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GEOLOGICAL SURVEY CIRCULAR 243

RECONNAISSANCE OF THE GEOLOGY AND GROUND-WATER RESOURCES OF THE LA PRELE AREA CONVERSE COUNTY WYOMING

By J. R. Rapp

WITH A SECTION ON THE CHEMICAL QUALITY OF THE GROUND WATER

By W. H. Durum

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary

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RECONNAISSANCE OF THE GEOLOGY AND GROUND-WATER RESOURCES OF THE LA PRELE AREA CONVERSE COUNTY, WYOMING

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ABSTRACT

The La Prele area is in the southern part of Converse County in eastern Wyoming and covers about 180 square miles. The area is characterized by a varied topography and has a total relief of about 1,400 feet. It is drained by the North Platte River and several tributaries--La Prele Creek being the principal one.

The La Prele area is underlain by a considerable thickness of sedimentary rocks that range in age from Cambrian to Recent and lie on crystalline rocks of pre-Cambrian age. These rocks crop out either within the area (pl. 1) or in adjacent areas. Two known pre-Tertiary units, the Cloverly formation and a sandstone member of the Benton shale of the Colorado group, contained water under considerable artesian pressure when penetrated in deep oil tests. The White River formation of Tertiary age and the slope wash and the alluvium of Quaternary age supply water to most of the wells in the area. The materials of the White River formation and the slope wash are capable of yielding only small amounts of water to wells; however, the alluvium probably would yield sufficient quantities of water for irrigation.

The ground-water reservoir is recharged by seepage from precipitation and from irrigation water applied to the farms and, to a lesser extent, from underflow into the area. Water is discharged from the ground-water reservoir by evapotranspiration, seepage into streams, wells, and underflow that leaves the area.

Most of the farmland in the La Prele area is underlain by a relatively thin mantle of slope wash, which overlies the siltstone and clay of the White River formation. As both the slope wash and the White River are only slightly permeable, the amount of recharge from irrigation and precipitation cannot be transmitted laterally by them under the existing gradient. The addition of recharge from irrigation to that from precipitation has resulted in a rise of water levels which, in turn, have caused waterlogging in low areas. Therefore, the application of additional water to the irrigated farmlands or the irrigation of additional lands that are upslope from them would result in an increase of the waterlogged areas.

The quality of ground water in the La Prele area in relation to its geologic source and its application to domestic and irrigation uses is discussed briefly. Accretion of mineral salts in three principal drainageways, as affected by irrigation return flow, is shown.

Water from 4 shallow sources less than 50 feet deep in unconsolidated materials differed widely in concentration; the dissolved solids ranged from 494 to 4,440 ppm. The dissolved solids in 10 samples of water from bedrock sources at depths of 30 to 725 feet ranged from 204 to 4,430 ppm.

Generally, the more highly mineralized water in both unconsolidated and bedrock samples was characterized by a high degree of hardness.

The sulfate content in about half the samples collected exceeded 250 ppm. The fluoride concentrations in some samples of water from bedrock were above the desirable limit for drinking-water supplies.

The water from some units of the White River formation appears to have been softened naturally by base exchange. Conversion of calcium sulfate to calcium carbonate appears to have occurred in formations containing natural gas. Water from bedrock is generally unsatisfactory for irrigation because of high percentages of sodium.

INTRODUCTION

Purpose and Scope of the Investigation

This investigation is one of a series of studies being made by the Department of the Interior for the control, conservation, development, and use of the water resources of the Missouri River basin. The purposes of this study were to determine the following: The possibility of developing ground water as a supplementary supply for irrigation; the cause of waterlogging in the area; whether the use of additional irrigation water in the area would increase the size of the waterlogged areas; and the chemical quality of the ground water in the area.

The field work upon which this report is based was done mainly during July and August 1950. The work was under the general supervision of A. N. Sayre, chief of the Ground Water Branch of the U. S. Geological Survey, and G. H. Taylor, regional engineer in charge of ground-water investigations in the Missouri River basin, and under the immediate supervision of H. M. Babcock, district engineer for Wyoming. The quantitative analyses of water-bearing materials were made by A. I. Johnson in the hydrologic laboratory of the Geological Survey in Lincoln, Nebr. The quality-of-water studies were under the general supervision of S. K. Love, chief of the Quality of Water Branch of the U. S. Geological Survey, and under the immediate supervision of P. C. Benedict, regional engineer in charge of quality-of-water studies in the Missouri River basin. The water analyses were made by M. B. Florin, W. M. Barr, and R. P. Orth, chemists in the laboratory of the Quality of Water Branch, Geological Survey, Lincoln, Nebr.

Location and Extent of the Area

The La Prele area is in the southern part of Converse County in eastern Wyoming (fig. 1). It lies within Tps. 32 and 33 N., Rs. 71 and 73 W., sixth principal meridian and baseline system, and covers about 180 square miles. Included in the area is the La Prele irrigation project, which is supplied irrigation water from the La Prele Reservoir. The location of this area is shown in figure 1, and the locations of other areas in the Missouri River basin where ground-water studies have been made under the Missouri River basin development program are shown in figure 2.

The area is transected by the Chicago and Northwestern Railway and the Chicago, Burlington, & Quincy Railroad, which serve the town of Douglas. U. S. Highway 87 crosses the central part of the area in a general east-west direction and State Route 59 goes north from its junction with U. S. Highway 87 at Douglas. One north-south road is oiled from its junction with U. S. Highway 87 south to the La Prele Reservoir. Several county roads, which are graded and maintained throughout the year, serve the remainder of the area.

Previous Investigations

Several studies of the geology and mineral resources of all or part of the La Prele area have been made in the past.

Darton (1908)[1] made a study of the Paleozoic and Mesozoic rocks in central Wyoming. Shaw (1909, pp. 151-164) studied and described the Glenrock coal field. In 1912, Winchester (1912, pp. 472-515) studied and mapped the Lost Spring coal field. Barnett (1914, pp. 49-88) made a study of the Douglas oil and gas field. In 1941, Beckwith (1941) studied and mapped the Elk Mountain district. Blackstone (1949) described the over-all structural pattern of the Powder River basin, and Barlow (1950) studied and mapped the geology of the southwestern part of the La Prele area. The information in these reports proved very help-

[1] See list of references at end of report.

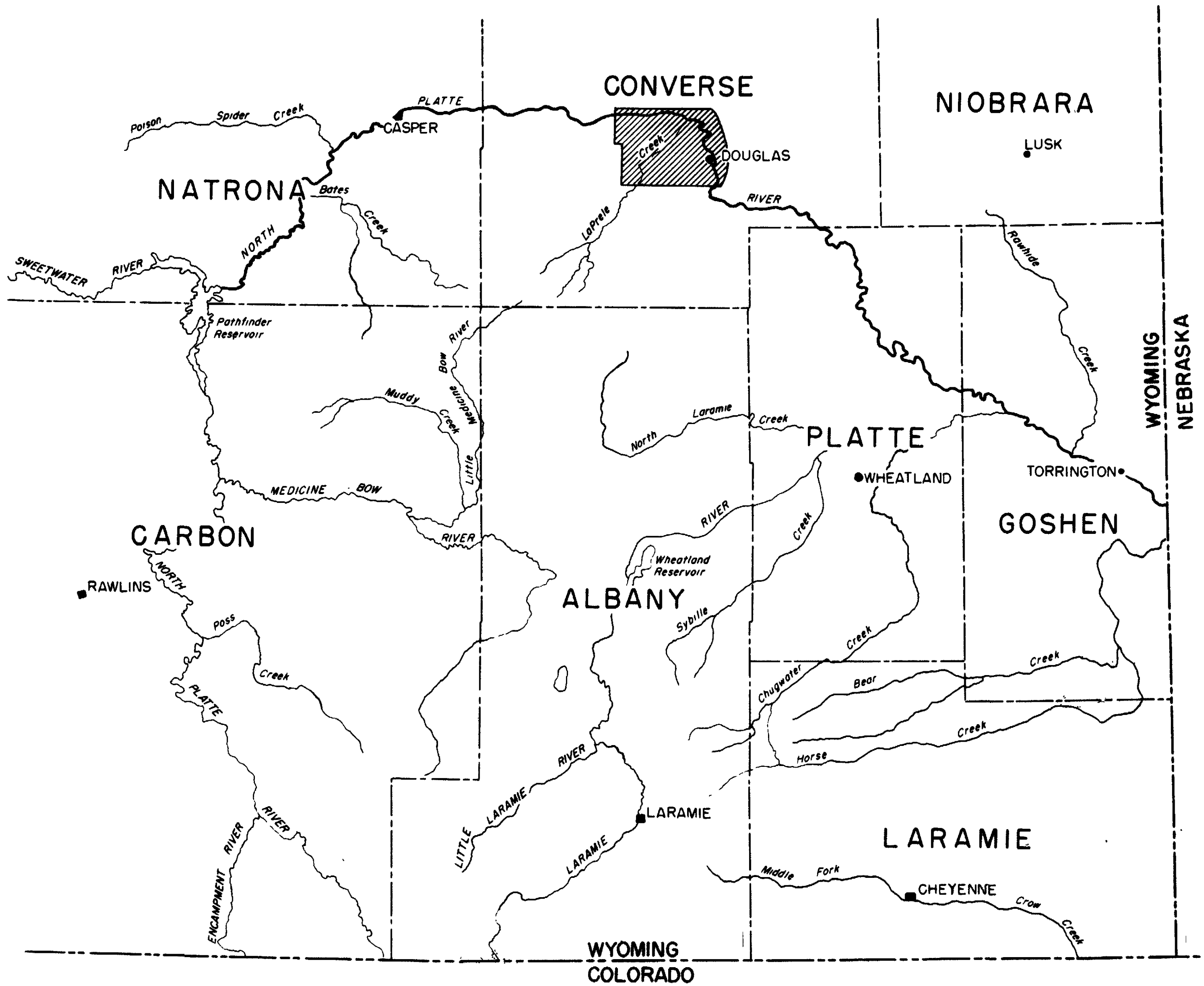

Figure 1.--Index map of southeastern Wyoming showing the location of the La Prele area.

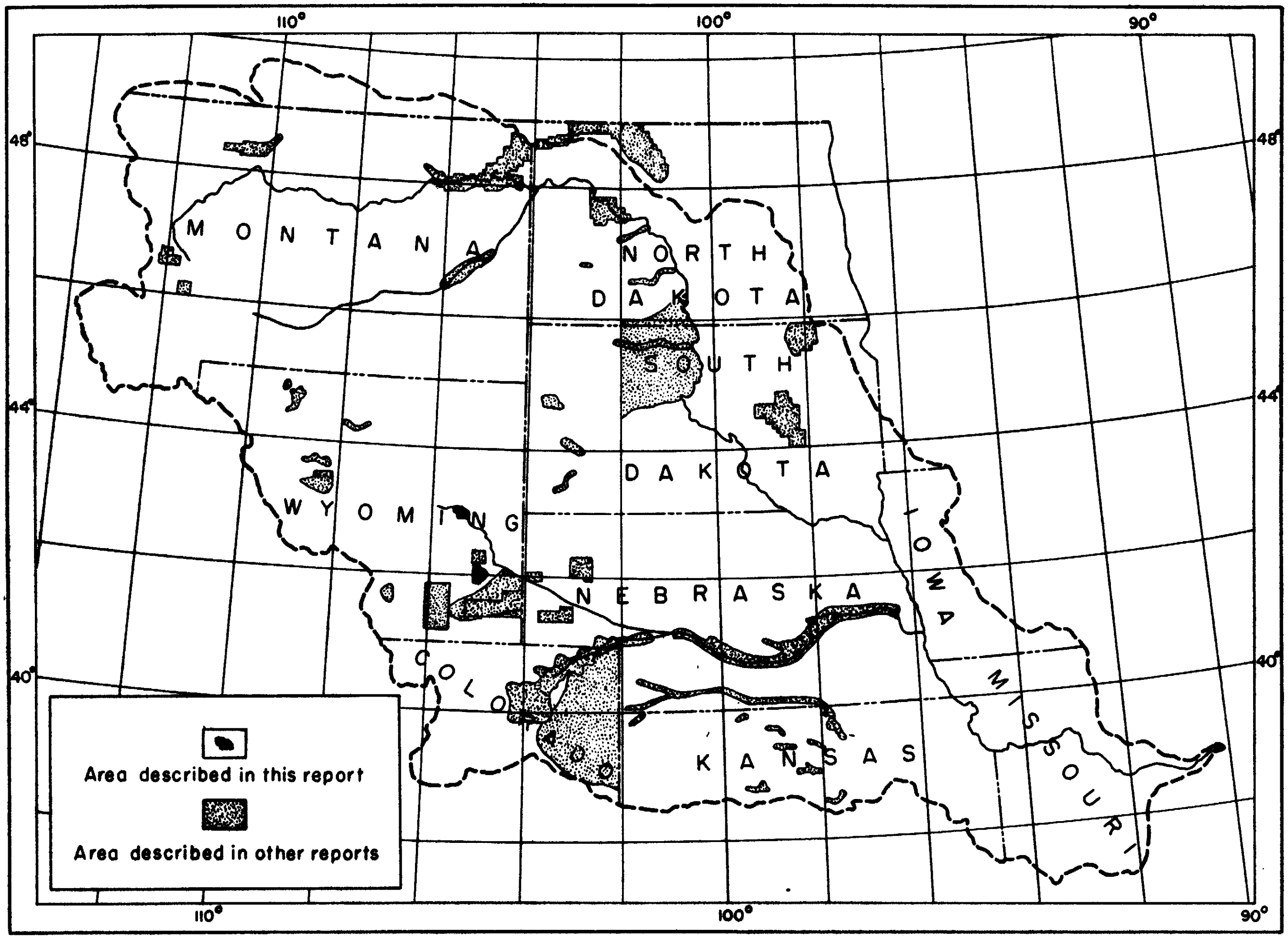

Figure 2.--Map of the Missouri River basin showing areas in which ground-water studies have been made under the Missouri Basin development program.

ful in this investigation and some of the data are included in the report.

Methods of Investigation

Records were obtained for 62 wells and springs in the area. Available information was obtained from well drillers and well owners. Most of this information was given from memory and did not include the yield or drawdown of the wells or the character of the water-bearing materials that were penetrated by the wells. Thirty-three of the wells were measured with a steel tape to determine their depth or the depth to water below some fixed measuring point, which generally was either the top of the well casing or the bottom of the pump base. Reported depths were recorded for those wells that could not be measured. Ten representative wells were selected for periodic measurement of the water level to obtain information on the seasonal fluctuations of the water table. Records of "shot holes" drilled during seismic surveys by oil companies were studied but are not listed in this report. Also, logs of oil wells drilled in the area were studied and 4 of these have been included in this report. Fourteen samples of water for chemical analysis were collected from representative wells and springs, and 3 samples were collected from creeks. One sample of alkaline incrustation was collected for chemical analysis, and 4 samples of water-bearing materials were collected for quantitative analyses.

The geologic and hydrologic field data were recorded on aerial photographs. The map of the area (pl. 1) was compiled from these photographs. The wells and springs shown on the map were located within the sections by use of an odometer and by inspection of the aerial photographs, and their locations are probably accurate to 0.1 mile.

Well-Numbering System

In this report, wells and springs are numbered according to their location within the Bureau of Land Management system of land subdivision. The well number shows the location of the well by township, range, section, and position within the section. A graphical illustration of this well-numbering system is shown in figure 3. The first numeral of a well number indicates the township, the sec-

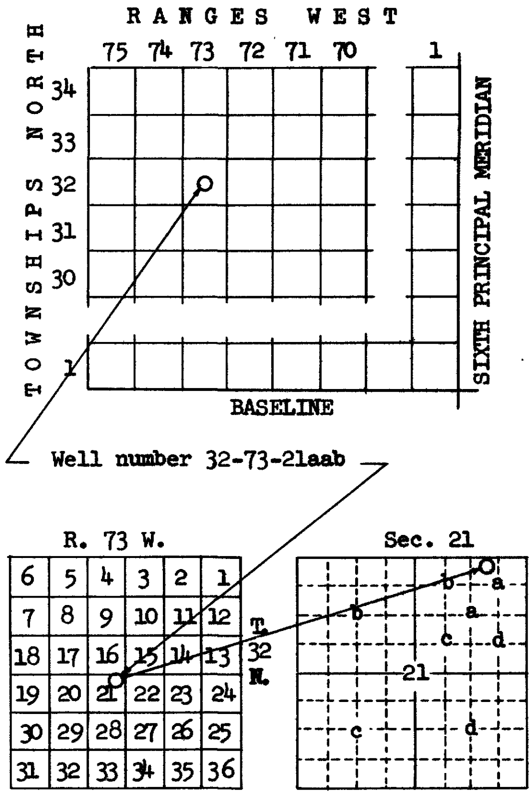

Figure 3.--Sketch showing well-numbering system.

ond the range, and the third the section in which the well is located. The lowercased letters following the section number locate the well within the section. The first letter denotes the quarter section, the second the quarter-quarter section, and the third the quarter-quarter-quarter section (10-acre tract). The subdivisions of the section are lettered a, b, c, and d in a counterclockwise direction, beginning in the northeast quarter. If more than one well is in a 10-acre tract, consecutive numbers beginning with 1 are added to the well numbers.

GEOGRAPHY

Topography and Drainage

The La Prele area is in the extreme southwestern part of the Missouri Plateau (unglaciated) section of the Great Plains physiographic province near the western limits of the High Plains section of the Great Plains physiographic province and the northern limits of the Southern Rocky Mountains physiographic province. The area is characterized by a considerably varied topography. The total relief of the area is about 1,400 feet. The highest point, which is in the mountainous section in the southern part of the area, is about 6,200 feet above sea level; and the lowest point, which is where the North Platte River leaves the area, is about 4,800 feet above sea level.

The extreme southern part of the area is characterized by mountains composed of pre-Tertiary rocks. Northward, pediments that slope from the mountains give way to a subdued badlands topography that is cut on Tertiary rocks. This badland terrain, which is characteristic of the central part of the area, consists of numerous, relatively small hills and near-level valleys. Farther northward, this comparatively gentle relief is broken by a series of large hills that consist of Upper Cretaceous and Eocene strata. Northward and eastward this rugged terrain drops off to the valley of the North Platte River. The south side of this valley consists mainly of pediments, which are graded to terrace remnants in places but generally slope to the flood plain of the river. Several terraces are present on the north side of the valley, generally within 50 to 60 feet above the flood plain of the river. Some of these terraces are underlain by gravel and some are underlain by bedrock. Along the eastern margin of the area the valley of the North Platte River consists mainly of pediment slopes that locally are interrupted by bluffs.

The drainage system of the La Prele area consists of the North Platte River and its tributaries: La Prele, Alkali, Fivemile, Sixmile, and Bed Tick Creeks. The drainage pattern of the area is shown in detail on plate 1. The inner valley of the North Platte River consists of the flood plain and lower slopes and is, in most places, about 3 miles wide. La Prele Creek, the main tributary in the area, is a perennial stream. It rises on the northern slopes of the Laramie Range, which is south of the mapped area, and flows northeastward across the area to its confluence with the North Platte River near the northeast corner of the area. Its average gradient is about 31 feet to the mile. The valley of La Prele Creek, which has been cut about 120 feet deep into the bedrock, characteristically is narrow, averaging about a third of a mile wide, and has steep sides.

Alkali, Fivemile, Sixmile, and Bed Tick Creeks are reported to have been ephemeral streams originally, but, since the introduction of irrigation in the area, they have received sufficient seepage and surface runoff to flow perennially. These creeks do not have well-developed valleys.

Climate

The climate of the area is similar to that of the western part of the High Plains. It is characterized by low precipitation, high rate of evaporation, a wide range in temperature, and a moderately high wind velocity. Although the weather varies from year to year, the summers generally are dry and mild and the winters are cold and usually free from heavy snowfall. All climatic data presented in this report were compiled from records of the U. S. Weather Bureau.

According to data that were recorded at the Weather Bureau station at Douglas, the least recorded annual precipitation in the area was 8.77 inches in 1913, and the greatest recorded annual precipitation was 21.95 inches in 1927. The normal annual precipitation for the period of record is 13.89 inches. Weather information was recorded at Douglas as early as 1899, but precipitation records have been kept continuously only since 1925. Graphs showing precipitation and temperature data are shown in figure 4.

The mean annual temperature for the period of record at Douglas is 45°F. The highest recorded temperature was 106°F and the lowest was -38°F. The greatest extremes in temperature were recorded in 1936, when the low was -38°F in February and the high was 100°F in July.

Agriculture

A small part of the La Prele area is irrigated; the major part is used for grazing. Income from the produce from the irrigated land, however, greatly exceeds that from ranching. The main crops in the area are hay, wheat, barley, oats, beets, and potatoes. Dairying is one of the important agricultural occupations in the area--1,000 gallons of milk per day reportedly was produced in 1948. Most of the farmland in the area is irrigated

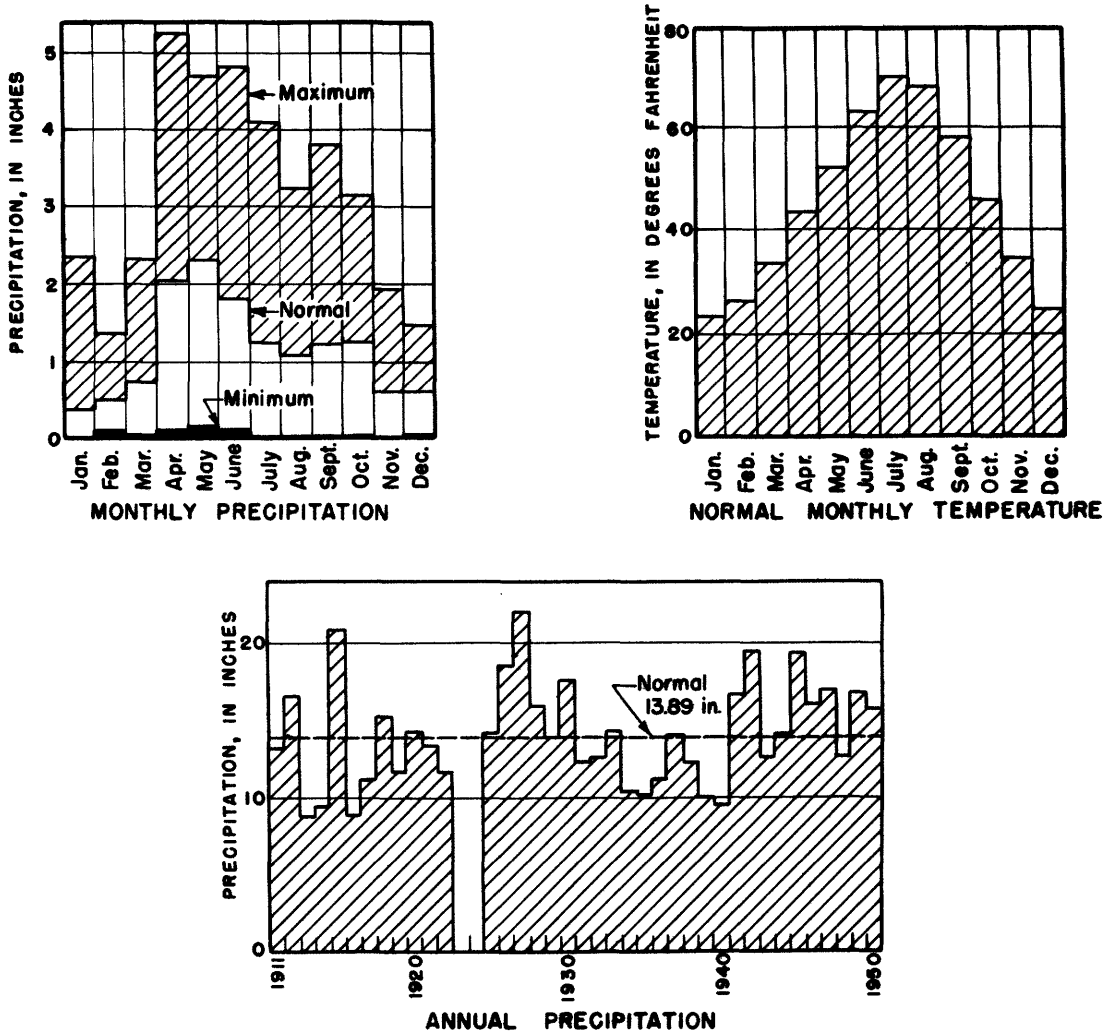

Figure 4.--Precipitation and temperature at Douglas, Wyo., 1911-50.

from the La Prele Reservoir; however, some farms are supplied water from local diversions of La Prele, Alkali, and Bed Tick Creeks and from the North Platte River.

Mineral Resources

During the period 1900-14, considerable drilling for gas and oil took place in the Brenning Basin, which is expressed surficially as a small topographic basin that is enclosed on three sides by highlands. This basin lies almost entirely within secs. 3, 4, 8, and 9 in T. 32 N., R. 73 W. Even though about 50 wells were drilled, only a very small over-all production resulted, and all the wells were abandoned with the exception of a few gas producers that were used temporarily for heat and light in a few individual farm units. Since the abandonment of the wells in the Brenning Basin, several unsuccessful attempts have been made to produce oil or gas in paying quantities in other parts of the area.

At one time coal was mined in the northern part of the area for local use, but none is mined in the area today. This coal is subbituminous and occurs in thin beds. In the past unsuccessful attempts were made to mine thin veins of poor-grade copper ore (chalcopyrite and bornite) in the southern part of the area. Several sand and gravel pits are operated occasionally to supply road metal.

GEOLOGY

Geologic History

The geologic history prior to the beginning of Tertiary time has been described in detail in earlier reports, and the reader is referred to the works listed in the section on previous investigations for this phase of the geologic history of the area.

Cenozoic Era

Tertiary period.--Lacustrine conditions prevailed during early Paleocene time, and the beds of sandstone, shale, and coal of the Fort Union formation were deposited. Subsequently, the La Prele area underwent considerable uplift and was deeply eroded. In the early part of this erosional stage, the materials that were eroded from the area probably were deposited to the north in the Powder River basin as part of the Wasatch formation. The erosion continued until a valley about 1,000 feet deep had been cut into what is now the central part of the La Prele area. During Oligocene time, locally derived materials mixed with volcanic ash from areas of considerable volcanic activity to the west accumulated in this valley, forming the White River formation. Some small-scale deformation during this time resulted in local angular unconformities between beds of the White River. The relatively uninterrupted deposition of White River sediments was terminated by uplift of the mountain areas. This uplift caused rejuvenation of stream action during Miocene time, which resulted in the cutting and filling of channels; the channel fill now makes up the basal conglomerate of the Arikaree sandstone. As erosion continued, the streams lost their transporting power and fanned out over wide areas and deposited the fine-grained sand that comprises the bulk of the Arikaree sandstone. Possibly during deposition of the upper part of the Arikaree or before deposition of the upper Miocene(?) deposits, faulting occurred in the La Prele area. The fault contact of beds in the White River formation with beds in the Arikaree sandstone in the vicinity of the town of Douglas (Chalk Buttes) indicates a vertical displacement of several hundred feet. Associated with the faulting are many local flexures, clastic dikes, and fractures in the White River strata. Some of the faulting may have taken place during late Oligocene time, but most of it is thought to have occurred during deposition of the upper part of the Arikaree. Near the end of Miocene(?) time, uplift and increased rainfall resulted in the deposition of coarse stream-laid materials in the area. Part of this deposition may have occurred during early or middle Pliocene time; however, no fossils were found to substantiate this supposition. During most of Pliocene time the area probably was high topographically, and, consequently, erosion was dominant in the area. In late Pliocene time the North Platte River is thought to have been flowing in essentially its present course.

Quaternary period.--As a result of uplift of the mountains to the west and the increased precipitation, the North Platte River was a degrading stream during early and middle Pleistocene time. It continued downcutting with little or no alluviation until late Pleistocene time. The climate then became drier, and with less flow the North Platte began to aggrade. Either through periodic increases in rainfall or uplift, or both, the river was rejuvenated and downcutting succeeded deposition. The terrace remnants (old alluvial plains) indicate the various stages of the river. The alluvium that underlies the present-day flood plain is thought to be of Recent origin; however, some of these materials may well have been deposited during Pleistocene time when the main channel was cut.

Geologic Formations and their Relation to Ground Water

Pre-Tertiary Formations

The La Prele area is underlain by a considerable thickness of pre-Tertiary formations, which crop out either within the area or in areas nearby (table 1). The age of the pre-Tertiary formations exposed in the area decreases from south to north, the oldest, the pre-Cambrian rocks, being exposed in the southwestern part of the area, and the youngest, the Lance formation of Late Cretaceous age, being exposed in the northern part. The age, physical character, thickness, and water supply of these formations are summarized in table 1.

North of the outcrop of the pre-Cambrian rocks, the strata of Paleozoic and Mesozoic age have been folded and faulted. The north-

Table 1.--Generalized section of the geologic formations in the La Prele area, Wyoming

System	Series	Subdivision	Physical character	Thickness (feet)	Water supply
Quaternary.	Recent.	Slope wash.	Clay, silt, sand, and gravel.	0-30±	Supplies water to a few domestic and stock wells.
		Alluvium.	Fine to coarse sand and gravel containing beds and lenses of clay and silt, cobbles, and boulders.	0-80±	Supplies water to a few domestic and stock wells. Probably would yield large quantities of water to wells in the North Platte River valley.
	Pleistocene.	Terrace deposits.	Sand, gravel, cobbles, and boulders.	0-60?	Mainly lie above water table and, hence, yield no water to wells. Serve as small infiltration areas for recharge from precipitation.
Tertiary.	Pliocene(?). Miocene(?).	Upper Miocene(?) deposits.	Poorly consolidated cross-bedded deposits of clay, silt, sand, and gravel.	0-30±	Lie above water table. Serve as small, relatively unimportant infiltration areas for recharge from precipitation.
	Miocene.	Arikaree sandstone.	Pinkish to gray massive loosely to moderately cemented fine-grained sandstone; contains hard sandstone concretions.	0-300+	Yields water to one well in the area for domestic and stock purposes. Would yield small quantities of water to other wells.
			Poorly sorted pebbles, cobbles, and boulders in a fine-grained siltstone matrix.	0-90±	Does not supply water to wells in the area; however, several springs issue along contact of the basal conglomerate with the White River group.
	Oligocene.	White River formation.	Massive buff-colored siltstone in its western exposures; eastward, contains greater percentage of clay, and channels and lenses of sandstone and conglomerate.	0-1,500±	Yields water from fractures to most of the domestic and stock wells in the area. In general, will yield only small quantities of water to wells.
	Paleocene.	Fort Union formation.	Sandstone and shale. In places the sandstone is hard, thin bedded, and ferruginous; in others it is soft, massive, and sugary textured, containing large ferruginous concretionary masses. The shale generally is dark, soft, and arenaceous, and in many places is carbonaceous. The formation contains two groups of coal-bearing strata.	0-2,800?	Yields water to a few domestic and stock wells in the area. In general, will yield only small quantities of water to wells.

Table 1.--Generalized section of the geologic formations in the La Prele area, Wyoming--Continued

System	Series	Subdivision	Physical character	Thickness (feet)	Water supply
Cretaceous.	Upper Cretaceous.	Lance formation.	Poorly consolidated sandstone and soft sandy shale, which are gray, green, light brown, and blackish. Contains beds of subbituminous coal.	0-3,000±	Yields no water to wells in the area.
		Montana group.	Shale and sandstone.	3,400±	Do.
		Colorado group.	Shale and sandstone.	1,800±	Sandstone member of Benton shale yields water under artesian pressure to one well in the area.
	Lower Cretaceous.	Cloverly formation.	Gray to pale yellow-orange fine-grained thick bedded resistant sandstone.	60	Yields water under artesian pressure.
			Yellow-orange thin-bedded nonresistant shale and sandy shale.	50	
			Light-gray medium-grained thick cross-bedded sandstone. Contains quartz and chert pebbles in lower part.	27	
Jurassic.		Morrison formation.	Variegated shale and sandstone. Upper part contains fragments of silicified dinosaur bones and petrified wood.	170	Ground-water possibilities not known.
		Sundance formation.	Gray to yellowish sandstone and variegated shale.	325	Do.
Triassic. ?	?	Chugwater formation.	Red siltstone containing red shale and red fine-grained silty sandstone. Beds of gypsum or anhydrite are few and thin in upper part and more numerous and thicker in lower part.	800	Do.
Permian.		Minnekahta limestone.	Purplish-gray to pink thin-bedded limestone containing calcite geodes and a few thin beds of red calcareous shale.	30	Do.
		Opeche formation.	Red sandy shale and siltstone containing calcite geodes and a few thin beds of reddish sandstone.	70±	Do.

Carboniferous.	Pennsylvanian.	Casper formation.	Consists of pink to gray sandstone, limestone, dolomitic limestone, and shale. At the base is a yellowish-gray conglomerate containing cobbles and boulders as large as 2 feet in diameter. Most of limestone beds contain calcite geodes and solution cavities.	850	Yields water to springs.
	Mississippian.	Madison limestone.	Upper part consists mainly of yellowish to orange dense thick-bedded dolomite and dolomitic limestone containing chert layers, calcite geodes, and solution cavities. Lower part consists of orange, pink, and gray layers of limestone, shale, and sandstone.	160	Ground-water possibilities not known
Cambrian.		Deadwood formation.	Mainly gray to brownish fine- to medium-grained resistant sandstone that is partly cross laminated and contains a few thin beds of shale. At the base is a conglomerate containing cobbles.	50±	Do.
Pre-Cambrian.		Igneous and metamorphic rocks.	Predominantly granite. Some gneiss, schist, and quartzite.		Do.

ward dip of these strata is about 25° to 30° in this area and it decreases to about 15° with greater distance from the outcrop of pre-Cambrian rocks. The Paleozoic and Mesozoic rocks generally lie at considerable depths beneath a thick cover of Tertiary sediments in most of the area; therefore, drilling water wells to penetrate them normally would be economically impractical. Some of these pre-Tertiary sediments will yield water under artesian pressure.

Tertiary Formations

Tertiary strata in the La Prele area include the Fort Union formation, the White River formation, the Arikaree sandstone, and the upper Miocene(?) deposits. These formations underlie most of the area. The Fort Union formation was determined to be of Paleocene age on the basis of plant remains found in it by Barnett (1941, pp. 49-88) and others. Classification of the White River as Oligocene in age was determined from vertebrate remains collected from these sediments in adjacent areas by P. O. McGrew (personal communication, 1950). Classification of the deposits of Miocene age (the Arikaree sandstone and the upper Miocene(?) deposits) was made on the basis of lithology and stratigraphic position. These Tertiary strata disconformably overlie or abut the erosional remnants of the folded and faulted older formations. The angle of discordance increases toward the mountain front.

Fort Union formation.--The Fort Union formation of Paleocene age is composed mainly of alternate beds of sandstone and shale. In many places the sandstone is hard, comparatively thin bedded, and ferruginous, and in others it is soft, massive, and sugary in texture. The soft massive sandstone commonly contains large ferruginous concretionary masses that weather into fragments and balls. The shale generally is dark, soft, and arenaceous, and in many places it is carbonaceous. The formation contains two groups of coal-bearing strata, which are separated by about 700 feet of noncarbonaceous sediments. The coal beds in the lower group are lenticular and relatively thin; the beds in the upper group are thicker and extend over large areas.

The Fort Union formation is exposed in the northern and northeastern part of the area. It unconformably overlies the Lance formation of Late Cretaceous age and is overlain unconformably by or abutted against younger sediments. The maximum thickness of the Fort Union formation in the La Prele area is about 2,800 feet.

Several domestic and stock wells in the area produce water from the Fort Union formation. In 1937 an attempt was made to develop a municipal supply from this formation for the town of Douglas. A well was drilled through several water-bearing sands in the formation to a reported depth of 540 feet (see log of well 32-71-7bbc), but it produced only a few gallons per minute. On the basis of the production of this well and other wells in the general vicinity of the La Prele area, the formation is assumed to yield only limited quantities of water to wells.

White River formation.--Where the White River deposits are exposed in Nebraska, the Dakotas, and Montana they consist of two formations which can be identified with comparative ease--the Chadron, which is the lower, and the Brule, which is the upper. Westward, into Colorado and Wyoming, the two formations progressively become less distinguishable by color, erosional characteristics, or lithology. In central Wyoming, the White River is nearly uniform throughout and locally is treated as a single formation.

In the La Prele area, the White River formation consists largely of beds of siltstone and clay interbedded with channels and lenses of sandstone and fine-grained conglomerate. The siltstone beds usually have a pronounced red- or green-, brown-, gray-, and buff-banded appearance. These beds are cut by many small fractures. The lenses and channels of sandstone and conglomerate generally are grayish, brownish, or greenish--these colors are not as intense as those of the finer grained materials.

The sedimentary rocks of the White River formation in the La Prele area vary so much that those exposed in the southeastern part of the area are very unlike those in the western part of the area. The western exposures of the White River formation in the area consist largely of massive buff-colored siltstone that greatly resembles the Brule formation where it is exposed to the southeast in the Glendo area (Rapp and Babcock, 1950). A sample of this material from $SE\frac{1}{4}$, sec. 28, T. 33 N., R. 72 W., was analyzed in the hydrologic laboratory of the U. S. Geological Survey in Lincoln, Nebr. The percent weight by grain size of this sample is as follows:

Grain size (diameter in millimeters)		Percent by weight
Less than 0.004	(clay)	22.0
0.004 - .0625	(silt)	67.0
.0625 - .125	(very fine sand)	7.6
.125 - .25	(fine sand)	3.4

Eastward, within the area, a banded coloring of the fine-grained materials is progressively more pronounced. The ratio of clay to silt is progressively larger eastward, and in the extreme southeastern part of the area the percent of each is about equal. In addition, channels and lenses of sandstone and conglomerate are progressively more numerous from west to east, and near the southeast corner of the area, they are relatively profuse. (See fig. 5.)

The White River formation is exposed in the central and southern part of the area. The general dip of the group is about 6° to 7° to the southwest, but, locally, the dip may be as much as 8° in any direction. The White River formation ranges in thickness in the area from about 1,500 feet to the vanishing point.

Many wells in the area produce water from fractures in the siltstone of the White River formation. Sufficient water for stock and domestic supplies generally can be developed from this siltstone, but, owing to the overall fine-grained character of the materials, sufficient amounts of water for irrigation probably cannot be developed.

Figure 5.--Outcrop of the White River formation in sec. 29, T. 32 N., R. 71 W., showing the abundant channels of sandstone and conglomerate.

Arikaree sandstone.--The Arikaree sandstone of Miocene age consists of two distinct units: a basal conglomerate that unconformably overlies the White River formation and a massive sandstone. Because the two units occur independently in isolated areas and also because they differ radically in lithology, they are discussed separately.

The basal conglomerate was recognized only in the southern part of the area, where it caps Table Mountain. (See pl. 1.) This conglomerate is composed of poorly sorted pebbles, cobbles, and small boulders of granite, feldspar, and schist in a matrix of fine-grained siltstone. The maximum thickness of the unit is about 90 feet. No wells in the area are known to produce from this conglomerate, but several springs issue along the contact of the conglomerate with the underlying White River formation--for example, spring 32-72½-12dad, which reportedly yields about 15 gpm.

The sandstone unit consists mainly of massive loosely to moderately cemented slightly pinkish to gray fine-grained sandstone. Included in this relatively soft sandstone are hard, tough fine-grained, brownish to dark-gray sandstone concretions. These concretions are as large as 2 feet in diameter by about 15 feet in length. This sandstone unit is exposed only in the Chalk Buttes and vicinity in the southeastern part of the area near the town of Douglas (pl. 1 and fig. 6), where about 300 feet of the sandstone are exposed. It yields sufficient quantities of water for stock and domestic purposes to well 32-71-18daa, which is the only well drilled in the unit.

numerous fragments of limestone, shale, and sandstone are also present in these deposits. The terrace deposits range in thickness from about 60 feet to the vanishing point.

No wells in the area are known to produce water from the terrace deposits. Several of the lower terraces along the North Platte River possibly would yield appreciable quantities of ground water if a sufficient thickness of saturated material were encountered.

Figure 6.--Chalk Buttes in sec. 18, T. 32 N., R. 72 W. Chalk Buttes, which are erosional remnants of sandstones of the Arikaree sandstone, are a distinct topographic feature in the area.

Upper Miocene(?) deposits.--The upper Miocene(?) deposits are present only in the south-central part of the area, where they cap high hills that are principally of White River sedimentary rocks. They consist mainly of poorly consolidated, cross-bedded deposits of stream-laid gravel, sand, silt, and clay. The thickness of these deposits ranges from about 30 feet to a knife edge. These deposits, which are small in extent, are relatively unimportant infiltration areas for recharge from precipitation.

Quaternary Deposits

Terrace deposits.--Several terrace levels are present in the La Prele area, but, as they are not readily distinguished, only the more extensive terraces were mapped (see pl. 1).

The terrace deposits, which are of fluvial origin, consist of poorly sorted and unconsolidated mixtures of sand, gravel, cobbles, and boulders. Crystalline rocks are the main source of these materials--fragments of granite, feldspar, and schist abound; however,

Alluvium.--In the La Prele area, the alluvium of Pleistocene and Recent age consists mainly of stream-laid deposits of fine to coarse sand and gravel that contain beds and lenses of clay and silt and small cobbles. In places large cobbles and boulders are encountered by drillers; however, small cobbles normally are the largest materials encountered. The alluvium occurs mainly in the valleys of La Prele Creek and the North Platte River. Owing to the occurrence of slope wash along the sides of the valleys, the limits of the alluvium are obscured; hence, the contacts indicated on plate 1 are only approximate. The alluvium of La Prele Creek is about 40 feet thick where U. S. Highway 87 crosses the creek and probably is considerably thicker at the junction of the creek and the North Platte River. The maximum thickness of the alluvium in the area is reported to be about 80 feet along the North Platte River.

The alluvium supplies water to a few domestic and stock wells in the area. No data were recorded as to the quantity of water that the alluvium would yield to wells; however, owing to its coarse-grained character, large saturated thickness, and similarity to known producing materials in other areas, the alluvium in the La Prele area, especially along the North Platte River, probably would yield sufficient quantities of water to wells for irrigation.

Slope wash.--The slope wash of Recent age consists of clay, silt, sand, and some gravel. Three samples of slope wash were taken by hand auger at the following sites: 32-73-9bdd, 32-72-1cdc, and 33-73-27abc. The average percent weight by grain size of the three samples is as follows:

Grain size (diameter in millimeters)		Percent by weight
Less than 0.004	(clay)	34.2
0.004 - .0625	(silt)	60.7
.0625 - .125	(very fine sand)	4.1
.125 - .25	(fine sand)	.9
.25 - .5	(medium sand)	.1

Generally, the slope wash underlies pediment slopes and occurs in relatively thin. isolated patches. It is derived from and overlies the older formations in the area. The slope wash accumulates in the lowland areas, except along the main stream valleys where it is readily removed. It ranges in thickness from about 30 feet to the vanishing point.

The slope wash yields small supplies of water to a few domestic and stock wells in the area. Laboratory tests show that this material has a very low permeability and yield; therefore, it would not yield large quantities of water to wells.

GROUND-WATER RESOURCES

General Considerations

In the La Prele area ground water occurs mainly in three aquifers: the White River formation of Oligocene age, the alluvium of Pleistocene and Recent age, and the slope wash of Recent age. The ground water in these aquifers generally is unconfined; however, in the White River formation ground water in some of the channels and lenses of sandstone and conglomerate is confined by overlying relatively impervious beds of siltstone and claystone. The hydrostatic head usually is sufficient to cause water levels to rise only a few feet in wells that penetrate these channels and lenses. The White River formation, which underlies most of the area, is considered the most important aquifer at present, in spite of its generally small yield to wells. The alluvium, which occurs along the main stream valleys, and the slope wash, which occurs in lowland areas, yield water for domestic and stock use to a few wells in the area. The alluvium, however, could yield larger supplies than are now being developed from it.

Ground water also occurs under confined or artesian conditions in older rocks that underlie the area. The Cloverly formation and a sandstone member of the Benton shale (Colorado group) yielded water under considerable head when penetrated at great depth by several oil-test wells. In some of these wells the hydrostatic head was sufficient to bring the water to the land surface. Several of these oil wells are now used to supply water for domestic and stock uses. No data were recorded concerning the quantities of water that wells in these formations yield, but the great depth at which the formations lie beneath the land surface in most of the area make the development of water supplies from these aquifers impractical.

Hydrologic Properties of the Water-Bearing Formations

The amount of water a formation will yield to wells or other recovery devices and the rate at which the water moves through the formation depend upon the physical and hydrologic properties of the material comprising the formation. Careful examination of the materials is useful in approximating these properties, but field or laboratory tests are needed to give more reliable quantitative data. Because it was not feasible to make field tests of the water-bearing formations in the area, samples were sent to the hydrologic laboratory for analysis. Four samples of materials in the area (1 of the White River formation at location 33-72-29ddc, and 3 of the slope wash at locations 32-72-1cdc, 32-73-9bdd, and 33-73-27abc) were analyzed to determine their permeability and yield and grain sizes of the materials. The grain sizes are given in the preceding section on geology. Samples of the alluvium were not collected, owing to the difficulty of obtaining representative samples.

Coefficient of Permeability

Permeability is a measure of the ability of a material to transmit water and may be expressed as the coefficient of permeability. The coefficient of permeability may be expressed as the number of gallons of water per day, at 60°F, that is conducted laterally through each mile of the water-bearing bed under investigation (measured at right angles to the direction of flow), for each foot of saturated thickness of the bed, and for each foot per mile of hydraulic gradient (Meinzer's coefficient). The coefficient of permeability for the sample of the White River formation was 0.001, which means that 0.001 gpd of water at 60°F would percolate through a cross section 1 mile wide and 1 foot thick under a hydraulic gradient of 1 foot to the mile. Locally, however, the permeability of the formation is greatly increased by fractures. Although the beds comprising the White River formation are lacking in continuity, homogeneity, and similarity, the sample is thought to be generally representative. The coefficients of permeability for the three samples of slope wash ranged from 0.4 to 0.6, averaging 0.43.

Specific Yield

The quantity of water a material will yield from storage depends upon its specific yield. The specific yield of a water-bearing material is defined as the ratio of (1) the volume of water that the saturated material will yield by gravity to (2) its own volume. The specific yield of the sample of the White River formation was 14.5 percent, and the specific yields of two samples of slope wash material were 10.6 and 14.2 percent. This indicates that, if allowed to drain for a long period of time, a cubic foot of the sample of material from the White River formation will yield about 0.145 cubic foot of water, and a cubic foot of slope wash material will yield about 0.124 cubic foot of water. A sample of saturated material will not yield its water at once, but the water will drain slowly; the rate of draining is proportional to the permeability of the material. Owing to their fine-grained character, the materials yield water slowly, and probably several months to a year or more would be required before the specific yield calculated in the laboratory would be reached. Consequently, the quantity of water that is removed from storage by a decline of the water table cannot be calculated from the specific yield that was determined in the laboratory, unless the material is allowed to drain for a long time.

Source and Movement of Ground Water

The source of ground water in the area is recharge from precipitation in this and areas nearby, from irrigation water applied to the land, and, to a lesser extent, from underflow in the valleys of the North Platte River and La Prele Creek. A part of the rain and snow that falls is added directly to the streams, a part evaporates, and the remainder goes into the ground. Most of the water that enters the ground is lost by evapotranspiration, but some reaches the zone of saturation.

The lateral movement of ground water is in the same general direction as the slope of the water table. In the La Prele area, the general direction of movement of unconfined ground water is from the upland areas of recharge toward the valleys, where it is discharged into streams or is lost by evaporation and transpiration in seeped areas. The rate of movement of ground water depends on the size, shape, and degree of interconnection of the pore spaces in the aquifer and on the slope of the water table. The silt and clay of the White River formation and the slope wash generally contain small pore spaces and the movement of water through them is slow. The alluvium, which consists largely of sand and gravel, is comparatively pervious and will transmit water more readily.

Depth to Ground Water

The upper surface of the zone of saturation of unconfined ground water is defined as the water table. The water table is not level but slopes gently and generally contains many irregularities. These irregularities may be caused by differences in thickness and permeability of the water-bearing beds and by differences in recharge to, and discharge from, the ground-water reservoir at different places. Along the stream valleys and in other lowland areas, depths to the water table generally are less than 20 feet below the land surface. In the high, interstream areas, depths to water generally are 50 to 150 feet below the land surface.

Fluctuations of Water Levels

The stage of the water table reflects the amount of water in storage in the ground-water reservoir. Changes of the water level in wells thus indicate changes in storage in the ground-water reservoir and reflect the variations in the recharge-discharge relationship. Water levels decline when ground-water discharge exceeds recharge, and vice versa.

Ten wells were selected for regular monthly observation of the fluctuations of the water table in the area. (See table 2.) The short period of record of measurements precludes the comparison of long-range fluctuations; however, the measurements do show a seasonal rise and decline of the water table. The water level in wells in areas where recharge is solely from precipitation generally declines during the summer months when evapotranspiration is greatest and precipitation is least. It begins to rise in September or October, when evapotranspiration decreases to a minimum, and reaches a peak in May or June, when precipitation is greatest. The water levels in wells in the slope wash and alluvium, which are affected mainly by recharge from irrigation, begin to rise in April or May, reach a peak in August or September, and then decline during the winter months.

Table 2.--Measurements of the water level in observation wells in the La Prele area, Wyoming, in feet below land-surface datum

Date	Water level	Date	Water level
32-71-7dcd			
Aug. 3, 1950	10.97	Mar. 28, 1951	11.98
17	9.91	Apr. 25	12.87
Sept.25	7.32	May 22	13.41
Oct. 26	8.02	June 26	13.96
Nov. 15	8.51	July 25	13.71
Dec. 11	8.79	Sept.20	10.09
Feb. 9, 1951	9.68	Oct. 27	8.08
28	11.02		
32-71-8acb			
Aug. 24, 1950	2.47	Dec. 11, 1950	2.46
Sept.25	2.65	Feb. 9, 1951	4.93
Oct. 26	5.36	28	5.06
Nov. 15	5.24	Mar. 28,	5.26

Table 2.--Measurements of the water level in observation wells in the La Prele area, Wyoming--Continued

Date	Water level	Date	Water level
32-71-8acb--Continued			
Apr. 25, 1951	4.97	July 25, 1951	2.32
May 22	3.42	Sept.20	3.12
June 26	3.62	Oct. 27	3.30
32-71-16cac			
July 26, 1950	28.40	Mar. 28, 1951	27.97
Aug. 24	28.27	Apr. 25	28.08
Sept.25	28.17	May 22	27.98
Oct. 26	24.51	June 26	27.83
Nov. 15	26.50	July 25	27.77
Dec. 11	27.60	Sept.20	27.95
Feb. 9, 1951	27.71	Oct. 27	24.15
28	28.52		
32-71-18daa			
July 9, 1950	40.79	Nov. 15, 1950	39.74
Aug. 24	44.27	Dec. 11	39.88
Sept.25	41.05	Feb. 9, 1951	39.13
Oct. 26	40.25		
32-71-31aaa			
July 10, 1950	20.32	Feb. 28, 1951	13.56
Aug. 24	14.36	Mar. 28	13.88
Sept.25	14.17	May 22	13.92
Oct. 26	14.04	June 26	14.06
Nov. 15	13.92	July 25	14.49
Dec. 11	13.86	Sept.20	13.97
Feb. 9, 1951	13.34	Oct. 27	14.08
32-72-13dcd			
July 9, 1950	14.70	Dec. 11, 1950	13.64
Aug. 24	21.82	Feb. 28, 1951	15.37
Sept.25	15.19	June 26	11.46
Oct. 26	13.03	July 25	12.73
Nov. 15	13.57	Sept.20	15.08
32-73-9bdd			
Aug. 2, 1950	6.20	Mar. 28, 1951	9.00
24	3.78	Apr. 25	9.02
Sept.25	1.03	May 23	7.70
Oct. 26	4.03	June 25	5.37
Nov. 15	5.64	July 25	2.10
Dec. 11	5.79	Sept.20	1.45
Feb. 9, 1951	6.03	Oct. 27	3.97
28	7.34		
33-73-27abc			
Aug. 24, 1950	6.45	Nov. 15, 1950	5.66
Sept.25	5.80	Dec. 11	5.58
Oct. 26	5.68	Feb. 9, 1951	5.34

Table 2.--Measurements of the water level in observation wells in the La Prele area, Wyoming--Continued

Date	Water level	Date	Water level
33-73-27abc--Continued			
Feb. 28, 1951	5.26	June 26, 1951	4.56
Mar. 28	5.18	July 25	4.83
Apr. 25	5.06	Sept.20	6.12
May 23	4.99	Oct. 27	5.53
33-73-34bcc			
July 31, 1950	5.92	Nov. 15, 1950	5.50
Aug. 17	4.46	Dec. 11	5.53
Sept.25	3.65		
33-73-34ccc			
July 31, 1950	26.10	Mar. 28, 1951	25.97
Aug. 24	25.85	Apr. 25	25.64
Sept.25	26.05	May 23	25.38
Oct. 26	25.99	June 26	26.03
Nov. 15	25.86	July 25	26.96
Dec. 11	25.76	Sept.20	26.15
Feb. 9, 1951	26.06	Oct. 27	26.05
28	26.01		

Discharge of Ground Water

Ground water is discharged from the La Prele area through evapotranspiration, seepage into streams, wells, and underflow that leaves the area. No attempt was made to determine the amount of water discharged through these processes.

Evapotranspiration is a major factor in the discharge of ground water in the area. The water table is at or very near the surface in the lowland areas and stream valleys; this results in seeps that support a very luxuriant growth of vegetation. The amount of water discharged by evapotranspiration in these areas varies with the season--the greatest discharge occurs during the growing season when temperatures are highest.

Most of the streams in the area (except La Prele Creek and the North Platte River) are fed mainly by the discharge of ground water and by surface runoff from irrigated fields. The amount of this discharge was not measured during this investigation, but it probably is large.

Water is pumped from wells only for domestic and stock use and probably does not exceed a hundred acre-feet a year.

Seeps

The water table lies at shallow depth throughout much of the lowland areas. In places, considerable damage to the farmland has resulted from the shallow-lying ground water, which drowns the crops, deposits harmful mineral salts on or in the soil, and renders the land unworkable. Most of the low areas that are downslope from irrigated lands are swamps, and it has been necessary for the farmers to control closely the amounts of water applied to higher farmlands to prevent an increase in the waterlogging of downslope farmlands. Most of the farmland is underlain by a relatively thin mantle of slope wash, which overlies the siltstone and clay of the White River formation. Both the slope wash and the White River formation have low coefficients of permeability and are not capable, under the existing gradient, of laterally transmitting the amount of water that is recharged from irrigation and precipitation.

In the future, if additional land is irrigated upslope from the existing farmland, the extent of the seep areas will increase. Also, if additional water is applied to the existing farmland, the extent of the waterlogged areas can be expected to increase.

CHEMICAL QUALITY OF THE WATER

By W. H. Durum

Introduction

The quality-of-water investigation in the La Prele area, although of reconnaissance scope, yields information that is useful in estimating the kinds and ranges of mineral substances in the water from the various formations. This information is of interest to the owners of the specific wells from which water samples were obtained and is an aid in the planning of additional drilling and further exploratory study. For example, in those parts of the La Prele area where ground water is available for irrigation or for other uses, the quality of the water determines to what extent the various sources can be utilized. In addition, the knowledge of the composition of the soluble substances in water is an index of the history of the water and, when used in conjunction with other hydrologic data, assists in determining the direction of ground-water flow. Also, the effect of the application of irrigation water on the soil chemicals can be determined by the nature and degree of mineralization of irrigation return flow to the streams and of shallow ground water. Information pertaining to the character of the soluble minerals in the water is also helpful in determining the source of the water.

The determinations of chemical substances in water samples from the La Prele area were made in accordance with methods commonly employed by the U. S. Geological Survey (1950) and the U. S. Public Health Service (1946). The constituents sodium and potassium were determined by the flame photometer. The boron concentration was determined by a modified method of the electrometric procedure as described by Wilcox and Hatcher (1947, pp. 22-28).

The process by which impurities occur in water may be summarized briefly as follows: Rain water in descending through the air and in percolating through the upper layers of soil absorbs carbon dioxide with which it forms carbonic acid. This action increases the solvent power of the water, enabling it to dissolve a certain amount of the mineral matter of the soil or rock with which it comes in contact. Hence, ground water obtained from either shallow or deep wells may be hard or soft depending on the mineral characteristics of the rocks through which the water has moved and in which the water is now in transient storage. Natural filtration through sand usually provides a water relatively free of turbidity and low in organic matter. Dissolved gases, unless they combine chemically with other substances, can be expelled by heat and are not considered as dissolved solids.

Scope of the Investigation

Fourteen samples obtained in August 1950 from ground-water sources and 3 samples of surface water obtained at low flow compose the source of data used in preparing this part of the report. (See fig. 7 and table 4.) The ranges of several constituents for the 4 water samples obtained from the unconsolidated materials, which include slope wash and alluvium, and 10 samples from consolidated rocks, which include the White River and Fort Union formations, Benton shale, and Casper formation, are shown in table 3.

A graphic representation of the chemical composition of water from the various sources is shown in figure 8. The combining power or equivalents per million of the cations appear on the left side of the column and the anions on the right side of the column. The sum of the equivalents as represented by the height of the two columns is a measure of the total concentration of the water.

Table 3.--Ranges in physical characteristics and chemical substances in water from unconsolidated materials and bedrock

Source	Depth (feet)	Temperature (°F)	Sulfate	Dissolved solids	Hardness as $CaCO_3$	Percent sodium
			Parts per million			
Unconsolidated materials...	8-40	52-64	105-2,750	494-4,440	52-960	59-88
Bedrock..................	30-725	50-65	2.0-2,650	204-4,430	8-1,280	27-97

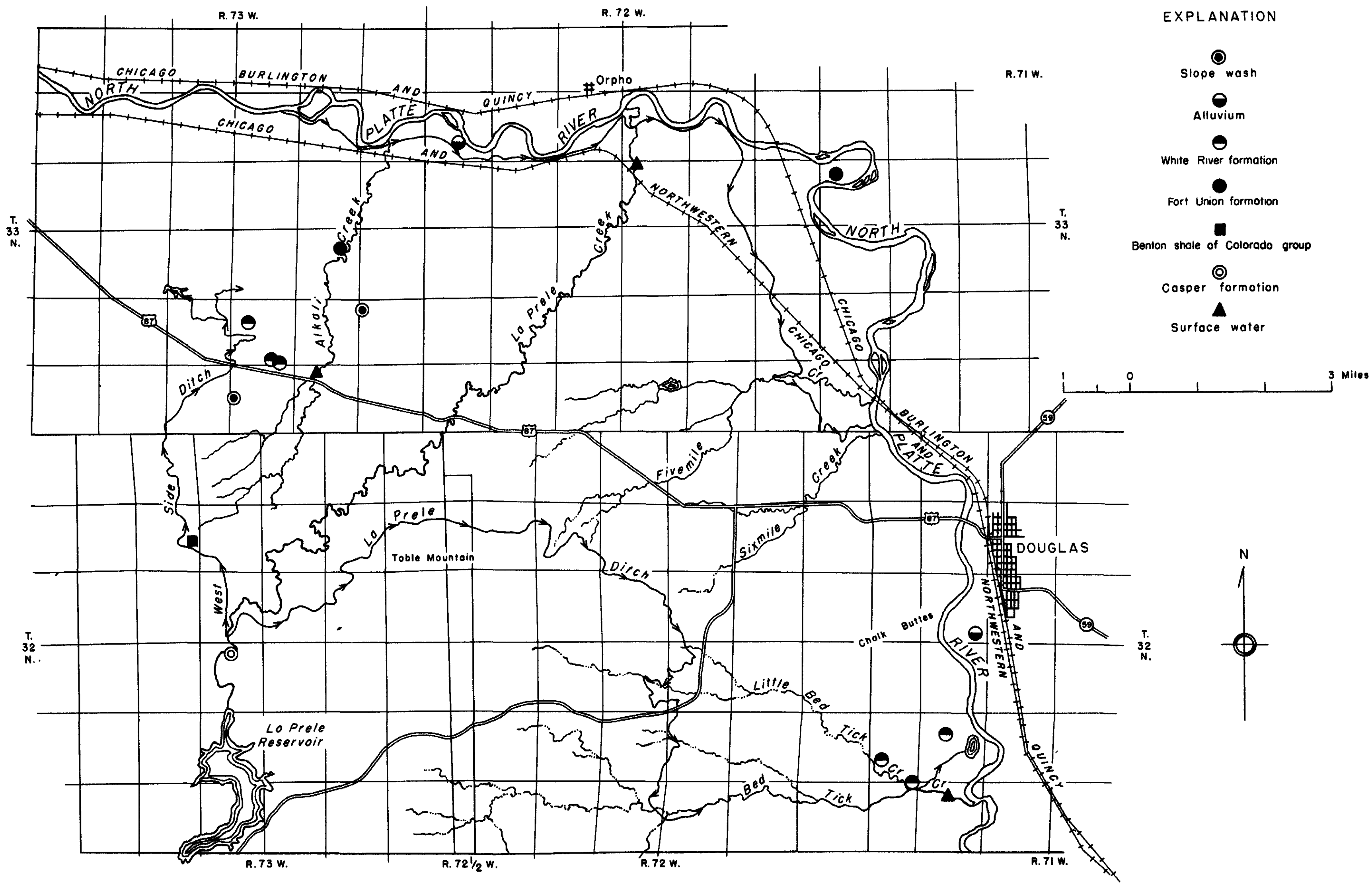

Figure 7.--Location of quality-of-water sampling points in the La Prele area, Wyoming.

Table 4.--Mineral constituents and related physical measurements of waters in the La Prele area, Wyoming
[Analytical results in parts per million except as indicated]

Location	Date of collection (1950)	Depth (feet)	Temperature (°F)	pH	Specific conductance (micromhos at 25°C)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium
																				Total	Noncarbonate	
Slope wash:																						
33-73-34bcc	8-17	8	56	7.8	5,350	43	2.8	305	49	995	37	0	388	2,750	30	1.1	19	1.3	4,440	960	642	68
25bbb	8-17	Spring	52	7.8	1,030	72	.04	20	.5	216	9.4	0	478	105	29	.8	2.8	.20	718	52	0	88
Alluvium:																						
32-71-17ddb	8-16	40	64	8.2	726	39	.07	39	7.3	115	8.9	4	258	124	17	.5	5.2	.23	494	127	0	64
33-72- 7dbc	8-17	12	54	7.6	2,120	17	.04	139	33	332	8.6	0	510	700	31	.6	2.3	.42	1,510	482	64	59
White River formation:																						
32-71-29bdb	8-16	110	60	8.0	2,410	27	.32	18	2.4	512	10	0	372	475	277	3.2	1.6	1.4	1,510	55	0	94
30cbd	8-16	35	50	7.6	3,320	24	6.9	80	21	690	26	0	708	1,080	96	.8	.7	.66	2,370	287	0	82
31aaa	8-16	84	52	8.6	854	12	.28	3.0	.1	207	4.1	18	406	38	35	2.6	.8	1.3	532	8	0	97
33-73-27bdb	8-17	92	50	8.1	1,450	64	1.8	25	1.0	309	16	0	616	205	32	.7	18	.45	974	67	0	89
27dcc	8-17	30	52	7.8	5,450	64	.04	263	57	1,060	42	0	464	2,650	26	1.0	33	1.2	4,430	892	512	71
27dcd	8-17	160	55	7.2	5,200	59	.04	157	13	1,130	46	0	343	2,500	41	.6	83	.82	4,200	447	166	83
Fort Union formation:																						
33-73-23aca	8-18	100	57	7.7	3,620	13	1.7	353	98	432	38	0	432	1,830	52	.3	.4	.20	3,030	1,280	926	41
33-71-18bdb	8-17	210	65	8.2	685	9.9	.04	16	7.4	137	4.6	6	351	43	13	1.1	3.2	.30	424	71	0	80
Benton shale of Colorado group:																						
32-73-8dab	8-16	725	51	8.2	1,340	13	4.1	8.5	.4	310	5.0	12	580	2.0	142	1.0	2.6	1.6	802	23	0	96
Casper formation:																						
32-73-21abb	8-16	Spring	65	7.9	316	23	.34	37	4.6	20	4.0	0	144	34	3.0	.4	1.4	.29	204	112	0	27
Surface water:																						
La Prele Creek south of Orpha, Wyo.	8-17	......	72	8.3	835	37	.04	58	19	108		8	358	123	15	.4	1.4	.41	744	223	0	51
Alkali Creek west of Douglas, Wyo.	8-16	......	71	8.5	1,550	44	.10	41	8.3	307		16	394	415	14	.7	1.4	.72	1,040	137	0	83
Bed Tick Creek south of Douglas, Wyo.	8-16	......	69	8.3	796	37	.04	48	7.3	126		4	296	143	17	.4	.6	.32	546	150	0	65

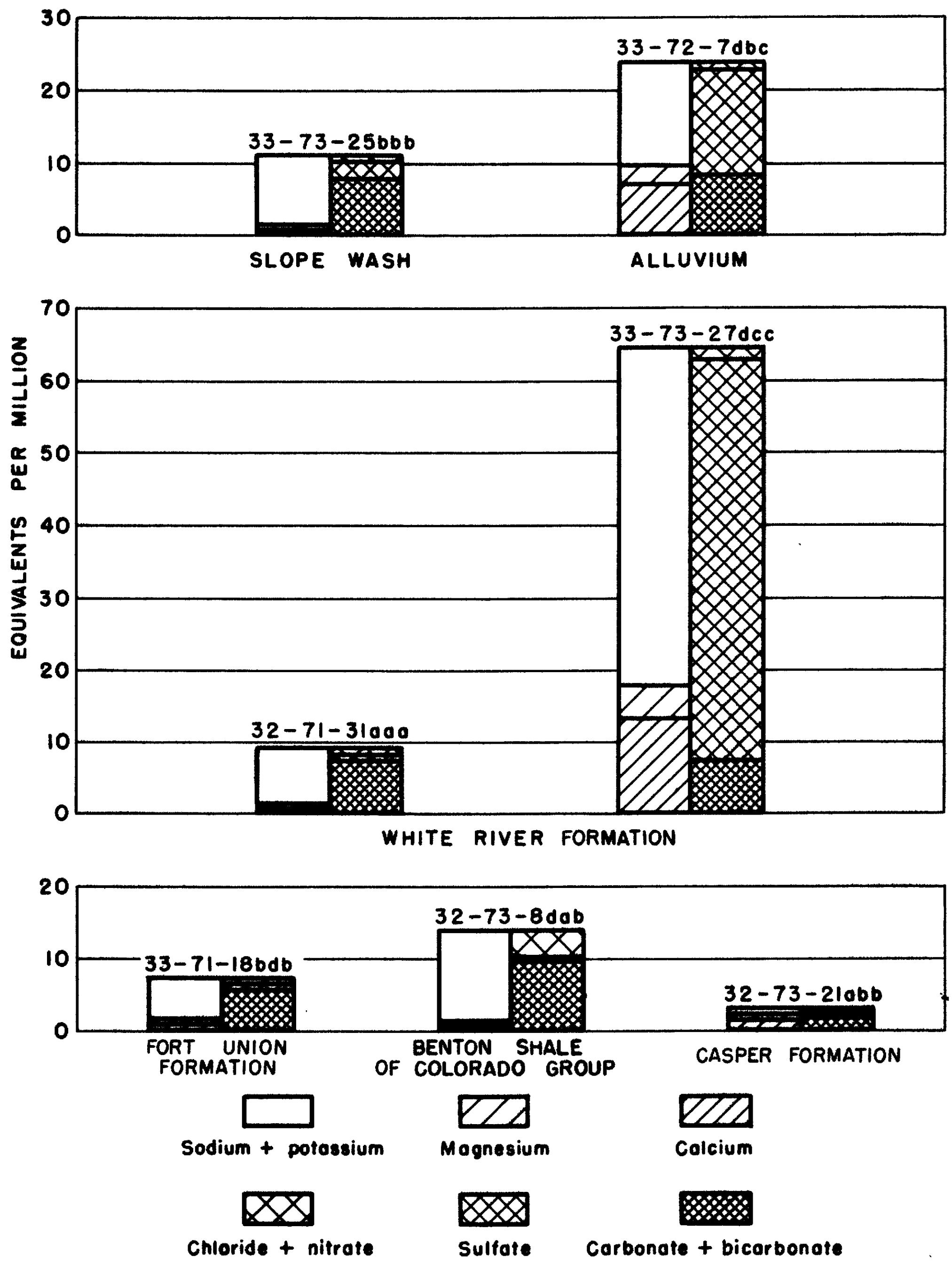

Figure 8.--Graphic representation of chemical composition of ground water from several aquifers.

Chemical Properties of the Water in Relation to Geologic Source

Unconsolidated Materials

The wide range in the chemical constituents in four water samples from the unconsolidated materials accounts for the difficulty in obtaining satisfactory supplies for domestic or irrigation uses in some parts of the area. Two of the samples contained more than 1,500 ppm of dissolved solids and had a hardness of more than 400 ppm. As is true of other mineralized water from bedrock, sodium and sulfate are the principal mineral substances in solution. One of the 2 samples was collected from a dug well 33-73-34bcc, 8 feet deep, in the slope wash. Although neither the nitrate nor the chloride is sufficiently high to suggest contamination, the well construction undoubtedly favors surface seepage.

Well 32-71-17ddb yielded the water of lowest mineral content of supplies from unconsolidated materials. Possibly the location of this well on the east side of the North Platte River and away from the irrigated area accounts for this more favorable supply. Also, the well is somewhat deeper than the other wells sampled in the unconsolidated materials--a factor of considerable importance where surface seepage is a problem.

The sample from the spring at 33-73-25bbb is characterized by its softness of 52 ppm as contrasted with that of the other sources in the unconsolidated materials. The extremely high percentage of sodium indicates that the water has been in contact with materials that have high exchangeable sodium; these materials probably are either in the older formations or in the silts and clays of the slope wash.

In summary, waters from unconsolidated materials are of variable quality. The hardness and other characteristics of water in the alluvium along the North Platte River depend on the interrelation of ground and surface waters. Where the aquifer is recharged by irrigation return flows, the chemical characteristics of the water-bearing materials suggest the accretion of a relatively high percentage of sodium. The water in wells recharged periodically by river water reflects the composition of the North Platte River water. The concentration of fluoride in unconsolidated materials is generally less than the suggested limit of 1.5 ppm for drinking-water supplies; boron is lower than the maximum allowable limit of 2.0 ppm for irrigation supplies and thus presents no problem.

Consolidated Rocks

White River formation.--Like water from unconsolidated materials, the samples obtained from the White River formation differ widely in range in content of dissolved minerals. Dissolved solids range from 532 ppm to 4,430 ppm; the content of dissolved solids in 4 of the 6 samples obtained from the White River formation exceeded 1,500 ppm. As is true of samples from unconsolidated materials, most of the differences in mineral content appear to be related to the quantity of sodium sulfate. The heterogeneity of the water quality is demonstrated by the group of 3 samples that were collected in the southeast corner of the area from wells which are 35, 84, and 110 feet deep. (See fig. 7 and table 4.) The content of dissolved solids ranged from 532 ppm to 2,370 ppm, and no particular correlation with depth was noted except for hardness, which was much greater for the sample from the shallow source. In contrast, the water from the deeper source had a much higher concentration of chloride and an undesirable concentration of fluoride. High percentages of sodium were common to the 3 samples.

Two samples from the same formation but at different depths in adjacent wells in a farmyard were similar in total mineral content and composition. The owner of the wells stated that the well 33-73-27dcd, 160 feet deep, probably was cased only to 70 feet; consequently, infiltration from the hard water zone above is probably mixing with the softer water at the greater depth.

The definite softening action that has taken place in some water supplies from the White River formation and in unconsolidated materials derived from the White River formation has been noted. This feature seems related to the bentonite found in the White River formation (table 6), which possesses the property of readily exchanging its bases. Renick (1924, pp. 53-72) points out that the reactions between the dissolved minerals and base-exchange silicates are rapid and that ground water may have its calcium and magnesium replaced by sodium and potassium by percolating through only a few feet of rock that contains materials capable of entering into base-exchange reactions.

The fine-grained character of the sediments in the White River formation markedly affects the quality of the water from this source; consequently, supplies of suitable quality for general farm use may be difficult to locate in some parts of the area.

Other water-bearing formations.--The two samples of water from the Fort Union formation are widely divergent in chemical character, which is probably largely due to the location of the wells and the source of recharge. (See fig. 7 and table 4.) Well 33-73-23aca may receive considerable return flow from irrigation of tracts east of West Side ditch, whereas well 33-71-18bdb is on the flood plain of the North Platte River and at times probably receives some recharge from this source.

The sample from the deepest well in the sampling program was from the Benton shale of the Colorado group at 725 feet. The log of the well (32-73-8dab) indicates that the water was cased off at 667 feet and that paraffin and natural gas had been encountered during drilling below a depth of 500 feet. The apparent reduction of sulfate resulting from decomposition by organic matter is illustrated in table 4 and figure 8. This reaction, which had been described by Riffenburg (1925, p. 39) proceeds as follows:

$$CaSO_4 + CH_4 \rightarrow CaS + CO_2 + 2H_2O \rightarrow CaCO_3 + H_2S \uparrow + H_2O$$

An equivalent amount of carbonate is produced for the sulfate reduced.

It will be noted that bicarbonate constitutes about 70 percent of the acid radicals in the sample from 32-73-8dab, that the water is very soft, and that sodium and chloride are very prominent.

The single sample from the Casper formation, as represented by a spring in Natural Bridge (Ayers) Park, indicated a source of slightly mineralized water. Although the water contained only 204 ppm of dissolved solids, a large percentage of the dissolved minerals was calcium carbonate, which indicated the limy character of this formation. The iron content was only a fraction of that found in the sample from the Benton shale.

In summary, insufficient data are available to describe adequately the supplies from sources older than the White River formation. In that formation, at least, undesirable levels of dissolved solids, sulfate, hardness, and fluoride are frequently encountered.

Chemical Quality of Stream Flow as Related to Ground-Water Inflow

Of the 3 surface drainageways that were sampled in the area, Alkali Creek showed the largest accretion of mineral salts that resulted from irrigation return flows. One sample collected about midway from headwaters to mouth (table 4) contained more than 1,000 ppm of dissolved solids, largely sodium sulfate—the principal mineral substance found in waters from the White River formation, which immediately underlies the area. A field resistivity measurement was made of Alkali Creek water near the junction with the North Platte River. A specific conductance of about 1,990 micromhos at 25°C indicated a significant downstream accretion of soluble materials.

The sample from La Prele Creek taken near its mouth was much less concentrated than that from Alkali Creek. Sulfate was proportionally lower and the quantity of calcium bicarbonate was proportionally higher than in the Alkali Creek sample, owing principally to dilution by surface runoff. The same can be said of the sample from Bed Tick Creek, which is the terminal for the La Prele ditch and is somewhat more dilute than might be expected from ground-water flow, particularly from the consolidated materials. Salt encrustations in those parts of the area where waterlogging is prevalent are the result of evaporation of shallow ground water that is brought to the ground surface by capillary action. A sample of a soil-salt encrustation was collected along U. S. Highway 87 near Alkali Creek where the encrustations are particularly noticeable. Analysis of the principal soluble constituents in a 500-milliliter extract of 100 grams of the soil-salt mixture yielded the following composition of the salts:

Constituent	Percent of total equivalents per million
Calcium (Ca)	2.64
Magnesium (Mg)	.53
Sodium and potassium (Na and K)	46.84
Chloride (Cl)	2.73
Nitrate (NO_3)	.03
Sulfate (SO_4)	45.60
Bicarbonate (HCO_3)	1.63
	100.0

Quality of Water in Relation to Use

A tabulation of the 14 supplies that were sampled establishes the following uses or combination of uses:

Domestic	7
Stock	9
Observation	2
Public	1

The results given in table 4 indicate that dissolved solids in 7 samples from both consolidated and unconsolidated materials are at much higher levels than the upper limit of 1,000 ppm as suggested by the U. S. Public Health Service (1946). Also, sulfate in about half the samples exceeded the suggested limits of 250 ppm. It was noted also that fluoride concentrations in 2 samples from bedrock were considerably greater than the desirable level of 1.5 ppm or less. Generally, the more highly mineralized water was very hard.

The spring, which originates in the Casper formation and is used as a public supply in Natural Bridge (Ayers) Park, is of satisfactory chemical quality for drinking or culinary use.

None of the wells that were inventoried are being used for irrigation, other than for lawns or gardens; however, it is important that some consideration be given to the quality of the supplies for irrigation. Because of the variable composition and concentration of minerals in the water in the area, the individual supplies should be carefully evaluated prior to application of the water to the lands. This evaluation involves consideration of at least three factors (Wilcox, 1948): (1) the total concentration of dissolved solids, (2) the percentage of sodium, and (3) the quantity of boron. Each must be considered in the light of factors, such as soil composition, permeability, drainage, irrigation practices, and crop tolerances. Application of irrigation water that is high in dissolved solids may increase the salinity of the soil solution, which may ultimately affect the permeability of the soils and reduce plant growth.

There is general agreement among authorities that irrigation water that contains high percentages of sodium may cause dispersion of soil particles, which may ultimately retard water and air movement through the soil.

Boron in quantities larger than about 2.0 ppm is a limiting factor in water for irrigation. However, as the waters examined in the La Prele area are low in boron content, this factor is not an important consideration in this area.

A diagram proposed by Wilcox (1948) is used to illustrate the suitability of water in the La Prele area for irrigation. (See fig. 9.) The water classes are determined by the quantity of the mineral substances as indicated by the specific conductance (or equivalents per million) and the percentage of sodium. As the mineralization and percentage of sodium increase, the water takes a progressively lower rating. It can be seen in figure 9 that waters from bedrock are generally of poor quality for irrigation. Supplies from the alluvium, particularly the hard water in the alluvium along the North Platte River, are more satisfactory for irrigation by reason of a lower percentage of sodium.

Some farms in the area are supplied irrigation water from local diversions of La Prele, Alkali, and Bed Tick Creeks and the North Platte River; consequently, some consideration should be given to the suitability of such supplies. On the basis of the meager data for low flow, the waters of La Prele and Bed Tick Creeks rate "permissible" and the water of Alkali Creek rates "doubtful" as a source of irrigation supply for the particular flow that was sampled.

Abridged chemical data for a total of 12 samples from the North Platte River at Douglas, Wyo., for the period June 1, 1949, to April 30, 1951 are shown in table 5. The data indicate that during the irrigation season, diversions from the North Platte

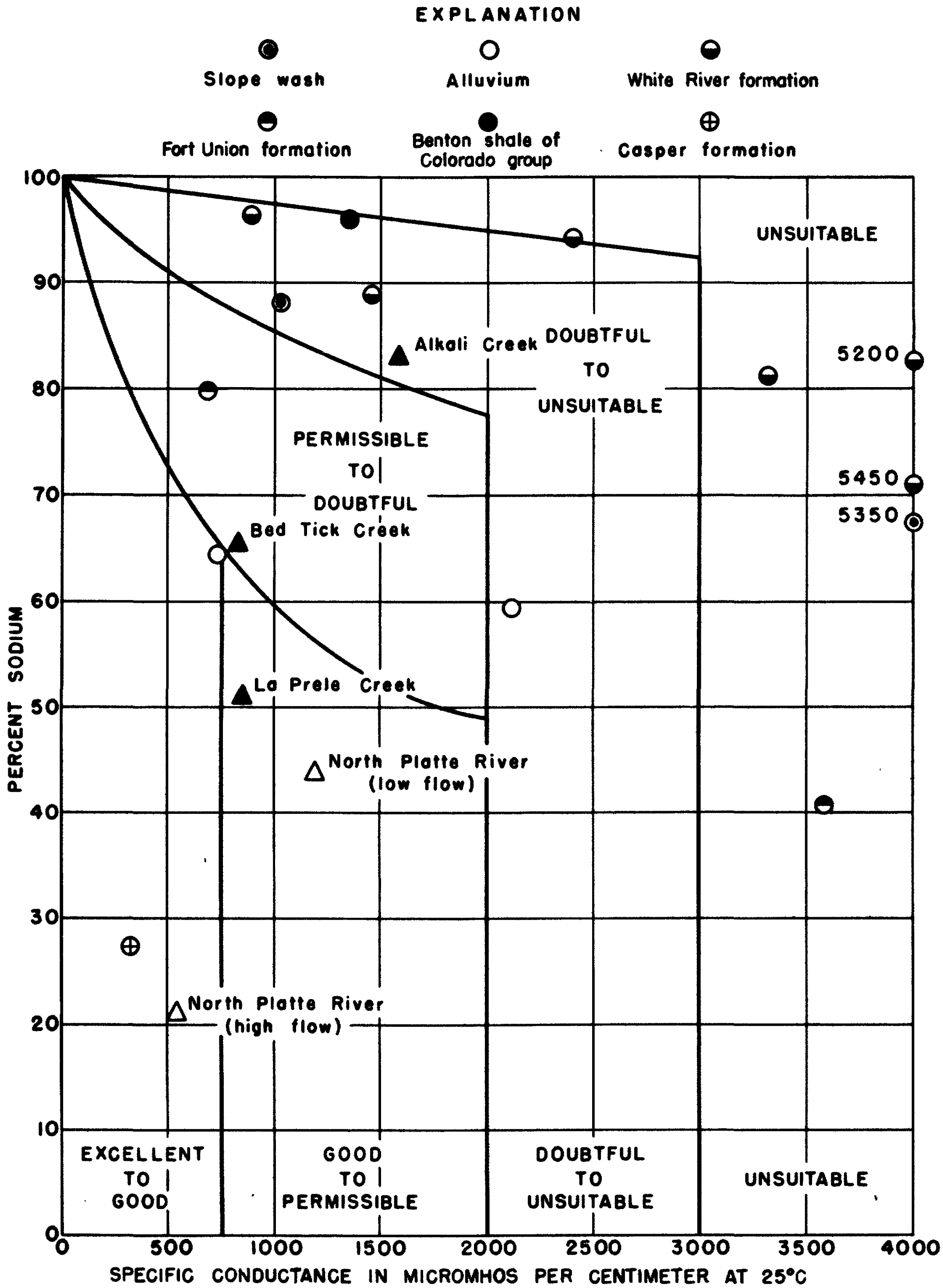

Figure 9.--Classification of waters in La Prele area for irrigation use. (After Wilcox.)

Table 5.--Classification of the North Platte River water for irrigation at high and low flow, Douglas, Wyo., June 1949 to April 1951

	Discharge (cfs)	Specific conductance (micromhos at 25°C)	Percent sodium	Rating
Maximum........	5,070	520	21	Excellent
Minimum........	180	1,210	44	Permissible

River rate "permissible" or better as irrigation supplies.

Re-use of low flow water from Alkali Creek for irrigation should be avoided, inasmuch as drainage returns to the stream are high in percentage of sodium and the concentration of salts seem to increase somewhat downstream.

CONCLUSIONS

The White River formation of Tertiary age and the slope wash and alluvium of Quaternary age are the principal sources of ground water in the area. The White River formation and the slope wash, which consist predominantly of fine-grained materials, are capable of yielding only relatively small quantities of water to wells. Where sufficient saturated thicknesses are encountered, the alluvium, which consists mainly of coarse materials, probably would yield enough water for irrigation needs.

Recharge from irrigation water and precipitation has caused waterlogging of farmland in the lowland areas. If, in the future, additional lands that are upslope from the present farmlands are irrigated, or if additional water is applied to the existing farmlands, the extent of the waterlogged areas will increase.

Results of analyses of 14 samples from unconsolidated materials and bedrock indicate wide variation in the amounts of mineral substances from the various sources. For the shallow wells, dissolved solids in excess of 1,500 ppm, extremes in hardness, and high percentages of sodium were observed. Most of the differences in mineral content are related to the quantity of sodium sulfate.

As is true of water from the unconsolidated materials, water from deeper sources in bedrock differs widely in concentration and composition. The fine-grained character of the rocks in the White River formation produces a marked effect upon the quality of water from this source; consequently, water supplies of suitable quality for general farm use may be difficult to locate in areas where the White River formation is the only aquifer. Dissolved solids range from 532 to 4,430 ppm. Concentrations of fluoride are somewhat greater than desirable in some water from the White River formation. No particular correlation of total mineralization with depth was noted except that water from shallow sources generally is harder. The definite softening action that occurs in some water from the White River rocks appears to be related to the bentonite, which is found in them. Reduction of sulfate is noticeable in one well, 725 feet deep, in the Benton shale where the water has encountered natural gas.

Waters from bedrock are generally of poor quality for irrigation because of high percentages of sodium; the hard waters of lower mineralization in the unconsolidated materials are of better quality for irrigation. Water diverted from Alkali Creek at low flow is considered to be of questionable quality for irrigation.

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LOGS OF WELLS

Table 6 contains logs of 4 oil tests and 4 water wells drilled in the La Prele area. The drillers' description was used because in many places it was impossible to interpret their meaning. The logs of the 4 oil tests and 1 water well (32-71-7bbc) are copies of drillers' logs; the logs of the other 3 water wells represent data reported by the well owners. The reported data are believed to be reasonably accurate and to give a reliable description of the material that was penetrated.

Table 6.--Logs of wells in the La Prele area, Wyoming

	Thickness (feet)	Depth (feet)
32-71-7bbc		
Sand, white, and shale....	35	35
Shale, blue..............	18	53
Shale, sandy.............	32	85
Shale, pink and blue......	10	95
Shale, sandy.............	25	120
Shale, gray..............	9	129
Sand (show of water only).	1	130
Shale, gray..............	25	155
Shale, pink and gray......	59	214
Shale, gray..............	3	217
Sand (water, about 10 barrels per hour).........	3	220
Shale, gray..............	30	250
Shale, dark..............	5	255
Shale, blue..............	10	265
Shale, gray..............	65	330
Shale, shelly............	35	365
Shale, sandy, black.......	15	380
Shale, gray..............	20	400
Shale, dark..............	5	405
Shale, gray..............	12	417
Sand (water, small show)..	3	420
Shale, sandy, gray........	25	445
Shale, gray..............	20	465
Shale, hard, shelly, gray.	19	484
Shale, sandy.............	6	490
Shale, gray..............	3	493
Sand, loose, coarse (water)	8	501
Shale, yellow; contains gray sand rock..........	4	505
Sandstone, hard gray......	5	510
Clay, hard...............	18	528
Shale, sandy, very hard, gray.................	9	537
Clay, hard...............	3	540
32-71-20add		
White River formation:		
Sand, very fine, shaly, brown with some green..	110	110
Sand, very fine, shaly, light-green..........	10	120
Shale, very sandy, brown	20	140
Sand, shaly, green and brown................	10	150
Sand, very fine, shaly, brown................	10	160
Sand, very fine, shaly, green................	10	170

Table 6.--Logs of wells in the La Prele area, Wyoming--Continued

	Thickness (feet)	Depth (feet)
32-71-20add--Continued		
White River formation--Continued		
Sand, very fine, shaly, brown	10	180
Shale, bentonitic, green; contains a little rust-colored fine shaly sand	10	190
Sand, fine, brown; contains some green bentonitic shale	10	200
Sand, very shaly, brown; contains a little green bentonitic shale	30	230
Sand, shaly, brown	20	250
No sample	10	260
Sand, very fine, shaly, green	20	280
Shale, bentonitic, brown; contains sand	10	290
Sand, very shaly, brown and light-green	10	300
Shale, bentonitic, brown; somewhat sandy	60	360
Shale, bentonitic, sandy, brown and light-green	40	400
Shale, bentonitic, sandy, light-green	10	410
Shale, bentonitic, sandy, brown	20	430
Sand, very fine, shaly, brown	10	440
Shale, bentonitic, sandy, brown	10	450
Shale, bentonitic, very sandy, brown	10	460
Shale, bentonitic, sandy, brown	10	470
Shale, very bentonitic, brown, slightly sandy	20	490
Shale, bentonitic, slightly sandy, brown and light green	10	500
Shale, bentonitic, slightly sandy, brown	30	530
Shale, bentonitic, sandy, brown (show of gas - 580 feet	50	580
Shale, bentonitic, sandy, brown	10	590

Table 6.--Logs of wells in the La Prele area, Wyoming--Continued

	Thickness (feet)	Depth (feet)
32-71-20add--Continued		
White River formation--Continued		
Shale, brown and green; contains sandy bentonite	10	600
Shale, bentonitic, slightly sandy, green and brown	10	610
Shale, very bentonitic, slightly sandy, brown and light-green	10	620
Shale, bentonitic, sandy, brown and light-green	30	650
Shale, very bentonitic, slightly sandy, brown	30	680
Shale, bentonitic, sandy, brown and green	20	700
Shale, bentonitic, sandy, green and brown	20	720
Shale, bentonitic, slightly sandy, green and trace of brown	10	730
Shale, bentonitic, very sandy, green and brown	10	740
Shale, bentonitic, sandy, brown and green (coarser sand)	30	770
Sand, coarse, angular; contains trace of sandy green shale	10	780
Sand, coarse, angular; contains light-green bentonitic shale	20	800
Corrected by pipe measurement	10	810
Sand, coarse, angular; contains some gravel; trace of brown bentonitic shale, trace of gray to brown slightly calcareous shale	5	815
Sand, coarse, angular; contains trace of green bentonitic shale (gas odor)	5	820
32-71-30cbd		
Gravel	6	6
Clay	25	31
Clay; contains gravel	4	35

Table 6.--Logs of wells in the La Prele area, Wyoming--Continued

	Thickness (feet)	Depth (feet)
32-72-13dcd		
Topsoil..................	6	6
Clay (went through a shale layer at about 70 feet..	74	80
32-73-8dab		
Water formation...........	10	10
Lime formation, brown (water at 36 feet)..........	70	80
Shale, gray...............	40	120
Shale, blue...............	70	190
Gumbo, blue...............	22	212
Gumbo, brown and green (water at 217 feet).........	50	262
Crystal formation.........	13	275
Gumbo, blue...............	10	285
Pink and brown formation..	25	310
Shales, mixed.............	22	332
Shale.....................	188	520
Sand - water (water flowed over top of hole)........	8	528
Shell rock, hard (strong flow of gas)............	1	529
Sand, black...............	13	542
Shale (water at 550 feet).	104	646
Paraffin..................	5	651
? (Water cased off at 667 feet; struck oil at 718 feet)..................	74	725

Table 6.--Logs of wells in the La Prele area, Wyoming--Continued

	Thickness (feet)	Depth (feet)
32-73-9aaa		
Shale (water at 12 and 22 feet)....................	308	308
Sand, coarse, white.......	2	310
Shale.....................	98	408
Shale, pale pink..........	24	432
Shale, red; hole caved....	26	458
Shale, green, and gray sand......................	10	468
? (Gas)...................	2	470
32-73-9cad		
Clay (water)..............	55	55
Shale, gray, and clay.....	263	318
Red rock..................	8	326
Sand (gas)................	8	334
Rock, yellow, and light shale.....................	29	363
Shale, black..............	42	405
Shale, black, and paraffin	45	450
Sand (oil)................	5	455
Shale, gray...............	13	468
Shale, black..............	7	475
33-72-36abd		
Gravel....................	4	4
Shale, dirty, brown, with some coal................	48	52
Sand rock, soft, very fine, white.....................	8	60

Table 7.--Records of wells and springs in the La Prele area, Wyoming

Well no.: See text for description of well-numbering system.
Type of supply: B, bored well; Dn, driven well; Dr, drilled well; Du, dug well; Sp, spring.
Depth of well: Measured depths are given in feet and tenths below measuring point; reported depths are given in feet below land-surface datum.
Type of casing: C, brick, cement, concrete, or tile pipe; N, none; P, iron or steel pipe; R, rock.
Character of material: Cl, clay, G, gravel; S, sand; Sl, silt; Sls, siltstone; Ss, sandstone.
Geologic source: Kb, Benton shale (Colorado group); Kcv, Cloverly formation; Pc, Casper formation; Qal, alluvium; Qsw, slope wash; Qt, terrace deposits; Ta, Arikaree sandstone; Tfu, Fort Union formation; Twr, White River formation.
Method of lift (first letter): C, cylinder; F, natural flow; N, none; T, turbine.
Type of power (second and third letter): E, electric motor; G, gasoline engine; H, hand operated; N, none; W, windmill.
Use of water: D, domestic; N, none; O, observation; P, public supply; S, stock.
Measuring point: Bpb, bottom of pump base; Epb, edge of pump base; Hc, hole in casing; Hpb, hole in pump base; Hph, hole in pump housing; Ls, land surface; Tbc, top of board cover; Tc, top of casing; Tpb, top of pump base.
Depth to water: Measured depths to water level are given in feet, tenths, and hundredths; reported depths are given in feet.
Remarks: Ca, sample collected for chemical analyses; D, discharge in gallons a minute (E, estimated; R, reported); L, log of well given in table 3; Ot, oil test; T, temperature in degrees Fahrenheit.

Well no.	Owner or tenant	Type of supply	Depth of well (feet)	Diameter of well (inches)	Type of casing	Character of material	Geologic source	Method of lift and type of power	Use of water	Measuring point: Description	Measuring point: Distance above (+) or below (-) land surface (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
32-71- 5caa	Bill Smith.............	Dr	.....	4	P	......	Tfu	C,H	D	Hph	+1.6	17.13	8- 2-50	T 52
7bbc	Town of Douglas........	Dr	540	...	P	......	Tfu	N	N	Ls	....	150	1950	L
7dcd	.....do................	Dr	51.4	12	P	S,G	Qal	T,E	O	Tpb	+1.2	12.17	8- 3-50	
8acb	U. S. Geological Survey	Dn	7.7	2	P	S,G	Qal	N	O	Tc	+3.4	5.87	8-24-50	
16cac	R. E. Smith...........	Dr	40	6	P	S,G	Qal	C,E	D,S,O	Hph	+2.2	30.60	7-26-50	T 52
17cda	Homer Hart.............	Dr	.....	6	P	S,G	Qal	C,W	D,S	Tc	+.1	8.37	7-10-50	
17ddb	Mrs. L. J. Gillespie...	Du,Dr	40	84	C	S,G	Qal	C,W,H	D,S	Hph	+1.1	33.48	7-10-50	T 64, Ca
18daa	Charles Stewart........	Dr	120	5	P	Ss	Ta	C,W	D,S,O	Tc	+2.6	43.39	7- 9-50	T 52
20add	Not known..............	Dr	820	...	P	Sls	Twr	N	N	Ls	....	50	1950	L, Ot
21dac	W. R. Silver...........	Dr	90	4	P	S,G	Qal	C,E	D,S	Bpb	-6.2	67.25	8- 2-50	T 54

Table 7.--Records of wells and springs in the La Prele area, Wyoming--Continued

Well no.	Owner or tenant	Type of supply	Depth of well (feet)	Diameter of well (inches)	Type of casing	Character of material	Geologic source	Method of lift and type of power	Use of water	Measuring point: Description	Measuring point: Distance above (+) or below (-) land surface (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
32-71-28caa	Wm. Silver............	Dr	65.6	4	P	Sls	Twr	C,H	D	Tc	+2.3	61.33	7-25-50	
29bdb	Clarence Nunn..........	Dr	110	6	P	Sls	Twr	C,E	D,S	Ls	....	85	1950	T 60, Ca
30cbd	E. G. Adair............	Dr	35	6	P	Sls	Twr	C,H	S	Bpb	+.6	8.81	7-26-50	T 50, Ca, L
31aaa	Mrs. S. Edwards........	Dr	84	6	P	Sls	Twr	C,H	D,O	Hph	+1.7	22.02	7-10-50	T 52, Ca
32baa	.....do................	Dr	91	6	P	S,G	Qal	C,W	D,S	Ls	....	40	1950	T 53
32-72- 1dcc	G. F. Rookstool........	Dr	128	6	P	Ss	Tfu	C,W	D	Ls	....	73	1924	T 54
2adc	A. G. Simms............	Dr	150	6	P	Ss	Tfu	C,W	D,S	Bpb	+.5	18.52	7-11-50	
10dac	Charles D. Read & Son..	Sp	.....	...	...	Sls	Twr	F	D,S	...	....	......	....	T 50, D 5 E
12dab	Herman and Ohme........	Dr	108	...	...	Ss	Tfu	C,E	D	Tc	+1.0	20.60	8-18-49	
13dcd	Stanley Lass...........	Dr	80	4	P	Sls	Twr	C,E	D,S,O	Hph	+1.5	16.20	7- 9-50	L
14ddd	L. C. Shaffer..........	Dr	120	6	P	Sls	Twr	C,E	D,S	Ls	....	20	1949	
15dbb1	C. E. Terry............	Du	28.9	...	R	Sl	Qsw	C,H	D	Tbc	0	23.53	8- 1-50	
15dbb2	.....do................	Dr	135	6	P	Sls	Twr	C,E,H	D,S	Hpb	+2.5	24.52	8- 1-50	
22dac	Arthur Howard..........	Du	17	12	C,P	Cl	Qsw	C,E	D,S	Hc	-6.2	1.60	7- 9-50	
23add	Joseph Gedney..........	Du	17	4	P	Sl,S,G	Qsw	C,E	D,S	Ls	....	10	1950	
23cdb	J. M. Stinson..........	Dr	65	6	P	Sls	Twr	C,H	D	Hpb	+1.8	31.80	7- 9-50	
32-72½-12aaa	Adam Mueller & Son.....	Sp	.....	...	...	Sls	Twr	F	S	...	....	......	....	T 56, D 10 E
12dad	.....do................	Sp	.....	...	...	Sls	Twr	F	D,S	...	....	......	....	T 55, D 15 R
32-73- 1bdd	W. E. Bigelow..........	Du	22	48	R	S,G	Qal	C,H	D	Tbc	+1.7	15.48	7-13-50	
3acd	J. F. Perrine..........	Dr	800	8	P	Ss	Kcv?	C,H	D,S	Tc	0	21.39	7-12-50	Ot
4bcc	W. S. Dixon............	Dr	.....	8	P	Sls	Twr	C,E	S	Tc	+.7	15.98	8- 1-50	
8dab	Not known..............	Dr	725	16	P	Ss	Kb	F	S	Ls	....	......	....	T 51, Ca, L, Ot
9aaa	.....do................	Dr	470	16	P	Sls	Twr	N	N	Ls	....	12	1903	L, Ot
9bdd	U. S. Geological Survey	B	14.0	¾	P	Sl	Qsw	N	O	Tc	+5.0	8.78	8-24-50	
9cad	W. L. Chamberlain......	Dr	475	...	...	Sls	Twr	N	N	Ls	....	10.78	8- 1-50	L, Ot

10bcc	Jack Werner............	Dr	.....	8	P	Sls	Twr	C,H	D	Tc	+.5	22.65	7-12-50	T 51
12aac	Frank Hiser............	Dr	180	8	P	Sls	Twr	C,H,G	D,S	Ls	....	100	1950	
21abb	Converse County Park...	Sp	.....	...	...	Ss	Pc	F	P	...	....	......	....	T 65, D 5 E, Ca
33-71-18bdb	Morton Ranch...........	Dr	210	6	P	Ss	Tfu	C,W	D,S	Ls	....	30	1950	T 65, Ca
19ccb	.....do................	Dr	220	6	P	S,G	Qal	C,W	D,S	Ls	....	30	1950	T 53
33-72- 4dcc	Roy Ohlson.............	Dr	246	6	P	Ss	Tfu	C,W	D,S	Ls	....	60	1950	T 55
7dbc	Fred Marberger.........	Dn	12	2	P	S,G	Qal	C,H	D	Ls	....	8	1931	T 54, Ca
10cad	E. S. Gibbs............	Dr	71+	24	P	Ss	Tfu	C,H,W	S	Tbc	+1.7	42.37	7-11-50	
10cca	.....do................	Dr	68	6	P	S,G	Qal	C,W,H	D,S	Ls	....	12	1950	
21aab	Mrs. Fleming...........	Dr	25	8	P	S,G	Qal	N	N	Tc	+3.0	15.65	7-31-50	
21aad	.....do................	Dr	200	6	P	Ss	Tfu	C,W	D	Ls	....	20	1950	
24cdb	Morton Ranch...........	Dr	220	6	P	Ss	Tfu	C,H	D,S	Ls	....	30	1950	T 53
26aad	.....do................	Dr	200	6	P	Ss	Tfu	C,W	S	Ls	....	100	1950	T 54
31cca	Albert Sewell..........	Dr	165	8	P	Sls	Twr	C,W	D,S	Ls	....	50	1950	
33ccb	J. M. Yardley..........	Dr	85	6	P	Sls	Twr	C,E	D,S	Ls	....	45	1950	
36abd	George Warner..........	Dr	60	5	P	Ss	Tfu	C,W	D,S	Ls	....	5	1949	L
33-73- 9dbb	J. R. Burks............	Du,Dr	50	72	R	S,G	Qal	C,W	D,S	Tbc	0	5.55	7-14-50	T 53
23aca	Charles Slichter.......	Dr	100	6	P	Ss	Tfu	C,H	D	Ls	....	60	1950	T 57, Ca
25abd	C. D. Lundberg.........	Du	38+	48	C	Ss	Tfu	C,H	D	Tbc	+.5	27.74	7-13-50	
25bbb	Henry Slichter.........	Sp	.....	...	...	Sl	Qsw	F	S	...	....	......	....	T 52, D 5 R, Ca
27abc	U. S. Geological Survey	B	14.0	3/4	P	Sl	Qsw	N	O	Tc	+3.8	10.25	8-24-50	
27bdb	I. O. Carlson..........	Dr	92	10	P	Sls	Twr	C,H	D,S	Epb	+1.0	9.79	7-14-50	T 50, Ca
27dcc	H. A. Blackburn........	Dr	30	8	P	Sls	Twr	C,E	S	Tc	-3.8	8.14	7-13-50	T 52, D 6, Ca
27dcd	.....do................	Dr	160	6	P	Sls	Twr	C,E	S	Ls	....	15	1950	T 55, Ca
34bcc	Not known..............	Du	8	60	N	Sl	Qsw	N	O	Tbc	+1.5	7.42	7-13-50	T 56, Ca
34ccc	Joe. L. Carmin.........	Dr	120	6	P	Sls	Twr	N	O	Tc	+1.0	27.10	7-31-51	
34ccd	.....do................	Dr	110	6	P	Sls	Twr	C,H	S	Ls	....	30	1950	T 50