240	.2	460	7.8	
16	1.1	.4	.8	234	230	.1	417	7.9	
10	1.0	.3	1.3	219	218	.1	398	7.9	Field pH; oil test well.
11	7.0	---	---	222	---	.2	---	7.7	Analysis by U.S. Geological Survey, Casper laboratory.
2.0	2.5	.2	5.5	246	240	.1	450	7.5	Dual completion well.
4.9	1.8	.2	1.8	222	220	.5	396	7.9	Do.
5.8	0	.2	2.1	323	220	.5	403	7.9	
6.6	1.8	.3	2.1	231	230	0	411	7.6	
130	5.5	.7	3.7	428	380	.2	685	7.8	
490	5.5	.8	2.7	881	670	.3	1,150	7.7	
9.9	1.8	.3	1.5	213	220	0	367	7.8	
5.8	1.4	.2	2.2	206	200	.1	366	8.0	
25	1.8	.4	0	179	120	.5	321	8.1	
22	2.5	.5	.1	174	120	.6	302	8.3	Sampled at end of pipeline to ranch in sec. 17, T. 48 N., R. 89 W.
18	0	.4	0	161	110	.5	301	8.0	
74	1.8	1.1	2.1	299	260	.2	503	7.7	Deepened from 400 to 600 feet after 1962(?); repaired hole in casing in 1974.
100	1.8	1.1	2.5	232	280	.2	547	7.8	Do.
19	1.8	.4	.3	175	140	.3	295	8.0	
12	1.8	.3	.4	165	130	.4	291	8.4	
81	3.6	.2	9.6	340	300	.1	559	7.8	
12	1.5	.2	.2	142	122	.2	273	8.2	
14	1.8	.3	.4	148	130	.1	255	8.0	
8.2	0	.3	1.1	159	150	.1	292	8.0	
9.1	1.8	.2	1.8	202	200	.1	335	7.9	
6.6	1.8	.2	1.5	188	180	.1	332	7.9	
74	1.3	.3	2.3	274	238	.1	438	8.2	Hyattville town well.
54	1.8	.4	2.2	261	230	.1	452	7.8	Do.
25	2.0	.3	1.8	229	215	.1	400	7.5	Nonflowing well.
118	5.5	.5	8.8	393	337	.2	636	7.4	
59	3.6	.3	4.0	305	280	.1	510	7.8	Deepened to 1,480 feet before 1970 but well caved with loss of flow.
2.0	.5	.2	2.0	190	188	0	354	7.5	Converted oil test well.
15	1.8	.2	1.9	210	200	.1	366	7.8	
25	2.0	.3	1.9	222	207	.1	391	7.5	
160	0	.3	.1	383	310	.2	613	8.1	
39	2.9	.9	3.3	246	220	.2	426	7.8	
38	1.8	.8	4.0	244	220	.2	422	8.0	
4.0	2.5	.2	1.7	213	213	0	390	7.6	
15	1.8	.3	1.1	237	240	0	404	7.7	Casing rusted out.
6.6	1.8	1.6	.8	189	170	.1	344	7.9	
8.6	2.0	.2	28	272	233	.2	476	7.9	
5.8	.7	.3	1.1	197	180	.1	362	8.1	
15	1.8	.3	.5	165	140	.2	282	8.1	
18	1.8	.2	.6	161	130	.2	281	8.1	
119	2.5	.4	3.1	335	278	.2	547	7.7	Converted oil test well.
210	3.6	.6	2.8	448	360	.2	678	7.8	
272	2.5	.8	4.6	526	416	.3	774	7.3	
220	1.8	.8	3.1	445	350	.2	681	7.7	
4.1	1.8	.2	1.2	191	190	.1	326	7.9	
4.1	1.8	.1	2.5	180	170	.1	322	8.2	
8.2	0	.2	2.2	197	190	.1	328	7.9	
4.9	1.8	.2	2.5	183	180	.1	329	8.1	

METRIC CONVERSION FACTORS

For the readers who prefer to use metric units, conversion factors for terms used in this report are listed below:

Multiply	By	To obtain
Area		
acre	0.4047	hectare
Length		
inch (in)	25.40	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
Volume		
acre-foot (acre-ft)	0.001233	cubic hectometer
Gradient		
foot per mile (ft/mi)	0.1894	meter per kilometer
Discharge		
gallon per minute (gal/min)	0.00006308	cubic meter per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year
Specific capacity (of well)		
gallon per minute per foot (gal/min)/ft	0.00006308	cubic meter per second per meter
Transmissivity (of aquifer)		
foot squared per day (ft^2/d)	0.09290	meter squared per day
Pressure[1]		
pound per square inch (lb/in^2)	6.895	kilopascal

Temperature can be converted to degrees Fahrenheit (°F) or degrees Celsius (°C) by the following equations:

$$°F = 9/5\,(°C) + 32$$
$$°C = 5/9\,(°F - 32)$$

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1 For calculating potentiometric head, pressures measured at wellheads are converted to an equivalent height of water above the measuring point using: (lb/in^2) v 2.31 = 1 foot (of water)

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