GEOLOGICAL SURVEY CIRCULAR 96

May 1951

GROUND-WATER RESOURCES OF THE PAINTROCK IRRIGATION PROJECT WYOMING

By

Frank A. Swenson and W. Kenneth Bach

With a Section on the

QUALITY OF THE WATER

By

Herbert A. Swenson

Prepared as Part of a Program
of the Department of the Interior
for Development of the Missouri River Basin

UNITED STATES DEPARTMENT OF THE INTERIOR
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GEOLOGICAL SURVEY
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Washington, D. C.

Free on application to the Geological Survey, Washington 25, D. C.

GPO 82-8000720

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ABSTRACT

The ground-water conditions of the area covered by the Paintrock irrigation project, in north-central Wyoming, were investigated during the summer of 1947. The purpose of the study was to obtain a general evaluation of ground-water recharge, discharge, and storage in the area now irrigated and in the adjacent areas where additional lands are to be irrigated.

Much of the area covered by this report consists of flat to gently sloping stream terraces and alluvial bottoms along Nowood, Paintrock, and Medicine Lodge Creeks. The stream-terrace materials consist of fluviatile sand, clay, and gravel. The alluvium is very fine grained and in general has low permeability. The materials underlying the stream terraces and the bottomlands become progressively finer grained and less permeable downstream.

The bedrock formations underlying the area studied range from the Madison limestone of Mississippian age to the Fort Union formation of Paleocene age. Beds have been folded into several prominent structures which trend northwest-southeast across the area. Several of the formations exposed in the area serve as aquifers and yield water to domestic and stock wells. The most important bedrock aquifers are the Fort Union, Lance, Meeteetse, Mesaverde, Frontier, Cloverly and Morrison formations, the Tensleep sandstone, the Amsden formation, and the Madison limestone. More than 7,000 feet of strata are exposed in the area, the older beds being exposed on the western flank of the Big Horn Range near the eastern end of the area.

The quality of the water in the project ranges within wide limits. The concentration of dissolved solids in seven samples of ground water ranges from 279 parts per million for a water in the Tensleep sandstone to 4,590 parts per million for a water in the Morrison formation. The hardness as calcium carbonate ($CaCO_3$) ranges from 13 to 1,680 parts per million. Limited data on the quality of water in Nowood and Paintrock Creeks indicate that these waters are suitable for irrigation. The water in Paintrock Creek near Tensleep is higher in mineral content and hardness than the water upstream at Hyattville as a result of return flow of the irrigation water that is applied to farm lands above Tensleep.

INTRODUCTION

LOCATION AND EXTENT OF AREA

The Paintrock irrigation project lies on the eastern flank of the Bighorn Basin in Big Horn County, north-central Wyoming. According to the 1947 Bureau of Reclamation plan, about 2,780 acres of new land will be irrigated and supplemental water supplies will be provided for about 6,020 acres now irrigated. These lands lie in a belt along Nowood, Paintrock, and Medicine Lodge Creeks east of Manderson, Wyo. The belt of land to be irrigated ranges in width from 1 to 3 miles and is about 25 miles long. (See fig. 1.)

SCOPE OF INVESTIGATION

The investigation upon which this report is based is one of a series being made in connection with the Missouri River basin development plan. The ultimate purpose of these studies is to make a comprehensive ground-water study of all important ground-water areas in the Missouri River basin. These studies are designed to give a qualitative and quantitative evaluation of ground-water recharge, discharge, and storage, especially in areas to be irrigated under the development program. The investigation of the Paintrock irrigation project included a study of the geology of the area in relation to the occurrence of ground water. An inventory was made of all wells in the area to obtain all pertinent available data on each. Data were gathered on the quantity and quality of water obtained from the various aquifers, the direction of ground-water movement, the amount of surface-water flow derived by ground-water seepage from irrigated lands, and the fluctuation of water levels in certain key observation wells.

The field work upon which this report is based was done during September and October 1947 by the writers, working under the general supervision of A. N. Sayre, chief of the Ground Water Branch, United States Geological Survey, and of G. H. Taylor, regional engineer in charge of ground-water investigations under the Missouri Basin program. The study of the quality of the water was under the general supervision of S. K. Love, chief of the Quality of Water Branch, United States Geological Survey, and of P. C. Benedict, regional engineer in charge of quality-of-water investigations under the Missouri Basin program.

PREVIOUS INVESTIGATIONS

In 1945, members of the Fuels Branch of the Geologic Division, U. S. Geological Survey, undertook the detailed mapping of three 15-minute quadrangles that included part of the Paintrock irrigation project. Their

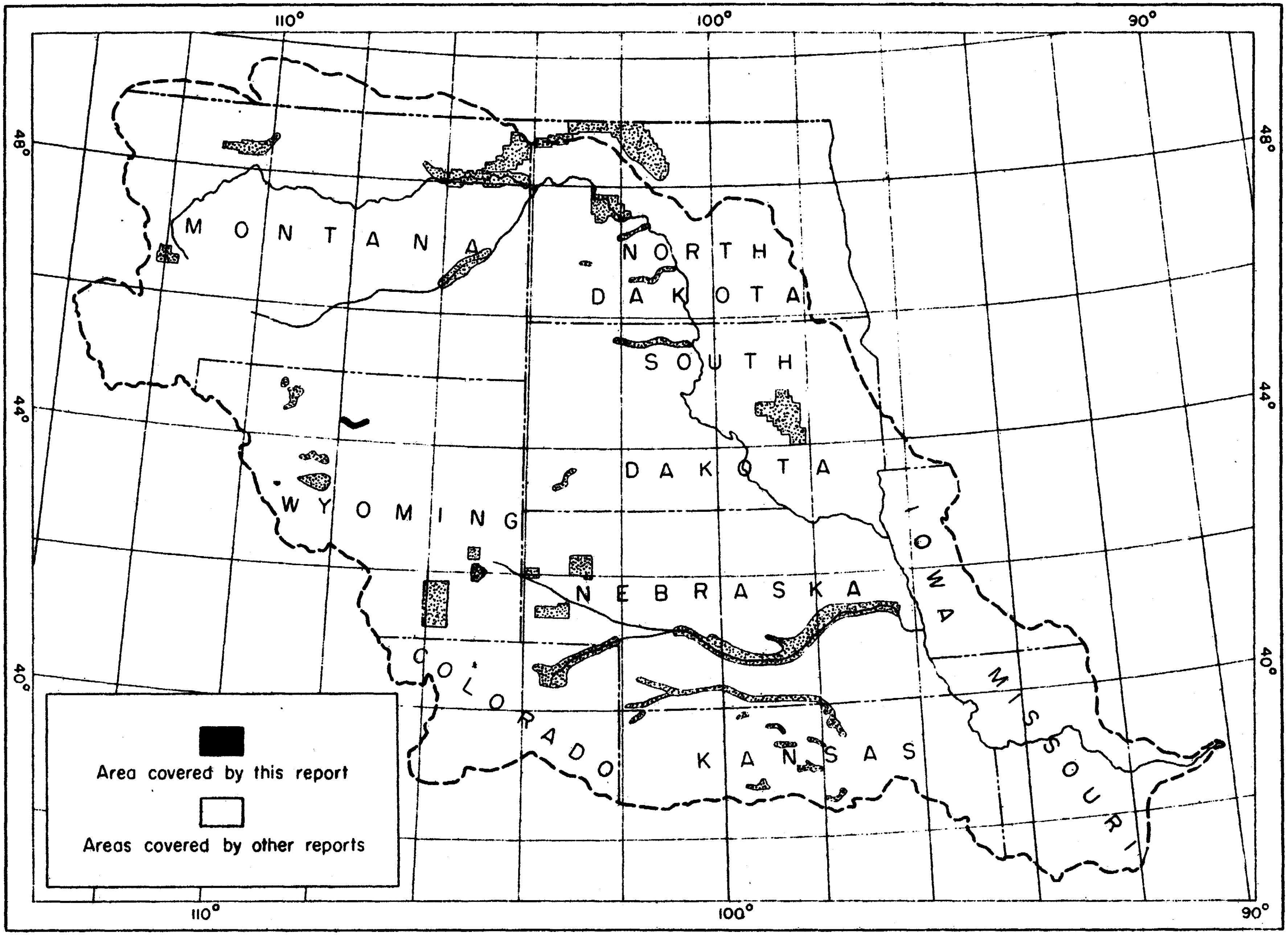

Figure 1 —Map of the Missouri River Basin showing areas in which ground-water studies have been made under Missouri Basin program

resulting maps and accompanying reports were published[1] in 1948. From those maps was taken much of the geology of that part of the area downstream from Hyattville that is shown on plate 1 of the present report.

The general regional geology of the area has been discussed in a number of papers. Among those that have been most useful are the following:

Darton, N. H., Geology of the Bighorn Mountains: U. S. Geol. Survey Prof. Paper 51, 1906.

Espach, R. H., and Nicols, H. D., Petroleum and natural gas fields in Wyoming: U. S. Bur. Mines Bull. 418, 1941.

Hewett, D. F., and Lupton, C. T., Anticlines in the southern part of the Bighorn Basin, Wyo.: U. S. Geol. Survey Bull. 656, 1917.

Hewett, D. F., Geology and oil and coal resources of the Oregon Basin, Meeteetse, and Grass Creek Basin quadrangles, Wyo.: U. S. Geol. Survey Prof. Paper 145, 1926.

Lee, W. T., Correlation of geologic formations between east-central Colorado, central Wyoming, and southern Montana: U. S. Geol. Survey Prof. Paper 149, 1927.

Mackin, J. H., Erosional history of the Bighorn Basin, Wyo.: Geol. Soc. America Bull., vol. 48, pp. 813-894, 1937.

Pierce, W. G., and Andrews, D. A., Geology and oil and coal resources of the region south of Cody, Park County, Wyo.: U. S. Geol. Survey Bull. 921-B, 1941.

Pierce, W. G., Geologic and structure-contour map of the Basin-Greybull area, Big Horn County, Wyo.: U. S. Geol. Survey, Oil and Gas Inv., Prelim. Map 77, 1948.

Rogers, C. P., Jr., Richards, P. W., Conant, L. C., Vine, J. D. and Notley, D. F., Geology of the Worland-Hyattville area, Big Horn and Washakie Counties, Wyo.: U. S. Geol. Survey Oil and Gas Inv., Prelim. Map 84, 1948.

Van Housten, F. B., Stratigraphy of the Willwood and Tatman formations in northwestern Wyoming: Geol. Soc. America Bull., vol. 55, pp. 165-210, 1944.

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1 Pierce, W. G., Geologic and structure-contour map of the Basin-Greybull area, Big Horn County, Wyo.: U. S. Geol. Survey Oil and Gas Inv., Prelim. Map 77, Feb. 1948; Rogers, C. P., Jr., Richards, P. W., Conant, L. C., and others, Geology of the Worland-Hyattville area, Big Horn and Washakie Counties, Wyo.: U. S. Geol. Survey Oil and Gas Inv., Prelim. Map 84, May 1948.

ACKNOWLEDGMENTS

The writers are indebted to many persons who have contributed information and assistance in the field and in the preparation and review of this report. Ivan Brown and Schyler Barrett, well drillers, furnished useful information on wells that they have drilled in the area. William P. Fulton, Surface Water Branch, U. S. Geological Survey, made regular monthly measurements of the observation wells during the winter of 1947. Since that time measurements have been made by D. A. Morris of the Riverton office of the Ground Water Branch. The writers are grateful to all the residents of the area whose wholehearted cooperation greatly assisted the field studies.

WELL-NUMBERING SYSTEM

The wells discussed in this paper are numbered in accordance with the Bureau of Land Management system of land subdivision, and the well number shows the location of the well by township, range, and section. The first numeral of a well number indicates the township, the second the range, and the third the section in which a well is located. The lower-case 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 or 10-acre tract. The letters are assigned in a counterclockwise direction, beginning in the northeast quarter of the section, quarter section, or quarter-quarter section. Where more than one well is located in a 10-acre tract, consecutive numbers beginning with 1 are added.

Figure 2 shows a graphical illustration of this method of well numbering.

GEOGRAPHY

CLIMATE

The Paintrock irrigation project has an arid climate characterized by great deviations from normal rainfall. The weather station with the most complete and longest record near the area is at Basin, Wyo., 10 miles north of Manderson, which lies at the western lower end of the area. Records of the U. S. Weather Bureau at Basin indicate that the precipitation during the period of complete record, 1919-46, averaged 7.33 inches annually. (See table 1 on the following page.

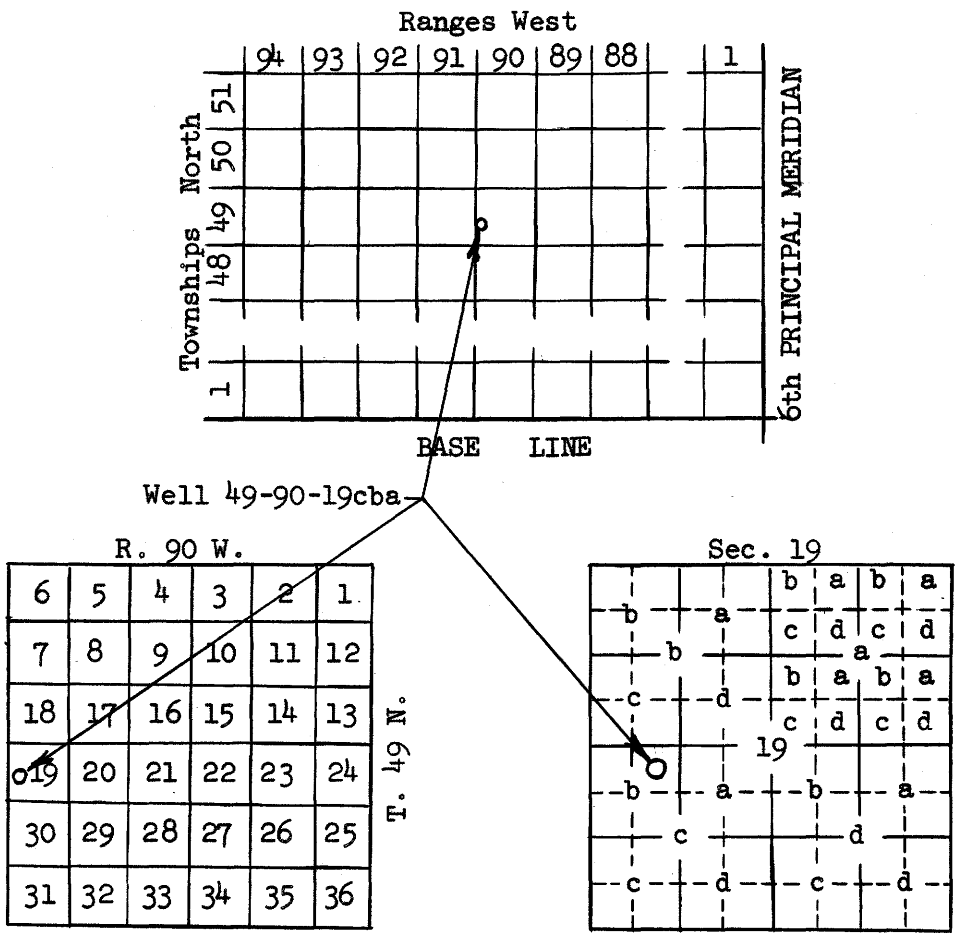

Figure 2.--Sketch showing well-numbering system.

Table 1.--Annual precipitation at Basin, Wyo., 1911-46

Year	Inches	Year	Inches	Year	Inches
1911	4.29	1923	10.54	1935	5.71
1912	.....	1924	11.09	1936	6.22
1913	10.00	1925	8.83	1937	7.27
1914	5.68	1926	8.04	1938	6.34
1915	.....	1927	10.64	1939	4.78
1916	.....	1928	9.92	1940	9.38
1917	.....	1929	10.14	1941	6.87
1918	.....	1930	7.72	1942	6.68
1919	5.13	1931	4.02	1943	5.06
1920	5.44	1932	10.31	1944	8.82
1921	6.21	1933	3.90	1945	7.45
1922	6.51	1934	4.38	1946	7.83

During this period the annual rainfall ranged from 3.90 to 11.09 inches. The graph (fig. 3) showing the cumulative departures from normal precipitation at Basin is helpful in indicating the long-term deficiencies and excesses of precipitation. The periods of above-normal rainfall are indicated by a rising line and periods of subnormal precipitation by a declining line. The only precipitation records within the area are those made intermittently at Hyattville, as shown in table 2 below:

Table 2.--Annual precipitation at Hyattville, Wyo., for years of complete record

Year	Inches	Year	Inches
1900	1.20	1916	3.94
1913	2.10	1917	4.49
1914	1.69	1918	10.19
1915	4.25	1921	6.11

The heaviest rainfall, comprising about 40 percent of the annual precipitation, comes during April, May, and June. A minor, secondary maximum comes in September and October, and comprises about 17 percent of the total. May is the wettest month with 15 percent of the annual precipitation, and November is the driest month, with 4 percent of the annual precipitation.

The growing season at Basin ranges from 100 to 130 days, according to the U. S. Weather Bureau; it begins in the latter part of April and ends during the latter part of September. Inasmuch as the wet period in the spring comes too early and the wet period in the fall too late for the growing season of most crops, the seasonal distribution of precipitation is not advantageous to agriculture. At times the fall precipitation proves to be a handicap in harvesting and causes some loss of crops. During the middle of the growing season the precipitation is scanty and the flow of streams is low, with the result that irrigation water is inadequate during the critical period of plant growth.

AGRICULTURE AND INDUSTRY

The principal crops raised on the Paintrock project, at present, are beans, small grains, hay, and alfalfa. All crops are irrigated, except some hay meadows that lie in areas where the water table is near the land surface and sufficient moisture is supplied by subirrigation. The hay, alfalfa, and small grains are largely used in the area for feeding sheep and cattle. Beans are the largest crop to reach the outside market.

The only mining in the area is at one active coal mine. The mine is 1½ miles north of Manderson and is operated on a small scale by two Snyder brothers, under the name of Snyder Coal Company. The coal is subbituminous and the total output is used locally.

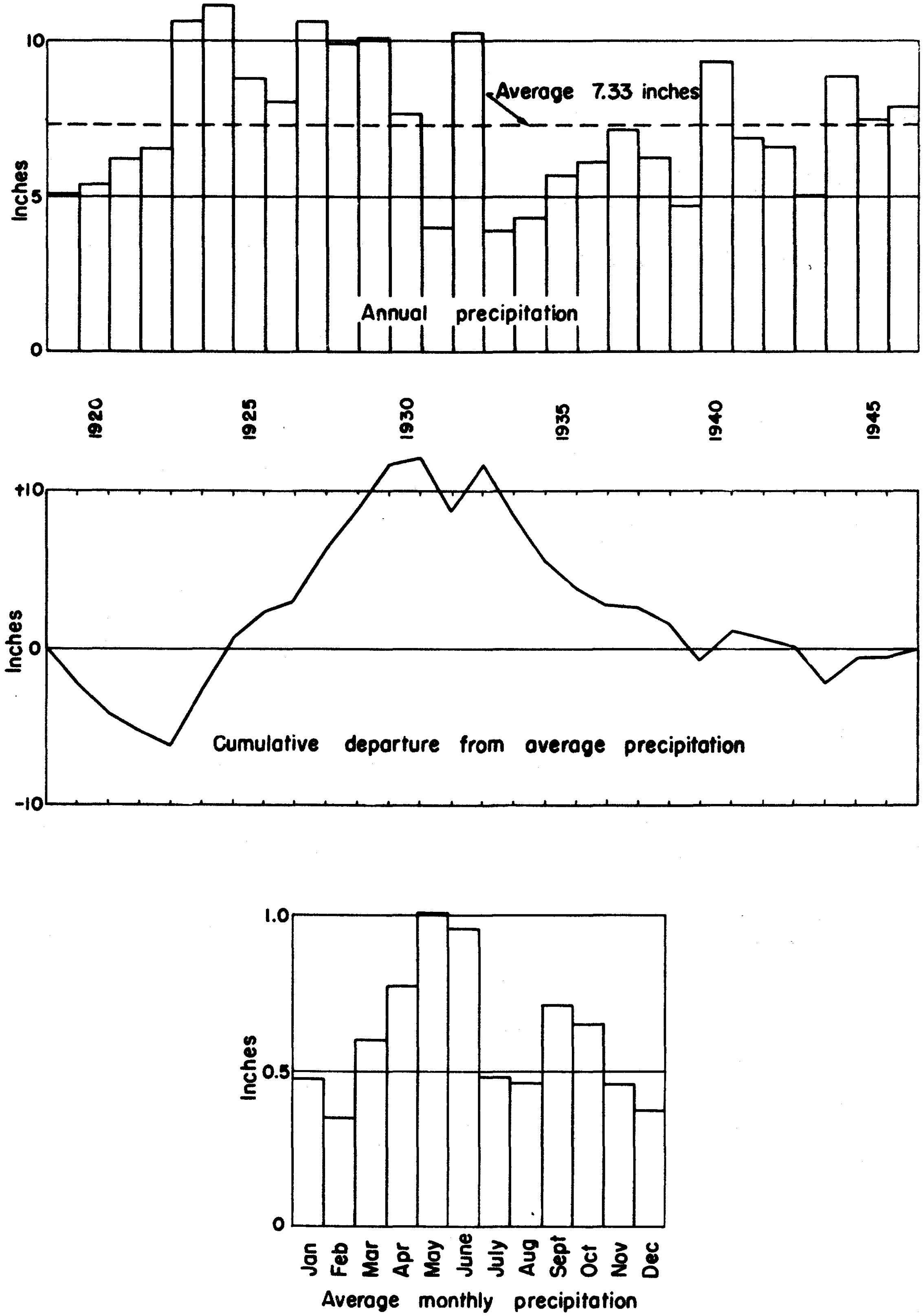

Figure 3. —Precipitation records at Basin, Wyo., 1919-1946

Lumbering is of some importance to the project area, although the timber grows east of the area considered in this report. There are many small sawmills and lumber camps in the Bighorn National Forest within a radius of 20 miles of Hyattville. The lumber is rough-finished and is used locally.

The oil industry is of some interest in the area. In the past many holes have been drilled for oil, chiefly in the vicinity of Bonanza. No commercial oil or gas production has resulted, but the exploration is continuing, one hole having been drilled during 1946.

TRANSPORTATION

The area covered by this report is traversed by an improved road, which is paved for a distance of 12 miles east of Manderson and which is graded and graveled in much of the remaining stretch. Except for secondary unimproved roads leading to Tensleep from Hyattville and Bonanza, all produce must move out of the area through Manderson. U. S. Highway No. 20 leads north and south through Manderson, northward to towns in the northern Bighorn Basin and Billings, and southward to Worland and Thermopolis.

The Paintrock area is served by the Billings-Denver branch of the Chicago, Burlington & Quincy Railroad Co., which passes through Manderson. Several trains pass through Manderson each day and a ready rail outlet is provided for the crops and stock raised.

HISTORY OF IRRIGATION

The earliest recorded irrigation on the Paintrock project took place 60 years ago when, in 1887, the Highland ditch was constructed to divert water from Medicine Lodge Creek for irrigation of 1,160 acres north of Hyattville. Water was first diverted in 1890 into the Harmony ditch from Nowood Creek for irrigation of 1,000 acres northwest of Manderson. The Van Alstine-Walker ditch was constructed in 1895 to irrigate 1,390 acres with water from Nowood Creek, and in 1896 the Anita (Mercer) ditch began to supply 2,700 acres with water from Medicine Lodge Creek. Since 1896, additional ditches have been constructed, and there are now 30 diversions supplying irrigation water to an estimated 10,000 acres.[2]

2 U. S. Bur. Reclamation Prelim. Rept.

PHYSIOGRAPHY

TOPOGRAPHY

The Paintrock irrigation project is located in the Middle Rocky Mountain physiographic province.[3] The major part of the area covered by this report is flat to gently sloping valley bottomland and stream terraces that lie as much as 100 feet above the present streams. The upper end of the tract to be irrigated lies about 4,700 feet above sea level and the lower end about 3,900 feet above sea level.

The highest land now irrigated lies a short distance below the point where the deep box canyons of Paintrock and Medicine Lodge Creeks open out into a valley about 2 miles wide. The lower slopes of the Bighorn Range rise steeply northeast of the irrigated land. The south bank of Paintrock Creek and the northwest bank of Medicine Lodge Creek rise sharply from the broad, gently sloping plain between the creeks. The highlands that border the plain have a definite northwest-southeast trend as a result of resistant strata rising on the flanks of the Bighorn Range. Slopes are bare or have a scanty cover of sagebrush, wheatgrass, and juniper. The timber in the mountains is restricted to the higher elevations. Cottonwood and willow border the main streams and older irrigation ditches.

The area irrigated at the eastern end of the project narrows as Paintrock and Medicine Lodge Creeks converge, and about a mile northeast of Hyattville the belt of irrigated land is only about 1 mile wide. About half this width is on alluvial bottomland and the remainder is on stream terraces as much as 100 feet above the present streams. The alluvium of the bottomlands is rather fine grained, and some areas are waterlogged or have a high water table. The materials making up the terrace deposits are much more permeable, and the water table is at greater depths. Much water is lost on the terraces, and the uncontrolled ground-water seepage from the terrace deposits causes some waterlogging on the bottomland.

Below Hyattville, Paintrock Creek flows close to the south valley wall and nearly all the irrigated land lies north of the stream. Bordering the alluvial bottom, which is approximately half a mile wide, are stream terraces as much as a mile in width. Toward the southwest the width of the terraces decreases, and a short distance above the junction of Paintrock Creek and Nowood Creek only small and much-dissected remnants of the terraces are present. The width of the alluvial bottom also decreases, to approximately a quarter of a mile where the Bonanza-Tensleep road crosses.

Downstream from Hyattville the materials in the terrace deposits, as well as those making up the alluvial bottoms, become progressively less permeable. Drainage is still fairly good under the irrigated lands on the terraces, but many small areas on the bottomlands are waterlogged or have a high water table. When additional water is applied to the fields, provision must be made for artificial drainage of the lands, especially those on the

3 Fenneman, N. M., Physiography of Western United States, McGraw Hill Book Co., New York, 1931.

bottoms. The walls of Paintrock Creek valley are steep, especially about 1½ miles above the confluence of Paintrock and Nowood Creeks, where one of the major anticlinal structures of the area crosses the valley. (See pl. 1 and fig. 4.) These upper slopes have scanty vegetation and many of the steeper slopes that are underlain by shale are barren. The vegetation consists mainly of saltbush, shadscale, sagebrush, rabbit bush, wheatgrass, and blue grama grass.

Below the junction of Paintrock and Nowood Creeks the valley widens and the alluvial bottomland is more than a mile wide. Bordering the bottomland are somewhat ragged stream terraces, which here have a maximum width of about half a mile. Nowood Creek meanders back and forth across its valley, impinging against first one valley wall, then the other. Where the stream has recently undercut the bank the valley wall is steep, or sheer, rising 100 feet or more to the terrace, whereas in other places the slopes ascend less steeply from the valley flat to the terrace. Few remnants of the stream terraces remain northeast of Nowood Creek in the first 5 miles below the junction with Paintrock Creek. In this section the stream is flowing in a northwesterly direction down a strike valley developed on weak shale beds. In this reach and southwest of Nowood Creek a terrace about half a mile wide has been developed. Preliminary plans of the Bureau of Reclamation indicate that this terrace will be supplied with water pumped from Nowood Creek above the confluence with Paintrock Creek. The westernmost of the terraces south of Nowood Creek is served with water by an existing irrigation ditch.

A considerable area of eroded terrace lies north of Nowood Creek, extending from about 4 miles northwest of Bonanza to the valley of the Bighorn River. This terrace is cut by numerous deep coulees and has no extensive flat or gently sloping land. Many of the coulees have cut through the terrace materials and into the underlying bedrock, but none has a perennial flow of water. The proposed Manderson Canal is designed to supply irrigation water to these terrace remnants.

Bordering the lower valley of Nowood Creek are rolling hills, some of which are considerably eroded. In places badlands have developed in soft bedrock strata of Late Cretaceous and early Tertiary age. The hills are bare or have a scanty vegetation consisting of saltbush, greasewood, shadscale, sagebrush with minor amounts of wheatgrass, blue grama grass, and needle-and-thread.

STREAM FLOW

The Paintrock irrigation project is traversed by three perennial streams: Paintrock, Medicine Lodge, and Nowood Creeks. During the early part of the irrigation season, in May and June of a normal year, these creeks usually furnish an ample supply of water. As the season progresses, however, the supply of water for irrigation decreases and during July and August it is inadequate to meet the demand, often resulting in crop damage.

Table 3.--Discharge records of Paintrock and Medicine Lodge Creeks, Wyo.

Hydro-graphic year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total for year
	Runoff, in acre-feet, of Paintrock Creek near Hyattville, Wyo.												
1919-20	.....	.....	.....	.....	.....	.....	.....	......	......	......	a 4,620	3,950	....
1920-21	2,370	1,370	1,230	1,230	1,110	1,360	1,630	27,100	42,100	6,700	3,000	2,120	91,300
1921-22	1,620	1,540	1,650	1,530	1,210	1,300	1,590	23,500	50,200	13,800	5,810	1,920	106,000
1922-23	1,790	1,700	1,460	1,430	1,020	1,370	1,600	21,400	49,700	29,300	9,280	7,860	128,000
1923-24	9,220	4,200	.....	.....	.....	.....	.....	......	71,400	24,100	5,410	4,160	....
1924-25	4,350	.....	.....	.....	.....	.....	4,320	40,300	35,600	18,000	7,930	4,390	....
1925-26	4,010	3,270	2,870	1,110	.....	2,230	5,630	37,100	28,700	18,700	7,750	6,600	....
1926-27	5,660	3,250	2,380	.....	.....	.....	.....	......	......	......	......	.....	....
1940-41	.....	.....	.....	.....	.....	.....	b 1,330	28,230	21,500	7,170	7,950	7,910	....
1941-42	4,670	2,040	1,470	1,310	1,030	1,080	6,210	19,070	26,840	11,780	2,310	1,950	79,760
1942-43	2,670	1,720	1,440	1,240	1,010	1,160	4,410	12,780	48,230	19,170	4,440	2,310	100,600
1943-44	1,550	1,650	1,310	1,040	840	880	1,210	24,520	42,680	20,960	4,010	2,750	103,400
1944-45	2,250	1,415	1,130	1,280	1,080	1,090	1,200	12,930	44,070	31,060	6,240	5,930	109,600
1945-46	3,440	2,250	1,590	1,430	1,140	1,240	9,060	17,470	49,030	14,890	3,900	5,250	100,700
1946-47	3,390	2,100	1,630	1,420	1,110	1,390	1,830	24,060	34,400	24,510	4,980	3,210	104,000
	Runoff, in acre-feet, of Paintrock Creek near Bonanza, Wyo.												
1909-10	.....	.....	.....	.....	.....	.....	.....	......	......	......	1,210	2,320	....
1910-11	4,700	3,950	a 808	2,460	2,220	2,170	1,260	18,600	33,100	3,490	2,240	1,520	....
1911-12	3,770	3,090	2,150	.....	.....	.....	2,340	11,800	67,200	29,100	10,800	6,190	....
1912-13	7,380	.....	.....	.....	.....	.....	.....	......	......	......	......	.....	....
1914-15	.....	.....	.....	.....	.....	.....	b 9,350	16,700	39,000	26,400	5,960	6,960	....
1915-16	8,240	5,250	.....	.....	.....	c 2,550	4,250	14,000	53,100	14,000	1,770	1,300	....
1916-17	4,780	d 1,480	.....	.....	.....	.....	e 1,570	22,300	60,100	26,000	3,470	3,450	....

a Aug. 8-31.
b Apr. 8-10.

1917-18	3,690	4,630	.....	.....	.....	f 459	3,760	19,000	78,000	13,200	3,470	4,390	....
1918-19	7,620	g 4,030	.....	.....	.....	h 243	5,220	28,300	8,750	552	229	875	....
1919-20	3,920	i 1,380	.....	.....	.....	j 1,290	2,200	16,500	58,500	20,100	3,730	3,150	....
1920-21	3,950	4,140	.....	.....	.....	k 1,500	2,800	25,100	43,700	3,310	658	1,090	....
1921-22	2,690	2,060	.....	.....	.....	m 271	1,950	20,500	48,500	10,500	3,320	922	....
1922-23	2,490	n 3,480	.....	.....	.....	.....	.....	......	......	......	.....	.....	....

a Dec. 1-7.
b Apr. 19-30.
c Mar. 12-31.
d Nov. 1-10.
e Apr. 11-30.
f Mar. 24-31.
g Nov. 1-23.
h Mar. 23-31.
i Nov. 1-10.
j Mar. 19-31.
k Mar. 15-31.
m Mar. 26-31.
n Gage discontinued.

Runoff, in acre-feet, of Medicine Lodge Creek near Hyattville, Wyo.

1942-43	.....	.....	.....	.....	.....	.....	.....	......	a 3,100	3,680	1,020	776	....
1943-44	722	683	656	660	564	587	566	6,590	12,340	4,460	1,090	910	29,830
1944-45	889	698	641	682	592	613	569	3,330	10,090	5,990	1,360	1,340	26,790
1945-46	1,290	952	766	680	593	688	2,220	5,830	10,400	3,050	986	1,320	28,780
1946-47	1,220	1,040	914	793	618	790	778	7,550	9,320	4,620	1,230	1,010	29,880

a June 24-30.

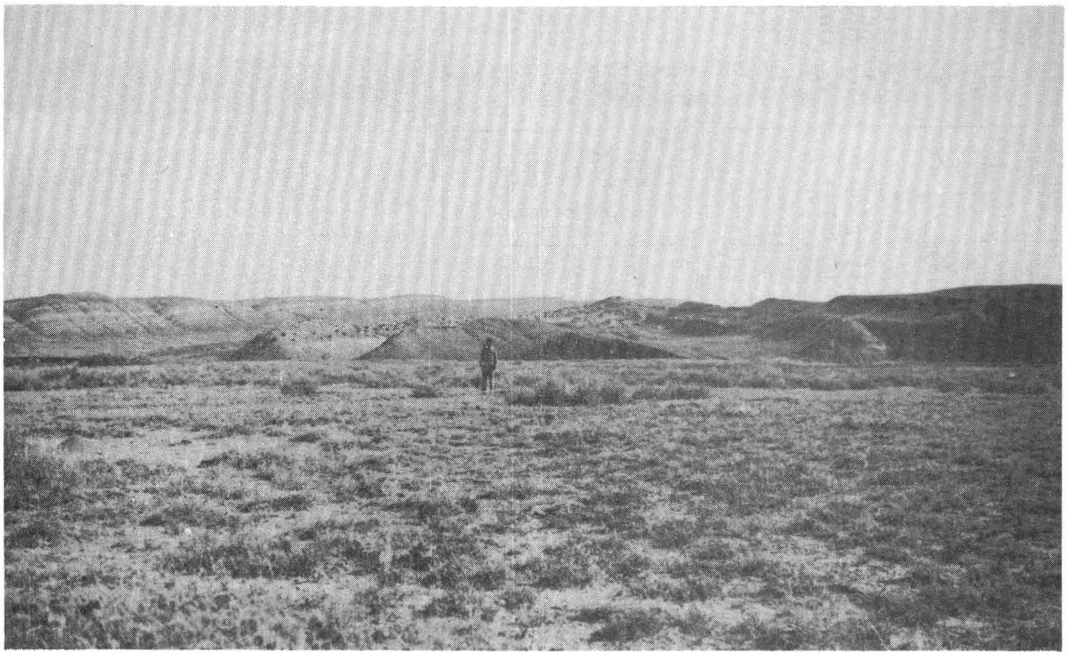

Figure 4.--View of Paintrock anticline from across the valley of Paintrock Creek. Small terrace remnant in foreground shows scanty vegetative cover. Thermopolis shale exposures in left background show prominent light-colored Muddy sandstone member. Mowry shale caps Thermopolis shale bluff. Lowland at base of main escarpment is developed on Cloverly formation and upper part of Morrison formation. Conglomeratic bed near middle of Morrison formation forms second escarpment to left of man pictured, and escarpments nearest man are formed by more resistant sandstone beds near base of formation. Sundance formation is exposed in valley developed on crest of structure directly behind figure. Photo by Geo. H. Taylor.

The stream-flow records for Paintrock Creek date back to July 28, 1910, when the U. S. Geological Survey established a gaging station 1½ miles above Bonanza at the Paumer Ranch. This station was in operation until November 1923. Daily gage heights were obtained during the summer months by Mrs. Paumer, but no winter readings were made because of ice conditions in the stream channel. In August 1920 a new gaging station was established on Paintrock Creek, 6 miles northeast of Hyattville (sec. 25, T. 50 N., R. 89 W.), with the result that there is about a 3-year overlap in records of the two stations. No stream-flow records are available for the period January 1927 to April 1941, but since April 1941 complete records have been obtained.

Paintrock and Medicine Lodge Creeks are characterized by high runoff during May and June from melting snow and spring rainfall, followed by a rather sharp decline in July and August. The decline continues until February, which is usually the month of least runoff. The drainage area above the present Paintrock Creek gaging station is 164 square miles. The observed discharge ranges from 6.2 second-feet (cubic feet per second) and a gage height of 1.58 feet, to 8,200 second-feet and a gage height of 9.80 feet. The gaging station on Medicine Lodge Creek has been maintained by the U. S. Geological Survey since June 1943. The station is 4½ miles northeast of Hyattville in sec. 22, T. 50 N., R. 89 W. The drainage area above the station contains 86 square miles, and one small irrigation diversion is above the station. The observed discharge ranges from 9 second-feet and a gage height of 0.55 feet, to 830 second-feet and a gage height of 4.10 feet.

Information on discharges at all stream-gaging stations maintained in the area by the U. S. Geological Survey is given in table 3 (pp. 12-13).

Normally the streams are clear, but during periods of high flow a considerable sediment load is carried. The coarser materials are deposited in the upper part of the area but the fine-grained materials are transported farther before deposition. This is a factor in the decrease in permeability of the alluvium downstream. Part of the alluvium is made up of slope wash from coulees draining the bare shale hills that border the valley, and this also is fine-grained.

GEOLOGY AND GROUND WATER

Rocks ranging in age from upper Paleozoic to Recent are exposed in the area covered by this report. The oldest rocks are exposed at the east or upper end of the project, where they are brought to the surface on the flanks of the Bighorn Range. In general, younger consolidated beds are found toward the west, but in places older beds are exposed along the axes of anticlinal folds. Four major asymmetric anticlinal folds cross the area, each having a general northwest-southeast trend. These anticlines have been named by previous investigators, from east to west, the Hyattville, Paintrock, Bonanza, and Manderson anticlines. Within a mile to the east of each anticline is a parallel syncline.

Table 4.--Generalized section of formations exposed in Paintrock irrigation project, Wyo.

System	Series	Formation	Thickness (feet)	Description	Water-bearing properties
Quaternary	Recent	Alluvium	0-45	Floodplain deposits as much as 1¼ miles wide along major streams. Consist of silt and clay with an admixture of fine sand and with sand and gravel lenses. In general grain size increases upstream toward the mountains. Land largely irrigated at present; is waterlogged in places.	Yields small to moderate supplies of water. Materials more permeable toward mountains and larger yields more likely in that part of area. Recharge obtained both from irrigation and from streams. Water quality better in eastern part of project.
	Pleistocene	Terrace deposits	0-45	Terrace deposits within a height of 125 feet above level of present streams. Consist of poorly sorted clay, silt, sand, and gravel; boulders occasionally found. Most gravels are well-rounded quartzite, chert, or crystalline rocks. Mantled in places by wedge-shaped deposits of slope wash derived from adjacent valley walls.	Permeable and yield moderate water supplies in eastern end of project. Permeability of terrace deposits decreases progressively away from the mountains and only small water supplies may be available in terraces downstream from Bonanza. Water from less permeable deposits likely of poorer quality.
Tertiary	Paleocene	Fort Union formation	1,000-1,500	Gray to buff sandstone and shale of continental origin with thin seams of carbonaceous shale and subbituminous coal. Sandstones are cross-bedded and range from resistant iron-cemented beds to weak friable sands. Workable coal seam near base of formation north of Manderson.	Small water supplies may be obtained by wells penetrating adequate thickness of formation. Principal sources of water are from discontinuous sandstone lenses, some of which may not obtain adequate recharge. Coal beds may provide larger yields but water is generally of poor quality for domestic use. Water from formation is generally soft but somewhat mineralized.
Cretaceous	Upper Cretaceous	Lance formation	600-775	Light-brown and gray sandstone interbedded with gray soft shale and some carbonaceous shale. Sandstones are poorly indurated and weather readily except where large calcite-cemented concretions are numerous. A lower cross-bedded somber-colored sandstone is somewhat more resistant than others above.	Small water supplies may be obtained by wells penetrating adequate thickness of saturated formation. Difficulty is experienced in screening out fine sand without materially decreasing yield of water. Shale beds are non-water bearing and may prevent recharge to lower sandstone beds. Water probably is considerably mineralized.
		Meeteetse formation	540-650	Poorly indurated light- to medium-gray argillaceous sandstone, white to gray sandstone, and carbonaceous shale. Bed of yellow-brown concretionary sandstone about 60 feet thick near middle of formation. Meeteetse formation commonly forms lowlands between outcrops of more resistant formations on either side.	Small to moderate supplies may be expected from wells penetrating adequate thickness of saturated sandy beds. Water is soft but is somewhat mineralized. Water may be under slight artesian pressure in some places.
		Mesaverde formation	±650	Well-indurated light-colored massive sandstone and some dark sandy shale. Bed of ferruginous brown to gray sandstone 100 feet thick at top of formation. Basal bed is light-brown massive sandstone 20 to 30 feet thick.	Small to moderate yields of water available to wells penetrating adequate thickness of saturated sandstone.
		Cody shale	3,000-3,500	Medium- to dark-gray marine shale with a few lenticular interbedded sandstone beds in upper 500 feet. Shale gypsiferous in places; calcareous concentrations and fossils locally numerous.	Not a source of water supply.
		Frontier formation	±550	Gray sandstone and some gray to black shale. Torchlight sandstone member at top consists of 5 to 25 feet of light-gray sandstone with layers of black and gray chert pebbles. Another series of sandstone beds about 50 feet thick lie about 100 feet below Torchlight sandstone member. A gray thick-bedded sandstone 60 feet thick occurs near base of formation. Some bentonitic shale beds separate sandstones.	May yield small to moderate supplies; water may be under artesian pressure under favorable conditions. Water likely to be considerably mineralized and may be unfit for domestic use.

Table 4.--Generalized section of formations exposed in Paintrock irrigation project, Wyo.--Continued

System	Series	Formation	Thickness (feet)	Description	Water-bearing properties
Cretaceous	Upper Cretaceous	Mowry shale	340	Mostly dark-gray to brownish-gray siliceous shale that weathers to a distinctive bluish-gray color; some thin beds of siltstone, sandstone, and bentonite. Shale is brittle, forming steep slopes where eroded.	Not a source of water supply.
Cretaceous	Upper Cretaceous / Lower Cretaceous	Thermopolis shale	400	Black fissile shale with a few brown siltstone beds near base. Muddy sandstone member near the middle, 8 to 30 feet thick, is locally cross-bedded and well indurated, and forms a prominent marker bed in most exposures.	Very meager supplies of strongly mineralized water may be locally available from Muddy sandstone member; remainder of formation is not a source of water supply.
Cretaceous	Lower Cretaceous	Cloverly formation	±150	Gray to yellow fine-grained sandstone interbedded with gray shale and variegated siltstone. Upper part marked by prominent ironstone beds 0.4 to 0.6 foot thick. The Greybull sandstone member, which occurs near the base, is 5 to 70 feet thick. Lower contact with Morrison formation indefinite.	May yield small supplies of water to wells penetrating adequate thickness of sandstone. Permeability of most sands is low and large yields cannot be expected. Water may be under artesian pressure and under favorable conditions flowing wells may be developed. Water is considerably mineralized.
Jurassic	Upper Jurassic	Morrison formation	±300	Variegated claystone and shale with interbedded lenticular sandstone in upper part. A conglomerate or conglomeratic sandstone 25 to 30 feet thick occurs near the middle, and the lower part of the formation is carbonaceous shale, brown to greenish-gray sandstone, and red and brown shale.	Conglomeratic bed locally supplies moderate to large quantities of water where recharge is adequate. Sandstone beds are lenticular and cannot be depended on for perennial supplies in most cases. Water from this formation may be considerably mineralized but locally is of good quality.
Jurassic	Upper Jurassic	Sundance formation	215-320	Upper half of formation is predominantly dark-gray to olive-gray silty fissile shale. Near middle of formation is about 50 feet of soft buff to gray sandstone with weak calcareous cement, near base of which some thin beds of oolitic limestone occur locally. Lower part of formation consists of interbedded soft sandstone and shale of variegated colors.	Meager water supplies may be available in fine-grained soft sandstone beds in lower part of the formation. Water is probably highly mineralized and may be unfit for domestic use.
Jurassic	Middle Jurassic	Gypsum spring formation	±200	Reddish-brown claystone and siltstone with several thin beds of limestone and a massive bed of gypsum some 50 feet thick near the base. Much of formation is calcareous or gypsiferous.	Little water available. Water probably of poor quality.
Triassic		Chugwater formation	±700	Red to reddish-brown shale, siltstone, and fine- to medium-grained sandstone. Lower part contains a few thin, lenticular beds of limestone and gypsum.	Not a source of water supply.
Permian		Embar formation	50-150	Maroon siltstone and sandstone with thin beds of limestone and dolomite and local beds of white gypsum. Chert-pebble conglomerate and sandstone at base.	Little water available. Water probably of poor quality.
Carboniferous	Pennsylvanian	Tensleep sandstone	150-260	White to pinkish-gray cross-bedded sandstone, with interbedded gray dolomite and limestone in lower part. Sandstone soft but in most places is well cemented.	Moderate to large supplies available to wells penetrating adequate thickness of saturated sandstone.
Carboniferous	Pennsylvanian / Mississippian	Amsden formation	±175	Cherty varicolored dolomite with red, purplish, and green shale and shaly sandstone. Red shale contains thin veins of gypsum locally. Dolomite resistant and ledge forming.	Small to moderate water supplies may be available where dolomite beds are fractured. Water possibly of poor quality.
Carboniferous	Mississippian	Madison limestone	±500	Massive, thick-bedded crystalline limestone and dolomite. Locally fractured and cavernous. Formation very resistant and one of principal cliff formers in Wyoming.	Large supplies of water available from fractures and caverns where they are below the water table.

Practically all the land proposed for irrigation is underlain by Quaternary deposits. The bottomlands along the streams are underlain by Recent alluvium and may become partly flooded in periods of exceptionally high water. Stream terraces, which are alluvial deposits of these same streams during earlier stages of erosion, border the major stream bottoms. Several different sets of stream terraces can be recognized but all that are of particular interest from the standpoint of irrigation, are those within a height of 125 feet above the present streams. Many of the terrace deposits are overlain by a wedge-shaped mantle of colluvium or slope wash from the immediately adjacent valley walls. These deposits thin toward the center of the valley and thicken toward the valley wall, from which they are largely derived.

In table 4 the formations are described, with interpretations of their probable water-bearing properties. Few wells in the area reach bedrock and no adequate tests of the water-yielding properties of the bedrock formations are available. For this reason, interpretations have been based on a study of the apparent permeability of the bedrock in exposures.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Recent Series

Alluvium

Areal extent.--The Recent alluvial deposits are restricted to the bottoms of the principal stream valleys. They range in width from a maximum of about 1¼ miles along Nowood Creek to about 100 feet along some of the small tributary streams. The width of the floodplain is controlled, to some extent, by the resistance of the bedrock into which the stream valley has been cut. The wider parts of the floodplain along the perennial streams are where the stream crosses wide belts underlain by weak shale formations. The floodplains are narrow where resistant beds are crossed. For example, the floodplain of Paintrock Creek narrows to a quarter of a mile where it cuts through resistant beds exposed in the Paintrock anticline. Here the stream is flowing in a gorge that contrasts markedly with the broad, open valley 3 or 4 miles upstream where the floodplain is almost a mile wide.

Description.--The alluvial deposits consist mainly of silts and clays, with scattered lenses of sand and gravel in the eastern or upper part of the area. The alluvium has been deposited by the streams and has been built up to a maximum height of 5 or 10 feet above the present streams. The major streams meander a great deal, and the numerous abandoned meander channels on the floodplain clearly indicate that the streams are slowly moving back and forth across their floodplains. The abandoned meander channels are slowly being filled by the growth of vegetation, by soil materials washed from the surrounding fields, and by fine materials carried into them during the higher stages of stream flow.

The alluvial bottoms are waterlogged in places at the present time. Some small areas have water standing on the land, at least during the irrigation season, but others are waterlogged because the capillary fringe of the water table reaches the land surface during at least part of the year. Evaporation of the water takes place and the mineral matter in solution is concentrated in the upper few feet of the soil. In general, the larger waterlogged areas are present where shale beds lie at or near the surface or where there is uncontrolled ground-water seepage from a higher irrigated terrace. Water moves freely through the fairly permeable terrace deposits, but the less permeable alluvium of the valley bottom cannot transmit equal quantities and the water is forced to the surface.

In the lower or western part of the area a somewhat greater proportion of the irrigated land is waterlogged. Low permeability of the alluvium is the main cause of waterlogging. The character of the alluvium is shown well by an auger hole in the SE$\frac{1}{4}$ sec. 29, T. 50 N., R. 92 W.; with this thick section of fairly impermeable material, it is not surprising that the land is waterlogged. In the present general investigation, the limits of the area of thick impermeable beds could not be determined.

Log of auger hole in the SE$\frac{1}{4}$, sec. 29, T. 50 N., R. 92 W.

	Thickness (feet)	Depth (feet)
Topsoil and clay	1.0	1.0
Clay, brownish, with small amount of fine sand	7.5	8.5
Clay, dense, gray, with brownish and orange streaks	2.0	10.5
Clay, dense, gray	1.0	11.5
Sand, fine, and pea-sized gravel	a .5	12.0

a Total thickness undetermined.

The factors that determine the areas of waterlogging are also the factors that limit the success of wells in the alluvial deposits. Wells located in the more permeable alluvium toward the eastern end of the area will have considerably greater capacities than those in the less permeable alluvium toward the west. Water drawn from the tighter alluvium will generally contain higher concentrations of soluble salts. This is due, in part, to the fact that the irrigation water, which provides the major recharge, is of poorer quality in the lower end of the area, and also to the fact that the soils themselves, through which the water must move, contain more salts.

Occurrence of ground water.--A permanent ground-water body occupies the lower part of the alluvium throughout most of its extent. This reservoir receives some recharge from rainfall and from the perennial streams, but principally from the downward percolation of irrigation water applied to the fields. The amount of recharge that takes place has a direct relation to the permeability of the alluvium. A considerably greater water loss takes place on the fields at the eastern end of the area than on the fairly tight soils that border the lower course of Nowood Creek. This ground-water reservoir probably shows a marked seasonal fluctuation of level, reaching its lowest stage in the spring just before irrigation begins. During the irrigation season there is considerable ground-water seepage into the streams. For example, at times when diversions of irrigation water from the Paintrock and Medicine Lodge Creeks leave little flow at Hyattville, an estimated 1.5 second-feet representing ground-water seepage is available for diversion $4\frac{1}{2}$ miles below the town. No large springs or surface flows from irrigated fields are visible, but numerous small seepage areas can be seen along the stream banks.

Pleistocene Series

Terrace Deposits

Areal extent.--The stream terraces are prominent physiographic features from one end of the area to the other. Several prominent terraces are present but only those within a height of 125 feet above the streams are discussed in this report and shown on the geologic map, plate 1. Practically all the irrigation north and east of Hyattville is on stream terraces. Between Hyattville and the confluence of Paintrock and Nowood Creeks all of the terraces lie on the north side of the valley. Near Hyattville the terraces are about half a mile wide but toward the west they have been nearly destroyed by erosion and only small remnants remain. Terraces up to half a mile in width are present along the south and west sides of Nowood Valley in the reach extending about 3 miles below Bonanza. Beyond this point the terraces are not as well developed on the south side of the valley, or they have been cut by more recent erosion. Along the lower 9 miles of Nowood Creek prominent terraces extend along the north side of the valley. Toward the east end of this belt the terraces are somewhat dissected but toward the west they are fairly well preserved, although cut in a number of places by deep coulees.

Description.--Terrace deposits consist of clay, silt, sand, and gravel with scattered boulders. The deposits are coarser-textured and the permeability is considerably greater near the east than near the west end of the area. Gravels are abundant in terrace deposits throughout the entire area, but admixture with progressively greater proportions of fine-grained material toward the western end of the area reduces the permeability correspondingly. Much of the fine-grained material probably originated as wash from the adjacent shale slopes and was only slightly reworked by the streams forming the terraces. The present terraces are mantled in many places by wedge-shaped deposits of slope wash, which have formed since the major streams became incised.

Occurrence of ground water.--Under the larger areas of irrigated terraces a permanent ground-water body has been formed. This ground-water reservoir receives its principal recharge from irrigation because precipitation is scanty, and for this reason there is probably a marked seasonal fluctuation of water level under the terraces. During the irrigation season considerable seepage occurs along the terrace edges where the permeable beds are exposed. Where terrace deposits extend down below the level of the alluvial bottoms, water moves directly into the alluvium without appearing as surface seeps at the foot of the terrace slope. The alluvium, which has a lower permeability than the terrace deposits, is unable to transmit this water as fast as it is received and the water table rises near enough to the land surface to cause waterlogging. At the present time there is very little waterlogging on the terraces. In the few places where waterlogging has developed it is the result of the presence of shale bedrock near the surface or of local deposition of less permeable slope wash over the terrace surface. In some places a terrace may appear to be wider than it actually is because the upper edge of the terrace grades almost imperceptibly into the pediment surface upon which the terrace deposits were laid down. The true terraces are underlain by unconsolidated stream deposits, whereas the pediments are underlain by bedrock at shallow depth.

Wells penetrating the terrace deposits will probably furnish enough water for domestic supplies, provided that adequate recharge is available. Where terraces are irrigated the recharge is assured unless wells are located too close to the terrace margins. Wells drilled near the upper margins of a terrace may encounter bedrock at an altitude above the lowest level to which the water table declines during the year, and the wells will probably go dry during periods of little recharge. Deeper drilling will not materially alter this condition if the underlying bedrock is shale. In like fashion, wells should not be located too near the inner edge of the terrace or near deep coulees, which may cut across it, as the water table in these locations will not stand high above the underlying bedrock. Wells in all cases should penetrate the complete thickness of terrace deposits to insure a water supply during the spring months when the water table is at its lowest. Large seasonal fluctuations of the water table will occur in some areas.

Wells in the eastern part of the area will have considerably greater capacities than those to the west. Little clay and silt is mixed with the sands and coarser materials of the terrace deposits east of Hyattville, and consequently these beds have a high permeability. West from Hyattville the fine clay and silt become increasingly greater in proportion to the coarser materials and the permeability likewise decreases. The water obtained from the more permeable beds will be of better quality because the recharge water will be of better quality in the eastern part of the area and the coarse material contains much smaller quantities of soluble salts. Water obtained from wells drilled on the terraces that have not previously been irrigated will be of very poor quality for at least a few years after irrigation begins. Soluble salts, which have been accumulating during the long period of arid climate, must be leached out before the water will be of good quality.

Paleocene Series

Fort Union Formation

Areal extent.--The outcrop of the Fort Union formation is restricted to a single belt trending in a northwest-southeast direction across the extreme western end of the area. The belt has a maximum width of three quarters of a mile and lies east of the bluffs that border the valley of the Bighorn River. The beds dip from 8 to 20 degrees southwest, off the flank of the Manderson anticline.

Description.--The Fort Union formation consists of a thick section of gray to buff sandstone and shale. The sandstone layers are quite uniformly fine-grained and have a relatively low permeability. Some of the shale is carbonaceous and at least one bed of subbituminous coal is present in the section exposed within the area. The coal bed is somewhat lenticular and attains a maximum thickness of about 7 feet.

Occurrence of ground water.--Small quantities of slightly mineralized water are available to wells penetrating an adequate thickness of the Fort Union formation where recharge is available. The only wells in the area that draw water from this formation are those in Manderson. These wells range in depth from 35 to 104 feet. A sample of water was obtained from the 104-foot well (50-92-31bba2) and the water was found to be soft and only moderately mineralized. (See the quality-of-water section of this report for more detailed data on this water sample.)

Upper Cretaceous Series

Lance Formation

Areal extent.--The Lance formation crops out near the western end of the area. The belt of outcrop is about half a mile wide south of Nowood Creek but on the north side of the valley the outcrop area widens to about 2½ miles as a result of reversals in dip on the Manderson anticline and the synclinal structure lying to the east. The beds dip toward the west under the overlying Fort Union formation on the west flank of the Manderson anticline. East of the Manderson anticline the dips are toward the syncline, which lies within a mile to the east of the anticline. The folding is rather gentle, although dips up to 34 degrees were observed.

Description.--The Lance formation consists of a fairly thick series of light-brown to gray sandstone interbedded with gray shale; some shale beds are carbonaceous. The shale is soft and sandstone beds are poorly indurated except for a lower cross-bedded somber-colored bed that is fairly resistant to weathering. Exposures are generally poor because of the weakness of most beds. Large calcite-cemented concretions are numerous in some of the sandstone beds.

Occurrence of ground water.--Small quantities of somewhat mineralized water are available to wells penetrating an adequate thickness of this formation where recharge is available. Recharge must be obtained from irrigation or from seepage into the formation from alluvial deposits in Nowood valley bottom. No existing well is known to draw water from the Lance formation in this area.

Meeteetse Formation

Areal extent.--The Meeteetse formation crops out in a belt ranging from about 2,000 to 5,000 feet in width near the western end of the area. South of Nowood Creek the formation is exposed east of the Lance formation, under which it dips to the southwest. The strike of the beds changes, as a result of the anticlinal and synclinal structures, and the belt of outcrop is parallel to the drainage for a distance of more than 3 miles on the north valley wall of Nowood Creek. The strike of the beds changes again and the belt of outcrop extends northwestward on the east flank of the syncline. The beds have dips up to 35° on the flanks of the syncline.

Description.--The Meeteetse formation consists of a fairly thick series of poorly indurated beds of light- to medium-gray argillaceous sandstone, white to gray medium-grained sandstone, and carbonaceous shale. Near the middle of the formation there is a bed of yellow-brown concretionary sandstone about 60 feet thick. Because the beds are poorly indurated, the formation commonly forms lowlands and is poorly exposed.

Occurrence of ground water.--Small to moderate supplies may be obtained from this formation where adequate recharge is available. The owners of the two wells in the area that obtain water from this formation report the water to be soft but somewhat mineralized. Little information is available concerning the quantity of water the wells will yield, but one well pumped with a gas motor is able to furnish at least 10 gallons per minute.

Mesaverde Formation

Areal extent.--The Mesaverde formation is exposed in offset belts about 3,000 feet wide trending northwest on both sides of Nowood Creek. In connecting the belts of outcrop on either side of the valley, the formation underlies the alluvium of Nowood Creek for about 3 miles. (See pl. 1.) The outcrop is slightly wider than the alluvial bottom, and the formation is exposed along both valley walls.

Description.--The Mesaverde formation consists of well-indurated light-colored massive sandstone and dark sandy shale. Of its total thickness of almost 700 feet, the top 100 feet of the formation is a ferruginous brown to gray sandstone that has considerable resistance to erosion and stands as a prominent escarpment bordering the lowlands developed on the weak Meeteetse formation. Sandstone is the predominant rock type in the formation.

Occurrence of ground water.--Small to moderate water supplies may be obtained by wells from the Mesaverde formation where recharge is adequate. Large amounts of water probably enter the formation from the alluvium of Nowood Creek, as the Mesaverde underlies the valley for more than 3 miles. One well (50-92-36bda) draws water from sandstone beds near the middle of the formation but does not enter the major sandstone beds near the top or the base of the formation. This well, equipped only with a hand-powered cylinder pump, reportedly cannot be pumped dry, but the low rate of pumping gives no indication of the potential yield of the formation. The water contains moderate to high concentrations of dissolved solids. (See the quality-of-water section of this report for more detailed information on the chemical quality of the water.)

Cody Shale

Areal extent.--The Cody shale is exposed in a wide belt east of the outcrop of the Mesaverde formation. North of Nowood Creek the belt of Cody shale extends from the west edge of R. 91 W., to more than 3 miles east of the flanks of Paintrock anticline. Here the dip of the beds ranges from 3 to 29 degrees to the southwest. South of Nowood Creek the belt of outcrop is almost 6 miles wide, as the result of folding on the Manderson and Bonanza anticlines and on the synclines that lie short distances east of each. A narrow belt of Cody shale is present in the trough of the syncline that extends southeast of the town of Bonanza and parallels Nowood Creek above its confluence with Paintrock Creek. The Cody shale underlies the alluvium of Nowood Creek from sec. 3, T. 49 N., R. 91 W., to beyond the west edge of R. 91 W., a distance of more than 6 miles.

Description.--The Cody shale consists of a very thick (3,000 to 3,500 feet) medium- to dark-gray marine shale with a few lenticular shaly sandstone beds in the upper 500 feet. In places the shale contains gypsum, and locally it contains calcareous concretions and fossils. The formation is practically impermeable.

Occurrence of ground water.--Wells drilled into the Cody shale can be expected to yield little or no usable water. Some very small quantities might be obtained from sandy beds in the upper 500 feet of the formation if recharge is available, but undoubtedly the water would be highly mineralized.

Frontier Formation

Areal extent.--The Frontier formation is exposed on the flanks of the Bonanza and the Paintrock anticlines and in the syncline that parallels Paintrock anticline on its east side. The belt of outcrop ranges in width from about 1,500 feet near Bonanza to almost 2 miles in the trough of the syncline lying east of the Paintrock anticline.

Description.--The Frontier formation consists mostly of gray sandstone and some gray to black shale and is about 550 feet thick. The Torchlight sandstone member at the top of the formation is 5 to 25 feet thick and consists of light-gray sandstone with layers of black and gray chert pebbles. About 100 feet below this member is another series of sandstone beds aggregating about 50 feet in thickness. Near the base of the formation is a bed of gray thick-bedded sandstone 60 feet thick. These three principal sandstone beds are separated by bentonitic shale beds.

Occurrence of ground water.--Small to moderate quantities of water would be available to wells where recharge is adequate. Locally the water may be under artesian pressure. One well (49-90-17ac) has been drilled into this formation, but the water was reported to be of such poor quality that the lower part of the well was plugged. Under more favorable conditions of recharge, however, the water may be fit for domestic use. No data are available regarding the potential yield of this formation.

Mowry Shale

Areal extent.--The Mowry shale is exposed in a narrow belt around the Paintrock anticline, on the crest of the Bonanza anticline, on the west flank of the Hyattville anticline, and in the trough of the syncline northwest of Hyattville. On the west flank of Paintrock anticline the belt of outcrop is about 1,200 feet wide but on the east flank the beds have steeper dips and the outcrop belt is only about 450 feet wide. On the gentle western flank of the Hyattville anticline, the outcrop belt is almost a mile wide. A remnant of the Mowry shale, about half a square mile in extent, is preserved in the trough of the syncline about 2 miles northwest of Hyattville.

Description.--The Mowry shale consists of dark-gray to brownish-gray siliceous shale with some thin beds of siltstone, muddy sandstone, and bentonite, and is about 340 feet thick. This formation is easily recognized by the distinctive bluish-gray color of weathered surfaces. The shale is brittle and the formation commonly forms steep bare slopes.

Occurrence of ground water.--It is unlikely that any usable water supplies can be obtained from this formation. All beds in the formation, including the thin beds of muddy sandstone, have extremely low permeability.

Upper and Lower Cretaceous Series

Thermopolis Shale

Areal extent.--The Thermopolis shale is exposed around the flanks of Paintrock and Hyattville anticlines. The belt of exposure on the west flank of Paintrock anticline is half a mile wide but on the east flank, where dips are much steeper, the outcrop belt is only about 800 feet wide. The belt of outcrop on the west flank of Hyattville anticline is about half a mile wide, but on the east side the outcrop area is about 1½ miles wide as a result of a reversal of dip in the syncline that lies just east of the anticline.

Description.--The Thermopolis shale consists mostly of black fissile shale and is about 400 feet thick. The Muddy sandstone member, which consists of light-gray cross-bedded sandstone 8 to 30 feet thick, occurs near the middle of the formation, and a few brown siltstone beds are present near the base. The shale is soft but the sandstone member is well indurated and forms a prominent marker bed in most exposures. The shale slopes are usually bare of vegetation and thus fairly good exposures are common.

Occurrence of ground water.--Very meager supplies of highly mineralized water may be obtained locally from the Muddy sandstone member where recharge conditions are favorable. The remainder of the formation is highly unfavorable for development of water supplies. One well (49-90-1bba) is believed to obtain water from the Muddy sandstone member.

Lower Cretaceous Series

Cloverly Formation

Areal extent.--The Cloverly formation crops out on the flanks of both the Paintrock and the Hyattville anticlines. The formation is thin, averaging about 150 feet in thickness. The outcrop belts are narrow in most places, ranging in thickness from a maximum of about 1,500 feet where dips are gentle on the west flanks of the anticlines to less than 300 feet on the east flanks. The formation crops out again east of Hyattville where it rises on the west flank of the Big Horn Range.

Description.--The Cloverly formation consists of sandstone, siltstone, and shale with several thin ironstone beds, and is about 150 feet thick. The Greybull sandstone member, consisting of 5 to 70 feet of light-gray to brown resistant fine-grained sandstone, is near the base. The exact contact with the underlying Morrison formation has not been fixed, but the available maps show contacts between lithologic units.

Occurrence of ground water.--Small supplies of mineralized water may be obtained from this formation under conditions of adequate recharge. The sandstone is fine-grained and its permeability is low; large yields cannot be expected. Flowing wells may be obtained from the Cloverly formation in some places in areas where it is overlain by impermeable shale. The water obtained from this formation is characterized by a rather high concentration of sodium sulfate, but it is considered suitable for stock water where better supplies are not available. One well (49-90-1aaa) that draws water from this formation has a flow of about 3 gallons per minute under a low head. (See the quality-of-water section of this report for more detailed data on the chemical quality of the water.)

Upper Jurassic Series

Morrison Formation

Areal extent.--The Morrison formation mantles much of the crest of the Paintrock anticline and is the oldest formation exposed on the Hyattville anticline. It also crops out east of Hyattville where it rises on the flanks of the Bighorn Range. This formation has a thickness of about 300 feet but its position high on the flanks of the anticlines give it a disproportionately large outcrop area. The outcrop belt on the west flank of Paintrock anticline is about 2,500 feet wide, but that on the east flank is only about 500 feet wide at the valley of Paintrock Creek. The outcrop area on the Hyattville anticline is more than a mile wide southwest of the town of Hyattville. The outcrop belt east of town, where the beds rise on the flanks of the Bighorn Range, is wide but detailed geologic mapping was not completed.

Description.--The Morrison formation in its upper part consists of variegated claystone and shale with lenticular sandstone beds; a prominent conglomerate or conglomeratic sandstone bed, 25 to 30 feet thick, is near the middle of the formation; and in the lower part are beds of carbonaceous shale and brown to greenish-gray sandstone and red and brown shale.

Occurrence of ground water.--Where recharge is adequate, moderate to large supplies of water may be obtained by wells drilled into the conglomeratic bed. The other sandstone beds present in the formation are lenticular and are generally too fine-grained to furnish dependable supplies except locally. The water obtained from the conglomeratic bed may be of good quality, depending to a large extent on the quality of recharge water and the distance from the source. The water locally available from the sandstone beds is considerably mineralized. Two wells (49-90-3aaa and 49-90-3aba) are believed to obtain water from the sandstone beds but neither well is used for domestic supply because of poor quality. A water sample was obtained from well 49-90-3aaa, and was found to have a high concentration of sodium, magnesium, and calcium sulfate. (See the quality-of-water section of this report for more complete data on the chemical quality of the water.)

Sundance Formation

Areal extent.--The Sundance formation is exposed along the axis of the Paintrock anticline and east of Hyattville where the strata rise on the flanks of the Bighorn Range. The area exposed in the crest of Paintrock anticline has a maximum width of 1,500 feet and a length of about $2\frac{1}{4}$ miles. The area east of Hyattville has not been mapped in detail, but the outcrop belt of the Sundance formation was determined to be about three-fourths of a mile wide.

Description.--The upper half of the Sundance formation is predominantly dark-gray to olive-gray silty fissile shale. Near the middle of the formation is about 50 feet of soft, buff to gray sandstone with weak calcareous cement, and near the base of this sandstone thin beds of oolitic limestone are locally developed. The lower part of the formation consists of interbedded soft sandstone and shale of variegated colors.

Occurrence of ground water.--Meager supplies of water may be obtained by wells drilled into the more sandy beds in places where adequate recharge is available. The fine-grained sandstones have low permeabilities and wells would have low yields. Water in this formation is probably highly mineralized and may be unfit for domestic use. No wells in the area draw water from this formation.

Middle Jurassic Series

Gypsum Spring Formation

Areal extent.--The Gypsum Spring formation is exposed about 2 miles northeast of Hyattville where the rock strata rise on the flank of the Bighorn Range. The formation is thin; but, as dips are gentle, the belt of outcrop has a width of as much as a mile in places.

Description.--This formation is about 200 feet thick and consists of reddish-brown claystone and siltstone with several thin beds of limestone, and a massive 50-foot bed of gypsum near the base. The limestone beds are 2 to 4 feet thick and are massive, finely crystalline, and resistant to erosion. Much of the formation is calcareous or gypsiferous.

Occurrence of ground water.--Little water can be obtained from this formation. The water is mineralized and probably not suitable for domestic use.

Triassic System

Chugwater Formation

Areal extent.--The Chugwater formation is exposed near the eastern end of the area, where the beds rise on the flanks of the Bighorn Range. The dips are quite gentle and the outcrop belt is about a mile wide. It is principally on this weak formation that the wide valley between Paintrock and Medicine Lodge Creeks has been developed. The formation is prominently exposed in steep bluffs rising northwest of Medicine Lodge Creek.

Description.--The Chugwater formation consists of a bright-red to reddish-brown shale, siltstone, and fine- to medium-grained sandstone, and is about 700 feet thick. The lower part contains a few thin, lenticular beds of limestone and gypsum. The beds are soft and poorly indurated but maintain steep slopes where overlain by beds more resistant to erosion.

Occurrence of ground water.--This formation cannot be expected to yield a usable supply of water. Permeability is low because the sandstone beds contain a large amount of clay. Water in this formation is highly mineralized and probably is not usable as a domestic supply.

Permian System

Embar Formation

Areal extent.--The Embar formation is exposed in a belt across the east end of the area, where the strata rise on the flanks of the Bighorn Range. A gradational lithologic change exists between this formation and the overlying Chugwater formation in this area, and a definite boundary cannot be drawn.

Description.--The Embar formation consists of maroon siltstone, sandstone, and gypsum and thin beds of limestone and dolomite. A chert-pebble conglomerate and sandstone marks the base of the formation.

Occurrence of ground water.--Small quantities of water may be obtained locally where recharge is adequate. Permeability is low because considerable clay is present in the siltstone and sandstone beds. Water in this formation is probably of poor quality and not generally suitable for use.

Carboniferous System

Tensleep Sandstone (Pennsylvanian Series)

Areal extent.--The Tensleep sandstone is exposed in a belt at the extreme eastern end of the area, just east of the point where the valley of Paintrock Creek widens out onto the plain that extends to Medicine Lodge Creek. The belt of outcrop is less than half a mile wide, as the strata here have dips of more than 20 degrees off the flank of the Bighorn Range. This formation is quite resistant to erosion and forms steep slopes bordering the narrow floodplain of Paintrock Creek.

Description.--The Tensleep sandstone consists of white to pinkish-gray cross-bedded sandstone, with interbedded gray dolomite in the lower part. The sandstone is well cemented but locally contains poorly indurated beds. It is fairly permeable because the sandstone is fine- to medium-grained and has a low clay content.

Occurrence of ground water.--Moderate to large supplies of water may be obtained from wells where adequate recharge is available. Wells penetrating soft sand beds may require screens. Well 50-89-26cac draws water from this formation but is equipped with a small-capacity pump, and no data are available as to the potential yield of the aquifer. The water is somewhat hard but otherwise of good quality. (See the quality-of-water section of this report for more detailed data on the chemical quality of the water.)

Amsden Formation (Mississippian and Pennsylvanian Series)

Areal extent.--The Amsden formation is exposed only at the extreme upper end of the area along Paintrock Creek. The formation is resistant to erosion and forms high walls on either side of the narrow alluvial plain of the stream. The outcrop belt is narrow, as the beds dip more than 20 degrees to the southwest on the flanks of the Bighorn Range.

Description.--The Amsden formation consists of about 175 feet of varicolored dolomite with thin beds of red, purplish, and green shale and shaly sandstone. Considerable brightly colored to drab chert is present in the dolomite as beds and nodules. The dolomite is resistant and forms cliffs. Some of the thin beds of red shale locally contain thin veins of gypsum.

Occurrence of ground water.--Small to moderate supplies of water may be obtained by wells where the dolomite beds are fractured and where recharge is available. The water may be of poor quality locally but is probably suitable for use. No wells in this area are known to obtain water from this formation.

Madison Limestone (Mississippian Series)

Areal extent.--The Madison limestone is not exposed in the area covered by this report, but it forms the steep front of the Bighorn Range immediately to the east, and it underlies the entire area. This formation is very resistant to erosion and is one of the principal cliff-forming rock formations in Wyoming.

Description.--The Madison limestone consists of a thick sequence of massive, thick-bedded crystalline limestones and dolomites. In the outcrop area these beds locally contain numerous fractures and caverns. Ancient caverns have, in places, become filled with red shale and fine sand but locally large open caverns remain. Limestone and dolomite beds usually have low permeability except for fractures and caverns.

Occurrence of ground water.--Large supplies of water are available to wells encountering water-filled fractures or caverns. Wells failing to encounter such openings below the water table may have very low yields but should not be abandoned without "springing" (blasting with high explosives to open up crevices). Drilling of water wells to this aquifer is not feasible in much of the area because of its great depth. Two deep oil tests (49-90-18ddb and 49-90-20cc) obtain water from this formation near the center of the area. Both wells flow at the surface, yielding about 50 and 30 gallons per minute, respectively. The water is mineralized. (See the quality-of-water section of this report for data on chemical quality of water.)

QUALITY OF THE WATER IN THE PAINTROCK IRRIGATION PROJECT, WYOMING

By Herbert A. Swenson

Proper evaluation of ground- and surface-water resources must take into consideration, among other factors, the composition and degree of mineralization of the water. The wide range in the mineral content of water in the Paintrock irrigation project area makes a study of the chemical character especially necessary. A determination of the types of water now known to exist in the Paintrock project will serve as a reference point for any future quality-of-water studies in the area. Such studies will define the changes in mineralization of the water that will be caused by the irrigation of the valley bottom lands and the stream terraces with water to be impounded by the proposed Lake Solitude Dam.

Water samples were collected from seven wells and from three surface-water sources in the area on September 11 and 12, 1947. Ground water in geologic formations that range from the Madison limestone of Mississippian age to the Fort Union formation of Paleocene age and surface water from

Paintrock and Nowood Creeks were sampled. The location of sampling points is shown in plate 1.

The results of the chemical analyses of the 10 water samples that were collected in this area are shown in table 5, where concentrations are given in parts per million. These analyses were made according to methods[4] in common use and report values for pH, specific conductance, silica, iron, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, fluoride, nitrate, dissolved solids, total hardness, noncarbonate hardness, and percent sodium. The analyses give little or no indication of the sanitary condition of the waters and do not include the determination of some of the rarer constituents of natural waters. A wide range in the concentration in both ground and surface waters is evident from examination of table 5. Dissolved solids range from 279 to 4,590 parts per million for ground water and from 102 to 1,330 parts per million for surface water. The hardness of the water as calcium carbonate ($CaCO_3$) ranges from 13 to 1,680 parts per million for ground water and from 82 to 776 parts per million for surface water.

GROUND WATER

It is pointed out that the formation from which some of the samples of ground water were obtained could not always be determined because of incomplete well logs. Several water-bearing strata were probably encountered in the drilling of some of the wells but no effort was made to case off completely the water from all but one level. It follows that any sample taken from such a well is not representative of any particular formation.

Well 50-92-31bba2 in the town of Manderson has a reported depth of 104 feet and yields a very soft, sodium bicarbonate water of moderate mineral content. (See table 5.) The well obtains water from the Fort Union formation. The small amounts of calcium and magnesium in this water suggest that some type of base-exchange reaction may be taking place. In such a reaction between the water and the rock material the calcium and magnesium in the water are exchanged for the sodium of base-exchange minerals in the rock materials. The concentration of 3.2 parts per million of fluoride is significant as it exceeds the maximum of 1.5 parts per million that is recommended by the United States Public Health Service[5] for a drinking water. A water containing much in excess of 1.5 parts per million of fluoride, if used for drinking by young children during calcification or formation of the teeth, causes the condition of the teeth that is known as mottled enamel.

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4 American Public Health Association, Standard methods for the examination of water and sewage, 9th ed., 1946.

5 U. S. Public Health Service, Drinking water standards: vol. 61, no. 11, p. 12, Mar. 15, 1946.

Table 5.--Analyses of water in the Paintrock irrigation project, Wyo.

[Analytical results in parts per million except as indicated]

Source	Date of collection (1947)	Depth of well (feet)	pH	Specific conductance (micromhos @ 25° C.)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$ Total	Hardness as $CaCO_3$ Noncarbonate	Percent sodium
							Fort Union formation												
50-92-31bba2	Sept. 12	104	8.4	1,280	7.0	0.04	3.0	1.3	307	6.4	642	7.7	101	3.2	3.5	776	13	0	97
							Mesaverde formation												
50-92-35aca	Sept. 12	76.0	7.5	2,490	9.0	.04	368	163	36	11	324	1,320	28	.0	2.5	2,100	1,590	1,320	5
-36bda	Sept. 12	122	7.8	1,330	10	.04	60	28	204	8.4	256	476	6.0	.6	4.2	926	264	54	62
							Cloverly formation												
49-90-1aaa	Sept. 11	140	7.6	3,540	200	.05	17	8.5	827	12	270	1,550	35	1.0	4.9	2,590	78	0	95
							Morrison formation												
49-90-3aaa	Sept. 11	40	7.6	5,190	20	.04	428	149	794	14	334	3,000	14	1.4	6.5	4,590	1,680	1,430	50
							Tensleep sandstone												
50-89-26cac	Sept. 11	16.5	7.9	476	18	.02	52	25	5.5	4.0	262	8.6	2.0	.2	28	279	233	18	5
							Madison limestone												
49-90-18ddb	Sept. 11	1,800	7.6	1,700	12	.04	178	50	153	13	178	802	7.0	2.8	.5	1,310	650	504	33
							Streams												
Nowood Creek near Manderson	Sept. 12	....	7.6	1,300	12	.08	146	55	68	7.6	202	550	6.0	.2	1.8	946	590	424	20
Paintrock Creek near Hyattville	Sept. 11	....	7.9	185	7.7	.08	18	9.0	3.4	1.6	102	4.0	1.0	.4	1.5	102	82	0	8
Paintrock Creek near Tensleep	Sept. 12	....	7.6	1,690	25	.02	199	68	113	12	292	756	6.0	.4	2.5	1,330	776	537	24

Water in the Mesaverde formation was sampled from wells 50-92-35aca and 50-92-36bda. Well 50-92-35aca, which has a measured depth of 76.0 feet, furnishes a water that is six times as hard as water in well 50-92-36bda, which is reported to be 122 feet deep, and that contains, in addition, more than twice the amount of mineral solids. As hard water from the overlying alluvium may enter the Mesaverde formation, it is probable that the water in well 50-92-35aca is a mixture of waters from the two aquifers, and the increase in hardness and mineral content is due to the influence of the alluvium. Mixing of the water may also result from deterioration of the well casing.

The Cloverly formation yields water to well 49-90-1aaa, a drilled well that is north of Hyattville and that has a reported depth of 140 feet. This water contains a considerable amount of sodium sulfate and is, in reality, a dilute solution of Glauber's salt. The water sample from the Cloverly formation, though somewhat soft, has 2,590 parts per million of dissolved solids.

Well 49-90-3aaa is believed to obtain water from the Morrison formation. Water from this well, which is reported to be 40 feet deep, has the maximum mineral content (4,590 p.p.m.) of all water samples that were collected in the course of the investigation. This water is essentially a sulfate water with sodium approximately equal to the sum of the calcium and magnesium, all expressed as equivalents per million. This is also the hardest of all the water samples that were collected in the area.

The Tensleep sandstone, which is exposed in the extreme eastern end of the project, furnishes water to well 50-89-26cac. This water, obtained from a shallow well that is 16.5 feet deep, is the least mineralized of those examined and consists largely of calcium and magnesium bicarbonates. The approximately equal concentration of the alkaline earths--calcium and magnesium--considered as equivalents per million, suggests the presence of dolomite, which is found interbedded with the Tensleep sandstone in the lower part of the formation.

A water sample was collected from a flowing well, 49-90-18ddb, that draws water from the Madison limestone at a reported depth of 1,800 feet. This well was drilled some years ago in connection with exploratory tests for oil and was abandoned after tapping the artesian aquifer. The well is not capped, and the water flows into a nearby irrigation ditch. The water is mineralized and hard, the solids consisting largely of sulfates of sodium, calcium, and magnesium.

The composition of the water samples is shown graphically in figure 5, where results are expressed in equivalents rather than in parts per million. The use of equivalents permits easy comparison of one analysis with another, as equivalents are multiples of the combining weights of the elements of radicals reported in the analyses. Thus, whereas 1 part per million of calcium is not chemically equal to 1 part per million of bicarbonate, 1 equivalent per million of calcium is chemically equal in reacting value to 1 equivalent per million of bicarbonate (or sulfate or chloride). In such diagrams the height of the individual constituent is proportional to the concentration expressed as equivalents per million.

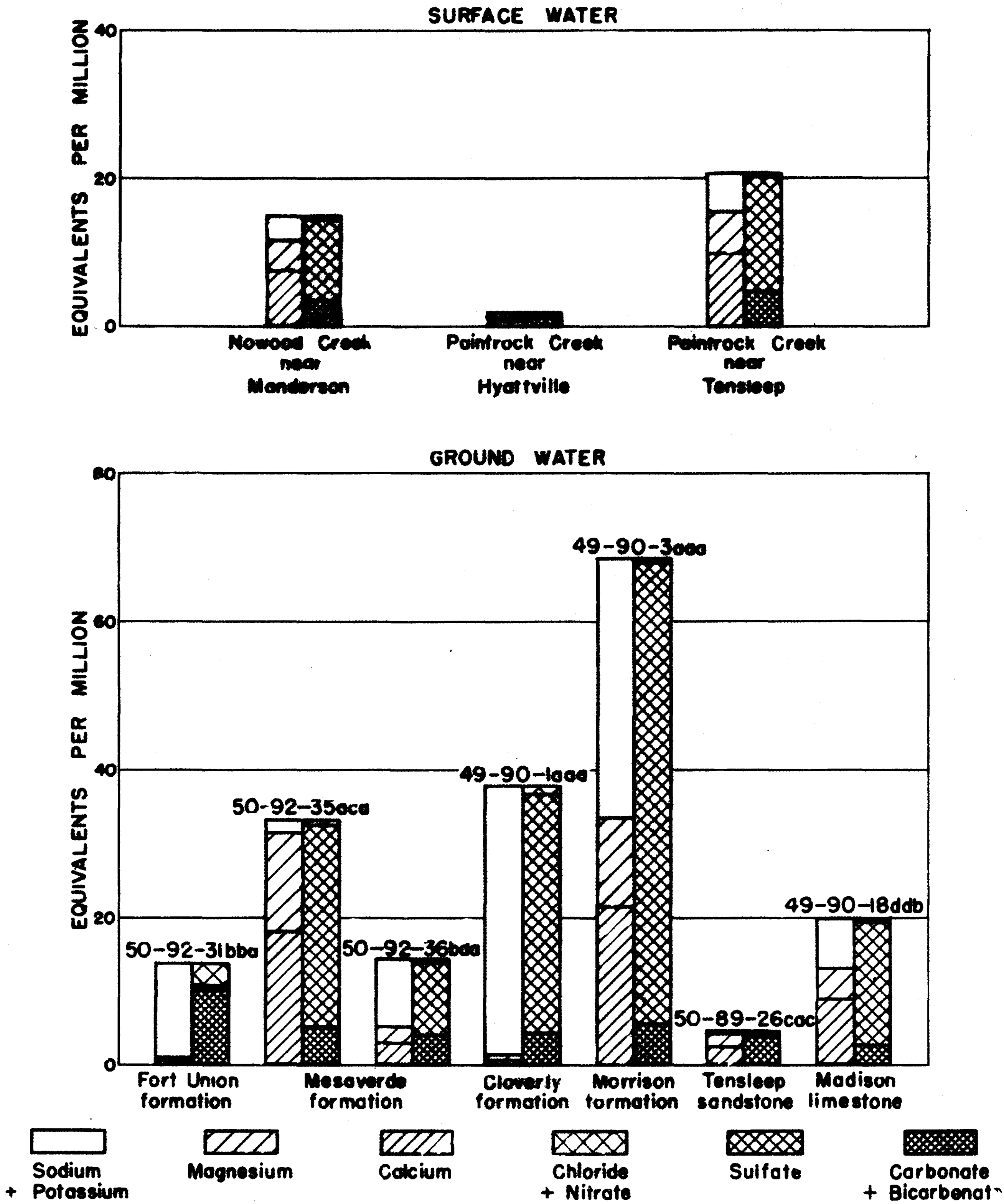

Figure 5.—Composition of water in Paintrock irrigation project, Wyo.

SURFACE WATER

Three samples of surface water in the Paintrock project were analyzed. (See table 5.) The data provide information on the quality of the water in Nowood Creek near the town of Manderson on the west side of the project; in Paintrock Creek near Hyattville at the gaging station, which is above all major ditch and canal diversions; and in Paintrock Creek near Tensleep and above the confluence with Nowood Creek. The sample near Tensleep illustrates the effects of return flow from irrigation.

In discussing the analyses of surface water it is emphasized that the analyses represent the concentration and composition of the water at the time of sampling only. Records over a long period of time are necessary to determine average weighted values of the principal mineral constituents in solution. Concentrations fluctuate with water discharge, and an analysis of water in a flowing stream at the same sampling point will vary from day to day, or during high runoff from hour to hour, or at even shorter intervals.

The quality of the water in Nowood Creek near Manderson is influenced by contributions upstream from Paintrock Creek, the major tributary to Nowood Creek. The creek water near Manderson is less saline than the water that is discharged by Paintrock Creek at its confluence with Nowood Creek. The lower concentration of dissolved solids in water from Nowood Creek near Manderson is the result of dilution of strongly mineralized water from Paintrock Creek at its mouth with relatively fresh water from Nowood Creek.

The analysis of the water in Paintrock Creek near Hyattville shows that this water has a low mineral content, most of which is calcium and magnesium bicarbonate. The water at the gaging station near Hyattville is free from major return irrigation flow. The percentage of sodium is very low and, if this analysis is typical of the creek water, any impoundment of the stream above the sampling point should produce an excellent water for irrigation. The instantaneous water discharge at the time the sample was collected was 49 second-feet.

An analysis of water in Paintrock Creek at a point 150 feet upstream from its confluence with Nowood Creek near Tensleep shows that the concentration of dissolved solids in this water is approximately 13 times that in the water near Hyattville. The increase in hardness is about ninefold. The increase in both dissolved solids and hardness is caused by return flow of irrigation water that is applied to upstream farm lands. Although the percentage of sodium is higher than that for the water near Hyattville, the water is still satisfactory for irrigation with respect to percentage of sodium.

The composition of the stream water is shown graphically in figure 5.

SUITABILITY OF THE WATER FOR USE

Of the seven wells from which water samples were collected for chemical analyses, five are used for domestic or stock purposes, one is used for irrigation of farm land, and one is not used. Water in both Nowood and Paintrock Creeks is used for irrigation. The following table summarizes the data as to the present use of the water that was sampled in the project:

Use of water in the Paintrock irrigation project, Wyo.

Well or stream	Present use of water	Remarks
50-92-31bba2	Domestic...........	Soft, moderately mineralized; fluoride above recommended limit.
50-92-35aca	None................	Hard, saline water; considerable amount of calcium and magnesium sulfates.
50-92-36bda	Domestic...........	Hard, moderately mineralized.
49-90-1aaa	Stock..............	Soft, saline; salinity mostly sodium sulfate (Glauber's salt).
49-90-3aaa	.....do.............	Very hard and saline.
50-89-26cac	Domestic...........	Hard, but least mineralized water sampled.
49-90-18ddb	Irrigation.........	Satisfactory as irrigation water.
Nowood Creek...	.....do.............	Do.
Paintrock Creek	.....do.............	Do.

Figure 6 shows the classification of the ground and surface water in the project as to irrigation use and is based on permissible limits for specific conductance (electrical conductivity) and percentage of sodium that are proposed by Wilcox.[6]

SUMMARY

The concentration and composition of surface and ground water in the Paintrock irrigation project range within wide limits. The concentration of dissolved solids in the samples of ground water ranged from 279 parts per million for a water in the Tensleep sandstone to 4,590 parts per million for a water in the Morrison formation. The hardness as calcium carbonate ($CaCO_3$) ranged from 13 to 1,680 parts per million. Ground water

6 Wilcox, L. V., The quality of water for irrigation use: U. S. Dept. Agr. Tech. Bull. 962, pp. 25-28, September 1948.

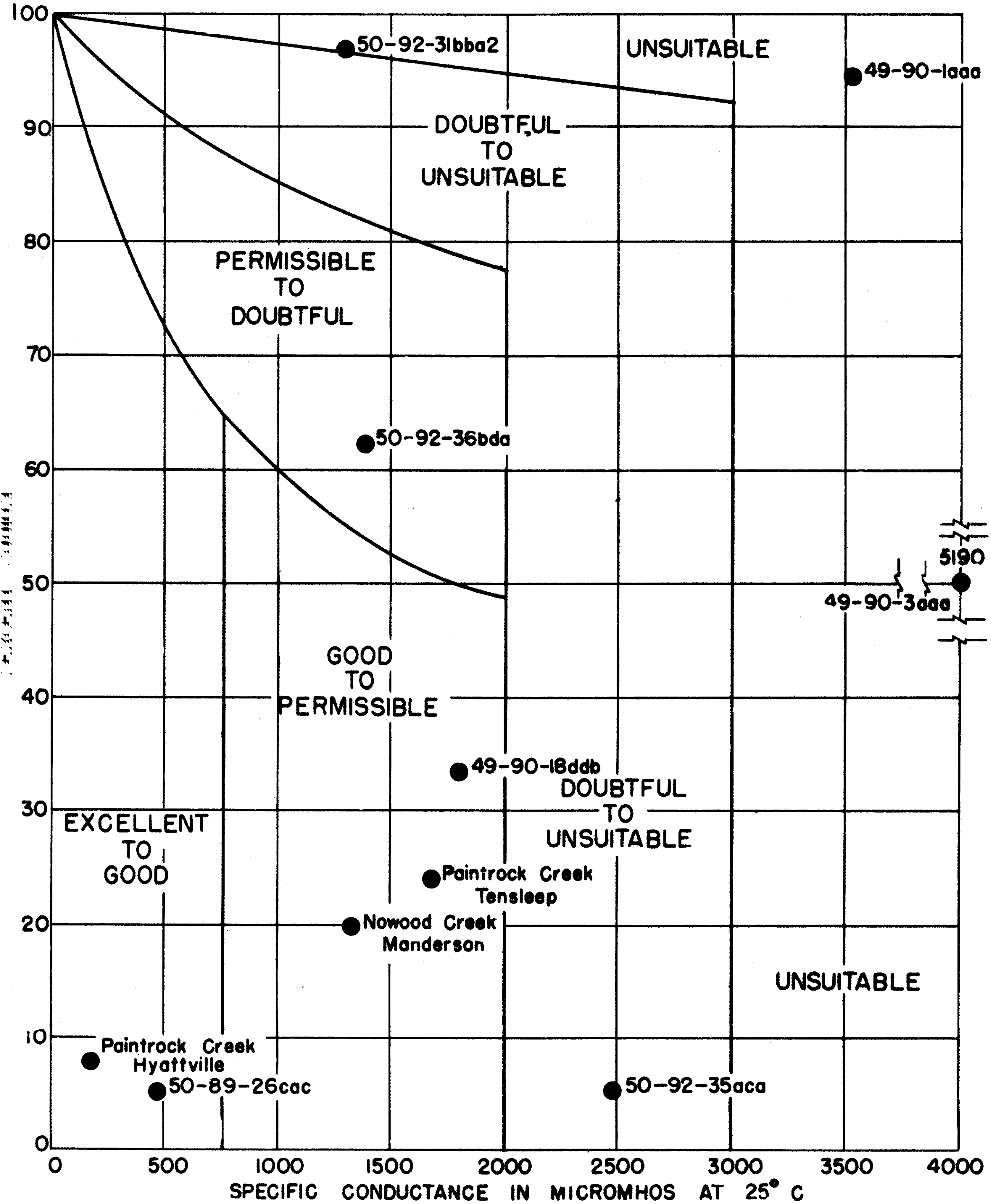

Figure 6.—Classification of water as to irrigation use, Paintrock irrigation project, Wyo.

is used almost exclusively for domestic purposes or for stock watering, although one flowing well is used for irrigation of farm land. Only general interpretation can be made of analytical results for surface water in view of the very limited number of samples. Water in both Nowood and Paintrock Creeks is satisfactory for irrigation.

OBSERVATION WELLS

Sixteen wells in the area were selected as key observation wells, and the depth to water in these wells is being measured periodically. The first measurements were made when the wells were inventoried in September 1947, and for this reason the period of measurement has been too short for significant interpretations. The periodic measurements should be continued for at least several years, so that data will be available as to the seasonal and long-term fluctuations of the water table. Such data often furnish pertinent facts regarding recharge and discharge, as well as information on any persistent upward or down ward trend of the ground-water level. Advance warning of waterlogging may be obtained from a study of the long-term fluctuations of the water table. With this advance warning it may be possible to start drainage plans before the land actually is damaged. Water-level measurements in the key observation wells in the Paintrock irrigation project are tabulated on the following page.

Table 6.--Water-level measurements in observation wells on the Paintrock irrigation project, Wyo.

Water level, in feet below land-surface datum, 1947

Well number	Date	Water level	Date	Water level	Date	Water level
49-90-1bcd	Sept. 5	7.20	Oct. 17	13.41	Nov. 21	14.17
-1daa1	17	6.86	17	8.00	21	8.83
-3aba	5	a 17.22	17	a 17.14	21	a 18.60
-3aba	5	b 25.72	17	b 24.18	21	b 25.62
-9cbc	5	8.00	17	9.20	21	13.98
-19cba	12	6.13	17	5.72	21	5.55
49-91-4dc	5	27.45	17	27.68	21	23.73
-14ad	5	c .72	17	c .99	....	.....
50-89-26cac	5	8.05	17	11.00	21	12.79
-32bca	8	5.00	17	6.57	21	7.22
50-91-31cba	4	7.25	17	6.70	21	6.88
50-92-30cac1	15	8.71	17	8.46	21	8.00
-31bba1	12	9.02	17	8.98	21	9.05
-32bbd	3	5.44	17	5.73	21	6.00
-34bb	3	4.52	17	3.97	21	3.84
-35bbb2	17	8.00	17	8.32	21	8.32
50-93-25ada	16	6.02	17	7.38	21	7.65

a Inside 4-inch casing.
b Between 4-inch and 6-inch casings.
c Water level, in feet above land-surface datum, 1947.

WELL RECORDS

The locations of all known water wells (except for some closely spaced wells in towns) are shown on plate 1. Table 7 (p. 41) gives pertinent available information on all wells shown on the map. In many cases it was impossible to obtain measurements of the depth of a well or the depth to water in a well, and the information given in the table is based on memory of the owners or drillers of those wells. No detailed records have been kept by the owners regarding depths of wells and materials penetrated, and considerable interpretation has been required in determining the geologic source of water. Data on adequacy of wells are based on statements of owners and do not indicate the yields accurately. However, they do indicate whether or not wells are yielding sufficient water for present needs.

The Paintrock irrigation project is on the eastern edge of the Bighorn Basin in north-central Wyoming. It is in a belt roughly 25 miles long and ½ to 3 miles wide and lies east of the town of Manderson. The area has an arid climate, with an average annual precipitation of about 7.33 inches; hence, farming is dependent on irrigation. The principal crops raised are beans, small grains, hay, and alfalfa. Parts of the area have been irrigated for the past 60 years. In ordinary seasons there is a shortage of irrigation water for the lands now under cultivation. The Bureau of Reclamation plans to furnish supplementary water supplies and to put additional acreage under irrigation.

The major part of the area considered in this report is flat to gently sloping valley bottomland and stream terraces. The altitude of the area ranges from about 3,900 to 4,700 feet above sea level. Water for irrigation is diverted from Medicine Lodge, Paintrock, and Nowood Creeks. Most of the irrigated land is underlain by alluvial and terrace deposits that are progressively finer-grained and less permeable toward the west. Bedrock underlying the area ranges from Carboniferous to Tertiary in age and is folded into several gentle structures that cross the area. The oldest rocks are in the eastern part of the area, where they rise on the western flank of the Bighorn Range, and the youngest rocks are in the western part of the area.

The principal sources of domestic ground water at present are the alluvium and the terrace deposits. Water from these sources is somewhat limited in quantity, especially toward the western end of the area. The water is hard and in places is highly mineralized. The rocks underlying the area contain 10 different aquifers, which differ greatly in potential yields. Because most of these beds have dips of at least several degrees, the belts of outcrop are narrow and the area in which it would be economically feasible to drill into a given aquifer is limited. Water from the bedrock aquifers is more highly mineralized, in general, than that from the unconsolidated sediments.

Parts of the irrigated alluvial bottomlands are waterlogged. In general, the larger waterlogged areas are present where shale beds are at or near the surface or where there is uncontrolled ground-water seepage from a higher irrigated terrace.

East of Hyattville domestic water supplies may be obtained from wells constructed in the unconsolidated alluvium and stream-terrace deposits. Such wells will yield adequate supplies of potable water. Wells in these deposits west of Hyattville will not be uniformly good as to both quantity and quality of water available. Wells located close to the zone of intake from a stream or irrigation ditch will provide water of better quality. In areas where wells can be economically drilled into the Fort Union and Mesaverde formations and the Tensleep sandstone usable domestic water supplies may be obtained. Some of the other formations will furnish water too highly mineralized for domestic use but suitable for stock.

Further detailed investigations of shallow ground-water conditions should be made preliminary to the design and construction of drainage systems, as the present general investigations was not designed to give the detailed data required for drainage developments.

Detailed studies should be made of the source and present volume of ground-water seepage into the Snyder Bros. Coal Company mine near Manderson. The mine workings extend under a terrace scheduled for irrigation, and considerable flooding in the mine may result from seepage of irrigation water.

Table 7.--Records of wells in Paintrock irrigation project, Wyo.

Well number: See text, p. 5, for description of well-numbering system.
Type of well: DD, dug and drilled; Dr, drilled, Du, dug.
Depth of well: Reported depths are given in feet below land surface; measured depths are given in feet and tenths below measuring point.
Type of casing: C, concrete (brick, tile, or pipe); P, iron or steel pipe; T, clay tile.
Water-bearing material: Cm, Madison limestone; Cpt, Tensleep sandstone; G, gravel; Jm, Morrison formation; Kc, Cody shale; Kcl, Cloverly formation; Kf, Frontier formation; Km, Meeteetse formation; Kmv, Mesaverde formation; Kt, Thermopolis shale; Tfu, Fort Union formation.
Method of lift: Cy, cylinder; F, natural flow; J, jet; N, none; P, pitcher pump.
Type of power: E, electric; G, gasoline; H, hand-operated.
Use of water: D, domestic; I, irrigation; N, not being used; S, stock.
Measuring point: L, land surface; Tca, top of casing; Tcu, top of curb.
Depth to water; Reported depths to water are given in feet; measured depths to water are given in feet, tenths, and hundredths.
Remarks: A, adequate supply; Ca, chemical analysis; F3, estimated flow in gallons per minute; I, inadequate supply; Ot, oil test.

Well number	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Water-bearing material	Method of lift and type of power	Use of water	Measuring point: Description	Measuring point: Distance above (+) or below (-) land surface (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks
49-89-6ccb	E. A. Ilg..........	Dr	25	6	P	G	J,E	D	L	...	10	9-16-47	A
49-90-1aaa	Mayland Brothers...	Dr	140	6	P	Kcl	Cy,F,G	S	L	...	.....	9- 9-47	F3,Ca
-1ada1	Cal Thomas.........	Dr	30	5	P	G	J,E	D	L	...	12	9-17-47	A
-1ada2	W. R. Fultz........	Dr	21	5	P	G	J,E	D	L	...	6	9-17-47	A
-1baa	Roy Williams.......	Dr	48	5	P	G	J,E	D	Tca	+0.2	8.45	9-16-47	A
-1bba	Williard Lester....	Dr	168	6	P	Kt	Cy,E	S	L	...	85	9- 8-47	A
-1bcd	John Mercer........	Dr	26.0	5	P	G	Cy,H	N	Tca	+.8	8	9- 5-47	
-1ccc	Clark Gapen........	Du	12	8	P	G	Cy,H	D	L	...	7-8	9- 8-47	A
-1daa1	....	Du	14.0	48	C	G	N	N	Tcu	+3.0	9.86	9-17-47	A
-1daa2	H. A. Deveraux.....	Dr	30	5	P	G	J,E	D	L	...	10	9-17-47	A

Table 7.--Records of wells in Paintrock irrigation project, Wyo.--Continued

Well number	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Water-bearing material	Method of lift and type of power	Use of water	Measuring point		Depth to water level below measuring point (feet)	Date of measurement	Remarks
									Description	Distance above (+) or below (-) land surface (feet)			
49-90-1daa3	R. J. Spratt.......	Dr	37	8	P	G	J,E	D	L	...	15	9-17-47	A
-3aaa	Ralph Mercer.......	Dr	40	5	P	Jm	J,E	S	L	...	19	9- 5-47	Ca
-3aba	Stella Mercer......	Dr	45.0	4	P	...	Cy,H	N	Tca	+2.0	a 19.22	9- 5-47	
-3aba	.....do............	..	....	6	..	...	......	...	...	...	b 27.72	9- 5-47	
-9cbc	John Weintz........	Dr	47.0	5	P	...	J,E	S	Tca	-6.5	1.50	9- 5-47	A
-9ccb	.....do............	DD	10	24	C	G	Cy,E	D	L	...	6	9- 5-47	A
-17acc	W. Paumer..........	Dr	27	4	P	Kf	J,E	S	L	...	10	9-23-47	A
-18ddb	Bata Ranch.........	Dr	1,800	6	P	Cm	F	I	Tca	+8.0	.....	9- 5-47	F50,Ca,Ot
-19cba	....	Dr	7.5	$1\frac{1}{4}$	P	...	P,H	N	Tp	+6.4	12.53	9-12-47	
-20cc	....	Dr	2,800	6	P	Cm	F	S	Tca	+3.0	11.95	11-21-47	F30,Ot
49-91-3cbb	Mrs. Susie Ackerman	Dr	46.0	8	P	...	Cy,H	D	Tca	+1.0	8.90	9- 4-47	A
-3dcb	G. A. Ilg..........	Dr	25	5	P	...	Cy,H	N	L	...	8	9- 4-47	
-4abd	Richard Rudland....	Du	8.0	24	C	...	Cy,H	N	Tca	+1.0	7.78	9- 8-47	
-4cc	Harry Taylor.......	Dr	....	5	P	...	Cy,H	D	Tca	+.6	8.82	9- 4-47	A
-4dbb	S. D. Mayer........	Dr	65	5	P	...	Cy,E	D,S	L	...	60	9- 5-47	I
-4dcb	.....do............	Dr	34.5	6	P	Kc	N	N	Tca	+.5	27.95	9- 5-47	
-12dba	....	Dr	2,000	6	P	Cm	F	N	Tca	+2.0	.....	....	Ot
-14adc	W. I. Kederly......	Dr	1,500	10	P	...	N	N	Tca	+1.5	.78	9- 5-45	Ot

a Inside 4-inch casing.
b Between 4-inch and 6-inch casings.

-23aa	Mrs. Elda Graves...	Dr	40	8	P	...	Cy,E	D,S	L	...	14	9- 5-47	A
-23aab	W. I. Kederly......	Dr	38	4	P	...	Cy,E	D,S	Tca	+.8	20.50	9- 8-47	A
50-89-26cac	Sam C. Hyatte......	Dr	16.5	6	P	Cpt	Cy,E	D	Tca	-3.0	5.05	9- 5-47	A,Ca
-27cdc	Lloyd Rannells.....	Dr	40	5	P	...	J	D	L	...	12	9-16-47	A
-28cbc	Sam C. Hyatte......	Dr	25	6	P	...	J	D	L	...	6	9- 8-47	A
-29dd	John Greer.........	Dr	40	5	P	...	J	D	L	...	9	9- 8-47	A
-32bc	E. J. Bolton.......	Du	12	54	C	...	P	D	...	+.4	5.40	9- 8-47	A
50-91-31cba	Frank E. Tharp.....	Dr	39.5	8	P	...	Cy,H	D	Tca	+.6	7.85	9- 4-47	A
50-92-30cad	William N. Smith...	Dr	48	8	P	Tfu	Cy,H	D	L	...	10	9-15-47	I
-30cac1	....	Du	11.5	8	T	...	Cy,H	D	Tca	+.5	9.21	9-15-47	
-30cac2	Vernon Sykes.......	Dr	62	6	P	Tfu	Cy,H	D	Tca	+.5	15.70	9-15-47	A
-30cdc1	Town of Manderson..	Dr	35.5	6	P	Tfu	Cy,H	D	Tca	+.2	11.40	9-15-47	A
-30cdc2	.....do............	Dr	55.5	6	P	Tfu	Cy,H	D	Tca	+.4	7.63	9-15-47	A
-31bba1	Manderson Hotel....	Dr	47.7	5	P	Tfu	Cy,H	D	Tca	+1.0	10.02	9-12-47	I
-31bba2	.....do............	Dr	104	5	P	Tfu	J,E	D	L	...	8	9-12-47	A,Ca
-32bbd	Helen Brome........	Dr	31.0	8	P	...	Cy,H	N	Tca	+1.0	6.44	9- 3-47	
-33abd	Virgil Beaver......	Dr	45	10	P	...	Cy,H	D	L	...	5	9- 3-47	A
-33bad	B. Hackney.........	Dr	30.5	5	P	...	Cy,H	D	Tca	+.7	4.70	9- 3-47	A
-34bbc	Prevo..............	Dr	45.0	5	P	...	Cy,H	N	Tca	+.8	5.32	9- 3-47	
-35aca	H. Luhring.........	Dr	76.0	5	P	Kmv	Cy,H	N	Tca	+.5	8.82	9- 4-47	Ca
-35bb1	S. Mullins.........	Dr	180	6	P	Km	Cy,H	D	Tca	+.2	9.47	9- 4-47	A
-35bbb2	.....do............	Dr	37.5	5	P	Km	Cy,G	S	Tca	+1.0	9.00	9-17-47	A
-36bda	Richard Redland....	Dr	122	4	P	Kmv	Cy,H	D	Tca	+.4	9.83	9- 4-47	A,Ca
50-93-24ddc	S. F. Sykes........	Dr	60	4	P	Tfu	Cy,E	D	L	...	9	9-16-47	A
-25ada	C. W. Mobley.......	Dr	65	5	P	Tfu	Cy,H	S	Tca	+.3	6.32	9-16-47	A