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EXPLORATORY DRILLING FOR WATER AND USE OF GROUND WATER FOR IRRIGATION IN STEPTOE VALLEY, NEVADA

BY

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WITH AN INTRODUCTION

BY

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INTRODUCTION.

By O. E. Meinzer.

GROUND WATER FOR IRRIGATION IN NEVADA.

The agricultural conquest of vast areas of arable land belonging to the public domain forms a brilliant chapter in the history of the United States. A consideration of the marvelous agricultural development by which these apparently boundless expanses of Government land were converted into thousands of productive farms and well-provided homes within the last few decades suggests at once, however, a serious problem of the not distant future. Only a few years ago the supply of agricultural land in the great West was commonly assumed to be inexhaustible; to-day the country is beginning to realize that practically all the tracts which can readily be made productive without irrigation have been occupied and that practically all the streams which can be utilized for irrigation without the installation of expensive storage projects have been appropriated. The limits of agricultural development, even with the greatest possible conservation of soil and water and the application of the best cultural methods, therefore appear to be not indefinitely remote, and the realization in recent years of the fact that the part of the public domain which has undoubted value for agriculture is rapidly being taken up has induced large numbers of those who are eager to find farms and homes of their own to settle unwittingly in areas where the conditions are so unfavorable or so poorly understood that failure and suffering are inevitable.

In Nevada the bedrock forms a surface consisting of rugged, nearly parallel mountain ranges and broad intervening troughs that are filled to great depths with rock waste washed from the mountains. These great deposits of rock waste were in large part laid down by torrential streams and are therefore relatively coarse and porous, so that the rain that falls upon them and the run-off that reaches them from the mountains sinks into them, and the desert valleys in which they lie consequently appear exceptionally arid. These deposits are, however, great water conservers, for they constitute huge reservoirs in which the supplies received by percolation are stored and, to the limit of the capacity of the reservoirs, are protected from evaporation.

So well are these supplies hidden that their existence was not suspected by many of the early travelers, and even to-day long desert roads without watering places lead over areas where ground water could easily be obtained.

The demand for farm homes is so great and will continue to be so great that strenuous efforts will be made to utilize by irrigation all available water. The ground water underlying the Nevada deserts will certainly receive more attention in the future than it has in the past, and costly projects for its recovery will be undertaken. Some of these projects will no doubt fail, but others will eventually be successful.

It is very desirable that the possibilities of these desert lands should be thoroughly investigated before they are taken up by home seekers. As the ground water is hidden beneath the surface there is necessarily much uncertainty as to its occurrence and quantity, and therefore corresponding caution should be observed in regard to ground-water projects. Many features of the ground water of desert valleys can be determined, however, even where no wells have been sunk, provided proper observations are made and proper criteria applied. It is generally possible to ascertain definitely the areas where the ground water is near the surface, and to make an intelligent forecast of the depth to water in other parts of the valley. If sufficient observations are made it is also generally possible to form a rough estimate of the quantity of water that is annually available and to predict to some extent the capacity of wells, the quality of the water, and the cost of recovery. To begin to develop the ground-water supply of a valley without first investigating its underground conditions is as unwise as it would be to start to build a railroad without first having the route surveyed, and the financial results are likely to be no less disastrous.

INVESTIGATIONS BY THE UNITED STATES GEOLOGICAL SURVEY.

Among the duties imposed by Congress on the United States Geological Survey is that of "gaging the streams and determining the water supply of the United States, investigating of underground currents and artesian wells, and the preparation of reports upon the best methods of utilizing the water resources." Accordingly, the Geological Survey has for many years been engaged in making a survey of the ground waters of the country with special reference to their larger recovery and use for all practical purposes, including domestic and public supplies, supplies for railroads, mines, and other industrial plants, watering places for live stock on the range and for travelers along desert roads, and supplies for irrigation. Work has been done on this truly large project in every State in the Union. In the West work is done both in regions of intensive ground-water development, such as the valley of southern California, and in regions with almost no ground-water development, such as Steptoe Valley, Nev. In regions of intensive development it is important to make close estimates of the quantities of ground water that are annually available and to investigate possible means of conservation, such as the spreading of storm waters over gravel beds to facilitate their percolation into the ground-water reservoirs. In undeveloped regions it is important to procure and publish for the guidance of prospective settlers reliable information as to the occurrence, quantity, head, and quality of the ground waters, and the methods and costs of their recovery and use. It is the aim of the Geological Survey, so far as possible, to do this work in advance of developments or of unsuccessful attempts to make developments.

The ground waters of Nevada are still for the most part unused. In 1911 the United States Geological Survey began a survey of the ground-water resources of the State, and this work has since been carried on systematically, though slowly, as there is only a small staff of water-supply geologists for the work of the entire country. The areas that have thus far been investigated are shown in the index map (Pl. I).

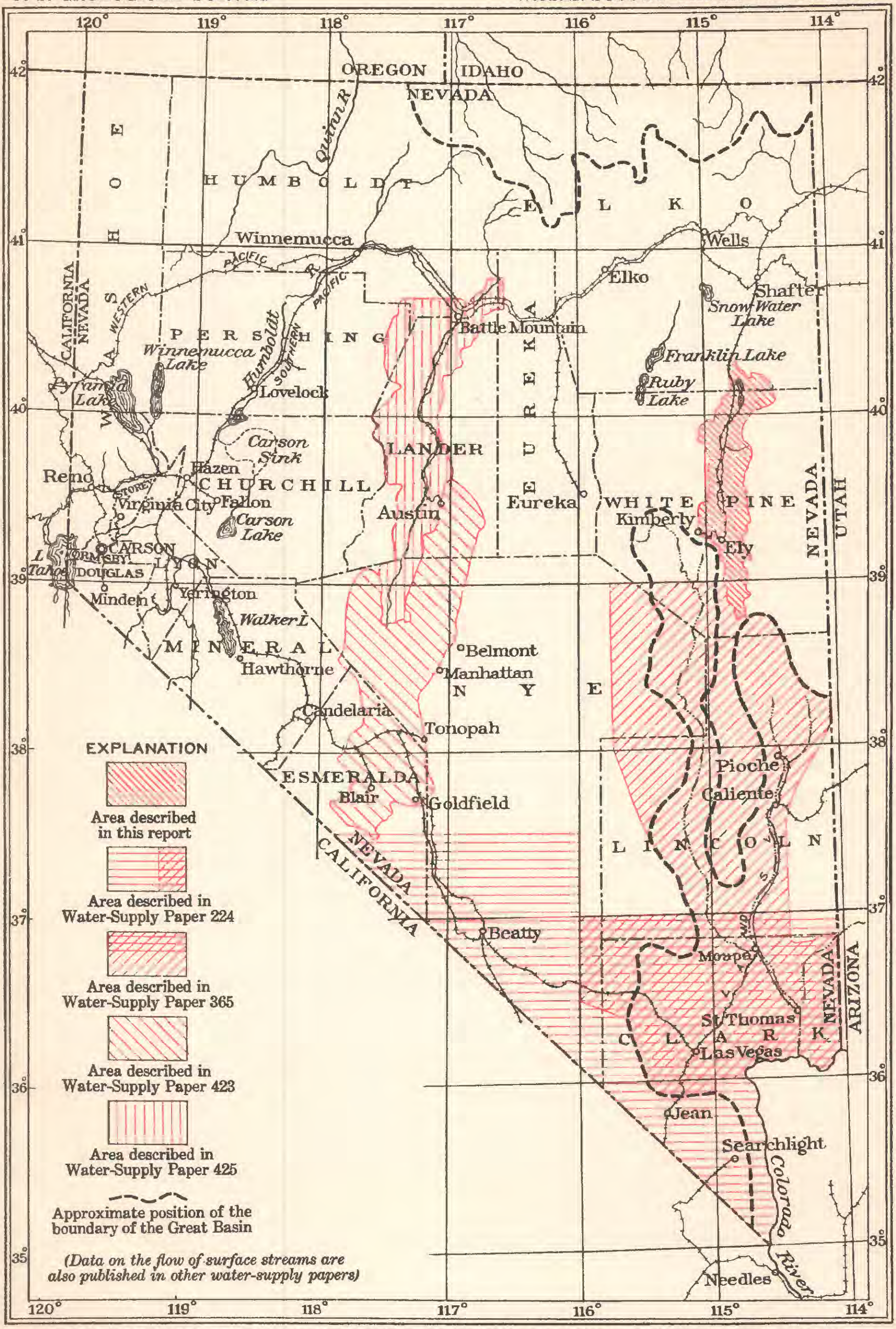
EXPLORATORY DRILLING BY THE UNITED STATES GEOLOGICAL SURVEY.

In connection with the regular appropriations for the fiscal year 1918 Congress specifically authorized the Geological Survey to expend as much as $25,000 in exploratory drilling in the arid regions to discover water for irrigation. In many places in the arid West it would be desirable to sink wells in search of water, but in comparatively few of these places is there much prospect for developing the very large supplies required for irrigation at the relatively low cost that is essential if irrigation is to be economically practicable. In selecting a locality for exploratory drilling the experience of the past was, of course, utilized. A total of many hundreds of thousands of acres of land in the United States is at present under irrigation with water obtained from wells, including much valuable citrus-fruit land in southern California. Most of this water is not derived from hard-rock formations, nor does it come from flowing wells. By far the largest part and the part that has the greatest value in crops produced is pumped out of wells that end in deposits of rock waste such as those that underlie most of the desert valleys of Nevada. Common sense, therefore, dictated that the tests be made in an undeveloped desert valley of this type in which the geologic conditions appear favorable for the discovery of suitable water and in which the soil, climate, and transportation and market facilities are as favorable as possible. Steptoe Valley was selected not because its ground-water conditions are exceptional but rather because it is representative of the most promising valleys of this type. It is perhaps superfluous to say that the climatic and crop conditions are not so favorable in the undeveloped valleys as they are in the highly productive valleys of southern California.

The decision was first reached to select for the test drilling some locality in western Utah or eastern Nevada. Accordingly, in August, 1917, the writer, in company with W. O. Clark, of the Survey staff, made an automobile trip of more than 800 miles, starting at Salt Lake City and ending at Wells, Nev. In this trip a reconnaissance was made of a number of valleys, including Deep Creek valley, Spring Valley, Ruby Valley, and Clover Valley, all of which contain considerable ground water. Spring Valley, which lies on the east side of the Schell Creek Range, was found to contain an extensive area of ground-water discharge and well-developed beach ridges which show that in the Pleistocene epoch the valley held a large lake. This valley, however, is not reached by any railroad. Ruby Valley also contains the remnants of a large ancient lake and bears evidence of having a considerable water supply at the present time, but it is likewise remote from any railroad. Moreover, its area of satisfactory soil with shallow water table is relatively small, most of this area being near the north end, where, in the fall of 1917, one satisfactory irrigation well had been drilled. Steptoe Valley was chosen in preference to the other valleys because of its railroad facilities and the market for farm produce afforded by Ely and the other mining towns in that vicinity. After this reconnaissance was completed and the decision was reached to recommend drilling in Steptoe Valley, the writer proceeded to attend to other duties, and Mr. Clark was placed in charge of the project. Mr. Clark was chosen for this duty because of his eminent success in previous investigations of ground water in the West and his thorough knowledge of the subject.

WORK IN STEPTOE VALLEY.

The project of drilling in Steptoe Valley was approved by the Secretary of the Interior on November 21, 1917; the first drilling was done on December 22, 1917, and the last on June 25, 1918. The last pumping test was made on July 4, 1918. J. M. Heizer was the drilling superintendent from the beginning of the work until March 8. D. H. Walker took charge soon after that date and was the superintendent until the work was completed. J. J. Hibbs and C. H. Gregory rendered efficient service as drill foremen. Especial credit is due to Mr. Hibbs for carrying on the work successfully during the interval when there was no drilling superintendent in the field.



MAP OF NEVADA SHOWING AREAS COVERED BY THE PRESENT AND OTHER WATER-SUPPLY PAPERS OF THE UNITED STATES GEOLOGICAL SURVEY

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It is appropriate in this connection to acknowledge the valuable service rendered to the Geological Survey in recent years by Mr. Walker, whose death from pneumonia occurred at Tonopah, Nev., only a few months after the completion of his work in Steptoe Valley. For a number of years he was associated with H. S. Gale in the Survey's search for potash and nitrate and had charge of the drilling and engineering work involved in those projects. The success of the drilling project in Steptoe Valley was in large measure due to his thorough knowledge of drilling operations and to the energy and enthusiasm wi h which he devoted himself to the work.

The work was done under extraordinary difficulties. The shortness of the interval between the approval of the project and the end of the fiscal year in which the work was to be done necessitated the organization and prosecution of the drilling during the cold winter period; moreover, the work had to be done while the war was in progress, when the necessary equipment, materials, and workmen were almost unobtainable and the cost of everything was excessive. The expenditures directly chargeable to the drilling project were as follows: Equipment and repairs, $6,596; casing, $4,315; freight and hauling, $1,968; fuel, $354; food supplies, $1,125; salary and expenses of superintendent, $3,204; wages of workmen, $3,349. On account of the unusual conditions under which the work was done, the cost data have no value for comparative purposes.

By the end of the fiscal year the work was well organized, but as no specific appropriation was made for drilling in the fiscal year 1919, it had to be stopped, and the advantage of the organization was lost. It is very doubtful whether the continuation of the exploratory drilling would have been justified at the time of national emergency, when every effort had to be put into the winning of the war, even though the work was presumably undertaken during the war because of its bearing on the problems of reconstruction, and was certainly yielding as favorable results as could be expected. Nevertheless, the fact remains that the efforts and expenditures which were made were largely to develop an effective drilling equipment and organization, and the point had just about been reached when the drilling could have been carried on systematically and efficiently. According to data compiled by C. W. Riddell, the cost of well No. 3, exclusive of the board for the workmen, depreciation, and the superintendent's salary and other overhead costs, was as follows: Moving and setting up rig, $28; labor in drilling 122 feet of 10-inch hole, $117: casing, $311; digging pit and perforating casing, $29; fuel, $48; incidentals, $30; total, $563. When this well was drilled a fairly complete outfit and a crew of experienced drillers were already in the field and organized for work. The items do not include any of the heavy initial costs involved in organizing the work.

In connection with the exploratory drilling a survey of the ground-water conditions in Steptoe Valley was made by W. O. Clark and C. W. Riddell, both of the United States Geological Survey. Most of the detailed mapping and investigation was done by Mr. Riddell. The report giving the results of this survey is published in the present paper. This report, with the accompanying map, interprets the information obtained in the test wells and gives the exploratory drilling its chief value. It is believed that exploratory drilling, whether by the Federal Government or by a State or county should always be interpreted by means of a comprehensive ground-water survey of the region in which the drilling is done. The wisdom of making an interpretive survey is the more evident when consideration is taken of the small cost of such survey as compared with the cost of drilling.

GROUND WATER FOR IRRIGATION IN STEPTOE VALLEY.

The conclusions that have been reached as a result of the test wells drilled by the United States Geological Survey and the accompanying hydrologic investigation in Steptoe Valley by Messrs. Clark and Riddell can be briefly summarized as follows:

1. Beds of water-bearing gravel underlie at least a part of Steptoe Valley. The strongest water-bearing beds discovered in the test wells drilled by the United States Geological Survey are within 125 feet of the surface and can therefore be tapped by relatively inexpensive wells.

2. In the vicinity of Geological Survey test wells Nos. 1 and 3 (see Pl. II, in pocket) properly constructed 10-inch wells will yield several hundred gallons a minute, with a drawdown of 20 feet. Such wells supply enough water for practical irrigation. Test well No. 3, which was constructed to be a model irrigation well, will easily yield a second-foot of water—a large enough supply to irrigate 80 acres. Successful irrigation wells can probably not be obtained in all parts of the valley, but it is difficult to forecast the unproductive areas.

3. Steptoe Valley contains about 185,000 acres of land that has a depth to the water table of less than 50 feet. Of this area about 80,000 acres has soil that is suitable for agriculture. The valley contains about 135,000 acres of land that has a depth to the water table of less than 20 feet, of which about 40,000 acres has soil that is suitable for agriculture. Water from the deeper water-bearing beds will generally rise in wells to the level of the water table, or a few feet higher. In test well No. 2 the water table lay 9.6 feet below the surface, but the water from the sand at 325 feet rose to a level only 4.7 feet below the surface. In test well No. 3 the water table lay 14.5 feet below the surface, and the water from the second, third, fourth, and fifth gravel beds rose to about the same level, but the water from the

sixth bed, which lies between the depth of 110 and 116 feet, rose to a level only 11.5 feet below the surface.

4. Most of the area in which the water table lies at a depth of less than 10 feet has soil that contains too much alkali to be satisfactory for agriculture, and most of the area in which the water table lies at a depth between 10 and 50 feet has good soil. For successful irrigation the land must have good soil. Heavy alkali soil should especially be avoided.

5. The ground water in Steptoe Valley is derived chiefly from the stream waters that are poured into the valley from tributary mountain areas and from rain and snow that fall in the valley. According to a series of measurements made by C. W. Riddell in 1918, the perennial streams contribute about 20,000 acre-feet a year to the ground-water supply. These streams drain only 22 per cent of the mountain area. Contributions from the remaining 78 per cent of mountain area and from the precipitation in the valley are doubtless also considerable, and the total quantity of water which in an average year is added to the ground-water supply is probably not less than 50,000 acre-feet. This would be only 4 per cent of the total precipitation in the drainage basin. It is not practicable to recover all this water by pumping from wells, but the available supply is sufficient to irrigate year after year some thousands of acres. The largest recovery can be accomplished by a wide distribution of wells throughout the belt of good soil and shallow water.

6. Ground water is being discharged, through evaporation from the soil or through the growth of native plants, over an area of about 115,000 acres in Steptoe Valley. The average annual discharge is doubtless about equal to the average annual replenishment. The discharge per acre is certainly much less than the quantity of water required per acre to irrigate useful crops, such as alfalfa, grain, or vegetables, and, moreover, not all of this water can be salvaged by pumping from wells. Nevertheless, the great extent of the area of discharge indicates a substantial supply of ground water that is available for irrigation.

7. The ground water of Steptoe Valley is, for the most part, satisfactory in quality for both domestic use and irrigation. Ten samples from several horizons in the three test wells drilled by the Geological Survey were analyzed, and all were found to be of good quality for irrigation.

8. The climate of Steptoe Valley is arid, the average annual precipitation being about 10 inches. The growing season is short but of sufficient length to mature under irrigation many of the hardier crops, such as wheat, oats, barley, timothy, alfalfa, sugar beets, potatoes, and garden truck. Three crops of alfalfa can be grown in a year.

9. There is a railroad in the valley, and several prosperous and relatively permanent mining towns provide a good local market for farm products. Considerable agricultural development must take place before enough will be produced to supply the local market. The raising of alfalfa or other fodder for winter feeding could be advantageously combined with stock raising.

10. On account of the high cost of materials and labor and especially on account of the high cost of fuel for producing power, pumping from wells will be expensive in Steptoe Valley, but market conditions are such as to warrant rather large expenditures in producing crops.

11. Wells for irrigation should be cased with double stovepipe casing at least 10 inches in diameter, and the casing should be abundantly perforated at all satisfactory water horizons. The best practice is to keep an accurate log of the well and to defer all perforating until the well has been sunk to its full depth and has been completely cased. After the perforations have been made the sand should be removed with a bailer or sand pump, and the well should then be pumped with a centrifugal pump for a long time at a gradually increasing rate in order to remove the fine materials near the intake of the well and thus to develop as large a yield as possible. These were the methods used in developing Geological Survey well No. 3.

12. The most practical type of pump for irrigation use is a centrifugal pump. If the water level is not far below the surface a horizontal centrifugal pump can be installed in a pit directly above the water level.

13. The establishment of a community power plant to generate electric current for operating the pumping units on a number of farms is worthy of investigation. In the absence of such a central power plant the most practical means of producing power is for each farmer to install at his pumping plant an internal-combustion engine adapted to burn a low-grade distillate.

14. Success in pumping for irrigation will depend largely on having a properly constructed well and an efficient, well-balanced, and well-installed pumping plant and on maintaining the plant in good running order.

EXPLORATORY DRILLING FOR WATER AND USE OF GROUND WATER FOR IRRIGATION IN STEPTOE VALLEY, NEVADA.

By W. O. Clark and C. W. Riddell.

GEOGRAPHIC SKETCH.

Steptoe Valley lies in White Pine and Elko counties, in east-central Nevada, 30 to 40 miles west of the Utah-Nevada line. It is just east of the 115th meridian and is crossed by the 39th and 40th parallels. It is about 95 miles in length and somewhat more than 9 miles in average width, and is approximately 900 square miles in area. It has a general north-south trend and extends from Bullwhacker Pass, near the northern boundary of T. 11 N., R. 63 E. Mount Diablo meridian, northward to a point near Currie, in T. 27 N., R. 64 E. (See Pl. I.)

This valley lies in a structural trough between northward-trending mountain ranges and contains large quantities of rock waste washed down from these mountains. It has no drainage outlet but with the tributary mountain areas forms a closed drainage basin of about 1,800 square miles. It is connected with Gosiute Valley to the north by a short narrow rock canyon, which at one time gave an outlet to its surface waters. The present almost imperceptible drainage divide lies somewhat south of this canyon and is underlain by valley fill. The average elevation of the valley is somewhat less than 6,000 feet above sea level, but in a few places the mountains that drain into the valley reach elevations of 11,500 feet.

The thriving mining towns of Ely and McGill are situated along the edges of the valley and are reached by the Nevada Northern Railway, which connects with the Western Pacific Railroad at Shafter and with the Southern Pacific Railroad at Cobre. There are only a few ranches in the valley, and most of the land is open range.

The climate is semiarid to arid. For the period for which records are available, 1888 to 1912, the annual precipitation at Ely ranged from 7 to 18 inches and averaged 11.80 inches. The valley is in most places covered with desert plants, such as shadscale (*Grayia spinosa*), greasewood (*Sarcobatus vermiculatus*), sagebrush (*Artemisia tridentata*), yellow sage (*Gutierrezia tenuis*), white sage (*Eurotia lanata*), button sage (*Artemisia frigida*), and rabbit brush (*Chrysothamnus graveolens*). (See Pl. II, in pocket.)

INDUSTRIAL DEVELOPMENT.

The industrial development of Steptoe Valley is largely coincident with the development of mining in the eastern part of the State of Nevada. For many years stock raising and mining were the only industries of the valley. The first notable mining camp in the drainage basin of Steptoe Valley was at Egan, near the lower end of Egan Valley, in secs. 14 and 15, T. 23 N., R. 62 E. Here the first mill for the reduction of ores in the eastern portion of the State is said to have been erected. It was operated by water power developed from Egan Creek. In 1872 the Cherry Creek deposits of high-grade silver ores were discovered, and in 1877 the camp of Ward, in this district, had a population of about 1,500. In 1880 the deposits of silver ore at Taylor were discovered, and by 1883 they had produced over $2,000,000. During the fall of 1867 gold, lead, and silver ores were discovered in Robinson Canyon, near the present town of Ely, and mining continued in this district with a checkered career until 1907, when the successful treatment of the low-grade copper ores was begun. At present the thriving towns of Ely, McGill, Ruth, and Kimberly are almost wholly dependent upon the successful operation of the mines in this district.

The possibilities for stock raising were recognized in the early history of the valley. The mountains furnished abundant range for stock during the summer months, and the white sage (*Eurotia lanata*), or "winter fat," as it is locally known, grew in abundance in the valley. This plant, together with the wild grass of the marshlands, furnished feed during the winter. Under these favorable conditions stock raising rapidly increased. The lands adjacent to the springs and creeks controlled the range and were quickly settled. Finally overstocking of the range made winter feeding necessary, and this stimulated agriculture.

The first attempt at agriculture in the eastern part of Nevada was made in 1861 in Ruby Valley, which is about 35 miles west of the north end of Steptoe Valley. Here the Wells Fargo Express Co., which operated the Overland Stage Route, "opened a farm and raised an abundance of barley, oats, potatoes, and vegetables at their stage station."[1] It is probable that the early agricultural operations in Steptoe Valley consisted largely in harvesting the wild hay on the marshlands in places along the axis of the valley, and the largest acreage is still devoted to raising wild hay, though the yield is less than a ton to the acre. At present about 1,400 acres is planted in alfalfa, and the average yield is about 4 tons to the acre. Small amounts of wheat, oats, barley, and rye are successfully raised, and truck gardens are profitable near the towns.

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[1] Bancroft's History of Nevada, p. 229.

RELATION OF INDUSTRIAL DEVELOPMENT TO WATER SUPPLY.

Except for the crops raised on the marsh lands, irrigation must be employed, and therefore agricultural development has been confined to the areas where water could be obtained either from streams or springs. Relatively few streams enter the valley, and their individual flow is small and as a rule is quickly absorbed on reaching the border of the valley.

For this reason the ranches are located along the sides of the valley near the mouths of canyons or near the springs and have only small acreages under cultivation.

The location of the industries of the valley bears a close relation to the water supply. Mill towns were located on streams, where water could be procured for the concentration or reduction of ores and for domestic use, and the ore was hauled from the mines to these points for treatment. The mill and smelter at McGill was built near the water supply from Duck Creek and the big spring on the McGill ranch. The site of the town of Ely was selected because of the springs in Murry Canyon.

SURFACE FEATURES.

For most of its length Steptoe Valley is narrow, but at its north end it widens toward the east and forms a large embayment. The valley is bordered on the east by the Schell Creek Mountains, which extend from the south end of the valley northward to a point east of Greens station, in T. 25 N. From this point the valley is bounded on the east and north by a portion of the Antelope Range. On the west the valley is bounded by the Egan Range, which rises with abrupt faces several thousand feet above the valley and is broken by faults and deeply carved by erosion.

The valley is in marked contrast to the mountains, both in the form of its surface and in the underlying formations. It presents the characteristic topography of most of the valleys of the Great Basin. It is a plain of easy gradients and comparatively slight relief, except along its borders, where there are great alluvial fans. The valley is underlain by unconsolidated rock waste derived from the erosion of the bordering mountains, which in this paper is called "valley fill."

In cross section the valley generally has a broad, open U shape, the sides being in some places as much as 1,000 feet above the central portion of the valley. The axis of the valley rises gradually from north to south. Its lowest portion is near the north end, where its altitude is probably less than 5,500 feet above sea level. At the south end the altitude is probably between 6,500 and 7,000 feet above sea level. There is a low divide south of Ely which is sufficient to retain the waters of Cummings Lake. This lake is a perennial body of water of considerable extent and is chiefly fed by springs. The lowest portion of the valley near the north end is sometimes covered by a shallow sheet of water of varying extent, but for the greater part of the time it is a dry playa.

MOUNTAINS.

Schell Creek Range.—The Schell Creek Range is a persistent and imposing range of mountains that borders Steptoe Valley on the east for a distance of about 80 miles. The highest portions of the range are east of McGill, where an altitude of 11,600 feet above sea level is attained. The range consists of three more or less distinct ridges each of which has been dissected on both sides, so that the summit of the divide presents a sinuous line. In T. 16 N., R. 65 E., the main divide trends northeastward, and the western ridge continues northward, forming the Duck Creek Mountains—a prong of the Schell Creek Range. (See Pl. II.) Between the Duck Creek Mountains and the main range lies Duck Creek valley, which drains into Steptoe Valley through Gallagher Gap, 6 or 8 miles north of McGill, in sec. 25, T. 19 N., R. 64 E. The east slopes of the Schell Creek Range drain into Spring Valley. The streams of both slopes have carved deep canyons.

The formations of the Schell Creek Range include quartzite, shale, and limestone, together with intrusions of granitoid rocks and rhyolite flows and also deposits of volcanic tuffs. These formations have different degrees of resistance to erosion, and hence the surface features developed upon them are interesting and varied. On disintegration they produce types of valley fill that differ greatly in porosity and permeability.

The foothills of the range are covered with a scattered growth of juniper (*Juniperus utahensis*) and mountain mahogany (*Cercocarpus montanus*) and on the higher slopes are found fir, piñon (*Pinus edulis*), and yellow pine, with aspen, birch, and willow along the creeks and near springs. In general, the mountains are covered with a good growth of grasses and furnish summer range for large numbers of sheep and cattle and a few horses. The timber is too small and scattered to be of economic value except for fence posts and fuel.

Antelope Range.—The Antelope Range forms the eastern boundary of Steptoe Valley north of the north end of the Schell Creek Mountains. A spur projects westward to Currie and forms a part of the northern boundary of Steptoe Valley. This range comprises a series of low-lying ridges, the highest of which rises to about 7,000 feet above sea level. It is almost entirely devoid of timber except for a few scattered junipers. It consists chiefly of volcanic rocks—

probably rhyolitic flows and tuffs. It contains no perennial streams that discharge into the valley, and hence its contributions to the ground water of the valley are made by ephemeral streams and by the underflow through the alluvium in the canyons and through the talus at the edge of the range.

Egan Range.—The Egan Range borders Steptoe Valley on the west throughout its length. It consists of four high, irregular mountain masses connected by lower ridges. These four mountain masses are known, respectively, as Ward Mountain, Heizer Mountain, Telegraph Mountain, and Cherry Creek Mountain. The Ward Mountain mass swings eastward around the south end of Steptoe Valley, where it connects with the Schell Creek Range and forms the divide between Steptoe and Cave valleys. In T. 15 N., R. 63 E., this mass culminates in Ward Mountain, about 10,955 feet above sea level, as measured by triangulation from a point whose altitude was determined by aneroid. To the north the Egan Range is lower and more broken. North of Ely it presents a more abrupt front to the valley. From Heizer Mountain northward the rocks dip away from the valley. Consequently, the canyons are short and steep, have small drainage areas, and do not contribute as much to the ground-water supply of the valley as the streams from the Schell Creek Range. Also the amount of rock waste contributed to the valley from this part of the range is less than that contributed by the Schell Creek Range. The Egan Range is covered with a scattered growth of juniper and piñon and furnishes summer range for a considerable number of stock.

STEPTOE VALLEY.

GENERAL FEATURES.

Steptoe Valley forms a plain whose relief is small in comparison with that of the bordering mountains but is nevertheless considerable. The borders of the valley are several hundred feet and in places possibly as much as a thousand feet higher than the axis of the valley. The slope of the valley ranges from nearly level at the axis to a fairly steep gradient where its borders blend with the talus slopes of the mountains. At many places along the axis of the valley marsh lands occur, and some of these lands have an abundant growth of wild grasses, whereas others are practically barren, owing to the high alkalinity of the soil.

ANCIENT LAKE BEDS.

Lower Steptoe Lake.—The lowest part of Steptoe Valley is near the north end. Here there is a long, irregular flat which has a highly alkaline soil and supports practically no vegetation. During a portion of the year this flat is covered with a shallow sheet of water, which accumulates during the period of low evaporation.

This body of shallow water is the remnant of a much larger lake that occupied the northern part of the valley in an earlier geologic epoch. Shore lines of this ancient lake can be traced for a distance of about 70 miles. (See Pl. II.) The lake was over 30 miles long and about 11½ miles wide at its widest part. It is believed that this lake was in existence during the Lake Bonneville epoch, when there were many lakes in Nevada (see Pl. III), and that it remained at the level of the present noticeable shore line long enough to produce the shore features.[2] Then followed a time of increased humidity, during which the surface of the lake was raised until it overflowed at the lowest point of the divide, and drained northward into the lake that existed in Gosiute Valley. Here the discharge of the lake eroded a canyon which eventually drained or nearly drained the lake in Steptoe Valley. The canyon is cut in bedrock, but the present drainage divide is somewhat south of the upper end of the canyon. The Nevada Northern Railway now passes through the canyon.

Upper Steptoe Lake.—There is evidence that an ancient lake, approximately 35 square miles in area, existed in the southern part of the valley. It was apparently formed by an alluvial divide that extended across the axis of the valley as a result of the uniting of the fans of Steptoe Creek with those adjacent to Ward Mountain. The lake was apparently drained by the dissecting of this alluvial divide.

ALLUVIAL FANS.

General features.—A large part of Steptoe Valley is occupied by alluvial fans, which form conspicuous topographic features on both sides of the valley. The largest fans extend well across the middle of the valley, and hence the axial drainage course forms a sinuous line, which bends away from the larger fans toward the opposite mountains. The slope of some of these fans is relatively steep and indicates that they were built by torrential streams descending from steep and high mountains. The apexes of some of the fans are several hundred feet, perhaps as much as 1,000 feet, above the axis of the valley.

Some of the fans, especially those south of Ely, have been considerably eroded. This erosion is attributed by Spencer[3] to periods of greater precipitation, which he correlates with the periods of high water in Lake Bonneville, whereas the building of the fans he correlates with the pre-Lake Bonneville period of aridity.

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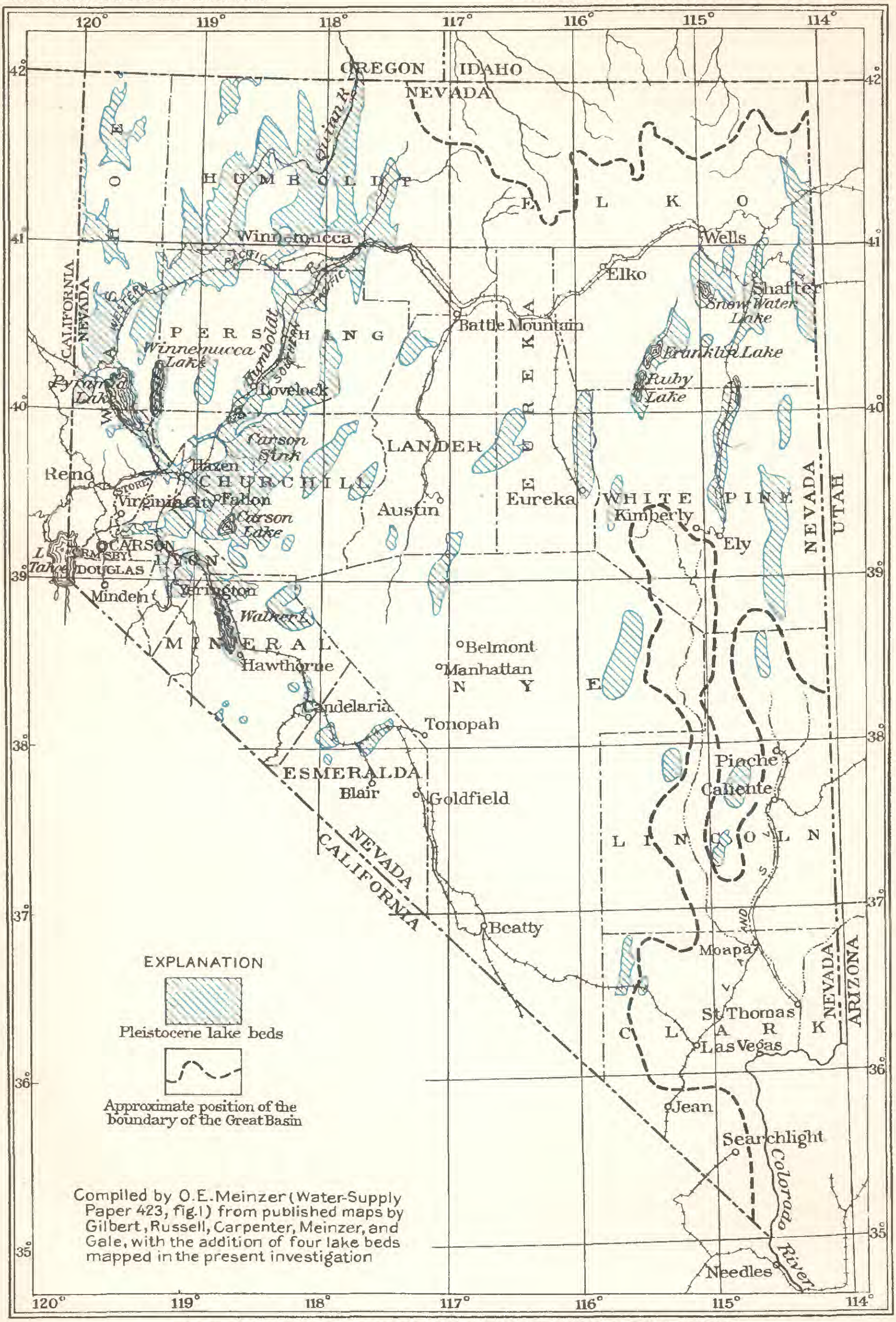
[2] Russell, I. C., Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: U. S. Geol. Survey Mon. 11, pp. 236, 261, 1885.

[3] Spencer, A. C., Geology and ore deposits of Ely, Nev.: U. S. Geol. Survey Prof. Paper 96, pp. 21, 30-33, 1917.



MAP OF NEVADA SHOWING PLEISTOCENE LAKE BEDS

1920

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

These alluvial fans have an important bearing on the ground-water supply of the valley. They are built out from the mouths of canyons where the streams from the mountains debouch into the relatively flat valley. They were built by streams which at times were subject to strong floods and at other times carried little or no water. The materials of which the fans are composed were all brought down from the adjacent highlands and represent the materials that once occupied the position of the present mountain canyons. The high altitude of the mountains, their steep slopes and rugged topography, their large daily range of temperature, which assists in breaking up the rocks, the steep-walled canyons, and the great irregularity of stream flow all tend toward the formation of large fans.

Streams that are building alluvial fans are continually shifting their channels over the surfaces of the fans. In times of flood the coarse materials are carried far from the mouths of the canyons and are deposited in the stream channels and finer sediments are deposited over the general surfaces of the fans by overflow waters. The gravels deposited in the channels tend to clog the streams and cause the channels to shift. Eventually the gravels become buried beneath later deposits.

The fans extend out from the mouths of the canyons because there the gradients of the streams become abruptly less, and hence their velocity is checked and a large part of their load of rock waste must be dropped. The spreading of the water after it leaves the confining canyon and the loss of volume by absorption into the fan cause further deposition of the load. The coarser materials are dropped first, and hence the upper parts of the fans, near the canyon mouths, are usually composed almost wholly of coarse materials. In times of very heavy floods coarse materials may be carried or rolled along the stream channels for long distances, and hence considerable gravel is found well out toward the margins of the fans. At times of low water fine materials may be deposited at or near the apex of a fan. At such times the whole stream may be absorbed before it reaches the lower part of the fan, and the whole load of both fine and coarse material is necessarily deposited, with a resulting tendency to choke up the channel. A stream that is building an alluvial fan repeatedly shifts its position and forms innumerable channels, each channel being in its turn abandoned and buried beneath later deposits. The mouth of the canyon is fixed and represents the pivot about which the stream may swing in its migrations over its alluvial fan. Hence, all old buried channels are connected at this point somewhat as the rays of a fan converge at its hinge. However, these old channels do not remain single and undivided as the rays of an ordinary fan, but divide and subdivide on their way to the margin of the alluvial fan. In most of these channels gravel was deposited at some time, and therefore if the whole underground system could be brought to view numerous gravel trains of different size and thickness would be seen. In the course of the upbuilding of the fan the channel is shifted so often that there may literally be thousands of these buried gravel trains, all more or less directly connected with the gravel core at the apex of the fan and hence forming conduits of relatively easy movement for the ground water. Wells sunk in alluvial fans derive the large quantities of water which they generally supply from these buried gravel trains.

Relation to ancient lake beds.—Some of the alluvial fans of Steptoe Valley may not be altogether normal in their development. From the meager well records available and from topographic evidence it is believed that the ancient lake in the northern part of the valley extended far south during a considerable period of its existence. The log of test well No. 2, in sec. 12, T. 19 N., R. 63 E., near the margin of the Duck Creek fan (Pl. V), shows an abundance of coarse alluvium from the surface to about 125 feet. Below this depth the material is mostly clay with a little sand and fine gravel and is believed to consist at least in large part of lake deposits. There is said to be no gravel in the 185-foot well at the Steptoe ranch, in sec. 11, T. 19 N., R. 63 E.

The data at hand do not warrant definite conclusions as to the sequence of geologic events that produced these deposits, although the matter is of great practical importance in determining the supply of ground water and in locating wells and forecasting the depths of wells to be sunk. The following tentative explanation is offered: The time of maximum growth of alluvial fans was during the pre-Lake Bonneville period of desiccation.[4] At this time the fans were steeper than they are at present and they did not extend as far out into the valley as they do now. Steptoe Valley was an area of closed drainage. The divide between it and Gosiute Valley was near Currie and was probably not more than 50 feet above the present floor of the valley, as is indicated by the depth of the small canyon which leads from Steptoe Valley into Gosiute Valley. According to this theory, during the first Lake Bonneville stage a lake was formed in Steptoe Valley that extended at least as far south as McGill and possibly much farther. This lake formed the old beach shown in Plate II and later rose until it found an outlet into the ancient lake of Gosiute Valley through a stream that flowed over the bedrock near Currie. This outlet was cut down until the lake was drained or much diminished in size, perhaps by the end of the first Lake Bonneville

[4] Spencer, A. C., op. cit., pp. 21, 30–33.

stage. During this first high-water stage there was a very rapid accumulation of sediments in the lake, due not only to the large amount of waste derived from the mountains but also to the erosion of the large and steep alluvial fans. During the inter-Lake Bonneville stage there may have been some steepening of the alluvial fans, but if so it has, according to Spencer,[5] been completely obliterated. During the second Lake Bonneville stage, as in the first, the increased humidity caused large amounts of débris to be brought down from the mountains and also caused the streams again to attack their fans. However, as the outlet to Steptoe Valley had been lowered by erosion in the first stage this valley did not contain any large lake during the second stage. The materials eroded from the mountains and from the upper parts of the fans were carried farther out into the valley and were spread over the lake deposits of the first Lake Bonneville stage. Therefore the outer parts of the present fans must be younger than the upper parts, which are nearer the mountains, and the alluvial deposits of the second Lake Bonneville stage rest upon the lake beds of the first Lake Bonneville stage.

This interpretation is at least not at variance with the general history of the region and will explain the presence of the veneer of alluvium over the fine-grained deposits in Geological Survey well No. 2. The great thickness of the fine-grained deposits is, however, somewhat difficult to explain on this theory. These deposits may also be of Tertiary age, as fine-grained Tertiary sedimentary beds are exposed in many places in Nevada.

SOILS.

The soils of Steptoe Valley may be divided on the basis of texture into gravelly, sandy, and clayey soils, and on the basis of chemical composition into alkali and nonalkali soils. The texture of the soils is due chiefly to the mechanical sorting of the sediments at the time they were deposited by water or wind. The presence of large amounts of alkali salts is due to the concentration of these salts by evaporation of surface or ground waters. Alkali soils are almost never found where the drainage is good. In the table on page 25 are given the analyses with respect to the alkali or water-soluble contents of soils at 14 points in the valley. The soil samples were collected by Mr. Riddell and were analyzed by the Bureau of Soils of the United States Department of Agriculture. The points where most of the samples were taken are shown on the map (fig. 1).

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[5] Spencer, A. C., op. cit., p. 31.

The gravelly soils are found chiefly on the lower slopes of the mountains and on the upper parts of the alluvial fans. Their extension into the valley is dependent upon the streams that built the fans. They blend into the sandy and loamy soils which are found in the middle and lower parts of the alluvial fans. Analyses 13 and 14 (p. 25) represent sandy loam and indicate that there is not much alkali in soil of this type. Most of the land that will be reclaimed in the valley is probably in the areas of sandy loam. The soils of the lower parts of the valley, along its axis, are composed largely of clay and fine silt that have been deposited by quiet water or water that

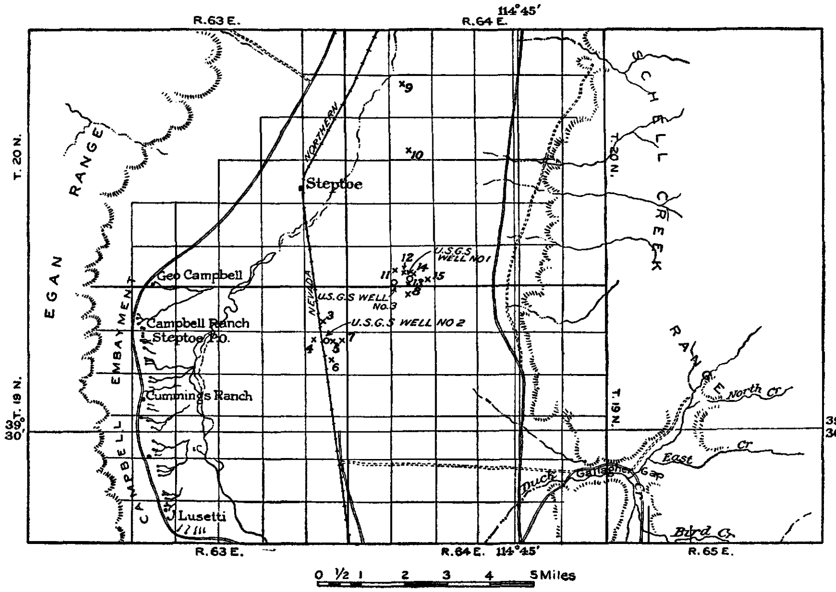


Figure 1.—Map of the area in which test wells were drilled by the United States Geological Survey, showing points at which samples of soil were taken.

had only slight current. On account of their large content of true clay these soils have a tendency to bake when they become dry. Where these soils are found the water table is as a rule only a short distance below the surface, and hence alkali salts have been accumulated by evaporation of the ground water. Analyses 3a, 3b, 4a, and 4b (p. 25) represent soils of this type. It is noticeable, however, that there is less alkali in the soils of the axis of Steptoe Valley than is generally found in soils in similar areas in the waste-filled valleys of the Great Basin. This difference is probably due to the draining of the ancient lake, whereby the soluble salts were largely carried out of Steptoe Valley.

Analyses of soils in Steptoe Valley.

[Analyses by U. S. Bureau of Soils. Water-soluble portion of soil; constituents in percentages of total soil.]

No. on fig. 1.	Location.				Depth of soil samples.	Dominant vegetation.	Total soluble salts.[a]	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3)	Chloride radicle (Cl).	Sulphate radicle (SO_4).
	Township north.	Range east.	Section.	Part of section.							
					Inches.						
1a	16	63	1	W. ½	0–8	Sagebrush	0.11	0.0	0.101	0.066	0.023
1b	16	63	1	W. ½	8–30	do	.16	.0	.08	.006	.023
2a	16	63	14	E. ½	0–8		.59	.006	.125	.104	.223
2b	16	63	14	E. ½	8–30		.41	.076	.113	.020	.064
3a	19	63	1?		0–8	Rabbit brush	1.15	.006	.178	.215	.731
3b	19	63	1?		8–30	do	.75	.046	.131	.09	.196
4a	19	63	12		0–8	Shadscale and greasewood.	.378	.004	.24	.04	.088
4b	19	63	12		8–30	do	.42	.006	.311	.048	.053
5a	19	63	12	NE. ¼	0–8	Rabbit brush	.28	.035	.149	.021	.031
5b	19	63	12	NE. ¼	8–30	do	.90	.111	.077	.173	.175
6	19	63	12		0–8	Greasewood	.17	.011	.109	.014	.025
7a	19	63	12		0–8	Rabbit brush	.36	.093	.053	.006	.028
7b	19	63	12		8–30	do	.54	.099	.101	.048	.186
8a	19	64	5	NW. ¼	0–8	Shad-scale	.12	.0	.097	.006	.024
8b	19	64	5	NW. ¼	8–18	do	.15	.011	.109	.006	.018
9a	20	64	8		0–10		.28	.023	.155	.034	.028
9b	20	64	8		10–30		.12	.0	.125	.006	.018
10a	20	64	17	S. ½	([b])	Rabbit brush	.63	.023	.125	.215	.147
10b	20	64	17	S. ½	10–24	do	.41	.07	.08	.09	.025
11	20	64	32	SW. ¼	0–8		.24	.023	.143	.014	.033
12	20	64	32	SE. ¼	10–16	Greasewood and shadscale.	.28	.006	.101	.055	.057
13	20	64	32	SW. ¼	0–6	Sagebrush	.17	.0	.131	.006	.031
14	20	64	32	S. ½	10–16	do	.41	.111	.041	.021	.028
15	20	64	32	SE. ¼	0–6	Greasewood and shadscale.	.12	.0	.097	.006	.035

[a] Determinations made with electrolytic bridge. [b] Top soil.

CLIMATE.

TEMPERATURE.

The climate of Steptoe Valley is healthful and invigorating. Here, as in other high desert valleys, the daily range of temperature is rather large and the growing season is short. The mean annual temperature at Ely is near the average for the entire State. There are, however, considerable differences in temperature within the drainage basin of Steptoe Valley. The mountains tributary to the valley reach an altitude of more than 11,000 feet above sea level, and occasionally snow remains on the protected slopes of the highest parts nearly all summer. The first snows of the autumn generally appear on the mountains during September, and some of this snow generally remains until late in the following July. Killing frosts have been known to occur in every month of the year, but as a rule the last killing frost of spring occurs during the last half of May, or the first half of June, and the first killing frost in the autumn occurs in the first half of September. Observations made at Ely and McGill indicate that the mean annual temperature at these points is 48° F. The mean temperature for the month of January is about 24°, and the lowest temperature on record in this month is −16°. The mean temperature for July is about 66°, and the highest temperature on record in this month is 94°. According to records obtained in 1917 and 1918, the prevailing winds are from the south.

Latest and earliest frosts at McGill, Nev., according to records of United States Weather Bureau.

[Altitude, 6,338 feet.]

Year.	Last killing frost in spring.	First killing frost in autumn.	Growing season.	Year.	Last killing frost in spring.	First killing frost in autumn.	Growing season.
			Days.				*Days.*
1888	June 21[a]	....	....	1904	May 25	Sept. 26	123
1889	May 18[a]	Sept. 14[a]	118	1906	....	Sept. 16	....
1890	June 29[a]	Sept. 6[a]	68	1907	June 16[a]	....	....
1891	July 12[a]	Aug. 8[a]	26	1908	June 23	Sept. 25	93
1892	June 14[a]	Aug. 29[a]	75	1909	June 10	Sept. 12	93
1893	July 11	Sept. 11	61	1910	May 23	Sept. 7	106
1894	June 21	Sept. 12	82	1912	June 16	Aug. 30	74
1895	June 17	Aug. 27[a]	70	1913	May 14[a]	Sept. 21	128
1896	May 19	Sept. 26	129	1914	June 6[a]	Sept. 13[a]	98
1897	June 28	Sept. 4	67	1915	May 5[a]	Sept. 14[a]	131
1898	June 4	Sept. 28	115	1916	June 22[a]	Sept. 10[a]	80
1899	May 30	Sept. 9	101	1917	June 1	Sept. 25	116
1900	May 17	...do...	114	1918	May 31[a]	Sept. 24[a]	116
1901	May 27	Sept. 23	118	Average growing season	....	....	98
1902	May 13	Sept. 25	134				
1903	May 28	Sept. 9	103				

[a] Represents last day in spring or first day in autumn with temperature 32° or lower, no killing frost being reported.

PRECIPITATION.

The precipitation is considerably greater in the mountains bordering Steptoe Valley than it is in the valley itself. Apparently the precipitation in the valley differs from place to place on account of the influence of local topographic features. During the time field work was in progress—a period of about 1 year, 1917–18—it appeared that showers occurred more frequently at some places than at others, but the observations were too few to warrant definite conclusions. The available records of precipitation are given in the following table:

Precipitation in inches in Steptoe Valley, Nev.

Ely (altitude 6,421 feet).

[Records of United States Weather Bureau.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1888	......	1.46	2.08	0.69	0.37	0.16	1.13	0.47	0.92	......	0.90	......	......
1889	1.01	.64	.94	.57	1.39	.23	0	2.11	.50	.95	.50	4.70	13.54
1890	1.39	.85	.90	.90	.70	0	Tr.	1.26	.18	.37	0	.61	7.16
1891	.65	1.34	1.30	2.47	3.96	2.07	.74	.75	2.03	.10	.30	2.30	18.01
1892	.60	.52	2.90	......	1.10	.68	.13	.03	0	.06	.54	.13	......
1893	1.30	.60	2.60	1.50	.58	0	.30	.85	Tr.	0	.35	1.06	9.14
1894	.65	2.50	4.30	.70	.80	.11	1.65	1.15	1.65	.05	0	3.15	16.71
1895	2.10	2.40	1.65	1.85	2.65	.25	.27	.65	.35	.80	1.60	.20	14.77
1896	.65	.20	1.00	2.25	3.55	Tr.	.79	1.05	.30	.70	1.10	.23	11.82
1897	1.20	3.75	2.65	.75	1.35	.15	.80	.55	.04	2.86	1.85	1.25	17.20
1898	1.40	.20	2.01	1.15	3.50	.50	.50	2.85	.15	.20	1.90	1.05	15.06
1899	2.05	.80	1.90	.50	1.95	.95	.61	1.50	.16	2.08	.50	1.35	14.35
1900	.20	.18	.43	5.52	.18	.01	1.15	.05	1.35	.79	.61	Tr.	10.47
1901	1.10	1.40	.60	1.20	.85	.36	.36	2.44	.50	1.53	.45	.72	11.51
1902	.91	.65	2.25	1.00	.39	.03	.31	.26	.86	.43	2.40	1.42	10.91
1903	.75	.40	.10	1.16	2.18	.18	Tr.	.18	1.10	.55	.36	......	......
1904	.50	1.99	1.13	.81	2.23	.15	.29	2.53	.02	......	......	......	......
1906	......	......	......	......	......	......	......	3.00	.73	.12	1.02	1.00	......
1908	.67	1.15	.23	Tr.	1.11	.68	.90	.99	1.08	.16	.28	.20	7.45
1909	2.03	.77	.89	.25	.89	Tr.	.16	2.43	2.46	.20	1.20	1.87	13.15
1910	1.36	.78	.13	.30	0	0	.94	.97	.83	.69	0	.62	6.99
1911	1.53	2.12	1.45	......	......	......	......	0	......	......	......	......	......
1912	.25	.11	1.96	.48	.11	.22	.72	.15	......	......	......	......	......
Average	1.06	1.12	1.52	1.27	1.49	.32	.56	1.14	.67	.66	.76	1.21	11.78

McGill (altitude 6,338 feet).

[Records of Nevada Consolidated Copper Co. and United States Weather Bureau.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1908	......	......	......	......	......	......	......	......	......	0.39	0.33	0.075	......
1909	1.48	0.60	0.67	0.55	0.83	None.	0.38	1.76	0.86	.36	1.19	.93	9.61
1910	.46	.70	.14	.06	.08	None.	1.30	.54	1.38	.76	.20	.25	5.87
1911	.45	1.32	2.19	.22	.60	1.25	.82	None.	1.54	.04	.05	.60	9.08
1912	.30	.50	2.81	1.06	.28	.29	.715	.15	.14	1.38	.57	.10	8.29
1913	.69	.70	.25	1.19	.78	1.48	2.80	1.07	.20	.65	1.01	.87	11.19
1914	2.14	.36	.08	1.48	.37	3.08	.72	.09	.08	.05	Tr.	.19	8.64
1915	.36	1.01	.18	1.63	2.75	.20	.07	.22	.17	Tr.	.24	.61	7.44
1916	4.61	.69	1.13	.19	.64	.29	.18	.34	.08	2.14	.40	1.67	12.36
1917	.43	.60	.53	1.42	3.22	.07	.32	1.20	.35	0	.25	Tr.	8.39
1918	.86	2.13	1.04	.96	2.49	3.25	.95	.18	1.15	1.36	.94	.90	16.21
Average	1.18	.86	.90	.88	1.20	.99	.78	.56	.59	.65	.48	.69	9.76

Cherry Creek (altitude 6,450 feet).

[Records of United States Weather Bureau.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1888	......	......	0.46	0.77	0.21	0.21	0.32	0.04	......	0.87	......	......	......
1908	......	......	......	.09	2.26	1.09	.53	1.29	......	.77	0	0	......
1909	1.84	1.39	.97	.57	.73	.09	.57	1.53	0.99	.79	2.69	2.11	14.27
1910	.51	.41	.11	.05	.07	.07	.46	.20	.72	.53	.30	1.03	4.46
1911	1.72	.86	1.29	.66	.38	2.17	.61	0	1.51	.20	.58	.39	10.37
1912	.37	.14	2.53	1.28	.60	.04	1.16	.61	.42	2.52	.40	.33	10.40
1913	.25	1.02	.45	1.16	1.66	2.92	2.10	1.33	.52	.51	.70	.54	13.16
1914	3.23	.85	.31	2.54	1.16	2.31	1.26	.77	.47	.39	.04	.31	13.64
1915	.49	1.03	.48	1.45	1.72	.65	.12	.06	.49	Tr.	.20	.68	7.37
1916	3.55	.57	1.89	1.07	.89	.14	.18	.30	.21	2.51	.42	.92	12.65
1917	.10	.47	.03	.26	1.74	0	.84	......	......	......	......	......	......
Average	1.34	.75	.85	.90	1.04	.88	.74	.61	.67	.91	.59	.70	9.98

The average annual precipitation at Ely, according to a record covering 16 years, is 11.72 inches. The average at McGill, according to a record covering 10 years, is 9.76 inches. The average at Cherry

Creek, according to the records given in the above table, is about 10 inches, but this record contains complete data for only eight years, including two years in which the precipitation was considerably below the normal at McGill and hence was probably also below normal at Cherry Creek.

The average annual precipitation is doubtless considerably greater in the mountain areas than at Ely, McGill, and Cherry Creek, where observations have been made. The average precipitation at 17 points at various altitudes in eastern Nevada is shown in the table on page 29, and the same data are shown graphically in figure 2.

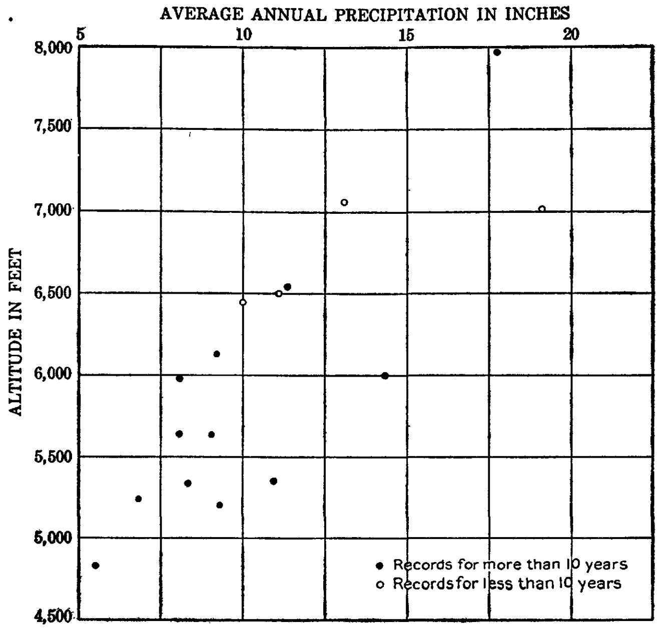


FIGURE 2.—Diagram showing relation of precipitation to altitude in eastern Nevada. Based on records of United States Weather Bureau given in table on p. 29.

It is believed that the average altitude of the 900 square miles of mountain area of the catchment basin of Steptoe Valley is about 7,500 feet above sea level. A comparison of the records of precipitation at points in eastern Nevada of different altitudes (see fig. 2) indicates that the annual precipitation on this area averages about 17 inches. If 10 inches is considered to be the average annual precipitation on the 900 square miles of the valley area, and 17 inches the average annual precipitation on the 900 square miles of mountain area, the average amount of water annually received by the entire drainage basin would be about 1,300,000 acre-feet. This water is dissipated in various ways—some is evaporated directly into the atmosphere, some is lost by transpiration of plants, some flows as surface water to the lowest parts of the valley, where it evaporates, and some sinks into the soil and joins the ground water, most of which eventually returns to the surface in the lowest parts of the valley and is there evaporated or returned to the atmosphere through the native plants.

Average annual precipitation at various altitudes in eastern Nevada, according to records of United States Weather Bureau.

Station.	County.	Altitude above sea level.	Period of record.	Length of record.	Average annual precipitation.
		Feet.		*Years.*	*Inches.*
Corlin	Elko	5,232	1870–1915	45	6.89
Cherry Creek	White Pine	6,450	1908–1915	7	10.00
Clover Valley	Elko	6,000	1894–1915	21	14.39
Cranes Ranch	do	5,350	1888–1906	18	10.98
Elko	do	5,342	1870–1915	45	8.40
Fenelon	do	6,128	1888–1907	19	9.23
Halleck	do	5,631	1870–1915	45	8.08
Hamilton	do	7,977	1877–1909	32	17.85
Hylton	do	7,081	1910–1915	6	13.02
McGill	White Pine	6,338	1888–1915	27	11.39
North Fork	Elko	6,500	1910–1915	6	11.08
Oceola	White Pine	6,500	1894–1898	4	11.09
San Jacinto	Elko	5,200	1904–1915	11	9.29
Stofiel	do	7,000	1891–1896	5	19.04
Tecoma	do	4,812	1877–1915	38	5.50
Toano	do	5,975	1870–1915	45	8.16
Wells	do	5,628	1870–1915	45	9.09

SURFACE STREAMS.

DUCK CREEK.

Duck Creek valley is bordered on the east by the Schell Creek Range proper and on the west by the Duck Creek Range. The creek debouches into Steptoe Valley through a narrow gap in the Duck Creek Range known as Gallagher Gap. Its drainage area includes the highest peaks in the drainage basin of Steptoe Valley. These peaks range from 9,000 to 11,600 feet above sea level. The floor of Gallagher Gap is underlain by fine unconsolidated material, which doubtless transmits some ground water by underflow into Steptoe Valley. Duck Creek valley has a northward trend and a length of about 20 miles and a width of about 4 miles at its widest part. The creek derives nearly all its water from tributaries which head in the mountains to the east. In general almost the entire flow of Duck Creek is used by the Nevada Consolidated Copper Co. at its smelter and mill at McGill. A reservoir has been constructed in sec. 6, T. 18 N., R. 65 E., in which the flow of the creek is impounded. From the reservoir the water is conveyed by a pipe 32 inches in diameter to McGill, a distance of 46,000 feet. An attempt has also been made to recover the ground water that passes through the alluvium of Duck Creek valley at a depth of about 40 feet. Just below the reservoir a tunnel was driven through the unconsolidated materials of the valley fill a distance of 1,150 feet. Drill holes were sunk through the floor of the tunnel, and one of them reached a depth of 1,130 feet, where it is reported to have encountered bedrock. The water which accumulates in the tunnel by infiltration or by rising in the wells is lifted into the reservoir by a hydraulic elevator operated by water from Bird Creek, a tributary of Duck Creek. About 2 second-feet of ground water is recovered in this manner.

To prevent loss by absorption on the upper parts of the alluvial fans of the tributaries of Duck Creek, pipe lines were constructed which convey the waters of the different creeks out of their canyons and across the upper parts of their fans.

The following table shows the record of the average monthly flow of Duck Creek from October 1, 1908, to October 1, 1916, as furnished by James Watson, engineer for the Nevada Consolidated Copper Co. at McGill. According to this table the average flow of Duck Creek is 15.98 second-feet, including the flow from the infiltration tunnel but not including the heavy flood run-off, nor about 0.8 second-foot that flows in Duck Creek below the reservoir. The measurements were made at the end of the pipe line at McGill, and as the pipe will not carry the flood water there is no record of flood flow. The area contributing this flow is given by Duncan[6] as approximately 85 square miles, of which about 23 square miles lies in Duck Creek valley, the direct run-off from which (exclusive of heavy flood run-off) is certainly much less than the amount of mountain water that it absorbs. If 15.98 second-feet is taken as the run-off of the 62 square miles of mountain area then 0.258 second-foot per square mile is the run-off from this mountain area.

An analysis of the water of Duck Creek is included in the table on page 43.

Average monthly flow, in second-feet, through Gallagher Gap pipe line, Oct. 1, 1908, to Oct. 1, 1916.

[Records of Nevada Consolidated Copper Co., McGill, Nev.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1908	......	......	......	......	......	......	......	......	......	16.44	14.00	13.00	......
1909	11.09	12.41	13.11	18.19	19.75	22.37	20.00	16.65	16.08	16.27	15.88	12.48	16.19
1910	15.73	15.72	19.56	19.48	21.34	18.91	13.98	12.98	12.92	13.19	13.52	11.67	15.75
1911	11.87	11.40	15.77	16.07	18.97	20.30	16.87	12.78	12.16	12.88	11.50	9.84	14.20
1912	10.46	10.80	11.69	13.83	18.14	21.37	19.40	16.15	14.75	11.55	14.52	10.54	14.43
1913	10.27	9.65	13.45	17.39	18.31	21.09	19.42	18.23	17.98	16.32	15.30	13.26	15.91
1914	11.06	13.48	18.28	18.63	21.38	21.50	21.86	22.00	20.89	20.24	17.08	14.28	18.39
1915	14.46	14.89	15.56	15.51	19.46	21.93	20.95	17.83	16.01	15.59	15.37	13.36	16.62
1916	12.02	13.83	16.19	18.76	21.27	21.43	19.15	14.58	13.36	......	......	......	......

NOTE.—The above records include the 2 second-feet of ground water that is recovered by infiltration tunnel but do not include about 0.8 second-foot which, according to Duncan's paper above cited, flows in Duck Creek below the reservoir.

[6] Duncan, Lindsay, paper read before Nevada section of American Institute of Mining Engineers at Ely, Nev., June 22 and 23, 1917.

STEPTOE CREEK.

Steptoe Creek heads in the Schell Creek Mountains in Tps. 15 and 16 N., R. 65 E., and flows westward to the axis of Steptoe Valley and thence northward along the axis of the valley. In the spring of the year, when snow is melting, it unites with the water of Duck Creek and forms a continuous stream, which enters Gosiute Lake. This condition, however, does not continue as a rule later than April 10. Throughout most of the year its flow does not extend farther north than sec. 12, T. 16 N., R. 63 E. During the summer the water is used for irrigation on a large ranch in secs. 5, 8, and 17, T. 15 N., R. 64 E., where about 900 acres is being farmed, of which 600 acres is in wild hay and 300 acres in alfalfa and grain.

The following measurements of the discharge of Steptoe Creek were made in 1918: On March 27 it measured 12.51 second-feet at the crossing of the Lincoln Highway, in sec. 1, T. 16 N., R. 63 E. At this time the flow was augmented considerably by melting snow in the valley, and there was a continuous stream flowing from the locality where Steptoe Creek reaches the axis of the valley northward to Gosiute Lake. On March 29 it measured 8.78 second-feet at its debouchure from the mountains. On May 23 it measured 10.56 second-feet at its debouchure and 9.66 second-feet at the lower end of its alluvial fan, showing a loss of 0.90 second-foot in a distance of about 3 miles. On June 18 it measured 9.07 second-feet at its debouchure from the mountains and 8.35 second-feet at the lower end of its fan, showing a loss of about 0.72 second-foot. On August 8 it measured 8.56 second-feet at its debouchure. These measurements give an average absorption of 0.81 second-foot in 3 miles, or 0.27 second-foot to the mile. It is believed that absorption at about this rate occurs for 7 miles from the mouth of the canyon. The loss in 7 miles at the rate of 0.27 second-foot to the mile would give a total loss of 1.89 second-feet.

The measured discharge of Duck Creek during the month of May is about 10 per cent of the measured annual discharge. If the discharge of Steptoe Creek in May is 10 per cent of the annual discharge, on the basis of measurements in May, the average annual flow of Steptoe Creek is about 9 second-feet. If the run-off to the square mile from the mountainous part of the drainage basin of Steptoe Creek is the same as that calculated for Duck Creek—that is, 0.258 second-foot—the average annual flow is about 9.25 second-feet.

FIRST CREEK.

First Creek is a small stream that heads in the Schell Creek Range, in secs. 31 and 32, T. 20 N., R. 65 E., and flows westward into Steptoe Valley, where it is completely absorbed by the loose materials that form the upper part of the fan. As this stream has its origin in springs, its flow is fairly regular. The following measurements were made at the mouth of the canyon in 1918: On April 15 the flow was 0.09 second-foot; on June 12 it was 0.18 second-foot; and on August 11 it was 0.12 second-foot. The average of the three measurements is 0.13 second-foot.

SECOND CREEK.

Second Creek heads in several spring areas in the Schell Creek Range, in secs. 19, 20, 29, and 30, T. 20 N., R. 65 E., and flows westward into Steptoe Valley. The water of this stream does not reach the axis of the valley but is completely absorbed by the porous materials of the upper part of its fan, except during the irrigation season, when it is diverted from its channel and used with the water of Third Creek for irrigation. The following measurements of the stream were made in 1918: On April 16, at the mouth of the canyon, 0.35 second-foot and on June 12, at the mouth of the canyon, 0.43 second-foot. On June 12 it was also measured near the lower end of the diversion ditch, after passing over approximately 1¾ miles of its fan. At this point the flow was 0.21 second-foot, showing a loss by absorption of 0.22 second-foot.

THIRD CREEK.

Third Creek heads in the Schell Creek Range, just north of Second Creek, in secs. 17 and 18, T. 20 N., R. 65 E., and flows southwestward into the valley. The flow of this stream, like that of First and Second creeks, is completely absorbed on its fan. The flow of Third Creek on April 16, 1918, was 0.64 second-foot and on June 12 was 1.01 second-feet. The combined flow of Second and Third creeks is used to irrigate approximately 40 acres of land.

FITZHUGH CREEK.

Fitzhugh Creek heads in the Schell Creek Range, in the northwest corner of T. 20 N., R. 65 E., and flows northwestward into Steptoe Valley. In sec. 6, T. 20 N., R. 65 E., the flow of the stream is diverted into a ditch by which it is conveyed into Indian Creek, about 3 miles distant. A considerable part of the water thus diverted is lost by absorption along the ditch. Two measurements were made on May 6, 1918, one in the ditch about half a mile below the point of diversion, which showed a flow of 0.66 second-foot, and the other where the ditch empties into Indian Creek, which showed a flow of 0.30 second-foot, or a loss of 0.36 second-foot. Below the point of diversion several springs occur along the creek, the combined flow of which measures 0.24 second-foot. This water is used for irrigation in sec. 1, T. 20 N., R. 64 E. The absorption from the ditch plus the flow of the springs, which is absorbed when not used for irrigation, gives a total measured absorption of 0.60 second-foot. When not used for irrigation the whole flow is absorbed, which includes the flow of 0.66 second-foot at the heading of the ditch plus the 0.24 second-foot from springs below, or a total of 0.90 second-foot.

INDIAN CREEK.

Indian Creek heads in the Schell Creek Range in a number of springs that issue from a limestone formation near the summit of the range, in sec. 32, T. 21 N., R. 65 E., and flows westward into Steptoe Valley. It has a drainage area of about 7 square miles, but except in time of heavy storms receives but little water in addition to the flow of the springs at its head. The following measurements were made at the mouth of the canyon in 1918: On May 6 the flow was 0.59 second-foot; on June 13 it was 0.88 second-foot; and on July 26 it was 0.32 second-foot. During the summer the water of this stream is used with that of Fitzhugh Creek for irrigation in sec. 28, T. 21 N., R. 64 E. A storage dam has been constructed in sec. 27, to impound the water during the nonirrigating season, but as it is constructed on the porous portion of the fan it is of little use, a large portion of the water impounded being lost by percolation. All the water of this drainage basin that is not used for irrigation is absorbed by the valley fill before reaching the axis of the valley.

MATTIER CREEK.

Mattier Creek heads in a number of springs in the Schell Creek Range and flows westward into Steptoe Valley. On May 6, 1918, near its debouchure from the mountains, it measured 0.47 second-foot, all of which was absorbed on the upper portion of its fan. During the summer the water of this creek is used to irrigate a small orchard and about 45 acres of alfalfa.

SCHELL CREEK.

Schell Creek heads in a thermal spring in Schellbourne Pass, in the Schell Creek Range, in sec. 6, T. 22 N., R. 65 E., and flows westward into Steptoe Valley. On May 21 the flow of the spring was 0.68 second-foot, and on August 10 it was 0.70 second-foot. On this date the temperature of the spring water was 75°. Other springs below added 0.34 second-foot to the flow, giving a total of about 1 second-foot. The water is used during the summer for irrigation at Schellbourne and at a ranch farther down the valley. When not used for irrigation the entire flow of the stream is absorbed before it reaches the axis of the valley.

A laboratory assay of the water of a creek on the west slope of Schellbourne Pass is included in the table on page 44.

GOSIUTE CREEK.

Gosiute Creek heads in Cherry Creek Mountain, in T. 25 N., R. 63 E., and flows eastward into Steptoe Valley, where it has built a large fan. In order to determine the loss by absorption, the following measurements were made, one at the mouth of the canyon and another near the point where the Cherry Creek-Currie wagon road crosses the creek, about 1½ miles downstream from the first station and well out on the fan. On May 23, 1918, the flow was 6.52 second-feet at the upper station and 2.93 second-feet at the lower station, showing a loss of 3.59 second-feet between these two stations. On July 18, 1918, the flow was 5.80 second-feet at the upper station and 2.05 second-feet at the lower station, showing a loss of 3.75 second-feet; on August 8, 1918, the flow was 2.07 second-feet at the upper station and 0.88 second-foot at the lower station, showing a loss of 1.19 second-feet. The percentage of loss was nearly constant and was only about 2 per cent higher for the lowest flow than for the highest flow measured.

EGAN CREEK.

Egan Creek heads in several springs on the west side of Telegraph Mountain in the Egan Range. It flows northward and eventually sinks into the valley fill of Egan Valley, but its water reappears in a spring area at the lower end of the valley, where the streamway enters Egan Canyon. On May 22 the flow of this spring area measured 0.77 second-foot. To this flow is added the flow from the North Mountain tunnel, which on the same date was 1.38 second-feet, making a total of 2.15 second-feet. The water of this creek is used to irrigate approximately 75 acres of alfalfa in secs. 18 and 19, T. 23 N., R. 63 E., but about 50 per cent of the water is lost by absorption before it reaches the farm. The flow of the stream was measured again on August 7 and found to be as follows: Above the mouth of the North Mountain tunnel it measured 0.83 second-foot, and the flow from the tunnel measured 1.56 second-feet, giving a total of 2.39 second-feet.

The drainage area of Egan Creek is about 65 square miles, but most of the mountain area is not high. The canyon that leads into Steptoe Valley has an alluvial floor, and it is probable that some of the water from this catchment basin passes through the canyon as ground water and is thus added directly to the ground water of Steptoe Valley.

MURRY CREEK.

Murry Creek drains the northeastern portion of Ward Mountain which lies south and west of Ely. The perennial portion of the stream has its source in a number of springs about 1½ miles above Ely. The flow of the springs is conveyed by a pipe line to a reservoir from which the towns of Ely and East Ely are supplied. The flow from these springs, as measured at the intake of the pipe line on March 1, 1918, was 8.53 second-feet. On June 18 it was 12.06 second-feet. The following measurements were made at the wagon-road bridge in central Ely in 1918: On April 2, 3.29 second-feet; on May 18, 4.84 second-feet.

WILLOW CREEK.

Willow Creek heads in a large spring at the foot of Ward Mountain, in sec. 35, T. 14 N., R. 63 E., and flows eastward, reaching the axis of the valley in sec. 32, T. 14 N., R. 64 E. Thence its water is conveyed by a ditch to sec. 28, T. 15 N., R. 64 E., where it is used for irrigation. About 60 per cent of the water of this stream is lost before it reaches the point of utilization. The following measurements were made in 1918: On May 24, 1.55 second-feet; on August 16, 1.13 second-feet. (See Pl. II.) The absorption along the channel of Willow Creek where it crosses its fan is small, owing to the fact that its water carries a large amount of lime in solution, some of which is deposited along its channel, which is thus made relatively impervious. An analysis of the water of North Fork of Willow Creek is included in the table on page 43.

SMALLER STREAMS AND SPRINGS.

A number of streams and springs of small flow in the aggregate add materially to the ground-water supply of the valley. These streams lose all their water, chiefly by absorption, after flowing short distances over their fans. During the month of July, 1918, 18 of these streams were measured and showed an aggregate flow of 5.5 second-feet.

Measurements of the flow of miscellaneous small springs.

	Second-feet.
Spring on north side of Gallagher Gap	0.20
Spring in sec. 31, T. 22 N., R. 65 E	.15
Spring in sec. 30, T. 22 N., R. 65 E	.51
Chicken Springs Nos. 1, 2, and 3	.13
Spring in Star mine tunnel	.24
Spring in Water Canyon	.46
Springs on Heizer Mountains	.47
Spring in Hercules Gap	.17
Springs Nos. 1, 2, and 3 south of Willow Creek	.54
Green Spring	.94
Lyon Spring	.20
Green No. 2 or Sage Hen Spring	.34
Cowcamp Spring	.38
Horse Corral Spring	.48
Connors Spring	.05
Spring west of Hercules Valley	.07
Spring south of Petrenies's place	.01
Frenchman Spring	.21
Total flow	5.55

GROUND WATER.

OCCURRENCE.

The ground water, with which this report is chiefly concerned, occurs for the most part in the unconsolidated valley fill, through which it moves slowly from the intake areas to the lower parts of the valley, where the water table reaches the surface, or nearly so, and here the water escapes into the atmosphere by evaporation and transpiration. The rate of flow underground depends on the character of the materials through which the water passes, on the gradient of the water table, and on the temperature of the water. In general, the finer the materials the slower the rate of flow and the steeper the gradient of the water table, and the higher the temperature of the water the more rapid the flow. Gravel and sand are the materials through which the water moves most rapidly and with least resistance, and consequently these are the materials that give up their water most readily when tapped by wells. It is chiefly from these materials that water for irrigation can be obtained.

The exploratory drilling that was done in connection with this investigation demonstrated the existence in the valley fill of beds of gravel that will yield large supplies of water, such as are required for practical irrigation. These beds belong to the alluvial deposits that comprise the upper part of the valley fill. In the vicinity in which test wells Nos. 1 and 3 were drilled (see Pl. II, in pocket) a series of six water-bearing horizons occur within about 125 feet of the surface. (See p. 50.) There is reason to believe that satisfactory water-bearing beds will be found in other parts of the valley, but as the character and succession of the deposits change from place to place further drilling will doubtless show that in some localities strong wells can not be obtained.

The Geological Survey well No. 2 (see Pl. II) was sunk to a depth of 915 feet to determine whether valuable water-bearing beds occur below the productive beds that were discovered in wells Nos. 1 and 3. Below the depth of 124 feet, however, the deposits are prevailingly clayey, with few beds of material coarse enough to yield much water. (See p. 53.) These deposits are believed to have been laid down in the quiet waters of an ancient lake. As explained on pages 22–23, there is some reason to believe that they may be underlain by alluvial deposits somewhat like those near the surface, which yield the large supplies of water. As the deposits penetrated in this well are sufficiently impervious to form effective confining beds, and as the water from the deeper strata in this well rose to a level less than 5 feet below the surface, it is not improbable that artesian flows would be obtained if the drilling were carried deep enough. It would have been desirable to sink well No. 2 to a depth of 1,500 or 2,000 feet.

The available drilling equipment was not adequate to do this, but the well has been left in such a condition that it can be carried deeper at any time. It is, however, not probable that deeper drilling will reveal any water supplies of as much practical value as those which were discovered nearer the surface in the exploratory drilling that has been done.

SOURCE.

Contributions from tributary mountain areas.—The main source of the water in the valley fill is the precipitation in the mountain areas that drain into the valley. Records of precipitation and of stream flow and seepage losses are given on pages 26–35. The floors of all except the smallest canyons are underlain by unconsolidated materials, which extend far up into the mountains. In the canyons that contain perennial streams there is doubtless considerable underflow through this material, which joins the ground water of the valley without appearing at the surface. In the canyons that do not contain perennial streams more or less water doubtless also percolates through the unconsolidated fill and is added to the ground water of the valley without appearing at the surface. The presence of this water is illustrated by the well at Keystone, in Robinson Canyon (well No. 3, Pl. II, in pocket; table on p. 65), where water was found on top of the bedrock.

Contributions from precipitation in the valley.—Owing to the light precipitation in the valley, the relatively high rate of evaporation, the dryness of the surface, and the relatively low permeability of the alluvium near the surface in the interstream areas, probably not more than 5 per cent of the precipitation in the valley is added to the ground-water supply.

Possible contributions by thermal springs to the supply in the valley fill.—There are several groups of thermal springs in Steptoe Valley, most of which issue from the alluvium at some distance from the borders of the valley. Some of these springs are near the middle of the valley, as, for example, the Collar and Elbow Spring, and some have large yields. The two groups that have the largest yield are those at the town of McGill, on the east side of the valley, and those in the Campbell embayment, about 10 miles northwest of McGill, on the west side of the valley. The springs that have the highest temperature are the Melvin Hot Springs, about a mile northwest of Warm Springs station, on the west side of the valley. The yield of the springs at McGill is large, and the one that contributes most of the water has a flow of 10 second-feet and a temperature of 78°.

The yield of the springs in the Campbell embayment is also large. Two of the best producing groups have a combined measured yield of 2.73 second-feet and a temperature of 76°. Perhaps a third of the water discharged by these two groups of springs did not pass the point of measurement and is therefore not represented in the 2.73 second-feet. Melvin Hot Springs have a yield of about 1.39 second-feet and a maximum measured temperature of 189°. It is evident that water of such high temperature must come from some deeper source than the valley fill. However, all the springs mentioned, except Collar and Elbow Spring and possibly Melvin Hot Springs, issue through coarse alluvium. The thickness of this alluvium is not known but is believed to be considerable.

On its way up from some deep source through the alluvium a part of the water doubtless passes out laterally and is thus added to the supply of water in the valley fill. It is also possible that rising thermal water in other places is thus entirely discharged into the valley fill, none of it reaching the surface. The amount of deep water contributed to the valley fill in this manner is of course not known but may be considerable.

DEPTH TO WATER TABLE.

The depth to the water table ranges from only a few inches in some of the lower parts of the valley to 250 feet or more on the outer edges of the valley. Lack of sufficient data prevents an accurate platting of the depth to the water table throughout the valley, but an attempt has been made to show by lines on Plate II the positions where the water table lies 10, 20, and 50 feet, respectively, below the surface. The data used in platting these lines were obtained by measuring the depth to water in the few existing wells (see table on p. 65) and by mapping the areas occupied by certain species of native plants that are considered fairly reliable indicators of depth to water. To determine the position of the 50-foot line, levels were run in certain places with hand level or with telescopic alidade and stadia, up the slope from points where the depth to the water level was revealed by wells or by vegetation. The 50-foot line should be considered as an approximation only. It is believed to be sufficiently accurate, however, to be of practical value in directing developments and in estimating the total area in the valley that has a depth to the water table of less than 50 feet. The following table has been prepared from the lines as shown on the map:

Estimated areas having specified depths to the water table in Steptoe Valley, Nev.

	Acres.
Depth to water table less than 10 feet	95,000
Depth to water table between 10 and 20 feet	40,000
Depth to water table between 20 and 50 feet	50,000
	185,000

Certain types of native vegetation in desert regions are fairly reliable guides to depth to ground water. The data obtained indicate that in general in Steptoe Valley greasewood (*Sarcobatus vermiculatus*) occupies tracts where the depth to water is between 12 and 20 feet, rabbit brush (*Chrysothamnus graveolens*) tracts where the depth is between 8 and 15 feet, rye grass (*Elymus condensatus*) tracts where the depth is less than 12 feet, and salt grass (*Distichlis spicata*) tracts where the water table is within a few feet of the surface. Depth to water is not the only factor governing the distribution of these plants, but it is perhaps the most important. Texture and alkalinity of soil are also important, but the alkalinity is largely dependent on the depth to water.

DISCHARGE OF GROUND WATER.

Over an area of approximately 75,000 acres in Steptoe Valley the water table stands less than 8 feet below the surface. Throughout most of this area ground water escapes into the atmosphere by evaporation from the soil, as well as by transpiration of plants. The water reaches the surface through the capillary pores of the soil and is also taken up by plant roots and discharged through their leaves into the atmosphere. In addition to this area where ground water is near enough to the surface to be drawn upon by capillarity, there is an area of approximately 40,000 acres covered by plants such as rabbit brush and greasewood, which draw upon ground water and dissipate it into the air.

Ground water also escapes from the alluvium through springs, and some may escape by percolation northward into Gosiute Valley.

No adequate estimate can be made as to the quantity of ground water discharged annually by evaporation from the soil and transpiration of plants. The discharge per acre is certainly much less than the quantity of water required per acre to irrigate useful crops, such as alfalfa, grain, or vegetables, but the total area over which such discharge takes place—probably not less than 115,000 acres—gives some idea of the magnitude of the process.

The pumping of ground water for irrigation on a large scale will lower the water table and will consequently lessen the loss by evaporation and transpiration. As the central portion of the valley where the water table is near the surface is relatively flat a slight lowering of the water table may result in a large decrease in loss by evaporation.

QUANTITY OF GROUND WATER.

The drilling that was done in Steptoe Valley shows that the valley fill is deep. The United States Geological Survey test well No. 2, in sec. 12, T. 19 N., R. 63 E., attained a depth of about 915 feet and did not reach bedrock. A well sunk by the Nevada Consolidated Copper

Co. in Duck Creek valley, in sec. 6, T. 18 N., R. 65 E., reached bedrock at a depth of 1,138 feet. A well sunk by the Nevada Northern Railway Co. on the edge of the valley fill, in sec. 7, T. 16 N., R. 64 E., attained a depth of 275 feet without reaching bedrock. Below the water table the valley fill is saturated with water. Obviously, therefore, this fill comprises a deep subterranean reservoir that contains much water. However, the water stored below certain levels is not of economic importance, as there is a limit to the depth from which it would be profitable to pump water for irrigation and also a limit to the depth to which wells can profitably be sunk. The first limit is one of operating cost but the second is one of initial cost and is largely dependent upon the quantity of water that could be obtained from deep sources and upon the level to which the deep water will rise in wells.

If the upper part of the valley fill is on an average porous enough to yield a quantity of water equal to 10 per cent of its volume, it could supply about 50,000 acre-feet for each foot that the water table was lowered. This stored supply is valuable as a reserve that can be drawn upon in periods of exceptionally dry years, when not much water is absorbed, but the average annual withdrawal during a long period, such as is contemplated in making irrigation developments, can not greatly exceed the average annual recharge. If there is an excess of withdrawal in certain years there must be a compensating excess of recharge in other years.

Measurements were made on practically all the perennial streams that enter Steptoe Valley in order to arrive at an approximation as to the amount of water which they discharge annually into the valley and as to the proportion of this water that seeps into the fill and is added to the ground-water supply. Measurements were made at the mouth of a canyon and as far below it as practicable. Owing to diversions for irrigation or other causes it was generally not feasible to make the lower measurements at the lower limit of absorption. For these streams the amount of absorption per mile was determined, and this factor was then applied to the number of miles along which active absorption was taking place, in order to arrive at the total absorption from the stream. Where more than one set of measurements were made the average was taken. It is recognized that absorption may be somewhat less rapid farther downstream. On the other hand, the flood waters were not measured, and no account was taken of the increased absorption likely to occur when the water of a stream is spread by diversion into ditches. Moreover, possible return waters from irrigated lands were disregarded. However, streams from which diversions are made and which would otherwise be wholly absorbed have a lessened absorption during the irrigation period. Some of these factors tend to increase absorption and some of them tend to decrease it. The precipitation during the first half of 1918, when most of the measurements were made, was somewhat heavier than the average.

Estimated absorption from streams and springs that discharge into Steptoe Valley.

	Second-feet.
Borchert John Spring	1.72
D. E.	.51
Egan Creek	1.75
First Creek	.13
Fitzhugh Creek	.90
Gosiute Creek	4.72
Indian Creek	.60
Indian Farm Spring	.60
Mattier Creek	.47
Murry Creek	4.80
Schell Creek	1.03
Second Creek	.39
South Willow Creek	.08
Steptoe Creek	1.89
Third Creek	.82
White Rock Spring	.24
Willow Creek	.90
Eighteen small springs	5.55
	27.10

On the basis of these measurements the average annual absorption from these streams is estimated at about 20,000 acre-feet. The mountain area drained by perennial streams comprises about 22 per cent of the total mountain area tributary to the valley. Owing to the percolation through the fill in the canyons that do not have perennial streams, these canyons contribute considerable water to the ground-water supply. If they contribute half as much per square mile of the area they drain as the area of perennial streams their contribution amounts to about 35,000 acre-feet a year. The average annual precipitation on the 900 square miles of the valley land is about 10 inches. If 5 per cent of this water finds its way downward to the ground water the contribution from this source is about 24,000 acre-feet.

It is recognized that the above calculations are based on assumptions that are not adequately supported by observed facts and that the chance for error is large. Obviously no great accuracy can be claimed for the results. However, the known facts seem to warrant the statement that the average annual contribution to the supply of ground water in Steptoe Valley is not less than 50,000 acre-feet.

QUALITY OF GROUND WATER.

Thirty-six samples of water from Steptoe Valley and adjacent areas were analyzed or assayed, including 10 samples from the different horizons in the test wells. All the samples from the test wells and nearly all the other waters were found to be of good quality for irrigation. In general, the water of Steptoe Valley was also found to be of good quality for domestic use. The results of all the analyses and assays and their classification for different uses, with the exception of those for the test wells (see pp. 50–58), are given below.

Laboratory assays and classification of water from wells in Steptoe Valley and other places in eastern Nevada.

[Parts per million except as otherwise designated. Assayed by Alfred A. Chambers, C. H. Kidwell, and Margaret D. Foster.]

	1	2	3	4	5
Determined quantities:					
Iron (Fe)	Trace.	1.6	1.2	1.2	1.3
Carbonate radicle (CO_3)	12	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	513	167	134	220	212
Sulphate radicle (SO_4)	26	17	43	22	22
Chloride radicle (Cl)	7.5	12	46	14	22
Total hardness as $CaCO_3$	381	121	129	118	126
Computed quantities: [a]					
Sodium and potassium (Na+K)	49	25	46	53	50
Total dissolved solids	560	240	250	290	300
Scale-forming constituents	430	170	180	170	180
Foaming constituents	130	70	120	140	140
Alkali coefficient (inches) [b]	19	48	40	17	20
Classification: [a]					
Mineral content	High.	Moderate.	Moderate.	Moderate.	Moderate.
Chemical character	$Ca-CO_3$	$Ca-CO_3$	$Ca-CO_3$	$Na-CO_3$	$Na-CO_3$
Probability of corrosion [c]	N	N	(?)	N	N
Quality for boilers	Poor.	Fair.	Fair.	Fair.	Fair.
Quality for domestic use	Poor.	Fair.	Good.	Good.	Good.
Quality for irrigation	Good.	Good.	Good.	Fair.	Good.
Date of collection	July 15, 1918.	Aug. 23, 1917.	Aug. 24, 1917.	Aug. 27, 1917.	Aug. 27, 1917.

[a] See standards for classification by R. B. Dole and Herman Stabler in U. S. Geol. Survey Water-Supply Paper 398, pp. 50–81, 1916.
[b] Depth of water, in inches, which would yield on evaporation sufficient alkali to render a 4-foot depth of soil injurious to the most sensitive crops.
[c] Based on computed quantity; N, noncorrosive; (?), corrosion doubtful.

1. Dug well, 47 feet deep, 4 feet in diameter, of E. B. Young, 18 miles north of McGill, Nev. (No. 25 on Pl. II).
2. Bored well, 102 feet deep, 18 inches in diameter, of T. N. Terry, in the NW. ¼ NW. ¼ sec. 1, T. 32 N., R. 60 E., in Lurline, Nev.
3. Pit well, 12 feet deep, of F. W. Tame, Tobar, Nev.
4. Drilled well, flowing, 200 feet deep, 2 inches in diameter, of George F. Toombs, jr., at Wells, Nev.
5. Humboldt well, open pitlike springs, at Wells, Nev.

Mineral analyses and classification of water from springs and streams in the drainage basin of Steptoe Valley, Nev.

[Parts per million except as otherwise designated. Analyzed by Alfred A. Chambers, C. H. Kidwell, and Margaret D. Foster.]

No.	Date of collection.	Determined quantities.											Computed quantities.[b]				Classification.[b]					
		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).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total dissolved solids at 180° C.	Total hardness as $CaCO_3$	Scale-forming constituents.	Foaming constituents.	Alkali coefficient (inches).[c]	Mineral content.	Chemical character.	Probability of corrosion.[d]	Quality for boiler use.	Quality for domestic use.	Quality for irrigation.
1	1918. May 24	19	0.15	49	19	1.2	0.0	225	13	3.5	Trace.	225	200	200	3	580	Moderate...	Ca-CO_3...	(?)	Fair......	Good..	Good.
2	Apr. 10	37	.22	51	23	19	.0	222	68	7.5	0.67	314	220	230	51	170	.....do.....	Ca-CO_3...	N	Poor......	Fair..	Do.
3	Apr. 6	32	.11	100	41	62	.0	240	308	25	.27	733	418	400	170	52	High.......	Ca-SO_4....	(?)	.....do....	Poor..	Do.
4	...do....	30	.08	34	8.3	18	.0	139	31	7.3	1.9	196	119	140	49	180	Moderate...	Ca-CO_3...	N	Fair......	Good..	Do.
5	Apr. 10	32	.10	54	21	12	.0	267	21	4.3	1.2	266	221	230	32	290	.....do.....	Ca-CO_3...	N	Poor......	Fair..	Do.
6	Apr. 9	32	.05	52	21	15	.0	268	20	4.5	2.1	268	216	220	40	130	.....do.....	Ca-CO_3...	(?)	.....do....	...do..	Do.
7	May 4	28	.07	47	25	12	.0	266	16	5.7	2.9	255	220	210	32	200	.....do.....	Ca-CO_3...	N	.....do....	...do..	Do.
8	Mar. 30	90	2.5	42	.6	20	.0	152	20	4.1	.28	275	108	210	54	66	.....do.....	Ca-CO_3...	(?)	.....do....	...do..	Do.
9	1917. Aug. 21	54	.19	67	21	[e]26	Trace.	324	25	6.6	.09	349	254	290	70	50	.....do.....	Ca-CO_3...	(?)	.....do....	...do..	Do.
10	1918. May 22	32	.18	47	19	4.4	.0	227	13	3.5	.34	231	195	200	12	490	.....do.....	Ca-CO_3...	(?)	Fair......	Good..	Do.
11	1917. Aug. 29	100	.12	13	1.1	[e]162	7.7	375	17	17	.75	518	37	140	440	4.4	High.......	Na-CO_3...	(?)	Very bad.	Fair...	Poor.
12	1918. July 5	22	.17	44	17	7.0	Trace.	197	22	7.2	.29	214	180	180	19	260	Moderate...	Ca-CO_3...	(?)	Fair......	Good..	Do.

[a] Computed.
[b] See standards for classification by R. B. Dole and Herman Stabler in U. S. Geol. Survey Water-Supply Paper 398, pp. 50-81, 1916.
[c] Depth of water, in inches, which would yield on evaporation sufficient alkali to render a 4-foot depth of soil injurious to the most sensitive crops.
[d] Based on computed quantity; N, noncorrosive; (?), corrosion doubtful.
[e] Determined.

1. North Fork of Willow Creek, 18 miles south of Ely, Nev.
2. Ely Warm Spring, in sec. 10, T. 16 N., R. 63 E., on Cherry Creek road, 1½ miles northeast of Ely, Nev. Temperature, 85° F.
3. Duck Creek, in sec. 12, T. 18 N., R. 63 E., 2½ miles northwest of McGill, Nev.
4. Spring No. 1, on Heizer Mountains, in sec. 33, T. 18 N., R. 63 E., 6 miles west of McGill, Nev.
5. Warm Spring, of Nevada Consolidated Copper Co., three-fourths of a mile west of McGill, Nev. Temperature, 84° F.
6. North group of Warm Springs, owned by W. D. Campbell, in the SW. ¼ sec. 5, T. 19 N., R. 63 E., about 6 miles north and west of McGill, Nev.
7. Spring of John Luzzetti, in the NE. ¼ sec. 32, T. 19 N., R. 63 E., 11 miles northwest of McGill, Nev.
8. North Creek, one-fourth mile above junction with East Creek, 200 yards above Steptoe Valley Mine & Smelting Co.'s dam, in sec. 20, T. 19 N., R. 65 E., 12 miles northeast of McGill, Nev.
9. Melvin Hot Springs, 1 mile northwest of Warm Springs, 17 miles north of McGill, Nev.
10. Borchert John Spring (owner, Mr. Borchert), 25 miles northwest of McGill, Nev. Temperature, 66° F.
11. Hot spring of George A. Young, about 1 mile southwest of the town of Cherry Creek, Nev.
12. Spring of Adams & McGill at Conners station, on Ely-Milford road, 27 miles southeast of Ely, Nev.

Laboratory assays and classification of water from springs and one stream in the drainage basin of Steptoe Valley, Nev.

[Parts per million except as otherwise designated. Assayed by Alfred A. Chambers, C. H. Kidwell, and Margaret D. Foster.]

	1	2	3	4	5
Determined quantities:					
Iron (Fe)	Trace.	0.20	Trace.	Trace.	....
Carbonate radicle (CO_3)	8.4	6.2	6.7	12	0.0
Bicarbonate radicle (HCO_3)	365	257	147	323	236
Sulphate radicle (SO_4)	28	21	27	8	26
Chloride radicle (Cl)	18	6.2	9.4	1.0	5.3
Total hardness as $CaCO_3$	255	138	125	241	192
Computed quantities: [a]					
Sodium and potassium (Na+K)	56	60	24	27	18
Total dissolved solids	450	320	240	360	[b] 248
Scale-forming constituents	300	190	180	290	240
Foaming constituents	150	160	60	70	50
Alkali coefficient (inches) [c]	17	13	71	29	130
Classification: [a]					
Mineral content	Moderate.	Moderate.	Moderate.	Moderate.	Moderate.
Chemical character	Ca-CO_3	Na-CO_3	Ca-CO_3	Ca-CO_3	Ca-CO_3
Probability of corrosion [d]	N	N	N	N	(?)
Quality for boiler use	Poor.	Fair.	Fair.	Poor.	Poor.
Quality for domestic use	Fair.	Good.	Good.	Fair.	Good.
Quality for irrigation	Fair.	Fair.	Good.	Good.	Good.
Date of collection	Apr. 6, 1918.	Sept. 6, 1917.	Mar. 30, 1918.	May 21, 1918.	Aug. 12, 1918.

[a] See standards for classification by R. B. Dole and Herman Stabler in U. S. Geol. Survey Water-Supply Paper 398, pp. 50–81, 1916.
[b] Determined at 180° C.
[c] Depth of water, in inches, which would yield on evaporation sufficient alkali to render a 4-foot depth of soil injurious to the most sensitive crops.
[d] Based on computed quantity; N, noncorrosive; (?), corrosion doubtful.

1. Spring in Hercules Gap, in sec. 6, T. 17 N., R. 63 E., 8½ miles west of McGill, Nev.
2. Spring of W. D. Campbell (on west side of valley), 6 miles northwest of McGill, Nev.
3. Warm Spring of Adams & McGill, in sec. 3, T. 18 N., R. 64 E., 2½ miles north of McGill, Nev. Temperature, 76° F.
4. Creek on west slope of Schellbourne Pass, 30 miles north of McGill, Nev.
5. Collar and Elbow Spring, 45 miles north of McGill, Nev. Temperature, 92° F.

Mineral analyses and classification of water from springs in eastern Nevada and western Utah outside of Steptoe Valley, Nev.

[Parts per million except as otherwise designated. Analyzed by Alfred A. Chambers, C. H. Kidwell, and Margaret D. Foster.]

	1	2	3	4
Determined quantities:				
Silica (SiO_2)	24	86	24	29
Iron (Fe)	.13	3.0	.14	.13
Aluminum (Al)	....	6.0	....	....
Calcium (Ca)	35	123	102	41
Magnesium (Mg)	6.3	72	57	20
Sodium and potassium (Na+K)	[a]6.4	849	512	29
Carbonate radicle (CO_3)	.0	6.7	.0	.0
Bicarbonate radicle (HCO_3)	129	305	332	215
Sulphate radicle (SO_4)	8.0	391	376	38
Chloride radicle (Cl)	9.2	1,200	636	12
Nitrate radicle (NO_3)	Trace.	1.7	.52	1.4
Total dissolved solids at 180° C.	158	2,978	1,906	263
Computed quantities: [b]				
Total hardness as $CaCO_3$	113	603	489	184
Scale-forming constituents	140	570	420	180
Foaming constituents	17	2,300	1,400	78
Alkali coefficient (inches) [c]	220	1.7	3.1	75
Classification: [b]				
Mineral content	Moderate.	Very high.	High.	Moderate.
Chemical character	Ca-CO_3	Na-Cl.	Na-Cl.	Ca-CO_3
Probability of corrosion [d]	(?)	C	(?)	(?)
Quality for boiler use	Fair.	Very bad.	Very bad.	Fair.
Quality for domestic use	Good.	Unfit.	Poor.	Good.
Quality for irrigation	Good.	Poor.	Poor.	Good.
Date of collection	July 5, 1918.	Aug. 15, 1917.	Aug. 15, 1917.	Aug. 28, 1917.

[a] Computed.
[b] See standards for classification by R. B. Dole and Herman Stabler in U. S. Geol. Survey Water-Supply Paper 398, pp. 50–81, 1916.
[c] Depth of water, in inches, which would yield on evaporation sufficient alkali to render a 4-foot depth of soil injurious to the most sensitive crops.
[d] Based on computed quantity; C, corrosive; (?), corrosion doubtful.

1. Spring of L. Merriott on Ely-Milford road, at Osceola, Nev.
2. Big Spring between ranch house and hot springs at Fish Springs, Utah.
3. Fish Spring at ranch house at Fish Springs, Utah.
4. Spring at Flowery Lakes, 6 or 8 miles southwest of Shafter, Nev.

SPRINGS.

Steptoe Valley contains a considerable number of springs. For convenience, these springs may be grouped in two classes—thermal and nonthermal. The thermal springs are the most conspicuous and yield the largest quantities of water. Their yields range from small seeps to 10 second-feet and their temperatures from slightly above normal to 174° F. Their temperature indicates that the water comes from considerable depths and is not a part of the ground-water body of the unconsolidated valley fill. The thermal springs, as a rule, are arranged in lines on either side of the valley nearly parallel to the mountain borders. This linear arrangement and parallelism suggests strongly that the springs occur along fault or fracture zones. Spencer[7] regards Steptoe Valley as a fault block which has been depressed relative to the blocks comprising the Egan and Schell Creek mountains. However, he states that these faults are predicated without detailed evidence and largely on the basis of analogy with other similar Great Basin ranges.

[7] Spencer, A. C., U. S. Geol. Survey Prof. Paper 96, p. 43, 1917.

Ely Warm Spring.—The Ely Warm Spring is about a mile and a half northeast of the town of Ely, near the Ely-Cherry Creek road, in sec. 10, T. 16 N., R. 63 E. (See fig. 3.) It is in the valley fill at the foot of the steep slope, near the north end of a seepage area which extends some distance south of the spring. There is no mineral deposit visible at the surface, but in a cut for an irrigation ditch across the seepage area about three-fourths of a mile south of the spring the valley fill is cemented by a material that appears to be a spring deposit. The yield of the spring is only about 0.05 second-foot. Its temperature on April 10, 1918, was 85° F. An analysis of the water is given on page 43.

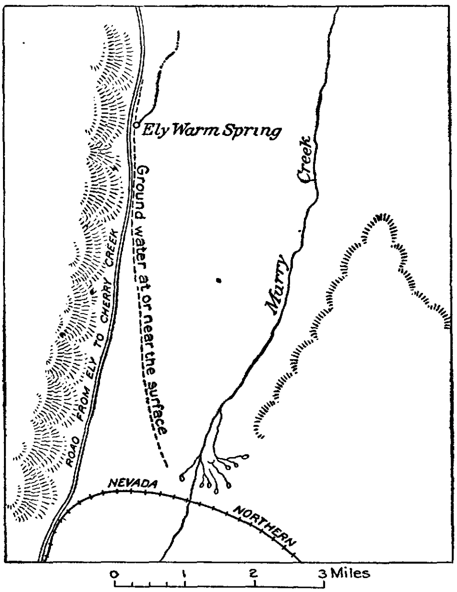


FIGURE 3.—Sketch map of the vicinity of Ely Warm Spring, Steptoe Valley, Nev.

McGill Warm Springs.—The area that contains the McGill Warm Springs begins near the south edge of the town of McGill and extends northward for a distance of about 5 miles nearly parallel to the Duck Creek Mountains. The springs occur at or very near the base of the steeper alluvial slopes. It is reported that a number of springs are now covered by the tailings from the mill and smelter. The springs range from small seeps to the largest thermal spring in Steptoe Valley, which has a discharge of about 10 second-feet. The temperature of this group of springs decreases from south to north, the temperature of the most southerly spring being 84° F., whereas that of the most northerly is 76° and that of the large spring somewhat south of the middle of the group is 78°. An analysis of water from one of these springs is given in the table on page 43 (No. 5).

The large spring of the McGill group is in the SE. ¼ NW. ¼ sec. 21, T. 18 N., R. 64 E. It has been developed by excavating a pool and building a dam on the lower side. The pool is perhaps 150 or 200 feet in diameter and is of considerable depth. The spring discharges through an earthen spillway over a weir. The water was formerly used for irrigation but is now used in the mill and smelter at McGill. The flow of this spring is said to vary somewhat, but when measured, in the summer of 1918, the discharge was 10 second-feet. It is not known whether the temperature varies, but at the time the spring was visited it was 78° F.

Campbell embayment area.—The springs that occur in the Campbell embayment area are on the west side of Steptoe Valley about 10 miles northwest of McGill. This area contains more springs and probably yields more water than any other area in the valley. In general, the springs occur along a line at the foot of the steep alluvial slope and nearly parallel to the Egan Range for a distance of 6 or 7 miles. The total number of springs is estimated to be between 500 and 800, and their temperature ranges from about 58° on the south to 76° at the Campbell ranch. The most productive part of the area is at the W. D. Campbell ranch, about a mile south of the northern end of the area, in the SW. ¼ sec. 5, T. 19 N., R. 63 E. The largest yield of any single vent probably does not exceed half a second-foot, but there are a number of vents that yield about a quarter of a second-foot. Mr. W. D. Campbell estimates that on his ranch alone there are about 300 springs. From a few of the largest of these springs Mr. Campbell irrigates about 1,000 acres, nearly all of which is in wild grass. The combined yield of the two largest groups of springs on the Campbell ranch was measured and found to be 2.73 second-feet on September 6, 1917. Probably a third or a fourth of the water did not pass the point of measurement. On April 9, 1918, the temperature of the water issuing from several of the more prominent of these vents was 76°. An assay of water from one of these vents is given on page 44 (No. 2). It is classified as a sodium-carbonate water, good for domestic use and fair for irrigation. There is little or no evidence that mineral deposits are being formed at the present time, but in places the alluvium has been cemented by deposits in the past.

Melvin Hot Springs.—The Melvin Hot Springs are about a mile northwest of Warm Springs station, at the foot of the steep alluvial slope in sec. 24, T. 21 N., R. 63 E. These springs are unique in Steptoe Valley in two respects—the highest temperatures are found here and the largest amount of mineral matter is being deposited. The springs consist of one main spring and several smaller ones, some of which are mere seeps. The largest spring has a flow of 1.39 second-feet. Its temperature was 174° on August 21, 1917, and 173° on April 9, 1918. The springs have built up a large mound of tufa or travertine, which covers about 12 acres and is about 20 feet high on the west side and perhaps at least twice as high above the valley floor on the east side. At present the large spring discharges near the western edge of the mound, but apparently the point of main discharge has migrated over the mound from time to time. When the deposit was built up about the mouth of the spring until it became somewhat higher than the rest of the mound, the spring would probably find a new outlet at a lower level. At present the spring discharges into an irrigation ditch, which has been dug into the mound from the west and has tapped the spring about 6 or 7 feet below its former point of discharge, which was on top of the mound near its highest point. Parts of the mound are composed almost wholly of spring deposits, whereas other parts have been built up, at least to a considerable extent, by wind-blown material and the growth of vegetation. At present mineral matter is deposited so rapidly that it clogs the irrigation ditches and makes it necessary to clean them frequently. Objects that fall into the ditches, such as weeds, snakes, and grasshoppers, are soon encrusted by a mineral deposit. However, the deposit on most of these objects is so incoherent that the specimen can not be removed from the water without injuring or wholly destroying it. The deposit near the mouth of the spring often completely bridges over the ditch. The color of the materials ranges from snow-white to buffs, brown, and green. Only buff or brown occurs in the older deposits.

At the mouth of the spring the water has much the appearance of boiling, due to the escape of gas. The gas was not studied, but it has no odor and is probably carbon dioxide (CO_2). The water is used for irrigation and is shown by the analysis (No. 9, p. 43) to be of satisfactory quality for that purpose. Some of the lowland on which the water has been used has, however, become so alkaline as to render it no longer productive. The water doubtless rises through a considerable thickness of alluvium. It is, however, doubtful whether any appreciable amount of water percolates into the alluvium before reaching the surface, because the alluvium surrounding the vent has probably been sealed by the deposition of calcareous materials.

Cherry Creek Hot Springs.—These springs are about 1¼ miles southwest of Cherry Creek, near the base of the Egan Mountains. There are three small springs that have a combined flow of 0.08 second-foot. The temperatures of the three springs are, respectively, 118°, 124°, and 135° F. The spring south of the road in the yard back of the house rises in a small pool 20 or 30 feet in diameter and about a foot deep. The water rises at a number of points in the bottom of the pool and a small amount of gas (probably CO_2) escapes in numerous bubbles. The temperature of this spring is 118°. The water from this spring, together with that from the other two, is used to supply a small bathhouse. Apparently no mineral deposit whatever is being formed by this spring.

Across the road, at a distance of about a hundred feet, are the two other springs. The temperature of these springs is 124° and 135°. Both of them issue from small cones which they have built, but there is very little deposit being formed at the present time. The water is used to irrigate a small garden and to help supply the bathhouse. An analysis of the water of the spring is found on page 43 (No. 11).

Collar and Elbow Spring.—This spring is several miles north of the northern end of the Schell Creek Mountains in the bed of the ancient lake. A mound of vegetable and wind-blown material is formed about its mouth. The mound covers about a quarter of an acre and is about 10 feet high. The spring has a flow of 0.04 second-foot and a temperature of 92°. An assay of the water is given on page 44 (No. 5).

Murry Springs.—About a mile south of Ely is a spring area in Murry Canyon. A number of these springs have been developed by open ditches and the water collected and led to a reservoir from which it is distributed to the towns of Ely and East Ely.

Ely has a population of about 2,500 and East Ely about 800.[8] The surplus of water from the spring, which is returned to Murry Creek, amounted to 3.29 second-feet on April 2, 1918, and 4.84 second-feet on May 18, 1918. The surplus is used to irrigate about 300 acres of alfalfa. The combined yield of the springs at the heading of the canal was found to be 8.53 second-feet on March 1, 1918, and 12.06 on June 18, 1918. The city engineer states that the yield is generally nearly constant at about 9 second-feet. On March 1, 1918, the temperature of the spring water was 55°.

Springs along ancient beach.—A number of springs occur along the shore line of the ancient lake on the west side of the valley and flow into the evaporating area in the axis of the valley. Their water is used in several places for irrigating wild hay.

Borchert John Spring.—The spring known as Borchert John Spring occurs on a talus slope of the mountains, probably in sec. 16, T. 22 N., R. 63 E. On May 22, 1918, the flow of its source was 1.72 second-feet and the temperature of its water was 66°. The water of this spring is used for irrigation. An analysis is given on page 43 (No. 10).

Springs along the axis of the valley.—Two large groups of springs occur along the axis of the valley—one just south of the fan of Steptoe Creek and one just south of the fan of Duck Creek. The rise of the ground water to the surface at these places may be due to the cross-bedding and the fine materials about the margin of these large alluvial fans which extend far out into the valley. The area around Cummings Spring south of the fan of Steptoe Creek is in secs. 20 and 21, T. 15 N., R. 64 E. Here the large fan built by Steptoe Creek extends far out into the valley and unites with the fans built out from Ward Mountain, on the west side of the valley. It is probable that

[8] Colwell, W. B., city engineer of Ely, letter of Apr. 27, 1919.

the springs owe their origin to these conditions. This area contains a number of springs that issue from small deep pools in the meadow at the upper end of Cummings Lake. It was impracticable to measure these springs, but their combined flow is estimated to be between 5 and 10 second-feet.

The other large group of springs in the axis of the valley is just south of the fan of Duck Creek, a short distance north of McGill, in sec. 13, T. 18 N., R. 63 E., and in secs. 18 and 19, T. 18 N., R. 64 E. The yield of this area could not be measured as the flow unites with the waste water from the McGill reduction works.

Cowcamp Spring.—Cowcamp Spring is a cold spring near the south end of Steptoe Valley. It rises along a fault in a limestone formation. Its flow, as measured, is 0.38 second-foot. This spring is a valuable watering place for range stock.

WELLS.

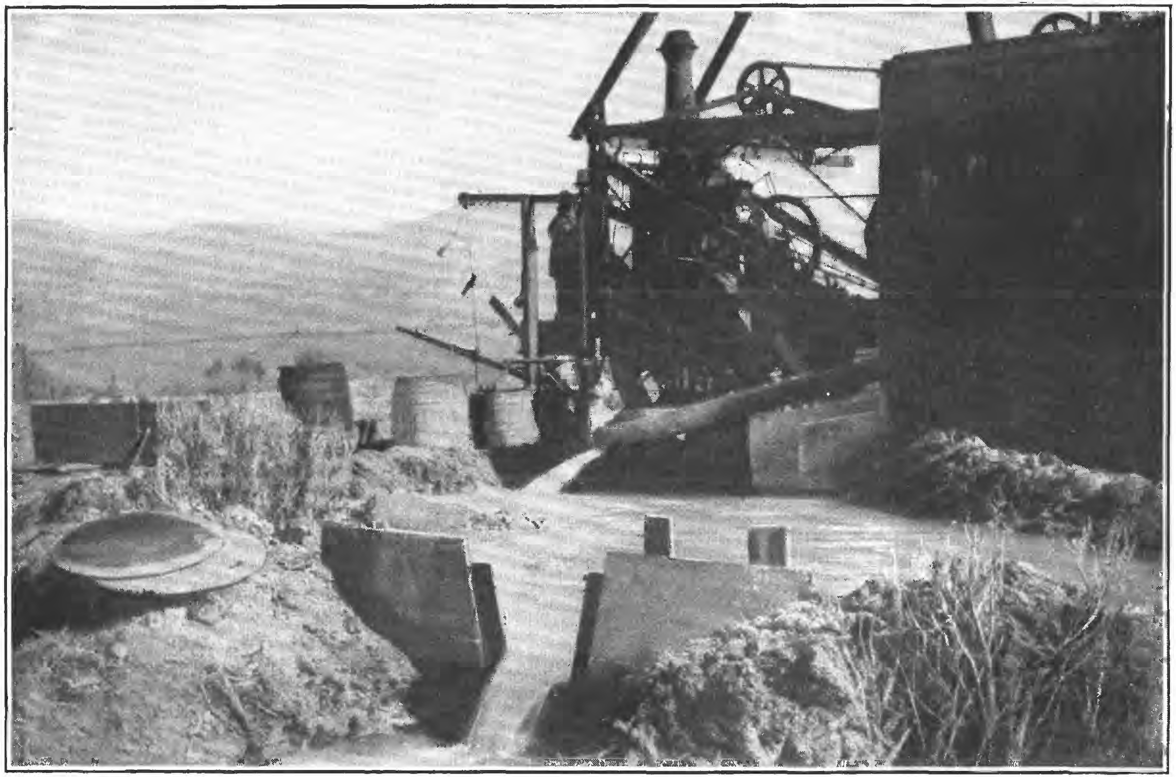
UNITED STATES GEOLOGICAL SURVEY TEST WELLS.

In connection with this investigation three test wells were drilled by the United States Geological Survey in a part of Steptoe Valley where the conditions appeared to be favorable for developing ground water for irrigation. (See Pl. II, in pocket.)

WELL NO. 1.

Well No. 1 is in the SW. ¼ sec. 32, T. 20 N., R. 64 E., on the northern slope of the Duck Creek fan and in the greasewood area, approximately 3 miles east of the axis of the valley and about the same distance west of the base of the Schell Creek Mountains. (See Pl. II.) It is 97 feet deep and is finished with 5⅝-inch inside diameter screw casing (light merchant's pipe). The casing is not perforated. The log of the well is given in figure 4.

The beds of the first horizon (the bottom of which is 34 feet below the surface) and of the second horizon (the bottom of which is 50 feet below the surface) were tested only by bailing, and were found to yield, respectively, about 10 and 30 gallons a minute. The yield of the beds of horizon No. 3 (the bottom of which is 71 feet below the surface) was determined by pumping first with a plunger pump and afterward with a No. 4 horizontal centrifugal pump placed in a pit 17 feet deep and driven by the engine used in the drilling. The method followed in testing this bed was as follows: A sand screen, consisting of a 4-inch pipe 16 feet long and bored with half-inch holes 2 inches between centers, was lowered to the bottom of the well at 71 feet; the casing was then drawn back so that the bottom of the casing was only a short distance below the top of the sand screen. The well was first pumped with a 4-inch plunger pump with



PUMPING TEST OF UNITED STATES GEOLOGICAL SURVEY WELL NO. 1, SHOWING METHOD OF MEASURING DISCHARGE.

a 32-inch stroke worked from the walking beam of the drill rig. This operation was continued until most of the sand was removed. The plunger pump was then taken out and the No. 4 horizontal centrifugal pump was installed in the pit. The center of the pump was placed

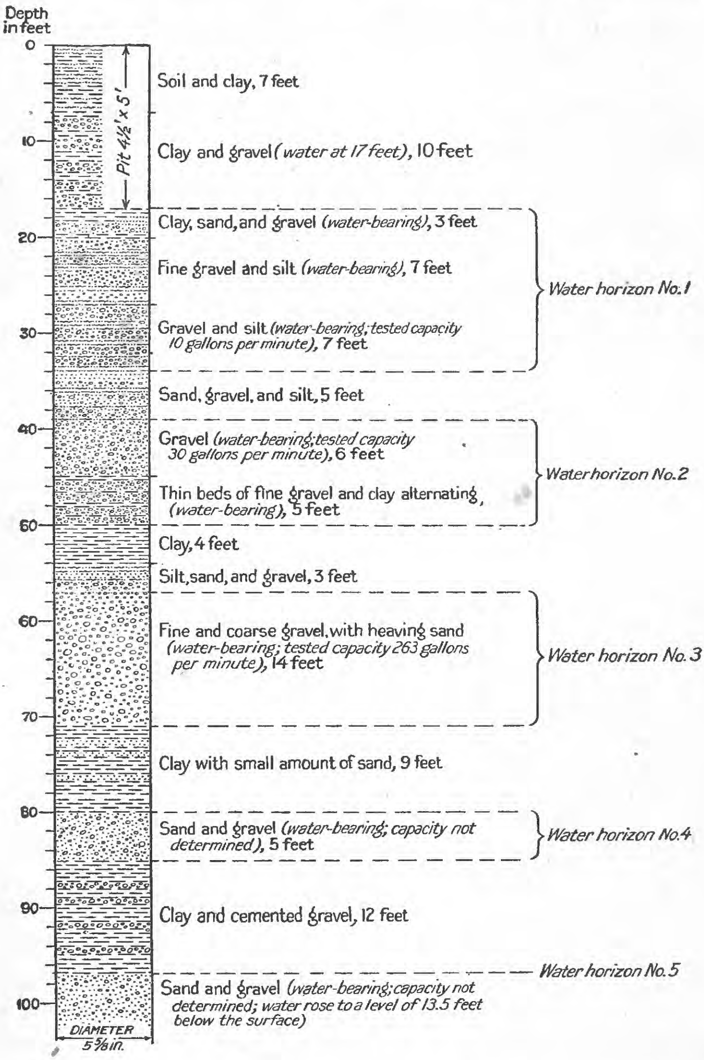


FIGURE 4.—Section of United States Geological Survey well No. 1, near McGill, Nev.

16 feet below the surface. The water was pumped into a pond from which it passed over a Cippoletti weir. (See Pl. IV.) The pump was operated at a speed of 825 revolutions a minute, at which it gave the greatest discharge.

Pumping test of water-bearing bed of horizon No. 3 in United States Geological Survey well No. 1, near McGill, Nev.

Duration of test	hours	6
Total water pumped	gallons	94,680
Average discharge	gallons a minute	263
Depth of water level below surface before test began	feet	17.2
Depth of water level below surface near end of test but while pump was still running	feet	36.1
Drawdown	do	18.9
Speed of steam engine	revolutions a minute	136
Speed of No. 4 horizontal centrifugal pump	do	825

The yields of the two horizons below 71 feet were not determined, but the character of the gravel at these lower levels indicates that they will add considerable to the total yield of the well. The aggregate thickness of the water-bearing beds penetrated in this well amounts to 40 per cent of the total depth of the well.

Three samples of water from this well were analyzed, as indicated below.

Mineral analyses and classification of water from United States Geological Survey well No. 1, in the SW. ¼ sec. 32, T. 20 N., R. 64 E., near McGill, Nev.

[Parts per million except as otherwise designated. Analyzed by Alfred A. Chambers and C. H. Kidwell.]

	1	2	3
Determined quantities:			
Silica (SiO_2)	29	30	158
Iron (Fe)	1.7	.50	7.2
Aluminum (Al)			8.5
Calcium (Ca)	48	48	81
Magnesium (Mg)	17	17	19
Sodium and potassium (Na+K)	13	14	16
Carbonate radicle (CO_3)	.0	Trace.	.0
Bicarbonate radicle (HCO_3)	219	224	259
Sulphate radicle (SO_4)	10	11	8.6
Chloride radicle (Cl)	10	10	8.6
Nitrate radicle (NO_3)	2.5	2.5	.30
Total dissolved solids at 180° C	235	238	534
Computed quantities:[a]			
Total hardness as $CaCO_3$	190	190	280
Scale-forming constituents	200	200	430
Foaming constituents	35	38	43
Alkali coefficient (inches)[b]	120	110	69
Classification:[a]			
Mineral content	Moderate.	Moderate.	High.
Chemical character	Ca-CO_3	Ca-CO_3	Ca-CO_3
Probability of corrosion [c]	(?)	(?)	(?)
Quality for boiler use	Fair.	Fair.	Poor.
Quality for domestic use	Fair.	Good.	Bad.
Quality for irrigation	Good.	Good.	Good.
Date of collection (1918)	Feb. 7	Feb. 6	Feb. 15

[a] See standards for classification by R. B. Dole and Herman Stabler in U. S. Geol. Survey Water-Supply Paper 398, pp. 50-81, 1916.
[b] Depth of water, in inches, which would yield on evaporation sufficient alkali to render a 4-foot depth of soil injurious to the most sensitive crops.
[c] Based on computed quantity; (?), corrosion doubtful.

1. Horizon No. 1, at a depth of 19 to 28 feet.
2. Horizon No. 2, at a depth of 39 feet.
3. Horizon No. 3, at a depth of 57 to 71 feet.

These samples were obtained from the three upper water-bearing beds—the first between the depths of 19 and 28 feet, the second at 39 feet, and the third between 57 and 71 feet. They contain, respectively, 235, 238, and 534 parts per million of total dissolved solids. All three are of good quality for irrigation. The results of the analyses and the classification of the water for different uses are given in the table.

WELL NO. 2.

Well No. 2 is near the center of the NE. ¼ sec. 12, T. 19 N., R. 63 E. It is near the middle of the valley, on the lower part of the Duck Creek fan, and is in the rabbit-brush area. To facilitate the handling of the casing, a pit was sunk to the water table, which is here 10 feet below the surface. The well was then drilled to the total depth of 915 feet. It was cased with heavy 12-inch inside diameter screw casing to a depth of 181 feet. Then a string of standard 8-inch screw casing was placed from the surface to a depth of 540 feet, below which depth no casing was used.

The log of the well is given below. A section of the well is shown in Plate V.

Log of United States Geological Survey well No. 2, in the NE. ¼ sec. 12, T. 19 N., R. 63 E., near McGill, Nev.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay and gravel	5	5
Sand and gravel (water at 9.6 feet)	6	11
Sand, gravel, and clay	8	19
Sand and gravel (water-bearing; tested capacity, 25 gallons a minute)	3	22
Clay, sand, and gravel	5	27
Clay	2	29
Sand and gravel (water-bearing; tested capacity, 8 gallons a minute)	2	31
Clay	12	43
Gravel and sand (water-bearing; tested capacity, 10 gallons a minute)	1	44
Clay and sand	2	46
Clay	8	54
Gravel and sand (water-bearing; tested capacity, 15 gallons a minute)	3	57
Clay	12	69
Gravel and sand (water-bearing; water level, 17.3 feet below surface)	1	70
Clay	7	77
Gravel and sand (water-bearing; tested capacity, 20 gallons a minute; water level, 15.3 feet below surface)	3	80
Clay	24	104
Sand and gravel (water-bearing; tested capacity, 35 gallons a minute; water level, 10.8 feet below surface)	1	105
Clay	18	123
Gravel (water-bearing; water level, 15.7 feet below surface)	1	124
Clay (12-inch casing to 181 feet)	138	262
Sand (water-bearing; water level, 4[illegible] feet below surface; tested capacity, 86 gallons a minute with drawdown of 20 feet)	5	267
Fine yellow clay	15	282
Sand and gravel (very little water)	3	285
Clay	15	300
Sand (no water)	1	301
Clay, gravel, and sand	4	305
Clay	10	315
Clay and sand in thin beds (water-bearing; water level, 4.7 feet below surface)	10	325
Pale yellow clay	51	376
Fine gravel, sand, and clay	3	379
Clay	2	381
Fine gravel, sand, and clay	4	385
Clay	37	422
Sand	2	424
Clay	16	440
Sand and clay	4	444
Clay	35	479

Log of United States Geological Survey well No. 2, in the NE. ¼ sec. 12, T. 19 N., R. 63 E., near McGill, Nev.—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Sand and clay	6	485
Sand (water-bearing)	1	486
Sand and clay	4	490
Clay	10	500
Sand	1	501
Clay	8	509
Sand	1	510
Clay	9	519
Sand	1	520
Clay	41	561
Sand and clay	1	562
Sandy clay	33	595
Cemented sand and clay	1	596
Sandy clay	5	601
Cemented gravel and clay	4	605
Sandy clay	23	628
Gravel and sand	2	630
Sandy clay	19	649
Dry brown sand and clay	4	653
Clay	7	660
Cemented sand	9	669
Clay and sand	3	672
Cemented sand with some clay	28	700
Sandy clay	16	716
Cemented sand	4	720
Sandy clay	7	727
Cemented sand	8	735
Clay and sand	15	750
Cemented sand	4	754
Gravelly clay	5	759
Clay	64	823
Sandy clay	1	824
Sticky clay with a little gravel	6	830
Cemented sand	8	838
Clay	13	851
Cemented sand	9	860
Clay	8	868
Cemented sand	2	870
Clay	10	880
Sand	8	887
Sandy clay	12	899
Gravelly clay	13	912
Blue clay with odor of hydrogen sulphide	3	915

The aggregate yield of all the water-bearing beds penetrated in this well is estimated at 250 to 300 gallons a minute. Little available water was found below 267 feet.

The water from the beds at 262 to 267 feet and at 315 to 325 feet rose within 5 feet of the surface. The character of the beds of fine materials penetrated between 125 and 915 feet indicates that they were not deposited by stream waters but that they are lake beds. These beds are possibly underlain by stream deposits that contain water-bearing gravels. As the thick series of fine-grained deposits that were penetrated would make an effective confining bed there is a possibility that if they are underlain by water-bearing beds such beds would yield artesian flows. Lack of sufficiently heavy drilling equipment made it impracticable to sink the well deeper, but it was capped and left in such a condition that it can be drilled deeper in the future if it is desired to test this rather remote prospect of finding an additional water supply.

Two samples of water from this well were analyzed—one obtained between the depths of 10 and 12 feet and the other between the depths of 54 and 57 feet. These samples contain, respectively, only 211 and 252 parts per million of total dissolved solids and are of good quality for both domestic use and irrigation. The results of the analysis, including the classification of the water for different uses, are given in the following table:

Mineral analyses and classification of water from United States Geological Survey well No. 2, in the NE. ¼ sec. 12, T. 19 N., R. 63 E., near McGill, Nev.

[Parts per million except as otherwise designated. Analyzed by Alfred A. Chambers and C. H. Kidwell.]

	Bed at depth of 10 to 12 feet.	Bed at depth of 54 to 57 feet.
Determined quantities:		
Silica (SiO_2)	26	31
Iron (Fe)	.15	.30
Calcium (Ca)	41	45
Magnesium (Mg)	16	19
Sodium and potassium (Na+K)	13	20
Carbonate radicle (CO_3)	.0	Trace.
Bicarbonate radicle (HCO_3)	202	229
Sulphate radicle (SO_4)	7.1	17
Chloride radicle (Cl)	10	12
Nitrate radicle (NO_3)	2.0	1.4
Total dissolved solids at 180° C	211	252
Computed quantities: [a]		
Total hardness as $CaCO_3$	168	190
Scale-forming constituents	170	200
Foaming constituents	35	54
Alkali coefficient (inches)[b]	98	75
Classification: [a]		
Mineral content	Moderate.	Moderate.
Chemical character	Ca-CO_3	Ca-CO_3
Probability of corrosion [c]	(?)	(?)
Quality for boiler use	Fair.	Fair.
Quality for domestic use	Good.	Good.
Quality for irrigation	Good.	Good.
Date of collection (1918)	Mar. 12	Mar. 15

[a] See standards for classification by R. B. Dole and Herman Stabler in U. S. Geol. Survey Water-Supply Paper 398, pp. 50-81, 1916.
[b] Depth of water, in inches, which would yield on evaporation sufficient alkali to render a 4-foot depth of soil injurious to the most sensitive crops.
[c] Based on computed quantity; (?), corrosion doubtful.

WELL NO. 3.

Well No. 3 was sunk about 200 feet northeast of the southwest corner of sec. 32, T. 20 N., R. 64 E., approximately 3½ miles west of the east edge of the valley fill. This well is 122 feet deep and has much the largest yield of the three. It is finished in such a manner that it may be regarded as a model for irrigation wells in this valley and in other valleys in Nevada where conditions are similar. The log of the well is given in figure 5.

The water of the first water horizon in this well stood 14.5 feet below the surface, and the water of the second, third, fourth, and fifth water horizons rose to about the same level, but the water of the sixth horizon (between 110 and 116 feet) rose within 11.5 feet of the surface.

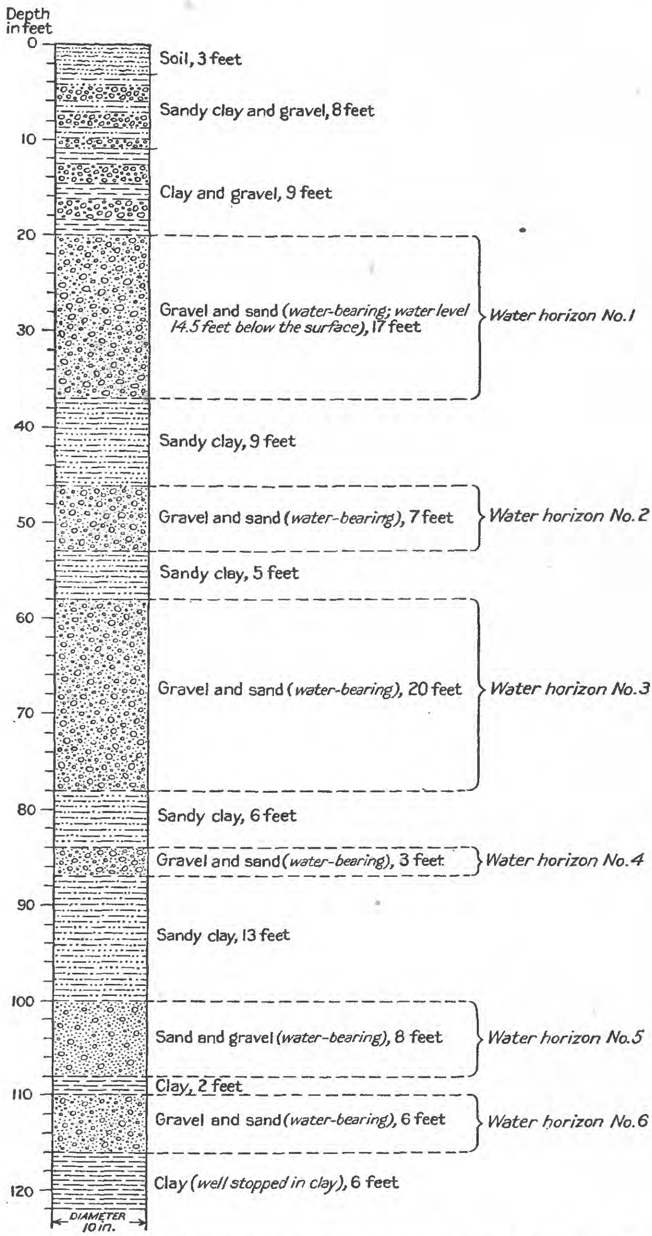


FIGURE 5.—Section of United States Geological Survey well No. 3, near McGill, Nev.

This well is cased with 12-gage 10-inch double stovepipe casing, set in clay at 122 feet. The casing was perforated with a four-way perforator the entire distance between the depths of 20 feet and 120 feet below the surface. The perforations are 1.2 inches long and 0.3 inch wide and are 1.2 inches apart. Altogether about 2,000 perforations were made in the casing, giving a total of 720 square inches of opening. After the casing was perforated the water level in the well dropped from 11.5 to 14 feet below the surface. When the perforating was completed the sand that had entered through the perforations was removed by means of a bailer, and a 4-inch horizontal centrifugal pump was then installed in a pit at a level 13.5 feet below the surface and was operated at low speed until only a small amount of sand was discharged. A pumping test was then made with the pump running at higher speed. The pump was driven by a 4-inch belt from a shaft set on the walking beam of the drill rig. The power was furnished by a steam engine. The water that was pumped was delivered into a pond, from which it flowed over a Cippoletti weir for measurement.

Pumping test of United States Geological Survey well No. 3.

Duration of test....hours..	3.50
Total water pumped....gallons..	44,780
Average discharge....gallons a minute..	262
Depth of water level below surface before test began....feet..	13.95
Depth of water level below surface near end of test but while pump was still running....feet..	21.75
Drawdown....do...	7.80
Speed of pump....revolutions a minute..	800

The rate of pumping was determined by the capacity of the pump and engine, not by the quantity of water that the well would supply. It was greatly regretted that the available equipment was inadequate to give the well a complete test. The test showed that the well yielded 262 gallons a minute with a drawdown of 7.80 feet, which is 33.6 gallons a minute for each foot of drawdown. If the well will maintain this rate of yield it will supply 672 gallons a minute with a drawdown of 20 feet. It is therefore safe to say that with a drawdown of 20 feet the well will yield somewhat over 1 second-foot of water.

Samples of water were collected from five horizons in this well as follows: No. 1 (between the depths of 20 and 37 feet), No. 2 (between 46 and 53 feet), No. 4 (between 84 and 87 feet), No. 5 (between 100 and 108 feet), and No. 6 (between 110 and 116 feet). The samples from Nos. 1, 2, and 6 were analyzed, but those from Nos. 4 and 5 were assayed, as the samples were too small to permit more detailed examination. Total dissolved solids in the samples ranged between 220 and 310 parts per million. From the examinations all the waters appear to be of good quality for both domestic use and irrigation. The analytical results and the classification of the water from each horizon are given in the following table:

Chemical composition and classification of water from United States Geological Survey well No. 3, in the SW. ¼ sec. 32, T. 20 N., R. 64 E., near McGill, Nev.

[Parts per million except as otherwise designated. Analyses and assays by Alfred A. Chambers, C. H. Kidwell, and Margaret D. Foster. Determinations on samples from horizons Nos. 1, 2, and 6 by analysis, and on samples from horizons Nos. 4 and 5 by laboratory assay (approximations only).]

	1	2	4	5	6
Silica (SiO_2)	29	26			28
Iron (Fe)	.40	.17			.26
Calcium (Ca)	50	42			38
Magnesium (Mg)	18	16			18
Sodium and potassium (Na+K)[a]	7.7	14	45	43	23
Carbonate radicle (CO_3)	.0	.0	5.3	4.8	.0
Bicarbonate radicle (HCO_3)	239	212	201	206	211
Sulphate radicle (SO_4)	9.9	15	32	28	28
Chloride radicle (Cl)	6.5	7.7	16	11	12
Nitrate radicle (NO_3)	Trace.	Trace.			Trace.
Total dissolved solids at 180° C.	231	220	[a]310	[a]290	255
Total hardness as ($CaCO_3$)	[a]199	[a]171	140	136	[a]169
Scale-forming constituents[a]	210	180	190	190	170
Foaming constituents[a]	21	38	120	120	62
Alkali coefficient (inches)[b]	270	130	25	24	93
Classification:					
Mineral content	Moderate.	Moderate.	Moderate.	Moderate.	Moderate.
Chemical character	Ca-CO_3	Ca-CO_3	Ca-CO_3	Ca-CO_3	Ca-CO_3
Probability of corrosion[c]	(?)	N	N	N	N
Quality for boiler use	Poor.	Fair.	Fair.	Fair.	Fair.
Quality for domestic use	Good.	Good.	Good.	Good.	Good.
Quality for irrigation	Good.	Good.	Good.	Good.	Good.
Date of collection (1918)	June 24	June 25	June 23	June 28	June 29

[a] Computed. See standards for classification by R. B. Dole and Herman Stabler in U. S. Geol. Survey Water-Supply Paper 398, pp. 50–81, 1916.
[b] Depth of water, in inches, which would yield on evaporation sufficient alkali to render a 4-foot depth of soil injurious to the most sensitive crops.
[c] Based on computed quantity; (?), corrosion doubtful; N, noncorrosive.

Horizon No. 1, at a depth of 20 to 37 feet.
Horizon No. 2, at a depth of 46 to 53 feet.
Horizon No. 4, at a depth of 84 to 87 feet.
Horizon No. 5, at a depth of 100 to 108 feet.
Horizon No. 6, at a depth of 110 to 116 feet.

METHODS OF SINKING WELLS.

A portable traction percussion drilling rig with folding derrick was used in drilling the test wells. At first a gasoline engine was used but later a steam engine was obtained and was more satisfactory, especially in cold weather.

Double stovepipe casing was used in well No. 3 and was better adapted to conditions in the valley than either the light or standard screw casing. This is the casing commonly used for irrigation wells in California. It is made of lap-riveted cylinders of 12-gage sheet steel, 2 feet in length. The cylinders are of two sizes, one fitting just inside the other. The joints are broken so that the joints of the outer cylinders come at the middle of the cylinders of the inner set. The ends are turned true so as to give complete bearing. The cylinders were added one at a time, and the outer and inner sets were united by denting with a heavy pick. This casing is generally nearly water-tight, but it may leak to some extent when first inserted. It will not stand heavy driving, and therefore hydraulic jacks are used when necessary to force it down. However, the jacks were not needed in sinking this well, as light driving was sufficient to keep the casing up with the drill. This was also found to be the condition in sinking the Moller dairy well, near East Ely, where stovepipe casing was used. (See p. 61.) This casing can be used with the percussion method of drilling and eliminates the necessity of digging a pit which often arises in handling long joints of screw casing.

The water-bearing bed in well No. 1 between 57 and 71 feet and in well No. 3 between 58 and 78 feet consists of incoherent sand and gravel, which at times rose 10 feet or more inside the casing, especially when the bailer was being used. The material frequently became so firmly packed beneath the drill bit as to cause considerable difficulty in cleaning the well. The method used with success in handling this sand and gravel in well No. 3 and also in Moller's dairy well was to keep the well filled with water and to add 20 to 25 shovels of adobe clay before lowering the drill tools, also to keep the casing with the drill and not to attempt to drill more than a few inches ahead of the casing shoe. By keeping the water at a high level in the well it exerted enough pressure to hold the sand and gravel back. The clay mixed with the water and prevented it from passing outward into the gravel and thus made it possible to keep a head of water in the well. The clay also mixed with the sand and gravel in the well and prevented them from settling before the bailer could be lowered. By using this method no further difficulty was encountered in penetrating the material.

METHODS OF PERFORATING AND DEVELOPING WELLS.

After a well has been sunk to the desired depth the casing should be seated in clay or other materials that will effectually seal the bottom of the well and prevent further settling of the casing. The casing should be perforated, and the perforations should not exceed three-eighths of an inch in width. If an accurate log of the well has been kept the casing can be perforated at all the water-bearing strata, or at as many of them as may be desired. The use of a four-way perforator is preferable, as the use of a one-way or two-way perforator in soft materials is apt to cause the casing to become elliptical in cross section, with the result that the knives may fail to penetrate it.

The perforator is attached to the string of tools instead of the bit, the jars being placed just above it, so that the tools are strung in the following order from the top: Rope socket, stem, jars, perforator. The tools are then lowered into the well to the point where the perforating is to begin, the knives are raised to position by means of a light cable, and the perforating is begun by driving the perforator downward by striking it with the tools above the jars. The four-way perforator here referred to makes four rows of perforations, which are vertical slots 1.2 inches long and three-eighths of an inch wide and the vertical distance between the perforations is 1.2 inches. (See fig. 6.)

After the casing has been perforated the well should be bailed out to remove the fine materials that have entered through the openings and have accumulated in the well during the process of perforating. It may be necessary to do some bailing before all the perforations are made, as the fine materials may enter at such a rate through the upper openings as to fill the lower part of the well and to prevent the making of the perforations at the desired depths. If this difficulty arises the point where the perforating is interrupted is recorded,

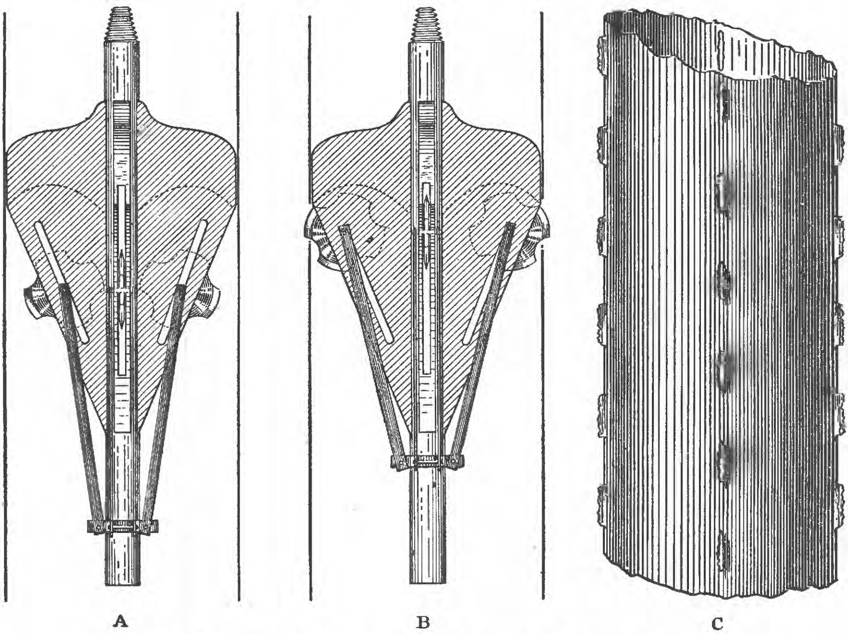


FIGURE 6.—Diagrams showing a four-way perforator and casing perforated with it.

the tools are pulled up, and the accumulated sand is removed with the bailer. The perforator is then again lowered to the point where the work was interrupted, and the perforation is continued.

On account of the character of the deposits in Steptoe Valley great care must be exercised in developing wells. The driller's equipment should include a pump having a capacity of 500 to 600 gallons a minute. The discharge opening of the pump should be provided with a gate valve, so that the discharge of the well can be regulated. At first the pump should be operated with the gate valve nearly closed, so that the discharge will be small, and as the conditions warrant the discharge should be increased until the full capacity of the well or that of the pump is reached. This rate of pumping should be continued as long as any appreciable amount of sand is brought up with the water. If the pumping is begun at too rapid a rate the well is likely to become partly filled with sand. If this happens, the sand should be removed with a bailer or sand pump, and the pumping process should be repeated. When the pumping tests are made, if conditions warrant, it is advisable to have the suction pipe extend within 10 or 12 feet of the bottom of the well. With this arrangement the well is less likely to become filled with sand. However, the use of this long suction pipe is recommended only for the process of development and not for the permanent installation, as the friction in the long suction pipe would increase materially the cost of pumping. It is estimated that in cleaning well No. 3 approximately 4 cubic yards of sand was removed during the first half hour of pumping. The removal of the finer materials increases the porosity of the material near the intake of the well and thus increases the capacity of the well.

MOLLER DAIRY WELL.

A well has recently been drilled at the dairy of F. A. Moller, in the NE. ¼ sec. 14, T. 16 N., R. 63 E., on the lower end of the Murry Creek fan, on a bench approximately 20 feet above the valley floor. This well was drilled by J. J. Hibbs, who used the methods employed by the Geological Survey in sinking well No. 3. It is 130 feet deep and is finished with 10-inch 12-gage double stovepipe casing similar to that used by the Geological Survey.

Log of Moller dairy well, in the NE. ¼ sec. 14, T. 16 N., R. 63 E.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay and loam	21	21
Fine gravel and sand (water-bearing)	12	33
Clay	4	37
Fine gravel and sand (water-bearing)	11	48
Silt and sand (contains some water)	37	85
Sand and gravel (water-bearing)	1	86
Silt and sand	4	90
Sand and gravel (water-bearing)	2	92
Silt and sand	3	95
Sand (water-bearing)	4	99
Silt and sand	6	105
Sand (water-bearing; water level, 19 feet below the surface)	2	107
Silt and sand	7	114
Sand and fine gravel	3	117
Clay and sand in alternating layers	2	119
Fine gravel and sand (water-bearing)	11	130

At the time this report was written the yield of this well had not been determined, owing to the fact that equipment for testing had not been procured. From the fact that 47 feet of water-bearing materials were penetrated and from the results obtained by the Geological Survey it is believed that this well will yield a few hundred gallons a minute. The well was put down for an irrigation well and is the first properly constructed private well for this purpose in the valley.

OTHER WELLS.

A number of wells have been sunk in the valley for other purposes than for irrigation. The Nevada Northern Railway Co. has several wells between Cobre and Ely which were sunk to obtain water for locomotive and domestic use.

A well 5 feet in diameter and 17 feet deep was dug at Goshute station, in T. 27 N., R. 64 E. The water stood 10 feet below the surface but was found to be too alkaline for use and was abandoned. A well was then drilled at the same place to a depth of 60 feet, and the shallow water was cased off. The quality of the deeper water was found to be satisfactory. This well contains two strings of casing, each extending downward from the surface. The first line consists of 36 feet of 9⅝-inch casing and the second consists of 58 feet of 5⅝-inch casing. The yield of the well was not determined.

Log of well at Goshute station, Nev.

[No. 32, Pl. II, in pocket; and table on p. 65.]

	Thickness.	Depth.
	Feet.	*Feet.*
Sand	3	3
Clay	15	18
Gravel (water-bearing; "alkaline" water)	8	26
Clay	14	40
Sand (water-bearing; water reported to be of satisfactory quality)	20	60

The railroad well at Greens station (No. 31 on Pl. II, in pocket, and in the table on p. 65), in T. 25 N., R. 64 E., is a dug well 12 feet deep and 6 feet in diameter. The water in it stands 7 feet below the surface and is reported to be satisfactory for both domestic and boiler uses.

The railroad well at Cherry Creek station (No. 28) is 100 feet deep and is cased with 7⅝-inch casing. It has an estimated capacity of 60,000 gallons in 24 hours (about 40 gallons a minute).

The railroad well at Warm Springs station (No. 26), in sec. 25, T. 21 N., R. 63 E., is a dug well 5 feet in diameter and 10 feet deep. The water stands 5.5 feet below the surface and is reported to be of satisfactory quality.

The railroad well at the old Steptoe station (No. 23), in the NE. ¼ sec. 24, T. 19 N., R. 63 E., was dug to a depth of 51 feet, and the water level is 48 feet below the surface. The capacity of the well is not known.

Log of railroad well at old Steptoe station (No. 23).

	Thickness.	Depth.
	Feet.	*Feet.*
Earth	7	7
Gravel	5	12
Clay	6	18
Cemented gravel	22	40
Sand and fine gravel	11	51

The railroad well at Glenn station (No. 20) is only 8 feet deep and has a water level 3 feet below the surface. Its yield has not been determined, but the water is reported to be of satisfactory quality for domestic use.

The railroad well at McGill Junction (No. 22) is 5 feet square and 15 feet deep, and has an estimated yield of 50,000 gallons in 24 hours (about 35 gallons a minute).

The well at High Line Junction (No. 17) is 275 feet deep and has a depth to water of 230 feet. It is finished with 5⅝-inch casing.

A well dug in the NW. ¼ sec. 8, T. 17 N., R. 64 E. (No. 15), to a depth of about 30 feet was originally equipped with a small gasoline engine and was also pumped with a windmill. However, at the time this well was visited it had been abandoned. It was reported to contain water-bearing gravel between the depths of 24 and 30 feet.

A well dug 24 feet deep in the NE. ¼ sec. 13, T. 16 N., R. 63 E. (No. 6), was equipped with a large windmill, doubtless for the purpose of irrigation, but it had been abandoned at the time it was visited. It penetrated sand and gravel below the depth of 12 feet.

The well of W. S. Douval, in the NW. ¼ sec. 36, T. 18 N., R. 63 E. (No. 19), was dug to a depth of 19 feet. Water was encountered at 16 feet in gravel. This well has been equipped with a small gasoline engine and a plunger pump having a capacity of about 48 gallons a minute and is used to irrigate a small garden.

The well of E. B. Young (No. 25), in the SW. ¼ sec. 13, T. 21 N., R. 63 E., is on the west side of the valley, approximately a mile north of Melvin Hot Springs. It is 47 feet deep, and the water level is 12 feet below the surface. This well is equipped with a 2-inch plunger pump and a 2-horsepower gasoline engine.

Log of E. B. Young's well (No. 25), in the SW. ¼ sec. 13, T. 21 N., R. 63 E.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	15	15
Shale	1	16
Clay	8	24
Lime shale	4	28
Clay and gravel	19	47

A test was made on this well which gave a yield of 45 gallons a minute and after pumping 35 minutes showed a drawdown of 7.4 feet. The formation in this well is cemented by what is believed to be a hot springs deposit similar to that now being formed about Melvin Hot Springs. The "shale" referred to in the log between 15 and 16 feet and between 24 and 28 feet is apparently of this character. The water from this well is used to irrigate a garden of approximately 5 acres. The plant is, however, too small to be of much economic value. An assay (No. 1, p. 42) showed this water to be good for irrigation but rather hard for toilet and laundry uses.

The well of George Millas (No. 18) is in the NE. ¼ sec. 25, T. 18 N., R. 63 E. It is only 10 feet deep and the water level is only 7 feet below the surface. The water comes from gravel. It is used for domestic purposes and for watering live stock.

A well (No. 10) has been dug in the SE. ¼ sec. 24, T. 17 N., R. 63 E., on what was apparently an abandoned homestead. The well is 84 feet deep and the water level is 80.4 feet below the surface. The well had been lined with boards so that it was impossible to get its log, but, judging from the materials on the dump, a large part of the section is gravel.

A well (No. 27) was drilled by J. A. Mangason on his place in sec. 28, T. 21 N., R. 64 E., to a depth of 190 feet, where a bed of water-bearing sand was encountered from which the water rose to a level 160 feet below the surface. No accurate log of the well was kept. The well is cased with 5-inch casing. The water is reported to be of good quality and is used for domestic purposes.

A well (No. 2) dug in the SW. ¼ sec. 8, T. 15 N., R. 64 E., consists of a pit 6 by 8 feet in diameter and 24 feet deep. It was intended to be used for irrigation, but at the time it was visited it was incomplete. It penetrated soil and clay in the upper 9 feet and gravel and sand from the depth of 9 feet to the bottom. Water was reached at 22 feet, and at the time the well was visited the water level was 19 feet below the surface. The success of this project is doubtful, as at no place in the valley have the water-bearing beds nearest the surface yielded enough water for irrigation.

A dug well (No. 4) in sec. 12, T. 16 N., R. 63 E., is 22 feet deep and penetrates the first water horizon at 13 feet. Drifts were run east and west 12 feet to increase the yield and the storage capacity of the well. The material penetrated consists of soil and clay to a depth of 8 feet and of gravel, sand, and clay below 8 feet. A No. 4 horizontal centrifugal pump and a 6-horsepower gasoline engine were installed, but the well furnishes only a small amount of water.

The following table summarizes the available data in regard to the private wells in Steptoe Valley:

Records of private wells in Steptoe Valley, Nev.

Number on Pl. II.	Owner or designation.	Location.				Altitude above sea level.[a]	Type of well.	Depth of well.	Depth to water level in well.	Date of measurement of water level.	Observed fluctuation of water level.
		Township north.	Range east.	Section.	Part of section.						
						Feet.		*Feet.*	*Feet.*		*Feet.*
1	Cummings	15	64	34	SW. ¼		Dug	17	13.6	Aug. 16, 1918	
2	....do	15	64	8	SW. ¼		...do	24	19.0	Aug. 17, 1918	
3	Nevada Consolidated Copper Co.	16	62	2	NW. ¼	6,740	Drilled.	338	55.0	Sept 15, 1918	
4		16	63	12	N. ½	6,215	Dug	22	13.3	Sept. 10, 1918	
5		16	63	12	SE. ¼		...do	14	13.4	Sept. 9, 1918	
6		16	63	13	NE. ¼	6,220	...do	24	17.1	....do	
7		16	63	13	NE. ¼	6,224	...do		21.8	....do	
8		16	63	14	NE. ¼	6,240	Drilled.	130	19.0	Sept. 20, 1918	
9	Railroad well at East Ely.	16	63	15	NW. ¼			10	5.5		
10		17	63	24	SE. ¼	5,939	Dug	84	80.4 80.4	July 30, 1918 Aug. 26, 1918	0
11		17	63	24	NE. ¼	5,920		73	69.0	Aug. 26, 1918	
12		17	63	36	NW. ¼	5,995	Dug		47.8 47.5 47.5 47.7	Apr. 10, 1918 May 18, 1918 June 17, 1918 Aug 26, 1918	.3
13	At corner saloon, McGill Junction.	17	64	5	NW. ¼		...do	25	16.4 16.2 16.4 16.5	Mar. 27, 1918 Apr. 10, 1918 May 18, 1918 June 25, 1918	.3
14	One-fourth mile northwest of No. 15.	17	64	5	NW.		...do		15.8 16.0 16.5	Apr. 10, 1918 May 18, 1918 July 27, 1918	.7
15	Railroad well at East Ely.	17	64	8	NW. ¼	5,880	...do	30+	31.0 26.8 26.3 26.5 26.8	Sept. 8, 1917 May 27, 1918 May 18, 1918 July 22, 1918 Aug. 26, 1918	4.7
16		17	64	31	NW. ¼	6,000	...do		62.9 63.5 61.8 61.4 61.3 61.9 61.9	Sept. 10, 1917 Sept. 27, 1917 Apr. 10, 1918 May 18, 1918 June 17, 1918 July 27, 1918 Aug. 26, 1918	2.2
17	High Line Junction	18	63	7	NE. ¼		Drilled.	275	230		
18	George Millas	18	63	25	NE. ¼		Dug	10	7.0	July 23, 1918	
19	W. S. Douval	18	63	36	NW. ¼		...do	19	15.1	July 27, 1918	
20	Glenn station	18	64	20	SW. ¼			8	3.0		
21	A. E. Leet	18	64	7	NW. ¼		Dug		7.3	June 18, 1918	
22	McGill Junction	18	64	32	SW. ¼			15	9.0		
23	Steptoe	19	63	24	NE. ¼	5,869	Dug	51	47.8 49.4	Apr. 10, 1918 Aug. 24, 1918	1.6
24	R. Finley	20	64	32	NW. ¼		...do		12.2 12.4	May 15, 1918 Aug 25, 1918	.2
25[b]	E. B. Young	21	63	13	SW. ¼		...do	47	12.0	July 15, 1918	
26	Warm Springs station	21	63	25			...do	10	5.5		
27	J. A. Mangason	21	64	28			Drilled.	190	160		
28	Cherry Creek station	23	63	3	NE. ¼		...do	100			
29	Star mine	24	63	1			Driven.	485	2.0		
30		25	63	25	SE. ¼		Dug	34	27.5	Aug. 8, 1918	
31	Greens station, Northern Nevada Railroad.	25	64				...do	12	7.0	....do	
32	Goshute station	27	64	26			Drilled.	60	10.0	Aug. 9, 1918	

[a] Altitudes at well No. 3 taken from contour map and other altitudes determined by aneroid barometer.
[b] For assay and classification of water see p. 42.

IRRIGATION.

AREAS SUITABLE FOR IRRIGATION.

It is estimated that about 185,000 acres of land in Steptoe Valley has a depth to the water table of less than 50 feet. Of this area approximately 95,000 acres has soil that is too alkaline for agriculture. Of the remaining 90,000 acres the water table in approximately 40,000 acres is less than 20 feet below the surface and about 7,000 acres of this area is in private ownership. Approximately 50,000 acres has the water table between 20 and 50 feet below the surface, and about 40,000 acres of this land is suitable for agriculture. Of this area of 40,000 acres between 7,000 and 8,000 acres is in private ownership. This leaves about 65,000 acres of Government land in Steptoe Valley suitable for agriculture under which the water table is not more than 50 feet below the surface.

COST OF IRRIGATION BY POWER-DRIVEN PUMPS.

The cost of irrigating land by power-driven pumps is controlled by so many different and varying factors that it is difficult to generalize upon the probable cost in Steptoe Valley. The first cost, or cost of installation, depends on the cost of labor and materials. Under the conditions in 1918, owing to the disturbances produced by the war, the cost of both materials and labor was so abnormally high that any estimate based on it would probably be of only temporary value.

The cost of engines and pumps was also abnormally high. Though future prices will doubtless be reduced, the amount of reduction is uncertain. The cost of distillate and gasoline is also high in this district, owing to the heavy freight tariffs in the valley. In 1918 coal retailed at $7 to $9 a ton. Some water power could perhaps be developed on Duck Creek and Steptoe Creek, but whether these developments could be economically made is doubtful because of the expense of obtaining the water rights. The feasibility of installing a community power plant for generating electric current by steam with coal for fuel and distributing the current to the users is worthy of further investigation.

The cost of the Moller dairy well, according to information furnished by Mr. F. A. Moller, the owner, is as follows: Casing (130 feet), $350; freight on casing, $20; labor, $329; fuel, $45; sharpening bit and other repairs, $15; total, $759. Data on the cost of Geological Survey well No. 3 are given on page 11.

DUTY OF WATER.

The amount of water required for irrigation in this valley depends largely on the kind of crop raised and on the amount of precipitation that may occur during the growing season. The State engineer of Nevada places the duty of water at 1 second-foot per 100 acres of land irrigated. This amount of water will be required for alfalfa, but grain, potatoes, and certain other crops may possibly be raised with even less.

AGRICULTURE.

The full possibilities of agriculture in Steptoe Valley have not been determined. Primarily this has been a mining and stock-raising country and in only a few places have attempts been made to do more than raise hay for feeding stock. However, where farming has been conducted with care and intelligence the results have been satisfactory. On the CCC ranch (a large ranch in secs. 5, 8, and 17, T. 15 N., R. 64 E.)—according to Mr. C. W. Stokesberg, the ranch foreman—the water of Steptoe Creek is used for irrigation. In 1918 there were 120 acres in oats, wheat, and barley, 180 acres in alfalfa, and 600 acres in wild hay. The stand of grain was heavy when visited, just before harvest began, and the prospects were good for large yields. Information was later received that the yield of barley was 2,810 pounds to the acre. It was reported that this crop of grain had received but two irrigations during the season and that the average yield of wheat harvested in previous years was more than 35 bushels to the acre. Good stands of well-filled wheat were seen on farms in sec. 23, T. 20 N., R. 64 E., in sec. 15, T. 21 N., R. 64 E., and in sec. 17, T. 26 N., R. 63 E. Aside from wild grass, alfalfa is the crop most extensively raised in Steptoe Valley. There is approximately 1,400 acres of alfalfa in the valley, with a reported total annual yield of about 5,000 tons. On land that is well farmed and properly irrigated three crops can be cut, but on most of the land only two crops are cut, owing to a lack of water or other conditions, the fall stand being used for pasture. Sweet clover was seen growing at one place. Its growth was heavy, and it measured 6 feet in height. Timothy was grown for hay at the Indian Springs farm with good success, the reported yield being 2 tons to the acre. Canadian field peas were growing as a mixed crop with oats. They had attained a height of about 3 feet and had good foliage.

Potatoes apparently do well. Reports by those who raise them show that a failure seldom occurs and that the yield is heavy. Several fields of growing potatoes were visited, all of which were doing well, but no yields were measured. Several truck gardens were visited near Ely and McGill in which ordinary garden vegetables, such as lettuce, onions, cabbage, peas, beans, garlic, radishes, carrots, turnips, pumpkins, squash, and rhubarb, were being raised. At one place sugar beets were growing, and their development was all that could be desired as to size, but no information is available relative to sugar content. The possibilities of growing sugar beets seem promising and warrant further investigation. Samples of alfalfa, oats, wheat, and sweet clover are shown in Plate VI.

The market conditions for all farm products at the mining camps in the regions are exceptionally good, and the known ore reserves give promise of good markets for years to come.

Stock raising has for many years been a profitable industry, but it is limited by the natural feed produced on the range and the amount of hay that can be produced for winter feeding. The amount of hay has hitherto been limited to that which can be cut from the marshlands and to the small amount that can be produced by irrigation from streams and springs.

SMELTER FUMES.

In the vicinity of McGill the presence of gases from the smelter is very noticeable. The prevailing winds are from the southwest and carry the fumes northward along the Schell Creek Mountains. Usually these fumes travel northward to Gallagher Gap, through which most of them pass into the Schell Creek Mountains and do not spread over the valley. Occasionally, however, they spread over large areas of the valley both to the north and to the south of McGill. However, it is believed that they will not interfere with agricultural development.

LAND SURVEYS.

Many of the subdivisional lines of the surveys in Steptoe Valley were run from 40 to 60 years ago. Consequently many of the original corner monuments are lost or obliterated. Some of the corners have been reestablished by private surveys, the accuracy of which is questionable. Before attempting to reclaim any of the lands it will be necessary to make resurveys, starting from known township or standard corners.

CROPS RAISED ON INDIAN SPRINGS RANCH.

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