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GROUND WATER IN YELLOWSTONE AND TREASURE COUNTIES MONTANA

BY

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AND

C. S. HOWARD

Prepared in cooperation with the State Engineer; the Department of Chemistry of the Montana State College, Bozeman; and the Water Laboratory of the Montana State Board of Health

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PREFACE

By O. E. Meinzer

In the development of the eastern and central parts of the State of Montana during recent years some of the most serious problems that have been encountered have related to water supplies. Except in certain areas no attempt has been made to obtain water for irrigation, but in many localities it has been difficult to develop supplies adequate in quantity and satisfactory in mineral composition for public waterworks, railroads, and domestic, stock, and industrial uses.

In this region, even more than in most others, the ground-water conditions are controlled by the geology. The prospects of getting a satisfactory well and the depth to which it is necessary to drill in a certain town or a certain quarter section depend on the rock formation that happens to lie at the surface. As the formations do not lie horizontal but dip, here in one direction and there in another, the ground-water conditions may be radically different even on adjacent farms or in different parts of the same village.

In 1915 and 1916 a reconnaissance of the ground-water conditions in the part of Montana lying south of Yellowstone River was made by the late Arthur J. Ellis, of the United States Geological Survey. In this work the State cooperated with the Geological Survey. The chemical analyses were made in the laboratory of the Montana State College and the State Board of Health, at Bozeman, under the supervision of W. M. Cobleigh, director of the laboratory, and the records of some of the wells were collected through correspondence by A. W. Mahon, State engineer. As a result of this reconnaissance it became possible for the Geological Survey to give advice to many of the residents of this section of the State in regard to obtaining water supplies by drilling wells.

In 1917–1919 a similar but somewhat more detailed ground-water survey was made by Mr. Ellis of the region that is now covered by Musselshell and Golden Valley Counties. This work was also done in cooperation with the State. The results have been published as a water-supply paper.[1]

[1] Ellis, A. J., and Meinzer, O. E., Ground water in Musselshell and Golden Valley Counties, Mont.: U. S. Geol. Survey Water-Supply Paper 518, 1924.

In 1921 a ground-water survey of Yellowstone, Treasure, and Big Horn Counties was made by George M. Hall, of the Geological Survey. These counties lie partly in the area south of the Yellowstone which had been covered in the reconnaissance by Mr. Ellis and partly in an area north of the river which had not previously been examined with respect to ground-water conditions. The present report relates to Yellowstone and Treasure Counties; a similar water-supply paper on Big Horn County is in preparation.

In 1921 it became impracticable for Doctor Cobleigh to continue his cooperation. Therefore, the samples of water collected by Mr. Hall in the course of his field work were analyzed in the Geological Survey at Washington. The present report was prepared by Mr. Hall, except the parts relating to the quality of the water, which were written by Mr. Howard.

In 1922 and 1923 a ground-water survey of Fergus County was made by Mr. Hall, and in 1923 a similar survey of the central and southern parts of Rosebud County was made by B. Coleman Renick. Thus a considerable part of eastern and central Montana has been covered by ground-water surveys, the results of which should be of much practical value in solving the innumerable problems of water supply that will certainly arise in this region in future years. The large amount of fairly detailed work was made possible by the fact that the geology of most of the region had previously been mapped by the Geological Survey and that therefore the field work on these projects could be devoted largely to hydrologic interpretation of the stratigraphy and rock structure.

GROUND WATER IN YELLOWSTONE AND TREASURE COUNTIES, MONTANA

By George M. Hall and C. S. Howard

INTRODUCTION

Yellowstone and Treasure Counties are situated in the south-central part of Montana (fig. 1) and have a combined area of 3,571 square miles. They lie near the western edge of the Great Plains and only about 150 miles east of the Continental Divide. The region

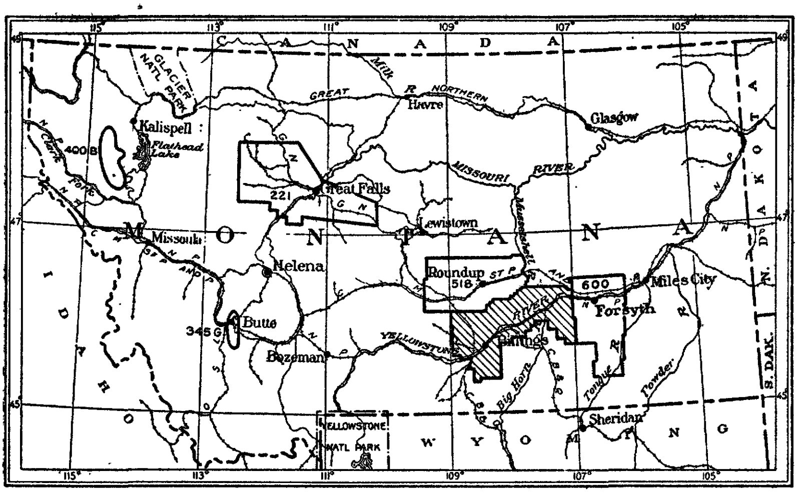

Figure 1.—Index map of Montana showing areas covered by this paper (shaded area) and other water-supply papers of the United States Geological Survey relating to ground water

is higher and more rugged than most of the remainder of the Great Plains province. The Yellowstone River flows northeastward across the two counties in a valley that ranges in width from a few hundred yards to 10 or 12 miles. Practically all the land in the valley is under irrigation, a part of it in the Huntley project of the United States Bureau of Reclamation and the remainder in private projects. The irrigated land produces large quantities of alfalfa and sugar beets as well as a variety of other products. The Northern Pacific

Railway follows Yellowstone River, and the principal towns in the area are along its line. Some of these river towns, such as Billings and Huntley, were started before the days of the railroad. Huntley was considered the normal head of navigation for the old flat-bottom, stern-wheel steamers, although in years of unusually high water Coulson, the prerailroad Billings, was reached.

There are several railroads in the area in addition to the main line of the Northern Pacific. A line of the Great Northern Railway runs north from Mossmain to Great Falls, and several prosperous towns have sprung up along it. A line of the Chicago, Burlington & Quincy Railroad running north from Sheridan, Wyo., joins the Northern Pacific just east of Huntley. A branch line of the Northern Pacific, originally called the Billings & Central Montana, runs from Billings to Shepherd. This line was projected to tap the Bull Mountain coal fields but has not yet been extended that far. It is useful in serving a large beet-growing district.

All parts of these two counties are accessible by automobile during the summer. The Yellowstone Trail, the Buffalo Trail, and the Custer Battlefield Highway all cross these counties and are used by many tourists. The roads in both counties are well graded except in the more thinly inhabited areas, such as the Bull Mountains and parts of the Crow Indian Reservation, where there has been little or no highway construction. Heavy rains make the dirt roads impassable for a few days, but the graveled roads are passable at all times during the summer. Many of the roads are impassable for automobile traffic in winter, but regular auto stages are maintained from Billings to Roundup and Winnett throughout the year except during the severest part of the winter.

The population of Yellowstone and Treasure Counties, according to the census of 1920, is 29,600 and 1,990, respectively. The largest towns are Billings (15,100) and Laurel (2,239). Most of the people live in the Yellowstone River Valley, though there is a considerable population on dry farms. The principal industries are farming and stock raising. The most important manufacturing industry is the making of beet sugar. In years gone by cattle and sheep raising were the major industries, but in recent years, with the fencing and "dry farming" of the upland grazing areas and irrigation in the valleys, farming has taken the lead. The reduction of the public grazing land due to homesteading led to a decline in stock raising.

The Northern Pacific Railway was granted by Congress the odd-numbered sections on both sides of its right of way for a distance of 40 miles. In some places the company has sold its rights to the surface but retained the mineral rights.

The following publications of the United States Geological Survey give reliable information on the areas covered by them:

Bulletin 647. The Bull Mountain coal field, Musselshell and Yellowstone Counties, Mont., by L. H. Woolsey, R. W. Richards, and C. T. Lupton; compiled and edited by E. R. Lloyd.

Bulletin 691–D. Geology and oil and gas prospects of the Lake Basin field, Mont., by E. T. Hancock.

Bulletin 711–G. Geology and oil and gas prospects of the Huntley field, Mont., by E. T. Hancock.

Bulletin 749. Geology of the Tullock Creek coal field, Rosebud and Big Horn Counties, Mont., by G. S. Rogers and Wallace Lee.

These publications have been drawn upon liberally, but it has not been practicable to give references in all places where they have been used.

The senior author wishes to express his appreciation of the kindness and consideration with which he was received and assisted by the citizens of Yellowstone and Treasure Counties. Everyone with whom he came into contact was ever ready to aid and assist in this work. Unfortunately, space does not permit the mention of their names.

DRAINAGE

All parts of Yellowstone and Treasure Counties are drained by Yellowstone River and its numerous tributaries. The Yellowstone flows northeastward across the counties in a rather steep-walled valley. The stream ranges in width from a few hundred feet to more than half a mile, the width depending not only on the cross section of the stream bed, but on the stage of the river. The river always carries a large volume of water and often rises rapidly, producing destructive floods in the lowland. The maximum flow at Huntley between 1907 and 1916 was 58,100 second-feet, the minimum 1,065 second-feet. The water is generally clear in summer and autumn, but occasional thundershowers send large quantities of silt into the stream, which makes the water very muddy for several days. In spring, during the melting of the snow on the mountains, the river is high and muddy for weeks at a time. Clark Fork, rising in the Beartooth Mountains, Pryor Creek, rising in the Pryor Mountains, and Big Horn River, rising in the Big Horn Mountains in Wyoming, are the perennial tributaries of the Yellowstone. Tullock Creek, which empties into the Big Horn only a few miles from the Yellowstone, carried a small volume of water during the summer of 1921. Sarpy Creek, a tributary of the Yellowstone, also flowed throughout the summer of 1921, an unusually dry season. All other streams in either county are more or less intermittent. These intermittent streams have cut steep valleys, however, and after rainstorms they may carry large volumes of water and silt to the Yellowstone.

PHYSIOGRAPHY

SITUATION AND SUBDIVISIONS

Yellowstone and Treasure Counties are near the western edge of the Great Plains province and are underlain by sedimentary rocks, chiefly sandstone and shale. The topography is the result of erosion subsequent to the folding and faulting of these rocks. There are no mountains in these counties except the rough, rugged hills called the Bull Mountains.

The total relief is about 2,100 feet, Sanders, on the Yellowstone at the eastern edge of Treasure County, being about 2,600 feet above sea level, and Eldridge Mesa about 4,700 feet, but the higher point is reached by relatively easy stages, so that there are practically no sections in which the total relief is more than 500 or 600 feet except in the heart of the Bull Mountains. Although the region is part of the Great Plains, it is not monotonously flat but is rolling and much dissected.

These counties can be subdivided into the Bull Mountain upland, the plains, the Yellowstone River valley, the terraces, and the zone of faulting.

BULL MOUNTAIN UPLAND

The Bull Mountains occupy parts of Musselshell, Yellowstone, and Treasure Counties and cover an area of about 1,200 square miles, mostly in Musselshell County. When compared with the Pryor, Big Horn, Beartooth, Crazy, and Big Snowy Mountains, the Bull Mountains are little more than low rugged hills, but their topography is distinct from that of the surrounding plains. Owing to their roughness and the difficulty of travel through them they were early called mountains rather than hills. Their maximum altitude is 4,700 feet above sea level, and their maximum relief is less than 2,000 feet. Their topography is the result of deep erosion in a semiarid climate acting on almost horizontal strata of sandstone and shale with some coal beds. The mountains consist chiefly of mesas and uplands preserved by the more resistant strata, from which the overlying softer beds have been removed. These uplands are not continuous but are interrupted by steep-walled valleys where the streams have cut through the resistant sandstone to soft shale and coal. Erosion of such alternating hard and soft beds in a semiarid region where there are occasional storms of great violence with heavy rainfall followed by considerable periods of slight precipitation usually produces a series of levels with intervening steep rises. Two such levels have been strongly developed in this region; the upper one forms the tops of the high mesas, and the lower one forms the divide between Musselshell and Yellowstone Rivers and most of the level upland in the mountains.

The high Bull Mountain mesas, ranging from 4,500 to 4,700 feet above sea level, are remnants of a more extensive plain whose preservation is due to their position in the center of a large syncline and to the burning of the upper coal beds, which has baked and indurated the overlying sandstone and shale, making them very resistant to erosion. The burning has changed the color of the rocks from blue, gray, and brown to red. Subsequent to the deposition of the Fort Union formation, the youngest formation present in the Bull Mountains, the rocks were folded, and at the same time or subsequently the region was elevated. The Fort Union formation has been eroded completely from the surrounding region and partly from this area. However, in this syncline the hard sandstone and the strata hardened by the burning of the underlying coal beds of the Fort Union were preserved and now stand higher than the beds in the region surrounding the Bull Mountains because the softer shale formations in the surrounding region rapidly succumbed to erosion when the more resistant, sandy Lance and Fort Union formations were removed. In some places the burning of the coal beds has resulted in fusion of the rocks, producing what is known locally as "slag," "clinker," or "lava." The red beds thus produced contrast strikingly with the more somber blue, gray, and brown unburnt rocks and are visible for miles, the red capped and banded mesas forming prominent landmarks. Taylor Mesa, Three Buttes Mesa, Bridges Butte, and the Eldridge Mesas are the chief remnants of the higher level. The largest Eldridge Mesa covers about 4 miles from north to south and 3 miles from east to west and is partly in Yellowstone County. The rest of this mesa and the other three mentioned are in Musselshell County. A few smaller and less conspicuous outliers reach this general level. These mesas lie in the highest, most rugged part of the region and are separated by steep-walled, narrow pine-covered valleys.

The lower surface, which forms the general level of the Bull Mountains, surrounds the high mesas and extends along the divide between the Yellowstone and the Musselshell. Part of this lower level can be seen in Plate 1, *A*. The streams on both the north and the south are eroding this level, but in general it is a broad plain sloping gently to the northeast, its altitude ranging from 4,200 feet in the southwestern part of the Bull Mountain coal field to 3,500 feet in the northeastern part. Near the divide the valleys are narrow and steep-walled, but farther out they widen, though retaining their steep walls. Between the streams the long, flat-topped ridges extend for miles and preserve this lower level. Many of these long, narrow uplands are dissected by coulees to such an extent that they are almost isolated. Because of the steep walls it is impossible to cross many of the coulees between these flat uplands, so that it is necessary to travel several miles around their heads. The steep walls separating the broad valleys from the uplands are called locally "rim rocks." A close view of one of these walls is given in Plate 1, *B*.

This province contains much valuable coal, some timber, and excellent grazing land. The coal crops out in many ravines and is much used by the homesteaders. There has been considerable prospecting in the past, and numerous seams of coal, many of commercial value, have been found. Large mines have been opened in Musselshell County at Roundup and Klein; but in Yellowstone County, on the south side of the mountains, the distance from the Northern Pacific Railway along the Yellowstone and the ease with which coal could be obtained from the Red Lodge and Bear Creek fields have retarded development. The timber is best suited for rough lumber and mine props. The trees grow chiefly on the steep hills, the level uplands being practically treeless. The pine is very useful to inhabitants of the surrounding plains but is most valuable in mining for timbering. The Bull Mountains afford excellent grazing, both the uplands and the valley having a heavy growth of grass, and the woods and "rim rocks" furnish adequate protection against the weather. However, the region has been homesteaded and all land sufficiently level for cultivation has been taken up, so that the range is reduced and water holes are fenced off. Dry farming has not been entirely successful, and many homesteads are now abandoned.

PLAINS

The plains constitute the largest part of the area here described. They are not entirely flat but are rolling and more or less dissected. The relief is moderate, rarely exceeding a few hundred feet between a stream bed and the adjacent hilltops. The rocks that crop out consist almost exclusively of shale and sandstone. The beds have been gently folded. The present topography is dependent largely upon the underlying rock, the shale weathering and eroding rapidly, whereas the sandstone is more resistant. The shale, where in thick beds, gives rise to broad, gently rolling flats which are separated by sandstone "rim rocks" and rough broken ridges. Where the sandstone is less resistant to weathering it gives rise to steep slopes. In the areas where shale alternates with resistant sandstone the country is more rugged and shows numerous steep slopes covered with scrub pine.

The streams have cut deep coulees in both the shale and the sandstone. Most of those in the shale are broader than those in the sandstone, but many of the streams flow in steep-walled troughs cut in shale. The region is semiarid, rains are infrequent, and most of the streams are intermittent, but occasionally terrific downpours rapidly erode the softer beds and cut boxlike troughs in the larger coulees. These deep coulees, whether their walls are shale or sandstone, are serious obstacles to vehicular traffic unless bridged. Before the land was fenced all trails took winding courses, avoiding the steep banks; but now most roads follow the section lines, and bridges and culverts have been installed.

YELLOWSTONE RIVER VALLEY

Yellowstone River crosses these counties in a general southwesterly direction. Its valley ranges in width, in this area, from a few hundred yards to about 12 miles and in depth below the upland plain from 100 to 500 feet, according to the kind of rock that underlies the plain. From the western boundary of Yellowstone County to the Eagle sandstone rim just east of Billings the river flows over the Colorado shale in a broad valley. On the north side there is a striking "rim rock" of brownish-gray Eagle sandstone more than 100 feet high; on the south the bare hills of Colorado shale rise abruptly almost from the bank of the river. Just east of Billings the river crosses the Eagle sandstone, which forms a high scarp both north and south of it. The valley is here less than half a mile wide, and on the south side there is but little room for the railroad. Immediately to the northeast the valley widens as the river flows across the Claggett and Judith River formations and the Bearpaw shale. At the village of Pompeys Pillar the valley once more narrows, and in the Bull Mountains it is bordered by the sandstone hills of the Lance formation. The stream flows over the Lance to Myers, where the valley broadens, and thence it flows over the Bearpaw shale to the eastern boundary of Treasure County.

This valley has numerous tributary valleys, a few with perennial streams and many with intermittent streams. The larger number come in from the south. These valleys are usually narrower than the main valley but are like it in that their width and depth are controlled by the kind of rock underlying the upland plain. Except those of the Big Horn and the Clark Fork, the tributary valleys are generally small and do not contain any farming lands, although the valleys of Pryor, Tullock, and Sarpy Creeks are of sufficient width for some farming. Along these valleys are innumerable side coulees which dissect the region and increase the difficulties of communication. Most of these coulees are too narrow for cultivation, and during severe storms they carry enormous quantities of water.

TERRACES

Large areas in Yellowstone and Treasure Counties are covered with gravel which ranges from cobblestones 6 inches in greatest dimension to small pebbles and in places to fine sand. Such gravel is found at various altitudes from the present stream bottoms to the highest points in these counties other than the Bull Mountains. Except the terraces along the river margin, none of the country north of Yellowstone River in either county is covered with gravel. The terraces are most conspicuous along Yellowstone River and are locally known as "benches." The term "bench" is also used by some inhabitants for level areas due to the removal of softer material above a harder and more resistant, almost horizontal bed. The gravelly benches or terraces, however, bevel the tilted shale and sandstone independent of their character. The depth of gravel cover ranges from a few inches to more than 50 feet but is usually less than 25 feet. Many of the higher terraces or "benches" are so much dissected that they are well drained and contain but little ground water. The lower terraces are less dissected and in general yield considerable amounts of water, which, however, is not always suitable for domestic purposes.

Were the observations confined to these counties, the lower terraces along the Yellowstone might perhaps be explained as the result of periods of temporary adjustment to the variable hardness of the underlying rocks, but a study of these terraces in connection with those along the Missouri and its other tributaries [2] makes it clear that the cause is regional and not local.

The highest points covered with gravel in these two counties are Pine Ridge, southwest of Custer, and the highest hills south and southeast of Huntley. In places, as in sec. 34, T. 1 N., R. 28 E., the gravel is cemented into a heavy conglomerate in which the pebbles consist of light and dark chert, quartzite, vein quartz, and many kinds of igneous rocks in a matrix of sand. The top of Pine Ridge is about 1,100 feet above Yellowstone River and 4,000 feet above sea level, and the tops of the hills southeast of Huntley are 1,000 feet or more above the river and over 4,000 feet above sea level.

These high-level gravel deposits cover a relatively small area and, although interesting, are of slight importance in connection with the subject of this paper, because they are rather thoroughly dissected and consequently hold little water.

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[2] Alden, W. C., Physiographic development of the northern Great Plains: Geol. Soc. America Bull., vol. 35, pp. 385–424, 1924.

These high-level deposits have been tentatively correlated by Alden with the gravel of the Cypress Hills. The Cypress Hills Plateau lies north of Havre, about 40 to 50 miles north of the international boundary, and is the highest feature in that part of the Great Plains, forming part of the Continental Divide. The plateau where not cut by erosion is very flat, sloping eastward at the rate of 14 to 15 feet to the mile, and is capped with a thick deposit of largely coarse, waterworn gravel, resting unconformably upon shale and sandstone of the Fort Union and Lance formations. Careful search by McConnell[3] and Lambe[4] has revealed the presence of vertebrate remains in the eastern part, which were referred by Cope[5] to the Oligocene. The gravel on the highest land south of Yellowstone River has not yielded any fossils, but because of its altitude and its height above the river it has been thought to be as old as Oligocene or Miocene. The pebbles are waterworn and rounded, with smooth and even polished surfaces, and show no evidence of transportation by ice. The predominance of quartzite and igneous rock in the pebbles and the absence of pebbles from the underlying rocks indicate a distant source, probably the Rocky Mountains or the Big Horn Mountains. Alden finds that the slope of these remnants projected southward and westward with a normal increase in gradient would strike high upon the flanks of the present mountains. The gravel was probably distributed by rivers that formed broad, gently sloping, coalescing alluvial fans near the mountain fronts, but farther away these fans narrowed to broad valley plains bordering the main streams when they were flowing where now are the tops of the hills.

Still more conspicuous than this highest terrace are several lower terraces along the river. Three sets of such terraces can be distinguished and have been designated Nos. 1, 2, and 3, from oldest to youngest, or from highest to lowest. They show that the region has undergone planation and uplift, the terraces having been cut during periods of quiescence between periods of relatively rapid uplift. In these two counties Nos. 1 and 2 are well developed but there is not a third terrace distinct from the river-bottom lands. Along the Yellowstone, in addition to the three main terraces, there are several sec-

[3] McConnell, R. G., On the Cypress Hills, Wood Mountain, and adjacent country: Canada Geol. Survey Ann. Rept., new ser., vol. 1, pp. 1c–78c, 1886.

[4] Lambe, L. M., A new species of *Hyracodon* (*H. priscidens*) from the Oligocene of the Cypress Hills, Assiniboia: Canada Roy. Soc. Proc. and Trans., 2d ser., vol. 11, sec. 4, pp. 37–42, 1906; Fossil horses of the Oligocene of the Cypress Hills: Idem, pp. 43–52; Vertebrata of the Oligocene of the Cypress Hills, Saskatchewan: Canada Geol. Survey Contr. Paleontology, vol. 3, pt. 4, 1908.

[5] Cope, E. D., The Vertebrata of the Swift Current Creek region of the Cypress Hills: Canada Geol. Survey Ann. Rept., new ser., vol. 1, pp. 79c–85c; The species from the Oligocene or lower Miocene beds of the Cypress Hills: Canada Geol. Survey Contr. Canadian Paleontology, 1891.

ondary or intermediate benches, which further complicate the problems of correlation.

Remnants of the highest and oldest of these three terraces, No. 1, are preserved south of Yellowstone River at a level about 600 to 700 feet above the river. These tracts are covered to a depth of 25 to 50 feet with gravel and more or less sand. This terrace was evidently once extensive but has been dissected by erosion. Unfortunately, diligent search for fossils on it has not yielded any results, and it can be correlated only on topographic position. This bench or terrace has been correlated by Alden with the Flaxville plain, north of Missouri River, in northeastern Montana,[6] described by Collier and Thom. Fossils found in that region were identified by J. W. Gidley as probably not older than Miocene or younger than Pliocene, with the exception of one fossil that may be Pleistocene. Because of the presence of the later fossils and of the occurrence of very old glacial drift on what appear to be remnants of the Flaxville plain in the Glacier Park region, Alden is inclined to the belief that the Flaxville plain was completed in late Tertiary time and is not older than Pliocene.

The next lower bench, No. 2, is well developed both north and south of the river. However, this terrace is really a double one, and where only one level is found, it is not always easy to tell which one is preserved. The interval between the two levels averages about 100 feet. In other words, during the cutting of No. 2 terrace there was a slight uplift or some other change affecting stream gradients. The lower level, 125 feet above Yellowstone River, is well shown in the bench northeast of Billings frequently called the "Billings Bench." The underlying rock is chiefly Bearpaw shale, on which is about 20 or 25 feet of sand and gravel.

In these counties the river has not developed No. 3 bench as a distinct terrace and then cut below it, possibly because of the retardation due to cutting through the Eagle, Judith River, and Lance sandstones, which are bowed up on the flank of the Big Horn anticline.

These terraces are shown in Figure 2.

LAKE BASINS[7]

The lake basins are without doubt among the most interesting physiographic features of south-central Montana. They are undrained or imperfectly drained depressions containing permanent or temporary lakes of variable size surrounded by stream and lake deposits of sand, clay, and gravel spread indiscriminately over eroded

[6] Collier, A. J., and Thom, W. T., jr., The Flaxville gravel and its relation to other terrace gravels of the northern Great Plains: U. S. Geol. Survey Prof. Paper 108, pp. 179–184, 1917.

[7] Part of this section is adapted from an unpublished paper by A. J. Ellis, entitled "Quaternary Lakes in Central Montana."

surfaces of older rocks. The Comanche Flat is the only one lying entirely within Yellowstone County. In the northwestern part of T. 4 N., R. 25 E., is a small portion of such a basin. Most of these

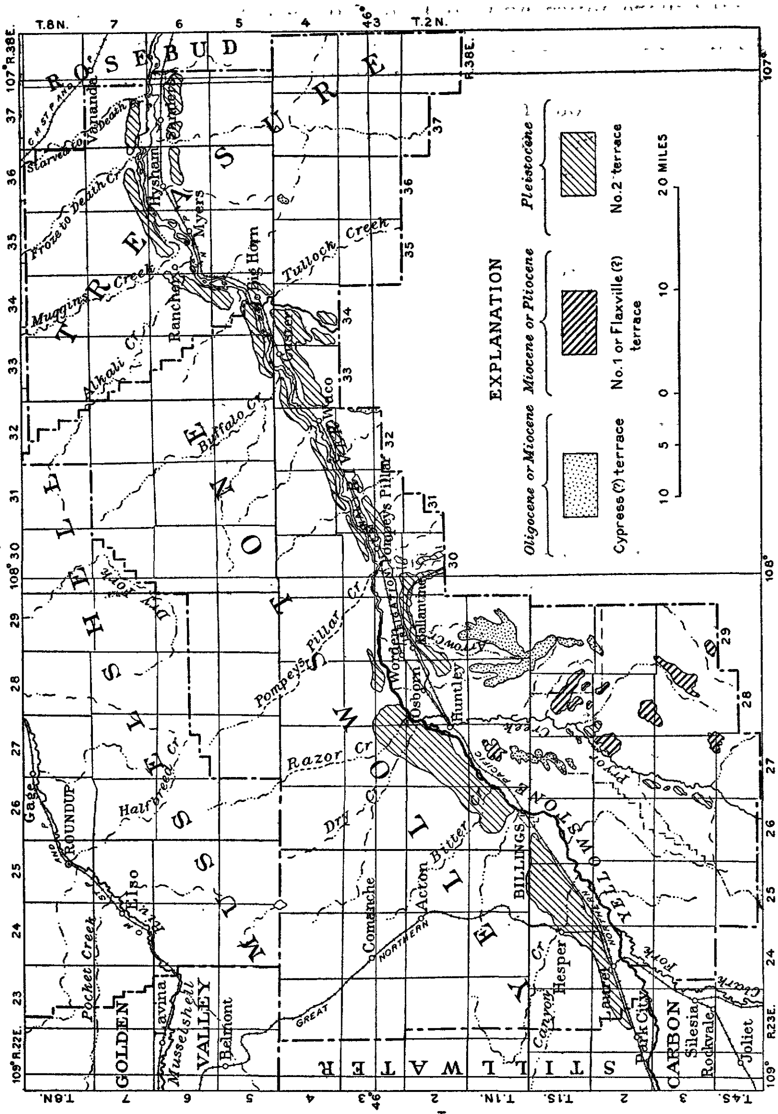

FIGURE 2.—Map showing present extent of terraces in Yellowstone and Treasure Counties

basins are nearly 50 miles from the nearest areas of mountain glaciation and 100 miles from the nearest region showing any traces of continental glaciation and are evidently not glacial features. They occur on rocks of various ages, both shale and sandstone, though the basins on shale are the most extensive, as might be expected because of the more impervious character of that rock.

The largest lake basin in south-central Montana is Comanche Flat, which is crossed by the Great Northern Railway. It covers about 60 square miles and contains no permanent body of water, though in some seasons considerable water stands in various places on the flat. From all sides short intermittent and perennial streams flow into the basin but fail to reach a master stream. The water is apparently discharged more by evaporation than by outflow. The area is covered by a mantle of lake and stream deposits ranging in thickness from a few feet near the edges to 75 feet or more toward the middle. The northern part of the basin is underlain by the Lance formation, and the rest by the Bearpaw shale. The course of Fivemile Creek before the formation of the lake deposits may have been along the south side of the basin. The small streams along the northern border probably belonged to a branch that drained the present basin, as is suggested by four confluent creeks. Without much difficulty a former drainage system may be imagined which would link up all the short streams with Fivemile Creek. Careful search has failed to reveal any shore-line phenomena, and therefore it is inferred that there has never been a permanent deep lake occupying the entire basin.

Scattered over the flat are numerous small lakes, which vary in degree of permanence. Some do not have any water in them for years, others contain water only for a few months in each year, and others go dry only after very long droughts. Some of them are obviously the result of wind work, small mounds or ridges, which are really small dunes, occurring on the northeast sides of the depressions, where they have been piled up by the prevailingly southwesterly winds. The alluvium has been scoured by the wind deflation and piled up in part on the leeward side. A dune or ridge of this type is shown in Plate 6, *A* and *B*. The fact that the deflation is still active might suggest the possibility that wind has formed the depression, but evidence is lacking. Careful search revealed no dunes or accumulations of wind-blown material on the uplands around the basin.

As shown on Plate 7, a belt of short faults is almost coincident with Fivemile Creek from its head to its mouth. These faults were believed by Ellis to have been formed in relatively recent time and to be largely the cause of both Comanche Flat and Lake Basin by interrupting the fall of the creek and blocking the stream course. He held that since the period of faulting Fivemile Creek has not yet been able to recapture the territory of which it was deprived by those movements. This explanation appears to be plausible, but there is no clear evidence that the movements along these faults have occurred recently, in a geologic sense. The faults are of post-Lance age, as rocks of Lance age are faulted, but there is nothing to show that movement has occurred since the end of the Pliocene epoch.

After Oligocene time there were several regional uplifts, which are clearly shown by the terraces along the streams. Comanche Flat is about 650 feet above Yellowstone River at Billings, or about at the level of the No. 1 terrace just east of that city. At the time Yellowstone River was flowing on the No. 1 terrace Fivemile Creek was a tributary of low gradient widening its valley by lateral planation, much more effectively where it flowed over the Bearpaw shale than where it flowed over the much harder Judith River formation and Eagle sandstone. The parts of the valley underlain by the Bearpaw were therefore much wider than those underlain by harder rocks. During this stage of valley widening the stream may have taken its present position, traversing the faulted zone. With the recurring uplifts Yellowstone River cut downward much more rapidly than Fivemile Creek, owing to its larger volume of water. During the cutting of No. 2 terrace insufficient time elapsed for the small stream to cut down through the sandstone blocks in the faulted zone and completely adjust its gradient, as it did during the cutting of No. 1 terrace.

After Pleistocene time the climate may have become more arid than before, so that Fivemile Creek, whose drainage area is entirely in a region of small precipitation, could not cut so rapidly as Yellowstone River, which derives much of its water from the mountains, where the precipitation is heavy. This explanation may account for the isolation of the broad Comanche Flat in the upper part of the valley, but it does not account for the fact that the surface of the Bearpaw shale slopes toward the center of the basin from the NW. ¼ sec. 1, T. 2 N., R. 24 E., where Fivemile Creek enters the flat. The original Bearpaw surface is covered with a mass of aluvial material, whose upper surface is almost horizontal, derived from the surrounding hills and brought in by the intermittent streams that may be former branches of Fivemile Creek. It is possible that after the cutting of the No. 1 terrace some slight movement took place along a deep-seated fault plane beneath the faulted zone and caused a slight tilting of the region and the isolation of the broad upper part of the valley. Immediately afterwards the streams began to fill the basin with alluvial material, a process that is still going on.

FAULTED ZONE

A narrow zone, in few places exceeding 6 or 7 miles in width, of numerous short faults extends through Yellowstone County, entering on the west side in the southwest corner of T. 3 N., R. 23 E., crossing Yellowstone River in the vicinity of Huntley and passing the eastern boundary into Big Horn County near the Montana base line. This faulted zone, so conspicuous in Yellowstone County, is but a part of the long belt that extends S. 70° E. for approximately 100 miles from the western part of Stillwater County and dies out in the eastern part of Big Horn County. The faults in general cross the zone at an angle of 45° to the general trend of the belt, but some of the faults deviate considerably from the average. Very few faults exceed 5 miles in length, and only one exceeds 7 miles. The displacement is small, usually less than 500 feet, although on some faults it is almost a thousand feet, as at Rattlesnake Butte. The faults shown on Plate 7 are only the larger ones, as many more have been detected in the field and could be plotted on larger-scale maps, but they are mostly short and of small displacement. Hancock[8] gives detailed descriptions of many of these faults. The faults are chiefly normal, although careful search discloses some reverse or thrust faults, one of which is shown in Plate 5, *B*. Usually the trace of a fault is a straight line, but many are curved, and a few appear to branch, though apparently none of them cross. A very noticeable feature of the faults between Acton and Rattlesnake Butte is the sagging down of the beds on the northwest side of the fault plane, whereas those on the opposite side are arched up or tilted to the east, and some blocks have been slightly rotated as well as moved vertically.

The zone or belt of faulting is conspicuous for its buttes, sandstone scarps, and irregular-shaped hills. The faulting has produced unusual successions of beds and abnormal contacts, with frequent changes of beds exposed at the surface. In some places Lance sandstones are in contact with those of Judith River age, which means that one walking across the fault trace fails to find the Bearpaw shale, which is normally present. On many faults changes in direction and amount of dip are most noticeable. The faulting has disturbed the normal circulation of ground waters in the underlying strata, making it difficult to predict depths at which water may be struck in drilling. A few springs are found in this zone, but they are not very large. The faults are not marked by lines of springs such as occur in many faulted regions.

Several explanations are given for the origin of this unusual narrow zone of transverse faults. Chamberlin[9] compares the phenomena to glacier flow and torsion and comes to the conclusion that the zone of faulting is attributable to the eastward movement of the southern position of the region relative to the northern, together with local torsion and incidental tension developed by the doming process.

[8] Hancock, E. T., Geology and oil and gas prospects of the Lake Basin field, Mont.: U. S. Geol. Survey Bull. 691, pp. 101–147, 1918.

[9] Chamberlin, R. T., A peculiar belt of oblique faulting: Jour. Geology, vol. 27, pp. 602–613, 1919.

Thom[10] accepts this explanation and suggests the presence of a deep-seated fault beneath the zone of faulting.

QUALITY OF WATER

During the course of the field work samples of ground water were collected from 97 sources in these counties and were analyzed in the Geological Survey in Washington. A few analyses made by Dr. W. M. Cobleigh, of the Department of Chemistry, Montana Agricultural College, and an analysis taken from Water-Supply Paper 274 representing water from Yellowstone River near Billings are included in this report. Analyses were made in the Geological Survey by the usual methods of water analysis, and the results are reported in parts per million. The constituents determined were total dissolved solids at 180° C., silica (SiO_2), iron (Fe), calcium (Ca), magnesium (Mg), sodium plus potassium (Na+K), carbonate (CO_3), bicarbonate (HCO_3), sulphate (SO_4), chloride (Cl), and nitrate (NO_3). Total hardness was calculated as calcium carbonate by use of the formula T. H.=2.5 Ca+4.1 Mg, in which T. H., Ca, and Mg represent parts per million of total hardness, calcium, and magnesium, respectively.

The quality of ground waters in Yellowstone and Treasure Counties is shown by the analyses given in the table on pages 18 to 27. The mineral constituents reported in these analyses affect the value of waters for domestic and industrial uses and for irrigation. These constituents do not give much indication of the sanitary quality of waters, which depends upon their freedom from pollution by disease-producing organisms. The sanitary quality of the water is likely to change much more quickly than the mineral character, so that statements in regard to the sanitary character of a water at a given time may be altogether inapplicable a few weeks later. Several of the waters analyzed contained so much mineral matter as to be unsatisfactory for drinking, and others were so highly mineralized as to be unfit for practically all purposes.

The analyses were grouped according to the source of the waters represented in order to compare the chemical character of waters from the same formation. The results are discussed in the descriptions of the geologic formations. The conclusions are general and indicate only the probable quality of the water to be found in the formations considered.

The usefulness of a water for any purpose depends on the amount and nature of the dissolved materials. Waters having more than 2,500 parts per million of dissolved solids are not satisfactory for domestic purposes. Waters containing chiefly sulphate, magnesium, and sodium or chloride and sodium may be objectionable for drink-

[10] Thom, W. T., jr., The relation of the deep-seated faults to the surface structural features of central Montana: Am. Assoc. Petroleum Geologists Bull., vol. 7, pp. 1–13, 1923.

ing if the mineral content is greater than 1,500 parts per million. Many waters that are objectionable to human beings because of their mineral content can be used for watering stock, but waters containing more than 10,000 parts per million of dissolved solids are not satisfactory even for stock and may have a harmful effect. The extent of the damage caused by waters used for irrigation depends upon the drainage and nature of the soil as well as on the chemical character of the waters. The more soluble salts (the alkalies) cause the most damage.

Silica (SiO_2) is an important constituent of sand and rocks, but in natural waters it is usually present in quantities less than 30 parts per million. Silica is one of the constituents that contribute to the formation of scale in boilers but is of little significance in other ordinary uses of water.

Iron (Fe) is dissolved from most rocks and to some extent from water pipes. Quantities of iron greater than 1 part per million usually precipitate when the water is exposed to the air. Several of the samples of water from Yellowstone and Treasure Counties contained a precipitate of iron when analyzed, although they were clear when collected. In these samples the quantities of iron precipitated and in solution were determined and the total quantity reported. Most of the waters analyzed contained less than 0.5 part per million of iron. Waters with large quantities of iron are objectionable because of the stains they make on clothes, enamel, and porcelain ware.

Calcium and magnesium are somewhat alike in chemical properties and when dissolved in water have similar effects on the quality. Calcium (Ca) is dissolved mainly from limestone, dolomite, and gypsum. In this area gypsum is probably the principal source of calcium. Magnesium (Mg) is dissolved mainly from dolomite, although some may come from deposits of magnesium sulphate. Calcium and magnesium cause hardness and contribute to the formation of scale in boilers. In natural waters the quantity of calcium is usually greater than the quantity of magnesium, but in some of the waters analyzed for this report magnesium is greater than calcium. More than one-half of the waters analyzed were so hard (calcium greater than 50 parts per million) as to make softening well worth while for laundries on account of the saving in soap. Some of the waters analyzed are objectionable for drinking because of the large quantities of magnesium sulphate (Epsom salt) that they contain.

Sodium and potassium (Na+K), the alkalies, are dissolved from practically all rocks, and their salts occur in considerable quantities in the formations in this area. These elements have similar chemical and physical properties and are usually determined together in water analyses. The quantity of potassium is usually small in proportion to the sodium. In most of the waters analyzed for this report the alkalies are greater than 200 parts per million. Large quantities of salts of the alkalies are detrimental to crops, and waters having more than 400 parts per million of alkalies when used for irrigation may on evaporation deposit sufficient salts to affect the productivity of the soil.

Carbonate and bicarbonate (CO_3 and HCO_3) result from solution of carbonates by waters containing dissolved carbon dioxide. Few natural waters contain carbonate.

Sulphate (SO_4) is derived from gypsum, from deposits of sodium and magnesium sulphate, and to some extent from the oxidation of sulphide ores. Sulphate is high in the ground waters of this area. Two-thirds of the waters analyzed carry more than 200 parts per million, and one-third have more than 1,000 parts per million.

Chloride (Cl) is dissolved in small quantities from most rocks. Two-thirds of the waters analyzed for this report have less than 30 parts per million.

Nitrate (NO_3) is dissolved mainly from oxidized organic material. It is usually present in small quantities in natural waters. In more than half of the waters analyzed for this report the nitrate is less than 1 part per million.

The principal source of surface water in Yellowstone County is Yellowstone River. Analyses of samples collected from this stream in 1905 are published in Water-Supply Paper 274. The total dissolved solids in weekly composites ranged from 138 to 354 parts per million and the suspended matter from 10 to 1,110 parts per million. The quantity of dissolved solids is less than in most of the ground-waters in Montana. The following table[11] gives the average of analyses of two composite samples taken over periods of about 2 months each:

Average analysis of two composite samples of Yellowstone River at Billings

	Parts per million
Calcium (Ca)	39
Magnesium (Mg)	11
Sodium and potassium (Na+K)	36
Bicarbonate radicle (HCO_3)	130
Sulphate radicle (SO_4)	89
Chloride radicle (Cl)	16
Nitrate radicle (NO_3)	.19
Total dissolved solids	278

The following table gives analyses of ground-waters, with notes on the sources of the samples. The quality of ground-water is discussed in detail under the headings "Rock formations and their water-bearing properties" (pp. 28 to 43) and "Ground-water conditions by townships" (pp. 62 to 116).

[11] U. S. Geol. Survey Water-Supply Paper 274, p. 140, 1911.

Analyses of waters collected in Yellowstone and Treasure Counties, Mont.

[Analytical results in parts per million]

No.	Location: Nearest post office	Location: Quarter	Location: Sec.	Location: T.	Location: R. E.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifer: Character of material	Aquifer: Geologic horizon	Water level above or below surface (feet)	Use of water
1[a]	Broadview	SW. ¼ NW	5	3 N.	21	Hailstone Basin Oil Co., Billings.	Drilled	3,000	15½, 6¼ in.		Cloverly formation	+8	Not used up to date of collection.
2[b]										Sandstone	Amsden formation		
3	Acton	NE	12	1 N.	23	Wm. W. Smith	Dug	33½	4 ft.		Judith River formation.	−14	Domestic.
4	Rimrock	SE	33	1 N.	23	J. A. Campbell, Hesper.	Spring			Sandstone and shale.	Near contact of Eagle sandstone and Colorado shale.	Flows	Do.
5	Comanche	SE	2	2 N.	23	Mrs. Ross Ballard, Acton.	Dug	42	3 ft.	Slate-colored hardpan.	Quaternary alluvium on Judith River formation.	−34	Stock.
6	Acton	NE	24	2 N.	23	W. P. Wall	Drilled	285–300	6 in.	Sandy layer	Judith River formation.	−30	Domestic.
7	do	SW	28	2 N.	23	C. N. Gowan	do	72	6 in.	Unknown	do		Do.
8	Broadview	NE	17	3 N.	23	C. U. Holtzclaw	Dug	16	3½ ft.	Sand	Alluvium	−12	Do.
9	Comanche	NW	28	3 N.	23	S. W. Grant	do	8	4 ft.	Blue sandstone	Judith River formation.	−3	Do.
10	Broadview	SE	12	4 N.	23	J. A. Beck	Drilled	97	6 in.	Sandstone	Lance formation	−30	Do.
11	do	NE	20	4 N.	23	Mayor and city council.	Spring			do	Judith River formation.		Public supply.
12	Laurel	SW	12	2 S.	23	F. W. Schauer	Drilled	2,285	16½, 4 in.	White sandstone	Cloverly formation	+2	Stock.
13	Acton	SW	10	1 N.	24	Joseph Wormser, Billings.	do	90	6 in.	Unknown	Claggett formation		Do.
14	do	SE	11	1 N.	24	R. W. Husband, Billings.	Dug	40	4 ft.	Sand and gravel	do	−20	Do.
15	do	NE	12	2 N.	24	A. D. Hanson	Bored	18	8 in.	Shale	Bearpaw shale	−4	Do.
16	do	NE	13	2 N.	24	Mrs. Betsy Iverson	Drilled	104	6 in.	Sandstone	Judith River formation.	−50	Do.
17	do	SE	20	2 N.	24	Not known	Spring				Contact of Judith River and Claggett formations.	Flows	Domestic.
18	do	NW	22	2 N.	24	M. J. McCarthy	Dug	10	5 ft.	Clay	Judith River formation.	−2 to −4	Stock.
19	do	NW	32	2 N.	24	Ed. Popelka	Drilled	92	6 in.	Blue rock	do	+46	Domestic.
20	Comanche	NE	12	3 N.	24	C. Watts	do	160	6 in.	Sandstone at 140 feet.	Lance formation	−100	Do.

[a] Sample from 1,000–1,035 feet.

[b] Sample from 2,800–2,865 feet.

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (C. S. Howard unless otherwise designated)
1	Hailstone Basin Oil Co., Billings.	Aug. 20, 1921	2,067	12	2.0	4.4	1.4	[a] 869	38	1,952	12	164	Trace.	17	
2	...do...	...do...	3,501	24	.18	518	122	319	0	315	1,889	182	Trace.	1,800	
3	Wm. W. Smith	Oct. 24, 1921	708	21	.30	58	58	115	0	529	151	32	1.7	383	
4	J. A. Campbell, Hesper	...do...	2,090	12	.17	119	96	425	0	517	1,094	34	Trace.	691	
5	Ross Ballard, Acton	Nov. 1, 1921	5,566	10	.55	169	85	1,378	0	359	3,265	66	Trace.	771	
6	W. P. Wall	Oct. 31, 1921	1,393	9.0	4.3	52	95	288	0	694	411	102	1.8	520	
7	C. N. Gowan	Oct. 26, 1921	1,227	8.8	.22	9.4	1.7	457	11	903	248	15	1.4	30	
8	C. U. Holtzclaw	Oct. 28, 1921	1,103	16	.18	165	52	98	0	389	482	9.0	Trace.	626	
9	S. W. Grant	Oct. 26, 1921	788	16	.14	85	22	156	0	490	232	16	Trace.	303	
10	J. A. Beck	Oct. 28, 1921	2,558	6.5	.11	51	43	755	8.4	476	1,332	103	Trace.	304	
11	Mayor and city council, Broadview.	...do...	638	5.5	.15	73	60	94	0	566	119	19	Trace.	428	
12	F. W. Schauer	Aug. 27, 1921	1,994	26	.21	6.0	1.0	799	103	1,791	2.8	109	Trace.	19	
13	Joseph Wormser, Billings	Oct. 25, 1921	6,899	8.8	1.6	570	477	600	0	405	4,075	90	4.7	3,380	
14	R. W. Husband, Billings	...do...	2,945	8.5	.14	270	170	[a] 305	0	300	1,707	10	Trace.	1,370	
15	A. D. Hanson	Nov. 1, 1921	9,608	14	1.1	471	556	1,346	0	440	5,732	23	Trace.	3,460	
16	Mrs. Betsy Iverson	Oct. 25, 1921	8,134	10	1.1	134	55	2,438	0	744	4,871	132	5.1	560	
17	Spring at Acton	Oct. 26, 1921	832	12	.07	30	18	261	0	543	223	16	1.2	149	
18	M. J. McCarthy	Oct. 31, 1921	4,152	12	.14	235	159	816	0	650	2,322	40	Trace.	1,240	
19	Ed. Popelka	Oct. 24, 1921	1,413	16	.21	35	29	436	0	852	419	30	1.8	206	
20	C. Watts	Oct. 28, 1921	644	12	1.7	7.6	.9	237	55	389	117	12	.79	23	

[a] Calculated.

Analyses of waters collected in Yellowstone and Treasure Counties, Mont.—Continued

[Analytical results in parts per million]

No.	Location					Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifer		Water level above or below surface (feet)	Use of water
	Nearest post office	Quarter	Sec.	T.	R. E.					Character of material	Geologic horizon		
21	Comanche	NW	20	3 N.	24	G. E. Sherwood	Dug	22½	3 ft	Sand and gravel	Quaternary alluvium on Bearpaw shale.	−20	Domestic.
22	do	NW	26	3 N.	24	August Krueger	do	12	4 ft	Sand	do	−6	Stock.
23	Laurel	SE	6	1 S.	24	W. M. Raines, Hesper.	Spring			Sandstone	Colorado shale	Flows	Domestic.
24	Hesper	SE	13	1 S.	24	I. D. O'Donnel, Billings.	do			Clay	do		Do.
25	Laurel	SE	7	2 S.	24	F. W. Schauer	Drilled	2,235	12, 4 in	Sandstone at 1,710–1,715 feet	Cloverly formation	+2	Not used.
26	Mossmain	NE	12	2 S.	24	J. J. Snyder	Driven	15	2 in	Gravel	Terrace deposits on on Colorado shale.		Domestic.
27	Laurel	NE	22	2 S.	24	C. B. Martin		9½		River gravel			
28	do	NE	12	3 S.	24	R. Bates	Drilled	1,000±	6 in		Cloverly formation	−140	Domestic (not drinking or cooking) and irrigation.
29	Billings	SW	4	1 N.	25	Malin Yates Co.	do	80	6 in	Sandstone	Eagle sandstone	−35	Domestic.
30	Acton	NW	18	2 N.	15	Chas. Bracken	do	70	6 in	do	Bearpaw shale (?)	−30	Do.
31	do	NW	19	2 N.	25	Great Northern Railway.	do	317	6 in	do	Judith River formation.	0 to −15	Do.
32	do	SE	20	2 N.	25	Dr. J. I. Wernham, Billings.	do	115	6 in		do	−40	Stock.
33	do	SW	22	2 N.	25	O. B. Johnson, Billings.	do	125	6 in	Sandstone at 100 feet.	Eagle sandstone	−60	Domestic and irrigation.
34	do	SW	34	2 N.	25	Daniel Dedrick, Billings.	do	50	6 in	Sandstone	do	−20	Domestic.
35	Billings	SW	34	2 N.	25	do	do	100	6 in	do	do		Do.
36	Broadview	SE	14	4 N.	25	W. S. Smith	do	160	6 in	do	Lance formation	−100	Do.
37	Laurel	NW	18	1 S.	25	Great Western Sugar Co.	do	40			Terrace deposits		
38	do	SW	15	2 S.	25	Emmet Williams, Billings.	Dug	24	4 ft		Colorado shale (?)	−12	Domestic.
39	Billings	NE	4	3 S.	25	F. L. Summers	Drilled	1,845	15½, 8 in	Sandstone	Chugwater formation.	+1	No use. Oil well in process of drilling.
40	Laurel	NE	4	3 S.	25	Ed. Summers, Billings.	do	1,095	12, 8 in	do	Cloverly formation	At surface	Stock.

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (C. S. Howard unless otherwise designated)
21	G. E. Sherwood	Oct. 28, 1921	1,567	12	.17	62	56	408	11	298	526	315	Trace.	385	
22	August Krueger	do	16,471	12	1.6	542	1,129	[a] 2,374	0	468	10,000	257	Trace.	5,980	
23	W. M. Raines, Hesper	Oct. 24, 1921	2,415	15	.16	164	119	378	0	362	1,330	29	.63	898	
24	I. D. O'Donnel, Billings	do	315	22	.21	38	23	43	0	250	64	8.0	Trace.	189	Margaret D. Foster.
25	F. W. Schauer	Aug. 27, 1921	3,398	27	.14	10	1.7	1,318	72	1,957	7.9	832	Trace.	32	
26	J. J. Snyder	Oct. 24, 1921	1,611	30	.31	154	103	174	0	395	801	18	Trace.	807	Do.
27	C. B. Martin		382	-----	Trace.	66	16	38	0	229	106	11	-----	131	W. M. Cobleigh.
28	R. Bates	Aug. 26, 1921	1,488	12	.50	6.8	2.2	602	67	1,493	1.6	21	Trace.	26	
29	Malin Yates Co.	Sept. 10, 1921	1,549	22	1.1	196	127	90	0	593	670	27	.29	1,010	
30	Chas. Bracken	Nov. 1, 1921	1,396	8.8	.53	35	16	424	12	495	616	13	1.4	153	
31	Great Northern Ry., Acton	do	1,618	11	.40	8.6	5.2	524	31	368	800	13	1.5	43	
32	Dr. J. I. Wernham, Billings	Sept. 10, 1921	3,453	13	5.2	16	9.7	1,210	90	1,543	1,272	14	.58	80	
33	O. B. Johnson, Billings	Sept. 13, 1921	1,329	22	2.2	77	47	307	0	547	576	8.0	4.8	385	
34	Daniel Dedrick, Billings	Sept. 10, 1921	470	23	1.9	39	24	89	6.0	271	120	21	.55	196	
35	do	Nov. 1, 1921	469	13	.24	55	24	70	0	342	87	15	1.3	236	
36	W. S. Smith	Oct. 28, 1921	2,056	14	.13	26	17	641	0	569	1,012	14	Trace.	135	Margaret D. Foster.
37	Great Western Sugar Co., Laurel.	November, 1920	14,591	6.4	18	585	767	[a] 3,008	-----	1,982	8,847	244	-----	4,607	J. T. Davis.
38	Emmet Williams, Billings	Aug. 19, 1921	1,335	14	.41	115	45	265	0	364	683	12	.57	472	
39	F. L. Summers	do	[b] 3687	19	6.2	611	172	[a] 200	0	235	2,344	24	Trace.	2,230	
40	Ed. Summers, Billings	do	1,929	16	1.3	5.8	3.3	782	131	1,426	2.5	251	Trace.	28	

[a] Calculated.

[b] Hydrogen sulphide 7.8 parts per million.

Analyses of waters collected in Yellowstone and Treasure Counties, Mont.—Continued

[Analytical results in parts per million]

No.	Location: Nearest post office	Location: Quarter	Location: Sec.	Location: T.	Location: R. E.	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifer: Character of material	Aquifer: Geologic horizon	Water level above or below surface (feet)	Use of water
41	Laurel	NW	6	3 S.	25	Albert Naiman	Dug	6	4 ft		Alluvium	−4	Domestic.
42	do	SW	7	3 S.	25	R. Bates	Drilled	1,000±	10 in	Sandstone	Cloverly formation	+3	Not used.
43	do	SW	9	3 S.	25	E. Paulus, Billings	Spring			Sandstone and shale.	Colorado shale	Flows	Domestic and irrigation.
44	do	NW	11	3 S.	25	L. Robbins, Billings	Dug	25	6, 4 ft		do		Domestic.
45	Billings	NE	18	3 S.	25	R. Bates	Drilled	650±	10 in	Probably sandstone.	Cloverly formation	+2	Not used.
46	do	NE	15	1 N.	26	J. P. Mossman	do	81			Claggett formation (?).	+4	Stock.
47	do	NW	23	1 N.	26	S. B. Pile	Dug	15	3 ft	Gravel	Terrace deposits on Claggett formation.	−7	Domestic.
48	do	{NE. ¼ SW.}	25	1 N.	26	Hugh Tanaka	Drilled	115	6 in	Quicksand	do	−40	Stock.
49	do	NW	36	1 N.	26	A. J. Peters	Dug	60	4 ft	do	Alluvium	−50	Do.
50	do	NW	14	2 N.	26	Charles Smart, Shepherd.	Twelvemile Spring.				Judith River formation.		Domestic.
51	do	SE	18	2 N.	26	H. E. Myers	Drilled	72	6 in	Sandstone	do		Do.
52	do	SE	22	2 N.	26	Unknown	Ninemile Spring.				Contact of Bearpaw shale and Judith River formation.	Flows	Do.
53	do	SW	23	2 N.	26	C. J. Hintt	Drilled	88		Sandstone at 43 feet.	Judith River formation.	−43	Do.
54	do	SE	7	3 N.	26	John Lang	do	100	6 in	Sandstone at 50 feet.	Lance formation	−25	Do.
55	do	NW	8	3 N.	26	A. H. Ammann	do	150	6 in	Sandstone	do	−26 to −100	Do.
56	do	SE	24	4 N.	26	J. I. Mayfield	do	104	6 in	Sandstone at 85–104 feet.	do	−54	Do.
57	do	NW	5	1 S.	26	James Steel	Dug	12½	3 ft	Terrace		−5 ft. 7 in	Stock.
58	do	NE	8	1 S.	26	Mrs. M. Flanigan	Driven	30	2 in	Sand and gravel	Terrace deposits on Colorado shale.		Do.
59	do	SE	13	1 S.	26	Walter Zweible	Drilled	70	6 in	Shale and slate	do	+2½	Never used.
60	Huntley	SW	24	2 N.	27	John Malla, Shepherd.	Spring			Gravel	Terrace deposits on Bearpaw shale.	Flows	Stock.
61	Billings	NW	15	2 S.	27	W. H. Brumfield	Dug	20	3 ft	do	Pryor Creek terrace deposits on Colorado shale.	−8 to −13	Domestic.
62	Pryor	NE	31	3 S.	27	F. M. Henry, Hardin.	do	35	4 ft		do	−26	Do.

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (C. S. Howard unless otherwise designated)
41	Albert Naiman	Aug. 26, 1921	1,194	21	.12	106	38	253	6.0	508	488	8.0	1.1	421	
42	R. Bates	do	1,725	18	.10	9.2	1.9	728	52	1,797	3.3	26	Trace.	31	
43	E. Paulus, Billings	Aug. 19, 1921	689	15	.21	71	35	[a] 112	17	273	298	2.0	Trace.	321	
44	L. Robbins, Billings	do	413	20	.60	33	33	86	12	386	37	7.0	3.4	218	
45	R. Bates	Aug. 26, 1921	1,896	16	.48	11	2.4	778	46	1,979	1.5	33	Trace.	37	
46	J. P. Mossman	Oct. 26, 1921	6,713	17	3.1	33	7.2	2,153	0	789	3,882	99	3.2	112	
47	S. B. Pile	do	571	29	.27	50	46	92	0	325	196	28	3.9	314	
48	Hugh Tanaka	Oct. 25, 1921	2,444	9.0	.17	21	1.0	819	44	492	1,235	60	2.0	57	
49	A. J. Peters	do	1,894	22	.40	188	119	159	0	295	1,028	24	1.9	958	
50	Charles Smart, Shepherd	Oct. 27, 1921	1,337	14	.19	31	28	403	14	389	679	9.0	.64	192	
51	H. E. Myers	do	1,153	8.4	2.6	8.2	5.1	406	50	506	412	15	2.4	41	
52	Ninemile Spring	Oct. 31, 1921	1,232	13	.14	131	54	[a] 155	0	340	572	9.0	Trace.	549	
53	C. J. Hintt	do	640	7.5	.76	3.0	2.3	222	13	314	220	5.0	1.0	17	Margaret D. Foster.
54	John Lang	Oct. 27, 1921	1,328	10	.13	6.2	.8	467	36	473	518	32	1.6	19	
55	A. H. Ammann	do	887	7.8	.05	15	6.4	302	40	443	266	17	Trace.	64	
56	J. I. Mayfield	do	400	8.2	.03	16	13	114	4.8	290	91	9.0	Trace.	93	Do.
57	James Steel	Oct. 25, 1921	3,055	30	.14	184	175	436	0	479	1,631	29	6.9	1,180	
58	Mrs. M. Flanigan	do	4,864	28	Trace.	298	214	832	0	423	2,879	64	2.8	1,620	
59	Walter Zweible	do	27,708	16	.23	282	289	8,249	0	996	17,995	229	1.8	1,890	
60	John Malla, Shepherd	Oct. 31, 1921	3,688	18	.22	452	189	327	0	376	2,084	99	4.0	1,905	Do.
61	W. H. Brumfield	Aug. 22, 1921	562	21	.14	80	46	55	0	359	185	4.0	Trace.	389	
62	F. M. Henry, Hardin	do	2,444	25	.17	276	142	228	0	486	1,167	100	5.5	1,270	

[a] Calculated.

Analyses of waters collected in Yellowstone and Treasure Counties, Mont.—Continued

[Analytical results in parts per million]

No.	Location					Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifer		Water level above or below surface (feet)	Use of water
	Nearest post office	Quarter	Sec.	T.	R. E.					Character of material	Geologic horizon		
63	Huntley	SW	16	2 N.	28	U. S. Government experiment station.		25			Alluvium		
64	Shepherd	NW	15	4 N.	28	W. T. Ross	Dug	20–22	5, 3 ft.	Gravel	Lance formation	−18	Domestic.
65	Pineview	SE	12	5 N.	28	John King	do	21	4 ft.	Red gravel	Fort Union formation.	−18	Do.
66	Shepherd	NW	30	5 N.	28	J. Carmichael	do	20	4 ft.	Gravel	Lebo shale member	−18½	Do.
67	Pineview	SE	3	5 N.	29	Chas. Rominger, Pompeys Pillar.	Spring at Hanson ranch.			Clay and sand	Fort Union formation.		Do.
68	do	SW	4	5 N.	29	G. W. Cook, Pompeys Pillar.	Drilled	130	6 in.	Blue shale at 100–110 feet.	do	−100	Do.
69	Huntley	Lot 14	6	1 S.	29	G. H. Wright	Spring			Shale	Claggett formation		Domestic and irrigation.
70	do	NE	6	1 S.	29	Jesse Baker, Teton, Idaho.	Drilled	108	6 in.	Sandstone	(?)	−80	Domestic.
71	Pineview	SW	7	6 N.	31	George Abel	Spring			Clay	Fort Union formation.	Flows	Do.
72	Melstone	NE	9	7 N.	31	Unknown	Wolf Spring				do	do	Do.
73	Waco	NE	26	4 N.	32	Well in Waco school district.	Drilled	121			Lance formation		School.
74	Pineview	SW	17	7 N.	32	Frank E. Holton, Minneapolis, Minn.	do	120	6 in.	Sandstone at 60–70 feet.	Fort Union formation.		Domestic.
75	Melstone	NW	18	8 N.	32	John Heide	Spring 3 feet above creek.				do	Flows	Do.
76	Custer			4 N.	33	R. W. McLeod	Drilled	200	4 in.		Lance formation		Do.
77	do			4 N.	33	Richard Bocky	do	60			Alluvium		Do.
78	do	SE	26	5 N.	33	C. R. Fraser	Bored	67	18 in.	Sand	Lance formation	−20	Do.
79	do	NW	6	6 N.	33	J. J. Botts, Newton Grove.	Drilled	220	6 in.	Blue shale at 190 feet.	do	−150	Do.
80	Rancher	SW	25	6 N.	34	J. L. Moaut	Dug	16	3 ft.	Sand and gravel	Alluvium on Lance formation.	−12	Do.
81	Sumatra	SW	12	8 N.	33	Chas. Ruskosky, Billings.	Drilled	140	6 in.	Unknown	Lance formation	−90	Do.
82	Myers	NE	26	8 N.	33	W. A. Ruskosky, Sumatra.	do	196	6 in.	Sandstone	do	−20	Do.
83	Rancher	NW	11	5 N.	34	John Ebbers	Dug	18	4 ft.	Gravel and sand	Alluvium on Lance formation.	−12	Do.

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (C. S. Howard unless otherwise designated)
63	U. S. Government experiment station.	Aug. 13, 1914	1,298	-------	-------	69	25	[a] 311	0	292	669	10	2.4	275	W. M. Cobleigh.
64	W. T. Ross	Aug. 31, 1921	2,194	18	.09	80	86	494	0	442	1,194	21	.74	553	
65	John King	Sept. 1, 1921	1,348	20	.18	79	80	248	0	488	622	9.0	.57	526	
66	J. Carmichael	Aug. 31, 1921	870	21	.09	76	62	112	0	337	382	8.0	Trace.	444	
67	Chas. Rominger, Pompeys Pillar	Sept. 1, 1921	899	18	.29	63	56	160	0	409	371	9.0	.68	387	
68	G. W. Cook, Pompeys Pillar	do	399	18	.81	72	34	21	0	334	69	5.0	.67	319	
69	G. H. Wright	Oct. 7, 1921	431	18	.12	68	29	48	0	348	88	4.0	Trace.	289	Margaret D. Foster.
70	Jesse Baker, Teton, Idaho	do	414	11	.05	13	14	120	9.6	277	101	10	Trace.	90	Do.
71	Geo. Abel	Sept. 1, 1921	675	11	Trace.	55	36	[a] 136	0	412	216	8.0	8.0	285	
72	Wolf Spring	Oct. 1, 1921	278	10	.13	49	31	[a] 6.4	0	257	47	3.0	Trace.	250	
73	Well in Waco school district	Sept. 25, 1916	1,110	6.2	[b] 1.0	3.8	1.2	[a] 400	18	463	423	22	1.9	14	W. M. Cobeleigh.
74	Frank E. Holton, Minneapolis, Minn.	Sept. 2, 1921	325	20	.61	55	22	22	0	227	80	4.0	1.3	228	
75	John Heide	do	823	17	.11	92	60	83	0	348	324	7.0	.77	476	
76	R. W. McLeod	Sept. 17, 1916	1,152	8.3	[b] .4	3.8	1.2	[a] 424	30	576	306	66	.26	14	Do.
77	Richard Bocky	do	2,654	15	[b] 2.0	58	36	[a] 811	0	531	1,463	68	.01	293	Do.
78	C. R. Fraser	Oct. 1, 1921	1,468	7.2	.34	39	22	[a] 445	0	577	628	20	Trace.	188	
79	J. J. Botts, Newton Grove	do	2,206	6.0	.10	16	6.6	[a] 745	16	572	1,113	21	2.4	67	
80	J. L. Moaut	Sept. 27, 1921	1,960	21	.14	110	51	467	0	536	909	73	6.2	484	
81	Charles Ruskosky, Billings	Oct. 22, 1921	2,460	9.6	.10	9.1	4.6	850	31	1,000	988	18	2.0	42	
82	W. A. Ruskosky, Sumatra	Sept. 19, 1921	2,675	7.8	.18	15	4.5	925	26	860	1,215	19	3.8	56	
83	John Ebbers	Sept. 27, 1921	1,046	20	.14	55	36	266	0	549	384	15	2.8	285	

[a] Calculated.

[b] $Fe_2O_3+Al_2O_3$.

Analyses of waters collected in Yellowstone and Treasure Counties, Mont.—Continued

[Analytical results in parts per million]

No.	Location					Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Aquifer		Water level above or below surface (feet)	Use of water
	Nearest post office	Quarter	Sec.	T.	R. E.					Character of material	Geologic horizon		
84	Big Horn	NE	27	5 N.	34	School district in Big Horn.	Drilled	110	6 in.	Blue shale	Lance formation	−10	Domestic.
85	do	SE	11	3 N.	35	G. H. Bishop	do	57	4 in.	Sandstone and shale.	do	−8	Do.
86	do	NE	33	4 N	35	Fred D. Glover	do	93	6 in.		do	−20	Stock.
87	Myers	NE	4	5 N.	35	T. O. Crandall, Hysham.	do	135	6 in.	Sandstone	do	−65	Domestic.
88	do	SW	3	6 N.	35	S. D. Wagner	Dug	21	3½ ft.	Gravel and sand	Terrace deposits on Bearpaw shale.	−19	Do.
89	Hysham	S½	9	5 N.	36	S. T. Likens	Spring			Shale and sandstone.	Lance formation		Do.
90	do	SW	1	6 N.	36	D. E. Wartensleben, Sheridan, Wyo.	Drilled	600	6 in.	Probably sandstone from 550 to 565 feet.	Judith River formation.	−2	Do.
91	do	NE	2	6 N.	36	do	Dug	15	3 ft.	Gravel and sand	Alluvium on Bearpaw shale.	−5	Do.
92	do	SE. ¼ NE. ¼	7	6 N.	36	Jas. Gallagher	do	15	3½ ft.	Gravel	do	−7	Stock.
93	do	NW	9	6 N.	36	Mayor and city council.	do	50	10 ft.	Quicksand at 36 feet.	do	−36	Municipal supply.
94	do	NE	36	6 N.	36	A. H. Wright	do	48	3 ft.	Sand	Terrace deposits on Bearpaw shale.	−45	Domestic.
95	do	SW	5	2 N.	37	C. C. Barkhuff	Drilled	43	6 in.	Quicksand	Lance formation	−25	Do.
96	do	NE	9	3 N.	37	Sarah Rumsey	do	66	6 in.		do	−15	Do.
97	Sanders	SW	7	6 N.	37	J. E. Cole	Dug	14	5 ft.	Gravel	Alluvium on Bearpaw shale.	−4 to −10	Do.
98	do	NW	9	6 N.	37	School district No. 16.	Drilled	190			Judith River formation.		
99	do	NE	9	6 N.	37	W. M. Hohenshelt	do	26			Terrace deposits		Do.
100	do	SE	26	7 N.	37	Jesse Smith, Vananda.	Dug	23	3 ft.	Sand and gravel	Alluvium on Bearpaw shale.	−19	Stock.
101	Hysham	SW	28	7 N.	37	V. Gustafson, Vananda.	do	18–20	4 ft.	do	do	−13 to −15	Domestic.

No.	Owner or name	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Analyst (C. S. Howard unless otherwise designated)
84	School district, Big Horn	Oct. 3, 1921	1,008	8.0	.53	7.4	3.0	357	53	468	298	22	1.1	31	
85	G. H. Bishop	do	2,090	8.2	.33	30	14	[a] 651	0	750	877	14	.88	132	
86	Fred D. Glover	do	2,568	5.8	1.0	31	7.3	815	0	573	1,349	18	2.1	107	
87	T. G. Crandall, Hysham	Sept. 16, 1921	820	13	.20	47	26	208	0	560	198	6.0	2.3	224	
88	S. D. Wagner	Sept. 22, 1921	406	26	.17	32	16	93	0	259	101	9.0	3.4	146	
89	S. T. Likens	Sept. 29, 1921	208	4.0	.12	30	17	[a] 8.5	0	156	31	2.9	.38	145	
90	D. E. Wartensleben, Sheridan, Wyo.	Sept. 24, 1921	2,079	10	.05	5.0	1.0	826	20	1,087	5.2	636	Trace.	16	
91	do	do	908	24	1.5	131	32	129	0	427	354	8.0	Trace.	459	
92	Jas. Gallagher	Oct. 4, 1921	5,102	22	.18	113	54	1,470	0	761	2,889	30	.38	504	
93	Mayor and city council, Hysham.	do	4,279	24	.09	208	144	942	0	761	2,411	33	6.0	1,110	
94	A. H. Wright	Sept. 30, 1921	1,145	31	.24	53	39	[a] 293	0	603	407	6.0	5.0	292	
95	C. C. Barkhuff	Sept. 21, 1921	924	20	.20	50	37	254	0	695	225	8.0	Trace.	277	
96	Sarah Rumsey	Sept. 29, 1921	943	8.0	.64	8.4	2.9	347	22	549	255	21	.77	33	
97	J. E. Cole	Sept. 24, 1921	2,075	18	.70	234	64	322	0	498	1,073	24	Trace.	847	
98	School district No. 16, Sanders		2,606		Trace.	175	61	[a] 620	48	668	1,327	19		688	W. M. Cobleigh.
99	W. M. Hohenshelt		1,399		Trace.	83	29	[a] 348	24	439	628	18		326	
100	Jesse Smith, Vananda	Sept. 22, 1921	6,284	28	.61	210	97	1,671	0	460	3,984	16	.50	923	
101	V. Gustafson, Vananda	do	1,844	30	.40	158	53	361	0	508	882	38	2.6	712	

[a] Calculated.

ROCK FORMATIONS AND THEIR WATER-BEARING PROPERTIES

GENERAL SECTION

Yellowstone County is underlain by beds of shale and sandstone about 5,000 feet in total thickness. The sandstones, in general, will yield water that is adequate in quantity and can be used for domestic purposes. The shales are usually dry or yield water that is unfit for domestic use. In many places the water from shale is so highly mineralized as to be unfit for stock. The sandstones do not yield enough water for irrigation except on a very small scale. In general public waterworks dependent on wells will find difficulty in obtaining sufficient supplies. Where the sandstones are shaly or deeply covered by shale the water may be of very poor quality. Shallow dug wells in coulees offer the best prospects for obtaining water from the shales.

The oldest formation yielding water to wells in these counties is the Amsden. It does not crop out in either county but is well exposed in the Pryor and Big Horn Mountains, to the south. The Madison limestone is the oldest formation exposed in the Pryor Mountains.

The following generalized section gives information concerning the formations in these counties that may be reached by wells:

Generalized section of geologic formations in Yellowstone and Treasure Counties, Mont.[a]

System	Series	Group and formation	Approximate maximum thickness (feet)	Lithologic character	Water supply
Quaternary.	Recent.		100	Alluvium, consisting of gravel, sand, and clay, deposited on bottom lands and in the lakes that periodically have covered parts of Comanche Flat during Recent and Pleistocene (?) time.	Generally water bearing and supplies shallow dug wells. Water generally poor and used only for stock. Best producers are in valley of Yellowstone River.
	Pleistocene.	Terrace deposits.	50	Gravel.	Not well developed, except south of Yellowstone River near Huntley. Should yield small supplies except where drained.
Tertiary.	Pliocene (?) and Miocene or Oligocene.				
	Eocene.	Fort Union formation.	2,000	Beds of massive resistant yellow to buff sandstone, clay, shale, and coal. At base 200 to 300 feet of dark olive-green to brown sandy shale and thin-bedded arkosic sandstone with beds of carbonaceous sandstone and coal, called Lebo shale member.	Generally water bearing, yielding small to medium quantities of water. Sandstone and coal are best water strata; shale usually dry. Wells in Lebo shale are usually weaker and poorer.
Tertiary (?).	Eocene (?).	Lance formation.	1,500	Upper fourth, or Tullock member, consists of yellow to yellow-gray shale, with numerous beds of yellow or brown sandstone and coal. Lower three-fourths, or Hell Creek member, consists of light-greenish to yellow shale, with heavy beds of sandstone and practically no coal.	Generally water bearing. Most wells draw supplies from sandstone. Shale usually either dry or yields highly mineralized water.

[a] Hancock, E. T., Geology and oil and gas prospects of the Lake Basin field, Mont.: U. S. Geol. Survey Bull. 691, p. 107, 1918; Geology and oil and gas prospects of the Huntley field, Mont.: U. S. Geol. Survey Bull. 711, p. 110, 1920. Woolsey, L. H., Richards, R. W., and Lupton, C. T., The Bull Mountain coal field, Musselshell and Yellowstone Counties, Mont.: U. S. Geol. Survey Bull. 647, p. 18, 1917. Section below Colorado shale from Thom, W. T., jr., and Moulton, G. F., The Soap Creek oil field, Crow Indian Reservation, Mont.: U. S. Geol. Survey press notice, 1921.

Generalized section of geologic formations in Yellowstone and Treasure Counties, Mont.—Continued

System	Series	Group	Formation	Approximate maximum thickness (feet)	Lithologic character	Water supply
Cretaceous.	Upper Cretaceous.	Montana group	Lennep sandstone.	350	Generally consists of a lower member of massive light-colored, in places cross-bedded sandstone, and an upper member of brown andesitic sandstone containing abundant tuffaceous material.	Has excellent prospects of being a good water bearer.
			Bearpaw shale.	1,000	Dark bluish-gray shale.	Generally dry. Few wells produce any water fit even for stock.
			Judith River formation.	400	Sandstone and shale.	Generally yields water supplies for domestic use.
			Claggett formation.	600	Dark-gray shale with considerable sandstone in some places.	Generally dry. Water when obtained is usually too highly mineralized for household use.
			Eagle sandstone.	300	Chiefly sandstone, but with a shaly member in middle.	Wells usually yield only small supplies. Water used for domestic purposes, though often hard.
			Telegraph Creek formation.	170	Thin-bedded sandstone and shale.	Probably a poor water bearer. The sandstone may yield some more or less highly mineralized water.
		Colorado shale.		2,250	Chiefly gray to black shale with some shaly sandstone.	Generally dry. Water when obtained is often unfit even for stock.
	Lower Cretaceous.	Cloverly formation.		325	Thick conglomeratic basal sandstone, a middle zone of variegated clay, and an upper zone of thin-bedded sandstone and sandy shale.	Yields water in wells drilled for oil. Some of these wells have artesian flows. The water may contain natural gas.
Cretaceous (?).	Lower Cretaceous (?).	Morrison formation.		80±	Chiefly variegated clay.	Poor water bearer.
Jurassic.	Upper Jurassic.	Sundance formation.		680	Greenish sandstone, white and pink limestone interbedded with shale.	Top sandstone is a good water stratum, struck only in deep wells drilled for oil.

Triassic and Carboniferous (?).	(?). Permian (?).	Chugwater formation.	600	Chiefly red sandstone and shale with some gypsum near top and base. Contains one or two thin beds of limestone.	Poor water bearer. The water obtained will doubtless be highly mineralized. Reached only in deepest wells drilled for oil.
Carboniferous.	Pennsylvanian.	Tensleep sandstone.	60	Coarse yellow sandstone containing nodules of black chert. In places this formation is quartzitic.	Should be an excellent source of water where porous. Reached only in deepest wells drilled for oil.
		Amsden formation.	275	Thin red and white limestone, quartzitic sandstone, and red shale.	Reached only in deepest wells drilled for oil. Yields water in the Soap Creek oil field.
	Mississippian.	Madison limestone.	1,000	Massive light-colored limestone.	Not reached in any well in these counties. Exposed in the Pryor Mountains. Yields considerable flows of water in Soap Creek oil field.

QUATERNARY ALLUVIUM

Quaternary alluvium, ranging from very coarse gravel to the finest silt, is found on the bottom lands and lower terraces in the valleys of Yellowstone River and its chief tributaries and in the Comanche Flat, where it has been deposited by the lakes which periodically have covered that area during Recent and probably Pleistocene time. The alluvium yields considerable quantities of water, but in most places the water is used only for stock. Most of the inhabitants of the valley prefer river water, on account of its lower mineral content, and store it in cisterns, which are filled either from the irrigation ditches or by hauling from the river. Only in a few places is the alluvium so fine grained that it does not yield adequate supplies of water.

The quantity of ground water present in the alluvium in the Yellowstone River valley is dependent not only on the usual sources of ground water but upon the irrigation of the land. Most ranchers use a great excess of water when irrigating. A certain portion of this excess water soaks down through the soil and joins the general body of ground water, raising the water table. Practically all the ranchers report a considerable rise of the water in dug wells during the period of irrigation and a drop during the winter. In some places so much water has been run on the land that the subsoil is saturated and the water table almost coincides with the land surface, producing areas of evaporation. As the water evaporates, the dissolved material is deposited on the surface and the productivity of the land is destroyed. Many of these areas have been restored to productivity by systems of underdrains.

The alluvium of the Comanche Flat yields considerable water, but most of it is good enough only for stock. The water from the surrounding hills flows out on the flat. Some of the streams are perennial, but most of them are intermittent. The water after reaching the basin has practically no escape except by evaporation, because the basin is almost undrained and is underlain for the most part by impervious shale.

In general the alluvium in these counties will yield large supplies of water, though little of it is suitable for household use. Hysham is the only town in either county dependent on ground water from the alluvium for a public water supply.

No attempt has been made to discuss separately the waters from the several terraces along the Yellowstone Valley. Apparently they are very similar. These terraces are probably of Pleistocene age, as suggested by Hancock. (See p. 34.) The number and the stage of development of these terraces vary from place to place.

The quality of water from the Pleistocene deposits is indicated in the following table, which shows the average, maximum, and minimum quantities of the mineral constituents in 27 samples. The analyses of two samples (Nos. 22 and 37) were not used in preparing the table. These two waters contain over 14,000 parts per million of dissolved solids, which is nearly five times the average of the other 27 waters from these deposits. Both contain large quantities of calcium, magnesium, sodium, and sulphate and are unusual in that the quantity of magnesium is greater than the calcium.

Average, maximum, and minimum quantities of dissolved constituents of 27 waters from Pleistocene deposits [a]

[Parts per million]

	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)
Average	2,271	22	0.35	140	73	473	452	1,194	44	2.3	647
Maximum	6,283	31	2.0	452	214	1,671	761	3,984	315	6.9	1,905
Minimum	382	9.0	Trace.	21	1.0	38	229	106	4.0	Trace.	57

[a] Based on analyses Nos. 5, 8, 21, 26, 27, 41, 47, 48, 49, 57, 58, 60, 61, 62, 63, 77, 80, 83, 88, 91, 92, 93, 94, 97, 99, 100, 101. (See table on pp. 18–27.)

All the waters analyzed are hard, and more than half have a noticeable bitter taste due to the sulphate. Few are wholly satisfactory for domestic use, but practically all can be used for stock. The table shows that waters from these deposits may vary considerably in dissolved solids, but as a rule the water will be hard and high in mineral content. In some localities more suitable water may be obtained from underlying formations. In other localities—for example, where these deposits are underlain by the Bearpaw shale—these are probably the best available sources of ground water.

OLIGOCENE OR MIOCENE AND PLIOCENE (?) TERRACE DEPOSITS

Deposits of gravel and conglomerate, in places underlain by sandstone, cap many of the higher areas south of Yellowstone River. The gravel and sand appear to have been spread out by stream action upon a comparatively even surface that sloped gently northward but is now represented only by the flat tops of the interstream areas. The surface was produced by stream planation, which cut the gently arched beds of alternating hard and soft rocks to the same level, and upon it were deposited the sand and gravel now locally indurated to sandstone and conglomerate. These materials range in size from silt to cobbles 10 or 12 inches in diameter, usually deposited heterogeneously but in places roughly sorted. The gravel cover ranges in depth from a few inches to 25 feet or more and completely masks the underlying formations, making it impossible to trace formational contacts without subsurface data. Plate 4, *B*, shows a bed of conglomerate about 8 feet thick in which some pebbles are 10 inches in diameter.

On the ground of topographic similarity Hancock[12] correlates these gravel deposits with the Flaxville gravel[13] and gives their age as Miocene or early Pliocene. Alden[14] suggests that the highest remnants may perhaps be as old as Oligocene and may be correlated with the gravel in the Cypress Hills, in southern Alberta and Saskatchewan.

In many places the gravel is so thoroughly drained that it contains but small supplies of ground water. In places where the country is not dissected the gravel should yield water to shallow dug wells. The waters from these terraces apparently closely approximate those from the Quaternary alluvium, and the analyses of samples from the two sources are grouped together.

FORT UNION FORMATION

The Fort Union formation, which underlies a large part of eastern Montana, is a valuable source of water. In the Bull Mountains, in the northeastern part of Yellowstone County, the thickest exposures of the Fort Union formation measured by Woolsey were nearly 2,000 feet thick, but farther east, in Treasure County, this formation is thinner. It consists of many beds of sandstone, shale, and coal of great variability, both in thickness and in extent. At the base is a series of dark shales with a persistent bony coal, known as the Big Dirty; these beds are called the Lebo shale member. They contain numerous plant fossils and a few fresh-water shells. The presence of these fossils as well as the coal indicates a fresh-water origin for the beds. Plate 2, *A*, gives a view of the contrasting types of topography of areas underlain by the Fort Union.

Water is obtained from sandstone beds of the Fort Union that are not too fine or too clayey and are far enough beneath the surface to be saturated. Beds of unconsolidated sand, which may be encountered here and there, may not only fail to supply water but may interfere with drilling, the quicksand running into the wells. The variability of the formation is so great that it is difficult to predict the exact depth at which water will be found, particularly in drilled wells. A sandstone struck in one well may be absent in another well only 50 yards away, but the second well will probably strike another lens of sandstone before the drill goes much deeper.

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[12] Hancock, E. T., The geology and oil and gas prospects of the Huntley field, Mont.: U. S. Geol. Survey Bull. 711, pp. 128–129, 1920.

[13] Collier, A. J., and Thom, W. T., jr., The Flaxville gravel and its relation to the other gravels of the northern Great Plains: U. S. Geol. Survey Prof. Paper 108, pp. 179–184, 1918.

[14] Alden, W. C. Physiographic development of the northern Great Plains: Geol. Soc. America Bull., vol. 35, pp. 385–422, 1924.

Many settlers can not afford to drill wells and consequently must depend on springs or shallow dug wells or must haul water, perhaps as much as 10 miles. Throughout most of the Bull Mountains dug wells in favorable places in the coulees should be successful and produce adequate supplies for household use from depths not exceeding 25 feet. In general wells should not be dug on the flat uplands but in steep coulees or on the small alluvial terraces in some of the wider valleys. A dug well under especially favorable circumstances will yield enough water for many head of stock. Before digging a well a homesteader should examine other wells in his vicinity to ascertain the depths at which water was obtained, the material encountered in digging, the quality of the water, the slope of the surface, the proximity and character of drainage channels, and so far as possible the thickness and character of the formations underlying the surface. Certain plants are supposed to afford evidence of the presence of ground water, but too much dependence can not be placed on such evidence. Areas of evaporation marked by moist soil, alkali crusts, or rank vegetation, usually indicate the presence of ground water.

As soon as a settler in the Fort Union area can afford to do so, it is advisable for him to drill a well unless he has a satisfactory spring or dug well. The fortunate owner of a satisfactory dug well or spring should exercise due care to prevent pollution. The Bull Mountain region is so rough and the Fort Union formation is so variable that there is great variety in the occurrence of the water, but on high, narrow divides drilled wells should be successful at depths of less than 300 feet.

At the base of the Fort Union is the Lebo shale member, from 200 to 300 feet thick, which is a less favorable source of water than the rest of the formation, though in places it yields adequate supplies.

On account of the large amount of shale present in the Fort Union formation all wells tapping this formation should be cased, and the casings should be perforated at the water horizons.

Average, maximum, and minimum quantities of dissolved constituents of 8 waters from Fort Union formation[a]

[Parts per million]

	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)
Average	702	17	0.25	68	48	99	352	264	6.6	1.5	364
Maximum	1,348	21	.81	92	80	248	488	622	9.0	8.0	526
Minimum	278	10	.09	49	22	6.4	227	47	3.0	Trace.	228

[a] Based on analyses Nos. 65, 66, 67, 68, 71, 72, 74, 75. (See pp. 18-27.)

These waters are only moderately high in mineral content and except for the hardness should be satisfactory for all ordinary uses. Water from the Fort Union formation will probably be more satisfactory than water from any other formations in Yellowstone County.

LANCE FORMATION

The Lance underlies the Fort Union and is at the surface over a large part of Yellowstone and Treasure Counties. A typical exposure of this formation is shown in Plate 3. It is an alternation of lenticular masses of shale and sandstone with some thin, unworkable coals near the top. A familiar landmark, called Pompeys Pillar, shown on Plate 4, *A*, is composed of Lance sandstone. The formation resembles the Fort Union, and nearly all the general statements made for the Fort Union apply to the Lance. Approximately the upper fourth of the formation consists of yellow to yellow-gray shale, with abundant beds of yellow or brown sandstone and many thin beds of coal, known as the Tullock member. The lower three-fourths consists of light-greenish to yellow shale, with many heavy beds of sandstone and practically no coal, to which the name Hell Creek member has been applied.

All wells in the Lance, as in the Fort Union, should be cased. The blue shale in the Lance will stand for a year or so, but unless the well is cased it finally starts caving, and then in a short time the well is a total loss.

Most wells in this formation yield small supplies of water that can be used for domestic purpose, though in some places the water is fit only for stock.

Average, maximum, and minimum quantities of dissolved constituents of 20 waters from the Lance formation [a]

[Parts per million]

	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)
Average	1,480	9.4	0.46	25	16	472	578	622	23	1.1	116
Maximum	2,675	20	1.7	80	86.	925	1,063	1,349	103	3.8	553
Minimum	208	4.0	.03	3.8	.8	8.5	156	31	2.0	Trace.	14

[a] Based on analyses Nos. 10, 20, 36, 54, 55, 56, 64, 73, 76, 78, 79, 81, 82, 84, 85, 86, 87, 89, 95, 96. (See pp. 18-27.)

The waters are moderately high in dissolved mineral constituents, but only a few are very hard. Sodium salts make up the greater part of the dissolved material and are present in some of the waters in sufficient quantity to require care in the use of the water for irrigation.

LENNEP SANDSTONE

The Lennep sandstone underlies the Lance formation and overlies the Bearpaw shale. It is present in this area only in the northwestern part of Yellowstone County, where it has a thickness of 300 to 350 feet. It generally consists of a lower member of massive light-colored sandstone, in places cross-bedded, and an upper member of brown andesitic sandstone containing abundant tuffaceous material. It commonly forms a prominent escarpment bordering broad valleys underlain by the Bearpaw shale.

The Lennep sandstone should be a fairly good source of water, but there are no wells in this area that obtain their supply from this formation, and no attempt has been made to find supplies in it. Its areal extent in Yellowstone County is small, and where it is overlain by the Lance there is usually no need of testing this sandstone.

BEARPAW SHALE

In Yellowstone and Treasure Counties the Bearpaw shale consists of 600 to 1,000 feet of dark-blue to gray-black marine shale containing fossiliferous calcareous concretions. It includes little or no sandstone. Areas in which the Bearpaw is at the surface have poor wells and springs.

This shale forms areas of depression between the more sandy overlying Lance formation and underlying Judith River formation. Hoskins Basin is one such depression, and the part of Treasure County north of the river is typical of a large area underlain by the Bearpaw. Every driller operating in these counties should be on the watch for areas of Bearpaw shale, because this formation is practically dry. In places it yields a little worthless water near the surface. The only hope for supplies in this formation is from shallow dug wells in coulees or near watercourses. The waters from these wells and springs are in general highly mineralized and fit only for stock. An analysis of a sample of highly mineralized water from the Bearpaw is given on page 19 (No. 15). Some of these waters are used for household purposes, but the mineral content is usually rather high. Except where there is less than 200 feet of Bearpaw shale it is not worth drilling to the underlying Judith River formation in an effort to obtain larger supplies of water fit for domestic use, because of the expense and the possibility of failure.

On pages 59 to 61 are described methods of impounding storm waters for stock use and of storing in cisterns rain water from roofs and from specially constructed water catches for drinking, cooking, and washing. In many places in the Bearpaw areas it may be necessary to depend on such surface sources for water supplies.

JUDITH RIVER FORMATION

The Judith River formation, underlying the Bearpaw shale, has a maximum thickness in Yellowstone County of about 400 feet and consists of alternating beds of sandstone and shale, the sandstone predominating. The alternation of the beds is well shown in Plate 5, *A*. The formation becomes progressively more marine toward the east, being of fresh-water origin in the western part of its area and of brackish-water origin in the eastern part. In general, in the western part it is more carbonaceous and contains remains of land vertebrates, land plants, and fresh-water invertebrates, and in the eastern part it includes littoral sands with fossil seaweeds. At the base, in the Huntley and Lake Basin fields, there is a brown, irregularly jointed hackly sandstone, alternating with zones of greenish-gray sandy shale, which represents the Parkman sandstone member of the Claggett formation in its type area. This sandstone is, for convenience of mapping and because of lithologic similarity, here mapped with the Judith River formation.

Over most of Yellowstone County the Judith River formation is a fairly good source of water, and adequate supplies for domestic purposes can be obtained from it at depths of less than 150 feet. In a few areas the water is not suitable for domestic purposes, though it is fit for stock. Few if any wells have been drilled through the Bearpaw shale into the underlying Judith River, and therefore little can be said concerning the question whether this formation will yield water where deeply buried beneath the Bearpaw shale. Where the Bearpaw is less than 200 feet thick drilling through it would be worth while, but where the Bearpaw cover is thicker than 200 feet no attempt should be made to reach the Judith River, because the uncertain yield and the possible inferior quality of the water may not justify the large expenditure required.

The range in quantity of the mineral constituents of the waters from the Judith River formation shown in the following table is so great that averages would have little significance:

Maximum and minimum quantities of dissolved constituents of 15 waters from the Judith River formation [a]

[Parts per million]

	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)
Maximum	8,134	21	5.2	235	159	2,438	1,726	2,322	636	5.1	1,240
Minimum	638	5.5	.05	3.0	1.0	94	340	5.2	5.0	Trace.	16

[a] Based on analy Nos. 3, 6, 7, 9, 11, 16, 18, 19, 31, 32, 50, 51, 53, 90, 98. (See pp. 18-27.)

Of the 15 waters analyzed 10 have less than 2,000 parts per million of total dissolved solids and 8 have less than 50 parts per million of hardness.

Waters from this formation will vary considerably in composition but as a rule can be used for most ordinary purposes. They are usually better than the waters obtained from underlying formations.

CLAGGETT FORMATION

The Claggett formation is a soft gray shale with very subordinate sandstone layers and immediately underlies the Judith River formation. At Canyon Creek there is an abnormal development of sandstone in the Claggett, but farther east the formation has but few sandstone beds. The maximum thickness of the Claggett formation is about 600 feet.

As a whole the Claggett is not a promising formation as a source of water. Most wells drilled in it are failures or yield meager supplies of highly mineralized water fit only for stock. In some wells the water is so highly mineralized than even stock refuse to drink it. Analyses of water from the Claggett shales are given on pages 19, 23, and 25 (Nos. 13, 14, 46, and 69). No. 69 represents a spring water of moderate mineral content. The other analyses, showing total solids from 2,900 to 6,900 parts per million, more nearly represent the quality of water found in this formation, although many waters from the formation are said to be even more highly mineralized.

In some areas it is feasible to drill through the Claggett in order to obtain supplies of potable water from the underlying Eagle sandstone. This practice may be successful in Yellowstone County but has not yet been very thoroughly tested. However, the Eagle sandstone is not a large producer in Yellowstone County, and probably it will not yield large quantities of potable water where it is deeply covered by the Claggett formation.

EAGLE SANDSTONE

The Eagle sandstone, which underlies the Claggett formation, is capable of a threefold division. Typically it consists of a thin-bedded upper member, a shaly middle member, and a massive lower member that forms the rim rock of many coulees. This lowest massive member has been named the Virgelle sandstone member of the Eagle sandstone. An exposure of this member is shown in Plate 2, *B*. In some places, however, the upper member may be massive and the middle member may lose its shaly character, so that the three members may together form high steep cliffs rising above the lowlands of Colorado shale. The Virgelle member of the Eagle forms the most conspicuous rim rocks in the region. The total thickness of the formation is from 200 to 300 feet in the western part of Yellowstone County; east of Billings it thins so rapidly that east of Pryor Creek only a thin sandy shale carrying an Eagle fauna remains. The Eagle sandstone is of littoral origin.

The Eagle sandstone is a good water bearer in some parts of Montana, but in Yellowstone County it is not. Most of the wells in this formation furnish only small supplies, and the water is hard, though generally potable. Analyses Nos. 29, 33, 34, and 35 on page 21 represent waters from the Eagle sandstone. These waters are hard but otherwise are suitable for most ordinary purposes.

TELEGRAPH CREEK FORMATION

In the southern part of Yellowstone County there intervenes between the Colorado deposits and the Eagle formation 170 feet of thin-bedded sandstone and shale of marine origin, to which Thom [15] has given the name Telegraph Creek formation, from the exposures of these beds at the head of Telegraph Creek. This formation is typically developed in T. 2 S., Rs. 28 and 29 E., and thins rapidly westward, dying out a few miles west of Coburn.

The Telegraph Creek formation consists essentially of sandy shale with a subordinate amount of sandstone, and although it may yield small supplies of water, there are no data available concerning wells that obtain their supplies at this horizon. The formation crops out in a very sparsely inhabited region, and no effort has been made to test the water-bearing qualities of either the sandy shale or the sandstone. Owing to the preponderance of shale in the formation the water may be somewhat highly mineralized.

COLORADO SHALE

Beneath the Eagle sandstone is the Colorado shale, the most unfavorable formation as a source of water in Yellowstone County. It is about 2,250 feet thick and consists largely of gray to black marine shale that yields little or no water. At certain horizons there are sandy beds, but these yield only meager quantities of unsatisfactory water.

The most conspicuous lithologic element of the formation, as exposed in the bluffs along the south bank of Yellowstone River, just west of Billings, is the bentonite, which occurs in white streaks about 1,100 feet above the base of the formation. The sandy beds called the Mowry shale are approximately 550 to 750 feet above the base of the formation, and another very argillaceous sandstone occurs

[15] Thom, W. T., jr., Oil and gas prospects in and near the Crow Indian Reservation, Mont.: U. S. Geol. Survey Bull. 636, pp. 35–55, 1923.

about 300 feet higher. These sandy beds are generally dry, though in some places they contain water of very poor quality.

In the northern part of the Crow Indian Reservation most of the hills have a thin sandstone near the top. Where the streams have cut back into the hills they have cut steep coulees, in which springs are common. The country is much dissected, and the numerous small springs in these coulees yield sufficient water for the range cattle. The springs range from very small seeps to springs flowing several gallons a minute. The water is highly variable in quality, some being potable and some unfit for stock. Analyses of waters from the Colorado shale are given on pages 21 and 23 (Nos. 23, 24, 43, 44, and 59.) With the exception of No. 59 the waters represented are unusually good for this formation. No. 59 has nearly as much dissolved material as is found in sea water, but its main constituent is sodium sulphate rather than the sodium chloride of sea water.

CLOVERLY FORMATION

The Cloverly formation, of Lower Cretaceous age, underlies the Colorado shale. The Cloverly is probably of fresh-water origin throughout. It consists of a thick coarse-grained to conglomeratic basal sandstone, a middle zone of clay and thin-bedded hard sandstone, and an upper member of sandy shale and thin-bedded rusty sandstone. The basal sandstone of the Cloverly, which is correlated with the Lakota sandstone of the Black Hills region, is one of the most conspicuous beds in this formation. The middle zone consists of varicolored clays, apparently closely matching in character the Fuson formation of the Black Hills, which overlies the Lakota. The thin-bedded sandstone and sandy shale are well exposed on the road from Billings to Pryor. These beds are approximately at the horizon of the "First Cat Creek sand" of the Cat Creek oil field and are very doubtfully equivalent to the Dakota sandstone of the Black Hills. The formation is about 320 feet thick in the Crow Indian Reservation.

The Cloverly corresponds in a general way to the Kootenai formation, which is extensively exposed farther north in the State, but no exact correlation can be given at this time.

There is a small area of outcrop of the Cloverly formation near the southern boundary of Yellowstone County. In this area shallow dug wells in the sandier beds should yield adequate supplies of fairly good water. Most of the wells drilled for oil in this county that penetrate this formation obtain water containing some gas and in some places faint traces of oil. The water is always under some head and rises in the casing. It flows in some wells but rarely in large volume.

Owing to the general northeastward dip the Cloverly is usually at a considerable depth below the surface, and consequently it is very expensive to obtain water from this formation.

Average, maximum, and minimum quantities of dissolved constituents of 7 waters from the Cloverly formation [a]

[Parts per million]

	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)
Average	2,071	18	0.68	7.6	2.0	840	73	1,772	4.5	205	Tr.	27
Maximum	3,398	27	2.0	11	3.3	1,318	131	1,979	12	832	Tr.	37
Minimum	1,488	12	.10	4.4	1.0	602	38	1,426	1.5	21	Tr.	17

[a] Based on analyses Nos. 1, 12, 25, 28, 40, 42, 45. (See pp. 18-27.)

These waters are unusually soft and contain very small quantities of sulphate for waters so highly mineralized. The dissolved mineral matter consists chiefly of sodium bicarbonate, although in No. 25 chloride is rather high. The low sulphate and high bicarbonate may be due to the reduction of the sulphate originally in the water by hydrocarbons of natural gas or oil. All the waters contain considerable carbonate (CO_3), which probably explains the softness of these waters, as only small quantities of calcium and magnesium will stay in solution in the presence of carbonate.

MORRISON FORMATION

The Morrison formation, underlying the Cloverly, is also of fresh-water origin. Its age is either Lower Cretaceous or late Jurassic. It consists chiefly of bright variegated clay, which caves badly when penetrated by the drill. Where exposed along the Big Horn Mountains this formation is about 80 feet thick. The clays forming the Morrison formation yield but little water.

SUNDANCE FORMATION

The Sundance formation, of late Jurassic age, underlies the Morrison, probably with slight unconformity, and is in part equivalent to the Ellis formation of central Montana. It consists of greenish sandstone and white or pink limestone interbedded with greater thicknesses of shale, greenish in the upper part of the formation and pink or red in the lower part. The total thickness ranges from 570 to 680 feet. The top of the Sundance is commonly marked by a fossiliferous sandstone which should yield water in considerable quantities, but the shale and limestone are less promising as a source of ground water.

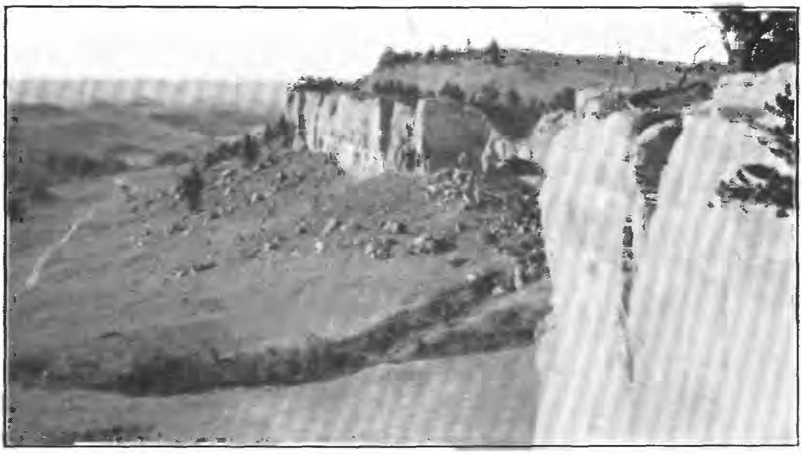
A. SOUTHEAST FRONT OF ELDRIDGE MESA AND ADJACENT PLATEAU

B. SANDSTONE "RIM ROCK" IN SEC. 5, T. 5 N., R. 31 E.

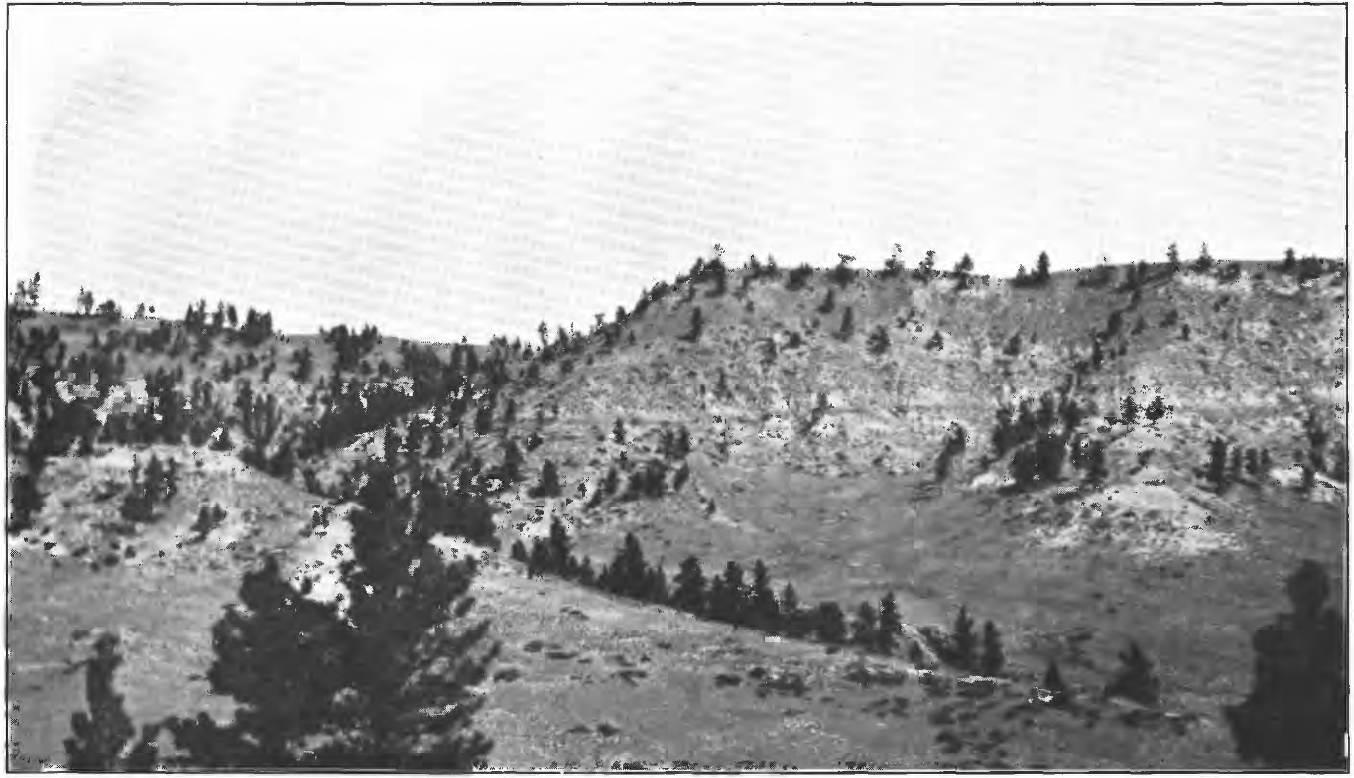
Showing abrupt change in bedding

A. CONTRASTING TOPOGRAPHY OF THE UPPER PART AND THE LEBO SHALE MEMBER OF THE FORT UNION FORMATION IN SEC. 34, T. 5 N., R. 30 E.

Upper part of formation at upper left; Lebo member in foreground



B. EAGLE SANDSTONE AS SEEN LOOKING NORTHWEST FROM THE TOP OF THE STEEP CLIFF IN THE NE. ¼ SEC. 19, T. 1 S., R. 27 E.

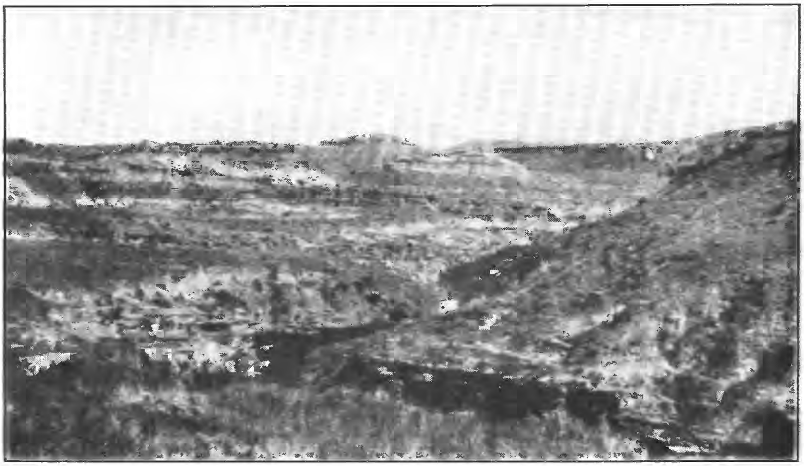


TYPICAL ESCARPMENT FORMED BY THE TULLOCK MEMBER OF THE LANCE FORMATION ON WEST CORRAL CREEK, SEC. 33, T 5 N., R. 36 E.

A. POMPEYS PILLAR, A LOW BUTTE FORMED BY THE SANDSTONE AT THE BASE OF THE LANCE FORMATION

Near the south bank of the Yellowstone about 2½ miles west of Pompeys Pillar station on Northern Pacific Railway

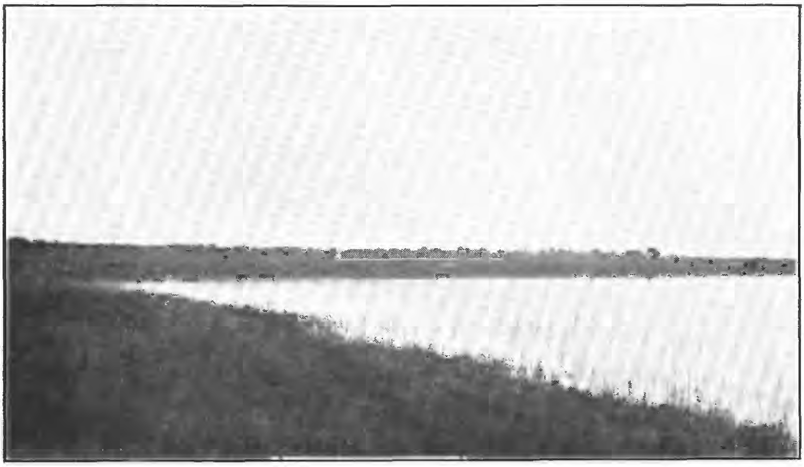
B. CONGLOMERATE CAPPING THE RIDGE IN THE SW. ¼ SEC. 34, T. 1 N., R. 28 E.



A. JUDITH RIVER FORMATION EXPOSED IN THE MUCH-DISSECTED AREA 1½ MILES SOUTH OF ACTON

B. FAULT IN THE SOUTHWEST CORNER OF SEC. 7, T. 2 N., R. 24 E.

A



B

RIDGE OR DUNE, 10 FEET HIGH, ON NORTHEAST SIDE OF SMALL LAKE SOUTHEAST OF COMANCHE

A, General view; *B*, Near view

CHUGWATER FORMATION

The Chugwater formation, which underlies the Sundance, consists primarily of dark-red sandstone and shale with thick local beds of gypsum near the top and base and one or two thin layers of reddish limestone. Its thickness along the Big Horn Mountains is about 650 feet; but in the Consolidated Oil & Gas Co.'s well, on Duck Creek, the Chugwater has thinned down to 250 feet, and doubtless a few miles north of the well it thins out. The water obtained from this formation will be in most places of small volume and poor quality. An analysis of a sample of water from this formation is given on page 21 (No. 39). This water is highly mineralized, containing large quantities of calcium and sulphate.

TENSLEEP SANDSTONE

The Tensleep sandstone, of Pennsylvanian age, which consists of coarse yellowish sandstone 60 feet or more in thickness containing nodules of black chert, is exposed on the flanks of the Pryor Mountains. In places this sandstone is exceedingly hard and dense and thus is a poor source of water unless thoroughly fractured; but the less thoroughly cemented parts should be excellent water bearers. The formation should yield flows in most places, because it crops out on the flanks of the Pryor Mountains at a considerable altitude above most of the surface of Yellowstone and Treasure Counties.

AMSDEN FORMATION

The Amsden formation, chiefly of Pennsylvanian age, underlies the Tensleep. In general this formation consists of about 275 feet of thin red and white limestone, quartzitic sandstone, and red shale. The Amsden is regarded as equivalent, at least in part, to the Quadrant formation of the Lewistown district. In general this formation is too deep to test, except at great expense, in most of Yellowstone and Treasure Counties, but in the Soap Creek oil field it yields large flows of water.

MADISON LIMESTONE

The Madison limestone, of Mississippian age, underlies the Amsden formation, probably with considerable unconformity. It consists of several hundred to a thousand feet of massive light-colored limestone, forming the backbone of the Pryor and Big Horn Mountains. Like most limestones, it is an uncertain source of water. It is untested in this area, but in the Soap Creek oil field it yields a large volume of artesian water. It is so deeply buried over most of Yellowstone and Treasure Counties that it has not been reached in drilling.

5616—29——4

ROCK STRUCTURE IN RELATION TO WATER SUPPLIES [16]

The rocks of Yellowstone County have a regional dip of a few degrees to the northeast—that is, they dip gently away from the Big Horn-Pryor Mountain uplift. This regional dip is more or less interrupted by the Bull Mountain syncline and other minor structural features shown on the geologic maps of the Lake Basin and Huntley fields in Bulletins 691 and 711, as well as some in the areas not included in those maps. Farther east, in Treasure County, this general dip is interrupted by a westerly dip from the flanks of the Porcupine uplift. Subsequent to the movements that folded and faulted the rocks erosion has cut the present surface. The formations consist of alternating beds of sandstone and shale of variable

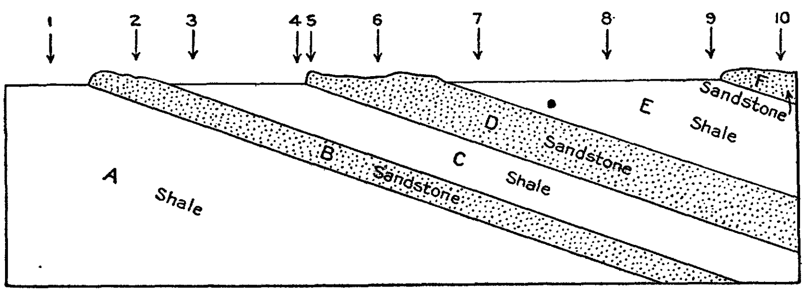


FIGURE 3.—Hypothetical section illustrating relation of ground water to rock structure in Yellowstone and Treasure Counties. Alternate beds of sandstone and shale (A to F) are tilted, and their eroded edges are exposed at the surface. The shale is worn down to form flat lowlands; the sandstone is more resistant to erosion and stands up in ridges and hills. As a general rule, the shale yields only meager supplies of poor water, whereas the sandstone yields somewhat larger supplies of better water. There are some exceptions to this general rule. Nos. 1 to 10 are the hypothetical well sites discussed in the text

thickness. On account of its greater resistance to erosion the sandstone, in general, forms areas of upland separated by more or less steep " rim rocks " from the areas of depression underlain by the soft shale. The sandstone usually yields more and better water than the shale, which yields little or none. If the few hints set forth below are followed, drillers can avoid much fruitless drilling in nonproductive shale. Their application is illustrated in Figure 3.

The prospects of drilling at sites 1 to 10, in Figure 3, are as follows: At site 1 the drill will be in shale to a great depth, and the prospects of getting a good well even by deep drilling are poor; at site 2 a satisfactory supply will probably be obtained at a moderate depth, but if the drill should pass through sandstone B and enter shale A without finding a satisfactory supply, the prospects of find-

[16] This section is largely adapted from Ellis, A. J., and Meinzer, O. E., Ground water in Musselshell and Golden Valley Counties, Mont.: U. S. Geol. Survey Water-Supply Paper 518, pp. 24–27, 1924.

ing a supply by drilling deeper would be very poor; at site 3 the drill will first encounter shale C, but without going to a very great depth it will penetrate sandstone B, in which a satisfactory supply will probably be found. At site 4 the drill will enter shale at the surface and will have to penetrate, obliquely to the bedding, virtually the entire thickness of shale C before it reaches a sandstone. A very deep well would reach sandstone B, in which it would probably find water. At site 5 the drill will penetrate considerable sandstone before it reaches shale C. The lower part of the sandstone may here be saturated and furnish a satisfactory well, or the formation may be drained dry from the top down to the shale. At site 6 the sandstone extends to a greater depth than at site 5, and the prospects are accordingly better. At site 7 the conditions are similar to those at site 3. At site 8 the drill will be in shale to a great depth, and it would have to penetrate about half of shale E before it would reach the underlying sandstone D, in which it might perhaps find a satisfactory supply. At site 9 the conditions are like those at site 8 except that about twice as great a thickness of shale would have to be penetrated before the underlying sandstone would be reached, and, moreover, the prospects of getting satisfactory water from the sandstone would be poorer. At site 10 the surface formation is a sandstone that is not found at any of the other nine sites. However, if this sandstone, F, has water-bearing characteristics similar to those of sandstones B and D, the conditions found at site 10 will resemble those at sites 2 and 6.

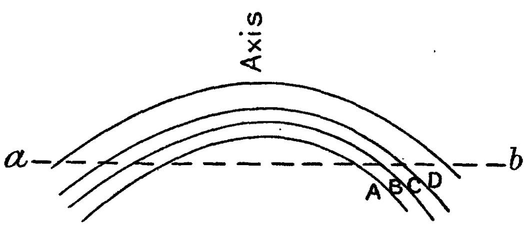


FIGURE 4.—Section showing a series of beds (A to D) that have been arched up to form an anticline. If they are eroded down to the broken line (*ab*) the oldest formation (A) is at the surface along the axis of the anticline, and successively younger beds appear at the surface on both sides

Where the formations have been warped up they form anticlines, as shown in Figure 4. In these places there has been much erosion, and hence the older formations are likely to be at the surface along the axes of the anticlines. There are no large anticlines in these counties, but there are several small ones. Where the formations have been warped down they form synclines, and the youngest formations are likely to be at the surface along the axes, as shown in Figure 5. The Bull Mountain area is the largest syncline in the region.

A narrow zone of faulting crosses the area from northwest to southeast. The faults are usually less than 6 miles long, trend northeast, and are of small throw. Some are normal, others reverse. In general the blocks concerned in the faulting have undergone some rotation. The ground-water conditions in this narrow zone have been greatly complicated by the faulting, and it is difficult to make any general statements concerning them. Strata that should yield satisfactory supplies are dry, and wells that might be expected to be poor producers give large yields. One well, which intersects a fault, is an excellent producer. Here and there a spring is located on a fault.

RECOMMENDATIONS FOR DEEP DRILLING

Over most of these two counties it is not feasible to drill deep wells—that is, wells from 1,000 to 2,000 feet deep. Although the water from these depths is usually under sufficient artesian pressure to bring it near the surface or cause it to overflow, the cost is generally prohibitive. In general the waters from the deeper beds are less highly mineralized than those from the shallower beds and are usable for domestic purposes. The amount of water obtained in a deep well may be so small as to furnish only enough for one household. The depth to favorable beds beneath the Colorado shale is generally more than 2,000 feet in the larger part of both counties and in some areas is more than 4,000 feet.

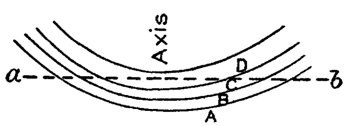


FIGURE 5.—Section showing a series of beds (A to D) that have been bent down to form a syncline. If they are eroded down to the broken line (*ab*) the youngest formation (D) is at the surface along the axis of the syncline, and successively older beds appear at the surface on both sides

Anyone who is badly in need of water is justified in testing beds less than 300 feet below the surface if the well can be sunk at a reasonable cost. In areas of the Lebo, Bearpaw, and Claggett shales where the depth to the Lance and Judith River formations and the Eagle sandstone, which are the respective underlying water-bearing formations, does not exceed 300 feet sufficient supplies may be obtained for all ordinary purposes. However, tests in such areas will not be uniformly successful.

ARTESIAN CONDITIONS

The most important requirement for flowing wells is that the water in the water-bearing formation is under so much pressure that when tapped by a well it will rise to the surface and flow. The water-bearing formation must be covered by an impervious bed; and the place where the water enters the formation must be high enough above the surface at the place where the well is drilled to force the water to the surface at the well. The water can not rise to quite the same altitude as that at which it entered the bed, on account of friction, and the source must be higher than the outlet to make a well flow. Artesian pressure may cause the water to rise in a well many feet above the level at which it enters, though not high enough to overflow. Artesian wells usually must be cased to prevent the water leaking into porous beds overlying the bed that yields the water and thus reducing the pressure.

The structure and stratigraphy of Yellowstone and Treasure Counties are favorable for artesian pressure. The structure is relatively simple, the strata dipping in a general northeasterly direction from the Big Horn Mountain uplift. The largest synclinal area is that of the Bull Mountains. On the east side of Treasure County the rock beds dip in a general westward direction from the flanks of the Porcupine uplift toward the Bull Mountain syncline. The rocks are a series of alternating sandstone and shale. Flowing wells are not common in either county, but practically all wells drilled in any water-bearing formation, except the unconsolidated alluvium, show some artesian pressure, the water rising in the casing from 5 to 100 feet above the water-bearing bed. Although the formations are favorable for artesian pressure, those that lie near the surface usually have so little difference in altitude between intake and well site that flowing wells are almost impossible. The formations close to the surface over most of both counties are exposed in areas of low rainfall, and consequently only small volumes of water enter them. This fact explains in part the small quantity of water available in certain sandstones in this region. The deeper formations, which crop out on the flanks of the Big Horn and Pryor Mountains in Big Horn County, when struck in this area in very deep wells drilled for oil yield flows of varying size. The outcrops, which constitute the intakes for the formations, are in a region of considerable rainfall, and consequently these beds have a large supply of water.

A well in sec. 15, T. 1 N., R. 26 E., 81 feet deep, flows 10 gallons a minute, but the water is used only for stock because of its bitter taste. (For analysis see No. 44, p. 23.) No log of the well was obtainable, and the mantle of terrace deposits completely obscures the structure of the underlying beds. A well in sec. 13, T. 1 S., R. 26 E., is only 80 feet deep and produces about a quarter of a gallon a minute of water that is unsatisfactory for all purposes. For analysis see No. 55, p. 23.) This water is drawn from a sandy bed approximately 1,000 feet above the base of the Colorado shale. The water enters the sandstone on the flanks of the Bitter Creek anticline, flows down, and is sealed in by the overlying impervious shale. In the NE. ¼ sec. 26, T. 4 N., R. 32 E., a drilled well 123 feet deep flows about one-tenth of a gallon a minute. The water is soft and is used for domestic purposes. (For analysis see No. 70, p. 25.)

This well is in the school yard, 35 or 40 feet above the river level, and the water barely flows. In the SE. ¼ sec. 32, T. 4 N., R. 32 E., a drilled well 93 feet deep flows about half a gallon a minute. This well is reported to have formerly had a much stronger flow, but owing to the disintegration of the casing the water is now leaking into the alluvium, and the flow at the casing head is decreasing. The water is used for domestic purposes and stock. This well is some 25 feet above the level of the river. Both of these wells are drilled through the alluvium to the underlying Lance formation, from which they draw their supply. These wells must be adequately cased to prevent the water leaking into the porous alluvium.

In the SW. ¼ sec. 1, T. 6 N., R. 36 E., a drilled well 600 feet deep formerly flowed a small amount of water, but on the date of the writer's visit, September 24, 1921, the well was not flowing, although the water was level with the surface. This well was drilled through the alluvium and underlying Bearpaw shale into the Judith River formation. This formation crops out east of Hysham, on the flanks of the Porcupine uplift, and dips westward.

Although the wells in secs. 26 and 32, T. 4 N., R. 32 E., mentioned in the preceding paragraph, yield only small flows, they show the presence of favorable structural conditions for flowing wells, as does likewise the rise of water in the casing of so many drilled wells in this region. These two wells are almost in the center of the broad Bull Mountain syncline, and other wells drilled in it at about the same height above the river should yield similar small flows. This broad syncline stretches from Pompeys Pillar to Myers along Yellowstone River, and wells drilled through the alluvium into the Lance formation close to river level between these points will show more or less artesian pressure, though not all the wells will flow. Throughout the Bull Mountain syncline there is some artesian pressure, but only where Yellowstone River cuts across the south end is there sufficient difference in altitude between intake and outlet to give rise to flowing wells.

The deeper flowing wells were all drilled for oil and draw their water from formations below the Colorado shale. The flow in some wells is due entirely to artesian pressure; in others the escape of natural gas assists in bringing the water to the surface. A most interesting deep well is in the Hailstone Basin, in Stillwater County, in the SW. ¼ NW. ¼ sec. 5, T. 3 N., R. 21 E., where a flow of about 150 barrels a day was struck at 1,000 feet and another of the same amount at 2,200 feet. A flow of not less than 15,000 barrels a day of water having a temperature of 113.5° F., charged with hydrogen sulphide, was struck at a depth of 2,800 feet. This flow neither decreased nor cooled during the 10 months after completion of the well. This well draws its heaviest flow probably from the Amsden formation. (For analyses of samples of water from the first and last flows, see Nos. 1 and 2, p. 19.)

A number of wells have been drilled in Yellowstone County in an effort to obtain oil, but none of them are commercial producers. Most of these wells have yielded flows of water. The Cloverly formation, immediately underlying the Colorado shale, usually yields small flows of fairly good water and may also yield more or less gas with traces of oil. Unfortunately this formation is at a depth of more than 2,000 feet in most of this area. The Sundance and Chugwater formations may yield flows, and the Amsden formation should yield flows of considerable volume, but the Amsden is very deep and has not been tested in these counties.

Very deep wells along the valley of Yellowstone River or some of its tributaries will probably flow several gallons of water a minute, but the supply will not be sufficient for irrigation on a large scale. On the uplands, where even small quantities of water are most valuable, the wells would have to be pumped and would not yield sufficient water for irrigation except on a very small scale.

WATER SUPPLIES

DOMESTIC AND STOCK SUPPLIES

In the Yellowstone Valley the river is the main source of water for domestic purposes, though many people living in this valley use wells or springs. On the uplands people must depend on springs and wells or haul water from the river, a laborious and expensive task. The river water is easy to obtain, particularly in the irrigated areas, where the ditch water is run directly into cisterns. Wells dug in the alluvium of the river valley are not expensive and furnish adequate supplies but in general yield water that is more highly mineralized than the river water. Though not generally suitable for domestic supply, they are an excellent source of water for cattle during the winter. On the uplands, where springs are not available, wells must be sunk by one of several methods. Drilled wells are the most expensive, but, considered in the light of their better sanitary features and their permanence, they are by far the best. Dug wells situated in the proper places may be excellent producers but are easily contaminated and may go dry in certain seasons.

The answer to the question whether a water is satisfactory for domestic use depends to a great extent on the person using the water. Of course, there is a limit for the total dissolved solids for potable waters, but habit is of great importance in its determination. Many waters are drunk in this region which would be rejected in regions where less highly mineralized waters are available. Moreover, a water that the members of one household in this region will condemn as unfit for drinking will be drunk by the members of another household without complaint. This statement applies to wells both in the irrigated districts and on the uplands.

On the uplands the quantity and quality of the ground water are closely related to the geology. The Eagle sandstone and the Judith River, Lance, and Fort Union formations usually yield supplies that are adequate for the domestic needs of a household. In places springs that will furnish sufficient water for a household are found. The Colorado, Claggett, and Bearpaw shales yield but little water. Most wells sunk in these formations are dry, and springs are not numerous. Much of the water obtained from these formations is so highly mineralized that it can not be used for any purpose. On the uplands the wells and springs, in general, are small producers. A new well drilled anywhere on the uplands can be expected to give a small yield of somewhat highly mineralized water, but unless it is drilled in one of the three unfavorable shale formations the water will be usable for domestic purposes, although some wells vary considerably from the average. Here and there wells in the most favorable formation yield water that is unfit for any use. Most people dwelling in the areas of the unfavorable shale formations are forced to haul water considerable distances from streams or from wells or springs that obtain their water from more favorable beds.

The problem in obtaining stock supplies is usually, but not always, a matter of quantity rather than quality, as the tolerance of animals for bad water is much greater than that of human beings. However, ground waters that are too highly mineralized for stock are not uncommon in this region. In the days before all the valley land was fenced the river was available for watering stock, but now fences block public access to the river at most places. With the advent of irrigation a generous supply of stock water was made available during the irrigation season to those whose land was irrigated, but when fall came these people were in need of water for their stock. Dug wells in the alluvium produce large supplies of water and unless very shallow do not go dry during the winter.

On the uplands, before the advent of the homesteader, there were sufficient springs, supplemented by some wells, to water all the stock on the range. As the land was fenced and the springs were inclosed, it became necessary to provide water supplies for the stock, and, in part for this reason, the number of animals was greatly reduced. Few drilled wells tapping the Eagle sandstone or the Judith River, Lance, or Fort Union formations yield water so poor in quality as to be unfit for stock, though such water is to be found in all these formations. Wells in the Eagle sandstone and the Judith River formation usually yield smaller volumes of water than those in the Lance and Fort Union formations. The shale formations, the Colorado, Claggett, and Bearpaw, yield almost no water fit for stock. The Bearpaw is the most unfavorable of the three, and the Colorado the least.

In the upland region, where the Colorado is at the surface, springs in the coulees furnish adequate supplies, as in the Crow Indian Reservation, but when the coulee lands are fenced and large areas are without available water, the failure of wells sunk in this shale will be serious.

Wells drilled or dug in the Claggett formation are usually small producers, and much of the water is so highly mineralized as to be refused by cattle. Most small ranches of less than a section, usually only half a section, if not in the unfavorable shale areas, can obtain sufficient water for 50 to 100 head of stock from one or more wells. In the shale areas arrangements must be made to store water in tanks for stock (see p. 60), or the rancher must have his grazing tract include a well or spring that obtains its water from some other formation, unless he is so fortunate as to own one or more of the springs that are to be found in places even in the unfavorable shale areas. A rancher who intends to lease a tract of land for grazing should first inquire as to the water supply. Wells that will water more than 100 head of cattle are very uncommon on the uplands, except in the Bull Mountains and possibly in the country south of Hysham.

IRRIGATION SUPPLIES

In a region where the average annual precipitation is less than 15 inches irrigation is desirable, in spite of the fact that crops can be grown by dry-farming methods. In Yellowstone County irrigation water can be obtained from Yellowstone River and three of its perennial tributaries—Clark Fork, Pryor Creek, and Big Horn River; in Treasure County, from Yellowstone River and Tullock and Sarpy Creeks. The areas in Yellowstone County that can be irrigated from Clark Fork and Pryor, Tullock, and Sarpy Creeks are small. Yellowstone and Big Horn Rivers furnish a large supply of water for irrigation, and many thousands of acres are under the ditch. The water is well adapted for the purpose, and where the soil is good large crops are produced by skillful cultivation.

On the uplands above the river valleys, where the cost of lifting the river water to available points is almost prohibitive, there has always been a hope that sufficient ground water would be obtainable for irrigation. This hope is doomed to disappointment, because it is improbable that water either in adequate quantity or of proper quality is available. None of the wells on the uplands overflow, and hence, even if wells of large enough yield could be obtained, they would have to be pumped, and pumping is very expensive. Most of the wells are small producers and yield water of a quality that might be detrimental to plant growth, if the water were applied to the land year after year in large quantities. However, in small gardens of less than a tenth of an acre the writer saw several excellent truck patches that were irrigated on a small scale by well and spring water. It is possible with some effort to raise small quantities of truck on many upland ranches, adding greatly to the variety of the food supply by furnishing fresh vegetables. Unless the well is pumped by an engine or a windmill irrigating even a small patch will be tedious and laborious. Windmills are economical, but they are subject to destruction by severe storms, and on calm days they produce no power. Many ranchers have therefore installed small gasoline engines for pumping wells. However, on many ranches the wells yield barely enough water for household and stock needs, with no surplus for irrigating a patch even as small as 20 feet square.

PUBLIC SUPPLIES

Wherever people dwell in close proximity, as in cities, towns, and villages, the problem of water supply becomes more pressing. Not only must sufficient water be available for the domestic use of individuals, but also a surplus for fire protection as well as an adequate supply for the industries in the community. Even in towns where there are no important industries it is frequently difficult or inconvenient, if not dangerous, for each household to maintain its own water supply. To solve these problems public supplies, either publicly or privately owned, must be developed. In certain regions it is difficult to obtain a single supply large enough for a public waterworks, although small supplies for individual families are available.

In Yellowstone County, Billings, Laurel, and Broadview have public water supplies. Billings and Laurel draw their water from Yellowstone River; Broadview from springs. In Treasure County the only town with a public water supply is Hysham, which obtains its water from a well.

BILLINGS

The modern filtration and pumping plant of the Billings water system is in the southeastern part of the city, immediately adjoining the plant of the Montana Power Co. In 1915 the city took over the ownership and operation of the water system. Prior to that year the system was privately owned.

The water is taken from Yellowstone River through the canal of the Montana Power Co. and run into a settling basin of 6,000,000 gallons capacity. The water then flows into the coagulating basin, where alum is used to clarify it, the quantity of alum used depending on the turbidity of the river water. The water is then run through rapid sand filters of the gravity type. After filtration the water is treated with chlorine to destroy harmful organisms that are not removed by filtration. The water is pumped into the mains by electrically driven pumps, having a capacity of 7,000,000 gallons a day.

At the north edge of the city, just under the " rim rock," a balancing reservoir has been built with a capacity of 1,500,000 gallons. This reservoir was constructed to obtain a practically uniform pressure in the mains of about 65 pounds to the square inch at all times. The water is pumped directly into the city mains and thence forced into this reservoir, the level of which rises until the pressure it produces by gravity is equal to that developed by the pumps. If the rate of consumption rises rapidly and exceeds the rate of pumping, the reservoir will supply the deficiency, and on account of its relatively great area compared with its depth, it will maintain an almost constant pressure, which is most useful in case of a large fire. This reservoir enables the city efficiently to supply the suburbs in the neighborhood of the Billings Polytechnic Institute.

In 1921 the city had 45 miles of mains in use, supplying 227 fire hydrants and 3,620 taps. The maximum consumption of water was 5,313,000 gallons a day, and the average was 2,617,550 gallons. The average daily consumption per capita was 163.5 gallons. An analysis of the water is given on page 17.

About 75 per cent of the water consumed is used by the inhabitants for domestic purposes and for irrigating lawns and gardens. The latter use requires large amounts of water during the hot, dry summer. About 15 per cent is used by the industries, such as sugar factories, packing houses, creameries, and laundries, and about 10 per cent by the railroads.

LAUREL

The town of Laurel obtains its supply of water from Yellowstone River. The water is pumped from the river by two 2-stage Worthington pumps having a combined capacity of 1,750 gallons a minute, or 2,520,000 gallons a day, to a 75,000-gallon tank on a 210-foot tower at the north edge of the town. The water is distributed by gravity to 54 fire hydrants and 600 taps at a pressure of 76 to 90 pounds to the square inch. The maximum consumption is 600,000 gallons a day; the average is 400,000 gallons. The water is chlorinated at the intake but receives no further treatment. All the water is consumed by the inhabitants for domestic purposes and irrigation. The plant is municipally owned and operated.

BROADVIEW

The town of Broadview depends on springs in secs. 20 and 21, T. 4 N., R. 23 E., for its supply. It is the only town in Yellowstone County where the public waterworks are dependent on ground water for the supply. The town owns the springs and also owns and operates the system. The water flows through a 6-inch wooden main about 1,000 feet long to the pumping station, where two pumps, each driven by a Fairbanks-Morse 20-horsepower kerosene engine, force the water to a 50,000-gallon tank elevated on a 150-foot steel tower. The base of the tower is about 75 feet above the town, giving the water a total head of 225 feet. The water is distributed by gravity to 11 hydrants and 82 taps at a pressure of 40 to 85 pounds to the square inch. The maximum daily consumption is 20,000 gallons and the average 12,000 gallons. The pumping equipment has a total capacity of 480,000 gallons a day, which is far in excess of the production of the springs. The water is neither filtered nor chlorinated, but when the waterworks were visited in 1921 proper precautions were being taken to prevent pollution. The springs are carefully inclosed in concrete boxes to prevent pollution by surface run-off or contamination by objects or animals falling into them. The entire supply is used by the inhabitants for domestic purposes and irrigation. (For analysis see No. 11, p. 19.)

HYSHAM

Hysham, the county seat of Treasure County, is on the Northern Pacific Railway and has a population, according to the 1920 census, of 360. The waterworks are owned and operated by the town, and the plant not only pumps the water but generates electricity. The water is obtained from a dug well 50 feet deep and 10 feet in internal diameter. The well is lined with concrete, and the lower part is finished with bricks set without mortar to allow the influx of the water from the alluvium. The plant is equipped with a 50-horsepower Foos gasoline engine driving a generator which supplies current for street and house lighting, as well as for pumping. The well is equipped with two 2-stage pumps, each having a capacity of 225 gallons a minute, driven by 10-horsepower induction motors connected directly to the pumps. The pumps are in the well at the water level. If both pumps are running, the drawdown is 8 feet in one and a half hours, and the capacity of the pumps is greater than the influx.

If only one pump is running, the drawdown is 8 feet in three hours, and the level of the water remains constant. The rate of influx after pumping ceased could not be learned. The water is pumped to a steel tank with a capacity of 30,000 gallons, on a steel tower 100 feet high, only a few yards from the well. The water is distributed by gravity through 12,500 feet of wooden mains from 4 to 8 inches in diameter to 21 fire hydrants and approximately 100 house taps at a pressure of 40 pounds to the square inch. The inhabitants consume about 15,000 gallons a day. In 1921 sufficient care was exercised to prevent pollution, obviating the necessity for treating the water. This water is highly mineralized and hard, containing 4,279 parts per million of dissolved solids consisting of large quantities of sodium and sulphate. (For analysis see No. 93, p. 27.)

OTHER TOWNS

In years to come, as the present towns grow, the demand will arise for more public supplies. Some towns in which each household now obtains its own supply could get along without public supplies if they were not unprotected from fire. For a public supply not only the adequacy but the quality of the water must be considered more carefully than for household supplies. Human beings can use water that would be undesirable for industrial purposes.

The upland towns will always be dependent on ground water and will have to use either wells or springs. Few springs in this region produce sufficient water for a small town, even at their maximum flow, and they fluctuate considerably with the season. Many springs are not only distant from a town but below its level, and the water must be pumped, which entails both the cost of the main and pumps and the expense of pumping. Wells in this area rarely yield adequate quantities of water for large numbers of people. Consequently the outlook for public supplies for the upland towns is not promising. Inasmuch as the location of wells and springs is largely dependent on the geology of the country, the villages in areas of the Bearpaw shale or the Colorado will have difficulty in obtaining ground water unless they have access to springs located along a "rim rock." Wells drilled through these shales might obtain water from the underlying sandstones, but there is always a possibility that the water will be of poor quality or small volume.

The towns along the river will always have the choice of taking the water from the river or from wells in the alluvium. The river furnishes a large supply of water, which usually has a smaller amount of total dissolved solids than the well waters but which is always more or less turbid and always exposed to pollution. On the other hand, wells can be drilled closer to the point of use, saving considerable expense for mains, and suitable precautions can be taken to prevent pollution, but the water may be very high in dissolved solids. The present systems of filtering and purifying water are not simple and require trained men to operate them correctly and efficiently. The plants are expensive to build, and the cost of maintenance is so high as to be prohibitive for a small town. Consequently, wells properly safeguarded are preferable for the small towns.

RAILROAD SUPPLIES

The principal use for water on a railroad is in locomotive boilers. For boiler use water should be low in foaming and scale-forming constituents. Waters of this type are not common in this area.

The Northern Pacific Railway, the pioneer road in this region, followed Yellowstone River, which has been an adequate source of supply for this road. Pumping plants have been installed along the river, and the water is pumped into tanks erected beside the tracks.

The Great Northern Railway, which runs north from Mossmain, on the Northern Pacific Railway, into Musselshell County, does not follow a perennial stream and consequently can not obtain a supply from surface waters. At Comanche the company endeavored to obtain water both from the alluvium and from the underlying Bearpaw shale. The water from the alluvium was unfit for steaming, and the underlying shale did not yield water. At present a dug well in use at this station can yield about 9,000 gallons of water a day. This water is so unsatisfactory that it is used only in emergencies. At Mossmain water from Yellowstone River is used, and at Rimrock a reservoir filled from the irrigation ditch, which obtains its supply from the river.

The Chicago, Burlington & Quincy Railroad does not have the same trouble in Yellowstone County because a short distance from the county line it enters the Yellowstone Valley and uses the Northern Pacific tracks, where the river water is available.

In general the ground waters of the formations above the Cloverly are so highly mineralized as to be unsatisfactory for boiler supplies, and the rivers must remain the chief source of water for railroads.

METHODS OF OBTAINING GROUND-WATER SUPPLIES

SPRINGS

The simplest method of obtaining ground water is to utilize springs. Most of the older ranches were located at or near springs, which supplied water for the people and cattle. In many places small springs or rather areas of evaporation of ground water were noticed, as well as some intermittent springs which flowed only after wet seasons. These places were dug up and suitably walled to form dug wells, which are commonly called "springs" in this region. At times they overflow, but during most of the year the water level is from 1 to 6 feet below the surface of the ground. Wells of this type usually supply adequate quantities of water, though they may go dry in very dry years.

In many parts of the two counties little or no attention is paid to the care of springs. Care should always be taken to improve a spring in order to prevent pollution by foreign objects or surface run-off and filling in with silt. Wooden boxes provided with light covers are better than nothing, but more permanent material, such as concrete, is preferable. More elaborate improvements, such as piping the water to the house, are usually impracticable, because many springs are located in the bottoms of the coulees, below the levels of the houses which they supply. Springs should be cleaned at frequent intervals to remove all animal and vegetable material, as well as soil blown in by the wind.

WELLS

It was early seen that the springs would not supply sufficient water, and therefore the settlers began to put down wells. To-day wells of several kinds are in use, as described below.

DRILLED WELLS

All the drilled wells are sunk with portable percussion rigs, driven by steam or gasoline power. A few years ago there were still several drilling outfits operated by horsepower, but they are now abandoned. Most of the drilled wells are 6 inches in diameter, but some are only 4 inches. The 6-inch wells are better adapted to the conditions of this region than wells of smaller diameter, and in many places 8-inch holes would probably be even more successful because of the larger reservoir afforded by the larger hole.

The necessity of casing wells varies from formation to formation. Wells drilled through shale must be cased, because even if the walls seem firm at the time the well is completed, they will ultimately cave and cause the loss of the well. Casing also decreases the danger of surface pollution. In view of the protection against these dangers that casing affords, the expenditure for it is profitable. One casing should not be expected to last indefinitely, and renewals should be made before the original casing disintegrates completely. The life of the casing depends on such factors as its type and quality, the chemical character of the water with which it comes into contact, and the rock in which it is set.

DUG WELLS

Dug wells, if shallow, require little equipment and no great expenditure of money or labor, and they afford a large reservoir for water, but on the other hand, they are difficult to keep clean and free from pollution. Great difficulty is found in keeping the curbing tight enough to prevent small rodents, in search of water, from falling into the well and drowning. Several kinds of casing or curbing are used for dug wells, but wood, brick, stone, terra-cotta pipe, concrete, and large culvert pipe are the most common. Few dug wells will stand without some form of curbing. So far as holding up the walls is concerned all are equally good, but concrete, terra cotta pipe, and brick (laid with cement above the water table) are tight and very durable. Culvert pipe is good at first but rusts and disintegrates. Rock casing properly set with an impervious cement above the water table is very good, and where rock is available, is cheap. However, rock casings are frequently poorly laid and settle, leaving open spaces. Wood casing, "curbing" or "cribbing" as it is frequently called in this region, is cheap and easily made, but it rots and requires renewal so frequently as to be very expensive over a term of years. It is almost impossible to make a wood casing tight, and even if this is done, rodents can cut through it and get into the well. Frequently the wood will give the water a peculiar taste.

Dug wells are usually boarded over, and a pump is placed on the platform. The boards soon warp, leaving large cracks through which dust, dirt, filth, and small animals enter the well. This should be eliminated by calking the cracks or by using tongue and groove boards or preferably constructing a tight platform of concrete or using a cast-iron platform.

BORED WELLS

In the areas underlain by the alluvium wells can be bored with a hand auger to a depth of about 25 or 30 feet with considerable ease except where coarse gravel is struck. This method is not much used in this region, though it produces almost as good a well as can be obtained by digging. The wells must be cased, and galvanized-iron well casing is the kind most commonly used. Concrete casing perforated below the water level makes an excellent casing and is most durable.

DRIVEN WELLS

Driven wells are not common in these counties and can not be constructed except in places underlain by loose material that does not contain much coarse gravel. A strong point should be used with a good strainer above it. As drive points are not expensive and the pipe is driven in with a sledge, a very cheap well is obtained when this method is successful.

Driven wells are very satisfactory and are safer from pollution than shallow wells of other types. The pump must be tightly clamped down to some solid foundation, or the pumping will so loosen the pipe that pollution can enter the open space between the pipe and the earth. Mr. J. J. Snyder, the blacksmith at Mossmain, has a driven well 15 feet deep which is very satisfactory. However, in the Yellowstone Valley more or less difficulty has been experienced with coarse or consolidated gravel beds obstructing the point.

STORAGE OF SURFACE WATER

CISTERNS

Cisterns are used on many ranches in Yellowstone and Treasure Counties. They are filled either directly from irrigation ditches or by hauling water from the river and are used to store water for domestic purposes by many people in the irrigated districts. On the uplands there are a few cisterns filled with water hauled from distant springs, wells, or streams. Cisterns [17] are easily constructed and have many advantages as well as disadvantages.

The use of untreated surface water for all domestic purposes may lead to typhoid fever, and as typhoid inoculation is not a perfect preventive it is recommended that no surface waters be used until they have been treated to destroy all harmful bacteria they may contain. Dr. W. M. Cobleigh, of the Montana State Board of Health, has devised the following method [18] of purifying cistern water:

When a surface water secured at a point below human habitations or other sources of contamination is used for domestic purposes a decided risk is involved. A water of this character should be purified before it is used for human consumption. The following procedure is recommended for purifying a contaminated water which is stored in a cistern for domestic use.

Calculate the number of gallons of water in the cistern. Add to the cistern water the proper amount of the solution of chloride of lime or bleaching powder according to the following procedure:

Secure a can of fresh bleaching powder or chloride of lime. Break up all lumps in a small portion of the powder. It has been calculated that one level teaspoon of the dry powder will disinfect under ordinary conditions approximately 315 gallons of water. Knowing the number of gallons of water in the cistern, calculate how many teaspoons of bleaching powder will be necessary to disinfect all the water in the cistern. In measuring the bleaching

[17] Fuller, M. L., Underground waters for farm use: U. S. Geol. Survey Water-Supply Paper 255, pp. 54–58, 1910. Ellis, A. J., and Meinzer, O. E., Ground water in Musselshell and Golden Valley Counties, Mont.: U. S. Geol. Survey Water-Supply Paper 518, pp. 43–46, 1924.

[18] Cobleigh, W. M., private communication.

powder fill a teaspoon even full by leveling off with a small stick or lead pencil. To the measured quantity of bleaching powder add a few drops of water, stir, and make a thick paste. This operation can conveniently be carried out in an ordinary bowl. The paste is then diluted with water and this thinner paste should then be poured into a 5 or 10 gallon pail of water. Allow the sediment in this solution to settle for a few minutes. Then pour the solution into the cistern and thoroughly mix it with the cistern water. This can be done with a pail to which is attached a rope. The pail can be alternately filled with water and emptied back into the cistern to assist in properly mixing, or the pail should be filled with water and then dropped from a convenient elevation back into the cistern again.

After thoroughly mixing the bleaching-powder solution with the cistern water, allow the action to continue for 10 minutes. Fill a drinking glass with water from the cistern and add a few drops of ortho-tolidin solution. If a slight yellow color appears when viewing the water through the glass, placed in front of a white sheet of paper, then it is certain that the proper amount of bleaching powder has been added. When this color appears it means that there is an excess of chlorine in the water which will destroy germs of the intestinal type in a very few minutes' time. If no yellow color appears on addition of ortho-tolidin, then it means that more of the bleaching-powder solution should be added to the cistern water. In that event add a little more of the bleaching-powder solution and repeat the color test with the ortho-tolidin. If this procedure is properly carried out there will be no disagreeable odors and tastes left in the water. This procedure does not introduce poisonous chemical substances into the drinking water. This method of water disinfection is perfectly safe and effective when controlled by the ortho-tolidin test.

The citizens of the State desirous of using this method of disinfecting cistern water may secure the necessary ortho-tolidin on application to the State board of health.

The method of catching rain water from roofs of houses is little used in this region, possibly owing to the irregularity and scantiness of the rains. However, a considerable amount of rain water can be collected even from a single shower. Rain water is the softest of all natural waters and when properly handled will remain in a usable condition for a long time. It can be used for all purposes. If the water is to be used for the house, care must be taken to allow the roof to wash off before turning the water into the cistern. This is also desirable but not absolutely necessary if cistern water is used for stock only. The advantages and disadvantages of cisterns have been discussed in previous Survey publications.[19]

TANKS FOR STOCK WATER

Settlers in regions where successful wells are difficult to obtain and springs are very rare, as in the areas where the Colorado and Bearpaw shales are at the surface, frequently construct "tanks" by damming small washes. These tanks hold enough water to supply herds of moderate size. Even in hot, dry summers they hold water for a considerable period, in spite of the high rate of evaporation.

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[19] Fuller, M. L., op. cit. Ellis, A. J., and Meinzer, O. E., op. cit.

The rancher should select a small wash or coulee with relatively low sides, and at a point where it narrows a little construct a dam. Great care must be used in selecting the proper wash and the best location in it for the dam. If the drainage area is too large or the fall of the stream at the point selected too great, the dam will be swept away by the first heavy rain. The best way is to watch the washes during storms and note the relative volumes of water and the rate of flow. One carrying a fairly large volume should be selected, and the dam should be located at the point where the velocity is small and the surroundings suited for the least amount of embankment.

These tanks have earth dams or embankments made by plowing up the soil and shale above the dam and putting it in place with scoops. The tramping of the animals' hoofs and the dragging of the scoops pack the earth. Great care must be taken to keep trash, rocks, roots, sagebrush, and greasewood from getting into the dam because, if this precaution is not taken, the water will percolate along these objects, move the fine particles, and finally wash out the dam. Generally a spillway should be provided to care for the excess water. This should be riprapped with stones or constructed of concrete. If stone is available it is of course much cheaper but not as satisfactory as concrete.

A tank having an area of 10,000 square feet (100 feet square) and averaging 4 feet in depth will hold 300,000 gallons of water. If the bottom is shale it is almost impervious, and almost the only loss is by evaporation. If two-thirds of the water were lost by evaporation, a liberal estimate, there would be left 100,000 gallons, which would be sufficient to supply 50 head of cattle for 100 days, allowing 20 gallons a day for each animal, which is also a liberal estimate.

The cost of constructing such a tank is difficult to estimate, as the average rancher would have no expenses except for labor in plowing and scooping the dirt and possibly hauling stone for riprapping. If a concrete spillway is constructed the cost will be higher and will vary with the price of cement at the railroad and the distance it must be hauled.

STORAGE OF ICE

In many parts of Montana the ranchers near streams or lakes cut ice and store it in ice houses. In some places tanks are used as a source of ice. The ice is taken out and used in summer, both as a cooling agent and as a source of water for domestic purposes. The water obtained from ice generally contains less mineral matter than the water from which it froze. In some regions where ice is not available snow is used. However, it should be remembered that ice cut from a body of polluted water or snow that has drifted and picked up surface filth is more or less polluted and dangerous to health.

GROUND-WATER CONDITIONS BY TOWNSHIPS

T. 1 N., R. 23 E.

The western tier of sections in T. 1 N., R. 23 E., lies in Stillwater County; the rest of the township is in Yellowstone County.

The oldest outcropping formation is the Colorado shale, which underlies the Eagle sandstone in the canyons near the south edge of the township. It is a very poor source of water and will probably yield only small quantities of highly mineralized water. The Colorado shale is approximately 2,250 feet thick in this region. The Cloverly sandstones, which underlie the Colorado shale, would probably produce considerable water and give rise to flowing wells in some places. The water from the Cloverly may, however, contain sufficient hydrogen sulphide or natural gas to make it unusable for domestic purposes. A few springs occur at or near the contact of the Colorado shale with the overlying Eagle sandstone. In the SE. ¼ sec. 33, on the property of J. A. Campbell, several springs near the Eagle sandstone-Colorado shale contact flow a few gallons a minute. The analysis of a sample of water collected from one of these springs (No. 4, p. 19) shows that the water is hard and has rather large quantities of sodium and sulphate.

The Eagle sandstone is not as good a source of water in this township as in some other parts of the county. Farmers are reported to have experienced difficulty in secs. 33 to 36 in obtaining adequate supplies by drilling. In the NW. ¼ sec. 35, on the property of John Wold, a spring flows a small quantity of water, which is used for domestic purposes. The water deposits some "white alkali" around the spring.

The Claggett formation overlies the Eagle sandstone and is at the surface in a broad belt extending across the township. Owing to the numerous sandstones in this formation the belt has a rough topography, with little land suitable for cultivation and few inhabitants. Hence there has not been much drilling into the Claggett in this township. The sandstone beds will probably yield water, but it is difficult to predict the quality. In the SE. ¼ sec. 24, on the property of C. Carter, there is a spring whose water is used for stock and considered to be of poor quality. In sec. 26, on the property of H. C. Hendrickson, a dug well 18 feet deep gets its water from the contact of the shale and sandstone. The water is considered to be fair and is used for stock.

The Judith River formation overlies the Claggett in the northern part of the township and forms elevated rolling farming country with a chocolate-brown soil. It is probably the best water-bearing formation in ths township and will usually yield supplies satisfactory for household purposes to wells drilled to a depth of about 100 feet. In the SE. ¼ sec. 1, on the property of William Smith, there is a good spring, and on the property of J. G. Conkley a dug well 20 feet deep, which yields water satisfactory for domestic use. In secs. 10, 11, 19, and 20 drilled wells ranging from 21 to 92 feet in depth produce adequate supplies of usable water. The water generally comes from a bed of sandstone. In the NE. ¼ sec. 12, on the property of W. W. Smith, a dug well 33 feet deep produces an adequate supply of water that can be used for most purposes. (See analysis No. 3, p. 19.) In secs. 8, 9, 10, 11, 12, and 16 numerous small springs are found in the coulees. In the NE. ¼ sec. 30, on the property of G. Downs, a drilled well 46 feet deep yields an adequate supply of water for domestic purposes as well as for irrigating a truck patch about 20 feet square. This well will yield about 100 gallons every 10 minutes.

T. 2 N., R. 23 E.

The western tier of sections in T. 2 N., R. 23 E., lies in Stillwater County. The Buffalo Trail runs north through the township 1 mile east of the county line. The Claggett is the oldest formation that crops out in this township, and the areal extent of its surface exposure is small. Erosion has brought it to the surface in only a few deep coulees. In the NE. ¼ sec. 36, on the property of C. H. Michels, a dug well 30 feet deep in a coulee yields water of poor quality. It ordinarily produces enough water for 11 head of stock, but it goes dry at times in the winter. In sec. 36 a well 220 feet deep was drilled through 50 feet of the Judith River and about 170 feet of the Claggett. This well yields only a small quantity of water reported to have a "soda" taste. Springs are found at places along the Judith River-Claggett contact, but they frequently dry up during long hot summers.

The Judith River formation, which overlies the Claggett formation, is at the surface over the entire township except in a few small areas. In the NE. ¼ sec. 24, on the property of W. P. Wall, there is a 6-inch drilled well about 285 feet deep, which draws its supply from a sandy stratum about 60 feet below the surface. The water is hard and contains 1,393 parts per million of total dissolved solids. (See analysis No. 6, p. 19.) The 20 Mile Oil Co. drilled a well in the same section and got a good supply of water at 120 feet. In the NW. ¼ of the same section a 10-foot dug well produces plenty of water for stock. In sec. 26, on the property of Henry Popelka, a 6-inch drilled well 75 feet deep produces a plentiful supply of water for household use from a sandy stratum 54 feet below the surface. In the SW. ¼ sec. 28, on the property of C. H. Gowan, a drilled well 72 feet deep produces an adequate supply of soft water, which is used for domestic purposes. This water contains 1,227 parts per million total dissolved solids, consisting chiefly of sodium and bicarbonate. (See analysis No. 7, p. 19.) In the SW. ¼ sec. 36, on the property of H. A. Rademacher, a drilled well 180 feet deep produces an adequate supply of relatively good water. In the SE. ¼ of the same section, on the property of F. Michels, a drilled well 220 feet deep yields a small amount of fairly good water. Generally, where the Judith River formation is not too thin it will yield fairly abundant supplies of good water to wells 150 feet or less in depth.

The Bearpaw shale rests on the Judith River formation in secs. 2, 3, 4, 5, and 6. It is exceedingly unsatisfactory as a source of water.

In the northern row of sections the Judith River formation is covered by Quaternary alluvium. In the SE. ¼ sec. 2, on the property of Mrs. Ross Ballard, a dug well 42 feet deep produces considerable water, which, however, is unfit for household use. This water contains 5,566 parts per million total dissolved solids, consisting chiefly of sodium sulphate (Glauber's salt). (See analysis No. 5, p. 19.) In sec. 4 a dug well 3 feet in diameter produces considerable quantities of water that is used for stock. The sand and clay of the Quaternary alluvium in this township generally produce water of poor quality.

T. 3 N., R. 23 E.

The Eagle sandstone crops out in secs. 6, 7, 8, 17, 18, and 19, T. 3 N., R. 23 E., on the east half of a prominent structural dome. In secs. 6 and 7 good wells are reported in this sandstone, but on the west half of the dome, in Stillwater County, well drillers have had difficulty in obtaining water from it.

Though the area of the Claggett formation, which overlies the Eagle formation, is considerable, very few attempts have been made to drill or dig in this shale to obtain supplies of water. This formation is unpromising as a source of water. In the NE. ¼ sec. 20, on the property of J. D. Welch, a spring issues from the Claggett and flows a few gallons a minute; the water is used for stock.

The Judith River formation, which is immediately above the Claggett formation, covers a considerable area in the township and is a good water-bearing formation. In the SW. ¼ sec. 4, on the property of William Reamer, a 6-inch drilled well 80 feet deep produces an adequate supply for household purposes, but the water tastes a little salty. In the SE. ¼ sec. 20, on the property of J. D. Welch, a drilled well 6 inches in diameter and 64 feet deep yields an ample supply of water for domestic use. In sec. 29 a spring, carefully boxed, yields a few gallons a minute, but the water is used only for stock. In the NW. ¼ sec. 28, on the property of S. W. Grant, a dug well 8 feet deep ending in a sandstone produces an adequate supply of water for domestic purposes. The water contains 788 parts per million total dissolved solids and should be satisfactory for most ordinary uses. (See analysis No. 9, p. 19.) In the NW. ¼ sec. 32, on the property of J. Hunt, a small spring supplies water for stock. In the SE. ¼ sec. 32 a 30-foot dug well in a coulee yields plenty of usable though somewhat hard water.

The Bearpaw shale, overlying the Judith River formation, is at the surface in only a small area and is unpromising as a source of water. It is not advisable to drill into this formation to reach Judith River beds where it is necessary to drill through the entire 800 feet of the Bearpaw. Small supplies are sometimes found by digging shallow wells in the coulees.

In the eastern part of this township the Quaternary alluvium of the Comanche Flat is well developed. Dug wells on this flat are usually successful as to the quantity of water obtained, but as a rule the water is so poor that it can not be used for domestic purposes. In the NW. ¼ sec. 17 Mr. Holtzclaw dug two wells only a few yards apart, both less than 20 feet deep. One yielded water unfit for use; the other yields potable water that contains 1,103 parts per million total dissolved solids. (See analysis No. 8, p. 19.)

It is not wise to drill through the Quaternary alluvium except in areas where the alluvium is underlain by the Judith River or the Lance formation, and in such areas great care must be taken to case out the alluvium waters.

The southwest quarter of this township is cut by a band of faulting, which greatly disturbs and complicates the ground-water conditions.

Charles Murray, who drilled a well 2,440 feet deep in the SW. ¼ sec. 7, obtained water from one of the sandier beds in the Colorado shale which contained 18,820 parts per million total dissolved solids. This water is unusual in that it contains 10,992 parts per million of chloride.

T. 4 N., R. 23 E.

The Claggett formation lies at the surface in the southwest corner of T. 4 N., R. 23 E. It contains some sandy beds that may yield water, but the topography is rougher than in most of the rest of Yellowstone County. Practically no drilling in this formation is reported.

The Judith River formation underlies much of the western part of the township and is a good source of water. Particularly noteworthy are the strong springs in secs. 20 and 21, which furnish the municipal supply of Broadview. The water from the spring in sec. 20 is hard, containing 638 parts per million total dissolved solids. (See analysis No. 11, p. 19.) Drilled wells have been universally successful, and water is usually struck at depths of less than 125 feet.

The Bearpaw shale forms a depression in which the town of Broadview is situated. This shale is unpromising for water, and practically all wells drilled into it are dry. One very deep but dry hole was drilled in this shale in Broadview.

The Lennep sandstone is a rather thin formation which apparently has excellent prospects of being a good source of water, but little or no drilling has been done in it, and consequently trustworthy predictions concerning its yield can not be made. The formation, which consists largely of andesitic sandstone, is porous, with numerous bedding planes. Its areal extent in this township is small.

The Lance formation, consisting of sandstone and shale, covers the northeastern part of the township. Wells in this formation usually yield only small supplies of moderately mineralized water, which may contain considerable quantities of sulphate, bicarbonate, and sodium. (See p. 36.) The wells range in depth from about 60 to 200 feet. In the SW. ¼ sec. 10, on the property of S. A. Waterman, a 6-inch well 90 feet deep produces an adequate supply of water for domestic purposes. In sec. 11 a drilled well produces some water, which is reported as having a "soda" taste. In the SE. ¼ sec. 12, on the property of J. A. Beck, a 6-inch drilled well 97 feet deep produces water in considerable quantities. This water contains 2,558 parts per million total dissolved solids, the principal constituents of which are sodium and sulphate. (See analysis No. 10, p. 19.) There are several other drilled wells in the section, but they produce poor water

The Quaternary alluvium of Comanche Flat rests upon both the Lance and the Bearpaw. Dug wells in the alluvium ranging in depth from 20 to 60 feet produce adequate quantities of water for stock, but only a few of the wells yield water that is usable for domestic purposes.

Broadview is the only town in either county with a municipal supply obtained from springs. (See p. 54.)

T. 1 S., R. 23 E.

In the part of T. 1 S., R. 23 E., lying in Yellowstone County the surface formation is the Eagle sandstone or the Claggett formation, except in a small area where the Colorado shale is at the surface. The township embraces some of the Canyon Creek region and is an area of considerable relief, some parts being rather inaccessible.

The Colorado shale, the oldest formation that crops out in the township, is a poor source of water. In places it contains gypsum. It has a thickness of about 2,250 feet, which prohibits drilling to the underlying water-bearing sandstone, except at great cost.

As a whole the Eagle sandstone has proved disappointing as a source of water in this township. In secs. 1, 2, 11, 12, 13, and 14 there has been little or no drilling for water. In the NE. ¼ sec. 22 a group of springs flow many gallons a minute and according to local estimates furnish sufficient water for 2,000 head of stock. In sec. 24 several wells were drilled in this formation, but none of them obtained adequate amounts of water. Secs. 23, 24, 25, 26, 35, and 36 are on a gently sloping upland underlain by the Eagle sandstone, in which three unsuccessful wells were drilled. In the NE. ¼ sec. 26, on the property of C. Clapper, a drilled well 65 feet deep yielded only 50 gallons a day of water, which was used for stock. This well is now abandoned. Owing to poor crops and poor water supply this area, once inhabited and farmed, is now almost abandoned, and little definite information concerning wells could be obtained.

As mentioned by Hancock,[20] in the Canyon Creek region the Claggett formation contains an unusual amount of sandstone, and consequently the topography is exceptionally rough. Few wells have been drilled or dug into this formation. Indefinite reports of failure to obtain water were heard, but nothing definite could be learned. In the NW. ¼ sec. 22, on the property of J. J. Meyers, a spring flows a few gallons a minute, and the water is used for domestic purposes. In the SE. ¼ sec. 28, on the property of the Dull estate, there is a reliable spring yielding several gallons a minute, and the water is used for stock.

Inasmuch as the Eagle sandstone has proved to be a poor source of water in this township and the Claggett is not very promising, the probabilities of obtaining adequate supplies for domestic purposes are rather remote.

T. 2 S., R. 23 E.

Only part of T. 2 S., R. 23 E., lies in Yellowstone County; the western tier of sections is in Stillwater County, and the part south of Yellowstone River is in Carbon County. The Eagle sandstone scarp runs through the northern tier of sections, dividing the river valley from the rolling uplands.

The Colorado shale is a very poor source of water itself, and its thickness, 1,700 to 2,000 feet in this area, almost prohibits, on account of the cost, drilling through it to the underlying formations. Only a small area is underlain by the Eagle sandstone, and most of this is so close to the scarp or so thoroughly dissected that it would probably not yield water.

Along Yellowstone River there are two and in places three more or less clearly defined terraces. The highest one in most places is clearly separated from the lower ones. It is generally covered by gravel, but the gravel is not everywhere sufficiently thick to contain much water. A large part of the highest terrace is so thoroughly dissected that it has been drained of all ground water.

At the foot of the highest river terrace in this township runs the so-called Cove irrigation ditch, and nearly all the land below it is irrigated. The irrigation and the seepage from the ditch have so saturated the gravel and sand overlying the impervious Colorado shale that many places have gone to "alkali"—that is, the water table and the land surface nearly coincide—and produce an area of evaporation, with the deposition of the salts contained in the water, ruining the land for farming. Some of the areas of "alkali" thus formed have been underdrained and are again productive. A plentiful supply of water can generally be obtained by drilling or digging to a depth of 50 feet or less in the alluvium in the valley. This water is usually too highly mineralized for human consumption but can be used for cattle. For domestic purposes the inhabitants use ditch water stored in cisterns.

One of the older inhabitants stated that about 40 years ago the depth to water in secs. 11, 12, 13, and 14 was approximately 30 feet and that there were no cottonwood trees except along the river banks. To-day the water level is in many places less than 10 feet below the surface. The cottonwood trees planted since the beginning of irrigation and now of large size are being rapidly killed by the rise of the water table.

In the SE. ¼ sec. 11, on the property of E. Coombs, a shallow dug well produces a large quantity of highly mineralized water which is used for stock. In the NW. ¼ sec. 14, on the property of H. Shay, a 50-foot dug well, a 50-foot

[20] Hancock, E. T., Geology and oil and gas prospects of the Lake Basin field, Mont.: U. S. Geol. Survey Bull. 691, p. 116, 1918.

drilled well, and a 15-foot dug well produce large amounts of fair water. The water in the dug wells stands about 10 feet below the surface. In the SE. ¼ sec. 15, on the property of A. G. Rich, a 6-inch drilled well, 21 feet deep, obtains from gravel a supply which is considered fairly good.

In some localities very close to the river the water in shallow dug wells is exceptionally good and is usable for all domestic purposes. However, people living close to the river generally haul water from the river instead of digging a well, preferring the river water on account of its lower mineral content.

In the SW. ¼ sec. 12, on the property of F. W. Schauer, a well was drilled for oil but has never been a commercial producer. It is now flowing about 8 gallons a minute of water that has a temperature of 67.5° F. and contains considerable natural gas and a very little oil. This well is 2,285 feet deep, but the water comes from a fine-grained white sand 1,950 to 1,955 feet below the surface. This water contains 1,994 parts per million total dissolved solids, consisting chiefly of sodium and bicarbonate. (See analysis No. 12, p. 19.) It apparently comes from the Cloverly formation underlying the Colorado shale.

T. 1 N., R. 24 E.

The southeastern part of T. 1 N., R. 24 E., is underlain by the Colorado shale. Where the Colorado is not covered by terrace gravel it is almost useless to seek supplies of water either by drilling or digging. In the SE. ¼ sec. 34, on the property of D. B. Bridenbau, two dug wells produce water of so poor a quality that it is only rarely used even for stock. In the SW. ¼ sec. 34, on the property of D. T. Gorrell, a 6-inch drilled well, 90 feet deep, furnishes a small supply of water, too poor for drinking or domestic use. A 60-foot drilled well in the same quarter section produces water unfit for any use.

The Eagle sandstone crops out over a large area, but it is not a good source of water. In secs. 31 and 32 difficulty has been experienced in getting good wells. A few springs occur at the contact of the Eagle and the overlying Claggett formation. A part of the belt in which this formation crops out is rough and thinly settled. Along the Buffalo Trail, in sec. 23, several wells have been drilled and several have been dug, but no information was obtainable, as the places were abandoned.

The Claggett formation lies at the surface in a large part of this township. The topography is rough, owing to an unusual number of sandstone beds in the shale. There are few houses and very few wells in this area. A dug well 60 feet deep, in sec. 1, produces water that is used for domestic purposes, though it is reported to be high in mineral content. In the SW. ¼ sec. 10, on the property of J. Wormser, a drilled well 90 feet deep produces an adequate supply of very hard water which is used for stock and which contains 6,899 parts per million total dissolved solids with a large quantity of sulphate. (See analysis No. 13, p. 19.) In the SE. ¼ sec. 11, on the property of R. W. Husband, a dug well 30 feet deep in a coulee produces an abundance of water, which contains 2,945 parts per million total dissolved solids and is similar in chemical character to the water in the well of Mr. Wormser. (See analysis No. 14, p. 19.) In the SW. ¼ sec. 11, on the property of Davis Robinson, a dug well 35 feet deep yields water that is used for domestic purposes, although it is highly mineralized. In sec. 30, on the property of L. G. Mason, a drilled well 160 feet deep, pumped by a windmill, yields a supply of hard water that is unfit for house use. In sec. 21 a dug well 35 feet deep in a coulee produces an adequate supply of water that is potable but is too hard to be satisfactory for washing. In sec. 32 a 6-inch drilled well 143 feet deep yields water that is used for stock. In the NE. ¼ sec. 12, on the property of M. York, a drilled well 105 feet deep yields sufficient water for domestic purposes, but the water is reported to have an "alkali" taste. The Claggett formation in this region is somewhat variable in the quantity and quality of water it yields, and in its area dug wells are usually more practicable than drilled wells because of their lower cost. The dug wells should be located in coulees.

The Judith River formation, which overlies the Claggett in the northwest corner of the township, is a good water bearer, and wells in it are almost uniformly successful. In sec. 6 S. Reid has several drilled wells ranging in depth from 50 to 140 feet, all producing moderate amounts of water suitable for domestic use. In sec. 8, where the dissection makes the draining away of the ground water less difficult, of four drilled holes 40 to 60 feet deep three are dry, and the other yields only a meager supply.

T. 2 N., R. 24 E.

T. 2 N., R. 24 E., has about equal exposures of the Claggett formation, forming depressions, and of the Judith River formation, forming uplands. The contact between these formations is the site of many springs and seeps. The Bearpaw is exposed in the northeastern part of the township, and the Quaternary alluvium in the north-central and northwestern parts. This township is crossed by several faults.

The Claggett formation as exposed in this township is more typical of the unit than the exposures in the Canyon Creek region, the sandstones being absent. In sec. 14 a dug well about 60 feet deep in a coulee supplies water that is used for domestic purposes and is without objectionable taste. In the NE. ¼ sec. 19 an unimproved spring flows several gallons a minute from the shale. There is considerable "white alkali" around this spring. In the SW. ¼ sec. 20, on the property of M. J. McCarthy, a dug well 18 feet deep furnished water that was regarded as satisfactory. A dug well 20 feet deep on the property of J. S. Coakley, in sec. 22, yields water that is used only for stock. A dug well in the NW. ¼ sec. 30 yields an adequate supply of water for domestic purposes. In the SW. ¼ sec. 30, on the property of H. J. Bollion, a drilled well 207 feet deep yields a very small supply of water that is considered soft. This well starts in the Judith River formation; the character of the water indicates that it probably comes from a horizon in the Judith River and not from the Claggett. In the NW. ¼ sec. 30 a dug well on the property of H. J. Bollion yields an adequate supply of water for domestic purposes. In the NW. ¼ sec. 31, on the property of S. Reed, a spring yields a few gallons a minute of water that is considered good. In the SE. ¼ of the same section is a very small spring. In sec. 32 a drilled well 53 feet deep produces plenty of water for stock. The water rises in this well within 16 feet of the surface. In the SE. ¼ sec. 31, on the property of H. H. Mammen, a dug well 28 feet deep yields an adequate supply of water for domestic purposes, though the water is reported to have a slight taste of "alkali." In the same quarter section is another dug well that went dry during the summer of 1921. In the SW. ¼ sec. 32 a supply of fairly soft water is obtained from sandstone at the bottom of a drilled well 105 feet deep. This well, on the property of H. Ross, can not be pumped dry by a 1½-horsepower gasoline engine. The quantity and quality of water obtained from the Claggett formation are variable, but in this township drilled wells should be successful at depths of less than 200 feet and dug wells in coulees at depths of not more than 35 feet. All wells will not yield water that is usable for domestic purposes.

The Judith River formation overlies the Claggett formation. In the NE. ¼ sec. 13, on the property of Mrs. B. Iverson, a 6-inch drilled well 104 feet deep produces a considerable quantity of water containing 8,134 parts per million total dissolved solids. (See analysis No. 16, p. 19.) This water is hard and contains large quantities of sodium and sulphate but is used for stock. Another drilled well in sec. 13, 40 feet deep, yields a small amount of bitter water, which stock will not drink. In the NE. ¼ sec. 20 a small spring at the Judith River-Claggett contact flows a few gallons a minute. The water, which is used for domestic purposes, is moderately hard, containing 832 parts per million total dissolved solids. (See analysis No. 17, p. 19.) In the southeast corner of sec. 20 a drilled well 300 feet deep is dry. In the NW. ¼ sec. 22, on the property of M. J. McCarthy, a dug well 10 feet deep produces a large quantity of hard water containing 4,152 parts per million total dissolved solids with large quantities of sodium and sulphate. (See analysis No. 18, p. 19.) The water is used for stock. In the NE. ¼ sec. 24, on the property of J. W. Woody, a drilled well, the exact depth of which could not be learned, furnishes domestic supplies of water that is considered to be only fair. In the NW. ¼ sec. 28, on the property of A. D. Hanson, a dug well 38 feet deep yields ample supplies of fairly good water. In the NE. ¼ sec. 30, on the property of M. J. McCarthy, a dug well 20 feet deep yields water that is used for stock. In the NW. ¼ sec. 32, on the property of E. Popelka, a 6-inch drilled well 92 feet deep yields about a barrel a day of moderately hard water which is used for domestic purposes. This water contains 1,413 parts per million total dissolved solids. (See analysis No. 19, p. 19.) In the NW. ¼ of the same section a 6-inch drilled well 250 feet deep produces only a very small quantity of fairly good water. Doubtless the water comes from the Judith River formation, and the last 175 to 200 feet of the well, in the underlying Claggett formation, is dry. These wells are not as good as is usual for Judith River wells. Drilled wells in the Judith River are not so numerous in this township as elsewhere. In general, drilled wells in this formation should yield supplies suitable for domestic use from depths of not more than 200 feet. Dug wells in coulees should yield adequate supplies from depths of not more than 30 feet.

The Bearpaw shale is a poor source of water. The town of Acton, on the Great Northern Railway, is situated on the Bearpaw, and the wells around the town yield rather poor water, so that almost all water for domestic purposes must be hauled to town from wells and springs. In the NE. ¼ sec. 12, on the property of A. D. Hanson, a bored well ending in shale, 18 feet deep, produces a moderate amount of highly mineralized water, containing 9,608 parts per million total dissolved solids. The water has large quantities of sulphate, calcium, magnesium, and sodium but is used for stock. (See analysis No. 15, p. 19.) In the SW. ¼ of the same section an 80-foot drilled well owned by Mrs. White yields water which is used for domestic purposes. In the SW. ¼ of the same section, on the property of the Acton Townsite Co., a drilled well 205 feet deep yields a small quantity of bad water. In the SE. ¼ of this section, on the property of A. D. Hanson, a dug well 10 feet deep yields bitter water which stock will not drink. However, in this same quarter section, on the property of E. C. Tressman a 20-foot dug well yields fairly good water. Several other attempts to drill and dig wells have ended in total failure.

The Quaternary alluvium and lake beds (?) cover part of the northern row of sections, which form a part of the large Comanche Flat. In the NE. ¼ sec. 2, on the property of M. Flanigan, a drilled well of unknown depth produces a good supply of water which is used for domestic purposes but which is reported to have a taste due to dissolved material. In the SW. ¼ sec. 6, on the property of M. Flanigan, a dug well 12 feet deep yields an adequate supply of rather hard water. In the NE. ¼ sec. 8, on the property of C. Mainwaring, a dug well 28 feet deep ends in gravel and yields an adequate supply of water that has sufficient dissolved material to give a taste but is used for domestic purposes.

T. 3 N., R. 24 E.

More than half of T. 3 N., R. 24 E., is in the Comanche Flat, where the Quaternary alluvium is at the surface. The Lance, Lennep, and Bearpaw crop out in the eastern part of the township.

The Bearpaw shale, which is at the surface in only a small area, yields very little water that is good enough to be used. In the SW. ¼ sec. 24, on the property of C. Looney, two shallow dug wells yield supplies for stock.

The Lennep sandstone appears to be a satisfactory source of water, but owing to its small area of outcrop and also the fact that the overlying Lance is fairly productive of ground water, the Lennep has not been thoroughly tested as to the quality and quantity of the water it will yield.

The Lance formation is an alternation of lenticular masses of sandstone and shale. Water supplies are usually obtained from the sandstone, though in places the shale yields small supplies. In the SW. ¼ sec. 4, on the property of O. H. Oswald, a 6-inch drilled well about 75 feet deep yields a fair supply of somewhat hard water that is used for domestic purposes. Close to this well in the same section is a dug well 30 feet deep producing a large quantity of fairly good water that is used for stock. In the NE. ¼ sec. 10 a drilled well 100 feet deep yields an adequate supply of water for domestic use. In the NW. ¼ and SW. ¼ of this section there are drilled wells approximately 100 feet deep. In the NE. ¼ sec. 12, on the property of C. Watts, a drilled well 160 feet deep produces a large supply of soft water that is satisfactory for all ordinary uses. This water contains 644 parts per million total dissolved solids. (See analysis No. 20, p. 19.) A 6-inch drilled well 200 feet deep in the SW. ¼ of this same section, on Mr. Carney's property, yields an adequate supply of water which is used for domestic purposes, though very hard. A 1½-horsepower gasoline engine running continuously can not pump this well dry. In the NE. ¼ sec. 15, on the property of Joseph Betts, a 6-inch drilled well 98 feet deep can not be pumped dry by hand, but the water tastes salty and is fit for stock only. A dug well 45 feet deep in the SW. ¼ of the same section, on the property of V. H. Smith, produces hard but usable water. In the summer of 1921 this well had 2 feet of water in it and was running low, barely supplying the needs of 30 head of stock. As a whole the Lance formation is a fairly good source of water. Wells in it usually do not produce large quantities of water, but the quality is generally satisfactory. Water is generally obtainable at a depth of less than 200 feet.

The Comanche Flat is covered with Quaternary alluvium consisting of sand, silt, and gravel ranging in a depth from only a few inches at the edge to 75 feet or more in some places. In the SW. ¼ sec. 10, on the property of H. O. Heffelfinger, a 6-inch drilled well produces about 4,000 gallons a day when pumped morning and evening. The water is considered to be soft and is used for domestic purposes. In the NW. ¼ sec. 20, on the property of G. E. Sherwood, a dug well 22½ feet deep produces a considerable quantity of hard water that is used for domestic purposes. This water contains 1,567 parts per million total dissolved solids. (See analysis No. 21, p. 21.) In sec. 20 a dug well 32 feet deep, belonging to the Great Northern Railway Co., is reported never to go dry. When it is cleaned out and in good condition it will yield about 9,000 gallons in 24 hours. Its water, however, is highly mineralized, and on account of its scaling and foaming properties it is used for locomotives only when absolutely necessary. In this same section only a few yards from the railroad well a dug well 16 feet deep produces fairly good water from "quicksand." In the SW. ¼ sec. 22, on the property of Ed. Beam, a dug well 25 feet deep produces a considerable supply of fairly good water that is used for domestic purposes. In the SE. ¼ sec. 26, on the property of G. Conover, a dug well 25 feet deep ends in blue clay and yields water that is objectionable for domestic use but is used for stock. In the NW. ¼ sec. 26, on the property of A. Krueger, a dug well 12 feet deep produces water containing 16,471 parts per million total dissolved solids. This water has very large quantities of sulphate, magnesium, calcium, and sodium but is used for stock. (See analysis No. 22, p. 21.) In the SE. ¼ sec. 30, on the property of G. F. Case, a dug well 25 feet deep produces a fair amount of water that is suitable for domestic purposes. In the NE. ¼ sec. 34, on the property of J. H. Loosee, a dug well only 15 feet deep furnishes an adequate supply of fairly good though hard water. In the SE. ¼ of the same section two dug wells go dry at times. In the NW. ¼ a dug well yields a fair amount of satisfactory water.

In most places the alluvium will yield water in considerable quantities at depths of less than 60 feet. This water, however, is rarely very satisfactory. Most of it can be used only for stock, and some is too bad for any use. In places the ground water is less plentiful, and the quality varies greatly within a small area.

Comanche, on the Great Northern Railway, is a small town on the alluvial flat without waterworks. The inhabitants get their water from wells.

T. 4 N., R. 24 E.

The only formations that crop out in T. 4 N., R. 24 E., are the Lance, the Lebo shale member of the Fort Union, and the Quaternary alluvium of the Comanche Flat.

The Lance formation consists of alternating lenticular masses of sandstone and shale. Usually more ground water is obtainable from the sandstone than from the shale, and many of the largest supplies come from sandstone underlain by impervious shale. In the SW. ¼ sec. 4, on the property of C. B. Barr, an 8-inch drilled well 165 feet deep, drawing its water from a bed 152 feet below the surface, yields an adequate supply of fairly good water, which rises within 47 feet of the surface. In the NW. ¼ sec. 8, on the property of N. Davids, a 6-inch drilled well 60 feet deep produces an adequate supply of water for stock. Close by this well is a 6-inch drilled well 100 feet deep producing a small amount of satisfactory water. In the SW. ¼ of this section, on the property of J. Schoorman, a 6-inch drilled well produces plenty of water, which is so hard that it must be softened for laundry use. In the NW. ¼ sec. 14, on the property of H. Reinsma, a drilled well 60 feet deep yields sufficient water of suitable quality for household uses. In the NE. ¼ sec. 22, on the property of C. H. Fry, a spring flows a few gallons a minute. The water is fairly good but is used only for stock. In the NE. ¼ of the same section, on the property of Mr. Fry, a drilled well 90 feet deep produces an abundant supply of water with a slightly "salty" taste for stock; and another drilled well 61 feet deep in the same section produces water which is so hard that it must be softened before using for laundry purposes. In the NE. ¼ sec. 28, on the property of W. Barkhuff, are two drilled wells 110 feet and 90 feet deep. The water from both wells is soft and is used for domestic purposes, though it is considered only fair. A dug well 19 feet deep in the SE. ¼ of this section, on the property of H. E. Nash, furnishes an adequate supply of water for domestic purposes. In the

SW. ¼ sec. 34, on the property of C. Haag, a drilled well 70 feet deep yields about 300 gallons, and after a few minutes' wait a like amount can again be obtained. The Lance is a good source of ground water, and wells yielding enough water for household use can usually be successfully dug or drilled in at depths of less than 200 feet. Wells that will yield enough to water large herds of cattle are not so certain. The quality of the water is most variable between the extremes of very hard and very soft, and the very soft water usually contains considerable quantities of sodium salts.

The Lebo shale member of the Fort Union formation covers an area of about 6 square miles in this township. What drilling has been done here shows the Lebo to be an area of weak wells with water of poorer quality than that from the underlying Lance and overlying Fort Union rocks. The Lebo shale consists mostly of a bluish soft shale, which in many places forms an area of level to gently rolling plains between the more rugged and rolling areas of Lance and Fort Union.

The Quaternary alluvium covers a much smaller area in this township than in those immediately south and west. This part of the Comanche Flat is largely deserted, and reliable records of wells dug or drilled in the alluvium are difficult to obtain. By report, the underground water conditions are much similar to those in the rest of the flat. Usually considerable amounts of water are obtainable, but generally the water is suitable only for stock.

T. 1 S., R. 24 E.

The Colorado shale is at the surface over a large area in T. 1 S., R. 24 E. Most of the shale area has been covered by terrace deposits of Yellowstone River. The larger part of the township is under irrigation, and owing to the poor quality of the ground water, most of the inhabitants store irrigation ditch water in cisterns for domestic use. The irrigation water is obtained from the Yellowstone and has a lower mineral content than most ground waters in this area.

The Colorado shale is a very poor source of ground water, and the drilling of water wells in the area of this formation is inadvisable. Where it is covered with sand and gravel, water for stock and in places water suitable for domestic purposes can be obtained at moderate depths. In irrigated areas, where the subsurface drainage is poor, the land is rapidly becoming waterlogged, and the water table coincides with the surface, producing swamp with rushes and patches of "alkali." In the SE. ¼ sec. 6, on the property of William Raines, a small spring on the bank of Canyon Creek flows a few gallons a minute. The water is hard, containing 2,415 parts per million total dissolved solids. (See analysis No. 23, p. 21.) In the NE. ¼ sec. 10, on the property of F. Buchannon, a dug well 20 feet deep produces large quantities of water having a brackish taste which is used for stock. A spring along Canyon Creek in the SE. ¼ sec. 13, on the property of I. D. O'Donnell, flows a few gallons a minute. This spring is used by many people in the neighborhood as a domestic supply during the winter. The water contains 315 parts per million total dissolved solids and is moderately hard but otherwise should be satisfactory for most purposes. (See analysis No. 24, p. 21.) In the NE. ¼ sec. 20, on the property of Charles Roberts, another spring, improved with a concrete box, yields a few gallons a minute. In sec. 31 a spring flows a few gallons a minute and shows a heavy deposit of "white alkali."

The Eagle sandstone forms high, almost vertical "rim rocks" on top of which there is more or less level land. In secs. 4 and 5 there is a small area of this formation, but no drilling should be done here, as the sandstone is thoroughly drained. In secs. 6, 7, 8, 18, and 19 the Eagle forms prominent scarps, with a small level area on top. It is reported that wells drilled in this area were poor producers, and the area is largely abandoned, owning to crop failure.

T. 2 S., R. 24 E.

Yellowstone River crosses T. 2 S., R. 24 E., from southwest to northeast, and Clark Fork traverses the southern part. The township is crossed by the main line of the Northern Pacific Railway and by branches of the Great Northern and the Burlington. The entire area is under the ditch except the southeastern part of the township. The town of Laurel, an important railroad point, which had 2,239 inhabitants in 1920, obtains its municipal supply of water from the Yellowstone. The entire township with the exception of sec. 32 and parts of secs. 29 and 31, which lie in Carbon County, is in Yellowstone County.

The township is underlain by the Colorado shale, though most of it is covered more or less thickly by terrace deposits. This shale is exposed in the high bluffs of Yellowstone River. In the area not covered by the gravel and silt wells are rare, as the Colorado is a poor source of ground water. However, in certain steep coulees springs are common beneath the thin sandstone that holds up the high hills. In the unirrigated section shallow dug wells in the coulees are very productive, and much of the water is fairly good.

In the NE. ¼ sec. 12, on the property of J. J. Snyder, a dug well 15 feet deep yields a good supply of water that is used for domestic purposes. A driven well 15 feet deep in the same section produces hard water, containing 1,611 parts per million total dissolved solids. (See analysis No. 26, p. 21.) The drilled well probably yields water with similar chemical composition. In the NE. ¼ sec. 22, on the property of C. B. Martin, a dug well 9½ feet deep produces a large supply of moderately hard water with low mineral content, the total dissolved solids amounting to 382 parts per million. (See analysis No. 27, p. 21.) In the same quarter section, on the property of A. Cook, a dug well 12 feet deep produces a large supply of water suitable for domestic purposes. A dug well 8 feet deep in the SW. ¼ sec. 23, on the property of M. Games, yields a large quantity of satisfactory water. In the NW. ¼ sec. 24 a dug well 20 feet deep yields an almost unlimited supply of satisfactory water. A dug well 10 feet deep in the SE. ¼ sec. 27, on the property of J. E. Flood, draws a supply of fairly good water from gravel. This water has a slight taste because of its mineralization. In sec. 28 dug wells average about 12 to 15 feet deep, but some have a strong taste, due to large quantities of dissolved material. In the SE. ¼ sec. 7, on the property of F. W. Schauer, a well was drilled for oil to a depth of 2,235 feet but has never been a commercial producer and flows at present about 10 gallons of water a minute. In addition to the water large volumes of natural gas, a little oil, and some material which appears to be natural paraffin escape with the water. This water tastes bad and is allowed to run to waste. The well is 2,235 feet deep, and the water comes from a fine-grained white sandstone at 1,710 to 1,715 feet. It contains 3,398 parts per million total dissolved solids, with large quantities of sodium, bicarbonate, and chloride. (See analysis No. 25, p. 21.) This water undoubtedly comes from a Cloverly sandstone underlying the Colorado shale. With the exception of a very small quantity of water struck at 840 feet, the hole was dry from the surface to 1,710 feet.

T. 3 S., R. 24 E.

The only formation that crops out in T. 3 S., R. 24 E., is the Colorado shale. Wells are not numerous, but springs occur in many places in the steeper coulees. In the NE. ¼ sec. 2, on the property of E. H. Slater, a drilled well 314 feet deep obtained water, but no pump has been fitted to the well. Only a few yards away another drilled well 71 feet deep produced a small and inadequate household supply but is now abandoned. The well of R. Bates, in the NE. ¼ sec. 12, is about 1,000 feet deep, and the water rises within a few feet of the top. The source of this water is probably a Cloverly sandstone. The water has a peculiar taste and can not be used for drinking or cooking. It contains 1,488 parts per million total dissolved solids, consisting chiefly of sodium and bicarbonate. (See analysis No. 28, p. 21.)

The outlook for ground water in this township is not promising except in the northwest corner of the township, where the Colorado shale is covered to a greater or less depth with Quaternary alluvium. Here shallow dug wells can be depended on to produce large quantities of stock water.

T. 1 N., R. 25 E.

The southern part of T. 1 N., 25 E., is in the Yellowstone Valley; the northern part is in the rolling uplands. The Colorado shale underlies the southern part of the township. Wells are not common in this part; the few that have been sunk are used chiefly for stock, and the water is unfit for household use. In the SE. ¼ sec. 34, on the property of Joseph Zimmerman, a bored well 8 inches in diameter and 10 feet deep produces stock water having a bitter taste. Part of the area of Colorado outcrop is covered by terrace deposits and is irrigated. Most of the houses below the rim rock in secs. 25, 26, 35, and 36 and the Billings Polytechnic Institute get their supplies from the Billings city water system, which draws water from Yellowstone River. Most of the people use cisterns filled from the irrigation ditches. No one drilling or digging in the Colorado or overlying terrace deposts in this township should be very sanguine of obtaining a supply of good water.

The Eagle sandstone crops out over most of the township. It rises in a high, almost vertical rim rock over which there is no road west of Alkali Creek for about 10 miles. Beyond the rim is a gently rolling country much of which slopes down the stratigraphic dip to the north and east. In places the upper part of the Eagle formation is clearly indicated by the peculiar beehive-like weathering forms, and here and there the top of this formation may be distinguished by the tiny pebbles of black chert found in the soil. Theoretically this should be the best source of ground water in the Montana group. The heavy sandstone, the Virgelle member, is underlain by the impervious Colorado shale and overlain by the shale member of the Eagle formation, above which is a thin-bedded sandstone. However, the formation is not an excellent water producer, the wells being in general weak, though the quality of the water is fairly good. In the SE. ¼ sec. 3, on the property of O. B. Parham, a drilled well 220 feet deep yields an adequate supply of water which is used for domestic purposes, although hard. In sec. 4, on the property of the Malin-Yates Co., eight wells were drilled to depths of 40 to 200 feet, one of which in the SW. ¼ was dry and abandoned at 180 feet. None of these wells are strong producers. All the waters are potable but somewhat hard. The water in an 80-foot well in the SW. ¼ is hard, containing 1,549 parts per million total dissolved solids. (See analysis No. 29, p. 21.) The attempts at drilling in sec. 26 were largely unsuccessful, as might be expected so close to the rim rock with a north and east dip of the rocks.

The Claggett formation, which overlies the Eagle sandstone, covers less than half a square mile in sec. 1. This shaly formation is usually a poor source of ground water, and the best chance of success lies in digging shallow wells in the coulees.

As the homesteads in this township are now largely abandoned, it is difficult to obtain accurate information concerning wells drilled here.

T. 2 N., R. 25 E.

The belt of faulting so prominent in this region crosses T. 2 N., R. 25 E., producing striking topographic forms and disturbing the underground water conditions. The Eagle sandstone is the oldest formation that crops out in this township. In the SW. ¼ sec. 22, on the property of O. B. Johnson, a drilled well 125 feet deep draws a large supply of hard water from a sandstone 100 feet below the surface. The water used for irrigating a garden contains 1,329 parts per million total dissolved solids. (See analysis No. 33, p. 21.) In the SW. ¼ sec. 34, on the property of D. Dedrick, a drilled well about 50 feet deep produces good water, with 470 parts per million total dissolved solids. Another well 100 feet deep only 25 yards away produces a little harder water of similar composition, containing 469 parts per million total dissolved solids. (See analyses Nos. 34 and 35, p. 21.) The Eagle produces only medium quantities of ground water, which is usually hard but fairly good. The depth of wells in it should be less than 200 feet, usually less than 100 feet.

The Claggett formation, which overlies the Eagle sandstone, forms depressions in the faulted belt between the hills of more resistant material. In sec. 22 a drilled well 165 feet deep produces a small quantity of fairly good water. In the NE. ¼ sec. 28, on the property of J. J. Mills, a 6-inch drilled well 140 feet deep supplies large quantities of water that is used for stock. This water is considered to be only fair by the users but has had no bad effects on the vegetable garden irrigated with it. This well can not be pumped dry by the gasoline engine now in use and is exceptional for a Claggett well. Ordinarily this formation is a poor source of ground water. In sec. 25 a spring flows a few gallons a minute of highly mineralized water.

The Judith River formation occurs in blocks in the faulted belt. In the NW. ¼ sec. 19, on the property of the Great Northern Railway, a drilled well 317 feet deep produces large quantities of soft water which is used for domestic purposes. This well probably draws its supply from a sandstone 55 to 58 feet below the surface. The water has 1,618 parts per million total dissolved solids, containing considerable sulphate. (See analysis No. 31, p. 21.) This well is reported to flow in the spring. As it is in the faulted belt the ground-water conditions are peculiar. In the SE. ¼ sec. 20, on the property of J. I. Wernham, a drilled well 65 feet deep produces a small quantity of water, which is used for domestic purposes, though not very potable. A drilled well 122 feet deep in the SW. ¼ of the same section, on the property of Mrs. M. Lowry, produces a highly mineralized water, which is used for domestic purposes. In the SE. ¼ of the same section, on the property of J. I. Wernham, a drilled well 115 feet deep yields a small quantity of soft water containing large quantities of sulphate, bicarbonate, and sodium. (See analysis No. 32, p. 21.) This water, which is used for stock, comes from a coal bed near the bottom of a well. Coal seams are not common in the Judith River formation.

The Bearpaw shale is here as elsewhere a very poor source of ground water. It is practically useless to drill or dig wells in this formation, because if the wells are not dry holes the water obtained will be unfit for any use. In the Bearpaw area surface tanks to catch rain water should be used. (See p. 60.)

In secs. 2 and 3 there are small springs at the base of the Lance. In the NE. ¼ sec. 8 a spring yields a very few gallons of water a minute. Considerable "white alkali" appears about it. In the NW. ¼ sec. 18, on the property of Charles Bracken, a drilled well 70 feet deep produces large quantities of moderately hard water containing 1,396 parts per million total dissolved solids. (See analysis No. 30, p. 21.) This water is used for domestic purposes. The well is in the faulted belt, where the ground-water conditions are difficult to ascertain. It may obtain its supply from a fault plane, or the Judith River formation may be very close to the surface, and the well may draw its supply from that source.

The Lance formation occupies only a small area in this township consisting chiefly of rocky slopes covered with scrub pine.

T. 3 N., R. 25 E.

The only formations that crop out in T. 3 N., R. 35 E., are the Bearpaw shale and the Lance formation. The Lance forms the uplands above the pine-covered rims; the Bearpaw forms the depression called Hotchkiss Basin or Hoskins Basin.

The Bearpaw shale is a blue to black fine-grained shale which forms heavy soils or "gumbo." It is the worst source of ground water in the Montana group, and 9 out of 10 holes drilled in it will be dry. Dug wells in the coulees may yield usable water, but the main reliance for stock water should be placed in surface tanks or dams to catch the run-off from showers. (See p. 60.) In sec. 22 a shallow dug well in a coulee yields domestic water reported to be good. In the summer of 1921 this well was almost dry. The Bowman Springs, in the NW. ¼ sec. 36, near the contact with the overlying Lance, flow a few gallons a minute.

The Lance formation is composed of alternating lenticular masses of sandstone and shale. The shale is more abundant, but the sandstone is so much more resistant to weathering that it is much more conspicuous. Only a few wells have been drilled in the Lance in this vicinity. In the SE. ¼ sec. 30 the Buffalo Spring flows many gallons a minute of fairly good water. The spring produces sufficient water for a large number of cattle. In the SW. ¼ sec. 30, on the property of L. Cook, a 6-inch drilled well 51 feet deep produces a small amount of satisfactory water from a sandstone 48 to 51 feet below the surface. The drilled wells in the Lance where there is much shale should be cased to the bottom, the casing being perforated at the proper places to admit the water. This precaution will prevent the loss of wells by caving. In general, wells producing small amounts of fairly good water can be expected at moderate depths in this formation.

T. 4 N., R. 25 E.

The only formation that crops out in T. 4 N., R. 25 E., is the Lance, except in the northwestern part, where there is a small area of Quaternary lake deposits surrounding a pond. The township is not thickly settled, and considerable areas can not be brought under cultivation, consisting chiefly of rock slopes and canyons covered with growths of scrub pine. In the SW. ¼ sec. 12 a drilled well 180 feet deep yields a small amount of fairly good water. In the NE. ¼ sec. 14, on the property of M. S. Pstnicker, a drilled well 160 feet deep yields water which is used for domestic purposes. A 160-foot drilled well in the SE. ¼ of the same section, on the property of W. S. Smith, produces plenty of moderately hard water from sandstone near the bottom. It has 2,056 parts per million total dissolved solids, containing large quantities of sodium and sulphate. (See analysis No. 36, p. 21.) In the northern part of the township few wells have been drilled. In most places except near the rim rocks sufficient water for domestic purposes can be obtained from drilled wells ranging in depth from 60 to 200 feet. They should be properly cased to prevent caving and consequent loss.

T. 1 S., R. 25 E.

All of T. 1 S., R. 25 E., is underlain by the Colorado shale, but north of Yellowstone River, which crosses the southeastern part of the township, this formation is covered to a greater or less depth with terrace material. South of the river the Colorado shale is exposed in high banks against which the river has been cutting. In places white streaks of bentonite are prominent in the bluffs. The area north of the river is irrigated.

Ground water is easily obtained in the terrace material. In the SE. ¼ sec. 1, on the property of G. Vandeveegaete, a shallow dug well produces water for stock. A drilled well 40 feet deep in the NW. ¼ sec. 2, on the property of F. Cardwell, draws its supply of water from a gravel stratum at a depth of 36 to 40 feet. The water is considered only fair by the owner and is used for stock. In the NE. ¼ sec. 3, on the property of Mr. Cardwell, a 40-foot dug well yields an adequate supply of water for stock. In sec. 5 a dug well 12½ feet deep supplies ample quantities of water for stock. The level of the water fluctuates with irrigation. In the NW. ¼ sec. 8, on the property of Mr. Kennison, a shallow dug well yields water that is used only for stock. This well, which is not in the alluvium, went dry in the spring of 1921. In the SW. ¼ sec. 11, on the property of N. B. Smith, a drilled well 28 feet deep draws its supply of water from gravel at the bottom, but the water is used only for stock. Close to this well is a dug well 8 feet deep which produces water used for stock. In the SE. ¼ sec. 14, on the property of C. Gabel, a spring produces large quantities of water, which is used for domestic purposes. This spring is just below the irrigation ditch, and in winter, when the ditch is shut off, the flow decreases and the amount of dissolved material in the water becomes greater. In the SE. ¼ sec 15, on the property of P. H. Garrell, a dug well 15 feet deep yields a good supply of water that is used for stock. In the SE. ¼ sec. 16, on the property of J. L. Barker, a driven well 32 feet deep produces a good supply of water for stock from gravel. In the NE. ¼ sec. 17, on the property of J. Ingle, a bored well 15 feet deep furnishes considerable quantities of water that is used for stock. In the same section a dug well 10 feet deep yields fairly large amounts of water in summer but dries up in winter. In the NW. ¼ sec. 18, on the Great Western Sugar Co.'s ranch, a drilled well 40 feet deep furnishes water that contains 14,591 parts per million total dissolved solids and is unfit for any use. (See analysis No. 37, p. 21.) In the NE. ¼ sec. 26, on the property of C. Wise, water for stock is obtained from a shallow dug well. Another dug well 20 feet deep yields highly mineralized water that is used for stock. A dug well in sec. 27 produces water for stock. Almost anywhere water suitable for stock can be obtained from the alluvium. No effort should be made to drill into the underlying Colorado shale, as the water, if found, will probably be much worse than that in the terrace deposits. For drinking and household water most people fill cisterns from the ditch.

South of the river the people living in the lowlands use river water. Those living on the uplands usually have difficulty in obtaining ground water, and drilled wells are very few in the upland area. Dug wells in the coulees give the greatest promise of success. On the flat-topped hills shallow wells dug to the sandy layer holding up the hills may yield fair water. Many springs occur in the steep, narrow coulees.

T. 2 S., R. 25 E.

Like the township to the north, T. 2 S., R. 25 E., is underlain by the Colorado shale. The northwestern part lies north of Yellowstone River and is level lowland; the rest lies south of the river and is hilly upland.

In the small area north of the river shallow dug wells in terrace sand and gravel produce almost unlimited supplies of water that can be used for stock. For household use the people in general fill cisterns from the irrigation ditches, but most of those immediately adjacent to the river haul river water. South of the Yellowstone the people close to the river depend on it for water, and those on the level stretches on top of the hills depend chiefly upon springs, wells being somewhat rare.

Duck Creek is the most prominent watercourse except Yellowstone River in this township. It runs continuously in some places but is interrupted in others. At the ends of these dry places the water rises again, forming so-called springs. In the SW. ¼ sec. 15, on the property of E. Williams, a dug well 24 feet deep yields sufficient water for household use. The water is hard, has 1,335 parts per million total dissolved solids, and contains enough iron to stain enamel ware. (See analysis No. 38, p. 21.)

The uplands are not favorable places for wells, the Colorado shale being a poor source of ground water. The coulees offer the best locations for shallow wells. Many of the steeper coulees contain springs, chiefly small ones, some perennial and others with only brief periods of flow in the spring.

T. 3 S., R. 25 E.

T. 3 S., R. 25 E., is entirely underlain by the Colorado shale. The area consists largely of uplands dissected by the tributaries of Blue, Duck, and Spring Creeks. In the SW. ¼ sec. 2, on the property of O. H. Ernest, a spring of fairly good water flows a few gallons a minute during part of the year but is usually dry for five months. In the SE. ¼ sec. 3 a small spring flows a few gallons a minute. In the summer of 1921 this spring ceased flowing but did not dry up. In the NE. ¼ of the same section there is a small spring. In the NE. ¼ sec. 4, on the property of F. L. Summers, a spring yields sufficient water in wet years to irrigate 35 acres, but in a dry year like 1921 its flow is much diminished. The water is also used for household purposes. In the NE. ¼ NE. ¼ sec. 4, on the property of F. L. Summers, a drilled well 1,845 feet deep flowed 3 gallons a minute. The water contains 3,687 parts per million total dissolved solids and is not very satisfactory for most purposes. (See analysis No. 39, p. 21.) The water comes from the Chugwater formation, far under the Colorado. The water contained 7.8 parts per million of hydrogen sulphide, and the temperature was 67° F. In the NE. ¼ of the same section a well drilled for oil to the depth of 1,095 feet by the Worland Oil Co. produces a small amount of soft water with 1,929 parts per million of total dissolved solids. The water rises to the surface but does not overflow, owing to evaporation and drinking by stock. This water comes from a Cloverly sand beneath the Colorado. (See analysis No. 40, p. 21.) In the SW. ¼ sec. 5, on the property of C. C. Porter, a dug well 9 feet deep in a coulee supplies satisfactory water from a sandstone at the bottom. This well went dry in the summer of 1921. In the NW. ¼ sec. 6, on the property of A. Naiman, a dug well 6 feet deep in a coulee produces a good supply of water for domestic purposes. This water is hard and has 1,194 parts per million total dissolved solids. (See analysis No. 41, p. 23.) In the SW. ¼ sec. 7, on the property of R. Bates, a drilled well about 1,000 feet deep flows about 200 gallons of water a minute. The well was drilled for oil and yields some gas. Little or no information is available concerning this well. No use has been made of the water, and it is flowing to waste. This water probably comes from a Cloverly sandstone beneath the Colorado shale. It contains 1,725 parts per million total dissolved solids, consisting chiefly of sodium and bicarbonate. (See analysis No. 42, p. 23.) In the NW. ¼ sec. 11, on the property of L. Robbins, a dug well 25 feet deep yields small amounts of fairly good water, which contains 413 parts per million total dissolved solids. (See analysis No. 44, p. 23.) This well is dug through shale to the sandstone holding up the hill. A good spring on a hillside in the SW. ¼ sec. 9, on the property of E. Paulus, produces considerable water that is used for domestic purposes and irrigation. This spring never goes dry. The water contains 689 parts per million total dissolved solids. (See analysis No. 43, p. 23.) In the NE. ¼ sec. 18, on the property of R. Bates, another well drilled for oil flows 8 gallons of water a minute at a level of 2 feet above the surface. The well is reported to be 650 feet deep, but little other information concerning it is available. No use has been made of this water, which contains 1,896 parts per million total dissolved solids, consisting chiefly of sodium and bicarbonate. (See analysis No. 45, p. 23.) This water may come from a Cloverly sandstone. In sec. 19 several springs produce considerable quantities of fairly good water.

T. 4 S., R. 25 E.

Only part of T. 4 S., R. 25 E., is in Yellowstone County; the remainder is in Big Horn County. The oldest formation that crops out in this township is the Morrison, which is at the surface in a very small area. The Morrison formation consists essentially of variegated clay and is probably a poor source of water.

The Cloverly formation, which overlies the Morrison, should be productive of water, but as it crops out in a sparsely inhabited part of the township, little information was available concerning the ground water in it. The Colorado shale, which overlies the Cloverly formation, is a poor source of water, and drilled wells in it are usually failures. Dug wells in the coulees should be successful, though the water might be poor. In many of the steeper coulees there are small springs, which supply water for most of the sparse population. Few wells have been drilled, and no one has yet drilled through the Colorado shale in an effort to obtain supplies from the underlying Cloverly formation. Where the Colorado shale is not too thick, such a project would be worth a test.

T. 1 N., R. 26 E.

Yellowstone River crosses the southeastern part of T. 1 N., R. 26 E., and has cut a rather narrow gap through the high, almost vertical Eagle scarp, which forms the rim rock and is probably the most striking topographic feature in this area. The northern part of Billings covers parts of secs. 32 and 33.

The Colorado shale is the oldest formation exposed in this township. This formation is covered in part by river terrace material, which yields considerable quantities of water for stock. It is practically useless to dig or drill into the Colorado shale, expecting to obtain a supply of water suitable for household use. Water might be obtained by drilling through this formation to the underlying Cloverly at a depth of about 2,000 to 2,250 feet, but it would doubtless contain considerable hydrogen sulphide and consequently have a bad odor and be unfit for domestic purposes.

The Eagle sandstone overlies the Colorado shale. Its lowest member, the Virgelle sandstone, forms the conspicuous rim rock mentioned above. The Eagle is usually an easily recognized formation, owing to the thick, massive sandstone forming the base, the shaly middle member, and the thin-bedded sandstone occurring at the top. The top member weathers into conspicuous beehivelike masses and small pebbles of black chert strewn over the surface. In sec. 8 a 6-inch drilled well yields sufficient water for household purposes; the water is reported as good but hard. In the SW. ¼ sec. 9, on the property of P. G. Anderson, a 6-inch drilled well about 75 feet deep yields an adequate supply, but the water is poor. The windmill can pump water for 24 hours without the well going dry, but even the stock do not like this water.

Part of the Eagle formation is overlain by terrace deposits. In the NE. ¼ sec. 27, on the property of W. Griffing, a well 32 feet deep, the last 4 feet of which is driven, produces an adequate supply of hard water. There is an area of Quaternary alluvium overlying the Eagle along Alkali Creek from which shallow dug wells should obtain supplies of fair water, satisfactory at least for stock, at depths of not more than 25 feet.

The Claggett formation overlies the Eagle and consists predominantly of dense gray shale and very subordinately of sandstone. Wells drilled in this formation will be dry or yield small quantities of unusable water. Dug wells in the coulees are the best for this formation, as they cost less, both in money and in labor. A considerable part of the Claggett in this township is covered by terrace materials in which dug or driven wells, usually less than 25 feet deep, obtain adequate supplies of water for stock use, and in places for domestic use. In sec. 14 a dug well 14 feet deep produces a large supply of water for household use. In the NE. ¼ sec. 15, on the property of J. P. Mossman, a drilled well that is 81 feet deep but obtains its supply from a bed at 69 to 70 feet flows about 5 gallons a minute of water containing 6,718 parts per million total dissolved solids. (See analysis No. 46, p. 23.) This water is probably from the Claggett formation. In the NE. ¼ sec. 22, on the property of A. W. Gard, a dug well 14 feet deep yields an adequate supply of water for domestic purposes. In the NW. ¼ sec. 23, on the property of S. B. Pile, a dug well 15 feet deep produces a large quantity of hard water, which is used for domestic purposes. This water contains 571 parts per million total dissolved solids. (See analysis No. 47, p. 23.)

The Judith River formation, overlying the Claggett, is at the surface in the northeast corner of the township. Except in sec. 2 and part of sec. 1, where little information could be obtained beyond the fact that two drilled wells had produced adequate supplies of fairly good water, this formation is covered with terrace deposits. These terrace deposits can be relied on to produce plenty of water satisfactory for stock from dug wells averaging about 25 feet in depth. In the NE. ¼ sec. 12, on the property of H. P. Dennis, a dug well produces plenty of water, which is used for stock but is considered to be only fair on account of the large quantity of dissolved material.

The Quaternary alluvium covers a considerable area on the south side of the river. Little or no attempt has been made by the residents in this area to dig or drill for water, as they prefer to haul river water. In the SW. ¼ sec. 25, on the property of H. Tanaka, a drilled well 115 feet deep produces an adequate supply of water that is used for stock; it contains 2,444 parts per million total dissolved solids, consisting chiefly of sulphate and sodium. (See analysis No. 48, p. 23.) In the NE. ¼ sec. 36, on the property of H. Tanaka, a drilled well 75 feet deep yields a large supply of water that is used for stock and reported as highly mineralized. In the NW. ¼ of the same section, on the property of A. J. Peters, a dug well 60 feet deep yields a large supply of hard water containing 1,894 parts per million total dissolved solids. (See analysis No. 49, p. 23.) This water is used for stock. In the NE. ¼ sec. 15, on the property of J. P. Mossman, a drilled well 81 feet deep flows 10 gallons a minute. The water is used for stock and contains 6,718 parts per million total dissolved solids, consisting chiefly of sodium and sulphate. (See analysis No. 46, p. 23.)

In the irrigated regions both north and south of the river the people use ditch water stored in cisterns for drinking and other domestic purposes. This water is derived from Yellowstone River and consequently is surface water.

T. 2 N., R. 26 E.

The most prominent topographic features of T. 2 N., R. 26 E., are in the zone of faulting that crosses the southern part of the township. The faulting not only produced irregular hills and peculiar scarps but profoundly changed the ground-water circulation, so that the prediction of ground-water conditions is very difficult. The most conspicuous eminence in the township is Rattlesnake Butte, in sec. 24. This butte is a remnant of the Lance formation which has been preserved on a down-faulted block.

The Eagle is the oldest formation exposed in the township and covers a relatively small area. This formation when drilled should yield small supplies of satisfactory though hard water.

The Claggett formation forms depressions between the more resistant underlying Eagle and overlying Judith River formations. There have been few attempts to obtain supplies of ground water from the Claggett, and according to reports most of these have been failures. The best chance for a supply of water in this formation lies in digging shallow wells in the coulees.

The Judith River formation, overlying the Claggett shale, is badly faulted. In this township the ground water of the Judith River formation is not as good as in some of the townships to the west. Supplies of domestic water are usually available in this formation, though in places the water is used only for stock. In the NW. ¼ sec. 14, on the property of C. Smart, a spring, known as the Twelvemile Spring, flows a few gallons a minute. This water contains 1,337 parts per million total dissolved solids, is moderately hard, and is used for domestic purposes. (See analysis No. 50, p. 23.) In the SE. ¼ sec. 18, on the property of H. E. Myers, a drilled well 72 feet deep produces a small quantity of soft water that is used for household purposes. The water contains 1,153 parts per million total dissolved solids, consisting chiefly of sodium, bicarbonate, and sulphate. (See analysis No. 51, p. 23.) In the SE. ¼ sec. 22 a spring known as the Ninemile Spring flows a few gallons of water a minute. This water is hard but is used for domestic purposes. It contains 1,232 parts per million total dissolved solids. (See analysis No. 52, p. 23.) In the NW. ¼ sec. 23, on the property of C. Adamson, a drilled well 87 feet deep produces a small quantity of water that is used for stock. In the NE. ¼ of the same section, on the property of E. W. Figgens, a drilled well produces an adequate supply of water considered by the owners to be fairly good. In the SW. ¼ of the same section, on the property of C. J. Hintt, a drilled well 88 feet deep produces an adequate supply of soft water for domestic purposes. This water contains 640 parts per million total dissolved solids. (See analysis No. 53, p. 23.) In the SE. ¼ sec. 26, on the property of E. Todd, a 6-inch drilled well 100 feet deep produces a sufficient supply of water, which is used for domestic purposes. In the NE. ¼ sec. 34, on the property of R. L. Dalke, a dug well in a coulee produces a large supply of water that is used for stock.

The Bearpaw shale overlies the Judith River formation. It is a soft blue-gray to black fine-grained shale weathering to a fine, compact soil that absorbs water rapidly. This formation is almost hopeless as a source of ground water. The inhabitants of the area in which it crops out have been forced to dam the stream beds to impound the surface water for their stock. Water for domestic purposes is usually hauled from adjoining areas, where it is obtained from wells or springs in some other formation. In the NE. ¼ sec. 4, on the property of Joseph Sweeney, a drilled well 87 feet deep obtained a little water unfit for any use. In the SW. ¼ of the same section, on the property of P. J. Burns, a drilled well 93 feet deep produced a small quantity of equally poor water. In the NE. ¼ sec. 5, on the property of C. Collier, a drilled well 160 feet deep was practically dry, and the little water obtained was unfit for use. In the NW. ¼ sec. 8 a drilled well 218 feet deep was dry. Another drilled well in the same quarter section 117 feet deep produced water unfit for any purpose.

T. 3 N., R. 26 E.

The largest part of T. 3 N., R. 26 E., is in Hotchkiss or Hoskins Basin, a depression of Bearpaw shale partly surrounded by a steep pine-covered rim rock of the Lance sandstone.

The Bearpaw shale, the oldest formation exposed in this township, is a blue-gray to black shale that weathers to a dark fine-grained soil which absorbs water so rapidly that the roads are impassable for automobiles for several hours after a very light shower. In the SE. ¼ sec. 3, on the property of Mr. Allen, a dug well 28 feet deep yields a small supply that is used for domestic purposes. In the NE. ¼ sec. 10, on the property of J. Ramsey, a drilled well 100 feet deep produces a small quantity of water reported to be of fair quality. In the NW. ¼ sec. 20, on the property of J. Lang, a drilled well 605 feet deep is dry except for a small quantity of worthless water at a depth of 50 feet. A drilled well 48 feet deep in a coulee in the same section produced a small quantity of water with a taste like Epsom salts. Another drilled well 50 feet deep was similar to the one in the coulee. In the SW. ¼ sec. 30, on the property of G. W. Cox, a 6-inch drilled well 100 feet deep produces a fair supply of water that is used for domestic purposes. In the SW. ¼ sec. 34, on the property of O. Carlson, a dug well 8 feet deep yields a large supply of water for stock. The chances of obtaining potable ground water from the Bearpaw are very remote, as most attempts have been failures, and homesteaders should dig shallow wells in the coulees. These wells will doubtless be more successful near the Lance rim rocks than out in the center of the basin.

The Lance formation, overlying the Bearpaw shale, covers the northern part of the township and consists of an alternation of sandstone and shale. Most of the water it yields is obtained from the sandstone, but in places the shale is fairly productive. All wells should be cased the entire depth, with perforations at the appropriate places to permit the influx of water, because the shale caves badly after the well has been in use some time. In the SW. ¼ sec. 2, on the property of T. Stevens, a drilled well 90 feet deep yields an adequate supply of water that is used for domestic purposes. In the SW. ¼ sec. 4, on the property of A. H. Ammann, a small spring flows a few gallons a minute throughout the year. This water is hauled by many ranchers living in the basin. In the SE. ¼ sec. 7, on the property of J. Lang, a drilled well 100 feet deep produces a large supply of soft water which is used for domestic purposes.

The water comes from a sand at a depth of 50 feet and rises within 25 feet of the surface. This water contains 1,328 parts per million total dissolved solids, consisting chiefly of sulphate, bicarbonate, and sodium. (See analysis No. 54, p. 23.) In the NW. ¼ sec. 8, on the property of A. H. Ammann, a drilled well 50 feet deep yields an adequate supply of soft water from a sandstone at a depth of 100 feet. This water, which is used for domestic purposes, contains 887 parts per million total dissolved solids. (See analysis No. 55, p. 23.) Drilled wells in this area should be successful in obtaining supplies of water for domestic uses at depths of less than 200 feet, usually at about 100 feet.

T. 4 N., R. 26 E.

The only formation exposed in T. 4 N., R. 26 E., is the Lance. The township has a rolling to rough topography, part of it being badly dissected. The Lance consists of alternating beds of sandstone and shale. Ground water is usually found in the sandstone, though some wells apparently obtain their supplies from the shale.

In the NW. ¼ sec. 12, on the property of H. J. Kuhn, a 6-inch drilled well 145 feet deep yields sufficient water for domestic purposes. In the SW. ¼ of the same section, on the property of I. Wagoner, a drilled well 75 feet deep yields considerable water that is considered by the owner to be very good. In the SE. ¼ sec. 20, on the property of A. M. Comly, a drilled well 90 feet deep produces a small quantity of water that is satisfactory for domestic uses. In the SE. ¼ of the same section, on the property of J. I. Mayfield, another drilled well produces water reported as good. A drilled well 104 feet deep in the SE. ¼ sec. 24 produces an adequate supply of water from sandstone at 85 to 104 feet. This water is slightly hard, contains 400 parts per million total dissolved solids, and is used for domestic purposes. (See analysis No. 56, p. 23.) In the NE. ¼ sec. 24, on the property of Mrs. J. I. Mayfield, a 6-inch drilled well 174 feet deep yields a small supply of water that is fit for domestic use, being reported as soft. In the SE. ¼ of the same section, on the property of J. Prysen, a drilled well 90 feet deep produces water for domestic purposes. In the SW. ¼ of the same section, on the property of Mrs. L. A. Whitman, a 7-inch drilled well 132 feet deep produces water that is used for domestic purposes. This well can not be pumped dry by a 2½-horsepower gasoline engine connected to a 3-inch cylinder pump. In the NE. ¼ sec. 26, on the property of C. N. Drogan, a drilled well 60 feet deep yields an adequate supply of water used for domestic purposes. In the NW. ¼ of the same section, on the property of J. A. Grisey, a drilled well 60 feet deep yields water that is considered good. In the SE. ¼ of this same section, on the property of C. N. Drogan, a drilled well about 50 feet deep, that can not be pumped dry with the hand pump, produces water that can be used for domestic purposes. In the NW. ¼ sec. 28, on the property of W. J. Young, a drilled well 90 feet deep produces a small amount of fairly soft water. In the SE. ¼ of the same section a drilled well about 90 feet deep produces a small amount of fairly good water. In this same quarter section a dug well 30 feet deep produces a large amount of water that is considered good. In the SW. ¼ sec. 30, on the property of J. Kramlich, a 6-inch drilled well 68 feet deep produces an adequate supply of water for domestic purposes. In the NW. ¼ of this section a dug well 25 feet deep yields a large supply of water reported to be good. In sec. 33 a small spring flows a few gallons a minute. In the SE. ¼ sec. 34, on the property of A. C. Malmin, a drilled well 90 feet deep produces an adequate supply of water that is used for domestic purposes, and a dug well 22 feet deep produces an adequate supply of water that is reported as good, though somewhat mineralized. Anyone drilling in the Lance in this township can expect to obtain sufficient water for household use at depths of 50 to 200 feet. The water usually rises within 50 or 60 feet of the surface. Large volumes of water, such as are necessary to water large numbers of cattle, are not usually obtainable. As the shale in the wells caves badly, all wells should be cased throughout, perforations being made at proper places to allow water to enter.

T. 1 S., R. 26 E.

The larger part of Billings, the county seat of Yellowstone County, lies in T. 1 S., R. 26 E. Yellowstone River cuts diagonally across the township, making two distinct topographic provinces, the river valley and the rolling uplands.

The Colorado shale is the oldest formation exposed in this township. North of the Yellowstone the Colorado is completely covered with terrace deposits varying in thickness from a few inches to 50 feet or more. This terrace material yields ample supplies of water suitable for stock. The depth to water varies from place to place with the amount of saturation of the terrace deposits by irrigation. Dug wells deeper than 20 feet practically never go dry. A dug well 12½ feet deep in the NW. ¼ sec. 5, on the property of J. Steel, produces a large supply of hard water that is used for stock. It contains 3,055 parts per million total dissolved solids. (See analysis No. 57, p. 23.) In the NE. ¼ sec. 6, on the property of R. G. Archibald, a dug well 14 feet deep yields an ample supply of water for stock, which is used at times for domestic purposes. In the NE. ¼ sec. 8, on the property of Mrs. M. Flanigan, a driven well 30 feet deep yields a large supply of water that contains 4,864 parts per million total dissolved solids. The water is hard and has large quantities of sodium and sulphate. (See analysis No. 58, p. 23.)

South of the river the Colorado has practically no terrace covering. Drilled wells are very few, and dug wells are almost as scarce. The chances of obtaining satisfactory water are small except in the creek valleys, where dug wells are usually successful. Drilled wells are usually dry or produce water unfit for consumption. In the SE. ¼ sec. 13, on the property of W. Zweible, a drilled well 70 feet deep flows one-tenth of a gallon a minute of water unfit for any use. This water contains 27,708 parts per million total dissolved solids, consisting chiefly of sodium and sulphate. (See analysis No. 59, p. 23.) In most parts of the township the Colorado is more than 1,500 feet thick, so that drilling to the underlying Cloverly is expensive. If a well is drilled to that sandstone, the water will probably contain natural gas and hydrogen sulphide, though it may flow in favorable localities. In the SE. ¼ sec. 12, on the property of Mrs. Paulson, a dug well 35 feet deep yields a small quantity of water, which is used for domestic purposes. This well went dry in the summer of 1921. There are many springs in the coulees of this area. These springs fluctuate considerably during the year, frequently drying up completely in summer. The quality of the water varies considerably, according to reports of the inhabitants.

The Eagle sandstone overlies the Colorado shale, forming a very prominent scarp or rim rock along the eastern edge of the township. The Eagle has not been very thoroughly prospected for ground water in this township, but it should yield small supplies of fairly good though hard water usable for domestic purposes. Drilling should not be done close to the rim rock. In the SW. ¼ sec. 1, on the property of W. J. Wachsmoth, a dug well 15 feet deep in a coulee yields sufficient water from sandstone to supply a household and eight head of stock.

A very small patch of Claggett shale lies on top of the Eagle in sec. 1. This shale is a poor source of water. Shallow dug wells are best in coulees, and drilled wells must be deep enough to reach water horizons in the Eagle sandstone. In the NE. ¼ sec. 1, on the property of D. Young, a dug well 15 feet deep produces a small supply of water which is used for domestic purposes. This well, situated in a coulee, almost went dry during the summer of 1921. Farther down the same coulee is a shallow dug well producing a larger quantity of water, but it is used for stock only.

T. 2 S., R. 26 E.

The only formation that crops out in T. 2 S., R. 26 E., is the Colorado shale. Little or no drilling has been done here, and there are but few dug wells. The Colorado is a poor source of water, and no very satisfactory water can be obtained from this formation. The best chances are along Blue Creek and its tributaries, where dug wells will probably be successful. In sec. 1, on the property of Mr. Cardwell, a dug well 60 feet deep yields a supply of fairly good water, but the owner uses a spring for domestic purposes. In sec. 3 two shallow dug wells produce an adequate supply of fairly good water. In the NE. ¼ sec. 4, on the property of J. F. Nieman, a dug well 16 feet deep in a coulee produces an abundant supply of fairly good water.

T. 3 S., R. 26 E.

All but the extreme western part of T. 3 S., R. 26 E., is in the Crow Indian Reservation, where few or no water wells have been drilled. The only formation exposed in this township is the Colorado shale. Several sandy beds in the Colorado crop out in this area and have been dissected by the tributaries of Pryor Creek, producing rough topography. All the steep coulees contain one or more springs, which furnish sufficient water for the stock grazing on this part of the reservation. Dug wells in the coulees would doubtless be successful. Drilled wells would have to be more than 750 feet deep to reach the underlying Cloverly, and the quality of its water in this township is not known. The Colorado shale can not be expected to yield satisfactory supplies of water.

T. 4 S., R. 26 E.

Only 24 sections of T. 4 S., R. 26 E., lie in Yellowstone County; the remainder is in Big Horn County. The entire township is in the Crow Indian Reservation.

The oldest formation exposed in this area is the Morrison, which crops out over a very small area. The formation consists chiefly of variegated clays, which have not been tested for water.

The Cloverly formation, which immediately overlies the Morrison, consists of sandstone and shale. The sandstone usually contains considerable water. As no wells have been drilled or dug in this formation in this township, little can be said as to the quality of its water. It should produce reasonable quantities of water suitable for most purposes, but, as shown in the deep wells in this formation, the water may contain objectionable gases.

Above the Cloverly is the Colorado shale, which is an extremely poor source of water. No one should drill into this formation except where it is thin and the underlying Cloverly can be reached without the expenditure of too large a sum of money.

Along Pryor Creek there are considerable deposits of terrace gravel and silt, which should produce water, but, if like most other terrace waters in this county, it will be fit only for stock. Indeed, a dug well 30 feet deep in sec. 12 produces highly mineralized water unfit for any use. Most of the inhabitants, who are chiefly Indians, drink creek water or depend upon springs, which are numerous in the steep coulees.

T. 1 N., R. 27 E.

Yellowstone River crosses the northeastern part of T. 1 N., R. 27 E. The river is wide, and on each side is a broad strip of Quaternary alluvium over which it meanders. Both north and south of the river the land is under irrigation.

The oldest formation that crops out in this formation is the Claggett, which in this region is a poor source of water, wells sunk in it being usually not very successful. In places the Claggett is covered to a considerable depth with terrace deposits, which are rather fine in texture and consequently not good sources of water.

The overlying Judith River formation has not been very thoroughly tested for water. The area in which it is exposed is not large and is somewhat rough and dissected. The terrace gravel on the Judith River is much dissected and contains but little water. There are a few springs in the Judith River area, as well as at the edge of the gravel terraces.

The Quaternary alluvium should produce considerable quantities of fairly good water, but most ranchers living on or near the alluvium claim that river water is better and more easily available. People living in the irrigated districts fill cisterns for all domestic purposes.

T. 2 N., R. 27 E.

Yellowstone River crosses the southeastern part of T. 2 N., R. 27 E. The town of Huntley, with about 250 inhabitants, lies largely in this township. Huntley has no waterworks, and most of the people obtain their supplies from the water tank of the Northern Pacific Railway, which is filled from Yellowstone River. The village of Shepherd is also in this township. It has no water supply except wells and cisterns filled with ditch water.

The oldest formation exposed in this township is the Claggett. Little water is normally expected in this formation. Except for the well put down in the NE. ¼ sec. 36 by the Gladys Belle Oil Co., little drilling has been done. This well produces no oil or gas but some water at 80 and 150 feet and a large amount at 120 feet, all coming from sandstone. The sandstone at 120 feet produced so much water, according to the drillers, that it could not be lowered by a 15-inch bailer on a standard rig. The most interesting thing in this well is that it struck the Colorado shale at a depth of 160 feet after passing through three very thin sandstones, showing the rapid disappearance of the Eagle sandstone to the north and east. No water was encountered below 160 feet.

Overlying the Claggett is the Judith River formation, which, in this township, is almost entirely covered by terrace deposits. The entire area is irrigated. Few wells are in use, as the water obtained from wells in the terrace material is usually suitable only for stock. Owing to the ease of filling cisterns from the irrigation ditches, few attempts have been made to drill through the terrace material to the underlying Judith River.

The Bearpaw shale overlies the Judith River formation. This shale will not yield usable water. Where the shale is overlain by terrace material adequate supplies of water for stock can be obtained from shallow dug wells. In the area above the ditch wells are very scarce, most people depending on tanks to retain the waters of the intermittent streams. The few springs in the area are very weak, and the water is poor. In the SW. ¼ sec. 24, on the property of J. Malla, a spring flows a few gallons a minute. The water is hard, contains 3,688 parts per million total dissolved solids, and is used only for stock. (See analysis No. 60, p. 23.) In the SE. ¼ sec. 21, on the property of J. A. McLane, a spring in a coulee flows a few gallons a minute from the terrace deposits. The water is only fair and is used for stock.

T. 3 N., R. 27 E.

The Bearpaw shale occupies roughly the south half of T. 3 N., R. 27 E.; the overlying Lance formation occupies the north half. Topographically the Bearpaw forms in general smooth to gently rolling depressions and the Lance a rolling to rugged upland, separated in many places from the Bearpaw by a steep rim rock.

The Bearpaw is a very poor source of water. The best chance for obtaining supplies of water from it is to dig shallow wells in the coulees, but the water from these will in general be fit only for stock. Surface waters can be caught by damming stream beds and will thus furnish in normal years an adequate supply for several head of stock.

The Lance formation contains both sandstone and shale. The country occupied by it is rolling and in places badly dissected. Many wells have been dug or drilled in the Lance of this township, but as they have been abandoned, little information concerning them could be obtained. In the SE. ¼ sec. 8, on the property of O. Weber, a drilled well 155 feet deep produces fairly good water, which rises 100 feet in the well. In the SW. ¼ sec. 9, on the property of H. E. Meyerding, a dug well 6 feet deep in a coulee produces plenty of water that is good enough to be used for domestic purposes. All drilled wells should be cased to the bottom to prevent caving, holes being punched in the casing at appropriate places to allow the inflow of water. Household supplies of water should be obtained by drilling in this area at depths of less than 200 feet, except on high, narrow divides.

T. 4 N., R. 27 E.

The Lance formation is at the surface in most of T. 4 N., R. 27 E. It consists of alternating beds of shale and sandstone. The region is rather rugged, with many steep pine-covered sandstone hills or "rims." In the SW. ¼ sec. 4, on the property of J. Hill, a dug well about 25 feet deep yields a plentiful supply of water for domestic purposes. In the SE. ¼ sec. 16, on the property of G. G. Calderwood, a spring flows a few gallons a minute the year round, but the water is considered by the users only fair. In sec. 21, on the property of the Northern Pacific Railway, a dug well 18 feet deep yields a large supply of water reported as good. In the SE. ¼ sec. 30, on the property of J. Winterringer, a dug well 8 feet deep in a coulee produces an adequate supply of water for domestic purposes. In the SE. ¼ sec. 31 a dug well 30 feet deep yields plenty of fairly good water. It is reported that two gasoline engines pumping water for 10,000 sheep did not lower the well 1 foot. Dug wells in coulees in this township are usually successful, and drilled wells should obtain adequate household supplies at depths of less than 200 feet.

Overlying the Lance formation is the Fort Union formation, the basal part of which is known as the Lebo shale member. The Lebo usually forms a depression between the underlying sandier and more resistant Lance and the overlying beds of the Fort Union. Wells in this shale are usually small producers, and the water in general is not as satisfactory as water from the overlying part of the Fort Union. So little of the post-Lebo part of the Fort Union is exposed in this township that it will not be discussed here.

T. 5 N., R. 27 E.

The Lance is the oldest formation that crops out in T. 5 N., R. 27 E. Its area is very small, occupying the southeast corner of this township. What is said concerning the Lance in Tps. 3 N. and 4 N., R. 27 E. (p. 87), applies to this area.

The Lebo shale member of the Fort Union is exposed in a belt extending across the southern part of the township. This belt is in general an area of depression, in which only small supplies can be expected from drilled wells. In places the wells may have to be deep enough to reach the sandstone of the underlying Lance.

The Fort Union area in this township is part of the Bull Mountains. The country is very rugged, with more or less isolated areas fit for cultivation. Very few wells have been drilled in this formation. Good supplies of water suitable for domestic uses can be expected at depths of less than 150 feet, except on the high, narrow divides, where the water table is considerably deeper. In the NE. ¼ sec. 26 a dug well 20 feet deep produces a large supply of fairly good water. Small springs occur in many of the coulees.

T. 6 N., R. 27 E.

Only one-third of T. 6 N., R. 27 E. is in Yellowstone County; the remainder is in Musselshell County. This is an area of rugged topography, and the highest altitude in the Bull Mountains, on Eldridge Mesa, one of the chief topographic features of the region, is crossed by the county line. The area is so rough that there has been little or no prospecting for water, either by drilling or by digging. Drilled wells should obtain water at depths of not more than 150 feet, and in the coulees shallow dug wells should be successful. Springs are found in many of the steep coulees.

T. 1 S., R. 27 E.

Most of the eastern half of T. 1 S., R. 27 E., is in the Crow Indian Reservation. The township has somewhat diversified topography. In the southern part are level to gently rolling plains of the Colorado shale, with the abrupt Eagle sandstone rim rock on the north. Overlying the Eagle is the softer Claggett formation, making relatively level country surrounding an elevated strip of the Judith River formation.

No drilling should be done in the Colorado shale, as little or no satisfactory water will be obtained. Dug wells in the coulees offer the best chance of obtaining supplies of water from this formation. The springs in the Colorado area are in general poor, and the water has a bitter taste, giving Bitter Creek its name.

The Telegraph Creek formation overlies the Colorado and consists chiefly of sandy shale with subordinate sandstone. There have been almost no attempts to find ground water in this formation, because the area in which it crops out is very thinly inhabited. Although it is probably a poor source of water, it should be better than the Colorado shale.

Overlying the Telegraph Creek formation is the Eagle sandstone. This formation forms a prominent rim rock of considerable height in places. The Eagle thins rapidly eastward and becomes very thin at the east edge of the township. In the NW. ¼ sec. 7, on the property of Mrs. E. Davis, a drilled well 90 feet deep produces a small supply of water that is used for stock. Drilled wells, unless near the edge of the rim rock, should produce small supplies of fairly good water, except in the eastern part of the township. These wells in general should obtain water at depths of less than 100 feet.

The Claggett formation overlies the Eagle sandstone. Little or no drilling has been done in this formation, and dug wells are scarce. The Claggett is not a good source of water. In the SE. ¼ sec. 7, on the property of L. Burnham, a dug well 15 feet deep in a coulee yields an adequate supply of fairly good water from sandstone at the bottom of the well.

The Judith River formation overlies the Claggett. The Judith River is ordinarily a good source of water, but as little drilling has been done in this formation it is difficult to predict either the quantity or quality of water obtainable. Dug wells in the coulees should be successful.

T. 2 S., R. 27 E.

All of T. 2 S., R. 27 E., except the northeast corner is in the Crow Indian Reservation. The Colorado shale is the only formation at the surface over the entire township except in about a quarter of a square mile in the northeast corner of sec. 1, where the Telegraph Creek formation crops out. Pryor Creek runs diagonally across the township in a fairly broad valley with rolling uplands on both sides, which are dissected by the tributaries of the creek.

The Telegraph Creek formation is at the surface over so small an area in this township that its water-bearing possibilities will not be described here. (See T. 1 S., R. 27 E., for fuller discussion.)

No hopes should be entertained of getting adequate and satisfactory supplies of water from the Colorado shale by drilling, but shallow dug wells in the coulees would probably be successful. Over most of the township the Cloverly formation is about 1,500 feet below the surface, so that it would be extremely expensive to test this horizon. Although the mineral content of the Cloverly water is usually not excessive, much of the water contains gases that make it unsuitable for domestic use.

In the NW. ¼ sec. 15, on the property of W. H. Brumfield, a dug well 20 feet deep yields sufficient water for household needs as well as for 20 head of stock. This water, which is obtained from the gravel, is hard and contains 562 parts per million total dissolved solids. (For analysis see No. 61, p. 23.)

In the valley of Pryor Creek dug wells less than 40 feet deep should yield plenty of water, but it would probably be suitable for stock only. Throughout the township small springs are common in the steep coulees. The quality of the water ranges from fairly good to bad.

T. 3 S., R. 27 E.

All of T. 3 S., R. 27 E., lies in the Crow Indian Reservation and is drained by Pryor Creek and its tributaries. The only formation that crops out in this township is the Colorado shale.

No drilling should be done in the Colorado shale with expectations of obtaining adequate supplies of usable water; and, except in the southwest corner of the township, where the Colorado is thin, the expense almost prohibits drilling through it to the underlying Cloverly. Shallow dug wells in Pryor Creek valley are successful, though much of the water is suitable for stock only.

In the NE. ¼ sec. 31, on the property of F. M. Henry, a dug well 35 feet deep produces a large quantity of hard water that is used for household purposes. This water contains 2,444 parts per million total dissolved solids. (See analysis No. 62, p. 23.)

T. 4 S., R. 27 E.

Only two-thirds of T. 4 S., R. 27 E., is in Yellowstone County; the remainder is in Big Horn County. The entire township is in the Crow Indian Reservation. Except in a small strip in the northeastern corner of that part of the township in Yellowstone County, along Pryor Creek, where the Cloverly formation crops out, the only formation at the surface is the Colorado shale.

The Cloverly formation consists chiefly of sandstone and subordinate shale and should be a good source of water, but few or no tests of it have been made in this township.

The Colorado shale, lying above the Cloverly, is a poor source of water. Dug wells in the coulees and in Pryor Creek valley should produce good supplies, but the water may be suitable only for stock. Except near the Cloverly-Colorado contact, the shale is so thick that to drill through it to the Cloverly would be very expensive and has not been tried. The wells should prove successful, though the water might carry hydrogen sulphide, making it unsatisfactory for domestic use. Numerous small springs are to be found in the steeper coulees. The water from these springs is variable in quality.

T. 1 N., R. 28 E.

Pryor Creek runs almost due north across the western tier of sections of T. 1 N., R. 28 E. The belt of faulting so prominent in this part of Montana crosses the northern part of the township and as usual greatly disturbs the ground-water conditions.

The oldest formation exposed in this township is the Claggett, a poor source of water. In parts of Pryor Creek valley, where the Claggett is covered by terrace deposits, dug wells yield some water. In the NE. ¼ sec. 30, on the property of T. S. Hogan, two wells 40 feet deep, dug through sand and gravel, produced water that was used for stock, but they are now abandoned. In the NW. ¼ of the same section a dug well 15 feet deep is abandoned.

Overlying the Claggett is the Judith River formation, which contains more sandstone than the Claggett and forms a rolling upland. It was difficult to obtain much definite information concerning the ground-water conditions of the Judith River in this area, but it is probable that drilled wells in this formation will obtain small supplies of fairly good water at depths of 100 feet or even less.

T. 2 N., R. 28 E.

Yellowstone River crosses the northwest corner of T. 2 N., R. 28 E. The conspicuous belt of faulting already mentioned crosses the southern part of this township.

The oldest formation exposed in this township is the Claggett. This formation is a poor source of water, and very few wells have been drilled or dug in the area where it crops out.

The Judith River formation, which overlies the Claggett, is badly broken by faulting, and the ground-water conditions in its area are much disturbed. The country is rather rough and hilly and not thickly inhabitated.

Overlying the Judith River formation is the Bearpaw, a dense blue to black shale that is almost hopeless as a source of water. Except where the Bearpaw is covered by terrace deposits and in the coulees, it is useless to dig wells in this formation. Drilled wells in it are usually failures. A considerable part of the Bearpaw area in this township is under irrigation. However, over most of the irrigated area the Bearpaw is not at the surface but is covered by a layer of terrace deposits. Wells in these deposits usually produce large quantities of water that can be used for stock, cisterns being filled from the irrigation ditches for domestic purposes. The level of the water in the wells so closely follows the irrigation of the land that it is noticed by the most casual observers. The land in some parts of this development has become so saturated that the level of the water in the wells is only 2 feet below the surface. Where the land has subsurface drains to carry off the excess irrigation the wells act as indicators of the condition and effectiveness of the drains. In the NE. ¼ sec. 10, on the property of D. J. Kern, a dug well 20 feet deep produces from gravel an adequate supply of water that is used for domestic purposes, though it should be softened for washing. At the Government experiment station on the Huntley project, in sec. 16, a well 25 deep produces an adequate supply of water that is used for domestic purposes. (See analysis No. 63, p. 25.)

T. 3 N., R. 28 E.

Yellowstone River crosses T. 3 N., R. 28 E. South of the river the land is irrigated, being part of the Huntley project; on the north bank only a small area is irrigated by privately owned ditches.

The Bearpaw shale is the oldest formation exposed in this township. South of the Yellowstone this shale is covered with terrace deposits of variable thickness, which usually yield reasonable amounts of water that is used only for stock, being in general too highly mineralized for domestic use. It is practically useless to drill through the terrace material to the underlying Bearpaw shale, as the shale is almost hopeless as a source of water. Shallow dug wells are successful all over the project at depths usually less than 25 feet. North of the river the Bearpaw shale is more dissected, and the higher terrace deposits are isolated patches. In the SW. ¼ sec. 30, on the property of W. W. Clark, a drilled well 405 feet deep was dry except for a small quantity of bad water at 30 feet. Dug wells in the coulees may be successful, though the water will be only fair.

In the north half of the township the Lance formation, which overlies the Bearpaw shale, is at the surface. In most places the Lance sandstones form a high, steep rim rock above the softer shale of the Bearpaw. The country is rather badly dissected and very rough. Some wells have been drilled here, but little information concerning them could be obtained. Water should be struck in this area at depths of less than 200 feet, but the wells, in general, will not be large producers. Dug wells in the coulees should be successful at depths not exceeding 30 feet. The water in wells of both types should be fairly good. Springs are not numerous.

T. 4 N., R. 28 E.

The Lance formation is at the surface in almost all of T. 4 N., R. 28 E., except in the northern tier of sections. The Lance is a fairly good source of water in this region. Wells in it will be uniformly successful, though usually small producers, at depths of not more than 200 feet, and the water will be fairly good. Dug wells in the coulees will be successful at depths of 25 feet or less. Usually a dug well will produce more water than a drilled well, but it may go dry in very dry years. In the NE. ¼ sec. 5 a dug well 20 feet deep produces sufficient water for household purposes as well as for several hundred head of stock. In the NW. ¼ sec. 15, on the property of W. T. Ross, a dug well 22 feet deep produces a large supply of hard water that is used for domestic purposes. This water contains 2,194 parts per million total dissolved solids. (See analysis No. 64, p. 25.) A dug well 25 feet deep in sec. 17 produces an adequate supply of water for domestic purposes.

The Lebo shale member of the Fort Union overlies the Lance. This shale is at the surface in parts of the northern tier of sections, and very few wells have been drilled in this formation. Generally it is a rather poor source of water, the wells usually being weak producers. In places it may pay to drill through this shale into the sandstones of the underlying Lance, where larger quantities of water should be available, and, except where the entire thickness, 200 to 300 feet, is present, the wells would not need to be very deep.

T. 5 N., R. 28 E.

The Fort Union formation is at the surface over all of T. 5 N., R. 28 E., the Lebo shale member, at the base, cropping out over a considerable area in the south half of the township.

The Lebo member in this section is regarded as a poor source of water. It crops out in a depression between the sandier Lance and the overlying beds of the Fort Union, and as coulees are not numerous the area is unfavorable for dug wells. Wells might be drilled through this formation into the underlying Lance in an effort to reach the water horizons in that formation.

The post-Lebo part of the Fort Union is usually a good source of water. The wells are good producers and generally obtain a supply of water at depths of less than 200 feet, and the water is satisfactory for most ordinary uses. In the SW. ¼ sec. 11, on the property of H. L. Spaulding, a dug well 20 feet deep in a coulee produces an adequate supply of water for domestic purposes. A windmill running continuously can not pump this well dry. In the SE. ¼ sec. 12, on the property of J. King, a dug well 21 feet deep produces large quantities of hard water that is used for domestic purposes. This water contains 1,348 parts per million total dissolved solids. (See analysis No. 65, p. 25.)

In the NW. ¼ sec. 15, on the property of F. M. Guthrie, a drilled well 160 feet deep produces a good supply of water that is used for domestic purposes. In the NE. ¼ sec. 16 a drilled well 180 feet deep produces a large supply of fairly good water. A 2½-horsepower gasoline engine can not pump the well dry. In sec. 19 a drilled well 170 feet deep produces a large supply of water from a coal bed. The water has a bad odor and bad taste. In the NW. ¼ sec. 20, on the property of L. H. Drake, a dug well 30 feet deep produces a small supply of water that is used for domestic purposes. In the SW. ¼ of the same section, on the property of F. M. Grove, a dug well 14 feet deep in a coulee produces a strong supply of fairly good water. In the SE. ¼ sec. 21, on the property of C. Conover, a drilled well 350 feet deep yields a small supply of fairly good water. In sec. 29 a strong spring, known as Picket's Spring, flows several gallons a minute. In the NW. ¼ sec. 30, on the property of J. Carmichael, a dug well 20 feet deep produces an adequate supply of hard water, which contains 870 parts per million total dissolved solids and is used for domestic purposes. (See analysis No. 66, p. 25.)

T. 6 N., R. 28 E.

Only the south half of T. 6 N., R. 28 E., is in Yellowstone County, the north half being in Musselshell County. The western part of the township is as rugged as any part of the Bull Mountains. A dug well in sec. 24 produces an adequate supply of water for domestic use. In the SE. ¼ sec. 34, on the property of R. A. Bridges, a dug well 17 feet deep in a coulee produces sufficient water for 400 head of cattle, as well as for domestic uses. The Fort Union, which is exposed throughout the township, is an excellent source of water, and drilled wells should obtain an adequate supply at depths of less than 200 feet. Dug wells in the coulees should be uniformly successful.

T. 1 S., R. 28 E.

All of T. 1 S., R. 28 E., except the two eastern tiers of sections is in the Crow Indian Reservation. There are few inhabitants, except along Pryor Creek. Little effort has been put forth to dig or drill wells on the uplands.

The Colorado shale is the oldest formation exposed in this township. This shale is a poor source of water; no drilling should be done in it. To reach the underlying Cloverly formation a well would have to be from 1,750 to 2,250 feet deep, and as the quantity and the quality of the Cloverly water have not been determined in this vicinity it would be an expensive and hazardous undertaking.

The Telegraph Creek formation overlies the Colorado shale and consists essentially of sandy shale with some concretionary sandstone. It forms more rolling country than the Colorado. Though probably a poor source of water, it should be superior to the Colorado shale.

The Eagle sandstone, which immediately overlies the Telegraph Creek formation, is more shaly and thinner here than in T 1 S., R. 27 E., and the rim rocks so conspicuous in that township are absent. The formation consists essentially of sandy shale and consequently will in all probability yield smaller supplies and more highly mineralized water than the sandier phase of the formation exposed in the western part of Yellowstone County. Small springs occur in secs. 8, 21, and 26.

The Claggett formation, which overlies the Eagle sandstone, is a poor source of water, in which it is inadvisable to drill. Efforts should be confined to digging wells in the more favorable coulees. In the NW. ¼ sec. 5, on the property of the American Land & Livestock Co., a dug well 15 feet deep produces an adequate supply of water that is used for stock.

T. 2 S., R. 28 E.

With the exception of the northeast corner, T. 2 S., R. 28 E., is in the Crow Indian Reservation and is very thinly inhabited. Little or no effort has been made to dig or drill wells in this area.

The Colorado shale, the oldest formation exposed in the township, is at the surface in two areas, one on the west side and the other in the northeastern part. The northeastern area is an interesting "window" in the overlying Telegraph Creek formation. It is almost useless to drill wells in the Colorado shale to obtain a supply of water either for stock or domestic uses, but dug wells in the coulees may be fairly successful. A few springs occur in the steeper coulees.

The Telegraph Creek formation, which is at the surface over a considerable part of the township, consists essentially of sandy shale which may yield small supplies of rather highly mineralized water. However, this formation is somewhat more promising than the underlying Colorado shale.

The Eagle formation in this township does not contain the conspicuous sandstones that form the high rim rocks west of Coburn and consists of sandy shale which is not easily separated from the underlying and overlying formations. In consequence of the shaly character, the Eagle is less promising as a source of water in this region than it is farther west.

T. 3 S., R. 28 E.

All of T. 3 S., R. 28 E., is in the Crow Indian Reservation and consists of open range with almost no inhabitants. No wells have been dug or drilled here, and the few springs in the steeper coulees furnish sufficient water for the stock on the range. If wells are necessary, digging in the coulees will probably be more successful than drilling.

The Colorado shale, the oldest formation exposed in this township, is at the surface over most of the area and is a very poor source of water.

The Telegraph Creek formation, which overlies the Colorado shale, consists chiefly of sandy shale and crops out in the northeastern part of the township. Although not promising as a source of water, it should be better than the Colorado shale and may yield small supplies of water that may be used for stock.

T. 4 S., R. 28 E.

Only the two northern tiers of sections of T. 4 S., R. 28 E., are in Yellowstone County, the remainder being in Big Horn County. The entire township is in the Crow Indian Reservation. The Colorado shale is the only formation that crops out in this township. Its water-bearing possibilities are no better here than in the two townships just described.

T. 1 N., R. 29 E.

The oldest formation exposed in T. 1 N., R. 29 E., is the Claggett, which occupies the southeast corner. It is a poor source of water and should be exploited only by digging shallow wells in the coulees.

The Judith River formation, which overlies the Claggett, usually yields considerable quantities of fairly good water in drilled wells. Little definite information concerning it could be obtained, but drilled wells are plentiful in the area it occupies, and the water obtained was considered good by the users. According to reports all the drilled wells are less than 200 feet deep, and many of them about 100 feet deep. The belt of faulting so prominent in this region crosses this township, disturbing the ground-water circulation in the Judith River.

The Bearpaw shale overlies the Judith River formation. Here, as in other areas, it is useless to drill in this formation expecting to obtain a supply of usable water. Streams should be dammed and surface water caught for stock.

T. 2 N., R. 29 E.

The only formations that crop out in T. 2 N., R. 29 E., are the Judith River, which covers less than a quarter of a square mile in sec. 36, and the Bearpaw shale, which occupies the rest of the area. The small area of Judith River beds lies in the faulted belt, where ground-water conditions are much disturbed.

Except in those parts of the Bearpaw area where the shale is covered by terrace deposits it is almost useless to attempt to obtain supplies of ground water from this formation. Where the terrace deposits mantle it adequate supplies of water suitable for stock are obtainable from shallow wells. A part of the northern tier of sections is irrigated. In the irrigated districts dug wells usually obtain large supplies of water for stock from depths not exceeding 15 feet. The water from some scattered wells can be used for domestic purposes, but most of the inhabitants of the irrigated districts fill cisterns from the ditches.

T. 3 N., R. 29 E.

Yellowstone River flows across T. 3 N., R. 29 E., from west to east, dividing it into two subequal parts. The area south of the Yellowstone is under irrigation, being part of the Huntley project.

The Bearpaw shale is the oldest formation exposed in the township. No drilling should be done in this formation with the expectation of obtaining supplies of water suitable for domestic purposes. Where the Bearpaw is covered by terrace deposits shallow dug wells usually produce considerable water that can be used for stock. In the irrigated district dug wells usually obtain large supplies at depths of less than 20 feet.

The Lance formation overlies the Bearpaw shale and crops out north of the river. Generally the Lance forms a rim rock above the depression underlain by the Bearpaw. Considerable drilling has been done in this formation, and the wells have been generally successful, but little definite information concerning them was available. According to reports the wells are not large producers, and the water is usually obtained at depths of 150 and 200 feet.

T. 4 N., R. 29 E.

Except in the northern part of T. 4 N., R. 29 E., the Lance formation is at the surface over the entire area. The region is much dissected, and pine-covered rims and coulees are numerous. A number of wells have been drilled in this area, but owing to abandonment of many places definite information concerning them is not available. According to reports the wells are not large producers, though the water is fairly good, and most of them are less than 200 feet deep.

Overlying the Lance is the Lebo shale member of the Fort Union formation. This member usually forms low rolling depressions between the overlying sandier Fort Union beds and the underlying Lance. As a whole, this shale is not a very good source of water. Shallow dug wells in the deeper coulees should be reasonably successful. Drilled wells must generally penetrate to the underlying Lance in order to obtain adequate supplies. Except where it is necessary to drill through the entire thickness of the Lebo (200 to 300 feet) the depth to the upper sandstones of the Lance does not prohibit, on account of cost, the testing of these sandstones where the Lebo shale is found to be dry.

T. 5 N., R. 29 E.

The Lance is the oldest formation that crops out in T. 5 N., R. 29 E. There has been but little drilling in the Lance area, which consists largely of pine-covered, rugged hills. Except on the high divides drilled wells in this area should obtain small supplies of water at depths of about 150 feet.

Overlying the Lance formation is the Lebo shale member of the Fort Union. This shale forms a broad rolling depression between the more rugged Lance and the overlying beds of the Fort Union. The shale is not an excellent source of water, but some wells in it yield small supplies. Usually it is more feasible to drill through this shale to the sandier beds of the underlying Lance. In the SE. ¼ sec. 28 a dug well 28 feet deep in a coulee produces a good supply of water that can be used for domestic purposes.

The post-Lebo part of the Fort Union is sandier and forms rolling to rugged uplands. It is a fairly good source of water. Wells in it usually produce water suitable for domestic purposes, and very few exceed 200 feet in depth. In sec. 2 there is a small spring. In the SE. ¼ sec. 3, Hanson's Spring flows 5 or 6 gallons of water a minute. This water contains 899 parts per million total dissolved solids and is hard but is used for domestic purposes. (See analysis No. 67, p. 25.) In the SW. ¼ sec. 4, on the property of G. W. Cook, a drilled well 130 feet deep yields a small amount of hard water containing 399 parts per million total dissolved solids. (See analysis No. 68, p. 25.) This water is used for domestic purposes. In the NW. ¼ sec. 6, on the property of A. Lindeen, a drilled well 80 feet deep yields a small amount of water for domestic purposes. The water in this well rises within 12 feet of the surface. Another drilled well in this same section is 64 feet deep and produces water for domestic use from sandstone. In this same section a dug well 25 feet deep yields considerable water. In the SE. ¼ of this section a drilled well 70 feet deep produces a small supply of water reported to be fairly soft. In the NE. ¼ sec. 8 a drilled well 56 feet deep yields a fair amount of water that can be used for domestic purposes. In the SE. ¼ of the same section a drilled well 174 feet deep yields a large quantity of water. In the NW. ¼ sec. 13, on the property of H. Hansen, a dug well 12 feet deep yields a large quantity of water that is used for household purposes. In sec. 14 a drilled well 180 feet deep yields an adequate supply of water for domestic use.

T. 6 N., R. 29 E.

The south half of T. 6 N., R. 29 E., is in Yellowstone County; the north half in Musselshell County. The only formation at the surface in the entire area is the post-Lebo part of the Fort Union, in which little or no drilling has been done. Drilled wells should be successful at depths of less than 200 feet, although they may not be large producers. In the SE. ¼ sec. 28 a dug well 28 feet deep yields a large supply of water considered good by the users. The inhabitants at present depend largely on springs or dug wells in the coulees. The dug wells in the steeper coulees are usually good producers.

T. 1 S., R. 29 E.

The oldest formation exposed in T. 1 S., R. 29 E., is the Telegraph Creek formation, which is at the surface in the southeastern part of the area. It consists chiefly of sandy shale with subordinate sandstone and is probably a poor source of water. The region in which it is at the surface is thinly settled, and no information concerning efforts to obtain ground water from it was available.

The Eagle does not show here the sandy character which is so conspicuous west of Pryor Creek, and the shaly phase exposed in this area is doubtless a rather poor source of water. Shallow dug wells in the steeper coulees may yield small supplies.

The Claggett formation, which overlies the Telegraph Creek formation and is at the surface over most of the township, is not a good source of water. In the SW. ¼ sec. 6, on the property of C. F. Campbell, a small perennial spring flows a few gallons a minute, and the water is used for domestic purposes. In lot 14, sec. 6, on the property of G. H. Wright, a small spring, which fluctuates considerably, flows a few gallons a minute of hard water containing 431 parts per million total dissolved solids. (See analysis No. 69, p. 25.) In this same section a drilled well 100 feet deep yields moderate quantities of water that is used for stock. In sec. 18, on the property of H. Flamm, a drilled well 80 feet deep yields an adequate supply of water for domestic purposes. As a rule dug wells in the coulees in the Claggett area will yield more and better water than drilled wells. Several springs issue from the sandier beds exposed in the coulees.

The Judith River formation overlies the Claggett. In the NE. ¼ sec. 5 a drilled well yields a fairly large supply of water, which is used for domestic purposes. In the NE. ¼ sec. 6, on the property of J. Baker, a drilled well 108 feet deep yields an adequate supply of slightly hard water for household use. This water contains 414 parts per million total dissolved solids. (See analysis No. 70, p. 25.) Drilled wells in the Judith River area should be successful at depths of less than 150 feet.

T. 2 S., R. 29 E.

The southern two-thirds of T. 2 S., R. 29 E., is in the Crow Indian Reservation. The oldest formation exposed in this township is the Colorado shale, in which no drilling should be done, as it is a very poor source of water. As the Colorado shale is from 1,500 to 2,250 feet thick in this area, it would be very expensive to try to obtain a supply of water from the underlying Cloverly formation. Shallow dug wells in some of the coulees may yield water that can be used for domestic purposes.

The Telegraph Creek formation overlies the Colorado shale and is at the surface in an area of more than 5 square miles in the northern and western parts of the township. This formation has not been tested as a source of ground water, but it is not promising. Dug wells in the steeper coulees may yield small supplies that can be used for stock.

T. 3 S., R. 29 E.

All of T. 3 S., R. 29 E., is in the Crow Indian Reservation, and most of it is open range and very sparsely inhabited. Small springs in the coulees supply enough water for stock. The Colorado shale, the oldest formation exposed in this township, is at the surface over most of the area. This shale is a very poor source of water for domestic purposes.

The Telegraph Creek formation, which overlies the Colorado shale, crops out in the northwest corner of the township. It is a sandy shale, and although not a very promising source of ground water, it has more favorable prospects than the Colorado. Dug wells in the steeper coulees may yield small supplies of somewhat highly mineralized water.

T. 2 N., R. 30 E.

The northern two-thirds of T. 2 N., R. 30 E., is in Yellowstone County; the southern third is in Big Horn County.

The oldest formation exposed in the Yellowstone County part of the township is the Bearpaw shale, into which it is almost useless to dig or drill in an effort to obtain a supply of usable water. Tanks to catch surface water are most convenient to obtain a supply of water for stock. (See p. 60.) Where the Bearpaw is covered by terrace deposits, as in the irrigated district, these deposits yield considerable volumes of water suitable for stock, and there are a few wells which yield water that can be utilized for household purposes. In the irrigated districts most ranchers store ditch water in cisterns for domestic use.

Overlying the Bearpaw shale is the Lance formation, which is at the surface in the eastern part of the township and forms an area of uplands and pine-covered sandstone hills. Little or no drilling has been done in this area. Drilled wells should obtain small supplies of water for domestic uses at depths of less than 150 feet.

The village of Anita, on the Chicago, Burlington & Quincy Railroad, with about 100 inhabitants, has no public waterworks but depends on wells and cisterns.

T. 3 N., R. 30 E.

Yellowstone River flows across T. 3 N., R. 30 E., from west to east. North of the river are conspicuous Lance uplands; south of it the surface consists mostly of plains covered in places with terrace deposits.

The oldest formation at the surface is the Bearpaw shale, dug or drilled wells in which are usually failures. Where this shale is covered by terrace deposits shallow dug wells usually obtain water, though in most places the water can be used only for stock. In the irrigated district the wells obtain large supplies at depths of 10 to 15 feet, but very few of these wells produce water suitable for household uses. In this district cisterns are filled from the ditches to provide water for domestic purposes.

The Lance formation is at the surface north of the river and in sec. 36. Wells in this formation, though not generally large producers, yield water that can be used for domestic purposes. On account of shale the wells should be cased from top to bottom, with perforations at appropriate places to allow the inflow of water. If this precaution is not taken the shale will cave and ruin the well.

On the south bank of the Yellowstone there is a considerable strip of Quaternary alluvium, a large part of which is irrigated. The few wells dug here have been successful, and those close to the river usually produce water suitable for household uses. Generally ranchers on the alluvium prefer to haul water from the river, claiming that they like river water better.

T. 4 N., R. 30 E.

Except in parts of the northern tier of sections the only formation at the surface in T. 4 N., R. 30 E., is the Lance. The Lance has the same characteristics here as T. 3 N., R. 30 E., just described.

The Lebo shale member of the Fort Union overlies the Lance. Its topographic expression is a broad depression between the rolling uplands of the Lance and the overlying beds of the Fort Union. It is not an excellent source of water, but some wells obtain adequate supplies from it, though it is generally necessary to drill through the shale to the underlying Lance to get a supply. Except where the Lebo shale is present in nearly its full thickness (200 to 300 feet) the wells do not have to be very deep to reach the Lance. All wells should be carefully cased to prevent caving.

T. 5 N., R. 30 E.

The Lance formation occupies only a small area in T. 5 N., R. 30 E., and is of the same character as in T. 3 N., R. 30 E. Immediately above the Lance is the Lebo shale member of the Fort Union, which is at the surface over a considerable area in this township, forming a low depression between the hills of the Lance and the post-Lebo part of the Fort Union. The Lebo shale is not an excellent source of water, but some wells obtain adequate supplies from it. Except where it is necessary to penetrate nearly its full thickness (200 to 300 feet) the depth to the underlying Lance is not very great. The wells should be properly cased to prevent caving.

In this township, which is some 10 to 12 miles from the center of the Bull Mountains, the topography is not as rough as in the area to the west. In the SW. ¼ sec. 4 a drilled well 130 feet deep produces a small supply of water for domestic use. In sec. 6 a dug well 12 feet deep in a coulee produces sufficient water for 100 head of stock. In the SW. ¼ sec. 6, on the property of A. Lindeen, a dug well 12 feet deep yields an adequate supply of water that is used for domestic purposes and stock. In the post-Lebo part of the Fort Union many wells are strong producers of water suitable for domestic uses at depths not exceeding 200 feet. Dug wells in the coulees obtain good supplies at depths of 10 to 25 feet.

T. 6 N., R. 30 E.

The only formation at the surface in T. 6 N., R. 30 E., is the post-Lebo part of the Fort Union. The topography is less rugged here than in the area to the west, though in places the surface is so much dissected as to be difficult to traverse. Very little information about the ground water was available, but drilled wells should be successful at depths of not more than 200 feet. Dug wells in the steep coulees should obtain water at depths of 10 to 25 feet.

T. 2 N., R. 31 E.

About one-third of T. 2 N., 31 E., is in Yellowstone County; the remainder is in Big Horn County. The only formation in the Yellowstone County area is the Lance. This is largely a region of pine-covered hills, where few wells have been drilled. The Lance is a fairly good source of water, and drilled wells in it should be successful at depths of less than 200 feet. These wells will not generally be large producers, but the water will, as a rule, be satisfactory for household uses. Dug wells in the coulees should be successful at depths of less than 25 feet.

T. 3 N., R. 31 E.

The oldest formation exposed in T. 3 N., R. 31 E., is the Bearpaw shale. This shale, except where covered by terrace deposits, yields but little water suitable for any purpose. The terrace deposits usually yield adequate supplies of water that can be used for stock.

In most of the township the Lance formation, overlying the Bearpaw, is at the surface. It is composed of alternating beds of sandstone and shale; the sandstones, while forming less than one-half the total thickness, are the more conspicuous because they weather into rim rocks, pinnacles, and other curious forms. The Lance is a good source of water, wells in it usually obtaining supplies adequate for household purposes at depths of less than 200 feet.

Yellowstone River flows eastward across this township, and on each bank is a narrow strip of Quaternary alluvium. Most of these strips are under the ditch, and the inhabitants use cisterns filled from the ditches for domestic water. Dug wells are used as a rule only for watering stock.

T. 4 N., R. 31 E.

The only formation exposed in T. 4 N., R. 31 E., is the Lance, which is of the same character here as in T. 3 N., R. 31 E., described above.

T. 5 N., R. 31 E.

The Lance formation is the oldest formation at the surface in T. 5 N., R. 31 E., and crops out over the eastern part of the township. The information concerning it given under T. 3 N., R. 31 E., applies here.

Immediately overlying the Lance is the Lebo shale member of the Fort Union formation, which forms an area of depression and in places weathers to badlands. This shale is not an excellent source of water, and in many places it is necessary to drill through the Lebo into the underlying Lance to obtain adequate supplies. Usually this member is less than 300 feet thick. The Lebo shale is at the surface over most of the township. Dug wells less than 30 feet deep, in favorable localities in coulees, will usually produce adequate household supplies of water.

The post-Lebo part of the Fort Union formation crops out in the western part of the township. This formation is usually an excellent source of water, and drilled wells should be successful at depths of less than 200 feet.

T. 6 N., R. 31 E.

The Lance formation is at the surface in the eastern part of T. 6 N., R. 31 E. Ordinarily it is a good source of water, and in its area drilled wells should obtain an adequate supply for household use at depths of less than 200 feet.

Overlying the Lance formation is the Lebo shale member of the Fort Union formation. This shale is at the surface over a large part of the township. In the NW. ¼ sec. 2, on the property of A. L. Pugh, a drilled well 125 feet deep produces an adequate supply of water for domestic purposes. The water comes from blue shale at a depth of 90 feet. In the SW. ¼ sec. 7, on the property of G. Abel, a small spring flows a few gallons of water a minute. This water, which is used for domestic purposes, is hard and contains 675 parts per million total dissolved solids. (See analysis No. 71, p. 25.) In the NW. ¼ sec. 12, on the property of A. F. Geren, a drilled well 140 feet deep produces a strong supply from blue shale at a depth of 125 feet. Usually drilled wells in the Lebo shale are not strong producers, and it may be necessary to drill through the shale to the Lance sandstones to obtain larger quantities.

The post-Lebo part of the Fort Union is a good source of water. Drilled wells in it are usually from 150 to 200 feet deep, and dug wells in the coulees are rarely over 30 feet deep. Springs occur in some of the steeper coulees.

T. 7 N., R. 31 E.

The Lebo shale member of the Fort Union is at the surface over a considerable area in T. 7 N., R. 31 E. In many places it is necessary to drill through this shale to the Lance to obtain adequate supplies of water for household use. In sec. 1 a drilled well 175 feet deep produces only a small supply of water suitable for domestic purposes.

The post-Lebo part of the Fort Union formation is ordinarily a fairly good source of water, but in this township several drilled wells that tap it are not strong producers. In the SW. ¼ sec. 6, on the property of A. C. Akenson, a drilled well 150 feet deep produces about 5 barrels in 24 hours, and in the NW. ¼ of the same section a drilled well 180 feet deep produces even less water. In sec. 14 a drilled well produces an adequate supply of water that can be used for domestic purposes. In sec. 23 a good spring flows a few gallons a minute.

The inhabitants of this township have depended largely on springs for water. Wolf Spring, in sec. 9, flows several gallons a minute. The water contains only 278 parts per million total dissolved solids but is hard. (See analysis No. 72, p. 25.) This spring was for many years the site of a ranch and trading post but is now abandoned. It is a remnant of the old cattle days, before the advent of the homesteader.

T. 3 N., R. 32 E.

All but the southern third of T. 3 N., R. 32 E., is in Yellowstone County. The Lance formation is at the surface throughout the township except in the northwest corner, where it is overlain by Quaternary alluvium. The Lance consists of alternating beds of sandstone and shale and is usually a good source of water. Drilled wells in it are generally successful at depths of about 200 feet, but are not as a rule strong producers. So far few wells have been drilled. Dug wells in coulees should be uniformly successful, though the water may not be of domestic grade.

The Quaternary alluvium is largely under the ditch. Dug wells in this formation usually produce plenty of water, but it is used only for stock. Most of the inhabitants use river water either stored in cisterns of hauled from the river.

T. 4 N., R. 32 E.

Yellowstone River cuts diagonally across T. 4 N., R. 32 E. The Lance is the only formation at the surface except along the rivers, where it is overlain by Quaternary alluvium.

In the NE. ¼ sec. 26, in the schoolhouse yard at Waco, a drilled well 123 feet deep flows about one-tenth of a gallon a minute. The water contains 1,110 parts per million total dissolved solids, is soft, and is used for domestic purposes. (See analysis No. 73, p. 25.) In the SE. ¼ sec. 32, on the ranch of C. B. Patterson, a drilled well 93 feet deep flows about half a gallon a minute. The water is used for domestic purposes, and the excess is piped to a stock trough in the barnyard. The Yellowstone in cutting across the syncline in this region has lowered the surface so that there is sufficient artesian pressure to form flowing wells. Similar small flowing wells can be obtained close to the river level, but none on the uplands. In this same quarter section Mr. Patterson has a dug well 12 feet deep which yields water for domestic purposes.

T. 5 N., R. 32 E.

The only formation exposed in T. 5 N., R. 32 E., is the Lance. There has been little or no drilling for water in this area, and the information given for T. 3 N., R. 32 E., applies here.

T. 6 N., R. 32 E.

The Lance formation is the only one at the surface in T. 6 N., R. 32 E. Little information concerning either drilled or dug wells was available. Two dry holes, one 300 feet deep and the other 160 feet deep, were drilled in the SW. ¼ sec. 2. The remarks concerning the Lance made under T. 3 N., R. 32 E., apply in this township.

T. 7 N., R. 32 E.

The Lance formation is at the surface in the eastern part of T. 7 N., R. 32 E. This area is rough, consisting largely of pine-covered hills. In general, wells should be successful here at depths of less than 200 feet, except on high divides, where the water table is much lower.

Above the Lance formation over most of the township is the Lebo shale member of the Fort Union, which forms a low depression and in places weathers into badlands. In the NE. ¼ sec. 6, on the property of J. Frisch, a dug well 24 feet deep produces a large supply of water suitable for domestic purposes. It takes half a day to pump the well dry with the pump now in use. In the NE. ¼ sec. 10, on the property of M. Morgan, a drilled well 170 feet deep produces an adequate supply of water that is used for domestic purposes. The water is obtained from blue shale at a depth of 160 to 170 feet. In the SE. ¼ of the same section, on the property of W. O. Johnson, a drilled well 120 feet deep produces a fair supply of water for domestic uses. In sec. 16 two shallow dug wells yield water used for domestic purposes. There is a small spring in the same section. In the SW. ¼ sec. 17, on the property of F. Holton, a drilled well 120 feet deep produces a small supply of hard water that is used for domestic purposes. This water contains 325 parts per million total dissolved solids. (See analysis No. 74, p. 25.) A small spring also occurs in this section. In the SW. ¼ sec. 22, on the property of A. Maier, a small spring flows a few gallons a minute. This water is used for domestic purposes. Ordinarily drilled wells in the Lebo shale are not strong producers. Dug wells favorably situated in coulees are usually successful.

T. 8 N., R. 32 E.

The western part of T. 8 N., R. 32 E., is in Yellowstone County and the eastern part in Treasure County. The area is not thickly settled, and the inhabitants are largely dependent on springs for water.

The Lance formation crops out along Alkali Creek and some of its tributaries. In this formation drilled wells should obtain supplies at depths of less than 200 feet and dug wells properly located in the coulees at depths of less than 25 feet.

The Lebo shale member of the Fort Union is at the surface over a large part of the area and forms a region of depression. Few wells have been drilled in this shale, and to judge from the conditions in T. 7 N., R. 32 E., little water could be expected here at a depth of less than 125 to 150 feet. Dug wells in the coulees should be successful at depths of less than 30 feet, but the water might be highly mineralized. Springs are fairly numerous, but by report the water of most of them is fit only for stock. A spring in sec. 4 is reported as fairly good.

The post-Lebo part of the Fort Union crops out in the western part of the township. Practically no wells have been drilled or dug in these beds. At the Heide ranch, in the NW. ¼ sec. 18, a good spring flows a few gallons a minute. The water is hard and has 823 parts per million total dissolved solids. (See analysis No. 75, p. 25.)

T. 4 N., R. 33 E.

Yellowstone River flows northeastward across the northern part of T. 4 N., R. 33 E. The Lance formation is at the surface over the entire township, except along the river, where it is covered with a mantle of Quaternary alluvium. The Lance is usually a good source of water. The well of R. W. McLeod, in Custer, is 200 feet deep. The water is soft, is used for domestic purposes, and contains 1,152 parts per million total dissolved solids. (See analysis No. 76, p. 25.) The drilled well of Richard Bocky is 60 feet deep and yields water containing 2,654 parts per million total dissolved solids. (See analysis No. 77, p. 25.) Few wells have been dug or drilled in the Lance either north or south of the river. The drilled wells should obtain water at depths of about 150 feet and dug wells favorably situated in the coulees at a depth of not more than 25 feet.

The Quaternary alluvium occupies a narrow strip on each bank of the river. The strip south of the river is largely under the irrigation ditch. Dug wells in the alluvium yield considerable quantities of water that is used for stock, though some yield water that can be used for domestic purposes. Most of the inhabitants depend on river water either run into cisterns from the ditches or hauled from the river in tanks.

The town of Custer, with about 300 inhabitants, has no public water-supply system, the inhabitants obtaining their supplies from wells, irrigation ditches, or the river.

T. 5 N., R. 33 E.

Except in the southeast corner of T. 5 N., R. 33 E., the Lance formation is at the surface over the entire township. In the southeastern part of the township the Lance is covered by the Quaternary alluvium of the Yellowstone River valley.

Wells in the Lance are usually successful but do not yield large quantities of water. In sec. 10 a dug well 17 feet deep in a coulee produces a considerable quantity of water that is used for domestic purposes. Another dug well within 50 yards of this one in the same coulee is very similar. The level of the water in both fluctuates considerably.

In sec. 26 a dug well approximately 25 feet deep produces an adequate supply of water that is used for domestic purposes. In the SE. ¼ of the same section a bored well 67 feet deep yields an adequate supply of moderately hard water that is used for household purposes. This water contains 1,468 parts per million total dissolved solids. (See analysis No. 78, p. 25.)

Shallow dug wells in the Quaternary alluvium should be successful. The water will in general be so highly mineralized that it will be fit only for stock, particularly in the irrigated district, but here and there water sufficiently low in mineral matter for domestic use will be obtained.

T. 6 N., R. 33 E.

Eight sections in the northeast corner of T. 6 N., R. 33 E., are in Treasure County; the remainder is in Yellowstone County. The Lance formation is the only formation exposed in this township. A drilled well 90 feet deep in sec. 6 produces a small supply of water for stock. Another drilled well 120 feet deep in the NW. ¼ of the same section produces a small supply of slightly hard water that is used for domestic purposes. This water contains 2,206 parts per million total dissolved solids. (See analysis No. 79, p. 25.) Immediately adjacent to this well are two dry holes, each about 150 feet deep. In the NE. ¼ sec. 6 a spring flowing a few gallons a minute is used for domestic purposes. In the NE. ¼ sec. 14 a drilled well 117 feet deep produces a small supply of water for domestic use. A dug well 18 feet deep produces a small quantity of fairly good water. This well was dug through sandstone and ends in coal, but the water comes from a sandstone bed about 4 feet above the coal. There is also a small spring in this quarter section. In sec. 26 a dug well produces a large quantity of poor water. In this township the Lance seems to be a much poorer source of water than it is over most of the rest of Yellowstone County. However, so few wells either dug or drilled have been sunk in it that it should not be definitely condemned. Both of the drilled wells in sec. 6 are less than 125 feet deep.

T. 7 N., R. 33 E.

Seven sections in the southwest corner of T. 7 N., R. 33 E., are in Yellowstone County; the rest is in Treasure County. The Lance is the only formation at the surface in the entire township. Few wells have been sunk in this region.

The Lance ordinarily is a good source of water, but to judge from several wells in the township to the south (T. 6 N., R. 33 E.) wells here may not be uniformly successful.

T. 8 N., R. 33 E.

The Lance formation is at the surface over all of T. 8 N., R. 33 E., with the exception of the northwest corner, where the Lebo shale member of the Fort Union is exposed.

The Lebo, which overlies the Lance formation, weathers into badlands, and little or no prospecting for ground water has been done in the area it occupies. Ground water is probably scarce in this formation, and drilled wells would have to penetrate the underlying Lance sandstones to obtain adequate supplies for domestic purposes.

The Lance formation consists of alternating sandstone and shale. In the SE. ¼ sec. 2, on the property of C. Whitney, a 6-inch drilled well of unknown depth yields an adequate supply of water for household use. In the NE. ¼ sec. 12, on the property of Philip Chessler, a dug well 15 feet deep furnishes an adequate supply of water for domestic use, reported to be fairly hard. In the SW. ¼ of the same section, on the property of Charles Ruskosky, a drilled well 140 feet deep yields an adequate supply of water that is used for domestic purposes. The water is soft and contains 2,460 parts per million total dissolved solids, chiefly sodium, bicarbonate, and sulphate. (See analysis No. 81, p. 25.) In the NE. ¼ sec. 26, on the property of W. A. Ruskosky, a 6-inch drilled well 196 feet deep yields an adequate supply of water for domestic purposes. This water contains 2,675 parts per million total dissolved solids and is similar in composition to the water in the Charles Ruskosky well. (See analysis No. 82, p. 25.) In the SW. ¼ of the same section, on the property of W. A. Williams, a drilled well 202 feet deep yields a small quantity of water suitable for domestic purposes. In sec. 11 an intermittent spring in a coulee was dug out and is now a dug well, the surface of the water being lower than the surface of the land during most of the year. In sec. 12 a drilled well yields an adequate supply of water. In sec. 17, on the property of O. Butler, a dug well 12 feet deep in a coulee yields an adequate supply of water that is used for domestic purposes. Drilled wells in the Lance formation are usually successful at depths of less than 200 feet, but there are some exceptions in this township, because the well may encounter chiefly shale and no water-bearing sandstone and may consequently either be dry or yield little water. Dug wells in the coulees range from 10 to 25 feet in depth and produce only small amounts of hard water.

T. 4 N., R. 34 E.

That part of T. 4 N., R. 34 E., west of Big Horn River is in Yellowstone County; the rest is in Treasure County. The Big Horn flows almost due north across this township in a fairly wide valley. Although part of the valley of the Yellowstone is included in the township, the river itself does not cross it.

The Lance is the only formation at the surface except strips of Quaternary alluvium in the Yellowstone and Big Horn Valleys. The Lance forms uplands in which few wells have been drilled. Drilled wells should be successful at depths of less than 200 feet, and dug wells in the coulees should be uniformly successful.

Dug wells anywhere in the Quaternary alluvium should obtain water at depths not exceeding 25 feet. In general, the water will be satisfactory for stock only. If necessary the drill could go through the alluvium and tap the underlying Lance, care being taken to case out the water from the alluvium. This is rarely done, as most of the people fill cisterns from the ditches for a domestic supply.

T. 5 N., R. 34 E.

The western part of T. 5 N., R. 34 E., is in Yellowstone County; the remainder is in Treasure County. Big Horn River flows into the Yellowstone in the southern part of the township. The Lance formation crops out in this township, but in the southern part, where Yellowstone River crosses, it is overlain by a cover of Quaternary alluvium, which is at the surface over a considerable area.

The Lance formation will yield fairly good supplies of water in this township to wells less than 200 feet deep. In the NE. ¼ sec. 27, in the school yard at Big Horn, a 6-inch drilled well 110 feet deep yields an adequate supply of water for domestic purposes. This well, which obtains its water from blue shale, is used as a source of water supply for many of the homes in the village of Big Horn. The water is soft and contains 1,008 parts per million total dissolved solids. (See analysis No. 84, p. 27.) In this well the harder waters of the alluvium are cased out and less mineralized water is obtained below. In the NW. ¼ sec. 11, on the property of J. Ebbers, a dug well 18 feet deep yields a large supply of water for domestic purposes. The well is 4 feet square and draws its water from sand and gravel in the lower 6 feet. The water is hard and contains 1,046 parts per million total dissolved solids. (See analysis No. 83, p. 25.)

T. 6 N., R. 34 E.

Yellowstone River flows across the southeast corner of T. 6 N., R. 34 E. The Bearpaw shale is exposed over a small area in the northeastern part. No drilling should be done in this shale with the expectation of obtaining potable water. If the wells are not dry, they will yield but small quantities of water that is highly mineralized.

The Lance formation, which overlies the Bearpaw shale, is usually a fairly good source of water. In the SE. ¼ sec. 2, on the property of S. E. Williams, a well dug 99 feet and drilled 4 feet more yields an adequate supply for domestic purposes. This water must come from a sandstone which is practically at the base of the formation. Dug wells are uniformly successful in obtaining water from the alluvium, but the quality of the water varies considerably.

In the SE. ¼ sec. 25, on the property of J. L. Moaut, a dug well 16 feet deep yields an adequate supply of hard water used for domestic purposes. The water comes from sand and gravel in the lower 4 feet, and contains 1,960 parts per million total dissolved solids. (See analysis No. 80, p. 25.)

T. 7 N., R. 34 E.

The Bearpaw shale is at the surface in the eastern part of T. 7 N., R. 34 E. Wells drilled in this shale are usually failures. In the SE. ¼ sec. 2 a drilled well 170 feet deep, on the property of E. Fisher, yielded very poor water.

The Lance formation is at the surface over most of the township. The region, as a whole, is much dissected and rugged, with numerous pine-covered rims, though there is some arable land. In the SW. ¼ sec. 2, on the property of E. Fisher, a 5-inch drilled well 80 feet deep yields a supply of water that is used for domestic purposes and reported to be soft. Drilled wells in most places in the Lance area should be successful at depths of 200 feet or less. Shallow dug wells properly located in coulees should yield sufficient water for domestic needs.

T. 8 N., R. 34 E.

The oldest formation at the surface in T. 8 N., R. 34 E., is the Bearpaw shale. This formation is the poorest source of water in Treasure County. It yields almost no water fit for domestic purposes.

The Lance formation, overlying the Bearpaw shale, consists of alternating beds of sandstone and shale. In sec. 4 a drilled well 180 feet deep yields an adequate supply of water reported to have a slight "soda" taste, due probably to high mineral content. In sec. 18 a drilled well 130 feet deep yields plenty of water which tastes slightly of "soda." In sec. 19 a drilled well 157 feet deep yields an adequate supply of water that has a slight "soda" taste. In sec. 30 a drilled well 130 feet deep yields a large quantity of water used for domestic purposes. Only 20 feet from this last well a drilled well 106 feet deep is a weak producer. In the area of the Lance formation drilled wells from 150 to 200 feet deep should be uniformly successful.

T. 3 N., R. 35 E.

With the exception of the Tullock Creek valley and some of its tributary valleys most of T. 3 N., R. 35 E., is rather hilly. The only formation exposed is the Lance, which is made up of shale and sandstone with very thin beds of coal. Some of the coal has burned, producing red clinker beds. On some of the steeper slopes there is a considerable growth of pine. In the SE. ¼ sec. 11, on the property of G. H. Bishop, a drilled well 57 feet deep yields an adequate supply of moderately hard water that contains 2,000 parts per million total dissolved solids. (See analysis No. 85, p. 27.) The water rises within 18 feet of the surface. In the same quarter section a small spring flows out of the hillside. In the valley drilled wells should be successful at a depth of 75 feet. Away from the valley proper the drilled wells must in general be deeper to obtain adequate supplies, because the dissection of the uplands tends to lower the water table. The water obtained from the Lance is in most places usable for domestic purposes.

The Lebo shale member of the Fort Union formation crops out in two small areas. It is not a good source of water.

T. 4 N., R. 35 E.

The oldest formation that crops out in T. 4 N., R. 35 E., is the Lance, consisting of alternating beds of sandstone and shale. In the SW. ¼ sec. 28, on the property of P. P. Treat, a dug well 22 feet deep yields an adequate supply of water, reported to be so hard that lye was used to soften it for laundry use. In the NE. ¼ sec. 33, on the property of F. D. Glover, a drilled well 93 feet deep yields an adequate supply of water for stock. This water is slightly hard but contains 2,568 parts per million total dissolved solids. (See analysis No. 86, p. 27.) In the SE. ¼ sec. 35, on the property of J. B. Greirsen, a 6-inch drilled well 235 feet deep yields an adequate supply of water that is used for stock. This water is considered by the owner suitable for domestic use, but there is no house on the property. Owing to the artesian pressure the water rises within 100 feet of the surface. The Lance formation is usually a fair source of water, but two of the wells mentioned above do not yield very good water. Wells in the Lance should be successful at depths of less than 200 feet, but much of the water will be somewhat highly mineralized. On some of the higher divides the wells will probably have to be deeper.

The Lebo shale member of the Fort Union formation crops out in the northeast corner of the township. It is not a good source of water.

In the northwestern part of the township, along Tullock Creek, is a small area of Quaternary alluvium. The water-bearing qualities of the alluvium are the same here as elsewhere. Wells in it will yield considerable volumes of water, but in places the water will not be suitable for household purposes.

T. 5 N., R. 35 E.

The oldest formation exposed in T. 5 N., R. 35 E., is the Lance, consisting of sandstone and shale. The area is hilly and dissected, and the steeper slopes are pine covered. Wells in this area should be successful at depths of less than 300 feet, but they will probably yield small supplies of more or less highly mineralized water. In the SW. ¼ sec. 2, on the property of William Eldring, a drilled well 200 feet deep yields a supply sufficient for household needs. In the same section another drilled well 200 feet deep is dry. In the NW. ¼ of this section a dug well 30 feet deep in a coulee yields a large quantity of water that can be used for domestic purposes. In the NE. ¼ sec. 4, on the property of T. O. Crandall, a drilled well 135 feet deep yields a large supply of water that is satisfactory for all domestic purposes except laundry work, for which it is too hard. This water contains 820 parts per million total dissolved solids. (See analysis No. 87, p. 27.) In secs. 10 and 11 there are excellent springs. In the SE. ¼ sec. 21, in a coulee on the property of S. S. Craig, a dug well 35 feet deep yields an adequate supply of water reported to have an "alkali" taste and used for domestic purposes. In the SW. ¼ sec. 27, on the property of J. C. Lawless, a dug well 30 feet deep obtains its supply from shale. This well is a small producer, but the water is usable for domestic purposes. Drilled wells should be successful at depths of less than 250 feet, and dug wells in favorable locations in coulees should yield adequate supplies. The water will vary greatly both in quality and quantity.

T. 6 N., R. 35 E.

Yellowstone River flows in a meandering course across T. 6 N., R. 35 E. South of the river the Lance formation is at the surface; north of it the Bearpaw shale crops out. The Quaternary alluvium forms a broad strip on both sides of the river except on the south bank in the western part of the township, where the Lance hills approach close to the river.

The Bearpaw shale is the oldest formation exposed in this township and is a poor source of water. In the SW. ¼ sec. 17, on the property of W. N. Tyler, a well 607 feet deep was dry. In the SW. ¼ sec. 19, on the property of H. Eldring, a drilled well 487 feet deep yields a small amount of water that is used for stock but is considered to be poor water for that purpose. It is almost useless to drill in this formation in an effort to obtain a supply of water. However, a dug well 21 feet deep in sec. 5, on the property of J. D. Wagner, yields an adequate supply of water for domestic purposes. This is an exceptionally good well for the Bearpaw and probably obtains its water from Quaternary alluvium.

The Lance formation forms the rugged hills south of Yellowstone River. Few wells have been drilled in this formation, and the data obtained concerning them are not very reliable. Wells in the Lance should yield adequate supplies for household purposes at depths of less than 200 feet. In the SW. ¼ sec. 32, on the property of Mr. McCullum, a dug well 34 feet deep in a coulee yields a large quantity of water that is used for household purposes. Another dug well near this one and of about the same depth also yields a large supply of satisfactory water.

The Quaternary alluvium is at the surface over a considerable area. In most places it is underlain by the Bearpaw shale, though in the western part of the township a smaller area is underlain by the Lance formation. In the SW. ¼ sec. 3, on the property of S. D. Wagner, a dug well 21 feet deep yields an adequate supply of moderately hard water that is used for domestic purposes. This water contains 406 parts per million total dissolved solids. (See analysis No. 88, p. 27.) On the same property a spring flows a few gallons a minute. In the NE. ¼ sec. 7, on the property of Herman Johnson, a dug well 21 feet deep yields an adequate supply of water suitable for domestic use. In the NE. ¼ sec. 13 a dug well 35 feet deep yields a small supply of water used for household purposes. There are two more shallow dug wells in this same quarter section, but they produce hard water. In the SW. ¼ sec. 9, on the property of J. B. Grierson, a spring flows about 10 gallons a minute. This spring is boxed in, and the water is piped 1,300 feet to the owner's residence. In the NE. ¼ sec. 16, on the property of J. Johnson, a dug well 15 feet deep yields a small quantity of water that is used for stock. This well will yield about 600 gallons a day when pumped every 12 hours. In the SE. ¼ of the same section, on the property of C. R. Stoll, two dug wells 9½ and 11½ feet deep yield water that is used only for stock. In the SE. ¼ sec. 17, on the property of G. R. Gibbs, a dug well 35 feet deep yields a supply of water that is used for domestic purposes, though it is reported as "rather highly mineralized." In the NE. ¼ sec. 18, on the property of Philip Isaacs, a bored well 45 feet deep yields an adequate supply of water for domestic purposes. In the NE. ¼ sec. 28, on the property of J. H. Brocke, a driven well 27 feet deep yields an adequate supply of water that is used for domestic purposes and is reported to be better when pumped frequently. The area occupied by Quaternary alluvium is thickly settled and highly developed. Numerous wells have been dug, and except where the alluvium is too fine grained, they are almost uniformly successful. The quality of the water varies considerably.

T. 7 N., R. 35 E.

The Bearpaw shale is at the surface over all of T. 7 N., R. 35 E., except a few square miles. It is a dark blue-gray to black dense shale and is an extremely poor source of water. The shale includes here and there thin layers of gypsum, which weathers out and covers the hillsides with glistening fragments. Where water is obtained from this shale it is generally so highly mineralized that it is unfit even for stock use. No one should drill or dig wells in this shale with the expectation of obtaining adequate supplies of water for any use. Water for stock should be provided by catching surface water as described on page 60, except where perennial springs can be used.

The Lance formation crops out in the western part of the township. The country is very rough, and very little effort has been made to dig or drill wells.

This township is an example of overhasty homesteading. Most of the land is level and was much sought for that reason, but no attention was paid to the soil or the climate, and to-day the region is deserted. Before the plow broke the sod the grasses grew luxuriantly and afforded excellent pasture for large herds; but now the land is all fenced, the grasses have not reestablished themselves, and there are no cattle.

The chances of success in drilling to underlying formations are extremely hazardous. The Judith River formation, immediately underlying the Bearpaw shale, is a fair source of water in some places, but in others it may be dry or yield highly mineralized water. Northeast of this township the Chicago, Milwaukee & St. Paul Railway sunk a deep well which was dry, but in the township north of this one there are successful wells which obtain hard water from the Judith River formation. Consequently anyone who undertakes to drill to horizons in the Judith River formation must not be surprised to obtain a dry hole or very small supplies.

T. 8 N., R. 35 E.

The oldest formation exposed in T. 8 N., R. 35 E., is the Judith River, which rises on the Ingomar dome from beneath the younger rocks. This formation contains some shaly sandstone, as well as shale, and is a fair source of water in some areas. The outcrops of the Judith River extend northward into Rosebud County, where the formation yields small supplies of hard but potable water. The Ingomar well, in sec. 26, T. 9 N., R. 35 E., was drilled to a depth of 3,040 feet and was dry except for a very small amount of water obtained in the base of the Judith River formation. The deeper horizons were dry, as they were in the deep test of the Chicago, Milwaukee & St. Paul Railway well south of Vananda. In this township the Judith River has not yielded much water.

The Bearpaw shale, which overlies the Judith River formation, is at the surface over most of the township. The statements made about this formation under T. 7 N., R. 35 E., apply here. In the valley of Froze to Death Creek there are a number of small springs whose water is too highly mineralized for human consumption, except in emergency, but can be used for stock. Some of the springs are perennial, but many are intermittent.

The Lance formation, which immediately overlies the Bearpaw shale, forms rough uplands in the interstream areas, in which little effort has been made to develop ground-water supplies.

T. 3 N., R. 36 E.

The youngest formation cropping out in T. 3 N., R. 36 E., is the Fort Union formation, consisting of shale below and alternating beds of sandstone and shale with a few coal beds above. The shale or Lebo member is at the surface, but is capped with later Fort Union beds on the high divides. Some of the coal beds have burned and partly fused the overlying sandstone and shale, producing the familiar and conspicuous slag or clinker beds, some of which from their bright-red color are visible for long distances. Whiskey Butte, in sec. 16, is the most prominent landmark in the township. The region is rough, and many of the steep slopes are covered with pine trees, some of which are fairly large. This township is not easily accessible and is thinly settled, although practically all the public land has been homesteaded. Owing to the rough topography, the water table is deep, and wells in some places must be sunk 400 feet to obtain adequate supplies. This depth may be due to the necessity of drilling through the Lebo shale into the underlying Lance. In favorable locations dug wells should be successful at depths of less than 30 feet. In general the water should be usable for domestic purposes, though it may be somewhat hard.

T. 4 N., R. 36 E.

The only formations at the surface in T. 4 N., R. 36 E., are the Lance and the Fort Union. The area is much dissected and rough and contains few welltraveled roads. Many of the highest hills are covered with a layer of gravel, but the gravel deposits are so much dissected and so thoroughly drained that they are poor sources of water. Plumer's spring, in sec. 7, flows a few gallons a minute and the water is used for domestic purposes. The conditions in this township are similar to those in T. 3 N., R. 36 E., and the remarks made concerning ground water there (p. 109) apply equally well here. Accurate information concerning wells and springs was unobtainable in this township.

T. 5 N., R. 36 E.

The Lance, the oldest formation exposed in T. 5 N., R. 36 E., is at the surface in the northern tier of sections and consists of alternating beds of sandstone and shale. In sec. 4, on the property of C. P. Fisk, a drilled well 230 feet deep yields an adequate supply of water that is used for domestic purposes, although it is reported to have a peculiar taste. The Lance formation in general should afford successful wells at depths of less than 300 feet. The yield is usually not large and the water may be so highly mineralized as to be unsatisfactory for domestic use. Dug wells favorably located in coulees should yield fairly large supplies, though the water will be somewhat highly mineralized.

In the SE. ¼ sec. 9, on the property of S. T. Likens, a spring flows a few gallons a minute. The water, which is used for domestic purposes, is moderately hard and contains only 208 parts per million total dissolved solids. (See analysis No. 89, p. 27.) In the NE. ¼ sec. 13, on the property of J. G. Baker, a dug well 25 feet deep yields a plentiful supply of water used for domestic purposes. In sec. 16 a small spring flows a few gallons a minute.

The Fort Union formation overlies the Lance and consists of sandstone and shale, with some coal beds. The Fort Union is usually a fairly good source of water, and drilled wells 200 feet deep, except in the more dissected areas, should yield adequate supplies of water for domestic purposes. However, only the Lebo member crops out in this township, and some difficulty may be experienced in obtaining water. Springs are fairly numerous and with careful development will supply sufficient water for homestead use. Dug wells in coulees are generally successful if favorably situated. The water is of variable quality but can generally be utilized for domestic needs.

T. 6 N., R. 36 E.

The town of Hysham, population 360 in 1920, the county seat of Treasure County, is in T. 6 N., R. 36 E. The oldest formation at the surface is the Bearpaw shale, a dark blue-gray to black fine-grained shale. This shale yields almost no water, although in places it supplies a little water unfit for any use. Wells should not be sunk in this formation in the expectation of obtaining adequate household supplies. In the SW. ¼ sec. 1, on the property of D. E. Wardensleben, a drilled well 600 feet deep yields an adequate supply of water. This well flowed when first drilled but was not flowing in September, 1921, when visited by the writer, although the water was level with the surface. The water is soft but contains 2,079 parts per million total dissolved solids. (See analysis No. 90, p. 27.) This well obtains its water from a sandstone at a depth of 550 feet. This sandstone is doubtless part of the underlying Judith River formation, the well having been drilled through the Quaternary alluvium and Bearpaw shale. The Judith River formation, consisting of shaly sandstone, sandy shale, and shale, does not crop out in this township, although it is exposed at the eastern edge of the county.

The Lance formation, which overlies the Bearpaw shale, consists of sandstone and shale and crops out in the southern part of the township. Few wells have been drilled in this formation, but water should be obtained from it at depths of less than 200 feet. The area where this formation is at the surface is thinly populated.

The Quaternary alluvium mantles the Bearpaw shale in the Yellowstone River valley. It consists of unconsolidated silt, sand, and gravel. In the NE. ¼ sec. 2, on the property of D. E. Wardensleben, a dug well 15 feet deep yields an adequate supply of hard water that is used for domestic purposes. This water contains 908 parts per million total dissolved solids. (See analysis No. 91, p. 27.) In the NE. ¼ sec. 7, on the property of James Gallagher, a dug well 15 feet deep yields a large supply of highly mineralized water that is used only for stock. This water contains 5,102 parts per million total dissolved solids. (See analysis No. 92, p. 27.) In the NE. ¼ sec. 12 a spring flows 20 gallons a minute, and the water is used for domestic purposes. The terrace above this spring is irrigated, and doubtless the spring gets part of its supply from the seepage. In the NE. ¼ sec. 36, on the property of A. H. Wright, a dug well 48 feet deep yields an adequate supply of hard water that is used for domestic purposes. This water contains 1,145 parts per million total dissolved solids. (See analysis No. 94, p. 27.)

In the NW. ¼ sec. 9 the municipal well of Hysham is 50 feet deep and yields an adequate supply of very hard water that is used by many for domestic purposes. This water contains 4,279 parts per million total dissolved solids, with a large quantity of sulphate. (See analysis No. 93, p. 27.) In general wells in the alluvium yield large quantities of water, but much of it is too highly mineralized for domestic use.

T. 7 N., R. 36 E.

Yellowstone River flows eastward across the southern tier of sections in T. 7 N., R. 36 E. The Bearpaw shale is at the surface in most of the township, but in the southeastern part is covered by Quaternary alluvium. The remarks made on the Bearpaw shale under T. 7 N., R. 35 E. (p. 108), apply equally well here.

Where the Quaternary alluvium is at the surface along the river, dug wells 25 feet or less in depth are uniformly successful, but the water is generally too highly mineralized for domestic use. Water for household purposes is usually hauled from the river or obtained from irrigation water stored in cisterns.

T. 8 N., R. 36 E.

The only formations that crop out in T. 8 N., R. 36 E., are the Judith River formation and the Bearpaw shale. The Judith River should yield small supplies of relatively hard water. Drilled wells should be successful at depths of less than 200 feet. The discussions of the Bearpaw shale in Tps. 7 and 8 N., R. 35 E. (pp. 108 and 109), apply well here. The whole township is in Treasure County except sec. 1, which is in Rosebud County.

T. 2 N., R. 37 E.

The north half of T. 2 N., R. 37 E., is in Treasure County; the south half is in Big Horn County. Sarpy Creek flows northward across the township in a narrow steep-walled valley. The oldest formation exposed in the area is the Lance, consisting of alternating beds of sandstone and shale. This formation crops out in the creek valley and in places has a thin cover of alluvium. In the SW. ¼ sec. 5, on the property of C. C. Barkhuff, a drilled well 43 feet deep yields a large supply of hard water that is used for domestic purposes. This water contains 924 parts per million total dissolved solids. (See analysis No. 95, p. 27.)

The Lance formation will furnish adequate supplies to drilled wells in the Sarpy Creek valley at a depth of less than 100 feet. The water can generally be used for household purposes, though some of it may be very highly mineralized.

The Fort Union formation overlies the Lance and forms rugged hills, many of which are pine covered. It consists of sandstone and shale with some coal beds. The usual division of the Fort Union into the Lebo shale member below and later beds above is retained in this area, although the striking topographic expression of these members seen in the Bull Mountains is not quite so well shown here. The Fort Union is a fairly good source of water, and wells in it should yield adequate supplies of water satisfactory for domestic use. Except on the high, narrow divides, drilled wells should be successful at depths of less than 200 feet. On the high divides wells 400 or even 500 feet deep may obtain very small quantities of water. If possible, such unfavorable places should be avoided in sinking wells. Dug wells favorably located in coulees should be successful at depths of less than 25 feet.

T. 3 N., R. 37 E.

The Lance is the oldest formation exposed in T. 3 N., R. 37 E., and is at the surface in the valley of Sarpy Creek. The creek runs northward across the township and is closely paralleled by the county highway. In the NE. ¼ sec. 9 a drilled well 66 feet deep yields an adequate supply of soft water that is used for domestic purposes. This water contains 943 parts per million total dissolved solids. (See analysis No. 96, p. 27.) In the south half of this same section a drilled well is reported to yield a large supply of good water. The Lance is a fairly good source of water in this area, and drilled wells in the creek valley should be successful at depths not exceeding 150 feet. Dug wells will probably obtain water at depths of less than 50 feet.

The Lebo shale member of the Fort Union formation overlies the Lance and is of the same character here as in the township just described.

T. 4 N., R. 37 E.

Sarpy Creek flows northward across T. 4 N., R. 37 E., dividing it into almost equal parts. The county highway lies in this valley. The oldest formation at the surface in this township is the Lance, which consists of sandstone and shale. In sec. 9, on the property of N. C. French, a drilled well yields an adequate supply of water for household purposes. Another drilled well but a few yards away also yields water that could be used for the same purposes. In the SE. ¼ sec. 21, on the property of James McKenzie, a dug well 25 feet deep yields an adequate supply of water that is used for most domestic purposes, though it is reported as being too hard for the laundry. In the NE. ¼ sec. 28, on the property of A. J. Plummer, a drilled well 90 feet deep yields an adequate supply of water that is used for domestic purposes. In sec. 33 a drilled well yields water that is considered poor. Drilled wells should be successful in the Lance formation at depths of less than 150 feet, and dug wells in the same formation will range in depth from 25 to 50 feet, according to location.

The Lebo shale member of the Fort Union formation overlies the Lance. The statements concerning it under T. 2 N., R. 37 E. (p. 111), apply equally well to this township.

In some places the Lance is overlain by a cover of alluvium that may reach a thickness of more than 25 feet, and a few dug wells obtain their supplies from this material. In the SE. ¼ sec. 4, on the property of A. J. Plummer, a dug well 25 feet deep yields an adequate supply of water that is used for domestic purposes.

T. 5 N., R. 37 E.

Sarpy Creek flows northward across T. 5 N., R. 37 E., in a fairly broad valley. The oldest formation at the surface in this township is the Bearpaw shale, which consists of dark blue-gray to black fine-grained shale that yields little or no water suitable for domestic use. In the SE. ¼ sec. 8, on the property of George Creswell, a drilled well 160 feet deep obtained a small amount of highly mineralized water at a depth of 80 feet, below which the well was dry. This well is now abandoned. No wells should be drilled in the Bearpaw to obtain adequate supplies for stock or domestic use, as they will be dry or yield water that is too highly mineralized for any ordinary uses. Dug wells are usually failures.

The Lance formation, consisting of sandstone and shale, overlies the Bearpaw. In the SW. ¼ sec. 6 a spring flows 5 or 6 gallons a minute of water that is used for domestic purposes. This water probably has a fairly high mineral content, to judge from the heavy white deposits surrounding the spring. The water comes from the Lance formation and flows out practically at the Lance-Bearpaw contact. In the SE. ¼ sec. 29 a dug well about 6 feet deep yields an adequate supply of water for household use. This shallow dug well is one of a common type called springs. It is dug in a coulee, and at certain periods, particularly in the spring, it flows. The Lance formation is usually a fairly good source of water, and drilled wells in it should be successful at depths of less than 200 feet, and dug wells favorably situated in coulees at depths of less than 25 feet.

Both the Bearpaw shale and the Lance formation in the Sarpy Creek valley have a covering of Quaternary alluvium of variable thickness. In the SE. ¼ sec. 6, on the property of E. W. Switzer, a dug well 30 feet deep yields an adequate supply of water that is used for domestic purposes. In the SW. ¼ sec. 17, on the property of E. Cleaver, a dug well 20 feet deep yields a large supply of water that is used for stock. In the NE. ¼ sec. 20, on the property of Mrs. E. Cleaver, a dug well 22 feet deep yields an adequate supply of water for domestic purposes. In general the alluvium will yield an adequate supply, but the water may be too highly mineralized for domestic use.

T. 6 N., R. 37 E.

Sarpy Creek flows northward across T. 6 N., R. 37 E., and empties into Yellowstone River, which flows eastward across the northern edge of the township. The Bearpaw shale is the oldest formation at the surface over most of the township except where it is covered by a mantle of Quaternary alluvium. It is a very fine-grained blue-gray to black shale which generally yields little or no water. In the NW. ¼ sec. 9, in the school yard, district No. 16, a drilled well 190 feet deep yields a small amount of water that is used for domestic purposes, although it contains 2,606 parts per million total dissolved solids. (See analysis No. 98, p. 27.) In the NE. ¼ sec. 10, on the property of N. Criger, a drilled well 130 feet deep yields an adequate supply of water that is used for domestic purposes and is reported to be very soft. These wells probably draw their water from the underlying Judith River formation rather than from the Bearpaw shale. The Bearpaw is a poor source of water, but the

Judith River, which is exposed in the bluff just at the east edge of the county, yields fair supplies. In the northeastern part of the township drilled wells should reach this formation at depths of less than 300 feet, but the water may contain considerable mineral matter, like that in the school well.

The Lance formation overlies the Bearpaw shale, but its areal extent in this township is less than 1 square mile. It forms a few rocky hills along the southern edge of the township.

The Quaternary alluvium is well developed along Yellowstone River and less so along Sarpy Creek. In the NW. ¼ sec. 7, on the property of J. E. Cole, a dug well 14 feet deep, lined with galvanized-iron culvert pipe, furnishes a large supply of water that is used for domestic purposes. This water is hard and contains 2,075 parts per million total dissolved solids. (See analysis No. 97, p. 27.) Other wells were dug or driven in this quarter section but produced poor water and are now abandoned. In the NW. ¼ sec. 6, on the property of A. G. Miller, a driven well 37½ feet deep yields an adequate supply of water considered good by the users. In the NE. ¼ sec. 9, on the property of William Hohenshelt, a drilled well 26 feet deep yields an adequate supply of hard water that is used for domestic purposes. The water contains 1,399 parts per million total dissolved solids. (See analysis No. 99, p. 27.) In the SW. ¼ sec. 10, on the property of Devenny & Knecht, a dug well 12 feet deep yields an adequate supply of water that is used for stock. The alluvium will supply large quantities to shallow dug wells, but the water will be highly mineralized, some of it so highly as to be unfit for domestic purposes. In this area along Yellowstone River cisterns filled with river water, either by hauling or from ditches, are much used.

T. 7 N., R. 37 E.

Yellowstone River flows across the southern edge of T. 7 N., R. 37 E. The Judith River formation, which is the oldest one exposed in the township, is brought to the surface along the flanks of the Porcupine uplift and forms a rolling upland along the eastern edge of the township. No definite information concerning wells in this formation could be obtained, as the region is very thinly settled. Drilled wells in it should yield sufficient water for household use, although the water might be rather highly mineralized.

The Bearpaw shale is at the surface over most of this township. Wells in this shale are generally failures. A supply for stock can be obtained from surface water impounded by the methods described on page 60.)

The Quaternary alluvium is found on the north bank of the river in belts about 2 miles in maximum width. In the SE. ¼ sec. 26, on the property of Jesse Smith, a dug well 23 feet deep yields a quantity of water that is used for stock. This water contains 6,283 parts per million total dissolved solids, is hard, and has large quantities of sodium and sulphate. (See analysis No. 100, p. 27.) Less than half a mile west another dug well 35 feet deep yields potable water. In the SW. ¼ sec. 28, on the property of V. Gustafson, a dug well about 20 feet deep yields water that is used for domestic purposes. This water contains 1,844 parts per million total dissolved solids. (See analysis No. 101, p. 27.) The alluvium can be depended on to yield large supplies of water for stock, but much of the water is too highly mineralized for domestic use, and most of the inhabitants prefer river water.

T. 2 N., R. 38 E.

The only formation at the surface in T. 2 N., R. 38 E., is the upper part of the Fort Union. Most of the region is rugged, and many of the hills and coulees are covered with pines. The upper part of the Fort Union formation consists of sandstone and shale, with some coal. Some of the coal beds are reported to be as much as 14 feet thick, though most of them are much thinner. Little drilling has been done in this township, but drilled wells not more than 200 feet in depth, except on the high, narrow divides, should yield sufficient water for domestic needs. Most of the inhabitants are reported to depend on small springs and shallow dug wells located in favorable places in the coulees.

T. 3 N., R. 38 E.

The oldest rocks exposed in T. 3 N., R. 38 E., belong to the Lance formation, which is at the surface in the northwestern part of the township. The Lance is a fairly good source of water, and drilled wells in it should be uniformly successful at depths of less than 200 feet, though they may yield only small quantities of water.

The Fort Union formation, which overlies the Lance, is at the surface over almost the entire township, and the Lebo shale member is well developed. The Lebo may yield small supplies of water usable for domestic purposes, but the overlying part of the Fort Union is a more promising source of ground water and, except on high divides, should afford successful drilled wells at depths of less than 300 feet.

T. 4 N., R. 38 E.

The oldest formation at the surface in T. 4 N., R. 38 E., is the Lance, which consists of sandstone and shale. Few wells have been drilled in this formation, but it is probable that drilled wells will be successful at depths of less than 200 feet and yield small supplies that can be used for domestic purposes. Dug wells in the steeper coulees should obtain water at depths less than 30 feet.

The Fort Union formation, which immediately overlies the Lance, is represented only by the Lebo shale member, the overlying beds being absent. The Lebo shale is a rather poor source of water, and where it is found to be dry the drill should continue to the underlying Lance, in which the chances of obtaining water are much more favorable.

T. 5 N., R. 38 E.

Only the western tier of sections of T. 5 N., R. 38 E., is in Treasure County; the remainder is in Rosebud County. The region is thinly inhabited.

The Bearpaw shale is the oldest formation exposed in the township, but there is small chance of obtaining supplies of water from it.

The Lance formation, which overlies the Bearpaw, is a fairly good source of water and should yield small supplies of fairly good water at depths not exceeding 200 feet. Dug wells properly located in the coulees should be successful at depths of less than 30 feet.

T. 6 N., R. 38 E.

Only the western tier of sections of T. 6 N., R. 38 E., is in Treasure County; the remainder is in Rosebud County. The oldest formation exposed in the township is the Judith River, which forms the bluff to the south of the railroad tracks just east of the village of Sanders. The Judith River is usually a fair source of water but is at the surface over a very small area.

The Bearpaw shale overlies the Judith River formation and is at the surface over a considerable area. There is little hope of obtaining supplies of water from it. In secs. 7 and 18, where the depth to the underlying Judith River probably does not exceed 300 feet, it is feasible to test the possibilities of that formation, which should yield small supplies of water usable for domestic purposes.

The Quaternary alluvium is at the surface in sec. 6. The alluvium usually yields large supplies to shallow dug wells, but the water may be too highly mineralized to be used for domestic purposes. Most inhabitants prefer river water on account of its lower mineral content.

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