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THE WATER RESOURCES OF BUTTE MONTANA

BY

O. E. MEINZER

Contributions to the Hydrology of the United States, 1914—G

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THE WATER RESOURCES OF BUTTE, MONTANA.

By O. E. Meinzer.

INTRODUCTION.

The Butte mining district, which is the most important mining center in the United States and which has a total population of over 50,000, is situated on the north side of a small rock-bound basin in the mountain region of western Montana. This basin, whose flat floor is a little more than a mile above sea level, occupies a reentrant in the Continental Divide, by which it is bounded on its north, east, and south sides and on a part of its west side. The small streams that rise on the mountainous sides of the basin unite to form Silverbow Creek, which drains through a canyon-like gap in the west wall of the basin and discharges into Clark Fork of Columbia River. Parallel 46° N. and meridian 111° 30′ W. intersect on the flat near the center of the basin. Four transcontinental railroads, the Northern Pacific, the Chicago, Milwaukee & St. Paul, the Great Northern, and the Oregon Short Line, enter the basin. On the west the railroads pass through the gorge of Silverbow Creek; on the east they cross the Continental Divide.

This basin, which for convenience will be called the upper Silverbow basin, has a north-south elongation, its maximum length being about 22 miles and its maximum width about 10 miles. The total area of the basin—that is, of the surface drained by Silverbow Creek through the gorge above Rocker—is about 130 square miles. (See fig. 5.)

The investigation of the water resources of the upper Silverbow basin was made by the writer in October, 1912, in response to an urgent request from the citizens of Butte for information as to the supply of ground water under the flat and the feasibility of developing it for industrial uses and for irrigation. A brief report was made to the Butte Chamber of Commerce immediately after the field work was completed and was published in the monthly organ of the chamber under date of October 31, 1912.

The writer is indebted to many citizens of Butte and other persons for data and for valuable assistance. He desires to acknowledge especially the help of P. W. Blake, secretary of the Butte Chamber of Commerce; Hugh McCloud and James Doull, of the Timber Butte

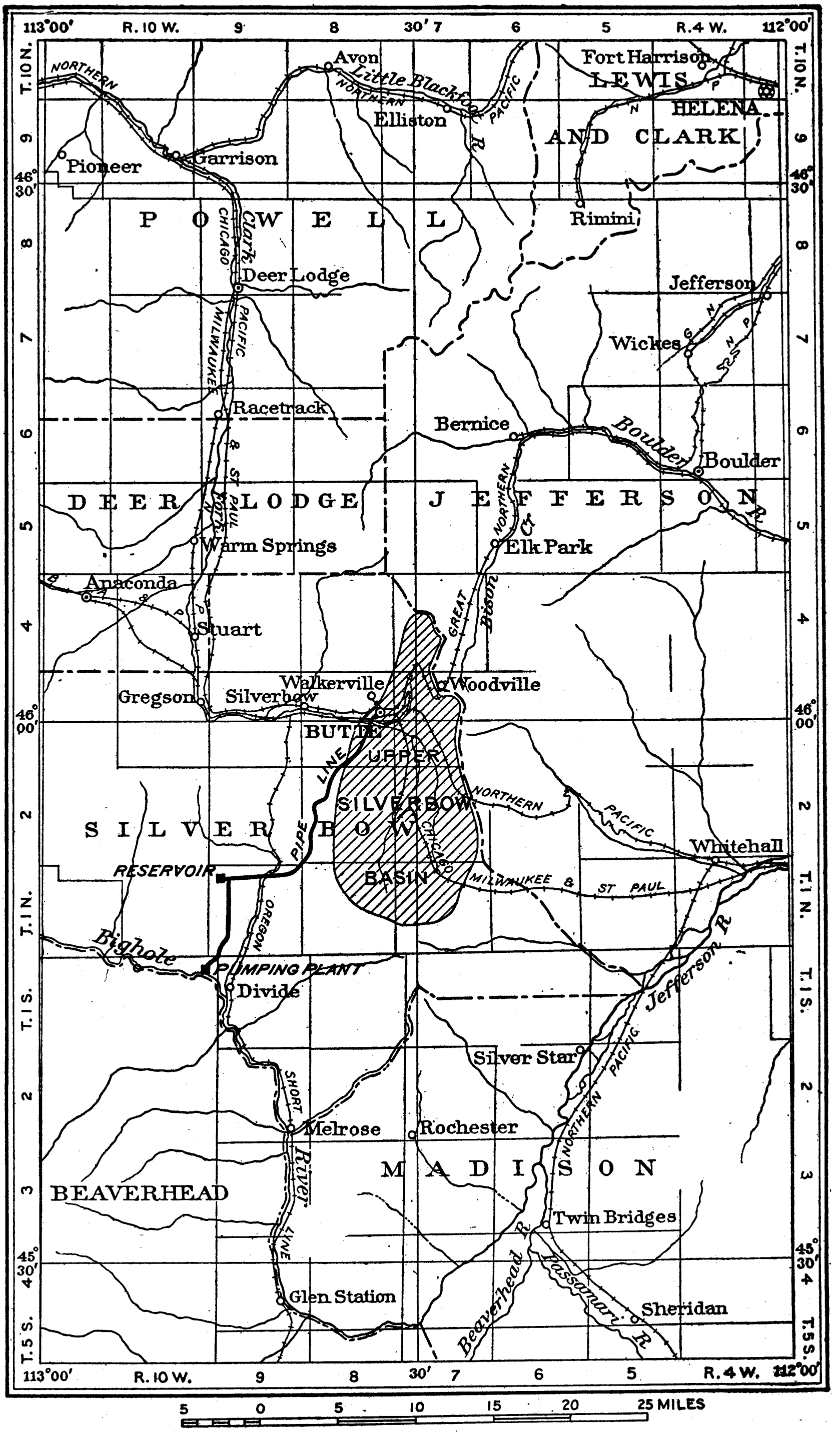


FIGURE 5.—Index map, showing the upper Silverbow basin and the Bighole-South Fork water-supply system.

Mining & Milling Co.; Eugene Carroll, superintendent and chief engineer of the Butte Water Co.; John Gillie, general superintendent of the Amalgamated Copper Co.; the engineers and G. N. Prentiss, chief chemist, of the Chicago, Milwaukee & St. Paul Railway Co.; Paul Gow, city engineer; L. F. Gieseker, of the Montana Agricultural Experiment Station; the representatives of the Butte Electric & Power Co.; E. C. Hancock; and S. V. Kemper.

PHYSIOGRAPHY.

THE MOUNTAIN BORDERS.

The upper Silverbow basin comprises two distinct physiographic provinces—the so-called flat, which occupies the interior and covers about 23 square miles, or somewhat less than one-fifth of the entire area of the basin, and the mountainous belt, which surrounds the flat and drains into it. (See Pl. VI.) The mountainous belt is composed almost entirely of granitic rocks; the flat is underlain by sediments washed from the mountains.

The mountain wall on the east side is steep and narrow, its top being from 2,000 to 3,000 feet above the flat and in a few places more than 8,000 feet above sea level. It is trenched by numerous steep and short canyons, which discharge their flood waters quickly after storms. This steep rock wall was apparently produced by extensive but rather recent faulting, as a result of which the interior of the basin was depressed and the rocks on the east side were relatively uplifted. W H. Weed [1] has shown that the notches or steps in the profile of the mountain wall indicate that displacement has occurred along several nearly parallel fault planes. Displacement is indicated also by a rock shelf that forms low foothills at several localities. This shelf is out of adjustment both to the exposed mountain wall and to the deeply buried rock floor below the flat. It is a step in the profile of the mountain side which, according to Weed's theory, was produced by two faults, one on each side of the shelf. Movement on one side presumably uplifted the mountains and movement on the other side depressed the rock floor, which now supports a heavy deposit of sediments.

The mountainous belt on the west of the flat is much broader and lower than that on the east. On the south there is a mountain region, standing in a few places more than 8,000 feet above sea level, over 50 square miles of which lies within the upper Silverbow basin and drains to the flat. On the north the basin tapers to a high, narrow mountain mass, which discharges considerable water southward to the flat.

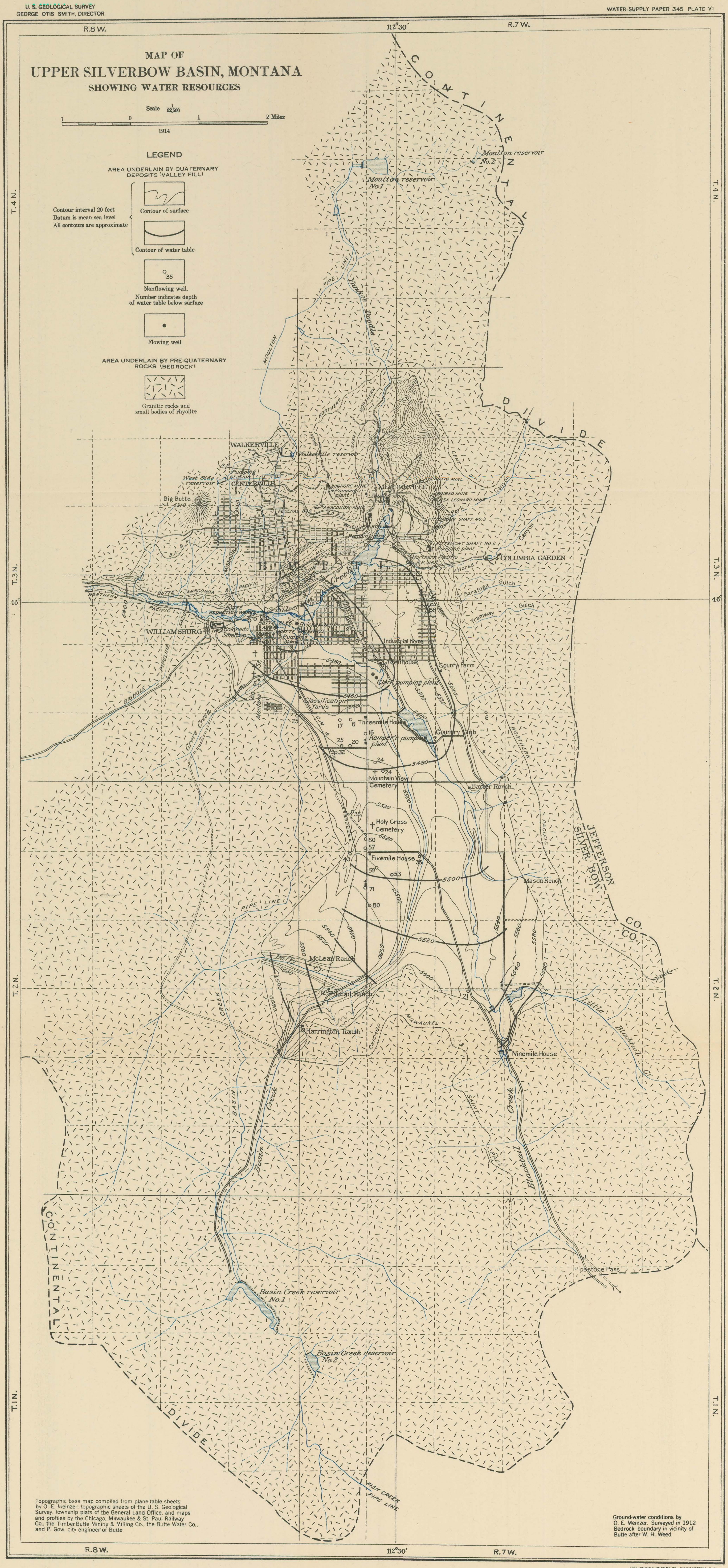
[1] Weed, W. H., Geology and ore deposits of the Butte district, Montana: U. S. Geol. Survey Prof. Paper 74, pp. 47–49, 1912.

The only break in the high, massive rock wall that incases the flat is on the west side, where Silverbow Creek discharges through a gorge that was obviously produced by stream erosion and that is scarcely wide enough to accommodate the railroads and wagon roads that enter through it.

THE FLAT.

As is shown by the contour lines in Plate VI, the surface of the so-called flat is far from level. It is flat only as compared with the rugged mountain country that lies around it. In its main features it has the typical topography of a débris-filled valley. Its surface as a whole was molded not by deformation nor by erosion but by the deposition of sediments brought from the mountains by numerous small streams. The sediments carried down by the streams and torrents have been deposited in largest quantities near the mountains, where these streams emerge from their canyons, and have consequently produced sloping surfaces that extend with decreasing gradient from the edge of the mountains to the interior of the basin. The highest and steepest of these slopes are near the north end of the flat. In the interior, between the stream-built slopes of perceptible gradient, is a broad belt which is underlain by sediments that were deposited by less torrential waters and that form the greater part of the so-called flat. Most of this belt lies south of the outlet, to which it descends with a gradient of only about 25 feet to the mile from the south end of the belt, where the largest supplies of water and water-borne sediments are received.

The smooth, concave surface formed by the sediments deposited by the waters discharged from the mountains is trenched by two broad stream valleys and by a number of smaller tributary valleys. The two large valleys are those of Basin and Blacktail creeks, which together drain most of the large southern mountain area and which enter the flat from the southwest and southeast, respectively. These two broad valleys lie nearly parallel to each other through almost the entire length of the main part of the flat, but they finally come together a short distance above the point where their mingled waters are discharged into Silverbow Creek. (See Pl. VI.) Both valleys are deepest at their upper ends and become gradually shallower downstream. Where Basin Creek leaves the mountains it enters a valley more than 60 feet deep, which is excavated entirely out of unconsolidated sediments; east of the Fivemile House its valley is 30 to 35 feet deep; a mile farther north it is about 20 feet deep; and still farther downstream it is only 10 feet, and finally little more than 5 feet deep. Blacktail Creek, on leaving the mountains, enters a valley of much less depth but of the same general character. This valley also decreases in depth downstream but much more gradually than the valley of Basin Creek. In general both valleys increase in



THE NORRIS PETERS CO., WASHINGTON, D. C.

width downstream, and in their lower courses they have flood plains nearly a quarter of a mile wide. The tributaries of both streams occupy valleys cut in unconsolidated sediments. The valleys of the large tributaries have wide, well-graded flood plains up to the mountains, but those of the smaller drainage lines are mere gullies which are still being eroded headward.

Duffy and Grove creeks, two west-side tributaries of Basin Creek, occupy deep valleys with broad flood plains, the valley of Duffy Creek being in part of its course fully 75 feet deep and 400 feet wide at the bottom. Several of the valleys that lead into Blacktail Creek from the east are also well developed, the one that descends from the Mason ranch, for example, being about 10 feet deep and 400 feet wide where it crosses the road and somewhat larger farther downstream.

The so-called flat, which is the part of the basin that is underlain by sediments, may be regarded as having a compound surface. The upland represents an old, continuous surface produced in an earlier epoch by stream deposition, and the valley floors represent a more recently developed surface with gentler grades produced mainly by stream erosion. Silverbow Creek above Blacktail Creek has not excavated any valley comparable with those of Basin and Blacktail creeks, the narrow northern part of the flat being for some reason not much affected by the erosion that has so greatly modified the topography of its main part.

Two significant features of the stream valleys are their wide flood plains and the terraces on their sides. The wide flood plains indicate that the streams have ceased cutting downward. There is evidence that they have partly filled the valleys which at an earlier stage they had cut below their present levels. The terraces indicate that the downward cutting did not proceed continuously but was interrupted during periods when the streams widened their valleys without sinking them deeper.

GEOLOGY.

PRE-QUATERNARY ROCKS (BEDROCK).

The bedrock exposed in the Butte region has been mapped and described by W. H. Weed.[1] The mountains within the upper Silverbow basin are formed almost entirely of granitic rock, which in most places has the composition of quartz monzonite and is known as the Butte quartz monzonite but in some places is represented by aplite. These rocks form part of a granitic mass that underlies a large area in this portion of the State. In certain localities surrounding the

[1] Weed, W. H., Geology and ore deposits of the Butte district, Montana: U. S. Geol. Survey Prof. Paper 74, 1612.

granitic mass there are sedimentary rocks many thousand feet thick, ranging in age from pre-Cambrian to late Cretaceous, and andesite and related volcanic rocks that are older than the granite. Weed has shown that the granitic rocks are intrusive bodies that were thrust up after the sedimentary rocks and andesite had been formed—probably in Miocene time.

Resting upon the granitic rocks in certain tracts in the northwestern part of the upper Silverbow basin and covering much larger areas outside of the basin are rhyolitic lavas that are younger than the granite through which they were erupted. The Big Butte, from which the city of Butte derived its name, is the remnant of a volcano that emitted a part of this rhyolite.

In the relatively low parts of the region west of the upper Silverbow basin there are extensive deposits of partly cemented clayey and gravelly sediments with beds of sand and tuff. According to Weed the rhyolitic ash which composes the tuff beds indicates that these deposits are of about the same age as the rhyolite, and vertebrate fossils found in them in certain localities indicate that they are of Miocene age. These deposits are generally regarded as lake beds, but in the area immediately west of the upper Silverbow basin they are in large part poorly assorted and irregularly stratified, indicating rapid deposition by turbulent waters. In some of the outcrops between the upper Silverbow basin and Sand Creek the beds are horizontal, but over a large part of this area they dip 10°-15° E., toward the mountains. This dip appears to be a true inclination of the formation rather than a cross-bedding. So far as is known, sediments of this age do not occur in the upper Silverbow basin, although in the region west of the basin they are found at altitudes higher than that of the flat.

QUATERNARY DEPOSITS (VALLEY FILL).

The flat is underlain by rudely stratified beds of unconsolidated and imperfectly assorted sediments derived from the weathering of the rocks in the surrounding mountains. These beds are exposed in natural outcrops on the sides of the valleys that dissect the flat, the largest and most satisfactory outcrops occurring along Duffy Creek and the upper part of Basin Creek, where valleys 50 to 75 feet deep have been cut. They can also be seen in cellars, dug wells, and other excavations and have been deeply penetrated in a number of mine shafts and drilled wells.

The thickness of these sediments is not known except in a few localities. The rugged rock topography and the great discordance in the depths at which rock has been struck in shafts not far apart indicate that the rock floor below the sediments is uneven and that the sedimentary deposits are correspondingly irregular in thickness, but the steep slopes of the inclosing rock walls and the data derived from various deep holes indicate that the thickness is generally several hundred feet and may in some places be more than 1,000 feet. In the Atlantic mine the unconsolidated sediments were found to be over 400 feet thick, and in the Sinbad mine bedrock was struck at 470 feet. In the Colusa-Leonard mine bedrock was struck at 370 feet, but a tunnel at the 600-foot level struck unconsolidated sediments about 40 feet from the shaft. In the Pittsmont shaft No. 2 bedrock was struck at 640 feet, but in shaft No. 3, about 2,000 feet north of No. 2 and about the same distance from the edge of the mountains, rock was found only 90 feet below the surface. (See Pl. VI.) A well drilled by George Cobban in the SE. ¼ sec. 19, T. 3 N., R. 7 W., is reported to be 500 feet deep and to end in unconsolidated sediments. The deepest well at the old Butte Water Co. pumping plant (see Pl. VI) is reported to have struck rock at 105 feet. Only a few wells in the main part of the flat are more than 100 feet deep, but there is no evidence that the rock is near the surface anywhere in the interior of the flat. Bedrock is exposed where Basin Creek crosses the east margin of sec. 18, T. 2 N., R. 7 W., but the creek is here very near the edge of the flat.

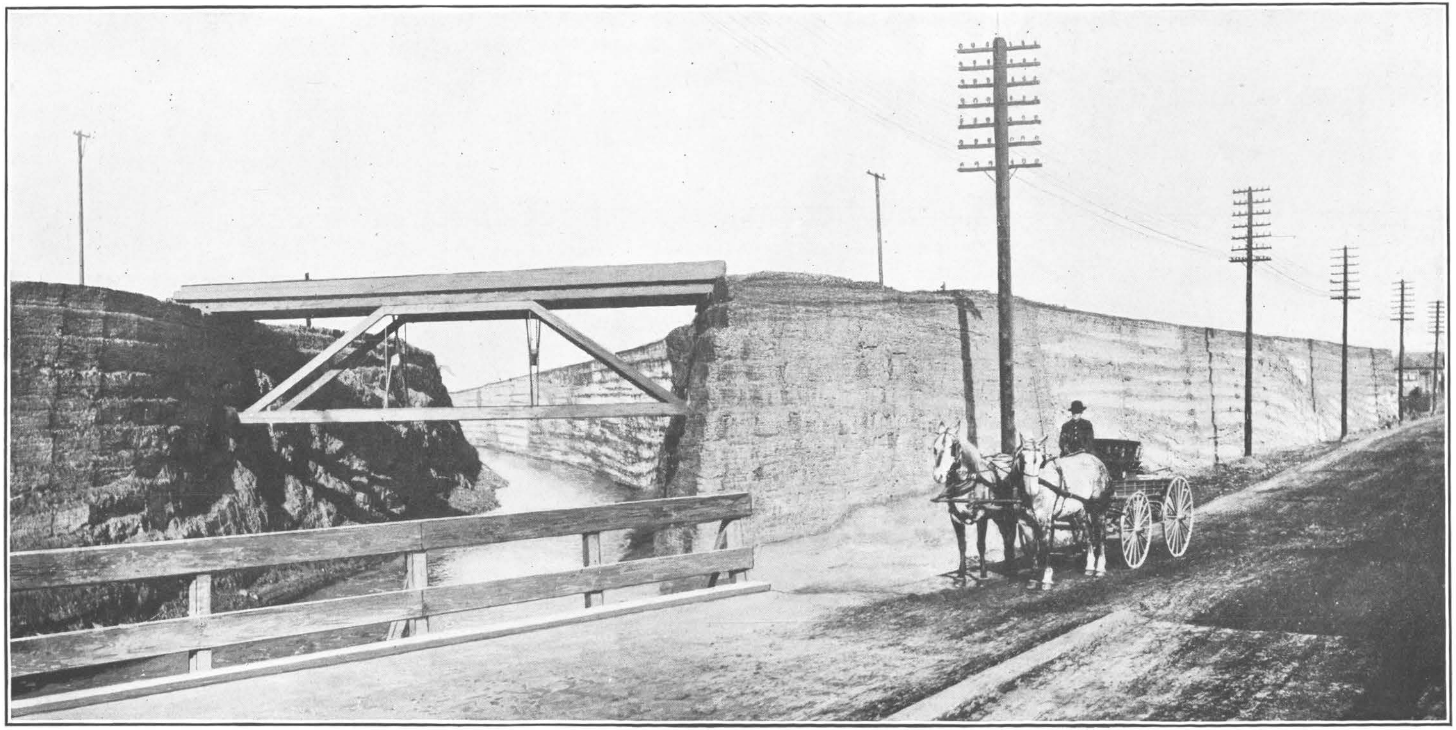
Over most of the flat there is a thin loam soil underlain by very coarse and clean grit composed chiefly of imperfectly rounded particles of granite. These grit particles are obviously derived from the surrounding mountains. They were broken from the parent rock, probably in the main through the action of frost and changes in temperature, and were washed to their present position before they had undergone much chemical weathering. This clean and very porous grit is exposed in numerous outcrops and excavations, but the largest outcrops and the wells of considerable depth show that it does not form the entire body of valley fill. At some depth it gradually gives way to more compact and clayey sediments and in places to beds of fine sand and of gravel. The transition is very irregular and indefinite and varies from place to place, but it may be said that in so far as explorations have gone there is much more clean coarse grit and less clayey material within the first 50 feet of the surface than at greater depths.

In a number of localities near the margin of the flat partly decomposed material resembling granitic residuum was observed at the surface, and similar material was exposed near the bottoms of the largest outcrops. The topography of these localities and their proximity to areas underlain by beds of unquestionable sedimentary origin make it probable that all this partly decomposed material has in fact been transported and deposited by water, the resemblance to residuum probably being due to the rotting and crumbling of the granitic grit. This disintegration of the granite particles after they have been deposited may also be in part the cause of the greater compactness and more clayey character of the deeper sediments.

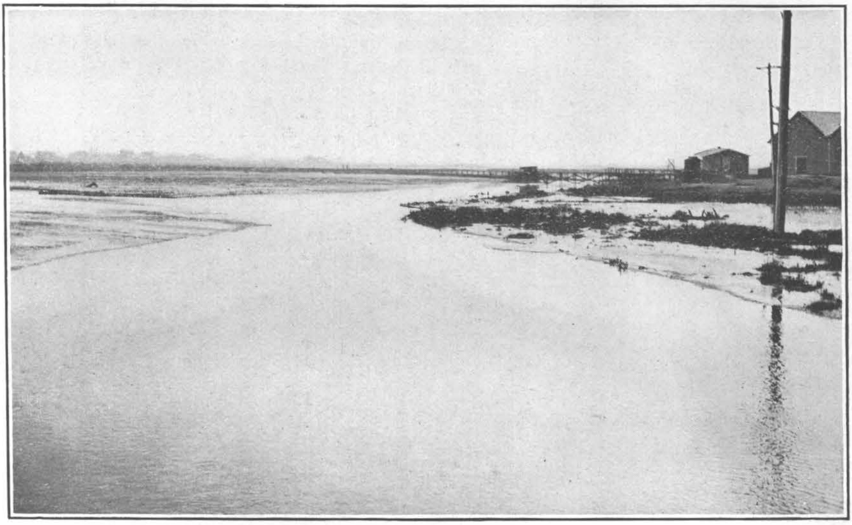
The sedimentary beds underlying the flat have in general the irregularity, rude stratification, and imperfect assortment typical of stream deposits, but certain of the best stratified of the outcropping beds may have been deposited under standing water, and there is no proof that some of the deeper beds are not lake deposits. No glacial drift nor other evidence of glaciation has been found in this basin, though two features that may indicate the presence of ice were observed: (1) Clay beds that are contorted like those found in stratified glacial deposits and that were probably deformed by ice pressure when in a frozen condition; and (2) embedded bodies of unconsolidated material that may have been transported as frozen masses of earth. Near the north end, where the marginal slopes are much steeper than elsewhere, the deposits are exceptionally heterogeneous and full of bowlders.

The sedimentary deposits underlying the flat in the upper Silverbow basin are regarded as much younger than the sedimentary deposits in the adjacent area to the west (p. 84), although there is no very decisive criterion for differentiating between these two formations. The deposits underlying the flat have the general appearance and position of the fill that is found in numerous structural valleys in the western part of the country and that is generally regarded, at least in its upper part, as Quaternary in age. The deposits west of the basin are somewhat more compact and better cemented and consequently appear older; they have apparently been tilted in some places; they contain volcanic ash, which correlates them with the greatly eroded rhyolites; and they are apparently continuous with beds that contain Miocene fossils.

The most recent deposits in the upper Silverbow basin are those produced by filling of the stream valleys. On the flood plains along the lower courses of Basin and Blacktail creeks there are accumulations of saline peat or peaty soil several feet in maximum thickness, and along Silverbow Creek there are extensive deposits produced through the activities of man in the last few decades. Rapid aggradation has resulted along the Silverbow from the obstruction of the valley by slag dumps, bridges, and other structures and to a greater extent from the overloading of the stream with various mine wastes. West of Montana Street the slag from the old Butte Reduction Works forms across the valley a wall in which there is an artificial canyon 30 feet wide and 25 feet deep and farther downstream a tunnel through which the creek discharges. (See Pl. VII.) At the confluence of Blacktail and Silverbow creeks the muddy waters of the Silverbow have built a low but extensive delta fan, around the margin of which the clear waters of Blacktail Creek find their way. (See



ARTIFICIAL SLAG CANYON OCCUPIED BY SILVERBOW CREEK AT BUTTE, MONT.



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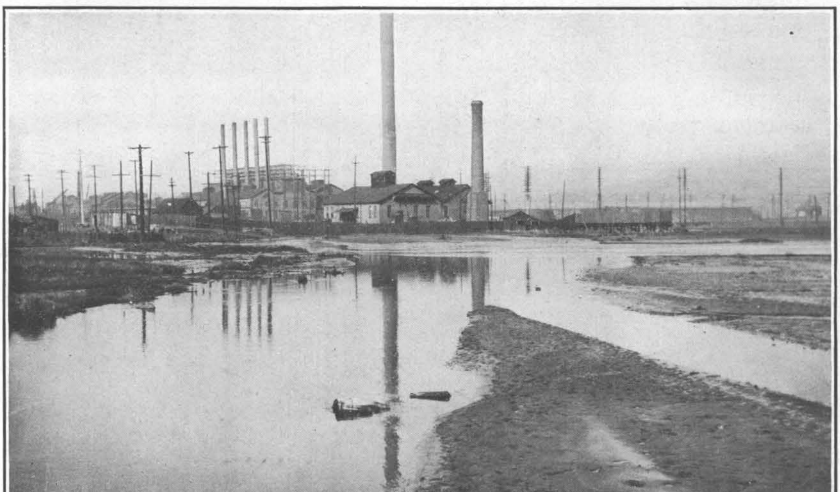

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SILVERBOW CREEK NEAR BUTTE, MONT., SHOWING AGGRADATION.

Pl. VIII.) The aggradation of the Silverbow Valley through these human agencies tends to impound Blacktail Creek and its tributaries and may be in part the cause of the swampy condition along these streams. Aggradation may also have resulted from the destruction of the forests in the mountains. But the oldest settlers report that the valleys were swampy and peaty before any changes of consequence were made by man, indicating that the basin is at present passing through a natural stage of aggradation, which is accentuated but not caused by the recent operations of man. The broad flood plains also indicate that downward cutting ceased long before the human stage began.

GEOLOGIC HISTORY.

The upper Silverbow basin probably came into existence as a distinct feature near the close of the Tertiary or the beginning of the Quaternary period as a consequence of pronounced earth movements. While these movements were in progress the basin was gradually filled with sediments washed from the mountains. The valley that forms the outlet may have been in existence before the basin was formed, but it was no doubt cut deeper and given its gorgelike character by the outflowing waters after the deformation that produced the basin was begun. The filling of the basin and the cutting of the gorge may have kept pace with the deformation, or they may at certain stages have fallen behind it, with the result that the basin contained a lake until the gradation processes could again catch up with the earth movements. Ultimately the basin was filled to the upland levels of the flat, giving its surface waters free exit through the gorge.

Then a change took place which caused the streams to undo a part of the work that they had done on the flat, for they began to erode the deposits they had made. As a result of this stage of erosion the flat became dissected by large valleys and the excavated material was for the most part carried out through the gorge.

After the erosion had been in progress for some time another change occurred which caused the streams to stop cutting deeper, except where head-end erosion was in progress, and to fill their valleys to some extent. Very recently this refilling process has been hastened by the changes produced by man.

The natural changes which caused the variations in stream activity can only be conjectured. Perhaps the most important were changes in climate. The filling to the upland levels of the flat was probably accomplished in an arid stage, when the streams had little carrying power and required steep grades. The subsequent erosion was probably accomplished in a more humid stage, when the augmented streams had greater carrying power and could transport their loads of rock waste with slighter grades. The refilling probably indicates the return of more arid conditions. It should be noted that the erosion of the valleys did not involve corresponding erosion of the gorge which forms the outlet, the valleys and upland surface of the flat both being adjusted to about the same base level but with different gradients. That some of the gradational changes may be due to recent deformation is suggested, however, by the great difference in the depths of the Basin Creek and Blacktail Creek valleys at the south end of the flat.

SOIL.

Most of the upland surface of the flat is underlain by a brown loam, in some places less than a foot thick, below which there is a very porous subsoil composed of coarse grit. Near the margins of the flat the difference between the soil and subsoil is less pronounced and the subsoil is generally denser and more clayey. In the northern part the soil is gravelly, but bowlders or even large pebbles are generally absent over the main part of the flat. In the stream valleys the soil is very different from that of the upland, being generally dark and peaty and more or less impregnated with salts.

The upland loam soil is derived from the decomposition of the granitic sediments and was probably formed since the general aggradation ceased and the valley cutting began. It is of good physical constituency for agricultural purposes and is no doubt rich in soluble minerals useful for plant growth. The following table, taken from Weed's paper on the geology and ore deposits of the Butte district,[1] shows the approximate composition of the material from which most of this soil is derived. The first column gives the average composition of fresh Butte quartz monzonite, the second gives the composition of the disintegrated material, and the third shows the loss or gain of the different constituents. The specimens of fresh rock contained 0.17 per cent of chlorine; those of the disintegrated rock had none. The fresh rock held 0.06 per cent of sulphur (as pyrites), the altered rock 0.05 per cent of SO_3.

Analyses showing effects of alteration of Butte quartz monzonite by weathering.

Constituents.	Fresh rock.	Altered rock.	Loss (−) or gain (+).
	Per cent.	*Per cent.*	
Silica (SiO_2)	64.03	65.14	+1.11
Titanic dioxide (TiO_2)	.60	.59	− .01
Alumina (Al_2O_3)	15.58	15.63	+ .05
Ferric oxide (Fe_2O_3)	1.96	2.37	+ .41
Ferrous oxide (FeO)	2.83	2.13	− .70
Manganese oxide (MnO)	.11	Trace.	− .11
Lime (CaO)	4.20	3.62	− .58
Magnesia (MgO)	2.15	1.85	− .30
Potash (K_2O)	4.11	4.29	+ .18
Soda (Na_2O)	2.76	2.63	− .13
Moisture combined	.73 } .96	.75	+ .02
Moisture below 110°	.23 }	.37	+ .14
Baryta (BaO)	.07	.10	+ .03
Strontia (SrO)	.04	Trace.	− .04
Phosphoric pentoxide (P_2O_5)	.18	.16	− .02
	99.58	99.63	....

[1] U. S. Geol. Survey Prof. Paper 74, p. 86, 1912.

Samples of soil collected on the flat were sent to the Montana Agricultural Experiment Station and examined by L. F. Gieseker, of that station, who reported that the soil is low in organic matter and is slightly acid. Soils of arid and semiarid regions, where plant life is scarce, are generally deficient in organic matter, and near Butte the organic matter may have been further reduced through the destruction of vegetation by smelter fumes. The acidity has probably been produced by the sulphurous acid in the smelter fumes, washed into the soil by the rain. Prof. Gieseker recommends the application of lime and a heavy coat of manure. This recommendation, in so far as it concerns the application of manure, accords with the successful practice of the Chinese gardeners of the flat. Lime and manure will both tend to overcome the acidity, and the manure will supply needed organic matter. On account of the porous character of the subsoil, only a small amount of moisture available for plants can be stored in the ground, and if irrigation farming is practiced comparatively frequent applications of water will be required.

The black peaty soil of the valleys is in marked contrast with the upland soil in being rich—in some places excessively rich—in organic matter. It also differs from the upland soil in containing more saline matter, especially where the water table is within a few feet of the surface.

The three injurious salts found most commonly in soil and generally called "alkali" are sodium carbonate, sodium chloride, and sodium sulphate, the carbonate being the most injurious and the sulphate the least injurious to crops. The valley soil in this basin contains some alkali, but the quantity is apparently not excessive, and none was observed in the upland soil. This saline matter is the soluble product of rock decay, taken up by the waters that leach the rock and soil and deposited by these waters when they evaporate. The decomposition of igneous rocks containing considerable sodium is likely to produce sodium carbonate, which has an alkaline reaction and can often be recognized in the field by the dark stains which it produces and by its "soapy" taste and burning sensation in the mouth. Although the Butte quartz monzonite is shown by the analyses to contain considerable sodium, no evidence of the presence of sodium carbonate was observed on the flat. The carbonate is in this region probably to a great extent replaced by sulphate derived from the sulphides in the rocks both by natural oxidation (see analyses) and by artificial oxidation in the large smelters formerly operated at Butte.

VEGETATION.

The settlement at Butte was started about 1864, when placer gold was discovered in this locality. The first large smelter, known as the Colorado, was built at Butte about 1879, and the other large smelter, the Butte Reduction Works, was built in 1886. Prior to the erection of these smelters the mountains were covered with timber, as is attested by the dead stumps still in existence and by such names as Timber Butte and Grove Creek. In this early period the flat was covered with a good growth of grass and the vegetation in the valleys was especially luxuriant, these conditions being reported by many of the old settlers and also being indicated by the peat in the valleys.

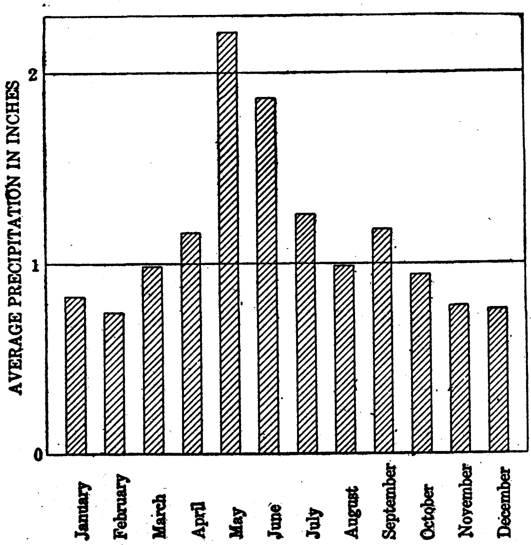

FIGURE 6.—Diagram showing average monthly precipitation at Butte, Mont.

When the large smelters were in operation great quantities of sulphurous fumes were emitted and hung over the basin, with the result that except in the most distant parts the vegetation was destroyed or greatly stunted. In 1900 the large Washoe smelter was erected at Anaconda, and later both the Colorado smelter and the Butte Reduction Works were shut down. In 1912 the basin was comparatively free from sulphurous fumes except those emitted by the Pittsmont smelter. (See Pl. VI.)

The destruction of the vegetation produced a desolation which, together with the other ugly features incidental to the mining operations, was most unfortunate. Since the large smelters were shut down the native vegetation has started to recover, but the vicinity of Butte as a whole is still barren and uninviting. There is, however, no reasonable doubt that, with proper manuring of the soil, trees, grasses, and vegetables can be successfully grown. Some of the public-spirited citizens of Butte realize the esthetic as well as economic value of gardens, lawns, and trees and are endeavoring to beautify the city and its environs with them. Such efforts are highly commendable and should receive all possible encouragement.

CLIMATE.

Owing to the high altitude and latitude the climate of Butte is rather rigorous. As shown by the following table, taken from the reports of the United States Weather Bureau, the mean annual temperature is only about 42° F. and the lowest recorded temperature is 29° below zero. The region is also characterized by high winds.

Temperature (°F.) at Butte, Mont.

[Altitude, 5,716 feet.]

	Length of record.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
	Years.													
Highest...	10	51	58	60	76	81	94	94	94	87	79	66	55	94
Lowest....	10	−25	−29	−19	6	21	26	33	27	20	5	−10	−18	−29
Average...	14	23.5	24.9	29.2	40.5	48.3	55.1	63.4	62.8	52.9	44.5	33.7	26.6	42.1

The most serious handicap to farming, gardening, or fruit raising in the basin is the cold climate. Late and early frosts greatly limit the crops that can be grown. The following table gives the frost data as observed in Butte by the representative of the United States Weather Bureau, but as cold air tends to sink to the lowest part of the basin it is probable that some of the frosts that occur on the flat were not felt on the somewhat higher land where the observations were made.

Frost at Butte, Mont.

Length of record	14 years.
Average date of first killing frost	September 15.
Average date of last killing frost	June 5.
Earliest date of first killing frost	September 5.
Latest date of last killing frost	June 26.

The climate is semiarid. In the 17 years for which a complete record is given in the following table, the annual precipitation at Butte ranged from 6.95 to 20.55 inches and averaged a little less than 14 inches. In the highest parts of the basin the precipitation is probably somewhat more than where the observations were made, and on the flat it may be slightly less. The precipitation is rather evenly distributed through the year, although heavier in spring and summer than in winter. (See fig. 6.) In average monthly precipitation, May ranks first, June second, and July third, these three months receiving nearly 40 per cent of the total precipitation. The winter precipitation is chiefly in the form of snow. Irrigation is necessary for the best results, especially with intensive crops.

Monthly and annual precipitation at Butte, Mont.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1894	......	......	......	0.93	1.00	1.78	1.86	0.87	1.41	0.64	0.14	0.22	....
1895	0.93	0.14	0.27	.25	1.09	.85	1.07	.19	1.19	.17	.31	.49	6.95
1896	.30	.37	.32	.55	1.43	1.07	1.19	.87	1.95	.47	1.62	.37	10.51
1897	1.20	.70	1.04	1.63	1.44	3.02	1.19	.30	.98	1.10	1.52	1.12	15.24
1898	.57	.55	1.56	.51	......	3.06	.54	.45	.91	......	......	......	....
1899	2.35	1.39	1.21	1.57	2.46	.55	.90	2.35	.55	1.65	.14	1.10	16.22
1900	.30	1.05	1.20	2.75	2.90	.66	1.13	.48	1.40	2.08	.20	.40	14.55
1901	.60	.65	1.65	2.35	3.40	2.00	.55	.30	.90	.45	Tr.	1.70	14.55
1902	Tr.	1.00	.75	1.35	3.20	.75	1.15	.25	.10	.20	.65	.90	10.30
1903	.42	.05	1.30	1.30	1.20	.80	.65	.60	.50	.70	1.90	.85	10.27
1904	1.40	2.92	2.05	.30	1.02	1.00	2.00	.35	.00	.05	.12	1.35	12.56
1905	.70	.10	1.15	.85	2.05	3.15	1.80	1.00	.45	.65	.35	.15	12.40
1906	1.10	1.70	.90	1.70	3.64	1.95	.20	2.20	.50	.10	.80	.95	15.74
1907	.80	1.00	.55	1.30	1.25	2.87	2.82	2.20	1.50	.20	.10	.24	14.83
1908	.50	.75	.90	.40	5.67	4.22	.70	.75	2.45	1.30	.20	.15	17.99
1909	1.60	.10	1.45	.85	2.50	1.80	3.50	.70	3.25	.95	2.65	1.20	20.55
1910	.70	.95	.75	.20	1.65	1.75	.50	.77	2.20	1.35	1.62	.30	12.74
1911	1.70	.60	.20	2.35	2.20	3.30	.40	1.70	1.20	3.30	.95	1.12	19.02
1912	.28	.55	.80	.64	1.97	.93	1.63	1.92	.95	1.20	.43	.68	11.98
1913	.32	.14	.64	1.41	1.57	8.86	1.69	1.09	.54	.65	.52	.12	17.55
Highest	1.70	2.92	2.05	2.75	5.67	8.86	3.50	2.35	3.25	3.30	2.65	1.70	20.55
Lowest	Tr.	.05	.20	.20	1.00	.55	.20	.19	.00	.05	Tr.	.12	6.95
Average	.83	.74	.98	1.16	2.20	2.22	1.27	.98	1.15	.90	.75	.71	13.89

Mean relative humidity at Helena, Mont.

Hour.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
8 a. m.	72	73	71	65	66	67	60	59	64	66	68	71	67
8 p. m.	66	63	56	42	42	41	31	30	39	48	56	65	48

SURFACE WATERS.

Silverbow Creek rises in the northern part of the upper Silverbow basin. After describing a curve around the southeast margin of the city of Butte it flows westward through the outlet gorge. Its name, which no doubt was at one time very appropriate, is at present singularly inappropriate because its waters are at all times exceedingly dirty. In its course through the upper Silverbow basin it receives one relatively large tributary and several smaller ones, the large tributary being Blacktail Creek, which drains the main part of the basin. After leaving this basin it receives two tributaries of consequence—Sand Creek, which enters from the south about 6 miles below the mouth of Blacktail Creek, and the stream from Browns Gulch, which enters from the north nearly 2 miles farther down. After receiving these two tributaries it passes through a short, precipitous canyon and enters the Deerlodge Valley, where it unites with other creeks to form Clark Fork.

The drainage system of Blacktail Creek comprises Blacktail Creek proper, which drains the southeastern part of the basin, and Basin Creek, which drains a larger area in the southwestern part and joins Blacktail Creek about 2 miles above its confluence with Silverbow Creek.

A number of smaller mountain streams also enter the flat and flow toward the main streams, either discharging into them or losing their water before reaching them. On the west side there are two principal tributaries—Grove Creek and Duffy Creek. On the east side there are a number of tributaries, most of which are small. They include Park Creek, near the north end, Little Blacktail Creek, near the south end, and at least eight small streams between these two.

It is obvious from the above description that the upper Silverbow basin, in spite of its small size and semiarid climate, is well supplied with streams. These streams have been of great value in furnishing domestic and industrial supplies to this important mining center. Their flow is now greatly modified by various artificial controls. Two reservoirs on Basin Creek and two at the headwaters of Silverbow Creek intercept a large part of the natural flow of these two creeks for the Butte public supply. Several reservoirs have also been built on Blacktail Creek, and the water in Park Canyon is conducted through pipe lines to Columbia Garden, the Leonard mine, and the Pittsmont smelter.

On the other hand stream flow is greatly augmented in the vicinity of Butte by both underground and surface waters. The surface waters are derived in part from streams within the basin and in part from outside sources. The water pumped from mines and eventually discharged into Silverbow Creek aggregates, according to the best information available, approximately 10 second-feet. The public supply, most of which also ultimately reaches the creek, is drawn only in part from the streams within the basin. A variable quantity, averaging several second-feet, is brought from Bighole River and from South Fork of Divide Creek, and perhaps 2 second-feet is introduced into the Basin Creek supply from Fish Creek, which is on the opposite side of the Continental Divide. The Park Canyon supply is likewise derived largely from Elk Park, on the other side of the divide.

According to estimates by Eugene Carroll, superintendent of the Butte Water Co., the supply intercepted by the Moulton reservoirs (Pl. VI) amounts to at least 1,000,000 gallons a day (approximately 1½ second-feet), and that intercepted by the reservoirs on Basin Creek (including the water from Fish Creek) amounts to about 4,000,000 gallons (approximately 6 second-feet) except in low-water seasons, when it is less. Weir measurements made September 12 to 26, 1912, by Hugh McCloud, engineer of the Timber Butte Mining & Milling Co., on Blacktail Creek below the point where Basin Creek enters, showed the flow to vary within the period covered from about 5 to 8 second-feet, but this flow was regulated by several reservoirs upstream and probably did not include the flow above the lower Basin Creek reservoir. In October, 1912, the flow of Grove Creek was estimated to be approximately 1 second-foot and that of Duffy Creek considerably more. The flow of the streams on the east side was less.

The streams undergo considerable annual fluctuation. Aside from the direct run-off produced by storms they are fed by the melting of snow and by the discharge of seepage springs whose sources are generally very near the surface. The streams are likely to rise in the latter part of March with spring rains and melting snow, and to continue to be more or less swollen during the spring months while the snow is disappearing and the heaviest rainfall is taking place. According to Mr. Carroll there are two annual low-water stages, one about August and the other about February. The first low stage is in a season when the rainfall is not above the average and when, owing to high temperature and low relative humidity, the evaporation is at a maximum. The second stage is near the end of the winter season, when the precipitation is least and falls in the form of snow, and when, owing to the frozen condition of the ground, the yield of springs is probably reduced.

WATER IN BEDROCK.

OCCURRENCE AND QUANTITY.

The unaltered granitic rocks are practically impervious, but water is absorbed by the porous mantle of disintegrated material and is carried to great depths through the joints by which the granitic rocks are broken, especially in the mineralized areas.

The water in the mantle of disintegrated material tends to percolate along the slope of the underlying firm rock and to reappear in springs where the rock outcrops. Thus the mantle serves a very useful function in conserving the water supply. In times of heavy rain or melting snow it becomes charged with water which it yields gradually to the streams in the dry seasons. Were it not for this natural conservation, the discharge of the mountain streams would be much more irregular and the shortage in the low-water stages much more serious.

The deep and extensive underground workings in the Butte mining district afford information of unusual character in regard to the occurrence and quantity of water in the granitic rocks of that vicinity. In 1912 the High Ore mine extended to a depth of 2,800 feet, or to a level only little more than 3,300 feet above the sea; a few other mines extended to depths of more than 2,000 feet; and the underground workings in the entire district were said to have an aggregate of more than 2,000 miles of tunnels. According to the best information obtainable, the total pumpage from all mines was between 4,000 and 5,000 gallons per minute continuously. The heaviest pumping was done at the High Ore and Leonard mines, into which the water drains from a number of other mines belonging to the Amalgamated Copper Co., an average of 1,200 to 1,400 gallons being pumped at each. A pumpage of 840 gallons was reported at the Pittsmont mines, and smaller amounts at several others.

Before the district was developed the joints and other voids in the rocks were filled with water nearly or quite to the surface—the water level in any given locality being regulated by the topography and by the occurrence of barriers produced by unfractured, impervious rock masses. Hence shallow wells furnished domestic water supplies in localities now covered by the city of Butte. Such conditions still prevail in the undeveloped mountain regions, where in some localities springs and shallow wells are found. The mining developments revealed the fact that water-bearing fissures extend to great depths, although, according to John Gillie, general superintendent of the Amalgamated Copper Co., who gave much valuable information on this subject, the quantity of water below the depth of 1,000 feet is small.

If the average annual precipitation is 18 inches, the pumpage from mines is equivalent to the precipitation on rather more than 7 square miles, or the entire area that is undermined. The pumped water is drawn from two distinct sources. It is in part the original supply with which the crevices in the rock were filled before developments were begun, and in part the supply that is furnished from time to time by local precipitation and artificial application and that percolates into the mines through the natural rock fractures and through the shafts or other artificial openings. At the Leonard mine the amount pumped fluctuates between about 1,200 and 1,600 gallons per minute. The largest amount is generally lifted in spring, when the snow melts and the heaviest rainfall occurs; the amount gradually diminishes during the fall and is generally least in winter, when the ground is frozen. Most of this water is collected at the 1,200-foot level and represents percolation from the surface, the fluctuations being due chiefly to seasonal variations in the surface supply. A part is derived from the water that is poured into the mine to extinguish a fire that has for years been smoldering above the 1,200-foot level. Between the 1,200-foot and 1,800-foot levels the mine is reported to be comparatively dry, indicating that the water at higher levels is derived chiefly from the surface. The 2,000-foot level had in 1912 been recently opened and only a few hundred feet of tunnel had been run. At this level the formation contained small fissures which were saturated with water that they yielded slowly to the tunnels, the entire pumpage from this level amounting to about 40 gallons per minute.

Obviously the water that is at present pumped is not all derived from the developed mining area, either as original water or percolation. The block of earth that is traversed by mine openings constitutes a great cavity toward which the water in the crevices of the rocks for miles around is percolating. The large amount of water that is constantly being pumped suggests to the casual observer that the rocks are very porous, but this conclusion must be radically modified when consideration is taken of the great extent of the exposed surface over which seepage may occur and the great head of the surrounding water relative to the levels from which the water is drained in the Butte district, and when, moreover, these conditions are compared with those found in the best water-bearing formations. For example, a 10-inch well 235 feet deep, recently tested in Sulphur Spring Valley, Ariz., yielded, under a head of only 19 feet, an average of 1,080 gallons per minute, or about one-fourth of the amount yielded by all of the Butte mines.[1] Before mining developments were made, such movement of ground water as occurred was no doubt in general downward, under the direct influence of gravity. In the upper few hundred feet there was no doubt appreciable movement due to the percolation of the water derived from the rain and snow along joints to points at lower levels where the rocks afforded openings through which the water could escape as springs. In the deeper crevices, far below the level of any local outlets, the circulation must have been exceedingly slow, if, indeed, the water was not entirely stationary.

There is evidence that no important quantities of water pass from the rock into the valley fill nor from the fill into the crevices of the rock where these two formations are in contact. The valley fill adjacent to Butte and even extending over the mine workings is full to overflowing with water, as is shown by the swamps, springs, and flowing wells to which it gives rise in this vicinity. In the Pittsmont mine, which was developed in the rock under the valley fill, the pumpage of 840 gallons per minute is derived chiefly from the rock at the 1,000-foot and 1,200-foot levels. The 800-foot level is relatively dry, apparently because it has been drained of its original water and receives but little percolation from the overlying saturated valley fill. A layer of clayey oxidized material is said to lie above the bedrock, practically sealing it from the water above. Most of the valley-fill water that enters the mine seems to get in along the shaft, which extends through the fill to a depth of 640 feet.

QUALITY.

As a rule the granitic rocks contain little soluble matter, and therefore yield soft water, but locally they include veins of precipitated mineral matter that becomes redissolved in the ground water, render-

[1] Meinzer, O. E., and Kelton, F. C., Geology and water resources of Sulphur Spring Valley, Arizona. U. S. Geol. Survey Water-Supply Paper 320, p. 208, 1913.

ing the water hard and otherwise mineralized. Below are two tables, the first containing the analyses of three samples from shallow sources in the granitic area and the second the analyses of seven samples of mine water in the vicinity of Butte, together with abbreviated comments by the analyst, W. F. Hillebrand. The first group of samples were collected by the Chicago, Milwaukee & St. Paul Railway Co.; the second group were collected by G. W. Tower in connection with the investigations of the ore deposits made by the United States Geological Survey.[a]

Analyses of water from shallow sources in the area of granitic rocks near Butte, Mont.[b]

Source of sample.	Date of collection.	Dissolved substances (parts per million).						
		Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).[c]	Sulphate radicle (SO_4).	Chlorine (Cl).	Sum of constituents.
Spring on east fork of Blacktail Creek at Penfield; locomotive supply	Feb. 3, 1909	14	4.7	22	23	52	5.9	122
Springs at Penfield; locomotive supply	Nov. 18, 1913	5.8	2.5	9.5	15	8.9	4.9	47
Well at Janney, 8 by 6 feet	Feb. 26, 1910	22	8.9	8.4	53	5.1	11	108

Analyses of waters from the mines of Butte, Mont.

[Parts per million. Analyst, W. F. Hillebrand.]

	1	2	3	4	5	6	7
Silica (SiO_2)	23.2	27.2	36.1	29.5	55.8	47.7	67.4
Titanic oxide (TiO_2)						None.	Trace.
Calcium (Ca)	151.2	92.7	49	512.1	39.1	132.5	307.7
Magnesium (Mg)	28.2	17.9	10.3	102.6	6.7	61.6	149.2
Potassium (K)	7.1	30.5	3.5	11.4	5	13.1	6.8
Sodium (Na)	16.2	176.9	11.1	82.8	30.1	39.6	41.7
Lithium (Li)	Trace.						Trace.
Zinc (Zn)	.3	1.8	1.9	None.	Trace?	852	411.2
Cadmium (Cd)						41.1	
Aluminum (Al)	None.					83.5	85.2
Ferrous iron (Fe″)	1.8	1.4	.9	.4	.4		49.8
Ferric iron (Fe‴)						159.8	
Manganese (Mn)	.5	Trace.	2.5	1.4	.8	12	13.2
Cobalt (Co)						.5	4.6
Nickel (Ni)							3.5
Copper (Cu)	Trace.	.4	Trace.	Trace.	None.	59.1	45,633.2
Tin (Sn)						17	
Lead (Pb)		Trace.	Trace?	None.	None?		
Arsenate radicle (AsO_4)	Faint.	Trace?	Trace.	None.	None.		Trace.
Phosphate radicle (PO_4)	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	1.5
Sulphate radicle (SO_4)	406.5	544.7	90.6	593.4	67.2	2,672	71,053.3
Chlorine (Cl)	6.8	118.5	11.8	842.8	15	13	17.7
Organic matter		Consid.	Little.	None.	Trace.	Considerable.	
Bicarbonate radicle (HCO_3)	78.1	Trace.	(d)	92.7			
Carbonate (CO_3)				8.8			
	719.9	1,012	217.7	2,277.9	220.1	4,204.5	117,846
Total carbon dioxide (CO_2)	27.2	167.2	[d] 59.9	[d] 73	102	23.7	8.9

[a] Weed, W. H., Geology and ore deposits of the Butte district, Montana: U. S. Geol. Survey Prof. Paper 74, pp. 100–101, 1912. Clarke, F. W., U. S. Geol. Survey Water-Supply Paper 364, p. 37, 1914.

[b] Analyses furnished by G. N. Prentiss, chief chemist Chicago, Milwaukee & St. Paul Railway Co.; recalculated from analyses reported as compounds in grains per United States gallon.

[c] Includes bicarbonates (HCO_3).

[d] Calculation shows insufficient carbon dioxide in the bicarbonate state to satisfy the bases; hence both normal and bicarbonates are to be assumed as present and the summation is raised to correspond.

Sample 1, from the 2,200-foot level of the Green Mountain mine, was taken to represent as near as practicable the composition of the water of the deep levels of the district. It is from a fissure in normal granite remote from any known veins and far from any old mine workings, coming from a fissure tapped by a newly opened crosscut the day before the sample was taken. * * * Its reaction is faintly alkaline. * * * Sample 2 came from the 200-foot south crosscut of the Glengarry mine and represents water from the upper part of the earth's crust in the vicinity of the workable ore deposits. The water deposited some ferrous sulphides and sulphur. Sample 3 came from the 800-foot level west of the Anaconda mine. It is faintly alkaline and may be fairly assumed to represent the water descending through that great vein at a point beyond the reach of oxidizing influences. Sample 4, taken from the Gagnon, on the 1,800-foot level 1,125 feet south of the shaft, is also a rock water and not a vein water in the ordinary sense. Sample 5, from the Nettie mine, taken from the 300-foot level at the end of the crosscut north, represents the composition of the waters found in the silver mines. Sample 6, from the 1,200-foot level of the crosscut of the St. Lawrence mine 90 feet from the shaft, is faintly acid and represents the waters descending along the quartz-pyrite vein. Sample 7 from the Mountain View mine, second level, is exceptional; it is perfectly clear, deep blue in color, and comes from surface waters seeping down from old stopes. The water has formed stalactites and stalagmites of perfectly clear and transparent chalcanthite, showing that it is probably a saturated solution. * * * The chlorine content varies widely in the different waters. * * * Analyses 6 and 7 are the only ones showing appreciable amounts of copper, the latter being a saturated solution of copper sulphate.

In the mineralized district the downward-percolating waters, by the aid of oxygen, decompose the pyrite and other sulphides in the granitic rocks, thereby forming soluble sulphates and sulphuric acid. The acid waters further dissolve copper from the ores with which they come in contact. This process of oxidation and solution has no doubt been greatly intensified by the aeration and circulation resulting from the mining operations. The waters pumped from the mines are largely of the acid copper-bearing type represented by analysis 7. Before being discharged into Silverbow Creek they are treated with scrap iron, which precipitates copper in sufficient quantities to be an important source of income.

WATER IN VALLEY FILL.

OCCURRENCE.

The bedrock forms a nearly impervious basin. Even the crevices in the rock do not generally furnish an outlet but are more commonly filled with water that does not escape from the basin. If no sediments had been deposited in this basin, it would contain a lake which would be supplied from the rain and snow that falls in the interior of the basin and on the mountain sides draining toward the interior and which would discharge water by evaporation from its surface and perhaps by overflow through the gorge. The sediments that have been deposited in the interior of the basin to an average depth of probably several hundred feet do not alter the essential conditions of the occurrence of water in the basin. This detrital deposit, or valley fill, is more or less porous and its pore spaces are full of water up to a certain level indicated by the water surface in the wells. The basin thus constitutes a natural reservoir in which is stored a large body of water. This body of ground water is practically coextensive with the valley fill except that its upper surface is in most places lower, leaving a barren zone between the surface of the flat and the water table. It differs from a surface lake in the quantity of water that it contains for each unit of volume, in the shape of its upper surface, in the conditions that govern the acquisition, circulation, and disposal of its waters, and in the methods that must be applied to recover its waters for human use.

Owing to the space occupied by the rock particles the quantity of water stored in the valley fill is much less than would be contained in a surface lake of the same dimensions. Moreover, a large part of this water could not be withdrawn through wells, because it would adhere as moisture to the rock particles, especially where these particles are so small that the intervening spaces are of capillary size. Some of the beds of coarse clean grit or gravel, such as underlie the soil in a large part of the flat, probably have a porosity of fully 30 per cent and nearly all of their supply would be yielded to wells, but the beds of clay and quicksand contain very little water except that held by capillary attraction. The poorly assorted beds, consisting of a mixture of coarse and fine particles, comprise the largest part of the saturated valley fill. They are less porous than the clean grits and a large part of their water is held by capillarity, but they nevertheless contain a moderate amount of water that can be withdrawn through wells. If 15 per cent of the entire space occupied by the valley fill below the water table contains available water the underground supply amounts to about 2,000 acre-feet for each foot in depth of the saturated fill. Only a part of the water in the saturated zone could be recovered at moderate cost; the rest would involve lifts that would be economically prohibitive. Ground-water supplies are, however, constantly replenished, in which respect they differ from ore deposits. Conservative ground-water developments are based not on the quantity of stored water but on the rate of recharge. Before discussing the subject of recharge it is necessary to describe the form and position of the water table and its seasonal fluctuations.

WATER TABLE.

The water table, or surface below which the valley fill is saturated, is not entirely level. (See Pl. VI.) It is highest near the borders of the flat and slopes gently from different directions toward the vicinity of the outlet. Its gradient from the southern border to Silverbow Creek, along the axes of Basin and Blacktail creeks, is nearly uniform and amounts to about 20 feet to the mile. Where these creeks flow out of the mountains upon the valley fill the water table is nearly 5,600 feet above sea level, in the vicinity of the Fivemile House it is not quite 5,500 feet above sea level, and at the Butte Reduction Works it is less than 5,440 feet above sea level. The slope of the water table indicates the direction in which the ground water is moving, the movement being away from the principal areas of intake and toward the principal areas of discharge. This slight inclination of the water table gives the gentle pressure that is necessary to force the water very slowly through the formation.

The water table generally slopes in the same direction as the surface of the flat (see Pl. VI), at a gradient less than that of the upland surface of the flat but nearly the same as that of the valley floors. (See p. 82.) Near the south end of the basin the water table, like the valley floors, is far below the upland surface of the flat, but northward the two surfaces gradually approach each other until, immediately south of Butte, the ground water stands nearly up to the general surface of the flat. In the southwest lobe of the flat, trenched by the deep valley of Basin Creek, the depth to water from the upland surface is much greater than in the southeast lobe, through which the shallower valley of Blacktail Creek passes. Only in comparatively small areas near the mountains is the depth to water more than 100 feet. The line marking a depth to water of 50 feet passes a short distance north of the Fivemile House with a northwest trend, broken by indefinite extensions up the principal valleys. The 25-foot line passes through Mountain View Cemetery with the same general trend, also extending indefinitely up the valleys. Along their entire courses through the flat the valleys of Basin and Blacktail creeks have very shallow water, and most of the minor valleys show a similar condition. In small areas near the mountains the valley fill is so thin that rock would be struck in drilling without reaching the water table.

The water table is not absolutely stationary, but fluctuates through a small vertical range on account of variations in the accessions and withdrawals of water that result from seasonal changes in the weather. Heavy accessions from rainfall and run-off in certain localities temporarily raise the water level in those localities, whereas heavy withdrawals by evaporation in shallow-water areas temporarily lower the water level in such areas. Heavy pumping also lowers the water level, at least locally.

At the time the investigation was made (October, 1912) not enough water had been artificially withdrawn from the ground-water reservoir to affect appreciably the water level, except to a small extent in the vicinity of the Clark pumping plant. (See pp. 109–112.) In order to make it possible to ascertain the effect of pumping on the water level, if in the future heavy withdrawals should be made, the depth to water was measured in a number of wells in different parts of the flat, and, through the voluntary assistance of Mr. E. C. Hancock, monthly measurements were made in one typical well.

The first table given below records the depth to the water level in a number of representative wells as measured in October, 1912. The depths are given with reference both to the land surface and to an arbitrarily established bench mark. Wherever practicable the bench mark, from which accurate measurements were made, was taken to be the upper surface of the well platform or some other substantial timber near the surface and was indicated by cutting three notches into the wood. The locations of these wells and the depth to water in them, in feet below the surface, are shown on Plate VI.

The second table records the monthly measurements made by Mr. Hancock in the western one of the two dug wells on the race track immediately north of Mountain View Cemetery. This well is situated near the south edge of the grounds, about 250 feet east of the county road, in the SW. ¼ sec. 32, T. 3 N., R. 7 W. The bench mark is indicated by three notches cut into the wood. The data given in the second table are graphically shown in figure 7.

The race-track well is not near any special area of intake nor any area where ground water is being discharged, and it therefore probably represents only such fluctuations as are general throughout the upland areas of the flat. The measurements show only slight fluctuations in level—the entire range being considerably less than a foot. The rise shown by the high levels in the summer of 1913 may be due, with some lag, to large accessions during the preceding months, especially June, and the decline in the fall and winter of both 1912 and 1913 may be due to the combined effects of rapid evaporation in the summer and small accessions in

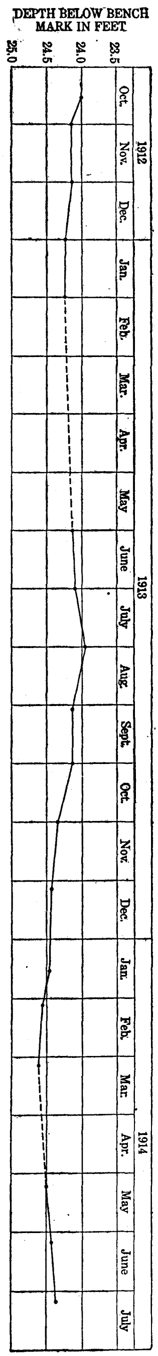

FIGURE 7.—Diagram showing fluctuation of water level in the race-track well, near Butte, Mont.

the fall and in the winter, when the ground is frozen. The somewhat lower levels in the fall of 1913 compared with corresponding dates in the fall of 1912 may be due to differences in precipitation.

The mass of slag at the large smelters has no doubt had an influence in obstructing the underflow in that vicinity, and the aggradation of the valley has also tended to raise the water table. According to reliable information the water table has risen about 10 feet in the vicinity of the smelters since they were built. (See Pls. VII and VIII, pp. 86, 87.)

Typical wells showing water levels in the upper Silverbow basin.

[Measurements made in October, 1912.]

No.	Location.			Situation in section.	Owner.	Description.	Depth.	Bench mark.[a]	Depth to water level—	
	Township N.	Range W.	Section.						Below surface.	Below bench mark.
							Feet.		Feet.	Feet.
1	3	8	24	SE. ¼, south of creek	Butte Water Co.	12 feet diameter; cased with brick; no pump.		Board cover, 3 notches	2	2.4
2	3	8	25	Short distance southwest of center, near Grove Creek.	Butte Butchering Co.	Dug; windmill and pump		3 notches	[b] 5	10.6
3	3	8	25	Near center of SW. ¼	John Sundberg	4 feet diameter; windmill and pump.	36	None	[c] 31	
4	3	8	25	Near south margin of SE. ¼, 19 Webster Street.	J. F. Smith	Dug; cased with stone; bucket	25	3 notches	11	15.0
5	3	8	36	Northeast corner		Dug		do	25	27.3
6	3	7	19	West side of Harrison Avenue, south of Cobban Street.		do		do	9	10.8
7	3	7	19	Near corner of Harrison Avenue and A Street.	H. C. Cammack	Dug; red windmill	15	do	9	9.6
8	3	7	20	Near southeast corner of NE. ¼		Dug; cased with boards	99	Platform	88	89.0
9	3	7	28	Near southeast corner of SW. ¼ SE. ¼	Joseph Merhar	Dug	12		6	
10	3	7	29	NE. ¼ SW. ¼ NW. ¼	Butte Floral Co	Dug; 15 feet by 2½ feet; in greenhouse.	14	Floor of greenhouse, 3 notches.	11	11.7
11	3	7	30	Near middle of south margin of NE. ¼	Mrs. Rose Strelar	Dug; bucket		3 notches	11	13.0
12	3	7	31	Near middle of north margin of NE. ¼		Dug and drilled	24	Platform	6	7.4
13	3	7	31	Near northwest corner of NE. ¼		Dug; uncased at top		do	17	17.4
14	3	7	31	One-fourth mile south of northeast corner.	S. V. Kemper	Dug and drilled; in pump house with two tanks.	76	3 notches	16	[d] 18.0
15	3	7	31	Middle south margin of NE. ¼		Dug; cased with boards		do	20	23.2
16	3	7	31	South margin of SW. ¼ NE. ¼		Dug; uncased at top		do	25	27.1
17	3	7	31	700 feet southeast of railroad crossing, near center of section.		6-inch iron casing; no pump	86	Top of casing	32	32.5
18	3	7	32	About 250 feet east and 1,500 feet north of southwest corner.	Race track	Dug		3 notches	22	24.0
19	3	7	32	About 1,000 feet east and 700 feet north of southwest corner.	Mountain View Cemetery	6-inch iron casing; n pump house with tank.	119		[c] 24	

[a] Wherever practicable, the bench mark, from which accurate measurements were made, is the upper surface of the well platform or some other substantial timber near the surface and is marked by three notches in the wood.
[b] Below stream level.
[c] Reported; not measured.
[d] Water level 0.8 foot above floor of well.

Typical wells showing water levels in the upper Silverbow basin—Continued.

No.	Location.			Situation in section.	Owner.	Description.	Depth.	Bench mark.	Depth to water level—	
	Township N.	Range W.	Section.						Below surface.	Below bench mark.
							Feet.		*Feet.*	*Feet.*
20	2	7	6	Short distance northeast of half-mile railroad crossing.		Dug; cased with boards		3 notches	35	36.3
21	2	7	6	About 950 feet north of southeast corner.		do		do	50	51.3
22	2	7	6	About 950 feet north of southeast corner.		4-inch iron casing with pump		Top of casing	50	51.4
23	2	7	6	About 250 feet northwest of southeast corner.	James Sullivan	Dug; cased with boards		3 notches	57	59.7
24	2	7	7	Near middle of east margin	Fivemile Schoolhouse	do		do	71	73.5
25	2	7	8	NE. ¼, south of road and west of creek		Dug		do	35	37.6
26	2	7	8	About one-fourth mile south and 800 feet east of northwest corner.		Dug; 3 by 4 feet; cased with boards; pumping plant.		do	59	60.1
27	2	7	8	Near northwest corner of SE. ¼ NW. ¼.	Stewart ranch	Dug; cased with boards		do	53	54.5
28	2	7	18	Near west margin, in valley, north of creek.	J. W. McLean	do	40	do		27.2
29	2	7	18	Near middle of south margin	Pitman ranch	Dug and drilled	31	Platform	12	12.0
30	2	7	19	Near middle of west margin		Drilled	43		13	
31	2	7	21	Near middle of north margin, west of road.		Dug		3 notches	21	23.6

Monthly measurements of depth to water in race-track well, about 250 feet east and 1,500 feet north of the SW. ¼ sec. 32, T. 3 N., R. 7. W.

[Measurements by E. C. Hancock.]

	Ft.	in.		Ft.	in.
October 16, 1912	24	0	October 1, 1913	24	1½
November 1, 1912	24	1½	November 1, 1913	24	4
December 1, 1912	24	1½	December 5, 1913	24	5
January 1, 1913	24	2¾	January 16, 1914	24	5½
February 1, 1913	24	2¾	February 3, 1914	24	6¾
June 1, 1913	24	1½	March 4, 1914	24	7½
July 1, 1913	24	1	May 7, 1914	24	6
August 1, 1913	23	11½	June 9, 1914	24	5
September 2, 1913	24	1½			

SOURCE AND DISPOSAL.

About 23 cubic feet of water per second, or 17,000 acre-feet a year, falls on the flat as rain or snow. A part of this water merely wets the soil and later evaporates without reaching the water table or joining the main body of ground water, and a part is drained off and is eventually discharged from the basin without having passed underground. The part that percolates to the water table and is incorporated with the ground-water supply is difficult to estimate but is without question important in quantity, the flat topography and porous subsoil both being favorable conditions. The loam soil, which is only moderately porous, absorbs and holds in a capillary condition most of the moisture of light rains and it no doubt impedes and to a great extent prevents the percolation of the water derived from the heavier rains and from the melting of snow. The soil is thin, however, and the subsoil is in most places remarkably porous. The water that gets through the soil therefore sinks rapidly to a depth from which it can not be withdrawn by capillary action, and it then percolates more slowly through the underlying denser beds until it reaches the water table.

The precipitation on the mountain areas tributary to the flat amounts to about six times as much as the precipitation on the flat itself. The greatest part of this large quantity of water is returned to the atmosphere before it escapes from the mountain areas. Most of the rest is delivered to the flat in the form of permanent or temporary streams or is collected in reservoirs and led away through pipe lines. Only a small part escapes by percolation through openings in the rock. A small part of the mountain area immediately adjacent to the flat sheds water upon the upland of the flat or into ravines leading to the larger streams. This water is disposed of in much the same manner as the precipitation on the flat. Most of the mountain area is, however, embraced in a few relatively large drainage systems and sends no water to the flat except that which is delivered through a few trunk streams that flow in deeply incised and well-developed valleys. The part of the mountain area tributary to these trunk streams receives about two-thirds of the total precipitation in the basin, but its only contribution to the valley fill is the percolation from these streams where they flow over the fill.

The quantity of water that annually percolates from the streams to the underground reservoir could be approximately determined by making weir measurements, in several different seasons and water stages, of the flow of these streams at a number of points along their courses in order to ascertain the quantity of water lost in those parts of the streams where percolation takes place. To make an adequate number of such measurements would involve much labor and expense, especially on account of floods and numerous artificial controls. It was not possible to make such measurements within the time available for the present investigation. Some general conclusions were, however, reached from the observations that were made.

Grove, Basin, Blacktail, and Little Blacktail creeks flow, through practically their entire courses over the valley fill, at levels that nearly coincide with the water table or are only a few feet above it. In October, 1912, Basin Creek in parts of its course above the Pitman ranch, Little Blacktail Creek in parts of its course, and Silverbow, Blacktail, and Basin creeks in their lower courses nearly coincided with the water table and were obviously not contributing to the ground-water supply. At the same time Grove Creek and Blacktail and Basin creeks along most of their middle courses flowed several feet above the water table but were apparently not losing much water by percolation. Duffy Creek, however, flowed considerably above the water table and was losing water by percolation. This creek is said to go entirely dry at some times in the summer. Other small creeks no doubt also contribute ground water.

The accessions to the underground reservoir are balanced by losses through seepage into the streams, evaporation from shallow-water areas, underflow in the gorge, and percolation into bedrock. The first two processes dispose of considerable water; the last two are less important. In the localities where the water table practically coincides with the stream levels the underground reservoir is literally overflowing. Weir measurements made by Hugh McCloud for the Timber Butte Mining & Milling Co. in September, 1912, showed that Blacktail Creek and its tributaries in the half mile above the point where it crosses the county boulevard (sec. 29, T. 3 N., R. 7 W.) had an average increase in flow of about one-third second-foot, even though during that period the Clark pumping plant, situated along this part of the creek, was in continuous operation. (See p. 109.) Where the ground water stands near enough to the surface to be drawn to the atmosphere by capillary action or through the agency of plants, loss by evaporation takes place. Ground water is lost by evaporation in the broad valleys of the principal streams of the flat over a total area of nearly 2,000 acres. From experiments made in other regions it is estimated that the annual evaporation over this area ranges, according to the character of the soil and the depth to water, from less than 1 foot to several feet and averages between 1 and 2 feet.

On taking into account all available information as to both accessions and withdrawals, the conclusion is reached that the quantity of water annually received by and discharged from the underground reservoir amounts to a few thousand acre-feet but is probably less than 10,000 acre-feet. A large part of this annual supply could be recovered by pumping from wells.

The valley floors of the principal streams virtually coincide with the water table. Since the grade of the valleys is adjusted to the load of rock waste that the streams carry and is not controlled by the water table, it may be inferred that the level at which the ground water stands is controlled by the stream levels. The streams do not contribute greatly to the underground supply because the reservoir is already full and the movement of the ground water is too sluggish to reduce the grade of the water table. The waters discharged through the stream valleys, however, constitute a reserve supply that would be contributed in greater quantities to the underground reservoir if, because of a series of dry years, heavy pumping, or any other change, the water level should be lowered.

ARTESIAN PRESSURE.

Flows have been struck in several wells in the shallow-water belt along Blacktail Creek below Basin Creek. (See Pl. VI.) At the Clark pumping plant, immediately south of Blacktail Creek and west of the county boulevard, in the SW. ¼ NW. ¼ sec. 29, T. 3 N., R. 7 W., eleven 6-inch wells were sunk in 1912, all of which overflowed. (See fig. 8 and p. 109.) The first one sunk is only 40 feet deep and is reported to pass through granitic grit the entire distance. The water rose from it to a level about 4 feet above the surface of the creek, and with the outlet 3 feet above the creek it flowed 27 gallons a minute. The others, except the last one sunk (No. 11), range in depth from 38 to 59 feet. No. 11 is 75 feet deep, passes through a layer of yellow clay between the depths 45 and 53 feet, and had a somewhat higher head than the others. The several wells interfered with each other to such an extent that the total natural flow of the first 10 amounted to only 80 gallons per minute.

Flows with slight head are likely to be struck wherever the water table is near the surface, but flows of large volume will probably not be found. The existing artesian pressure is caused by an alternation of beds of different porosity that slope from the borders toward the interior of the flat. The slight amount of pressure is due to the perviousness of the confining beds, as is shown by the wells at the Clark pumping plant. The bedrock has no artesian structure.

YIELD OF WELLS.

Most of the wells on the flat were dug by hand and do not extend far below the water level. They generally yield ample domestic or other small supplies but would probably not stand severe tests. At different times, however, more or less successful attempts have been made to develop large water supplies by putting down wells.

Several wells were sunk 15 or 20 years ago by the Butte Water Co. on its property south of Blacktail Creek, in the SE. ¼ sec. 24, T. 3 N., R. 8 W., and were for some time pumped for the public supply. (See Pl. VI.) The system consisted of a dug well and an 8-inch drilled well, each about 30 feet deep, and of a dug hole 12 or 15 feet deep, in the bottom of which were drilled three 3-inch holes. Two of the 3-inch wells extended to depths of 40 to 60 feet and the other to 105 feet. All the wells discharged by natural head into the shallow hole, from which the water was pumped. Although the water normally rose practically to the surface, the effective head by this arrangement was not great. Moreover, the fine strainers with which the drilled wells were finished were not adapted to the kind of material from which the water was derived and apparently they soon became partly clogged. The yield from this system is reported to have been between 200,000 and 250,000 gallons per day at first but to have diminished in the course of time.

A group of about eight 2½-inch wells, ranging from 14 to 30 feet in depth, were driven at the Butte Reduction Works, on the west side of Montana Street (see Pl. VI), and are said to have been pumped from 1902 to 1910 at the rate of about 200 gallons per minute. A group of about eight wells, 8 to 10 inches in diameter, situated on the east side of Montana Street but also belonging to the Butte Reduction Works, are reported to have been pumped at about 800 gallons per minute. A very shallow dug well, known as the Bricker well, situated between Blacktail and Silverbow creeks near the east margin of sec. 24, T. 3 N., R. 8 W. (see Pl. VI), is said to have been pumped at a rate of several hundred gallons per minute. In 1912 all these plants had been abandoned, but about 100 gallons per minute were being pumped from a well 3½ feet in diameter and 24 feet deep at the electric plant on the west side of Silverbow Creek. (See Pl. VI.) When pumped at this rate the water in the well stood 7½ feet below the surface.

A combination dug and drilled well, 76 feet deep, situated in the NE. ¼ sec. 31, T. 3 N., R. 7 W. (Pl. VI), has been used for several years by S. V. Kemper for the irrigation of about 4½ acres. A double-acting deep-well cylinder pump is inserted several feet below the normal water level, 16 feet below the surface, and is operated by a 6-horsepower gasoline engine that lifts the water into four elevated wooden tanks having a combined capacity of about 7,000 gallons. In a 4½-hour test made October 22, 1912, the well was pumped at a rate of 21 gallons per minute, but the drawdown could not be ascertained. Mr. Kemper reports that the well was formerly pumped at 33 gallons a minute and that this rate of pumping caused a lowering of the water level of about 8 feet while the pump was in operation.

A well 119 feet deep has recently been drilled at the Mountain View Cemetery, in the SW. ¼ SW. ¼ sec. 32, T. 3 N., R. 7 W. (See Pl. VI.) This well, in which the water stands 24 feet below the surface, is finished with 6-inch iron casing to the depth of 107 feet, below which there is a 12-foot strainer. It is pumped by means of a deep-well cylinder inserted near the bottom and operated by a 5-horsepower electric motor. In a test on October 26, 1912, covering one hour, this well yielded 17 gallons a minute, but the drawdown could not be ascertained. According to H. J. Worth, the driller, the maximum yield of the well when it had reached the depth of 72½ feet was 12 gallons a minute, the water being admitted through the same 12-foot strainer that was later inserted in the completed well.

A well 33 feet deep was dug at the classification yards of the Chicago, Milwaukee & St. Paul Railway (see Pl. VI) but was later abandoned. According to a report made by representatives of the railway company, the well passed through a sort of quicksand that caved readily and did not supply as much water as was required at the yards.

A well 30 feet in diameter was sunk to a depth of 80 feet at the shops of the Northern Pacific Railway, in the S. ½ sec. 9, T. 3 N., R. 7 W. (See Pl. VI.) This well, which is cased with stone, is pumped by electric power about 10 hours each day at a rate of 120 gallons per minute. At the end of the 10-hour run the water in the well is reported to be lowered nearly 20 feet.

The best data on the yield of wells were obtained at the pumping plant of the Timber Butte Mining & Milling Co., situated on the Hamilton ranch, in the W. ½ SW. ¼ NW. ¼ sec. 29, T. 3 N., R. 7 W., commonly known as the Clark pumping plant. (See Pl. VI and fig. 8.) At this plant there are 10 wells ranging between 38 and 59 feet in depth and cased with 6-inch standard pipe, the lowest 15 feet of which is perforated with three-eighth-inch holes. Brass strainers with small openings were at first used, but they were not very successful and were therefore discarded, the perforated casings being used in their stead.

Well No. 1 (fig. 8) was tested at 165 gallons per minute, and the maximum test given any single well was at the rate of 185 gallons per minute. The 10 wells were then connected by pipes at the surface and water was drawn from them by means of a single set of pumps (fig. 8). The pumps were in continuous operation from September 14 to some time after October 30, 1912, except for an

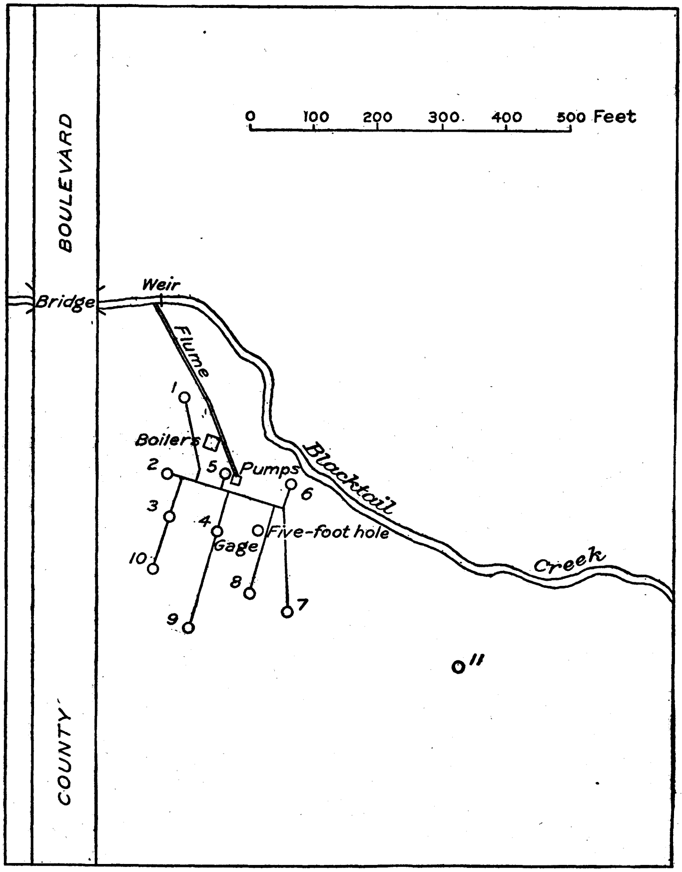

FIGURE 8.—Map showing the Clark pumping plant, in the W. ½ SW. ¼ NW. ¼ sec. 29, T. 3 N., R. 7 W., near Butte, Mont. After Hugh McCloud, engineer, Timber Butte Mining & Milling Co. Circles indicate wells. All wells except No. 11 are connected by pipe lines.

interval of 32 minutes on October 12, when vacuum gages were inserted, and for a short time on a later date. Well No. 11, which is 75 feet deep and situated about 300 feet from the nearest one of the 10 wells (fig. 8), was not connected. Before pumping was begun the water from all of the wells rose a few feet above the surface. The rate of pumping varied slightly with the amount of steam in the boiler but averaged about 800 gallons per minute, as measured by Kutter's formula. The average of six readings of the vacuum gage between October 12 and 28 was 16.1 inches of mercury, which is equal to a lowering of the water in the wells to about 18 feet below the gage, or 15½ feet below the surface at well No. 4. Since the yield of 10 wells was 800 gallons per minute the average yield per well was 80 gallons per minute, or about five gallons per minute for each foot of draw-down.

When the pumps were stopped on October 12 the water rose rapidly in the wells. In well No. 4 it rose to a level 6.3 feet below the surface in 2 or 3 minutes, 4.2 feet in 5 minutes, and 1.8 feet in 25 minutes. In the lowest wells it stood above the surface at the end of the half-hour period that pumping was stopped. In well No. 11 it rose from a level 3.05 feet below the top of the casing to a level 0.95 foot below, or nearly even with the surface. In this well the water continued to rise for perhaps a minute after pumping was resumed and then dropped rapidly to its former level of about 3 feet below the top of the casing. In a 5-foot dug hole near well No. 4 (fig. 8) the water stood about 3½ feet below the surface before the pumps were stopped. When the pumps were stopped the water rose very slowly and continued to rise for some time after pumping was resumed. Just before pumping was resumed the water was observed to stand 0.09 foot above its original level and 40 minutes after pumping had been resumed it had risen 0.17 foot.

From October 12 to 28 the water in the 5-foot hole went down 0.35 foot, but there is no record of the fluctuation in the stream level during the same interval. The vacuum gage (at well No. 4) and the water level in well No. 11 fluctuated with slight changes in the rate of pumping. If there was any weakening of the wells it was so slight that it could not be detected with the method that was used for measuring the discharge. In the following table are given all of the data that were obtained on water levels in wells Nos. 4 and 11 and in the 5-foot hole.

Water levels in wells at the Clark pumping plant.

Date.		Well No. 4.[a]		Well No. 11.[b]	Five-foot hole.[c]
Day.	Hour (p. m.).	Mercury on gage.	Depth below top of casing.	Depth below top of casing.	Depth below bench mark.
		Inches.	*Feet.*	*Feet.*	*Feet.*
September 14	Before pumping began		Flowed.	Flowed.	
September 20				2.40	
October 11				3.20	
October 12	2.37 (pumping stopped)			3.05	4.00
	2.39		6.3		4.00
	2.42		4.2		3.99
	2.48		2.6		
	2.52		2.3		
	2.58		2.0		
	3.03		1.8		
	3.05				3.91
	3.08			1.08	
	3.09 (pumping started)				
	3.10			.95	
	3.10½			1.00	
	3.11			1.10	
	3.12			1.25	
	3.13			1.42	
	3.14			1.60	
	3.15			1.78	
	3.17			2.00	
	3.18			2.10	
	3.23	16.1	16.7		
	3.44			2.89	
	3.48				3.83
	4.17			3.10	
	5.00	15.1	15.6	2.90	
October 17		14.9	15.3	2.95	3.94
October 24		15.9	16.5	2.96	4.20
October 28		16.6	17.3	3.17	4.35

[a] Top of the casing is about 1 foot above the surface, and center of the gage is about 1.5 feet above the top of the casing.
[b] Top of the casing is somewhat less than 1 foot above the surface.
[c] Bench mark is 0.5 foot above the surface.

The investigation shows that the valley fill yields its water less freely than is indicated by its granitic origin and its porous character in most of its outcrops, but that it is of such a character that the rate at which it supplies wells depends largely on the manner in which the wells are constructed. It is believed that with proper methods of construction a yield of 100 gallons per minute from a single well can be developed in most parts of the flat. Such a well would be adequate for the irrigation of a truck farm of 10 acres.

CONSTRUCTION OF WELLS.

The valley fill of this basin is poorly assorted and incoherent. That is, it consists of a mixture of large and small particles that are not attached to each other. In developing ground-water supplies advantage must be taken of these two conditions. The small particles must be drawn into the well and removed in order that the intake of the well may be surrounded by coarse, clean, porous material that will transmit water freely.

As fine strainers are designed to prevent small particles from entering the well they are not adapted for developing large supplies in this basin. Moreover, the yield of a well finished with a fine strainer is likely to decrease because in the course of time the openings in the strainer become clogged with fine particles drawn toward the well by the inflowing water and cemented together by calcium carbonate, which is precipitated from the water because of the loss of carbon dioxide by the reduction of pressure incident to pumping.

The best results will generally be obtained if wells are finished with casings that are 6 to 10 inches in diameter and are perforated with holes at least one-fourth inch in width or diameter wherever they pass through beds coarser than quicksand. In order to develop such wells to their greatest possible capacity it is necessary to clean them out thoroughly. This can be done by first using a bailer or sand pump and later by applying some other lifting device. Air lifts are best adapted for this purpose because they agitate the sediments in the well and consequently expel them with the water. Centrifugal pumps can also be used to advantage, but cylinder or plunger pumps, are less successful because their valves are worn by the sand in the water. Whatever device is used, the water should, if possible, be removed as rapidly as it is supplied by the well, and the rate of removal during the final stages of the cleaning process should preferably be more rapid than the rate at which the water is to be pumped afterward. Great quantities of sand, silt, and clay are often removed from wells of this type, with the result that the capacity of the wells is increased. There are, however, some failures in the use of this method owing to the absence of coarse material or the slumping of overlying beds of clay or quicksand.

Various methods of sinking wells may be used, the hydraulic or jetting methods [1] and the sand-pump or mud-scow methods [2] being best adapated to the conditions. Heavy iron casing has been used almost exclusively in this vicinity, but less expensive double stovepipe casing, Nos. 10 to 14 gage, would also be adequate.[3] On account of the tendency of the incoherent material to cave, it is expedient to sink the casing as rapidly as the hole is excavated. If the position of the water-bearing beds is known in advance it may be convenient to perforate the casing before inserting it; otherwise a careful log should be kept of the materials penetrated and the perforations should be made at the proper depths, after the casing has been inserted, by means of tools manufactured for that purpose.[4]

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[1] Bowman, Isaiah, Well-drilling methods: U. S. Geol. Survey Water-Supply Paper 257, pp. 70–78, 1911.
[2] Idem, pp. 40, 69.
[3] Idem, pp. 68, 70.
[4] Idem, pp. 67, 69.

QUALITY OF WATER.

As shown in the following table most of the waters analyzed from the valley fill of the upper Silverbow basin contain only moderate amounts of dissolved mineral matter, the total solids in all samples analyzed for the Geological Survey, except that from Mr. Le Toile's well, being between 100 and 200 parts per million. The principal constituents are silica, calcium, and the bicarbonate radicle. In these samples (not including the Le Toile sample) the content of silica ranged from 26 to 56 parts per million, the calcium from 21 to 30 parts, and the bicarbonate radicle from 96 to 123 parts. In these four samples the magnesium ranged from 5.6 to 8.4 parts per million, and the sodium and potassium together ranged, according to the calculated amounts, from 3.2 to 10 parts. In the same samples the sulphate radicle ranged from a trace to 14 parts, chlorine from 5.5 to 10.5 parts, and the nitrate radicle from 0 to 3 parts. The sample from Mr. Le Toile's well, in the southern part of Butte, was more highly mineralized than the others, sodium, chlorine, and the sulphate and nitrate radicles being especially abundant. The analyses of the water from the wells at the Butte classification yards also show higher mineralization. The sample from the well at the Fivemile School contained a comparatively large amount of iron and some hydrogen sulphide gas. The sample from the well of J. H. Enright, in the lower Silverbow basin, contained more mineral matter than most of the samples from the valley fill of the upper basin, but the quantities were not excessive. None of the samples contained normal carbonates.

Analyses of water from the valley fill in upper Silverbow basin, near Butte, Mont.

Samples collected by U. S. Geological Survey, October, 1912. Analyst, S. C. Dinsmore.

Location: Township N.	Location: Range W.	Location: Section.	Owner.	Description.	Depth (feet).	Depth to water (feet below surface).	Dissolved substances (parts per million): Total solids.	Silica (SiO_2).	Iron (Fe).	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).	Temperature (° F.).
3	7	19, near corner of Harrison Avenue and A Street.	—— Le Toile	Dug; wooden casing; bucket	16	10	688	74	0.05	111	14	74	0	178	97	91	150	44
3	7	29; see fig. 8	Timber Butte Mining & Milling Co.	Dug	5	4	173	53	.15	30	8.4	7.7	0	123	11	10.5	Tr.	....
3	7	....do	....do	Ten wells; 6-inch standard pipe, perforations in lowest 15 feet	38–59	Flow.	153	50	.05	28	6.6	3.2	0	96	14	6	3	45¾
3	7	31, NE. ¼	S. V. Kemper	Dug and drilled; pumping plant.	76	16	145	56	.60	25	5.6	4.1	0	100	3.2	5.5	2.8	....
2	7	7, at Fivemile School, near middle of east margin.	School district	Dug; cased with wood; iron pump.	71+	71	120	26	[b].1	21	5.7	10	0	108	Tr.	7	0	....

[a] Calculated.

[b] A heavy deposit of iron was precipitated after the sample was taken.

Analyses furnished by G. N. Prentiss, chief chemist, Chicago, Milwaukee & St. Paul Railway Co.[a]

Source of sample.	Date.	Dissolved substances (parts per million): Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).[b]	Sulphate radicle (SO_4).	Chlorine (Cl).	Sum of constituents.
Railroad well near Butte classification yards (SW. ¼ sec. 30, T. 3 N., R. 7 W.?); dug; 33 feet deep	July 26, 1909	94	31	44	153	93	39	454
Butte yards, well No. 1	Oct. 12, 1908	42	10	44	68	68	42	274
Butte yards, well No. 2	....do	42	9.8	52	59	51	76	290
Well at Butte Reduction Works	July 15, 1908	37	9.9	20	62	51	14	194
Well of Butte Land & Irrigation Co	....do	27	5.3	19	38	51	9.9	150

[a] Recalculated from analyses reported as compounds in grains per U. S. gallon.

[b] Includes bicarbonates (HCO_3).

Analysis of water from J. H. Enright's well, west of Sand Creek, in the lower Silverbow basin, near middle of south margin sec. 24, T. 3 N., R. 9 W.[1]

	Parts per million.
Total solids	451
Silica (SiO_2)	104
Iron (Fe)	.12
Calcium (Ca)	67
Magnesium (Mg)	12
Sodium and potassium (Na+K)	14
Carbonate radicle (CO_3)	0
Bicarbonate radicle (HCO_3)	104
Sulphate radicle (SO_4)	20
Chlorine (Cl)	95
Nitrate radicle (NO_3)	8

The mineral substances dissolved in the water are derived chiefly from the granitic rocks or from the sediments formed from these rocks. The following table gives the principal constituents of the prevailing type of granitic rock in this basin, of the decomposed rock, and of the mineral matter dissolved in the water of the valley fill as shown by an average of the four typical analyses given in the foregoing table. The composition of the rocks is taken from Weed's paper.[2] For purposes of comparison all the constituents are computed as oxides and are expressed as percentages of the total. The oxygen equivalent of chlorine was not calculated.

Principal constituents of fresh granitic rock, decomposed rock, and dissolved mineral matter in the water of the valley fill, upper Silverbow basin.

[Percentage of total solid matter.]

	Granite.	Altered rock.	Difference (+ or −) between composition of granite and of altered rock.	Mineral matter in water.	Difference (+ or −) between composition of granite and of mineral matter in water.
Silica (SiO_2)	64.0	65.1	+1.1	28.8	−35.2
Alumina (Al_2O_3)	15.58	15.63	+ .05	Small.	−15.58 (nearly).
Lime (CaO)	4.2	3.6	− .6	22.1	+17.9
Magnesia (MgO)	2.1	1.8	− .3	6.8	+ 4.7
Potash (K_2O)	4.1	4.3	+ .2	5.2	− 1.7
Soda (Na_2O)	2.8	2.6	− .2		
Carbon dioxide (CO_2)	None reported.			31.1	+31.1
Sulphate (SO_3)	[a] .2	[a] .1	− .1	3.7	+ 3.5
Chlorine (Cl)	.2	.0	− .2	4.5	+ 4.3

[a] The fresh rock contained 0.06 per cent of sulphur, as pyrite; the altered rock contained 0.05 per cent of SO_3.

[1] This is a dug well 53 feet deep, with water level 50 feet below surface. Sample collected in October, 1912. Analyst, S. C. Dinsmore.

[2] Geology and ore deposits of the Butte district, Montana: U. S. Geol. Survey Prof. Paper 74, p. 86, also pp. 31–36, 1912.

As the minerals of the granitic rocks are only slightly soluble they furnish little matter to the water except as they undergo chemical decomposition whereby soluble minerals are produced. The chemical changes, however, proceed slowly—in this climate much more slowly than mechanical disintegration. Therefore, except where vein minerals occur (pp. 96–98) or other special conditions are found, the water in the sediments derived from the granitic rocks does not contain much mineral matter. One of the principal processes in the chemical decomposition of the rock is carbonation, whereby soluble carbonates or bicarbonates are formed through the agency of carbon dioxide.

Every constituent present in a smaller proportion in the altered rock than in the fresh rock is present in a larger proportion in the water than in the fresh rock, and vice versa. Obviously the soluble products of decomposition are removed by the water, leaving the insoluble ones in larger proportions. Silica, which forms two-thirds of the parent rock, is difficultly soluble, but is present in the water in comparatively large proportions. Alumina was not determined in the water analyses, but it is so nearly insoluble that it is probably present in only small proportions. Calcium is present in much larger proportions in the water than in the rock. It obviously went into solution as calcium bicarbonate. Magnesium is also present in larger proportions, but the difference is not so great as in the case of calcium. Sodium and potassium, taken together, show a slight proportional decrease, but if these two elements had been separated in the water analyses they would no doubt show very different changes. Potassium, which shows an increase in the altered rock, would probably show a great decrease in the water, for it is rarely present in water in large amount. On the other hand, sodium, which shows a proportional decrease in the altered rock, would no doubt show an increase in the water. As already explained (p. 98), the soluble sulphates are derived chiefly from pyrite or other sulphides, which are rare in the granitic rock itself but are abundant in the veins. Chlorine, which is present in the rock minerals in small amounts only, forms very soluble substances when these minerals decompose, and therefore practically all of it passes into solution.

The proportional changes do not depend entirely on the solubility of the minerals produced by decomposition of the rock. Calcium shows a much greater increase than sodium, although it forms less soluble salts. This may be due to the fact that not all of the dissolved matter is derived directly from the decomposing granite. Much of the calcium is no doubt derived from secondary minerals in the veins, such as calcite and gypsum.[1] It should be noted, however,

[1] Weed, W. H., Geology and ore deposits of the Butte district, Montana: U. S. Geol. Survey Prof. Paper 74, pp. 82–84, 1912.

that calcium carbonate (or bicarbonate) is only relatively abundant. That it is not abundant in this basin as compared with most débris-filled basins in arid or semiarid regions is shown by the uncemented character of the valley fill.

So far as is shown by the partial analyses, the water of the valley fill is generally satisfactory. It is only moderately hard and will form only a moderate amount of scale in boilers. It can be softened by heating, whereby much of the calcium will be precipitated as calcium carbonate. As it contains only small amounts of sodium it will not foam in boilers nor injure crops if used for irrigation. The Le Toile, railroad, and Enright samples are harder and otherwise more highly mineralized than the other waters that were analyzed, but even these are good enough for irrigation. Waters with large mineral content may be found in exceptional wells, and in some localities, especially in the vicinity of Butte, the ground waters may be polluted by sewage or mine wastes.

The water from the well at the Fivemile School is locally regarded as very bad water, although it contains less mineral matter than any other water that was analyzed. So far as the analysis shows, this water contains nothing injurious to health, but the hydrogen sulphide gas in it gives it an unpleasant odor, and the large amount of iron in solution gives it an unpleasant taste and, on precipitation, discolors the vessels in which the water is held. As both of these substances go rapidly out of solution on exposure to the air, the water could be improved for drinking by allowing it to stand exposed to the air for some time or by aerating it in some other manner.

IRRIGATION.

The problem of irrigation on the flat involves several factors, among which are quality of soil, climate, quantity and quality of ground water, cost of developing and pumping the water, and market facilities. The excellent market in Butte for foodstuffs, especially vegetables, makes agriculture on the flat practicable under conditions that would be too adverse with an ordinary market. The food consumption of Butte is so large that there is no danger of overproduction on the flat. The most serious limitation to agriculture or horticulture is imposed by the cold climate. The soil over a large part of the flat can be made productive by proper cultural methods. The supply of ground water, although not large, is sufficient for extensive truck farming and its quality is satisfactory. The cost of developing water supplies is rather great, owing both to the small yield of wells and to the high cost of labor and materials, but it is not prohibitive if intensive agriculture is practiced. With proper equipment and management the cost of pumping will not be excessive, the lift and the cost of power both being moderate.

Centrifugal pumps, placed in pits near the water level, are in general the most economical and satisfactory, especially for large plants. Deep-well cylinder pumps, however, have a fairly high efficiency if kept in repair, and they may be preferable for some small pumping plants, especially if the wells yield only small supplies. Electric current is available on the flat and in general provides the most convenient form of power, but gasoline engines or other internal-combustion engines are also practicable.

PUBLIC SUPPLY.

Nearly the entire water supply of Butte and adjacent settlements is provided through an extensive and ingeniously devised system owned and operated by the Butte Water Co. The information in regard to this system was obtained through the courtesy of Mr. Eugene Carroll, the superintendent and chief engineer of the company.

SOURCES.

The supply is brought to the city through three pipe lines, known, respectively, as the Basin Creek, Moulton, and Bighole-South Fork lines (Pl. VI).

The Basin Creek supply is derived from the run-off of the upper part of the Basin Creek drainage area, comprising about 13 square miles, and from the headwaters of Fish Creek, which is on the opposite side of the Continental Divide and empties into Jefferson River. The Fish Creek water is taken from several branches at an altitude of about 8,000 feet and led by gravity through a 16-inch pipe line, 23,880 feet long, across the divide, where it is delivered to Basin Creek. The capacity of the Fish Creek pipe line is reported to be about 2,500,000 gallons a day, and the average daily supply obtained from this source is perhaps 1,500,000 gallons. The water of Basin Creek, including that contributed by the Fish Creek pipe line, is stored in two reservoirs, from the lower of which the supply is led by gravity through a 24-inch pipe line to the southern part of Butte. (See Pl. VI.) The upper reservoir has a concrete dam, the top of which is 40 feet above the creek bed, or about 6,200 feet above sea level. The lower reservoir has a granite masonry dam, the top of which is 65 feet above the creek bed, or 5,860 feet above sea level. The capacity of the upper reservoir is 60,000,000 gallons and of the lower 189,000,000 gallons. The Basin Creek system is reported to supply about 4,000,000 gallons daily during most of the year, but although it has a large storage capacity its supply is diminished during the low-water stages about February and August.

The Moulton supply is derived from the run-off of a few square miles of mountain area in the extreme northern part of the upper Silverbow basin, drained by Yankee Doodle Creek, which forms the headwaters of Silverbow Creek. (See Pl. VI.) There are two storage reservoirs, known as the Moulton reservoirs Nos. 1 and 2. (See Pl. VI.) The upper reservoir (No. 2) retains a relatively small quantity of water behind a low earth dam; the lower reservoir (No. 1) has an earth dam with a cement core, the top of which is about 60 feet above the stream bed, or 6,750 feet above sea level, and it has a capacity of 215,000,000 gallons. The water is led by gravity through an 8-inch pipe line from Reservoir No. 1 to a small distributing reservoir, and thence through a 12-inch pipe line to the high-level mines and settlements north of Butte. Owing to its large storage capacity the Moulton system is expected to yield a minimum of about 1,000,000 gallons per day.

The Bighole–South Fork supply is derived entirely from sources outside of the Silverbow basin. A pumping station is situated on Bighole River at a point about 2½ miles northwest of Divide station and about 1 mile downstream from the power house of the Montana Power Co., in the SE. ¼ sec. 12, T. 1 S., R. 10 W. (See fig. 5.) From this point the water is pumped through a pipe line, 24 to 26 inches in diameter and nearly 10 miles long, to a reservoir on South Fork of Divide Creek, situated in the NW. ¼ sec. 8, T. 1 N., R. 9 W. (see fig. 5), where the pumped water mingles with water furnished by South Fork. The capacity of the reservoir is 13,500,000 gallons. From the reservoir the water is carried by gravity through a pipe line, 24 to 26 inches in diameter and about 18 miles long, to the West Side reservoir in Butte. This system has a daily capacity of about 8,000,000 gallons.

A gaging station was established by the United States Geological Survey in 1910 at Young's bridge, 4 miles above Dewey and about 9 miles above the pumping plant. At this station the following records of stream flow have been obtained: [1]

Monthly discharge of Bighole River near Dewey, Mont., for 1910.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
September 15–31	387	187	271	9,140
October	542	304	393	24,200
November	524	430	500	29,800
December	478	....	367	22,600

NOTE.—Discharge estimated December 11 to 31 by comparison with stations on Beaverhead River at Barratts and Jefferson River near Silverstar, Mont.

[1] Surface water supply of the Missouri River basin, 1910: U. S. Geol. Survey Water-Supply Paper 286, p. 36, 1911; Idem, 1911: U. S. Geol. Survey Water-Supply Paper 306, p. 40, 1914.

Monthly discharge of Bighole River near Dewey, Mont., for 1911.

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
January			[a]300	18,400
February			[a]250	13,900
March	655		343	21,100
April	2,000	680	1,160	69,000
May	2,600	1,360	1,870	115,000
June	10,400	1,900	6,590	392,000
July	4,560	755	1,640	101,000
August	870	265	551	33,900
September	350	250	276	16,400
October	605	280	488	30,000
November	430	280	365	21,700
December	315		245	15,100
The year	10,400		1,170	848,000

[a] Estimated.

NOTE.—Discharge March 1 to 11 estimated at 250 second-feet per day; December 16 to 31, 225 second-feet per day.

In the Basin Creek and Moulton systems the water is transported entirely by gravity; in the Bighole-South Fork system most of the water must be pumped from Bighole River to the South Fork reservoir, a lift of 840 feet. The distributing system is so arranged that a maximum amount of gravity water and a minimum amount of pumped water is used, different adjustments being made for high and low water stages. For about two months in the spring, about the middle of April to the middle of June, when the stream flow is greatest, little or no water is pumped from Bighole River.

Most of the pipe lines are made of wooden staves wound with wire, but stretches that have high pressures are provided with riveted steel pipe.

DISTRIBUTION AND CONSUMPTION.

The waterworks comprise four connected distributing systems, which in this paper will be called the high-level, Walkerville, middle, and low-level systems.

The high-level system distributes the Moulton supply by gravity to the highest areas north of Butte.

The Walkerville system distributes water by gravity from the Walkerville reservoir (see Pl. VI) to a belt, including Walkerville and Centerville, that lies lower than the areas supplied by the high-level system but much higher than most of Butte. The Walkerville reservoir is supplied chiefly with water pumped from the west-side reservoir, but it also receives by gravity all of the Moulton supply not required at higher levels. The quantity that must be pumped ranges from little or nothing to the entire consumption of the Walkerville system, according to the amount of water available from the Moulton supply. The Walkerville reservoir is constructed of concrete and has a capacity of 3,200,000 gallons. When it is full its water surface is 6,255 feet above sea level.

The middle system distributes water by gravity from the west-side reservoir to the upper parts of Butte, which, however, lie considerably lower than the belt served by the Walkerville system. The west-side reservoir, which is supplied entirely from the Bighole–South Fork pipe line, is constructed of concrete and has a capacity of 14,000,000 gallons. When it is full its water surface is about 5,960 feet above sea level.

The low-level system distributes water to the lower parts of Butte. It derives most of its water from the Basin Creek supply, but in low-water stages this supply is inadequate and water is admitted from the west-side reservoir through the mains of the middle system.

The average daily consumption is roughly estimated at 9,000,000 gallons, of which about 1,000,000 gallons is distributed by the high-level system, 1,500,000 gallons by the Walkerville system, 2,500,000 gallons by the middle system, and 4,000,000 gallons by the low-level system. The different systems are so adjusted to each other that pumped water can be supplied when necessary to all except the high-level system, whereas the less expensive gravity water can be used exclusively when an adequate supply is available. One lift is necessary to deliver Bighole water to the middle or low-level systems, and two lifts are necessary to deliver this water to the Walkerville system. Under the most favorable conditions pumping is entirely dispensed with, the high-level and Walkerville systems being supplied with Moulton water, the low-level system with Basin Creek water, and the middle system with water furnished by South Fork.

If the average daily consumption is 9,000,000 gallons, the total annual consumption amounts to about 10,000 acre-feet. If the total population that is supplied aggregates 55,000 persons, as is estimated by the superintendent of the waterworks, the average daily consumption per capita is about 165 gallons. This figure includes, however, the large quantities used by mines, railroads, and other industrial concerns.

COST.

The value of the entire plant of the Butte Water Co. is estimated by the company at $4,513,600. The small consumers commonly pay for the water according to a schedule of flat rates, the minimum monthly rate for a small residence without bath or toilet being $1.50. Large consumers are given sliding meter rates, ranging from 50 cents per 1,000 gallons, where less than 25,000 gallons is used in a month, to 20 cents, where more than 600,000 gallons is used, a charge of $1 per month additional being made if the monthly bill amounts to less than $10.

QUALITY OF CITY SUPPLY.

The following table gives analyses made for the United States Geological Survey of samples of water collected October 16, 1912, from the three supplies with which the waterworks are provided. In these analyses only the principal mineral constituents were determined.

Analyses of the public water supply at Butte, Mont.

[Analyst, S. C. Dinsmore.]

Supply.	Point where sample was taken.	Constituents (parts per million).										
		Total 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).	Chlorine (Cl).	Nitrate radicle (NO_3).
Basin Creek....	Lower Basin Creek reservoir.	87	27	0.7	14	4.5	Tr.	0.0	46	9.8	3	0.1
Moulton........	Residence of Henry Miles.	102	37	.5	17	2.6	0.9	.0	46	12	4	.1
Bighole-South Fork.	West-side reservoir.	91	9	.1	16	4.3	Tr.	.0	51	9	1.5	.1

The three supplies are similar to each other in composition. The mineral constituents are present in nearly the same proportions in these supplies as in the typical waters of the valley fill but in smaller quantities. The city water is therefore softer than the ground water. It is of good quality for use in boilers and also, at least in so far as mineral constituents are concerned, for drinking and culinary use.

The drainage areas that furnish the Basin Creek and Moulton supplies are small and nearly uninhabited, and with proper policing they can be protected from pollution. The Bighole drainage area is, however, extensive and contains a considerable agricultural population, making sanitary protection of the water less feasible. No sanitary inspection of any of the supplies was made in connection with the present investigation.

The lower Basin Creek reservoir was constructed in 1893 and 1894. During the first two years of its existence serious difficulty was experienced with algal growths, from which the impounded water acquired an odor and taste that rendered it very objectionable. After a costly and ineffectual attempt had been made to remedy the difficulty by removing the soil and vegetable matter from the bottom of the reservoir, the water was treated, under the advice of G. T. Moore, of the United States Department of Agriculture, with a solution of copper sulphate. This treatment proved entirely successful.[1] It is inexpensive and has since been used whenever necessary.

Copper sulphate is also used in the South Fork reservoir for bacterial disinfection, but as calcium hypochlorite and chlorine gas are now recognized to be more effective in destroying disease germs their use is recommended in place of copper sulphate for this purpose.[2]

SUMMARY.

The principal conclusions reached in this investigation can be summarized as follows:

1. The bedrock in the area covered by this paper forms a nearly water-tight basin, but it contains small quantities of water near the surface, where the rock is partly disintegrated, and in joints at greater depths.

2. The bedrock will yield enough water in some localities for domestic purposes but not enough for irrigation or industrial use. It has no artesian structure.

3. The basin formed by the bedrock is partly filled with more or less porous deposits of clay, sand, and gravel derived from the disintegration of the rock. These deposits, which in this paper are called the valley fill, are saturated with water below the water table.

4. In only small areas near the mountains does the water table lie more than 100 feet below the surface; over a considerable part of the flat it lies less than 25 feet below; and in the principal stream valleys it is nearly at the surface.

5. The valley fill is incoherent and poorly assorted. To develop maximum yields, wells sunk into the fill should have casings perforated at the water-bearing beds with holes at least one-fourth inch in diameter or width, and these wells should be thoroughly cleaned out in order to remove the fine sediments.

6. With proper methods of construction a yield of 100 gallons per minute from a single well can probably be developed in most parts of the flat.

7. Flows with slight head are likely to be struck at any point on the flat where the ground water is near the surface, but flows of large volume will probably not be found.

8. The valley fill receives a considerable part of the water which falls on the flat as rain or snow and a small part of the water which falls on the mountain areas that drain toward the flat. It loses water

[1] Carroll, Eugene, Treatment of a reservoir of the Butte Water Co. with copper sulphate: Engineering News, vol. 52, pp. 141-143, 1904. Moore, G. T., and Kellerman, K. F., A method of destroying or preventing the growth of algal and certain pathogenic bacteria in water supplies: U. S. Dept. Agr. Bur. Plant Industry Bull. 64, 1904; Copper as an algicide and disinfectant in water supplies: U. S. Dept. Agr. Bur. Plant Industry Bull. 76, 1905.

[2] Johnson, G. A., The purification of public water supplies: U. S. Geol. Survey Water-Supply Paper 315, 1913.

by seepage in the valleys, by evaporation in shallow-water areas aggregating nearly 2,000 acres, and probably to a small extent by underflow in the gorge of Silverbow Creek and by percolation into the bedrock.

9. The quantity of water annually received by and discharged from the valley fill amounts to a few thousand acre-feet, but is probably less than 10,000 acre-feet. A large part of this annual supply could be recovered by pumping from wells.

10. If, by heavy pumping or other agency, the water table is drawn down to a level below the floors of the principal stream valleys these streams will contribute more largely to the underground supply than they do at present. Overdrafts in the vicinity of Butte will to some extent lower the water table in the parts of the flat farther south, but can not withdraw all of the available supply from those parts.

11. The typical soil of the flat is of good physical constituency and is rich in soluble minerals useful for plant growth. It is, however, low in organic matter and is slightly acid but can be improved by the application of lime and manure.

12. The ground water is of satisfactory quality for irrigation.

13. On account of the porous character of the subsoil, the duty of irrigation water will be rather low, and frequent applications of water will be necessary. A supply of 100 gallons per minute will, however, be sufficient for a 10-acre truck farm.

14. The cost of developing ground-water supplies is high, but the cost of pumping is moderate, provided there is proper equipment and efficient management. The costs need not be prohibitive if intensive agriculture is practiced.

15. The most serious handicap to farming, gardening, or fruit raising on the flat is the cold climate. Late and early frosts limit greatly the crops that can be grown.

16. The quality of the public water supply was investigated only in regard to the principal dissolved mineral constituents. So far as the investigation was carried the water from all three sources was found to be soft and otherwise satisfactory for domestic and industrial use. In general the ground water underlying the flat is harder than the public supply but is also of good quality for domestic and industrial use. In exceptional wells, however, the water has a high mineralization or contains objectionable amounts of hydrogen sulphide, iron, or other constituents.

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