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GROUND-WATER RESOURCES AND GEOLOGY OF THE WIND RIVER BASIN AREA, CENTRAL WYOMING

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INTRODUCTION

This investigation of the ground-water resources of the Wind River basin area was made in cooperation with the Wyoming State Engineer to obtain general information of the quantity and quality of ground water that is being used, and to determine the possibility of additional development of ground-water resources.

Data for many wells were obtained from records of the Bureau of Land Management and from water-well drillers operating in the area; however, when possible, depths to water and depths of wells were measured by the authors. A reconnaissance sampling of water from wells provides general information of the chemical quality of water in the aquifers.

The geologic map was adapted and generalized from a preliminary map compiled by W. R. Keefer, Toni D. Dunrud, and R. L. Koogle from previous geologic investigations in the Wind River Basin. The authors are grateful for permission to use this map, in advance of publication of the more detailed map in a U.S. Geological Survey professional paper. Descriptions of stratigraphic units on sheet 3 were abstracted largely from published works, which are listed in the selected references. A ground-water study of the Riverton irrigation project (Morris, D. A., and others 1959), an area of about 470 square miles, provided much of the hydrologic data in that part of the project area.

The project area of this report consists of about 12,000 square miles in central and west-central Wyoming and includes all of Fremont County and parts of western Natrona and northern Carbon Counties. Altitudes in the Wind River Basin range from about 4,600 feet where the Wind River enters the Wind River Canyon to 13,785 feet on Gannett Peak in the Wind River Mountains, the highest point in Wyoming. The average altitude in the Basin is about 5,500 feet, although numerous isolated mountains and escarpment of Beaver Rim rise several hundred feet above the general surface. South of Beaver Rim, altitudes range from about 5,500 feet at the confluence of the Sweetwater and Platte Rivers to about 9,500 feet on the crest of the Ferris Mountains.

Perennial streams in the Wind River Basin are the Wind, Little Wind, and Popo Agie Rivers, whose tributaries rise on the flanks of the Wind River, Washakie, and Owl Creek Mountains and drain most of the area north of Beaver Rim (about two-thirds of the region). The North Platte River and its tributary, the Sweetwater River, drain the region south and east of Beaver Rim. The northeastern part of the project area is drained by the Powder River. Streams rising within the Basin, such as the Powder River, generally are intermittent or ephemeral, flowing in response to sporadic precipitation.

The climate ranges from humid in the Wind River and Owl Creek Mountains to arid in the central part of the area and seasonal temperatures and precipitation vary greatly. The mean annual temperature at Riverton, the most centrally located weather-reporting station in the Basin, was 43.6°F (1931–63); winter temperatures frequently drop below 0°F for short periods, and summer temperatures commonly exceed 100°F. During the same period (1931–63), the annual precipitation at Riverton ranged from 4.85 to 14.74 inches, and the average annual precipitation was 8.55 inches. The average annual precipitation (1953–63) at Shoshoni, in the northern part of the Basin, and at Lander, at the base of the Wind River Mountains, was 5.5[illegible] and 12.63 inches, respectively.

GENERAL GEOLOGIC FEATURES

The Wind River Basin is a large structural depression (structural feature map). Large scale overthrusting, or reverse faulting, accompanied uplift along the northern and eastern margins of the Basin, particularly along the southern flank of the Owl Creek Mountains (Geologic section) and the western limb of the Casper arch. As the Basin subsided with reference to the bordering mountains, several thousand feet of Tertiary deposits accumulated within the depression. The thickest accumulations were along the northern (Geologic section) and eastern margins (Keefer, 1965a, p. A6). Strata of pre-Tertiary age, which are exposed largely around the periphery of the Basin, dip basinward at angles ranging from 10° to 20° on the flanks of the Wind River Mountains

to vertical or overturned along the base of the Owl Creek Mountains.

That small part of the project area south of the Sweetwater uplift is not a part of the Wind River Basin proper, but was included to join a hydrologic atlas of the Great Divide and Washakie Basins (Welder and McGreevy, 1966, sheet 1). The area south of the Granite Mountains is underlain by strata that have been extensively folded and faulted by the southwestward overthrusting of the Granite Mountains block, which marks the axis of the Sweetwater uplift.

The stratigraphic section and geologic map are generalized for the purposes of this report. The geology of most of the area has been mapped previously in considerable detail, and the reader is referred to the list of selected references for publications giving more complete descriptions.

GROUND WATER

Ground water occurs under both artesian and water-table conditions. Artesian conditions are prevalent in the Wind River Formation and in older sedimentary rocks. These older formations, except for the massive sandstone and limestone that occur near the base of the sequence, consist largely of nearly impermeable shale and siltstone interbedded with relatively permeable sandstone. Water in an unconfined (water-table) condition occurs in the outcrop areas of artesian aquifers, in the Arikaree Formation, and in alluvial and windblown sand deposits.

The physical and water-bearing characteristics of the geologic formations in the project area are summarized on sheet 3. The following discussion of the occurrence of ground water in the aquifers supplements that table and is based largely on records of wells and drillers' logs. Because the younger rocks are generally more important aquifers, rock units are discussed from youngest to oldest. There has been little development of ground water in the older rocks because of their considerable depth below land surface in most of the basin. Conclusions regarding the older rocks are based principally on data from other areas. In this report, the comparative terms "small," "moderate," and "large," as applied to quantities of water, are given arbitrary values of less than 50 gpm (gallons per minute), 50–300 gpm, and more than 300 gpm, respectively.

ROCKS OF QUATERNARY AGE

Alluvial deposits (Qal on geologic map) in the valleys of perennial streams that head in the Wind River and Owl Creek Mountains contain coarse sand and gravel beds that are capable of yielding moderate to large quantities of water to wells penetrating a sufficient saturated thickness. Lander obtains an estimated 4,000 gpm from a collection gallery using 1,600 feet of 24-inch perforated pipe buried in the alluvium of the Middle Popo Agie River about 3 miles southwest of the city. A shallow well in the alluvium of the Little Wind River at Ft. Washakie reportedly produced 40 gpm with a drawdown of only 0.5 foot during a 5½-hour pumping test. Alluvial deposits of perennial streams have not yet been developed as a source of water for irrigation, because surface-water supplies generally are adequate for present needs.

Alluvial deposits along ephemeral and intermittent streams that rise within the basin generally consist of fine to coarse sand intermixed with silt and clay and normally yield to wells only enough water for stock or domestic supplies. Recharge is mainly from precipitation on the drainage area, and the amount of ground water available to wells fluctuates accordingly. During prolonged dry periods, yields of wells may become inadequate, or the wells may go dry.

Test holes augered across the valley of the Sweetwater River (Lithologic sections) penetrated a maximum thickness of 63 feet of saturated material consisting predominantly of coarse sand and gravel, and test holes augered in the alluvium of Kirby Draw penetrated as much as 45 feet of saturated material. Alluvial deposits along Muddy and Fivemile Creeks, tributaries to the Wind River, average 30 feet and 40 feet in thickness, respectively, and contain a large proportion of gravel (Morris and others, 1959, p. 38). The alluvium along the Wind and Little Wind Rivers and the lower reach of the Popo Agie River is generally less than 45 feet thick. An irrigation well in the valley of the Middle Popo Agie River near Lander, however, penetrated 45 feet of sand and gravel, apparently without reaching bedrock.

Terrace deposits contain extensive bodies of ground water in areas where surface water has been applied for irrigation. Wells drilled in these areas generally yield adequate quantities of water for stock or domestic supplies, although yields fluctuate in response to irrigation, and some of the shallower wells go dry or yield inadequate supplies during the winter. Wells rarely penetrate the full thickness of the deposits, and deeper drilling in most cases would assure a more dependable supply. The construction of deeper wells, however, is complicated by the difficulty of drilling through the cobble and boulder beds that occur in some places.

The chemical quality of water in alluvial depos-

its differs from place to place, depending on the source and amount of recharge, and the type of bedrock underlying the alluvium. Water in the flood-plain deposits of perennial streams is generally good in the upper reaches of the stream, but the quality deteriorates downstream. A well drilled in the alluvium of the Wind River valley in the NW¼NW¼ sec. 13, T. 2 N., R. 1 E. yields a calcium bicarbonate water that contains 272 ppm of dissolved solids; whereas, a well in the SE¼ SW¼ sec. 31, T. 1 N., R. 4 E., about 16 miles downstream, yields a sodium sulfate water that contains 1,230 ppm (parts per million) of dissolved solids. Water samples from two shallow dug wells in the alluvium at the confluence of the Little Popo Agie and Popo Agie Rivers which supply the town of Hudson were of a similar chemical type but contained 743 and 1,430 ppm of dissolved solids, respectively. The well yielding the better quality water taps alluvial deposits that are recharged largely by water from the Popo Agie River and a nearby irrigation ditch; whereas, the other well yields water that probably is derived, in part, from infiltration of irrigation water. The water is more mineralized because it has more contact with soluble material in the soils. The water quality reportedly fluctuates seasonally and is best during late spring when streamflow is augmented by snowmelt in the headwaters. The quality gradually deteriorates as the irrigation season progresses.

The quality of water in the alluvium of the Sweetwater River valley is similar to that in the underlying Arikaree Formation, which apparently contributes much of the recharge to the alluvium (Lithologic sections).

Water from the alluvial deposits underlying the Riverton irrigation project area, including the ground-water discharge into Ocean Lake and Fivemile Creek, generally is highly mineralized and unsuitable for domestic and irrigation use and often marginal for stock use. Water in these alluvial deposits is derived mostly from irrigation water. Ocean Lake occupies a natural basin that was gradually filled by the rising water table after irrigation began in the area.

Ground water in the flood-plain deposits of intermittent and ephemeral streams in the project area is likely to be moderately to highly mineralized. Water samples from two test holes augered in Kirby Draw had dissolved-solids contents of 1,460 and 4,090 ppm, and a sample from an augered test hole in the valley of Beaver Creek had a dissolved-solids content of 1,300 ppm. A 240-foot well drilled in the Wind River Formation at Moneta yields water that is believed to be contaminated by water from the alluvium of Poison Creek; it had a dissolved-solids content of more than 3,000 ppm. A well of similar depth about 300 feet away yields water from the Wind River Formation that had a dissolved-solids content of 1,790 ppm.

Springs issuing from terrace deposits along the Wind River in the northwestern part of the project area, principally in the vicinity of Dubois, yield as much as 500 gpm. The source of much of the water is leakage from irrigation ditches and seepage from irrigation water applied on the terraces, because the yields of the springs fluctuate widely and are greatest during the irrigation season. The water is of good quality, and some of the smaller springs have been developed for domestic supplies.

Deposits of windblown sand (Qs on geologic map) in the northeastern part of the project area are important sources of small quantities of ground water where the deposits are underlain by rocks of low permeability, or by rocks that yield water of poor quality. Yields from the windblown sand are small, but generally adequate for stock or domestic supplies, and the water is of good quality. The water in the windblown sand deposits is derived principally from local precipitation.

ROCK OF TERTIARY AGE

The Arikaree Formation contains water under water-table conditions, and depths to water are governed largely by the local topography—a well drilled in a topographically low area will penetrate the water table at a shallower depth than a well drilled on a nearby hillside or ridge crest. Depths of wells range from 40 to 850 feet and average about 190 feet. Depths to water range from 6 to 374 feet and average 92 feet. About 70 percent of the wells penetrate less than 100 feet of the saturated zone in the Arikaree Formation and 40 percent penetrate less than 50 feet.

Yields of wells in the Arikaree Formation differ greatly, depending on the permeability of the water-bearing material, the depth of penetration, and well construction. Some outcrops of the Arikaree indicate that fractures may greatly increase the permeability of the formation in some areas.

Logs of stock wells drilled in the formation in the upland areas bordering the Sweetwater River valley generally show a fine-grained friable sandstone interbedded with subordinate amounts of shale. Bailing tests made when the wells were completed indicate that most of these wells yield less than 0.5 gpm per foot of drawdown. The low yield of some wells may be attributable to sand invading the casing and thereby reducing the entrance area for water. Logs of two industrial wells

drilled in the Sweetwater River valley near Jeffery City describe fine-grained sandstone underlain by a "sandstone conglomerate" that yielded 800 and 1,100 gpm during 24-hour pumping tests. The specific capacities of the wells were 9 and 15 gpm per foot of drawdown, respectively.

Water from the Arikaree Formation is characteristically a calcium bicarbonate type and is good for most uses though generally hard. The specific conductances of water from most of the wells tested were less than 500 micromhos per centimeter, indicating a dissolved-solids content of less than 350 ppm. The relation of dissolved solids to specific conductance for most of the water samples from the Arikaree Formation averaged about 0.67.

The Wagon Bed and White River Formations have not been extensively developed as sources of ground water because, except in small areas of outcrop, they are overlain by aquifers that yield adequate supplies to stock and domestic wells. The Wagon Bed Formation, which is exposed only in the Beaver Rim escarpment, yields a highly mineralized (2,590 ppm) magnesium calcium sulfate water to one spring. The sample contained 0.01 ppm selenium. Several wells drilled in White River outcrops on Beaver Divide have yields that are comparable to those of wells tapping the Arikaree Formation, and the chemical quality of the water is similar.

The Wind River Formation consists largely of an interbedded sequence of shale and siltstone that contains lenticular beds of fine- to coarse-grained sandstone of variable thickness and extent. The coarser material is more abundant along the margins of the Wind River Basin. The altitude of the piezometric surface may differ appreciably between individual sandstone beds, indicating there is little hydrologic connection between them.

Depths of 173 wells in the Wind River Formation range from 50 to 1,200 feet, and the average depth is about 250 feet. Water levels in 136 wells range from flows at the land surface to depths of 480 feet, and the average depth to water is about 80 feet. Most stock and domestic wells yield only small quantities of water because drilling usually is terminated when an adequate supply is assured. Specific capacities of 52 stock wells, determined from bailing tests made when the wells were completed, ranged from 0.02 gpm (essentially a dry hole) to 2.25 gpm per foot of drawdown. The average specific capacity was 0.48 gpm per foot of drawdown.

The Riverton and Shoshoni municipal wells yield water from the Wind River Formation. Pumpage from the Riverton well field (11 wells 500 to 600 feet deep) in 1965 was 493,240,000 gallons. Most of the pumps are set to yield about 200 gpm, but not all of them are operated at the same time except during the summer. The drawdown at this pumping rate is not known, but a 450-foot well drilled in the Wind River Formation in the SE¼SW¼ sec. 4, T. 1 S., R. 4 E., had a drawdown of 167 feet after being pumped 129 hours at an average rate of 350 gpm. The specific capacity was 2.1 gpm per foot of drawdown. The two wells that supply the town of Shoshoni are about 500 feet deep; one of the wells had a water level about 17 feet below the land surface in 1951. In 1954, the wells were individually pump tested at 300 gpm for 48 and 72 hours; drawdowns in the wells were 194 and 242 feet, respectively, and the specific capacities were 1.55 and 1.24 gpm per foot of drawdown. A well in the SW¼NE¼ sec. 29, T. 38 N., R. 94 W., not shown on figure 4, 446 feet deep, had a drawdown of 111 feet at a sustained yield of 250 gpm—a specific capacity of 2.25 gpm per foot of drawdown—when tested in 1951.

Several wells in the Gas Hills area produce water from the Wind River Formation for industrial and domestic supplies. Depths of the wells range from about 100 to 400 feet, and reported depths to water range from 20 to 125 feet. A well in the NE¼NE¼ sec. 32, T. 33 N., R. 90 W., 200 feet deep, had a reported specific capacity of 20 gpm per foot of drawdown after 18 hours of pumping, and a 415-foot well in the SE¼SW¼ sec. 28, T. 33 N., R. 90 W. had a reported specific capacity of 10 gpm per foot of drawdown after 16 hours of pumping. Several other wells yield 250 to 350 gpm, but drawdowns are not known.

The quality of water in the Wind River Formation differs throughout the project area. Analyses of water samples (table 1) from 34 wells indicate that water in the Wind River Formation is predominantly a sodium sulfate (17 samples) or calcium sulfate (8 samples) type. Six samples were sodium bicarbonate type and three were calcium bicarbonate. Concentrations of dissolved solids range from 284 to 4,530 ppm; however, 63 percent of the samples contained less than 1,000 ppm of dissolved solids. Specific conductances of water from 56 additional wells indicate that 64 percent yield water containing less than 1,000 ppm of dissolved solids. Water of lowest mineralization was generally from wells that are more than 250 feet deep. To convert specific conductance to dissolved-solids concentration, a factor of 0.72 generally is applicable for water from the Wind River Formation.

Water from the Wind River Formation in the Gas Hills area is consistently a calcium sulfate

type and is very hard, and water from the formation in the Riverton area is chiefly a sodium bicarbonate type and is very soft. Uraniferous zones in the formation in the Gas Hills area yield water that contains dangerous amounts of radioactivity, and water should be analyzed before it is used for a domestic or stock supply. Selenium, which is reportedly present in ground water in some parts of the Wind River Basin, was not detected or showed only a trace in samples analyzed for selenium. Several samples contained undesirable amounts of fluoride for domestic use. The high percentage of sodium in most of the water samples indicate that water from the Wind River Formation is generally unsuitable for irrigation except on soils of good permeability that have adequate drainage.

The Fort Union Formation is known to yield water to several wells in the project area, and there are probably other wells in the formation that were not visited by the authors. A well in the SE¼ sec. 36, T. 36 N., R. 86 W. penetrates about 600 feet of the formation and yields 15 gpm of water that has a specific conductance of more than 2,500 micromhos per centimeter and contains a high concentration of iron. A well in the NW¼ sec. 9, T. 1 S., R. 2 E. is 430 feet deep and yields about 2 gpm of water that has a dissolved-solids content of 995 ppm (table 1). The water is a sodium bicarbonate type and contains high concentrations of chloride and fluoride. Two deep oil tests drilled in T. 36 N., R. 90 W. reportedly found water of good quality (746 and 1,068 ppm dissolved solids) in the Fort Union and underlying Lance Formation (table 1). Moderate to large yields might be developed from the Fort Union in some areas, but the cost of the deep wells probably would be prohibitive for most uses.

The Wiggins, Tepee Trail, Aycross, and Indian Meadows Formations, and undifferentiated rocks of Tertiary age, might yield moderate to large supplies of water from coarse sandstone and conglomerate beds that are widely distributed in the formations. These rocks have not been tested as potential sources of ground water, but the Battle Spring Formation (included in Tu on geologic map), which crops out in the south central part of the area, is considered to be a potential source of large quantities of ground water in the Great Divide Basin (Welder and McGreevy, 1965).

ROCKS OF CRETACEOUS AGE

Rocks of Cretaceous age consist principally of shale containing minor amounts of fine-grained silty sandstone and siltstone and, except near the margins of the Wind River Basin or in areas of local uplift, lie at great depths. Although water in these formations is generally under artesian pressure and water levels in wells are likely to be near the surface, Cretaceous rocks commonly are not considered good aquifers because of their generally low permeability and poor quality of the water. The few wells that penetrate Cretaceous strata are where a better source of water is not economically available. The Lance and Cloverly Formations may be exceptions to this generalization, however, but areas in which the formations lie within economical drilling depths are small.

The Cloverly Formation is the principal source of domestic water in some parts of the Gas Hills area because water from the shallow aquifers often contains large amounts of radioactive material. The wells range in depth from 484 feet in the NW¼NW¼ sec. 15, T. 33 N., R. 89 W. to 1,720 feet in the NE¼NE¼ sec. 22, T. 33 N., R. 90 W. and reportedly yield from 45 to 350 gpm. The water is under artesian pressure, and water levels in wells range from 28 to 356 feet below the land surface. Drawdowns generally are great, and the specific capacities of the wells average only about 0.25 gpm per foot of drawdown. The water is a sodium sulfate or sodium bicarbonate type and dissolved-solids concentrations are generally less than 1,000 ppm (table 1).

No wells in the project area are known to yield water solely from the Lance Formation. Wells drilled in the Lance in the adjacent Powder River Basin generally yield supplies adequate for stock and domestic use, but the water is usually too mineralized for a desirable domestic supply.

Water from the few wells in the project area that tap the Mesaverde Formation, Cody Shale, or Frontier Formation is generally unfit for domestic use, and in some wells it is so unpalatable that stock will not drink it. Wells that were sampled yield a sodium sulfate or sodium bicarbonate water. One sample from the Frontier Formation contained 3.8 ppm of fluoride.

ROCKS OF PRE-CRETACEOUS AGE

Formations underlying rocks of Cretaceous age are deeply buried throughout most of the project area. They form narrow outcrops on the flanks of the Wind River, Owl Creek, and Bighorn Mountains and in some of the major anticlinal structures within the basin. Few wells in the project area penetrate these formations because drilling depths are great, except in or near the outcrops.

The Morrison Formation yields water to only three of the wells inventoried during the investigation. A 215-foot well drilled on the axis of a plunging anticline in the SW¼SE¼ sec. 23, T.

33 N., R. 99 W. probably taps the Morrison Formation. It flows about 5 gpm and yields a soft sodium sulfate water that contains 1,720 ppm dissolved solids. Two wells drilled in Morrison outcrops in the foothills of the Wind River Mountains (SE¼NE¼ sec. 24, T. 1 S., R. 2 W. and SE¼SE¼ sec. 26, T. 33 N., R. 100 W.) are 41 feet and 98 feet deep and reportedly yield 12 gpm and 20 gpm; the drawdown at these pumping rates are not known. The water contains only about 420 ppm of dissolved solids. A sample from one of the wells was a calcium sulfate type and very hard.

The Sundance Formation probably is the source of water for a 350-foot well drilled in the NW¼ NE¼ sec. 34, T. 32 N., R. 99 W. The well yields 6 gpm with 150 feet of drawdown, and the water is a sodium sulfate bicarbonate type that contains 799 ppm of dissolved solids. Water samples from both the Morrison and Sundance contained undesirable concentrations of fluoride. The Gypsum Spring Formation is likely to yield water that is highly mineralized and unfit for most uses.

Little is known of the potential yield of the Nugget Sandstone, but examination of outcrops suggests that the formation would yield at least moderate quantities of water where the formation is saturated, and perhaps large amounts if the rock is fractured. The only well in the Nugget that was inventoried during the investigation is in the outcrop in the SE¼SW¼ sec. 24, T. 1 S., R. 1 W. and taps about 25 feet of saturated material. The well reportedly yielded 10 gpm with a drawdown of 2.5 feet during a 2-hour pumping test. The indicated specific capacity (4 gpm per foot of drawdown) is somewhat larger than would be expected unless the rock were fractured or weathered. No water samples were obtained from the Nugget Sandstone, but it should be of good chemical quality in or near the outcrop.

The Chugwater Formation should yield at least small quantities of water to wells, but its potential yield is not known because only two of the wells inventoried produce solely from the formation. The well in sec. 26, T. 1 S., R. 2 W. is 56 feet deep and yielded 9 gpm with a drawdown of 2 feet during a 2-hour pumping test. If the reported test data are reliable, the formation at this site probably is fractured; the apparent specific capacity is much greater than can be expected at most places. Normally, a specific capacity of 1 gpm or less per foot of drawdown can be expected. Wells penetrating a great saturated thickness might yield moderate quantities of water, but pumping lifts probably would be proportionately great. The chemical quality of water in the Chugwater Formation is not known, but it should be suitable for stock use in or near areas of outcrop.

The Park City formation and equivalents apparently yield large quantities of water from two wells in T. 30 N., Rs. 96 and 97 W. One well, which is 269 feet deep, flows a reported 700 gpm from the upper 45 feet of the Park City and equivalents; the yield was increased to 900 gpm with a booster pump in the line to supply water for a road construction project. The other well is 408 feet deep, penetrates 258 feet of the formation, and has a water level that is about 50 feet below the land surface. It yields 150 gpm with a drawdown of about 17 feet. These higher yields from the Park City and equivalents are, undoubtedly, due to fractures and solution cavities in the formation, because normally the interbedded limestone, dolomite, and sandstone are relatively impermeable. The abnormally high temperature (71°F) of water from the flowing well suggests that the source of the water is not from local recharge to the Park City and equivalents but that it is coming from a deeper zone, perhaps the Tensleep Sandstone. The water from these wells is a calcium sulfate type. The dissolved-solids content ranges from 877 ppm to 1,020 ppm, and the water is very hard.

The Tensleep Sandstone yields water to several wells in the central and western parts of the project area, and probably is the source of the water issuing from Chief Washakie Hot Spring in the NE¼ sec. 2, T. 1 S., R. 1 W. Three wells in the Gas Hills area drilled for industrial and domestic supplies range from 1,362 to 1,685 feet in depth. The wells penetrate 63 feet, 94 feet, and 250 feet of Tensleep, and the reported specific capacities are 270 gpm, 2 gpm, and 12 gpm per foot of drawdown, respectively.

Two irrigation wells 700 and 900 feet deep in the foothills of the Wind River Mountains in T. 33 N., Rs. 100 and 101 W. reach the Tensleep Sandstone at depths of 400 and 500 feet, respectively. The shallower well had a measured flow of 75 gpm, and the other had a reported flow of 100 gpm. The well in the NE¼SW¼ sec. 25, T. 3 N., R. 100 W. drilled to supplement the Lander municipal supply is 3,334 feet deep and reportedly flowed 539 gpm from the uppermost 300 feet of Tensleep when completed in 1942. An oil test drilled to a depth of about 2,800 feet on the north end of Dallas Dome, about 6 miles southeast of Lander, had an estimated flow of about 500 gpm from the Tensleep. Chief Washakie Hot Spring reportedly flowed about 1,200 gpm in 1945. A large spring in the NW¼ sec. 15, T. 32 N., R. 81 W. flows 7,500 gpm from a sandstone in the Casper Formation

that may be, in part, the equivalent of the Tensleep Sandstone. The large-yield springs and the most productive wells are associated with local structures where fracturing and solution have increased the permeability of the formations.

The two water samples from the Tensleep in the Gas Hills area were a calcium sulfate and calcium sodium sulfate type and had a dissolved-solids content of 1,010 and 1,418 ppm, respectively. Samples from water wells and from several oil-test holes in the western part of the project area are a calcium bicarbonate type, and dissolved-solids concentrations range from 205 to 245 ppm. Chief Washakie Hot Spring yields water that is a calcium sulfate type, and has a dissolved-solids content of 801 ppm. Water sampled from the Tensleep is suitable for irrigation, and except for the water from the Gas Hills wells and from Chief Washakie Hot Spring, which has undesirable concentrations of sulfate and fluoride, is suitable for domestic use, though generally hard. The presence of hydrogen sulfide in water from most wells causes the water to be unpalatable until it has been aerated. The water from the spring in the Casper Formation is a calcium bicarbonate sulfate type and has a dissolved-solids content of 387 ppm.

The Madison Limestone yields water to an industrial well in the NW¼NW¼ sec. 13, T. 30 N., R. 99 W. The well is 1,627 feet deep, and reached the top of the Madison at a depth of 1,013 feet. The water level is 446 feet below the land surface. The Madison at this location has a low permeability and yielded only 130 gpm with a drawdown of 900 feet (a specific capacity of 0.13 gpm per foot of drawdown). In many areas, outcrops of the Madison contain cavernous zones that were developed by the solvent action of water. A spectacular example of cavern development is in Sinks Canyon west of Lander where the normal flow of the Middle Popo Agie River disappears into an opening in the Madison and reappears about half a mile downstream. Where fractured and cavernous zones are saturated, they will yield large quantities of water to wells penetrating them. Flows of as much as 2,500 gpm are obtained from some irrigation wells drilled into the Madison Limestone near Hyattville, in the eastern part of the Bighorn Basin (Lowry, M.E., 1962, table 1).

The one water sample from the Madison Limestone was a calcium bicarbonate type and contained 397 ppm of dissolved solids. The water is suitable for domestic use but very hard. Mineralization of water in the formation normally will increase with depth and with distance from the outcrop, but the water should be suitable for most uses where the Madison lies at economical drilling depths.

Formations underlying rocks of Mississippian age in the project area are either deeply buried or crop out in inaccessible areas and, therefore, have not been tapped by wells. Numerous springs issue from pre-Mississippian rocks in the mountains. The water is of good quality (less than 300 ppm of dissolved solids), as indicated by field measurements of specific conductance. The chemical analysis of one sample from a spring issuing from Precambrian granite shows that the water is a sodium bicarbonate type with a dissolved-solids content of 267 ppm.

POTENTIAL SOURCES OF LARGE SUPPLIES OF WATER

Alluvial deposits in the valleys of the Wind, Little Wind, Popo Agie, and Sweetwater Rivers would yield moderate to large supplies of ground water, but surface-water supplies along these streams are generally adequate to meet existing irrigation needs. The quality of the ground water is generally inferior to that of surface water and in some areas, such as the Riverton irrigation project area, it may be unsuitable for some types of irrigation.

The Wind River and Arikaree Formations contain permeable zones that are capable of yielding large supplies of water to wells at depths of less than 500 feet, and yields of most wells could be increased by deeper drilling. Large yields are obtained from coarse deposits in the Wind River Formation along the margin of the basin and in the Arikaree Formation near granite outcrops. Unconsolidated zones, particularly in the Arikaree, are potential sources of large supplies of water, but special drilling and completion techniques may be required to properly develop wells in them. Many wells have been terminated in these zones because of the difficulty in keeping the hole open when special drilling and casing techniques are not used.

Water from the Wind River Formation ranges widely in quality, but it apparently improves with depth. However, the deepest well known to yield water from this formation is only 1,200 feet deep and the quality-depth relation may not extend to greater depths. Water from the Arikaree Formation is suitable for most purposes.

Large supplies of water can be obtained locally from sandstone and limestone formations in zones of secondary permeability (permeability due to fracturing or solution). Several large yielding springs and wells derive water from the Park City and equivalents and Casper Formations and from the Tensleep Sandstone. A well tapping the Nugget Sandstone and a well tapping the Chugwater

Formation had yields larger than expected for the aquifer, suggesting secondary permeability. Fractures observed in outcrops of the Arikaree, if present at depth, would yield large supplies of water to wells.

WATER QUALITY CRITERIA

Criteria have been established for determining the suitability of water for different uses, but in many parts of the project area, water is utilized that does not meet the suggested suitability standards.

The U.S. Public Health Service (1962) has recommended the following standards for water used for drinking and culinary purposes on interstate carriers:

Constituent	*Recommended maximum concentration (ppm)*
Iron (Fe)	0.3
Manganese (Mn)	.05
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride (F)	.8–1.7
Dissolved solids	[1] 500

[1] 1,000 ppm where water of better quality is not available.

Hardness in water is caused principally by calcium and magnesium in solution. It is classified as follows: 60 ppm or less, soft; 61–120 ppm, moderately hard; 121–180 ppm, hard; and more than 180 ppm, very hard.

Studies at the Wyoming Agricultural Experiment Station have resulted in the following classification of the suitability of water for stock (Beath and others, 1953).

Dissolved solids (ppm)	*Classification*
Less than 1,000	Good.
1,000 to 3,000	Fair (usable).
3,000 to 5,000	Poor (usable).
5,000 to 7,000	Very poor (questionable).
More than 7,000	Not advisable.

The most significant properties that affect the suitability of water for irrigation are the dissolved-solids content (salinity hazard), the percent sodium, and the sodium concentration relative to the calcium and magnesium concentrations (sodium-adsorption ratio). The salinity hazard of a water having a specific conductance of less than 250 is low; 250–750, medium; 750–2,250, high; and greater than 2,250, very high (U.S. Salinity Lab. Staff, 1954, p. 80). Water in which the concentration of sodium is appreciably greater than 50 percent of the total cations is of limited suitability for irrigation, and the limitations increase as the sodium percentage increases.

The sodium-adsorption ratio is a refinement of the percent sodium criterion, and is more significant in the evaluation of the suitability of water for irrigation. The following approximate relation between sodium-adsorption ratio (SAR) and the sodium (alkali) hazard in water of high sodium content for irrigation has been established by the U.S. Salinity Laboratory Staff (1954, fig. 25).

SAR (approx)	*Sodium (alkali) hazard*
0–10	Low.
10–18	Medium.
18–26	High.
More than 26	Very high.

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TABLE 1.—*Chemical analyses of ground water in the Wind River basin area, central Wyoming*

[Analyses by U.S. Geological Survey except as indicated. Analytical results in parts per million except as indicated]

Location: Section	Location: T.	Location: R.	Depth (feet)	Principal producing interval (feet)	Date of collection	Temperature (° F)	Silica (SiO_2)	Total iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Residue on evaporation at 180° C	Dissolved solids: Sum	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25° C)	pH	Sodium adsorption ratio	H_2S, hydrogen sulfide Se, selenium, in ppm
Precambrian granite																												
SE¼NE¼, 16	30 N.	90 W.	Spring	--------	7-21-65	46	25	[1] 0.00	20	5.2	66	4.6	206	0	36	7.1	1.0	1.3	0.14	252	267	71	0	65	405	6.7	3.4	
Madison Limestone																												
NW¼NW¼, 13	30 N.	[2] 99 W.	1,627	1,013–1,500	4- 8-65	----	----	0.2	93	37	3	1	275	0	7	117	----	1	----	--------	397	------	------	----	--------	7	------	
Tensleep Sandstone																												
SE¼NE¼, 2	1 S.	1 W.	Spring	--------	5-18-45	116	34	------	162	41	49	----	290	0	362	41	2.6	0.1	----	--------	801	573	336	16	1,180	7.3	0.9	H_2S.
NW¼SW¼, 18	33 N.	89 W.	1,668	1,574–1,668	7-16-64	101	21	0.23	158	40	93	20	222	0	482	79	3.1	.0	0.32	1,060	1,010	559	377	----	1,430	7.0	------	H_2S.
SW¼NW¼, 24	33 N.	90 W.	1,362	1,050–1,362	1-15-64	131	38	.01	208	38	170	29	144	0	710	143	2.4	.0	----	1,440	1,418	699	581	----	1,920	6.8	------	
NE¼SE¼, 35	33 N.	99 W.	2,803	--------	8-17-65	96	21	.00	36	19	15	68	180	0	45	12	2.7	.0	.04	240	245	171	23	15	410	7.0	.5	H_2S.
SE¼NW¼, 18	33 N.	100 W.	900	500–900	---do---	56	8.5	.00	47	25	4.9	.7	268	0	8.2	5.3	.2	1.2	.01	242	233	219	0	5	430	7.2	.1	
NE¼SW¼, 25	33 N.	100 W.	3,334	3,000–3,334	---do---	82	14	.00	31	20	10	4.2	159	0	36	11	.7	.0	.03	202	205	160	30	12	347	7.5	.3	H_2S.
NW¼NE¼, 13	33 N.	101 W.	700	400–700	---do---	49	8.8	.00	44	25	2.0	1.6	254	0	8.2	3.5	.3	1.1	.01	234	220	213	5	2	413	7.4	.1	
SW¼NW¼, 32	42 N.	107 W.	Spring	--------	9-21-65	82	18	.00	123	38	17	7.0	479	0	84	23	1.2	.0	.11	486	547	464	71	7	937	6.8	.3	Gas in water.
Park City Formation and equivalents																												
NW¼NW¼, 7	30 N.	96 W.	269	229–269	8-18-65	71	21	0.00	137	36	120	19	180	0	480	90	2.0	0.0	.28	1,030	994	490	342	34	1,470	6.6	2.4	H_2S, Se 0.00.
NW¼NW¼, 11	30 N.	97 W.	408	150–408	---do---	60	13	[1] .00	149	44	60	10	192	0	467	38	1.5	.0	.15	942	877	553	396	19	1,260	7.4	1.1	H_2S, Se 0.00.
Park City and equivalents, Dinwoody, and Chugwater Formations																												
NE¼SE¼, 14	5 N.	6 W.	980	120–980	9-30-64	51	9.4	[1] 0.29	409	68	557	18	734	0	1,560	219	2.1	0.0	0.48	3,240	3,210	1,300	698	48	3,920	----	6.7	H_2S.
NW¼NW¼, 7	30 N.	96 W.	290	68–290	8-18-65	75	24	.00	129	39	130	23	171	0	484	105	1.3	.6	.33	1,060	1,020	480	340	36	1,520	7.2	2.8	H_2S.
Sundance Formation																												
NW¼NE¼, 34	32 N.	99 W.	350	335–347	10-14-65	50	10	[1] 0.15	1.8	0.4	297	0.8	380	52	239	6.6	2.3	0.8	0.79	819	799	6	0	99	1,300	9.1	53	
Morrison Formation																												
SW¼SE¼, 23	33 N.	99 W.	215	31–46	10-13-65	48	7.9	[1] 1.2	3.0	1.3	614	1.2	475	31	792	26	4.0	1.2	0.86	1,740	1,720	13	0	99	2,400	8.5	74	

Cloverly Formation																												
SW¼NE¼. 15	33 N.	89 W.	537	405–485	7-16-64	58	12	0.04	23	6.9	120	7.0	288	0	111	6.0	1.2	1.0	0.42	445	430	86	0	74	694	7.6	......	
NE¼SW¼. 22	33 N.	90 W.	1,489	1,425–1,489	1-15-64	73	14	[1].35	5.1	0	396	2.0	336	16	533	17	1.5	.0	....	1,150	1,140	13	0	98	1,760	8.5	......	
SW¼NW¼. 23	33 N.	90 W.	1,048	930–1,040	1-15-64	43	18	.75	47	8.5	198	5.4	192	0	405	10	.4	1.0	....	792	788	153	0	73	1,180	6.9	......	
SW¼NW¼. 28	33 N.	90 W.	1,048	965–1,048	9-19-61	68	16	[1].06	36	7.8	232	5.6	219	0	390	9.0	.5	1.4	....	806	806	122	0	78	1,230	6.8	......	
Muddy Sandstone Member of Thermopolis Shale																												
SE¼SE¼. 13	37 N.	86 W.	1,611	1,599–1,611	11- 9-65	75	12	1.00	0.4	3.5	1,000	9.5	1,960	94	0.0	270	4.3	0.0	....	2,380	2,360	16	0	98	3,640	8.5	109	
Frontier Formation																												
NW¼NW¼. 33	1 N.	[2] 1 E.	712	543-628	10-30-57	....	....	......	0.4	1.3	772	3.5	951	117	500	57	....	....	....	1,798	......	......	......	99	2,530	9.1	......	
SW¼SW¼. 14	4 N.	4 W.	400	322-329	1- 4-65	....	7.4	0.21	33	11	680	2.4	166	0	1,230	116	1.6	1.0	2.0	2,220	2,170	126	0	91	3,170	7.9	26	
SW¼SW¼. 8	1 S.	1 W.	548	....	5-19-45	....	....	......	1.0	1.3	435		430	70	430	20	3.8	.0	....	....	1,170	8	0	99	1,800	....	......	
Cody Shale																												
NE¼SW¼. 15	27 N.	89 W.	120	....	9-24-65	50	8.5	0.00	201	192	1,070	7.6	578	0	3,080	70	2.0	0.0	0.93	5,150	4,920	1,290	816	64	6,020	7.3	13	
Mesaverde Formation																												
NW¼SE¼. 10	33 N.	[3] 96 W.	2,600	2,100–2,600	....	....	....	......	30	11	1,627	....	1,891	84	7	1.390	....	....	....	4,080	......	120	......	99	....	8.3	......	
NW¼NW¼. 13	34 N.	91 W.	212	....	9-14-65	51	5.9	0.22	2.6	2.3	445	4.1	583	9	357	66	0.9	2.7	0.49	1,100	1,180	16	0	99	1,780	8.4	48	Se 0.00.
SE¼SW¼. 27	34 N.	94 W.	312	250–312	6-27-65	....	8.2	18	166	147	1,390	15	852	18	3,140	86	.6	9.8	.71	5,500	5,420	1,020	291	74	6,600	8.3	19	
Lance and Fort Union Formations																												
SE¼SE¼. 1	36 N.	[3] 90 W.	8,648	....	....	....	....	......	8	1	405		57	60	148	128	....	....	....	1,068	......	......	......	97	....	8.3	......	
NW¼NW¼. 28	36 N.	[3] 90 W.	6,960	....	....	....	....	......	131	37	44		220	....	362	12	....	....	....	746	......	......	......	35	....	7.5	......	
Fort Union Formation																												
NW¼NW¼. 9	1 S.	2 E.	430	365–413	11- 6-65	....	6.9	0.60	8.3	1.8	387	3.1	561	16	1.5	291	2.6	0	0.18	1,010	995	28	0	96	1,760	8.4	32	

TABLE 1.—*Chemical analyses of ground water in the Wind River basin area, central Wyoming*—Continued

[Analyses by U.S. Geological Survey except as indicated. Analytical results in parts per million except as indicated]

Location: Section	Location: T.	Location: R.	Depth (feet)	Principal producing interval (feet)	Date of collection	Temperature (° F)	Silica (SiO_2)	Total iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Residue on evaporation at 180° C	Dissolved solids: Sum	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25° C)	pH	Sodium adsorption ratio	H_2S, hydrogen sulfide Se, selenium, in ppm
Wind River Formation																												
SW¼NE¼, 17	1 N.	3 E.	285	246–280	11- 8-65	----	11	0.36	4.2	0.4	148	0.4	52	2	251	15	2.4	0.0	0.33	474	461	12	0	96	743	8.4	19	
SE¼SE¼, 27	1 N.	4 E.	600	353–600	12- 3-65	50	12	[1].00	.8	.2	136	.9	204	0	122	11	.6	.0	.10	400	384	3	0	99	627	8.2	34	
SE¼NE¼, 34	1 N.	4 E.	609	345–609	do	50	7.5	.00	1.2	1.7	165	1.4	187	10	174	11	.8	.0	.13	486	465	10	0	97	725	8.5	22	
NE¼NW¼, 34	1 N.	4 E.	535	450–507	do	50	8.3	.00	.8	.1	132	.9	165	21	99	8.9	.7	.0	.07	354	353	2	0	99	470	8.7	41	
SW¼SW¼, 24	2 N.	1 E.	180	--------	9-15-65	55	26	.13	94	14	15	3.1	334	0	47	3.0	.4	1.7	----	373	368	293	19	10	586	8.0	0	
SE¼NE¼, 18	2 N.	2 E.	498	475–498	11- 1-60	----	20	.00	59	7.8	72	2.0	190	0	170	.1	.8	.7	----	448	429	179	24	44	658	8.0	------	
SW¼SW¼, 7	3 N.	2 E.	380	340–380	10-29-60	----	16	.30	8	.0	210	.4	88	2	345	21	2.0	.0	----	608	647	20	0	96	974	8.5	------	
SW¼NE¼, 15	3 N.	6 E.	495	435–495	10-27-60	----	10	.08	4.8	1.0	179	.6	168	2	234	12	3.0	.7	----	565	530	16	0	96	847	8.3	------	Se 0.00.
NW¼SE¼, 36	4 N.	3 E.	120	--------	10-29-60	----	28	.13	320	224	520	8.2	254	0	2,510	56	1.0	.0	----	4,040	3,790	1,720	1,510	40	6,180	7.7	------	
NW¼NE¼, 4	3 N.	3 W.	55	33–55	11- 4-65	----	23	.05	39	17	66	.8	190	0	23	1.0	.5	.7	.02	203	205	168	12	8	340	7.8	0	
SW¼NW¼, 17	1 S.	3 E.	150	105–140	do	----	17	.17	59	12	73	2.1	162	0	208	8.2	.9	.3	.10	492	461	196	63	44	696	7.8	23	
SW¼NE¼, 11	1 S.	5 E.	204	--------	do	55	16	.26	150	39	340	7.4	469	0	782	77	1.2	.3	.33	1,710	1,650	534	149	58	2,320	8.0	64	
NW¼SE¼, 12	1 S.	5 E.	800	300–800	12- 3-65	54	19	[1].03	51	22	92	5.4	177	0	270	7.1	1.6	.0	.10	590	555	219	74	47	869	8.1	3	
SE¼SE¼, 22	33 N.	90W.	112	90–99	6- 8-57	----	12	[1].05	278	33	68	10	7	0	214	9.0	.3	.0	----	1,370	1,330	829	824	13	1,600	5.3	------	
NE¼NE¼, 28	33 N.	90W.	84	78–84	1-14-64	48	30	1.7	295	70	27	13	257	0	780	45	.4	.0	----	1,510	1,389	1,025	814	5	1,750	7.0	------	
SW¼SW¼, 28	33 N.	90W.	105	--------	11-19-62	----	15	1.2	151	29	74	15	242	0	403	15	.4	23	----	834	846	496	297	24	1,193	7.7	------	Se <0.03.
NW¼SE¼, 28	33 N.	90 W.	265	--------	11-15-64	50	21	0.00	106	20	65	14	232	0	285	4.8	0.3	0.6	----	652	631	347	157	27	921	7.6	------	
NE¼NE¼, 32	33 N	90 W.	207	159–203	11-19-62	----	26	.92	240	23	72	12	296	0	598	8.5	.2	.2	----	1,144	1,127	694	451	18	1,480	7.5	------	Se<0.03.
SW¼NW¼, 10	33 N.	[3] 96 W.	90	31–61	--------	----	----	------	120	34	335	----	293	----	815	8.2	----	----	----	1,427	------	440	------	----	--------	7.7	------	
SE¼SE¼, 19	34 N.	93 W.	200	152–162	9-18-65	50	5.9	.00	17	8.1	840	9.8	315	27	1,490	82	2.4	4.8	0.23	2,700	2,640	76	0	----	3,680	8.5	42	
NW¼NE¼, 20	34 N.	93 W.	390	265–360	8-25-65	52	6.8	.10	2.6	1.1	355	3.0	549	57	125	69	.6	2.0	.25	870	892	11	0	98	1,440	8.5	47	Se 0.00.
SE¼NE¼, 11	34 N.	94 W.	225	195–220	do	50	7.7	1.9	80	6.2	1,230	3.1	83	0	2,610	33	1.2	2.6	.18	4,130	4,020	225	157	92	5,350	7.2	36	
SE¼SE¼, 2	35 N.	90 W.	300	--------	do	50	10	.11	150	39	25	5.4	101	0	504	7.1	.6	.0	.00	834	791	534	451	9	1,080	7.8	1	Se 0.00.
SW¼SW¼, 23	36 N.	87 W.	8	--------	11- 8-65	50	10	.10	.8	2.7	190	4.0	372	4	110	7.1	.5	.0	.00	526	510	13	0	96	812	8.3	23	
NW¼NE¼, 25	36 N.	89 W.	--------	--------	do	----	16	.02	36	22	18	5.5	73	0	143	11	.8	.0	.03	276	288	181	121	----	413	7.6	.6	
SE¼NE¼, 18	36 N.	93 W.	240	218–235	8-27-65	52	6.7	.06	36	2.4	525	3.1	153	3	945	58	1.3	.0	.22	1,610	1,660	100	0	92	2,380	8.3	23	Se 0.00 .
SW¼SE¼, 36	36 N.	94 W.	104	50–90	do	50	5.0	.04	88	36	720	4.1	201	0	1,620	16	.9	.7	.09	2,560	2,590	368	203	81	3,470	8.1	16	Se 0.00.
SW¼NE¼, 23	37 N.	91 W.	265	--------	10-18-60	----	6.0	[1].00	47	1.5	540	1.4	34	0	1,150	21	2.0	.7	----	1,910	1,790	124	96	90	2,690	8.2	------	
SW¼NW¼, 25	37 N.	91 W.	113	105–110	9-14-65	50	9.8	.21	83	22	310	4.4	189	0	757	20	.9	1.3	.15	1,320	1,300	298	143	69	1,720	8.1	8	
NW¼SE¼, 7	38 N.	90 W.	110	85–105	do	50	9.8	.11	187	64	1,160	6.7	168	0	2,930	85	.6	6.3	.19	4,630	4,530	730	592	77	5,000	8.2	19	Se 0.00.
SW¼NW¼, 18	38 N.	90 W.	110	--------	9-15-65	52	9.8	0.00	4.2	1.3	360	2.7	247	15	481	34	2.0	.0	0.04	1,000	1,030	16	0	98	1,560	8.6	39	
SW¼SW¼, 6	41 N.	[2] 106 W.	50	--------	6-22-65	----	----	------	50	13	36	2	214	0	56	7	----	.2	.01	--------	284	176	-----	31	413	8.2	------	
NW¼SW¼, 28	41 N.	106 W.	235	90–235	9-27-65	42	18	.00	69	25	4.5	2.4	333	0	4.1	7.1	.4	11	.00	308	306	273	0	3	502	8.2	.1	
NW¼NE¼, 12	41 N.	[2] 107 W.	103	--------	9- 3-65	----	----	------	87	31	95	7	278	0	301	20	----	.1	----	--------	770	------	-----	37	1,012	7.6	------	
NW¼NE¼, 12	41 N.	[2] 107 W.	50	16–50	6- 9-65	----	----	------	91	31	95	6	372	0	229	14	----	7	.08	--------	710	------	355	36	1,002	7.5	------	
NE¼SE¼, 11	42 N.	107 W.	101	--------	9-21-65	42	12	8.4	182	65	312	8.5	271	0	1,120	44	.8	.0	.07	2,130	1,880	720	498	48	2,690	7.6	5	Se 0.00.
Wagon Bed Formation																												
SE¼NW¼, 26	32 N.	95 W.	Spring	--------	9-20-65	----	24	0.00	294	90	293	9.8	250	0	1,480	7.4	1.3	0.0	0.20	2,590	2,440	1,100	895	36	2,940	7.1	3.8	Se 0.00.
White River Formation																												
SE¼SE¼, 31	31 N.	95 W.	135	65–135	7-21-65	50	44	[1]0.00	35	7.3	17	3.4	180	0	5.8	5.3	0.3	3.8	0.02	216	211	119	0	23	318	7.3	0.7	
NE¼NE¼, 11	32 N.	90 W.	Spring	--------	10- 3-63	48	53	.04	7.8	.1	79	7.2	206	0	23	2.4	.3	1.5	.16	271	276	20	0	86	362	7.9	------	Se 0.01.

Arikaree Formation																												
SE¼NW¼, 6	28 N.	85 W.	850±	-------	10- 5-65	52	44	0.05	31	4.7	12	3.7	132	0	10	4.5	0.4	2.0	0.02	176	177	97	0	20	249	7.2	0.5	
NW¼SW¼, 8	28 N.	88 W.	100±	-------	..do...	50	48	.05	137	52	36	9.0	346	0	328	12	.3	.4	.17	831	793	556	272	12	1,100	7.4	.7	
NW¼SW¼, 31	29 N.	86 W.	250	220–250	..do...	50	56	.02	38	8.5	13	5.6	165	0	27	5.3	.4	.0	.20	248	235	130	0	17	330	8.1	.5	
SE¼NW¼, 2	29 N.	[4] 92 W.	223	145–161	1962	----	37	.10	58	10	----	----	189	----	85	12	----	----	----	----	375	186	----	----	440	7.6	----	
NW¼NE¼ 15	29 N.	95 W.	Spring	-------	8-18-65	86	27	[1] .00	62	26	126	18	200	0	220	119	1.6	.0	.40	698	698	260	96	49	1,140	7.7	3.4	Se 0.00.
SW¼NE¼, 15	29 N.	95 W.	Spring	-------	8-18-65	42	41	[1] 0.00	40	7.3	40	6.7	200	0	41	9.9	0.4	0.0	0.10	278	284	130	0	39	440	6.8	1.5	Se 0.00.
NE¼SW¼, 14	31 N.	91 W.	220	91–220	7-21-65	48	52	[1] .00	33	8.6	33	7.8	154	0	50	12	.6	6.5	.09	284	280	119	0	36	411	7.1	1.3	
SW¼SE¼, 25	31 N.	91 W.	150	40–150	..do...	52	28	[1] .00	32	6.0	31	4.9	192	0	14	5.3	.4	2.8	.04	228	218	105	0	38	358	7.3	1.3	
Alluvium																												
SW¼SE¼, 31	1 N.	4 E.	9	4–9	11- 6-65	53	24	0.50	128	33	243	3.9	488	0	495	64	0.6	0.0	0.17	1,270	1,230	456	56	55	1,790	7.7	5	
NE¼NE¼, 15	1 N.	5 E.	29	9–29	9-27-65	51	12	.80	42	8.0	461	1.9	417	0	695	31	1.5	.0	.27	1,490	1,460	138	0	89	2,140	8.2	17	
NW¼NW¼, 13	2 N.	1 E.	60	4–60	9-15-65	----	13	.10	56	9.4	25	1.6	188	0	68	6.2	.2	.0	.02	284	272	178	24	23	447	7.8	1	
SW¼NE¼, 17	3 N.	2 W.	45	35–45	11- 4-65	----	19	.10	46	10	18	2.4	170	0	52	4.0	.2	.2	.03	240	236	157	18	20	380	7.7	1	
NW¼NW¼, 8	4 N.	3 W.	30	10–30	..do...	50	29	.37	104	17	89	3.6	526	0	84	10	.3	.3	.07	601	597	331	0	36	911	7.9	2	
SW¼NE¼, 4	1 S.	1 W.	24	4–24	..do...	----	10	.00	53	22	14	3.1	220	0	63	5.7	.3	1.2	.10	292	280	222	42	12	476	7.6	.4	
NW¼SW¼, 10	1 S.	1 W.	60	6–60	..do...	47	7.9	1.3	40	18	200	2.4	343	0	306	7.2	.5	3.4	.96	772	757	173	0	71	1,170	7.8	7	
NW¼NW¼, 22	1 S.	1 E.	30	12–30	8-13-65	----	17	.05	238	121	226	4.6	313	0	1,220	17	1.0	6.0	.47	2,230	2,010	1,090	833	31	2,500	8.2	3	
SW¼NE¼, 32	1 S.	1 E.	45	-------	10- 5-65	----	19	.07	49	31	11	2.1	284	0	38	2.6	.9	2.5	.05	293	296	250	17	9	492	8.1	.3	
NW¼NW¼, 9	1 S.	2 E.	20	5–20	11- 3-65	54	20	.01	168	80	161	4.6	395	0	694	18	.9	3.6	.32	1,450	1,340	746	422	32	1,780	8.2	2.6	
NE¼SE¼, 33	1 S.	4 E.	22	2–22	9-29-65	52	18	1.3	184	48	169	7.4	271	0	648	88	1.0	.1	.22	1,380	1,300	656	434	36	1,780	8.1	2.9	
SE¼NW¼, 11	1 S.	5 E.	34	21–34	10- 6-65	52	14	.34	168	55	1,100	4.7	409	0	2,450	95	.8	.1	.49	4,600	4,090	646	311	79	5,650	8.2	19	
NE¼SW¼, 25	29 N.	87 W.	35	20–35	..do...	48	28	[1] .29	44	9.0	29	5.1	163	0	61	16	.2	.1	.04	273	274	147	13	28	400	8.0	6.9	
NE¼SE¼, 20	34 N.	98 W.	27	6–27	10-12-65	54	12	[1] .00	56	58	96	5.8	210	0	400	12	.5	.0	.07	796	743	378	206	35	1,290	8.2	2.2	H_2S.
SW¼SW¼, 21	34 N.	98 W.	22	10–22	..do...	50	12	[1] .00	90	83	240	8.4	271	0	831	34	.6	.0	.25	1,510	1,430	566	344	48	1,970	8.1	4.4	
SE¼SE¼, 7	41 N.	106 W.	20	5–20	9-27-65	----	72	.00	69	28	72	8.0	415	0	94	5.3	.4	4.2	.10	540	513	286	0	35	820	7.3	1.9	
SW¼NW¼, 16	41 N.	106 W.	11	6–11	..do...	48	26	.05	52	20	24	4.4	278	0	40	6.0	.5	.0	.01	314	310	211	0	19	490	8.1	.7	
NW¼SE¼, 23	41 N.	106 W.	Spring	-------	..do...	46	19	.00	32	11	3.7	2.0	146	0	16	.0	.4	.0	.06	152	156	126	6	6	263	8.0	.1	
NE¼NE¼, 3	41 N.	107 W.	16	8–16	9-21-65	41	34	.00	110	35	30	9.2	500	0	71	22	.9	.0	.10	576	558	420	10	14	924	8.1	.6	
SW¼NE¼, 30	42 N.	107 W.	15	7–15	..do...	41	32	.00	45	37	21	3.4	360	0	.0	7.1	.4	.1	.02	336	323	265	0	14	543	7.8	.6	

[1] In solution at time of analysis.
[2] Analysis by Wyoming Department of Agriculture.
[3] Analysis by Chemical and Geological Laboratories, Casper, Wyo.
[4] Analysis provided by Western Nuclear, Inc., Jeffery City, Wyo.