ARTESIAN WATER FOR IRRIGATION IN LITTLE BITTERROOT VALLEY, MONTANA.

By Oscar E. Meinzer.

INTRODUCTION.

Little Bitterroot River is a small stream in northwestern Montana. It rises about 20 miles north of the north boundary of the former Flathead Indian Reservation, and about 25 miles west-northwest of the north end of Flathead Lake, flows south-southeastward for about 65 miles, and discharges into Flathead River, which forms the outlet of Flathead Lake and leads to the Clark Fork of the Columbia. (See fig. 1.)

The drainage basin of the Little Bitterroot covers about 600 square miles, or approximately 385,000 acres. On both sides and at its upper end this basin consists of more or less mountainous country, but in the interior it contains a sharply contrasting plain, 1 to 8 miles wide and about 100 square miles in extent, through which the river flows in the last 40 miles of its course. This plain, which includes the Little Bitterroot Valley, is an arm of the large glacial-lake plain that lies south of Flathead Lake, in the heart of the former Flathead reservation. At its upper end it is connected with the shores of the lake by the peculiar feature known as the Big Draw. It lies entirely within the former Indian reservation.

In 1910 the reservation was opened to white settlers, and in 1915 the Little Bitterroot Valley had a considerable population. Small villages have grown up at the west edge of the valley on both sides of the Camas Hot Springs, which form a notable feature of the region and are much frequented as a health resort. The valley can be reached from Perma or Plains, stations on the main line of the Northern Pacific Railway, which are connected with Camas Hot Springs by automobile roads. It can also be reached from Kalispell, on the Great Northern Railway, either by automobile or by boat and automobile by way of Flathead Lake and the Big Draw. From the eastern part of the reservation it can be reached either by way of the Big Draw or by way of Sloan Ferry, which is at the mouth of Little Bitterroot River. (See fig. 1.)

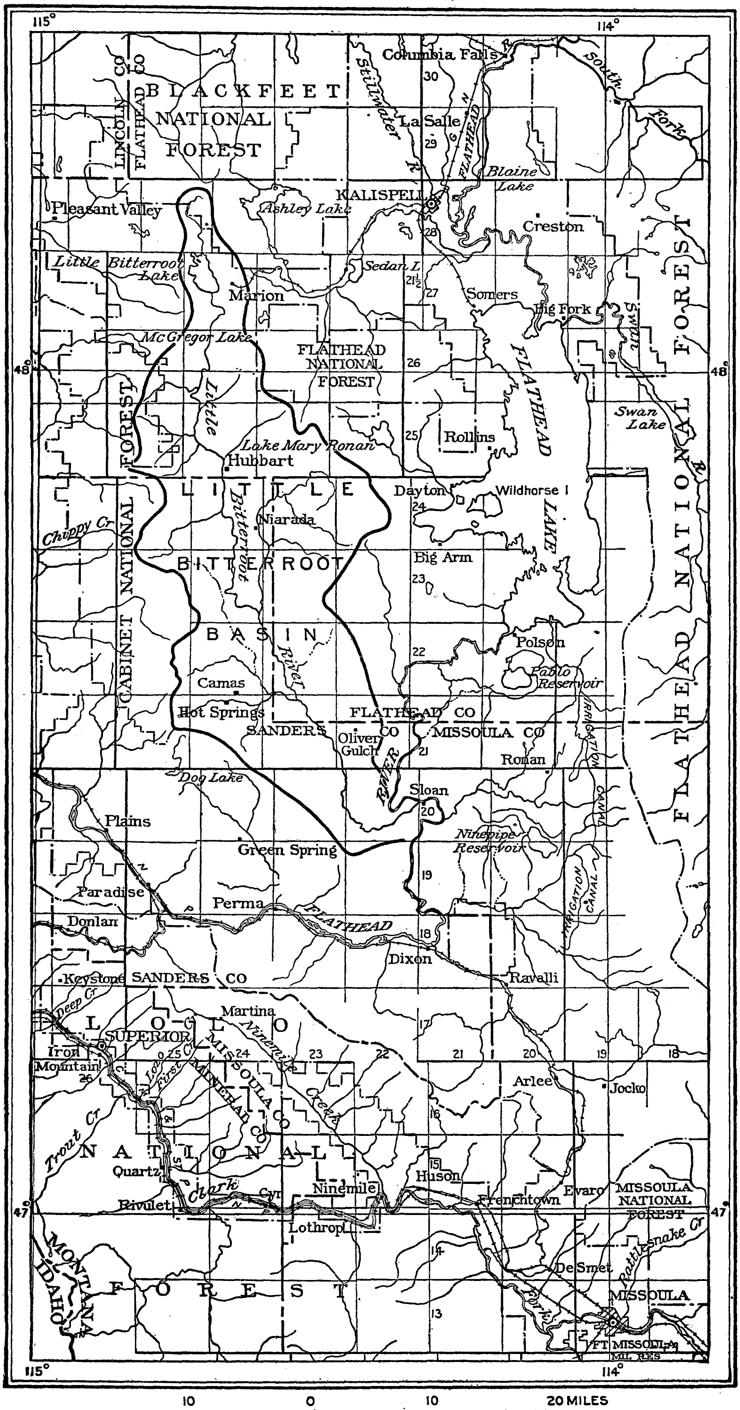
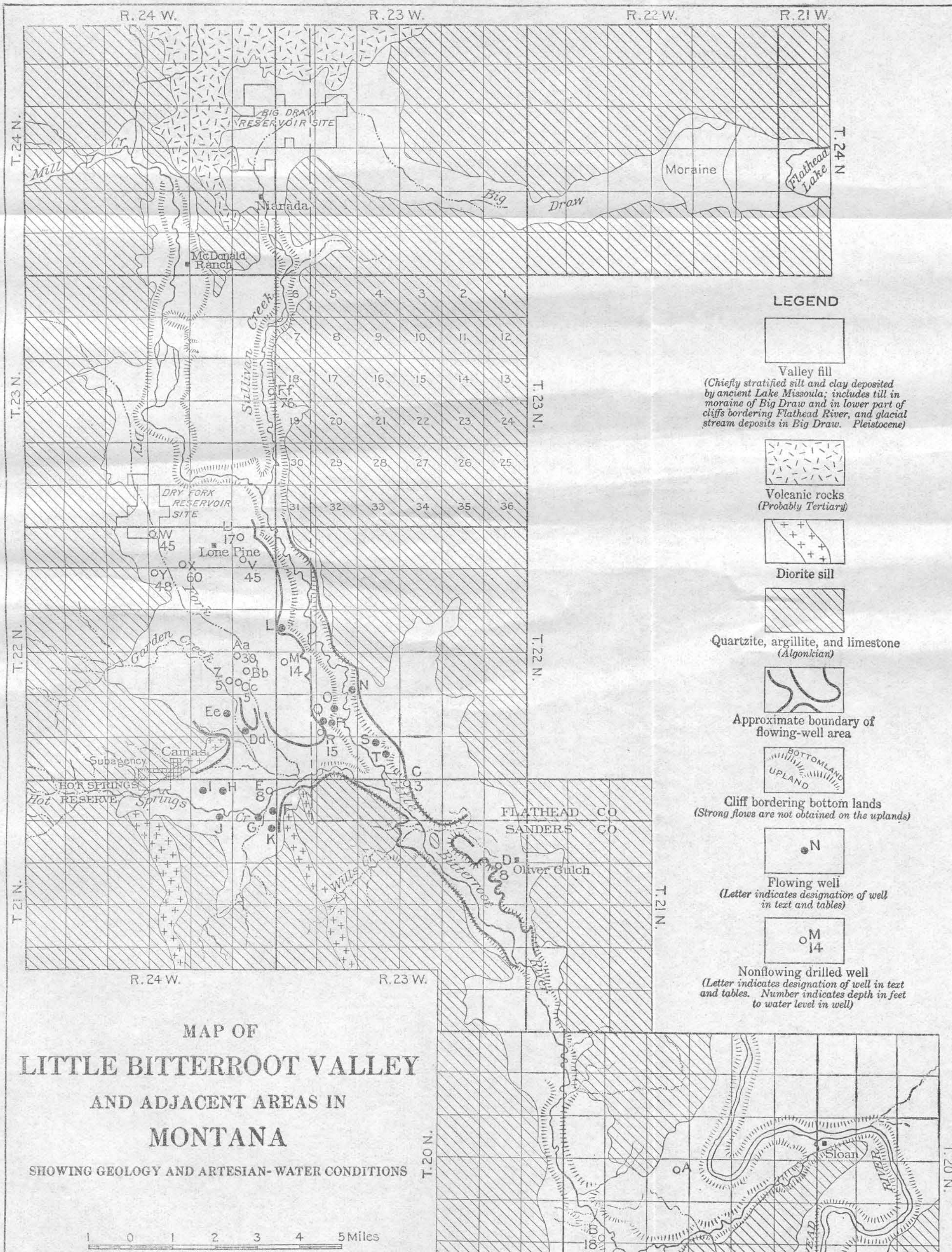


Figure 1.—Map showing drainage basin of Little Bitterroot River and adjacent region, Mont.



Base map compiled from maps of Office of Indian Affairs and General Land Office

Artesian water data by O. E. Meinzer. Surveyed in 1915. Geology taken, with slight modifications, from unpublished map by R. W. Stone and Eugene Stebinger

The climate of the region is semiarid, the average annual precipitation being about 16 inches at Kalispell and 13 inches at Plains. Agriculture without irrigation is therefore uncertain. The Flathead project of the United States Reclamation Service will, when completed, bring about 150,000 acres of the reservation lands under the ditch. A tract of about 14,000 acres in the Little Bitterroot Valley is included in the Flathead project and was sold in small holdings to be supplied with water through the impounding of Little Bitterroot River and several smaller permanent or intermittent streams. Unfortunately for the settlers the appropriations for the Flathead project have been inadequate, and in the fall of 1915 no construction work had been commenced on this part of the project.

In 1911 a flowing well was obtained on the farm of Dr. A. H. Brown (F, Pl. I) and flows were struck at several other places. In 1913 strong flows were discovered in drilling on Ralph Bartlett's farm (O, Pl. I) and on the bottom land owned by E. G. Sisty (N, Pl. I). By August, 1915, about 40 wells had been drilled to the artesian horizon. Seventeen of these were flowing wells, a few of which were used for irrigating small fields. The question consequently arose to what extent the artesian water could be substituted for or used in connection with the surface waters for irrigation in the Little Bitterroot Valley, and the United States Geological Survey was requested to make an investigation of the artesian-water supply. In response to this request the writer spent about 10 days during the month of August, 1915, in the region, making a general survey of the valley, gathering well data, measuring the discharge of the flowing wells, and collecting samples of the well water. The results of previous geologic studies in the region by J. T. Pardee,[1] R. W. Stone, and others of the United States Geological Survey have been freely used in preparing this report. Through cooperation with the Montana State Board of Health and Montana State College 10 samples of water were analyzed by Carl Gottschalck, under the direction of W. H. Cobleigh, director of the laboratory. The Geological Survey, however, is responsible for the conclusions presented in this report.

PHYSIOGRAPHY AND DRAINAGE.

The surface of the Little Bitterroot drainage basin consists essentially of three parts—(1) mountainous or hilly country, shaped by the mature erosion of elevated and deformed masses of bedrock; (2) an elongated plain, built up in the trough between the mountains, chiefly by sedimentation on the floor of a great lake that existed in the glacial epoch; and (3) bottom lands, along the Little Bitterroot and tributary streams, produced by recent erosion of the lake plain.

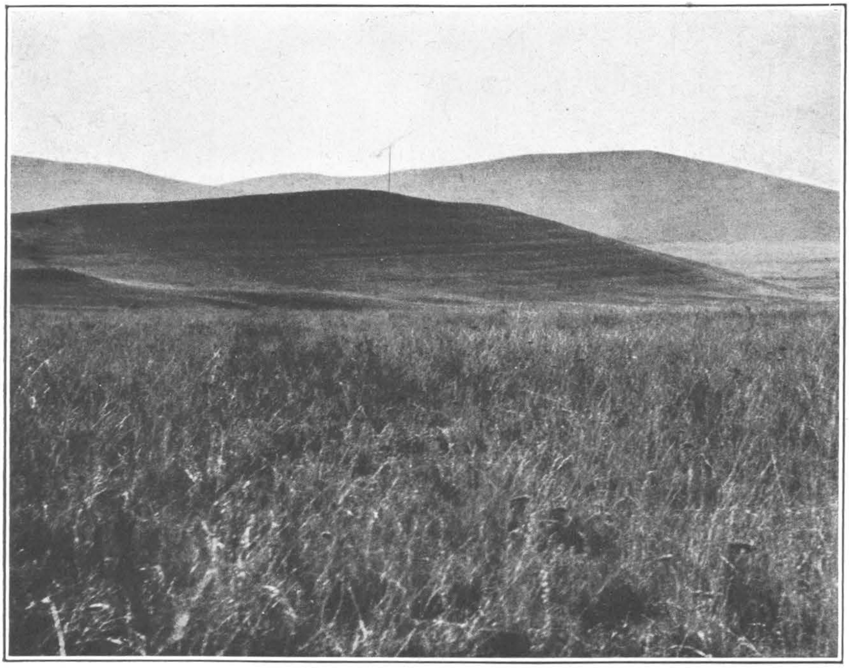
[1] Pardee, J. T., The glacial Lake Missoula: Jour. Geology, vol. 18, pp. 376-386, 1910.

The mountainous or hill country, which constitutes about five-sixths of the entire drainage basin, does not stand very high above the valley, and in many places consists of hills rather than mountains. The hills and mountains on the east side of the valley are nearly treeless, but those on the west side apparently receive more rain and snow, for they support a forest of large trees. The sides of the mountains are marked with horizontal lines that show the levels at which the water stood in the great lake that extended over this region in the glacial epoch. (See Pl. II, *A*.)

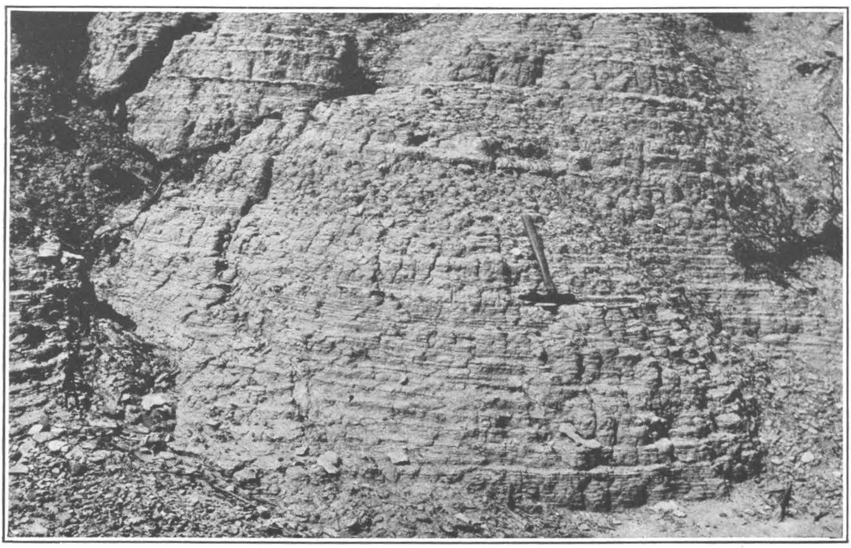
The lake plain, the upland surface of the valley, increases in width southward to the vicinity of the Camas Hot Springs, where it is about 8 miles wide, but farther south it becomes narrower. Where it has not been eroded the plain is smooth, and it abuts abruptly against the mountains on both sides. It slopes gradually southward, however, and is no doubt several hundred feet higher at the north end than in the vicinity of Sloan Ferry, where it forms cliffs 200 feet high overlooking Flathead River. (See Pl. III.) Near the principal drainage lines the plain has been eroded and presents an uneven surface.

Into this lake plain Little Bitterroot River has cut a flat-bottomed trench a quarter of a mile to a mile in width and nearly 100 feet in average depth. This strip of bottom land extends southward from the northwest corner of the valley along the west side for about 9 miles, thence swings directly across the valley and extends southward along the east side to the bend in the valley east of Camas, where it recrosses to the west side. Farther south it swings from one side to the other of the comparatively narrow valley to the point where the stream is deflected by the south wall, where it takes a northeastward trend to its mouth. Near its mouth the Little Bitterroot leaves the lake plain and for about a mile passes through a canyon, 175 feet deep, which is cut into the rocks of the south mountain wall. Within the canyon the stream flows in a rock channel and descends about 75 feet in a series of small rapids. The base level to which the Little Bitterroot is adjusted is therefore not the level of Flathead River but the level of the rock barrier in the canyon, and this may account in part for the fact that the Little Bitterroot, although a small stream, has developed a relatively wider and more mature trench than the large Flathead River. Below the canyon the Little Bitterroot has been diverted from its old course and now enters the Flathead half a mile farther upstream than formerly, leaving the old channel entirely dry. (See Pl. IV and fig. 2.) At some time in the geologic future the Flathead is likely to tap the Little Bitterroot above the rock canyon, with the result that the Little Bitterroot will rapidly cut deeper to adjust itself to its lowered base-level.

The streams in the Little Bitterroot Valley do not seek its central axis, as is the habit of streams in ordinary débris-filled valleys whose



A. SHORE LINES OF ANCIENT LAKE MISSOULA—THE FAINT HORIZONTAL LINES THAT CONTOUR THE HILL IN THE FOREGROUND.



B. STRATIFIED BEDS DEPOSITED IN ANCIENT LAKE MISSOULA.

surfaces are elevated along the margins by the deposition of sediments washed in from the sides. Instead the streams in this valley show a tendency to keep near the margins. Little Bitterroot River flows first along the west and then along the east side of the valley. The two principal drainage lines tributary to the Little Bitterroot are Sullivan Creek and Hot Springs Creek. Sullivan Creek, which receives the drainage of the Big Draw, keeps close to the east side until it encounters the Little Bitterroot. Hot Springs Creek forms the outlet of a draw known as Dry Fork, which has its course along the west side of the valley and carries the waters discharged by all the small west-side canyons from the point where the Little Bitterroot crosses the valley to the vicinity of the Hot Springs. (See Pl. I.) The trench

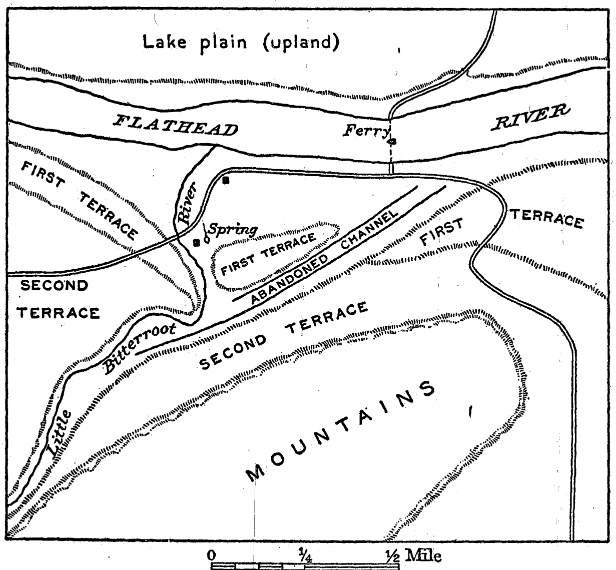


FIGURE 2.—Sketch map of vicinity of Sloan Ferry, Mont., showing abandoned channel of Little Bitterroot River.

cut by Sullivan Creek is similar to that of the Little Bitterroot, but not so wide or deep; the draw of Dry Fork is wide but shallow.

Near its head, about 4 miles below the McDonald ranch, Dry Fork approaches very close to the bottom lands of Little Bitterroot River, but instead of discharging into the river in that vicinity it takes a different course and ultimately leads to Hot Springs Creek, which discharges into the river 10 miles farther downstream. The youthfulness of the postlacustrine erosion cycle is shown by the fact that the upper part of Dry Fork has not yet been captured by a gully tributary to Little Bitterroot River.

The so-called Big Draw is a unique feature of this drainage basin. It is a very definite gap in the mountainous area, about 1 mile wide and more than 10 miles long. Near its east end it is crossed by a high, irregular ridge that is clearly a moraine built by the ice in the glacial epoch. This ridge forms a part of the divide between the Little Bitterroot and Flathead basins. To the east the surface descends steeply several hundred feet to the level of Flathead Lake. To the west the surface descends regularly and less steeply to the mouth of the draw, where it is continuous with the plain of Little Bitterroot Valley. In this so-called draw there is a small streamway that carries the flood waters into Sullivan Creek. The moraine appears to be marked by indistinct shore lines. It is probable that at some time before the moraine and lake plain existed Flathead River had its course through the gap now occupied by the Big Draw and thence down the Little Bitterroot Valley.

GEOLOGIC FORMATIONS.

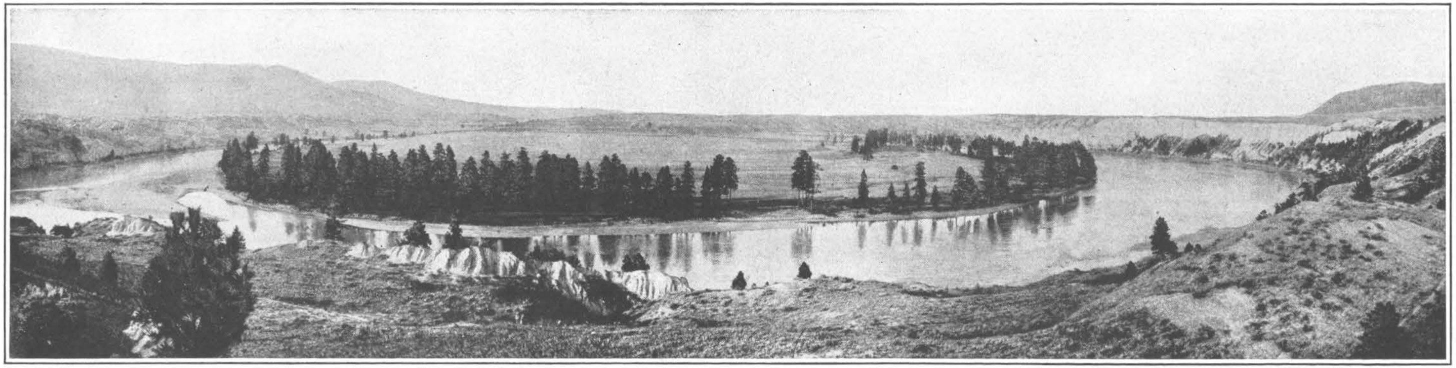
BEDROCK.

The principal rocks underlying the mountainous areas adjacent to Little Bitterroot Valley are quartzite, argillite, and limestone, several thousand feet in aggregate thickness, belonging to the Belt series of the Algonkian system. Between the strata in some localities are intruded masses of diorite. These strata have been greatly deformed. In this region they have in general been bent into folds whose axes run about north. The two belts of diorite southeast of Cames Hot Springs (see Pl. I) are regarded as outcrops of a sill on opposite sides of an eroded anticline, and the belt extending northeastward on the north side of the spring is regarded as an outcrop of the same sill at a place where the anticline pitches steeply toward the north. North of the valley there is a considerable area of volcanic rock of probable Tertiary age. These facts regarding the geology of the basin have been furnished by R. W. Stone and Eugene Stebinger, of the United States Geological Survey.

VALLEY FILL.

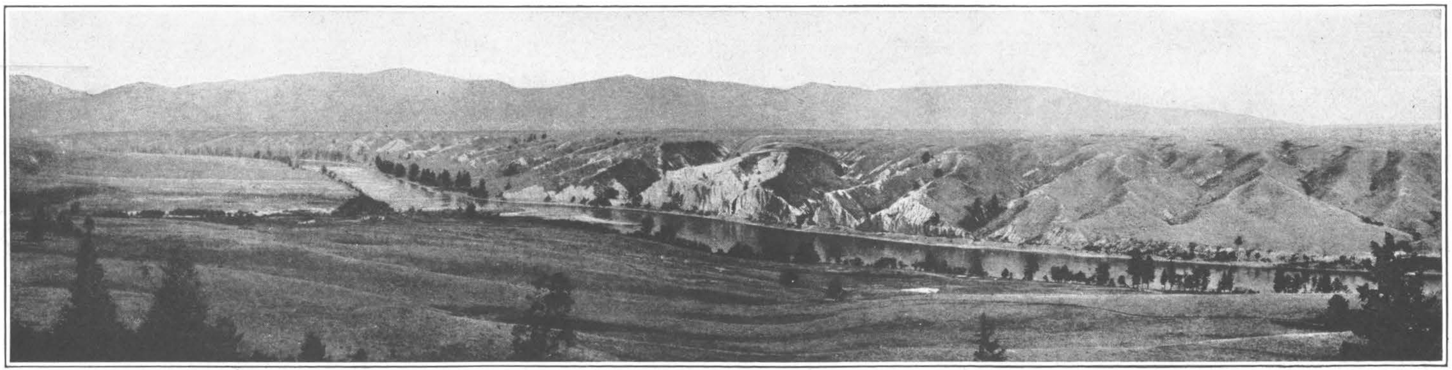
The unconsolidated deposits that underlie the Little Bitterroot Valley and the Big Draw, like those that underlie the plain east of Flathead River, are nearly all of glacial origin and consist of lake beds, till, and stream deposits.

Lake beds.—The lake beds consist almost exclusively of horizontally stratified layers of dense silt and clay and minor amounts of fine sand. They are prevailingly of light-yellowish color. The silty layers resemble the loess of the Mississippi Valley, and, like the loess, they contain numerous irregular, white, calcareous concretions. The lake beds east of Flathead River include many glaciated pebbles and boulders, some of them beautifully polished and striated, that were obviously dropped by floating ice to the floor of the glacial lake and



A. VALLEY OF FLATHEAD RIVER AT BEND ABOVE SLOAN FERRY, MONT.

Showing wide flood plain and spit on concave side of river with steep cliffs on convex side.



B. VALLEY OF FLATHEAD RIVER AT SLOAN FERRY, MONT.

Incised in the till and lake beds underlying the ancient lake plain.

became incased in the otherwise well-stratified and well-assorted deposits. At some localities in the Little Bitterroot Valley, chiefly in its lower part, the lake beds contain similar pebbles and boulders, though in smaller numbers, but in most of the valley these beds contain few if any such erratics, their scarcity apparently indicating the general absence of icebergs in this arm of the ancient lake.

The lake beds underlie practically the entire valley from the mouth of the Big Draw to the cliffs overlooking Flathead River. At many places they are well exposed to the depth of nearly 100 feet, the depth to which the stream has cut, and they have also been penetrated in numerous dug wells to depths not generally greater than 100 feet. Most of the drilled wells extend about 300 feet below the lake plain and end in gravel, but the deposits they penetrate above the gravel are apparently fine sediments like those exposed in the upper 100 feet. Most of the drilled wells are reported to pass through 5 to 20 feet of "quicksand," which generally lies between 100 and 150 feet below the surface. In the dug well of J. J. Taylor (SW. ¼ sec. 14, T. 22 N., R. 24 W.) about a foot of gravel was encountered at a depth of 80 feet between the ordinary clayey beds, but gravel or even coarse sand is rare except at the horizon in which the drilled wells end.

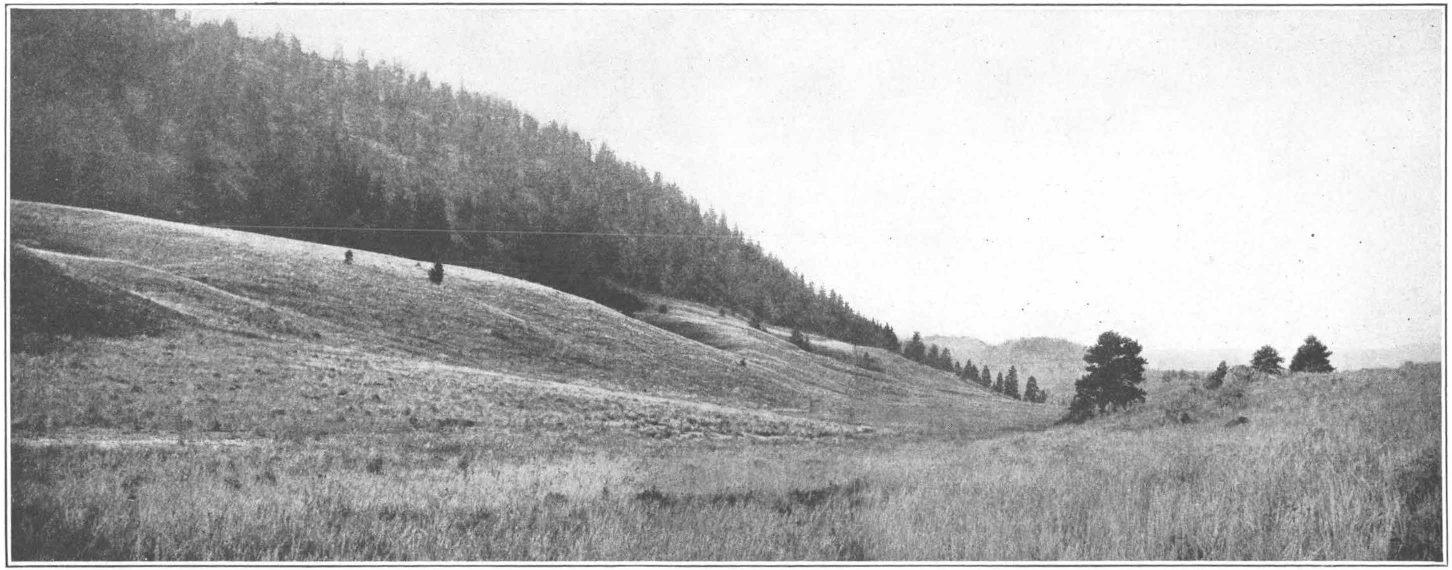
Till.—Glacial till, or boulder clay, is unstratified and unassorted material deposited directly by glacial ice. It is found in large quantities in the Flathead Reservation, chiefly in moraines overlooking the lake plain and in outcrops below the lake beds that underlie the plain. In its typical form it resembles the lake beds in having a matrix of very similar pale-yellow dense silt and clay, in which are embedded glaciated pebbles and boulders, but it is very different from the lake beds in being wholly massive and heterogeneous, the lake beds being distinctly stratified. In the Little Bitterroot Valley till was found only in the moraine that extends across the Big Draw and in outcrops near the mouth of the Little Bitterroot. That it is generally absent in Little Bitterroot Valley, at least to the depth reached by the drilled wells, is indicated by the fact that pebbles and boulders are not found in drilling through the silt and clay deposits.

In the cliffs of Little Bitterroot River below the rock canyon, in the vicinity of Sloan Ferry, fully 100 feet of dense till containing numerous pebbles and boulders and a few lenses of gravel is exposed. The till rests on the bedrock and is overlain by remnants of lake beds. At the bend of the Flathead between 2 and 3 miles west of Sloan Ferry the cliffs, about 200 feet high, consist of till and lake beds. The lake beds rest on the till with pronounced unconformity. In the southeastern part of the bend the till is exposed more than halfway to the top of the cliff, but on the west side of the bend at a place less than a mile distant the till appears to be absent and the lake beds extend to the bottom of the exposure. This till was probably deposited by an ice sheet that spread over the lowland east of Flathead River and blocked the mouth of the Little Bitterroot. There is no evidence that the ice was pushed up the Little Bitterroot Valley.

Stream deposits.—On the moraine in the Big Draw, at the Floyd Frye ranch (NE. ¼ sec. 22, T. 24 N., R. 22 W.), a well 560 feet deep passed through bouldery unconsolidated deposits and ended at a level considerably below Flathead Lake without reaching bedrock. From the moraine to the mouth of the draw, the surface formation consists of poorly assorted bouldery gravel, which appears to have been washed out from the ice sheet when it extended westward into the draw and formed the terminal moraine. This origin is also suggested by the grade of the draw, which is such as would be formed by a stream flowing down from this source. The bouldery gravel bed thins out downstream, and near the mouth of the draw (NE. ¼ sec. 20, T. 24 N., R. 23 W.), it gives way abruptly to typical fine-grained lake beds, under which it apparently passes. In the well of P. E. Poe (N. ½ sec. 27, T. 24 N., R. 23 W.), the bouldery deposits are only 8 feet thick and are underlain by about 50 feet of fine, dry, mealy sand, below which lies 1 foot of sticky blue clay, 2 feet of moist quicksand, and next water-bearing sand and gravel resting on clay. These conditions indicate a somewhat complicated glacial history.

A widespread deposit of clean sand and gravel occurs in the Little Bitterroot Valley below the lake beds, from the main mass of which it is generally separated by a relatively hard layer. This deposit carries the artesian water. That it is widespread is shown by the fact that it has been found in practically all drilled wells in the valley except those very near the mountains. As the drilled wells are finished in this deposit no information has been obtained as to its thickness nor as to whether it rests on older unconsolidated sediments or on bedrock. It is, however, thick enough and coarse and clean enough to yield water freely. So far as known, it is nowhere exposed at the surface, and could not have been discovered except by digging or drilling to it.

The origin of this gravel can only be conjectured. The information obtained by drilling on the plain east of Flathead River does not indicate that such gravel deposits occur generally below the lake beds outside of the Little Bitterroot Valley. Such deposits are most commonly formed by large streams, a fact which suggests that the artesian formation was probably laid down either at a time when Flathead River flowed through the Little Bitterroot Valley or when a large amount of débris-laden water was poured through the valley from glaciers that pressed into its drainage basin from the north and east before the glacial lake came into existence.



ABANDONED CHANNEL OF LITTLE BITTERROOT RIVER AT SLOAN FERRY, MONT.

GEOLOGIC HISTORY.

The history of the Little Bitterroot Valley, so far as it is known, can be summarized as follows:

In the Algonkian period sediments were deposited in this region to a depth of several thousand feet These later became indurated, forming strata of quartzite, argillite, and limestone The strata were intruded by a molten rock that solidified to form sills of diorite and were bent into huge folds. These folded rocks were extensively eroded.

In the Tertiary period volcanic materials were ejected and the region was exposed to further erosion. At one time in the Tertiary or Quaternary period Flathead River probably flowed through the trough known as the Big Draw and thence through the Little Bitterroot Valley.

In the glacial epoch of the Quaternary period, in late geologic time, Clark Fork of the Columbia River was impounded by an ice sheet to such an extent that a great part of the Flathead reservation was submerged beneath a large, deep lake, which is known as Lake Missoula. This lake extended into the Little Bitterroot basin, and at its highest level it submerged the Little Bitterroot Valley to a depth of several hundred feet. The level of the lake fluctuated greatly and its changing shore lines were incised on the mountain sides. On its bottom about 300 feet of fine sediments was deposited.

During the glacial epoch a tongue of the ice sheet pressed into the head of the Big Draw, where it formed a large terminal moraine, and another extended to the mouth of the Little Bitterroot Valley, where it deposited a mass of till that was covered by lake beds. Whether these two ice incursions were contemporaneous, whether they were single or recurrent events, and just how they were related to the history of Lake Missoula are questions that have not yet been definitely answered. The Little Bitterroot arm of the lake was for the most part walled off from the glaciers by low mountains and contained only small amounts of floating ice; the Flathead arm of the lake, on the other hand, was exposed to the front of a large ice sheet, and was at least in some places crowded with icebergs.

When the glacial lake was drained by the thawing of the ice barrier its bottom remained as a more or less even surface over which a new drainage system was developed. For some reason the stream that drains the Little Bitterroot Valley left the lake plain just before reaching Flathead River and took the last mile of its course through a rock canyon. Like the other streams of the drainage system it cut into the lake beds and formed a valley at a lower level.

SURFACE WATER.

Little Bitterroot River rises about 20 miles north of the former Flathead reservation. In the spring and early in the summer it is a rather large stream, but later in the season it normally diminishes to a flow of only a few second-feet. It receives an increment from Mill Creek, which enters it from the west in T. 24 N., R. 24 W., about where the lake plain begins. Its channel below Mill Creek is in the dense and nearly impervious lake beds, which absorb little of the river water but, on the other hand, yield little seepage water to the river. In August, 1915, when the river had reached a low stage, it had practically no tributaries below Mill Creek except Sullivan Creek and Hot Springs Creek, both of which were small. Although stream measurements were not made at different points, it was evident that the volume of the stream remained nearly constant from point to point, and that there was no great net gain or loss between the mouth of Mill Creek, where the river begins to flow over lake beds, to Sloan Ferry, where it empties into the Flathead. Where the river emerges from the mountainous area it was clear and sparkling, but after flowing over the lake beds for several miles it became very roily.

In August, 1915, nearly all the water of Sullivan Creek came from springs north of Niarada. There is no permanent stream in the Big Draw, but flood waters are discharged from it in the spring.

In August, 1915, Hot Springs Creek received a small stream from the mountains in addition to the water from the Camas Hot Springs, but its discharge into the Little Bitterroot was very small. The Dry Fork carried no water, although it forms the drainage outlet of an extensive mountainous area on the west side of the valley and is reported to receive water from a number of canyons in the spring.

The following tables give the data obtained by the United States Geological Survey on the flow at two stations on Little Bitterroot River. (See fig. 1.) The first station is just below the outlet of Little Bitterroot Lake; the second is above the canyon leading to the second fall of Little Bitterroot River, about 1½ miles west of the ranch of the Hubbart Cattle Co. The records for 1909 to 1912 are compiled from United States Geological Survey Water-Supply Papers 272, 292, 312, and 332. The records for 1913 and 1914 are taken from Nos. 362 and 392, in preparation. The records for 1915 are taken from unpublished data in the files of the Survey.

Average monthly and annual discharge, in second-feet, of Little Bitterroot River near Marion, Mont.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1910	*a* 4	*a* 4	*a* 28	28.4	22	26	20	3.7	8.3	6.4	3.3	2.8	31.1
1911				*b*8.70	15.2	16.1	10.6	3.43	2.60	2.60	2.60	3.14	
1912				5.10	10.8	6.95	7.21	2.15	2.39	1.56	*c*1.13		
1913				*d*8.41	19.7	23.3	2.82	1.14	1.76	1.90	1.50	1.18	
1914				6.94	10.5	7.43	4.54	.62	.85	2.81	.87		
1915	.29	.37	.74	.51	1.06	1.23	1.35	1.14	3.83				

a Estimated by comparison with estimates obtained on the Little Bitterroot near Hubbart.
b Apr. 24–30.
c Nov. 1–13.
d Apr. 13–30.

Monthly and annual run-off, in acre-feet, of Little Bitterroot River near Marion, Mont.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1910	*a* 246	*a* 222	*a*1,720	1,690	1,350	1,550	1,230	228	494	394	196	172	9,490
1911				*b* 121	935	958	652	211	155	160	155	193	
1912				303	664	414	443	132	142	96	*c*29		
1913				*d* 300	1,210	1,390	173	70	105	117	89	73	
1914				413	646	442	279	38	51	173	52		
1915	18	21	46	30	65	73	83	70	228				

a Estimated by comparison with estimates obtained on the Little Bitterroot near Hubbart.
b Apr. 24–30..
c Nov. 1–13.
d Apr. 13–30.

Average monthly and annual discharge, in second-feet, of Little Bitterroot River near Hubbart, Mont.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1909				*a*57	*b*89			22	13	13	24		
1910	*c* 18	*c* 18	133	133	80	47	29	12	13	16	17	*c*16	44.3
1911				42.8	65.1	50.0	28.3	17.4	10.5	6.72			
1912				72.4	70.6	30.4	16.3	12.5	11.0	10.4	*d*11.9		
1913							*e*12.3	11.2	9.4	10.5	*f*7.6		
1914				47	46.6	22.9	12.6	4.4	2.6	1.9	3.13		
1915				37	33.4	20.5	13.2	9.38	10.2				

a Apr. 22–30.
b May 1–22.
c Estimated.
d Nov. 1–11.
e July 23–31.
f Nov. 1–14.

Monthly and annual run-off, in acre-feet, of Little Bitterroot River near Hubbart, Mont.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1909				*a*1,020	*b*3,880			1,350	774	779	1,430		
1910	*c*1,110	*c*1,000	8,180	7,910	4,920	2,800	1,780	740	774	984	1,010	984	32,200
1911				2,550	4,000	2,980	1,740	1,070	625	413			
1912				4,310	4,340	1,810	1,000	769	655	640	*d*260		
1913							*e*220	689	559	646	*f*211		
1914				2,800	2,870	1,360	775	271	155	117	186		
1915				2,200	2,050	1,220	812	577	607				

a Apr. 22–30.
b May 1–22.
c Estimated.
d Nov. 1–11.
e July 23–31.
f Nov. 1–14.

SPRINGS.

Few springs are found along Little Bitterroot River, but there are many near the mouths of the canyons on the west side of the valley. Most of these springs are seepage areas that support dense thickets but discharge comparatively little water. They have larger flows in the spring and early in the summer than in the fall. They seem to be produced largely by the small underflow that comes down the canyons and is forced to the surface when it reaches the impervious lake beds. In the reentrant of the valley drained by Hot Springs Creek (secs. 33 to 36, T. 22 N., R. 24 W., and secs. 2 to 4, T. 21 N., R. 24 W.) springs are especially numerous. Many of them yield cold water and are of the ordinary seepage type, but a number of springs in this locality yield hot water and are known as the Camas Hot Springs.

The Camas Hot Springs are near the northwest corner of sec. 3, T. 21 N., R. 24 W., near the outcrop of a large diorite sill that has a steep dip. The high temperature and the mineral character of the water indicate that it comes from considerable depth. (See pp. 30–34.) A bathhouse has been built, and the springs are visited each year by hundreds of people who suffer from various ailments.

Large springs north of Niarada (secs. 24 and 25, T. 24 N., R. 24 W.) form the head of Sullivan Creek. The water, which has only about normal temperature, probably comes from crevices in the rock, but it may be brought to the surface by the lake beds acting as a barrier.

SHALLOW GROUND WATER.

The lake beds are in general so compact and impervious that they furnish very little water, but at certain horizons, far above the artesian horizon, they include sandy or gravelly strata that yield small supplies to dug wells. The water levels in these wells apparently represent a surface that practically coincides with the bottom lands along the streams and that rises only gradually below the lake plain away from the streams. This surface may be regarded as the water table, or surface below which all porous strata are saturated. In some localities, especially near the mouths of the canyons, there is ground water near the surface that is prevented from sinking to the normal water table by the impervious underlying lake beds.

At the mouth of the Big Draw the ground water stands nearly at the surface, but up the draw the depth to water increases steadily until at the moraine the depth is in general very great. In the Frye well (NE. $\frac{1}{4}$ sec. 22, T. 24 N., R. 22 W.) the water level is reported to be about 400 feet below the surface. Small supplies of perched water are found nearer the surface in the vicinity of the moraine, but they are not dependable.

The data that were obtained in regard to the water levels in dug wells are given in the following table, and the data in regard to the quality of the water will be found on pages 29–31.

Data relating to dug wells in Little Bitterroot Valley.

Location.	Physiographic situation.	Depth.	Depth to water level.
		Feet.	*Feet.*
Sec. 30, T. 21 N., R. 22 W. (near center)	Lowland	20	[a] 12
Oliver Gulch post office (SE. ¼ sec. 12, T. 21 N., R. 23 W.).	Lake plain	5	17
Do	Small draw in lake plain	8	
Do	do	5	
SW. ¼ sec. 18, T. 22 N., R. 23 W. (southwest corner).	Lake plain		58
NE. ¼ sec. 20, T. 22 N., R. 23 W	Bottom land of Little Bitterroot River		14
SE. ¼ sec. 32, T. 22 N., R. 23 W	Draw of Hot Springs Creek		29
Lone Pine post office (NE. ¼ sec. 2, T. 22 N., R. 24 W.).	Lake plain	94	76
SW. ¼ sec. 3, T. 22 N., R. 24 W. (west margin)	Draw of Dry Fork		26
NW. ¼ sec. 11, T. 22 N., R. 24 W. (middle west margin).	Lake plain		62
NW. ¼ sec. 13, T. 22 N., R. 24 W. (west margin)	do		52
SW. ¼ sec. 13, T. 22 N., R. 24 W. (southwest corner).	do		60
S. ½ sec. 14, T. 22 N., R. 24 W. (near middle south margin).	do	80	50
NW. ¼ sec. 20, T. 22 N., R. 24 W	About 20 feet above bottom land of Little Bitterroot River.		30
NW. ¼ sec. 23, T. 22 N., R. 24 W. (north margin)	Lake plain	92	67
SW. ¼ sec. 25, T. 22 N., R. 24 W. (near northwest corner).	do	104	55
Sec. 12, T. 23 N., R. 24 W. (near center)	Bottom land of Sullivan Creek		10
SW. ¼ sec. 31, T. 23 N., R. 23 W	Bottom land of Little Bitterroot River		3
NE. ¼ sec. 20, T. 24 N., R. 23 W. (north margin)	Big Draw		20
NW. ¼ sec. 22, T. 24 N., R. 23 W. (near southwest corner).	do		41
NE. ¼ sec. 27, T. 24 N., R. 23 W. (north margin)	do	73	[a] 66

[a] Reported by owner.

ARTESIAN WATER.

WELL RECORDS.

The following table gives the data that were obtained in regard to the drilled wells in the valley, nearly all of which extend to the main artesian horizon:

Data relating to drilled wells in Little Bitterroot Valley.

Map symbol (Pl. I).	Owner.	Location.	Approximate elevation above Little Bitterroot River or Sullivan Creek (feet).	Depth (feet).	Diameter (inches).	Natural flow.		Estimated head above or below surface (feet).	Estimated yield for each foot of head (gallons per minute).	Total cost.	Cost per second-foot of water.	Temperature of water (°F.)	Date of completion.
						Gallons per minute.	Second-feet.						
A	J. F. Maine	Sec. 21, T. 20 N., R. 22 W.		265	6			—100(?)			$500		May, 1915.
B	Big Bend School (District No. 9).	SE. ¼ sec. 30, T. 20 N., R. 22 W.	10	120	6			— 18		$400			Do.
C	Fred Hannaman	NW. ¼ sec. 3, T. 21 N., R. 23 W.	70	301	4			— 2.6					1911.
D	Wm. McEvers	NW. ¼ sec. 13, T. 21 N., R. 23 W.		302	4			— 8					
E	Mrs. Ray Billings	NE. ¼ sec. 1, T. 21 N., R. 24 W.		80	5			— 8					
F	Dr. A. H. Brown	SE. ¼ sec. 1, T. 21 N., R. 24 W.		90	5	4	0.009	+		115	12,800	59½	July, 1911.
G	Henry Johnson	do.		360		([a])	([a])	+		258			
H	A. C. Hammons	NE. ¼ sec. 2, T. 21 N., R. 24 W.		237	3¾	1		+		415	Great.		
I	F. A. Hammons	NW. ¼ sec. 2, T. 21 N., R. 24 W.		82	3¾	[b] 23	.051	+		145	2,900	53	
J	O. H. Spies	SE. ¼ sec. 2, T. 21 N., R. 24 W.		98	1¼	⅔		+					October, 1913.
K	S. E. Waller	NE. ¼ sec. 12, T. 21 N., R. 24 W.		52	5	3½	.008	+		40	5,000	57½	
L	R. R. Loder	NW. ¼ sec. 18, T. 22 N., R. 23 W.	50	267	4	14	.031	+ 7	2	349	11,250	91	
M	C. A. Jellison	NW. ¼ sec. 19, T. 22 N., R. 23 W.	70	296	5			— 14	Large.	370			May, 1913.
N	E. G. Sisty (No. 1)	SE. ¼ sec. 20, T. 22 N., R. 23 W.	10	232	3¾	365	.81	+ 55	7	[c] 350	430	71½	
N	E. G. Sisty (No. 2)	do.	10	232	4	([d])	([d])	+ 55				78	Do.
N	E. G. Sisty (No. 3)	do.		232	3¾	([e])	([e])	+ 55					Do.
O	Ralph Bartlett	NW. ¼ sec. 29, T. 22 N., R. 23 W.	35	244	5⅝	245	.55	+ 37	7	[f] 350	635	120	Do.
P	F. Kopps	SW. ¼ sec. 29, T. 22 N., R. 23 W.	60	260	3	85	.19	+ 12	7	250	1,300	99	March, 1913.
Q	B. B. McGraw	do.	70	274	3	25	.06	+ 3	8(?)	[f] 262	4,700	92½	September, 1914.
R	G. E. McGraw	do.	87	303				— 15		[g] 600			October, 1914.
S	A. Wink	NW. ¼ sec. 33, T. 22 N., R. 23 W.	25	240	2	33	.073	+ 45	⅔				1911.
T	O. P. Monroe	NE. ¼ sec. 33, T. 22 N., R. 23 W.	18	242	3¾	200	.44	+ 50	4	300	675	55	
U	S. H. Murray	NW. ¼ sec. 1, T. 22 N., R. 24 W.	60	275	4½			— 17				62	September, 1914.
V	Duncan Campbell	SW. ¼ sec. 1, T. 22 N., R. 24 W.		303	3¾			— 45		380			
W		NW. ¼ sec. 3, T. 22 N., R. 24 W.						— 45					
X	—— Patten	SE. ¼ sec. 3, T. 22 N., R. 24 W.		285±				— 60					
Y	W. W. Von Segan	NW. ¼ sec. 10, T. 22 N., R. 24 W.		218				— 48					
Z	J. E. Cline	SE. ¼ sec. 23, T. 22 N., R. 24 W.		274±	3¾			— 5					
Aa	C. H. Warren	NW. ¼ sec. 24, T. 22 N., R. 24 W.		270±				— 30					
Bb	A. Weinreiter	do.		267	4½			— 4½					
Cc	Ray Brandt	SW. ¼ sec. 24, T. 22 N., R. 24 W.		270±				0					
Dd	Wm. Maxon	SW. ¼ sec. 25, T. 22 N., R. 24 W.		247±	2¾	[h] 50	.11	+		[i] 300	2,700	65	
Ee	—— Romain	NE. ¼ sec. 26, T. 22 N., R. 24 W.			5¼	[c] 25		+				59	1911.
Ff	Mrs. S. Strand	SE. ¼ sec. 13, T. 23 N., R. 24 W.	65	197	4½			— 76					July, 1914.

[a] Very small, less than 1 gallon a minute.
[b] Discharging 5 feet above surface.
[c] Estimated.
[d] Closed at time of investigation. Reported to yield more than No. 1.
[e] Clogged and abandoned. Reported to have had originally largest yield of Sisty group of wells.
[f] Not including board of drillers and other incidental expenses.
[g] Including board of drillers and other incidental expenses.
[h] Discharge pipe reduced to 1¼ inches.

OCCURRENCE.

The principal artesian-water bed lies about 300 feet below the lake plain, or somewhat more than 200 feet below the level of Little Bitterroot River, this approximate depth being shown by the drilled wells from the vicinity of Lone Pine post office to the vicinity of Oliver Gulch post office. This bed consists of clean, porous sand and gravel that is not known to outcrop. The overlying deposits of dense, uniform lake silt constitute an effective confining bed. The underlying formations have not been penetrated by the drill, and it is not known whether the artesian-water bed rests on older valley fill or on rock. It is therefore possible that there are still deeper water-bearing beds in valley fill below the recognized artesian horizon.

The character of the artesian-water bed indicates that it was deposited by a stream or streams which flowed through the Little Bitterroot Valley before the lake sediments were laid down. The wells that have been drilled seem to show, however, that it occurs generally below the main part of the valley. No doubt there are important local differences in the water-bearing capacity of this gravel bed, but in general the wells that are known to tap it yield freely, either by natural flow or by pumping, according to their elevation.

In the reentrant of the valley drained by Hot Springs Creek (chiefly in T. 21 N., R. 24 W.) drilled wells either have been unsuccessful or have obtained only weak flows. Some of these wells are shallow, but several are deep enough to give a thorough test. The ancient stream which apparently deposited the gravel of the main artesian bed probably never flowed through this reentrant, and the water-bearing deposits which are encountered in drilling were probably formed by local streams. Several wells near the margin of the valley, such as the Waller and Brown wells (K and F, Pl. I), reach the bedrock and apparently draw their supplies from fissures or porous materials near the contact.

In the upper part of the Big Draw and on the lake plain in the lower part of Little Bitterroot Valley—the vicinity of Big Bend and beyond—there has been poor success in obtaining water, due largely to the great depth of the water table in these localities, but in part perhaps to the absence of suitable water-bearing gravels.

In the well of J. F. Maine 30 feet of water-bearing gravel was reported, and the water is said to stand 100 feet below the surface. (See table, p. 22.)

HEAD.

Flowing wells can be obtained over approximately 20 square miles, or about one-fifth of Little Bitterroot Valley. The flowing well area, as outlined in Plate I, includes (1) the bottom lands of Little

Bitterroot River from above the mouth of Sullivan Creek to a considerable distance below the mouth of Hot Springs Creek; (2) the bottom lands of the lower parts of Hot Springs Creek, Garden Creek, Dry Fork, and probably Sullivan Creek and some smaller tributaries of the Little Bitterroot; (3) ravines and small upland tracts adjacent to the bottom lands, especially in the southern part of T. 22 N., Rs. 23 and 24 W. (See Pl. I.)

No direct measurements of pressure were made, but the plane to which the artesian water rises was determined by measuring the depth to water in nonflowing drilled wells, and the head of many of the flowing wells was estimated by obtaining their elevations relative to this plane by use of the hand level. The results are given in the table on page 22.

Wells with considerable head and consequently strong flows are practically confined to the river bottom lands. Within the limits of the irrigation project (north of the south lines of secs. 10 and 11, T. 21 N., R. 23 W.) they are obtained over an area of about 4½ square miles, or 2,700 acres. The best head and strongest flows are obtained in the southern part of T. 22 N., R. 23 W., where the water rises to a level nearly or quite 70 feet above the river level (C, O, P, Q, R, S, T, Pl. I). Toward the north the head relative to river level gradually declines. According to results obtained with the hand level, the water rises only 56 or 57 feet above river level near the points indicated by L and M and 43 feet near the point indicated by V (Pl. I).

In the well of Mrs. S. Strand (Ff, Pl. I) the water level stands about 11 feet below the level of Sullivan Creek, which is just west of the well. If this represents the head of the main artesian supply it indicates a rapid decline in artesian pressure northward from the point marked V, or from the mouth of Sullivan Creek. However, as this well extends only 132 feet below the level of the creek it may not reach the main artesian horizon. Flows could no doubt be obtained on the river bottom lands above the mouth of Sullivan Creek, but the water levels in the drilled wells of the adjacent uplands indicate that the head would not be great.

Just as the head of flowing wells on the bottom lands decreases toward the north so the depth to the water level in the nonflowing wells on the upland, or lake plain, increases in the same direction. In the southern part of T. 22 N., Rs. 23 and 24 W., and in the adjacent parts of the township next south the water rises to the upland level, or at least to the level of small ravines or draws in the upland plain, but at the middle of T. 22 N., R. 24 W. (Aa, Pl. I), it stands 30 feet and in the northern part of the township from 45 to 60 feet below the upland surface.

At the south line of T. 22 N., R. 23 W., the artesian pressure is near its maximum, as is shown by the well of Fred Hannaman (C, Pl. I) in which the water level is estimated to be 70 feet above river level. Southward the head apparently declines, but not at a rapid rate. In the McEvers well (D, Pl. I), about 3 miles southeast of the Hannaman well, the water rises nearly to the upland level, indicating that good flows could be obtained on the bottom lands in this vicinity except where bedrock occurs near the surface, cutting out the gravel bed. Ten miles farther south is the Big Bend schoolhouse well, which is reported to go to a depth of 120 feet, or 110 feet below river level, but in which the water level is 18 feet below the surface, or about 8 feet below river level. According to one report rock was struck in this well at a depth of 40 feet.

In general the level to which the water from the artesian bed rises is considerably above the water level in dug wells that end at higher horizons. On the bottom lands, where the water table nearly coincides with the river level, the difference is greatest and amounts to a maximum of about 70 feet. Under the lake plain at some distance from the river the water table is considerably above river level, and the difference is not so great. In some places where there is perched water, as the upper part of the draw of Dry Fork and the vicinity of Oliver Gulch post office, the water table may stand higher than the level to which the artesian water will rise.

In the area that contains most of the flowing wells the artesian pressure was appreciably less in August, 1915, than it had been when the first wells were drilled. In the well of C. A. Jellison (M, Pl. I) the water was reported by the owner to have at first stood 5 feet below the surface, but in August, 1915, it stood 14 feet below the surface, indicating a drop of about 9 feet. The water level is said to have dropped when the Bartlett well (O) was sunk and again when the Sisty wells (N) were sunk. In the flowing well of R. R. Loder (L) there has been considerable decrease in yield, and it appears that the head was 4 feet lower in August, 1915, than it had been in the spring of 1913, when the well was drilled. The owner reports that the flow decreased when the Sisty wells were drilled.

In the well of G. E. McGraw (R), completed in 1911, the water is reported to have at first stood 6 feet below the surface, and when tapped at 9 feet below the surface it discharged into a near-by coulee. In August, 1915, the water level was 15.4 feet below the top of the casing, or about 14.5 feet below the surface, indicating a drop of about 9 feet. Measurements of the flow of the well of Ralph Bartlett, in December, 1913, and in August, 1915, indicate a decline of about 15 per cent in yield; if there was a proportional decline in head the loss of head amounted to 6 or 7 feet.

In the well of E. J. Cline (Z) the original water level was reported to have been 1.5 feet below the surface, but in August, 1915, it was about 5 feet below, indicating a drop of 3 or 4 feet. The well of Ray Brandt (Cc) was originally a flowing well, but in August, 1915, no water was discharged from it. A loss of head in the Romain well is indicated by its great decrease in flow.

The well of Fred Hannaman (C) was drilled in 1911 and is reported to have flowed until 1914, when the Monroe well (T), somewhat less than a mile distant and on land 50 feet lower, was drilled. Mr. Hannaman stated that within 24 hours of the time artesian water was struck in the Monroe well his well ceased flowing. In August, 1915, the water level stood 2.6 feet below the surface. The well of William McEvers (D), about 3 miles southeast of the Hannaman well, was evidently once tapped about 5 feet below the surface, but in August, 1915, the water stood 8 feet below, apparently indicating a loss of head of at least 3 feet.

YIELD.

The natural yield of nearly all the flowing wells was measured either by observing the time required for them to fill vessels of known capacity or by installing weirs. The results are given in the table on page 22.

The largest flows are found on low ground adjacent to the river in T. 22 N., R. 23 W., where there is strong pressure. The Sisty wells (formerly known as the Jarnigan wells, N, Pl. I) are on the bottom lands, only about 10 feet above river level, and were estimated to have a head of 55 feet. Well No. 1 is $3\frac{3}{4}$ inches in diameter and well No. 2 is 4 inches in diameter. In August, 1915, well No. 1 flowed 365 gallons per minute, or approximately 7 gallons per foot of head. The flow of well No. 2 was not measured but is reported to be somewhat larger than that of No. 1. The Bartlett well (O), 5 to $5\frac{5}{8}$ inches in diameter, is about 35 feet above river level, and was estimated to have a head of 37 feet. Its flow in August, 1915, was 245 gallons per minute, or about 7 gallons per foot of head. The Monroe well (T), 2 to $3\frac{3}{4}$ inches in diameter, is about 18 feet above river level and was estimated to have a head of 50 feet. Its flow in August, 1915, was 200 gallons per minute, or about 4 gallons per foot of head. The 3-inch Kopps well (P), which is about 60 feet above river level, was estimated to have a head of 12 feet. Its flow was 85 gallons per minute, or about 7 gallons per foot of head. The relation of yield to head in these wells is graphically shown in figure 3.

The natural flow of none of the wells at higher levels is large, and the flow of some of them is very small. Some of these wells, for example, the Maxon well (Dd), appear to have rather large specific capacities, and would probably yield freely if they were pumped.

Some of the wells in the group southeast of Camas Hot Springs would, however, probably not yield much water, even if they were pumped. The nonflowing Jellison well (M) is reported by the owner to have been pumped with a 3-inch centrifugal pump, rated at 250 gallons per minute, throughout the working day for many days in succession. The Murray well (U), also nonflowing, was pumped in a test in August, 1915, at 36 gallons per minute. In neither well was the amount of drawdown ascertained.

The total natural flow of the 16 or 17 flowing wells in Little Bitterroot Valley in August, 1915, amounted to about 3½ second-feet, or 1,570 gallons per minute. Of this amount about 3.30 second-feet, or 1,480 gallons per minute, was supplied by the six wells whose yield was more than 0.10 second-foot, or 45 gallons per minute.

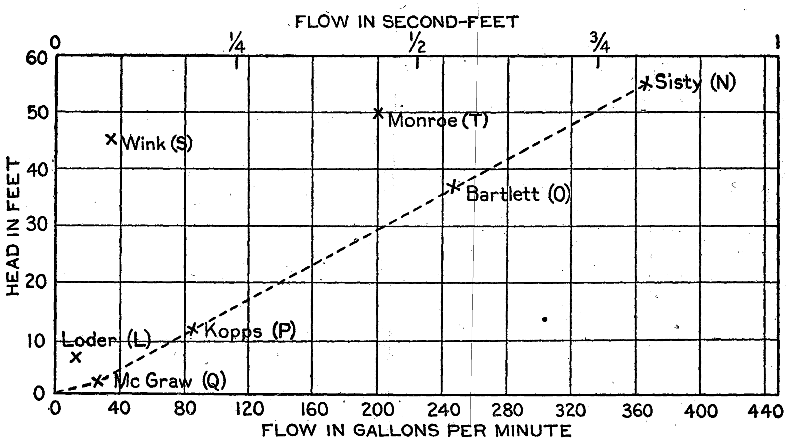


Figure 3.—Diagram showing relation of natural flow to estimated head in several wells in Little Bitterroot Valley, Mont.

The decline in the yield in some of the flowing wells and its relation to the decline in head has already been mentioned. The most definite information was obtained regarding the Bartlett well. This well was drilled in March, 1913, and the Sisty wells were drilled in May, 1913. In December, 1913, the natural flow of the Bartlett well was measured, by means of a weir, by E. F. Tabor, project engineer of the Flathead irrigation project, and was found to be 290 gallons per minute. In August, 1915, in connection with the present investigation, it was again measured, by means of a weir, and was found to be only 245 gallons per minute, indicating a decline of 45 gallons per minute, or fully 15 per cent.

A gradual decline in the yield of flowing wells occurs in most artesian basins. It may be caused (1) by the interference of more recently drilled wells, (2) by self-exhaustion; that is, depletion of the supply in the vicinity of the well, or (3) by underground escape of the water through rusted or otherwise defective casing. There can be no doubt that the flowing wells in Little Bitterroot Valley interfere with each other, the effect being most noticeable in wells with slight head when other wells are drilled near by at considerably lower levels. The decline in the Bartlett well, however, appears to be due chiefly to the gradual depletion of the supply in that vicinity.

The decline in yield should serve to emphasize the fact, frequently demonstrated but seldom appreciated by well owners, that an artesian supply is a definitely limited quantity of water, and that the extent to which it is wasted determines the quantity remaining available.

QUALITY.

Ten of the 14 samples of water of which analyses are given in the following table were collected in August, 1915, in connection with the present investigation, and were analyzed by Carl Gottschalck in the laboratory of the Montana State Board of Health and the Montana State College, under the supervision of W. M. Cobleigh, director of the laboratory. The analysis of the Camas Hot Springs water was made in the same laboratory but at an earlier date. The analyses of the samples from Flathead Lake and the wells of Henry Hilt and R. A. Calkins, both east of Flathead River, were made by S. C. Dinsmore for the United States Geological Survey, in connection with another investigation.

Analyses of water from Little Bitterroot Valley, Mont., and adjacent areas.

[Analysts, W. M. Cobleigh, Carl Gottschalck, S. C. Dinsmore. Quantities in parts per million.]

Map symbol (Pl. I).	Owner or name.	Description.	Depth of well.	Silica (SiO_2).	Iron oxide and alumina (Fe_2O_3+Al_2O_3).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).[a]	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4).	Chlorine (Cl).	Nitrate radicle (NO_3).	Total dissolved solids.	Quality for domestic use.	Quality for boiler use.	Quality for irrigation.
			Feet.														
B	Big Bend school	Drilled well	217	16	7.2	24	1.2	40	....	171	7.0	3.2	....	180	Fair	Good	Good.
I	F. A. Hammons	Flowing well	82	26	.8	28	8.2	36	....	201	8.2	4.9	0.5	250	Good	Fair	Do.
K	S. E. Waller	do	52	31	1.2	35	8.2	36	....	204	23	2.7	5.6	252	do	do	Do.
	Camas Hot Springs[b]	....	....	52	None.	7.1	4.2	79	55	95	5.8	20	Tr.	318	do	do	Fair.
	Ed. Lamoureaux[c]	Warm spring	....	78	1.0	4.0	.4	94	56	113	14	11	....	326	do	do	Do.
L	R. R. Loder	Flowing well	267	36	....	7.2	.4	154	....	369	.2	37	....	426	do	Poor	Poor.
N	E. G. Sisty	do	232	42	.6	7.2	1.4	150	....	360	2.1	35	3.6	460	do	Fair	Do.
O	Ralph Bartlett	do	244	43	.8	6.0	.5	150	....	354	1.4	35	1.2	480	do	do	Do.
T	O. P. Monroe	do	242	29	1.8	9.7	.6	122	....	320	.2	19	2.7	362	do	do	Do.
U	S. H. Murray	Drilled well	275	20	2.0	14	.3	131	....	329	.4	34	4.2	384	do	do	Do.
	George O'Neal[d]	Dug well	94	30	2.0	39	.7	84	....	268	58	3.2	....	333	do	do	Fair.
	Henry Hilt[e]	do	26	47	.75	40	23	28	....	295	Tr.	10	....	280	....	....	
	R. A. Calkins[f]	Drilled well	462	28	.10	44	13	3.2	....	200	Tr.	4.5	....	146	....	....	
	Flathead Lake[g]	Lake	....	26	....	25	6.7	Tr.	....	102	Tr.	3.0	....	94	(g)	Fair	Good.

a Calculated.

b Location: NW. ¼ sec. 3, T. 21 N., R. 24 W. Ammonia (NH_4), 0.5 part per million. Contains hydrogen sulphide and possibly other sulphur compounds.

c Sec. 4, T. 21 N., R. 24 W.

d Lone Pine post office, NE. ¼ sec. 2, T. 22 N., R. 24 W.

e Location: SW. ¼ sec. 6, T. 19 N., R. 20 W. Sample collected October, 1912, by O. E. Meinzer and analyzed by S. C. Dinsmore. Iron 0.75 part per million.

f Location: SW. ¼ sec. 18, T. 19 N., R. 20 W. Sample collected October, 1912, by O. E. Meinzer and analyzed by S. C. Dinsmore. Depth to water level in well 168 feet; yield small; iron 0.1 part per million.

g Sample taken from tap at Lakeview Livery, Polson, Mont., by O. E. Meinzer, October 6, 1912, and analyzed by S. C. Dinsmore. Iron, 0.5 part per million. The water is soft and otherwise good for domestic use in so far as dissolved mineral matter is concerned but is liable to be locally polluted.

70547°—wsp 400—17——3

The ground waters in Little Bitterroot Valley are not highly mineralized, the samples examined ranging in total dissolved solids from 180 to 480 parts per million. They are nearly all sodium carbonate waters, and most of them have an odor of hydrogen sulphide, but they nevertheless differ considerably in mineral content and in this respect fall into two or more groups.

The deep artesian waters, represented by the Loder, Sisty, Bartlett, Monroe, and Murray samples, are very low in calcium and magnesium and relatively high in sodium; they are relatively high in bicarbonate, moderate in chlorine, and very low in sulphate. They are pronouncedly sodium carbonate in character.

The Hot Springs waters are equally low in calcium and magnesium and are distinctly lower in sodium. They differ from the artesian waters and from all other waters examined in containing normal carbonate (CO_3). They contain considerably less bicarbonate, slightly more sulphate, and a little less chloride. The general similarity in chemical character, however, of the Hot Springs waters to the deep artesian water suggest a common origin, at least in large part.

The sample from the well of George O'Neal, at Lonepine post office, is the only water from a dug well that has been analyzed. Although it is also sodium carbonate in type, it contains much more calcium than the deep artesian water and the Hot Springs water and somewhat less sodium than the deep artesian water. It also differs from the waters of both of these groups in being higher in sulphate and lower in chlorine.

The other well waters examined—those from the Big Bend schoolhouse well and from the Hammons and Waller shallow flowing wells—resemble most nearly the water from O'Neal's dug well but are still lower in sodium.

The water of Flathead Lake is very different from the deep artesian waters and the Hot Springs waters; it appears to be more closely related in mineral content to the shallow well waters. It is higher than the deep artesian waters in calcium and much lower in sodium; it is also lower in bicarbonate, sulphate, and chloride. The chemical difference between the lake water and the deep artesian waters can not be satisfactorily explained by changes that might occur to the water on its underground journey, and it provides evidence that the contribution from the lake to the artesian supply is not great.

The differences outlined in the foregoing paragraphs are summarized in the following table:

Summary of mineral content of ground waters from Little Bitterroot Valley, Mont., and of water from Flathead Lake.

[Parts per million.]

	Number of analyses.	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).
Loder, Sisty, Bartlett, Monroe, and Murray wells	5	6–14	0.3–1.4	122–150	....	321–359	0.2–2.1	19–37
Springs at Camas Hot Springs	2	4–7.2	.4–4.3	79–93	55–56	96–110	5.8–14	11–25
O'Neal dug well	1	39	.7	85	....	268	58	3.2
All other wells	3	24–35	1.2–8.2	36–40	....	171–204	7–23	2.7–4.9
All ground-water samples.	11	4–39	.3–8.2	36–150	0–56	96–359	.2–58	3.2–37
Flathead Lake	1	25	6.7	Trace.	....	102	Trace.	3.0

In so far as they were tested, all the waters from Little Bitterroot Valley are of satisfactory quality for drinking and other domestic uses, unless an exception is made of the Lone Pine well water, which has a somewhat foul taste, due to the presence of hydrogen sulphide or to some other cause. No sanitary examinations of the waters were made. None of the waters that were analyzed are very hard, and the deep artesian and hot springs supplies are exceptionally soft.

The waters from all sources are of fair quality for use in steam boilers. The deep artesian and hot springs waters will form very little scale and are probably not corrosive in boilers but may cause some trouble by foaming. The shallower waters will form only moderate amounts of scale, will probably not be corrosive, and are less likely to give trouble by foaming than the deep artesian and Hot Springs supplies. The hydrogen sulphide may cause some corrosion of well casings.

The deep artesian waters are of rather poor quality for irrigation, owing to their large content of sodium and of bicarbonate, which are in time likely to produce harmful amounts of black alkali in the soil. If they are used for irrigation all practicable means should be employed to prevent the accumulation of alkali. The artesian water should be applied sparingly and should not be used exclusively if it is possible to substitute stream water for it a part of the time. The danger from alkali may be greater on the bottom lands, where the water will probably be chiefly used, than it would be on the uplands, where the soil is less dense and the drainage is better. With proper methods, however, it may be possible to use the artesian water for the irrigation of the bottom lands without serious damage.

TEMPERATURE.

A notable feature of the artesian water is its high temperature. The water from a few of the wells is hot, though that from other wells has a normal temperature or a temperature slightly above normal.

According to the records of the United States Weather Bureau the mean annual temperature of the atmosphere during 11 years has been 42.4° F. at Kalispell and 44.7° F. at Plains; the temperature of the water from the dug well at Lone Pine post office, 94 feet deep and with a depth to water of 76 feet, in August, 1915, was 52.5° F.; and the temperature of the water from 11 of the artesian wells at the same time ranged from 53 to 120° F. (See table, p. 22.)

The hottest water was found in the Bartlett well, which in August, 1915, had a temperature of 120° F. Ranking next in temperature were the Kopps well, 99° F.; the McGraw well, 92.5° F.; and the Loder well, 91° F. The temperature of the water from the Bartlett well appears to have declined somewhat, for in December, 1913, it was found by Project Engineer E. F. Tabor to be 126° F.

The high temperature seems to relate the artesian water in its origin to the water of the Camas Hot Springs and to indicate that it comes in part from some deeper source than the artesian horizon. The great difference in temperature of waters apparently coming from the same formation and only short distances apart is noteworthy. Thus the water from the Sisty wells is not nearly so hot as that from the Bartlett well, only half a mile distant, and the water from the Monroe well, only 1½ miles from the Bartlett well, is rather cool. In general the temperature bears but little relation to the yield, although in the group of wells on sec. 29, T. 22 N., R. 24 W. (the Bartlett, Kopps, and McGraw wells), which have the highest temperatures, the temperature appears to vary directly with the yield. Moreover, in the Bartlett well the decline in temperature appears to have been proportionate to the decline in yield, as is shown by the diagram in figure 4.

SOURCE.

The artesian-water bed is so effectively covered by the overlying lake beds that it apparently has only poor intake facilities. There are no gravelly alluvial fans at the mouths of the mountain streamways through which the waters shed from the mountains might sink to the underground reservoir, as there are in most waste-filled valleys in arid and semiarid regions. The dense lake beds nearly everywhere extend to the edge of the mountains. The most important exception is in the Big Draw, which is underlain by gravelly deposits that may feed water to the artesian bed, but this draw does not drain a large area and at best can not contribute very great amounts of water.

That the dense lake beds tend to block the water discharged from the mountains and prevent it from sinking is shown by the springs and perched shallow-water bodies near the mountains, especially in localities where the principal streamways reach the lake plain. At the ranch of S. E. Waller (sec. 12, T. 21 N., R. 24 W.) there is shallow water with springs and a shallow flowing well near the base of the mountains, but only a short distance out on the lake plain wells must be sunk to considerable depths before they strike water. Obviously in such localities the lake beds act as an underground dam.

It should, however, not be assumed that none of the surface water can get into the artesian reservoir. The margin of the valley is many miles in total length, and if there is only a moderate amount of percolation in the marginal zone the total contribution to the artesian supply may be large.

According to the data at hand the water level of Flathead Lake is somewhat more than 100 feet above the level to which the artesian water rises in the area of the principal flowing wells, and it is therefore possible that water is contributed by the lake to the artesian reservoir through the valley fill in the Big Draw. That the lake is not the principal source of the artesian water is, however, indicated by the fact that the artesian water is radically different from the lake water in mineral character and that the differences are not such as would be likely to be produced by percolation through the gravel bed. (See p. 30.)

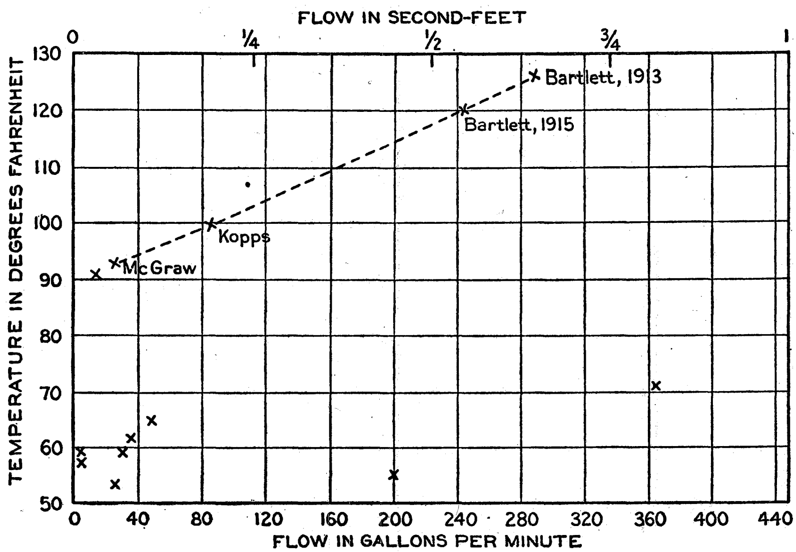


FIGURE 4.—Diagram showing relations between temperature of artesian water and flow of artesian wells in Little Bitterroot Valley, Mont. The Bartlett, Kopps, and McGraw wells are in the same locality.

The high temperatures and sodium carbonate type of the artesian water (see pp. 28–32) appear to correlate it with the hot, sodium carbonate water of the Camas Hot Springs and to indicate that it comes in part out of deep fissures in the underlying rock and from rather remote sources. The evidence of this origin is strengthened by the relation of the springs and artesian waters to the diorite sill (p. 14), and by the fact that the greatest artesian pressure, with reference to river level, coincides approximately with the highest temperatures and most pronounced sodium carbonate type.

Obviously the conditions are such that estimates of the rate of recharge of the artesian supply can not be made.

METHODS AND COST OF DRILLING.

Jetting or hydraulic drilling rigs are now used in Little Bitterroot Valley and are well adapted to the conditions that prevail there. In those rigs water pumped down through hollow drill rods comes up on the outside, and cutting drill bits are operated by the spudding method. Rigs of this type have an advantage in two respects over the standard cable percussion rigs for drilling through the lake bed—they can be operated more rapidly and they are much better adapted to sinking through the strata of quicksand that are encountered. The standard cable percussion rigs are, however, required for drilling in rock. Heavy iron casings are generally used and are required for satisfactory results in the flowing wells.

The prices at first charged for drilling in the valley fill were as high as $2 to $3 per foot, but in 1915 the prevailing prices, including casing, were about $1 for wells with 3-inch casing, $1.25 for wells with 4-inch casing, and $1.50 for wells with 5-inch casing. If a series of wells were to be sunk the work could probably be accomplished at a somewhat lower cost.[1]

USE FOR IRRIGATION.

A small amount of irrigation has been accomplished with artesian water. As no reliable estimate of the quantity of artesian water or of the annual rate of recharge can be made it is not possible to predict how much land could be irrigated permanently with the artesian supply. It is probably a mistake to assume, on the one hand, that the artesian supply is inexhaustible, or, on the other, that the supply is too small to be of substantial value for irrigation. The important matter is to devise, if possible, some practicable plan for utilizing the artesian supply and to put this plan into effect.

Development of irrigation supplies from flowing wells is practically limited to the river bottom lands—probably to that part of these lands that lie south of the northern boundary of T. 22 N., R. 24 W.—and the lowest bottom lands in the Hot Springs Creek drainage basin. Artesian supplies can be obtained on the bottom lands in considerable quantities at low cost, but on the higher lands in only small quantities and at very high cost for irrigation.

[1] Information by E. G. King, driller. Since these figures were obtained the price of casing has advanced.

The data in the table on page 22 show the high cost per second-foot of the artesian water obtained on the uplands and the low cost of that obtained on the bottom lands. Thus the cost per second-foot was $1,300 in the Kopps well, $675 in the Monroe well, $635 in the Bartlett well, and $430 in the Sisty well No. 1. The cost of the six wells that furnish 3.30 second-feet, or about 95 per cent of the total developed supply, was $1,900, or about $575 per second-foot. On the assumptions that the irrigating season extends over 100 days and that the depth of irrigation required is 2 feet per season, one second-foot of water would irrigate about 100 acres, and the cost of the water supply derived from the six wells mentioned would amount to only $5.75 per acre. If an additional supply were developed by drilling on the bottom lands the unit cost might be higher because of unsuccessful wells or wells having small yields and because of inevitable interference of wells and depletion of the supply, but even allowing for these factors the cost should not exceed $1,000 per second-foot, unless the area is overdeveloped, and in that case the yield would decrease and the cost per second-foot would increase indefinitely.

It is roughly estimated that in the belt of bottom lands extending from the north margin of T. 22 N., R. 24 W., to the southern limits of the project, a distance of about 9 miles, there are 2,000 acres of irrigable land. This is practically the only land on the project to which the flowing-well water could be conveyed except by pumping. If after the irrigation project is installed it should be found that the return waters from irrigation at higher levels make additional irrigation on the bottom lands unnecessary the artesian water could probably not be profitably utilized on the project but it could be led farther downstream and used for the reclamation of bottom lands beyond the limits of the present project. It is, however, likely that the artesian supply will be needed on the bottom lands of the project.

The artesian supply is securely stored in an underground reservoir, where it can be preserved from year to year, and can be drawn upon whenever desired. In this respect it has an important advantage over surface supplies, which can not be stored indefinitely. Instead of being used lavishly all the time it ought to be regarded as the ultimate reserve, to be drawn upon only when there is a shortage in the surface-water supplies. Thus in years with considerable rainfall and adequate quantities of surface water the flowing wells should be kept closed and allowed to recuperate, and in exceptionally dry years, when the supplies of surface water are inadequate, the artesian water should be heavily drawn upon. In this connection attention should be called to the importance of casing wells properly with heavy pipe and of securely plugging abandoned wells, for the leakage from a few defective or abandoned wells situated at low levels may practically ruin a small artesian basin such as the one in the Little Bitterroot Valley.

The flowing wells on or adjacent to the bottom lands yielded in 1915 a little more than 3 second-feet. If they were allowed to flow continuously this yield would amount to about 2,000 acre-feet in the course of a year, or an average depth of 1 foot of irrigation water per season for all of the 2,000 acres under consideration. If the artesian water were used only as a reserve this would probably be as much as would be required for the 2,000 acres. However, to make the supply available when needed an adequate number of wells would be required. Thus, if the maximum irrigation requirement is one-half foot in a month there would need to be wells enough to yield 1,000 acre-feet per month, or about 17 second-feet. At $1,000 per second-foot such a development would cost $17,000, or $8.50 per acre. The wells could probably be so located that no additional canals or ditches would be required, but reservoirs of sufficient size to hold the discharge overnight and increase the head in the ditches might be desirable.

It would be inadvisable to make so large a development at first, but a start could be made and action on the rest deferred until experimental data could be obtained as to the amount of return water, the adequacy of the artesian supply, the behavior of the alkali in the water and soil, and other uncertain factors. With a weir and an attachment for a pressure gage at each well, observations of discharge and pressure could be made from time to time and the resulting records would before long show the approximate magnitude of the artesian supply.

The foregoing plans are devised for the utilization of the artesian supply in connection with the previously planned surface-water project in Little Bitterroot Valley. They are based on the assumption that the surface-water supplies are rather meager and may in some years prove inadequate for the irrigation of all the land included in this unit of the Flathead project. If, however, this assumption is incorrect and the surface supply proves to be adequate the artesian water can be used for irrigating bottom lands farther downstream, provided, of course, that it does not prove injurious to crops.

Several more years may elapse before the surface-water project is completed, but the artesian supply may be developed at any time for the irrigation of the bottom lands. However, if it is practicable, before the main project is completed, to divert river water that now runs to waste for the irrigation of the bottom lands, correct principles of conservation require that the river water be so used and that the artesian supply be saved for future use. At all events no artesian water should be allowed to run to waste.

The artesian wells now in existence belong to the private land owners, some of whom, it is understood, desire to withdraw from the irrigation project and to depend on their artesian supplies. There are, however, reasons why the artesian wells should be owned and controlled as a part of the project:

1. The uncertainties regarding the artesian supply involve a risk that can better be borne by the entire community than by the individual. If the artesian supply should become exhausted or prove injurious to crops a great hardship would result to any individual who had withdrawn from the project and was depending entirely on artesian water; whereas if the artesian wells belonged to the project their failure would involve no serious loss to anyone, and the distribution of the surface waters could be so readjusted that the supply for none of the settlers would be very greatly reduced.

2. The principles of conservation demand that the wells be controlled as a part of the project. Experience has shown that where flowing wells are permitted to remain without restriction in the possession of private owners, the artesian water is generally wasted until the supply that remains does not amount to much for irrigation.

3. The equities in the case would seem to be best satisfied by project ownership. It would obviously be unfair to the other settlers on the project to burden them with that part of the cost which, according to the original plans, was to be assessed against the lands on which artesian water has been discovered. On the other hand, if the artesian water is to be used on lands within the project it is only fair that the cost of the wells, like the cost of the other irrigation developments, be borne by the entire project.

The procedure recommended for consideration is that the Government take over the existing flowing wells that yield enough to be of consequence for irrigation, paying the owners for the cost of the wells and providing taps with faucets for domestic and stock use. These wells and such others as would be drilled on the bottom lands would then be controlled by the project manager and would be opened only when the water would be needed. With such an arrangement the settlers on the bottom lands would retain their water rights, in common with the rest of the settlers in this irrigation unit, and would have the additional protection of the artesian reserve supply. Moreover, the dependability of this reserve supply would be greatly increased by project control. The wells on higher land, which yield only a few gallons a minute, such as those in T. 21 N., R. 24 W., will not waste enough water to make their control by the community imperative, although it would be desirable to have them also closed when the water is not used. State legislation prohibiting the wasting of artesian water is greatly needed.