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AN INTENSIVE STUDY

OF THE

WATER RESOURCES OF A PART OF OWENS VALLEY, CALIFORNIA

BY

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Prepared in cooperation with the Bureau of the Los Angeles Aqueduct and the State of California

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INTRODUCTION.

This paper presents in final form the results of studies made by the Department of Public Works, Bureau of the Los Angeles Aqueduct, city of Los Angeles, in cooperation with the United States Geological Survey and the State of California, for the purpose of determining the available underground water supply of Owens Valley, Cal.

The ideal conditions in this valley for obtaining accurate and reliable data regarding ground-water sources and outlets, the comprehensive field investigations carried on, and the general applicability of the ideas and results to ground-water conditions in valleys of arid regions make this a study that should be of general interest.

Owens Valley lies in east-central California and receives its relatively abundant water supply from precipitation on the eastern slope of the Sierra Nevada. It is an inclosed basin so lined by impervious rock formations that its ground waters have practically no subterranean outlet. Farming has been practiced here for more than 40 years, but because of the isolation of the valley the principal crops raised are alfalfa, corn, and grain, which can be consumed at home by live stock. The climate is arid, and irrigation is necessary for the production of crops. Canal systems deliver on the land water from Owens River and the tributary mountain streams. The area at present irrigated is limited by the natural flow of the streams in dry years during the period of maximum irrigation draft. The city of Los Angeles plans to develop a municipal water supply from the surplus surface waters reaching the lower end of the valley and from the underground sources, which have so far remained untouched.

The investigations were carried on under the supervision of William Mulholland, chief engineer of the Los Angeles aqueduct. The writer planned and executed all field and office work, and was competently aided at various times by two to six technical assistants. Field observations extended over a period of three years—from June, 1908, to June, 1911.

The study is based on the fact that the porous valley fill of the Owens Valley occupies an impervious undrained rock basin and that its void spaces constitute an immense underground storage reservoir. The principal source of supply of this reservoir is percolation from precipitation upon its surface, from stream channels crossing its surface, and from irrigation. The only outlets for the water in Owens Valley as a whole are afforded by evaporation from water surfaces and damp soil and by transpiration from vegetation. However, considering any isolated portion of the valley fill, the channel of Owens River provides an outlet for excess surface water which is not absorbed by the atmosphere. Owens Lake receives all such excess surface water from the river, and ultimately provides an outlet by evaporation from its expansive surface.

This paper presents and analyzes the data gathered in the Independence region, an isolated portion of the valley. The data are discussed under the following headings: Physical features of the region, precipitation, stream flow, evaporation and transpiration, percolation, ground water.

PHYSICAL FEATURES.

TOPOGRAPHY AND DRAINAGE.

Relation to adjacent territory.—Owens Valley lies along the western edge of the Great Basin, and has the general characteristics of that region, except within the tributary mountain zone to the west, where the typical features of the high Sierra prevail. It is bordered on three sides by desert regions. To the north lies the Mono basin; to the east the White, Inyo, and Coso mountains; and to the south a series of open valleys. The well-watered Sierra Nevada lies to the west, and three large rivers of the central valley of California, the San Joaquin, Kings, and Kern, have their sources along the same crest as streams tributary to Owens River. Owens Valley and its tributary mountain drainage exhibit within one hydrographic basin a very interesting combination of diverse climatic and resulting physiographic conditions. The higher levels of the Sierra Nevada receive abundant precipitation in the form of snow, whose annual variations are similar to those existing over the adjacent portion of its western slope. The remainder of Owens Valley has the characteristics of the desiccated valleys of the Great Basin, with the difference, however, that portions of its floor are covered with salt-grass meadows instead of desert sands, and the lowest depression is occupied by a large saline lake instead of a salt or alkali marsh. This difference is due to the relatively abundant water supply, and should this supply be suddenly cut off the valley would soon acquire all the characteristics of the dried-up valleys or ancient lake basins of which Death Valley is a well-known type. For a clear understanding of the surface and underground-water conditions in Owens Valley and their relation to climate, it is therefore of advantage to be familiar with the region west of the Sierra Nevada crest, where stream flow and precipitation records of considerable duration are available, and east of the White and Inyo mountains, where the partial desiccation exhibited in Owens Valley has advanced to completion.

Dimensions and areas.—In shape the valley is long and narrow, with a northwest-southeast trend. Its length from the Mono divide to the south end of Owens Lake is 120 miles; its width from crest to crest of the confining mountain ranges varies from 40 miles at the north end to 25 miles at Owens Lake, its minimum width being 15 miles, between Bishop and Big Pine. The total area of the valley as far south as Olancha, with its tributary mountain drainage, is about 3,300 square miles, of which 1,200 square miles is occupied by desert mountains that yield practically no run-off; 536 square miles in the Sierra Nevada yield a large run-off; and 1,580 square miles consist of transition slopes, valley floor, and the surface of Owens Lake.

A secondary range, extending from a point a few miles north of the town of Bishop to the Mono divide, separates the upper valley into two parts, the western part being known as Long Valley. A depression called Round Valley lies between Owens Valley proper and Long Valley. Owens Valley extends as far south as the south end of Owens Lake, a distance of 80 miles, and its floor ranges in width from 2 to 8 miles.

Elevations and slopes.—The elevation of the valley floor ranges from about 8,000 feet above sea level at the Mono divide to 3,570 feet at Owens Lake, the lowest point in the valley. The average slope in Long Valley is between 25 and 35 feet to the mile, and the elevation at its lower end is about 6,670 feet. From the end of Long Valley to the head of Owens Valley proper there is a drop of 2,200 feet in a distance of about 20 miles. Owens River has here cut a deep gorge through a lava sheet which extends across the valley. From the big bend in the river northeast of Bishop, at an elevation of about 4,100 feet, the slope to Owens Lake is fairly uniform and averages 7.5 feet to the mile. The average elevation of the outer borders of the valley along the base of the Sierra Nevada is about 6,000 feet and the elevation along the eastern rim ranges from 4,000 feet near Owens Lake to 6,000 feet at the base of the White Mountains. The slopes that lie transverse to the valley are steep. The eastern face of the Sierra Nevada drops off at an average rate of 1,500 to 2,000 feet to the mile, and the slopes of the alluvial deposits flanking the range vary from 350 to 600 feet to the mile. The slopes of the western faces of the White and Inyo mountains range from 700 to 2,000 feet to the mile. The valley floor has very light transverse slopes.

The elevation of the crest of the Sierra Nevada averages 12,500 feet, though many peaks exceed this altitude, some of them by more than 1,500 feet. The lowest portion of the range is that extending from Mammoth Pass northward to the head of Glass Creek, the most northerly tributary of Owens River, and the highest is in the vicinity of Mount Whitney. The White and Inyo mountains have an average elevation of 10,000 feet and northeast of Bishop thay attain a height of over 13,000 feet.

Drainage.—The drainage system of the valley consists of a trunk stream, Owens River, fed by about 40 small tributaries entering at fairly regular intervals from the west. Water reaching the river from the east is derived from cloud-bursts, which occur at long intervals, and is negligible in amount. The river discharges into Owens Lake, a saline body of water that has no outlet except by evaporation. The productive drainage areas of the tributary streams are the mountain canyons of the Sierra Nevada. The discharge from these canyons is perennial and represents true run-off, but in crossing the porous alluvial formation of the valley the streams lose much water, so that only a small part of this run-off reaches Owens River directly. This river provides a partial outlet for underground waters, however, and during low stages a large part of its flow is made up of seepage and spring waters.

STRUCTURE OF THE VALLEY.

The geologic structure of the Owens Valley region has interested geologists for many years. The following summary of facts concerning the structure is abstracted from a report by W. T. Lee.[1] The information presented has been verified by the writer. The valley is a V-shaped trough, whose bottom is filled to considerable depth with unconsolidated alluvial débris carried from the steep confining mountain faces by running water. The trough was probably formed by faulting along the parallel planes represented by the steep eastern faces of the Sierra Nevada and White mountains, accompanied by elevation of the eastern margins and westward tilting of the great crustal blocks represented by the ranges. There was probably also local faulting of the White Mountain block along its western face and settlement of the detached block which at present lies buried beneath the valley fill. The western face of the trough is the granite escarpment of the Sierra Nevada, and the eastern face is composed of the sedimentary and igneous rocks of the White Mountains.

There are not a sufficient number of deep well borings to determine the character of the valley fill, but in general lake and river deposits occupy the lower portions of the valley and coarse mountain wash the

[1] Geology and water resources of Owens Valley, California: Water-Supply Paper U. S. Geol. Survey No. 181, 1906.

upper edges, a zone of interbedded fine and coarse material lying between.

Inequalities in precipitation have resulted in marked inequality in the development of detrital cones along the bases of the parallel ranges. The cones at the base of the Sierra Nevada (Pl. II, *A*) are connected with one another, forming a continuous slope, and are of immense size, rising to a maximum elevation of 2,000 feet above the river and extending out into the valley for 3 to 7 miles; those along the White Mountains are isolated and have maximum elevations of 1,000 feet and widths of half a mile to 2 miles.

The porous nature of the valley fill and the imperviousness of the rock basin in which it lies make ideal conditions for the storage of underground water.

GROUND-WATER REGIONS.

Considering the valley fill as an immense underground storage reservoir, there are four divisions, or ground-water regions, into which the reservoir is naturally divided by topographic and geologic features. These basins and their tributary drainage areas will be designated as the Long Valley region, the Bishop-Big Pine region, the Independence region, and the Owens Lake region. They are separated by transverse ranges of hills, which partly isolate sections of the valley fill and to a large extent cut off underflow from one region to another. (See Pl. I.)

The Long Valley region includes Long Valley and the tributary drainage above the proposed dam site, and has a total area of 444 square miles. Of this area 23 per cent is the steep eastern slope of the Sierra Nevada and is productive of run-off, 16 per cent consists of desert mountains, 31 per cent is an elevated plateau with rolling hills that support a scattered growth of Jeffrey pine and are covered with a deep surface mantle of loose volcanic ash and pumice, and 30 per cent is made up of lower mountain slopes and desert valley floor. Conditions are very favorable for underground storage, as is proved by the abundance of springs and the regular flow of Owens River at the point where it leaves the valley. A lava sheet has buried the original topography between Long Valley and Owens Valley so that it is difficult to determine to what extent the underflow is cut off, but numerous springs emerging from the lower edge of the lava indicate an outlet through and beneath it.

The Bishop-Big Pine region includes an area of 609 square miles lying between Owens River and the Sierra crest and extending southward to the Poverty Hills, which extend eastward across the valley from Tinemaha Point within 1½ miles of the base of the White Mountains. The high mountains constitute 41 per cent of the area, lower mountain faces and outwash slopes 45 per cent, and valley floor 14 per cent, a large part of the valley being cultivated or meadow land. The surface of the valley fill is very extensively irrigated and the region is also peculiar in having a few large streams draining the adjacent Sierra instead of many small ones. The underflow past Tinemaha Point is of necessity small, because of the contracted cross-sectional area, light gradient, and fineness of the material. The desert area east of Owens River is not included in the region because of its negligible contribution to the water supply.

The Independence region extends westward from Owens River to the crest of the Sierra and southward to the Alabama Hills. The eastern base of the Alabama Hills is 3 miles from the Inyo Mountains. The underflow past the Point of the Alabamas is small, though probably greater than that past Tinemaha Point, because of the larger cross section. The underground water resources of this region are the subject of this paper, and its physical features are described in detail.

The Owens Lake region embraces the territory between Owens River, Owens Lake, and the Sierra crest and extends southward to include Olancha Creek. Its area, exclusive of the lake, is 275 square miles, of which 36 per cent consists of high mountains, 42 per cent lower mountain faces and outwash slope, and 22 per cent valley floor, only a small part of which is cultivated or meadow land. The area of Owens Lake is about 90 square miles. South of Owens Lake, at Haiwee, the bedrock cuts off any possible ground-water outlet in that direction.

Owens Valley is therefore a water-tight basin receiving its supply entirely from precipitation and disposing of it only by evaporation and transpiration. All waters not thus disposed of in the upper regions flow down the channel of Owens River to Owens Lake and there have an outlet by evaporation from the water surface.

Because of the isolation of its valley fill, its simple topographic and geologic structure, its uniform run-off features of large contiguous areas, the small extent of its irrigation, its mild winter climate, and its accessibility, the Independence region was selected at the commencement of fieldwork as the most favorable part of Owens Valley for a careful study of underground-water conditions. It has all the typical features of an underground reservoir of the arid region, developed with remarkable regularity and completeness, making it an ideal location for these investigations. For the purposes of this study its surface has been classified as high mountain drainage, intermediate mountain slopes, outwash slope, and valley floor (Table 1 and Pl. I).

The high mountain drainage (Pl. II) embraces the eastern slope of the Sierra Nevada and consists of a series of seventeen small canyons which are the productive drainage basins of streams tributary to Owens River (Table 2). These canyons are all narrow at the

A. SIERRA NEVADA FROM INDEPENDENCE SHOWING OUTWASH SLOPE, INTERMEDIATE SLOPE, AND HIGH MOUNTAINS.

B. CREST OF SIERRA NEVADA FROM KEARSARGE PEAK.

A. TERMINAL MORAINE IN CANYON OF SOUTH FORK OF OAK CREEK.

B. SLIDE AND MORAINAL MATERIAL IN CANYON OF NORTH FORK OF OAK CREEK.

mouth (the 6,500-foot level) and broaden out more or less toward the summit, presenting a shape that is roughly triangular. They are separated by high knife-edge ridges, which terminate in triangular slopes facing the valley. They have been cut by water erosion and sculptured by active glaciation above the 7,500-foot level, their upper portions being well-developed glacial cirques. In many places below the cirques are series of benches occupied by glacial lakes or meadows. Cross sections of the canyons within the region of glaciation have the typical U shape, but below the 7,500-foot contour the V shape produced by water erosion prevails. Most of the cirque floors are buried beneath morainal accumulations; some of the polished canyon bottoms between the 11,500 and 8,000 foot levels are swept clean of débris; others are completely buried by morainal material. Terminal and lateral moraines of considerable size occupy the canyon floors between the 8,000 and 7,000 foot levels. (See Pl. III, *A*.) The canyon walls are encumbered by three types of rock débris—talus, slide, and decomposed rock in place—whose bases are superposed upon the morainal deposits of the canyon floors. (See Pl. III, *B*). The talus lies at the bases of cliffs in continuous slopes or cones that do not reach great height. The slides lie on steep slopes that are subject to rapid weathering and attain considerable size, in places reaching the ridge crests. The decomposed-rock mantles cover the canyon walls below the region of glaciation. In general, the morainal deposits of the cirque floors and the talus cones are composed of angular blocks with but little fine material, and the lower morainal material is a well-graded mixture of all sizes from glacial meal to large bowlders. The slides are of both types, but the mantle rock is largely fine material. The general formation is granitic but includes here and there overlying bodies of metamorphosed slates. The solid granite, although checked and disintegrated at the surface, is unfissured beneath, and is therefore impervious to water. The exposed glaciated surfaces show very little weathering. These conditions have been described in detail because of their important bearing on run-off.

The intermediate mountain slopes (Pls. II, *A*, and IV, *A*) are the triangular areas terminating the ridges between the canyons and probably represent the original face of the range before it had been actively eroded (Table 3). Their lower boundary has been arbitrarily placed at the 6,500-foot contour, and their apexes reach a maximum elevation of about 12,000 feet. They have a steep uniform slope of 2,000 to 3,000 feet to the mile and in general are covered with a mantle of disintegrated rock and slide material which merges into the valley fill.

The outwash slope (Pl. II, *A*) is the desert portion of the surface of the valley fill, extending from the 6,500-foot contour at the base of the Sierra Nevada to the upper edge of grass and irrigated land in the valley (3,900 to 4,000 feet). Its surface is composed of loose bowlders, gravel, and sand deposited during past ages by torrential streams coming from the mountains. This deposit is of unknown depth and lies upon a buried ancient rocky surface, the higher hills of which appear above the present surface as buttes or knolls. The channels of streams draining the mountain canyons cross this slope in trenches, which near the mountains are 25 to 50 feet deep.

The valley floor (Pl. XXX, p. 84) embraces the area between the outwash slope and Owens River, and its surface may be classified as cultivated land, grass or meadow land, alkali land, and desert. The upper edge has a maximum slope of about 120 feet to the mile, but within a short distance it merges into the practically level valley. The surface is soil to a depth of 1 to 3 feet except on the desert land, where it is fine sand. Lying beneath the surface material are thin alternating layers of clay, sand, and gravel to unknown depths. The cultivated land is largely located along the upper margin of the valley floor adjacent to the creek channels. It is described more fully below in connection with experiments on the duty of water. The grass or meadow lands lie between and to the east of the ranches and extend well out into the level valley. The growth is most luxuriant in the spring zone, which is about a quarter of a mile wide and is situated at the upper edge of the valley floor. Here are numerous small flowing springs, with temperatures of about 62°, which start the meadow grass early in the season and keep it green until late in the autumn. Farther out in the valley the salt grass makes a green carpet from May until late July, when it begins to turn yellow for lack of water. In the salt-grass land there is always a deposit of alkali about the plant roots, and the soil surface is crusted. The spring zone, however, is free from alkali. The alkali land is practically bare of vegetation and is thickly crusted with white salts. It lies in the more level areas in the center of the valley. Desert land lies between the grass land and the river. Because of its elevation above the surrounding valley and its position with respect to bluffs it is usually well subdrained. The bluff along the earthquake fault of the year 1872 and the river bluff are both at the east edge of desert zones. Along the fault line is a succession of springs, meadows, and undrained lakes which are discussed in connection with ground-water phenomena.

The desert area to the east of Owens River yields no appreciable run-off, and owing to its light precipitation, it makes no contribution to the ground water. It is of no interest to this study, therefore, except in connection with chemical analyses of its well waters.

A. VIEW OF KEARSARGE PEAK, SHOWING INTERMEDIATE MOUNTAIN SLOPE BETWEEN OAK AND LITTLE PINE CREEKS AND LOCATION OF RAIN GAGES NOS. 10 AND 11.

B. SNOW MELTING AND DRAINING INTO SLIDE MATERIAL.

PRECIPITATION.

GENERAL CONDITIONS.

The water which occurs within a drainage area, whether found upon the surface or underground, is in general derived from precipitation within the boundaries of the area. This is true of the Independence region, and therefore the determination of the amount and distribution of precipitation upon its surface is the first step toward obtaining knowledge of the quantity of its underground water resources. The problem is far from being a simple one, for not only is the region visited by three distinct types of storm, each of which exhibits local peculiarities, but the topography has a marked influence on the amount and distribution of precipitation. Records kept in the valley are entirely inadequate to furnish knowledge of the quantity, intensity, and distribution of precipitation in the adjacent mountains, and large differences occur even upon the valley floor. An average precipitation computed for the Independence region as a whole would thus be meaningless and lead to erroneous conclusions. It is possible, however, so to divide the area that by establishing gages at well-chosen points average values can be obtained for the several subdivisions—the method adopted in these investigations.

The following discussion of precipitation describes the sources and characteristics of Owens Valley storms, lists the various records available in the region and adjacent territory, and considers in detail the distribution of precipitation with regard to time and geographic position.

CHARACTER OF STORMS.

There are three distinct types of storm which yield precipitation over the Independence region, two of them of distant origin and widespread in extent and the third local. Both of the general types advance over the western border of the North American Continent from the Pacific Ocean, one from the north Pacific, appearing first along the coast of British Columbia, Washington, and Oregon, and the other from the south Pacific, appearing along the coast of southern California and extending over the valley of the Colorado. The local storms gather along the high crest of the Sierra Nevada and occasionally reach out over the valley or form around secondary storm centers in the Inyo Mountains.

The storms appearing from the north Pacific are those which cause precipitation over Washington, Oregon, California north of Tehachapi, and occasionally southern California and the region to the east. Their frequency and intensity in California is greatest during the rainy season, which in the extreme northern part of the State extends from October to April and in the vicinity of San Francisco from November to March. Whether the California rainy season is wet or dry depends upon the distance south to which these north Pacific storm centers or "lows" extend. Even during a wet season few of them reach the extreme south end of the State with sufficient intensity to produce rain. McAdie [1] states that not one-tenth of the north Pacific "lows" have any appreciable effect on the climate of San Diego.

The high Sierra as seen from Independence is a very sensitive indicator of approaching storms over northern and central California from September to May, inclusive. The coming of one of the north Pacific storms is at once indicated either by a dark haze gathering above and to the west of the crest line, which soon thickens and settles on the mountains, or by a thick, heavy mist rising from the western slope of the range and gradually creeping over the summit, enveloping the desert slope to a level several thousand feet below the crest. This condition lasts only a few hours if the "low" does not extend very far south, but if the storm is one of considerable intensity in central California and reaches into southern California the enveloping clouds will remain for several days and during a portion of the time will extend out over Owens Valley. In either event precipitation in the form of snow occurs on the high Sierra, ranging in amount from a few inches in depth to many feet, depending on the length of time the clouds remain and the intensity of the storm. During September, October, April, and May precipitation does not often occur from these storms beyond the base of the mountains. From November to March, however, storm clouds are likely at any time to extend out over the valley, yielding snow or rain. These storms illustrate most strikingly the effect on precipitation of elevation. They supply the major part of the precipitation in the Independence region.

The storms from the south Pacific, or "Sonoras," as they are locally known in the region of their first appearance, cause rain throughout southern California and eastward over the California desert into the Great Basin region. They are sufficiently intense to yield precipitation in Owens Valley during September and October, averaging about two a year. They cover the valley as a whole, favoring neither the Sierra nor the Inyo Range, and are characterized by many small storms which travel up the valley, often crossing from one range to the other several times. These small storms yield rain along their paths, sometimes of considerable intensity, and are often accompanied by electric phenomena. Rain-gage observations after such a storm may appear inconsistent, large readings being obtained in the paths of the storm clouds and small readings elsewhere, although usually a slight increase is noticeable from the valley toward the mountains. This type of general storm yields a

[1] McAdie, A. G., Climatology of California: Bull. U. S. Weather Bur. No. L, 1903.

large proportion of the precipitation observed at stations along the east edge of the valley, such as Keeler, Laws, and Aqueduct gage No. 18, but a relatively smaller amount near the Sierra Nevada.

The storms of local origin are the afternoon thunder showers of the high Sierra, which occur during July and August. They are usually confined to the higher levels of the Sierra Nevada, though occasionally one will develop sufficient intensity to cause precipitation over the entire valley floor and upon the Inyo Mountains. The higher elevations of the Inyo Range seem to act as secondary storm centers toward which clouds detached from the Sierra will travel. These storms are always accompanied by electric discharges. They often gather about a mountain crest, appearing in the form of a thick black cloud, from which rain will suddenly commence to fall with such intensity as to be called a cloud-burst, filling the stream channels and washes with water and bringing destruction to everything in its path. These storms are said by old residents to have greater frequency and intensity after a dry winter and have followed that rule during the period of these investigations. Precipitation from these storms forms a greater relative part of the annual total along the eastern rim of the valley floor than on the west. Stream flow from the Sierra is augmented during their prevalence.

OBSERVATIONS IN THE INDEPENDENCE REGION.

Observations of precipitation were made in the Independence region as early as 1865, under the direction of United States Army officers stationed at Fort Independence. The record extends unbroken from September, 1866, to August, 1877, and was obtained under conditions sufficiently similar to permit its being combined with the more recent Weather Bureau record at Independence. The latter covers the periods from September, 1892, to August, 1895, and September, 1898, to August, 1910, so that in all there are 26 seasons for which precipitation records are available (Table 4). These observations were made according to the methods practiced by each organization and by men instructed and detailed for that purpose. The Weather Bureau, in fact, maintains a completely equipped meteorologic station at Independence, where continuous records of temperature, barometric pressure, wind, and sunshine and 12-hour measurements of humidity are made, in addition to the measurements of precipitation. The data can therefore be considered as reliable as the ordinarily accepted rainfall records in use by engineers. These records are the only ones available within the region, other than those gathered in the investigations for the Los Angeles aqueduct.

In connection with the aqueduct project there have been established and maintained 20 precipitation stations, distributed systematically over the accessible portion of the region. Most of this area is uninhabited and during the period of greatest precipitation in the spring, fall, and winter months, it is practically impossible to get into the higher mountains because of the depth of light, feathery snow and the rugged topography. The gages were distributed over the valley floor and outwash slopes and could be reached during one day by mounted observers stationed at points in the valley where shelter was available. After a heavy snow it took more than 12 hours continuous traveling on the longer routes, part of the time on horseback and the remainder on snowshoes, to cover even this area. The only methods by which observations can be obtained in the high Sierra are to erect shelters which can be occupied permanently by observers during the winter, or to install snow gages which will hold a season's catch. Although desirable, it was not considered necessary to obtain records of precipitation within the high mountain area, and no direct attempt was made to get them.

Two considerations determined the general location of the precipitation gages. First, they were each to be representative of a specific portion of that area of the Independence region over which it was essential to have data on precipitation; second, they were to be so arranged that a study could be made of the influence of elevation upon precipitation. In carrying out these purposes the gages were placed approximately in straight lines extending from the valley floor directly up the alluvial slopes and as nearly at right angles to the trend of the Sierra Nevada crest as was practicable. The intersections of the 500-foot contours with these lines determined the approximate vertical location of the gages. The exact locations were selected with respect to accessibility from roads or trails and the recognized requirements for good exposure. (See Pls. IV, *A*, and V, *A*.)

The location of the aqueduct gages is shown on Plate I and a description of them is given in Table 5. The following are additional notes bearing on the reliability of the records. Gage No. 1 was established near Black Rock Springs in connection with the record of evaporation from water surface at that point and was observed daily by a reliable man from a neighboring aqueduct camp. Gage No. 1-A was established at the Black Rock ranch and observed daily by the ranch foreman. Gages Nos. 2 to 6 comprise the Taboose group and were observed at the end of each general storm by an engineering field assistant. Gage No. 6-A was located on the summit of a narrow ridge, where the catch was about 30 per cent too small, as was discovered by establishing gage No. 6 near by on the unbroken slope of the mountain. Gages Nos. 18, 17, and 7 to 11 comprise the Oak group and were observed at the end of each general storm by an engineering field assistant. Gages Nos. 12 to 16 con-

A. RAIN GAGE No. 11 AFTER A SNOWSTORM.

B. GAGING STATION ON OWENS RIVER AT CHARLIES BUTTE.

stitute the Bairs group and were also observed after general storms. Gage No. 19 was established at the Forest Service station on Oak Creek and was observed daily by the resident ranger. The observations were carefully made and the record is reliable. Gage No. 20 was established at aqueduct power plant No. 2 on Division Creek and was observed daily by the head operator. The record is reliable.

The gage used was the ordinary 8-inch cylindrical gage of the United States Weather Bureau described in its "Instructions for cooperative observers." The funnel-shaped receiver, however, was dispensed with, so that the catch fell directly into the 8-inch cylinder. The mounted observer carried a measuring tube and cedar stick and poured the catch from the container into the smaller tube for measurement. Considerable difficulty was encountered in reducing snow to equivalent water. During the first season an attempt was made to follow the Weather Bureau instructions, but this was almost impossible under field conditions. The use during the second season of a spring balance which could be carried by the observer proved very satisfactory. The catch and container were weighed together, the weight of the container subtracted, and the depth of water computed from the cross-sectional area of the container on a basis of 62.5 pounds to the cubic foot of water. The snow catch in gages of this type is liable to considerable error, due to wind currents carrying the flakes across the mouth of the gage. The relative error was the same in all the gages, however, as the exposures were all on the open slope without the protection of trees or other obstacles, and no attempt was made to correct or obviate it. The results of the observations for the seasons 1908–9 and 1909–10 are given in Tables 6 and 7.

OBSERVATIONS IN ADJACENT AREAS.

Records which are valuable for comparison have been kept in other portions of the Owens Valley, both north and south of the Independence region. Cooperative Weather Bureau observers report from Bishop and Lone Pine and railroad agents have made observations at Laws and Keeler. (See Pl. I, p. 10, for location of these stations.) The railroad records are not as reliable as are the Government records, however, because 3-inch diameter gages were used and exposures were poorly chosen. These records cover the following seasons: Bishop, 1894–95 to 1908–9; Laws, 1883–84 to 1895–96; Keeler, 1884–85 to 1907–8; Lone Pine, 1904–5 to 1909–10. They are reproduced in Tables 8 to 11, expressed as seasonal totals for the rainfall year, September 1 to August 31.

Seasonal precipitation in Owens Valley, although derived from three types of storm, shows the predominence of the north Pacific type, which is practically the sole source of supply on the adjacent western slope of the Sierra Nevada and in the San Joaquin Valley.

It is a reasonable assumption, therefore, that if relative seasonal variations at stations located in the areas just mentioned show a general similarity, the variations in Owens Valley and especially in the high Sierra have the same peculiarities and could be investigated from the records at stations west of the Sierra crest when local data are not available. Furthermore, a study of the relation of rainfall and run-off for the rivers draining the west slope of the Sierra Nevada is desirable for comparative purposes. Such Weather Bureau records as are available in this area are presented in Tables 12 to 17, computed for a rainfall year extending from September 1 to August 31. Values which appear inclosed in parentheses indicate that one or more months are missing in the published record; the figures given were obtained by estimating the missing quantity on the assumption that monthly variations at near-by stations are similar unless conditions indicate otherwise. Thus the record for October, 1907, is missing at Visalia. The mean of 20 observed Octobers at Visalia is 0.51 inch; the mean of the same 20 observed Octobers at Fresno is 0.64 inch. The precipitation at Fresno in October, 1907, was 69 per cent greater than the 20-month average at that point; therefore, the same ratio being assumed, the precipitation at Visalia in October, 1907, was 0.86 inch. Similar methods were used in filling in other incomplete records.

The data were drawn from Water-Supply Paper 81 of the United States Geological Survey, from monthly and annual climatological reports, and Bulletin L of the Weather Bureau, and from correspondence with the Weather Bureau and with persons having records in their possession. Where discrepancies were observed in the same record as given by different authorities, the published Weather Bureau record was used.

It will be noted by examination of Tables 12 to 17 and Plate VII (p. 28) that records at stations within or near the drainage areas of six large Sierra streams adjacent to Owens Valley have been grouped. The streams chosen are Tuolumne, Merced, Kings, Kaweah, Tule, and Kern rivers and are those for which studies of the relation of rainfall and run-off were made, the grouping being intended to assist in the computations of run-off. Many of the records are of short duration; therefore, to obtain comparable long-term mean values for all stations within each drainage area, computations were made, based on the longest record in the area. Thus four base stations are available for the Merced drainage area (Table 13)—Merced, with observations for 38 seasons; Crockers and Summerdale, with 14 each; and Yosemite, with 7. The observed 14-year mean at Summerdale is 54.90 inches. The mean for the same years at Merced is 11.30 inches and for 38 observed years 10.79 inches. The 38-year mean at Summerdale is

52.40 inches, computed by multiplying the 14-year mean by the ratio $\frac{10.79}{11.30}$. Long-term means for the other base stations in the Merced area were computed similarly. The observed and computed means for each base station are given in the tables.

A number of records at stations distributed along two transverse sections of the Sierra Nevada are also a subject for study in this report in connection with the phenomena of precipitation in the range. The detail of these records is of no value here, however, and is omitted, the observed and computed long-term seasonal means being given in Tables 19 and 20. These groups of gages lie along the Central Pacific and Mokelumne sections shown in Plate VII and will be discussed later in this report. A few other precipitation records have also been used for various purposes, but it is not considered necessary to incorporate them here.

TIME DISTRIBUTION OF PRECIPITATION IN THE INDEPENDENCE REGION.

The distribution of total precipitation with regard to time will be considered from its annual, monthly, and daily aspects. The mean annual precipitation at various stations and the departures therefrom are important as showing the average volume of water derived from this source; the extent of areas which, because of similar storm conditions, receive about the same percentage of the mean precipitation from year to year; the general variations to be expected in annual stream flow; and the variations in ground-water supplies as influenced by precipitation. A knowledge of the percentage of the mean annual precipitation falling during the several months of the year is important in determining the type of storm which predominates in certain areas, the effectiveness of precipitation as a source and regulator of stream flow, and its value as a source of underground water. Records of daily variations are also useful in determining the value of precipitation as a source of underground water. As stream flow is an important source of underground water in the Independence region, the knowledge of the time distribution of precipitation is especially important.

In general the distribution of precipitation in Owens Valley and adjacent areas is controlled by the types of storm from which it is derived. Each type has its peculiarities of annual and monthly variation, as well as distinctive characteristics for shorter periods. In general the annual yield from north Pacific storms will vary from twice to one-third the normal, 80 per cent of it occurring between November 1 and March 31 and most of the remainder in October, April, and May. Precipitation in these storms is not confined to any portion of the day and never occurs in intense local cloudbursts, although heavy downpours often continue for periods greater than 24 hours. The annual yield from the Sonora storms is very erratic and subject to wide variation. It favors the months of July, August, September, and October and is often characterized by local cloudbursts. The prevalence of mountain thunderstorms is also extremely variable from year to year. They ordinarily occur in the afternoon during the months of July and August and are often accompanied by cloudbursts. The time distribution of precipitation at any point in the area under consideration depends on the predominant type at that point.

The characteristics of monthly distribution for the Owens Valley and adjacent regions are shown graphically in figure 1. This shows monthly distribution as percentage of mean annual precipitation and is especially useful in determining the prevailing storm types by reason of the tendency to concentration in certain months. It is to be noted that the north Pacific type prevails almost exclusively in central California, the Sierra Nevada, and the valley of southern California. Exceptions are to be noted at San Diego, which receives precipitation to a small extent from Sonora storms and in the high Sierra, where if records were available the yield from local storms would be apparent. Great Basin stations such as Hawthorne, which are situated far enough east to be beyond the influence of the Sierra Nevada, show the prevalence of both general storm types by the uniform monthly distribution throughout the year, the precipitation during the months November to March being but 54 per cent of the annual. Stations near the Sierra, such as Reno and those in Owens Valley, are also visited by both types, but the north Pacific storms predominate, so that the typical concentration of precipitation from November 1 to March 31 is still very marked. Keeler, however, which is close to the desert, shows a more uniform distribution. It would appear, therefore, that in Owens Valley the north Pacific storms yield the bulk of precipitation but that in crossing the valley from west to east the Sonora storms become relatively more important. Study of figure 1 also shows that precipitation in Owens Valley falls largely during the winter months, when low temperatures and high humidity prevail. Conditions therefore favor the storage of water in the mountains as snow from winter to summer and also favor maximum percolation from precipitation into the porous materials underlying the valley.

Variations in mean seasonal precipitation for Owens Valley and adjacent regions are presented graphically in Plate VI and figure 2. Plate VI shows the relative amount falling in each year over several river drainage areas. It was prepared by computing for each precipitation base station listed in Tables 12 to 17 the percentage each year's rainfall bears to the long-term mean and averaging the percentages for all stations included in each drainage area. The latter process is justified by the close agreement of percentages for all stations in each drainage area. The assumption that these percentages apply to the upper portions of the drainage areas where records are not available is justified by figure 2, showing the general agreement of percentages at stations along the Southern Pacific Railroad from Sacramento, Cal., to Reno, Nev. In general, Plate VI shows that similar storm conditions exist over the west slope of the Sierra Nevada, the San Joaquin Valley, and southern California,

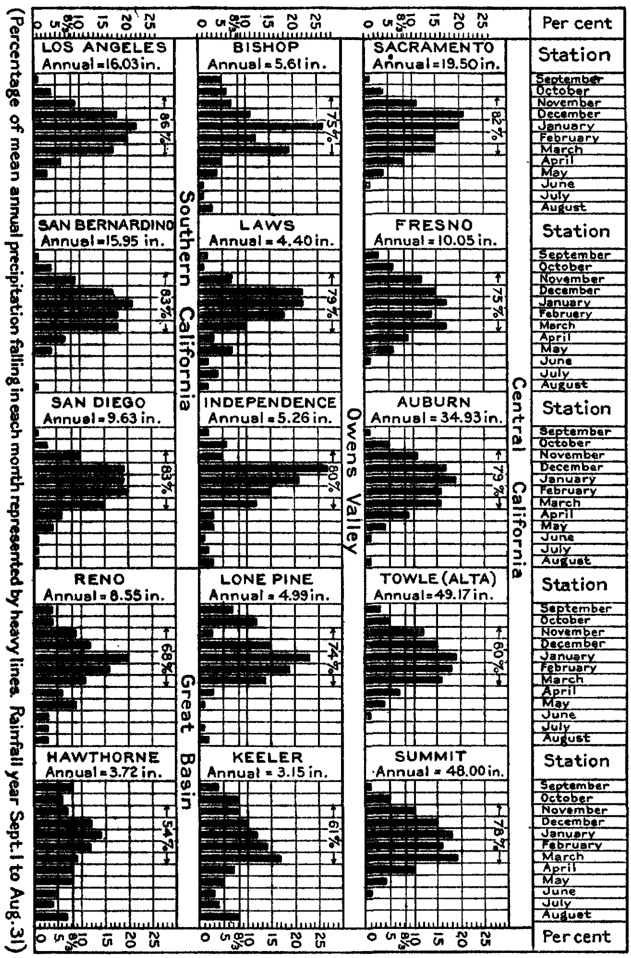


FIGURE 1.—Monthly distribution of precipitation in Owens Valley and adjacent areas.

as the percentages for any given year have a general similarity. There is a noticeable tendency, however, for years which are normal or below normal in central California to be progressively drier toward the south, as is illustrated by the two series of dry seasons, 1880–1883 and 1897–1900. Protracted shortages in precipitation do not exceed three years in length, and, except in the notably dry period of 1897 to 1900 in southern California, do not include years of very severe drought. Such years occur singly, and north of the Tehachapi Mountains there has been but one such year during the 40 years of record. In southern California, however, there have been seven years of severe drought within 38 years, six of which occurred in the eleven seasons, 1893–94 to 1903–4, inclusive. Great secular variations and very severe run-off shortages are therefore to be expected in this region.

Annual variations at Owens Valley stations are not in close agreement with those of either central or southern California, and a glance

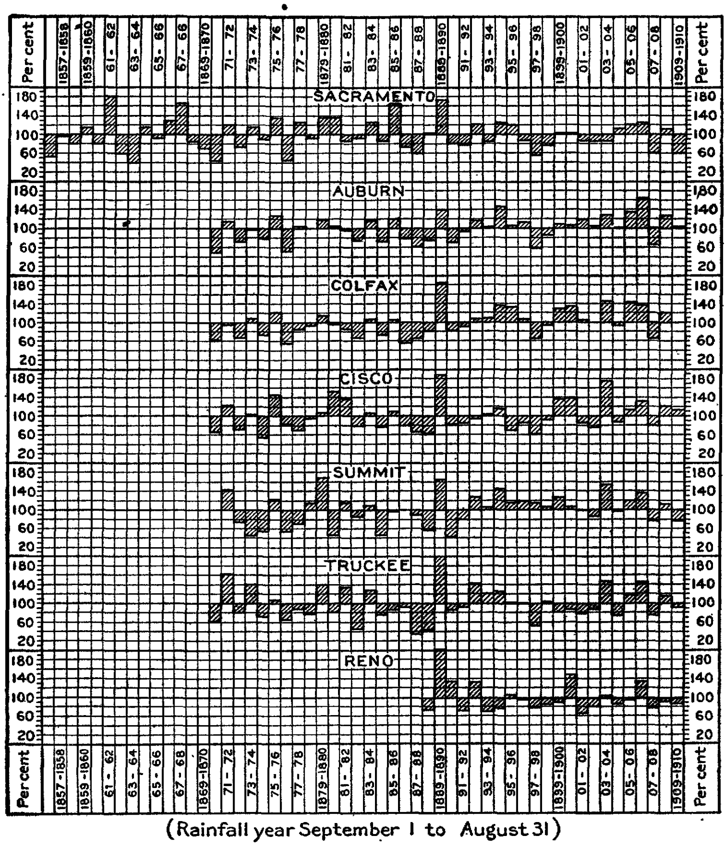
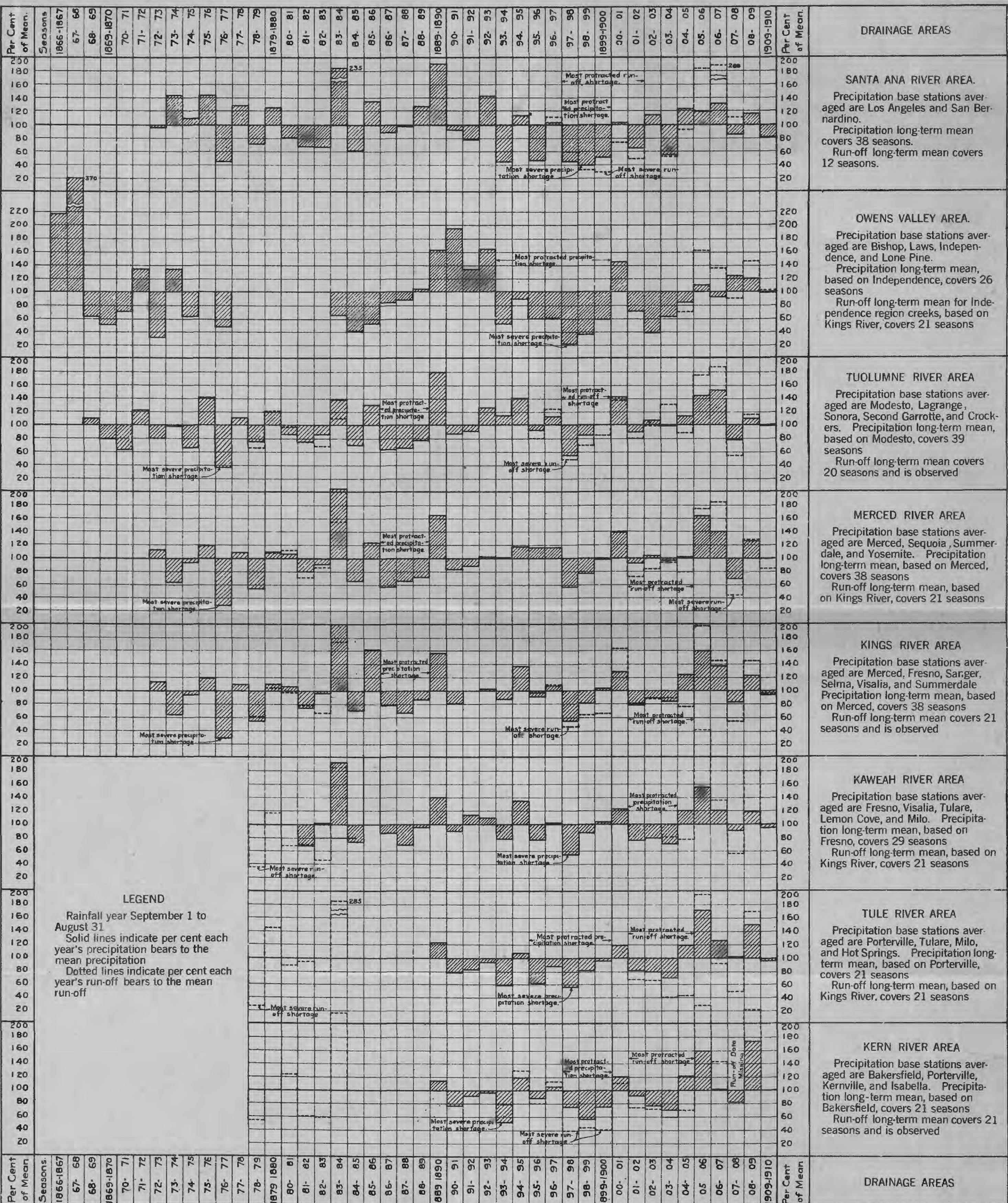


FIGURE 2.—Variation in seasonal precipitation at stations on Southern Pacific Railroad between Sacramento and Reno.

at Table 18 will show that there is not complete agreement among the individual base stations. The reason for this is the position of the stations in the valley where total precipitation is small, and where storm types other than the north Pacific have greater relative importance. It is very probable that mountain stations located east of the Sierra Nevada crest would show variations similar to those for Kings and Merced rivers, for seasonal variations in flow of



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VARIATION IN SEASONAL PRECIPITATION AND RUN-OFF EXPRESSED AS PERCENTAGE OF COMPUTED LONG-TERM MEANS FOR OWENS VALLEY

Independence region creeks agree very closely with those of Kings River. Variations over the floor of Owens Valley may be said to agree in a general way with those in southern California, the tenden-

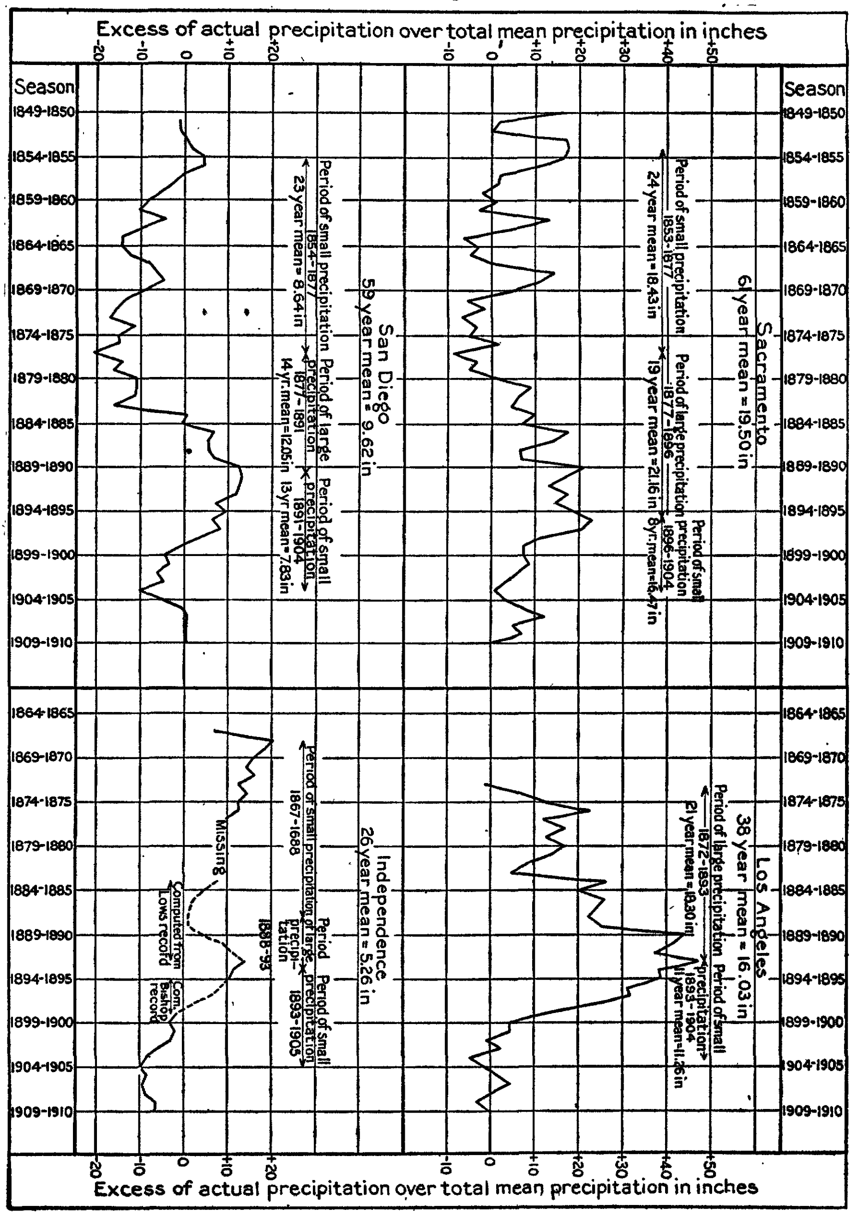

FIGURE 3.—Residual mass curves of precipitation for stations in Owens Valley and adjacent areas.

cies observed in the latter region being in the former developed into prominent characteristics. The percentages in Table 18 are to be considered as applying to only the valley portion of Owens Valley, the tributary mountain drainage areas of the Sierra Nevada having the annual variation observed for the adjacent west slope of the range. It will be noted from Plate VI that Owens Valley stations are subject to extended periods of drought, the longest one covering seven years and including the driest year on record. The annual variations are extreme, ranging from 350 to 20 per cent of the mean. Therefore, should it be found that direct percolation from precipitation is the principal source of ground water for the Independence region, large annual fluctuations in the ground-water surface would be expected, while if percolation from streams was the most effective source the fluctuations would be small.

The residual mass curves presented in figure 3 for Sacramento, San Diego, Los Angeles, and Independence are useful in studying secular variations in precipitation, for they indicate tendencies covering periods of many years. Spear's description [1] of the construction of such curves is as follows:

> The ordinate of any point on these curves represents the excess of the total actual precipitation, from the beginning of the period considered to the given time, over the total that would have fallen during the same period had the precipitation occurred at a rate equal to the mean precipitation from the beginning to the end of the whole period that is considered.

In a region where ground water is replenished solely by percolation from precipitation these diagrams are very instructive, as fluctuations of the ground-water surface represent the cumulative effect of precipitation for many years. In general, over central and southern California there was a period of small precipitation from 1853 to 1877 and a period of large precipitation from 1877 to the early nineties, followed by a period of drought extending to 1904. The Los Angeles record, being of shorter duration than those of Sacramento and San Diego, does not agree exactly as to critical years, but shows similar general tendencies. Both Los Angeles and San Diego began to experience the dry period of the later nineties earlier than Sacramento. From the diagram it appears that Sacramento has received 6 per cent less than the 61-year mean for a period of 24 years and 14 per cent less for 8 years; San Diego has received 10 per cent less than a 59-year mean for 23 years and 19 per cent less for 13 years; and Los Angeles has received 30 per cent less than a 38-year mean for a period of 11 years. The secular variations in central California are therefore not as extreme as in southern California, and in the latter region they appear to be greater inland than on the coast. The Independence record is so broken that it is of little value except to show a general similarity to conditions at Los Angeles. Secular variations in the Sierra Nevada correspond in general with those observed at Sacramento.

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[1] Spear, W. E., Study of the water-supply sources of Long Island: Rept. Comm. Additional Water Supply, New York, 1903, App. 7, p. 753.

GEOGRAPHIC DISTRIBUTION OF PRECIPITATION.

The distribution of total precipitation with respect to geographic location in the Independence region and adjacent areas depends to a great extent on topographic features, notably mountain ranges and valleys, although a consistent variation is also evident with changes in latitude. The controlling topographic feature is the Sierra Nevada, which has a general northwest and southeast trend, and lies between the San Joaquin and Owens valleys. A zone of maximum precipitation exists on the western slope of the Sierra between the 4,000 and 6,000 foot levels. There is a marked decrease west of this zone toward the San Joaquin Valley and a slight decrease eastward toward the Sierra crest, beyond which there is a very marked decrease to the general level of the Great Basin, of which Owens Valley is a part. The change of precipitation with latitude is exhibited by a persistent decrease from north to south over the whole area, mountain, and valley alike.

In order to present these various features comprehensively, a map of the Sierra Nevada, including Owens Valley and adjacent territory, has been prepared, upon which have been platted isohyetal lines, or lines connecting points that have equal annual precipitation. (See Pl. VII.) The first attempt to construct such lines for extensive areas in California was made in 1886 by C. E. Grunsky, under the direction of the State engineer, William Ham. Hall.[1] In 1900, with longer and many additional records available, the California Water and Forest Association published a map of the State upon which isohyets were platted under the direction of Marsden Manson.[2] Since then no general revision for the State has been made, but in 1908 Edwin Duryea, jr., amended portions of the Water and Forest Association isohyets, after careful studies made over the drainage areas of streams draining the west slope of the Sierra Nevada between American and Kings rivers. The writer has certain additional revisions to propose, based on recent records available in the Kaweah, Tule, and Kern drainage areas and observations by the Bureau of the Los Angeles Aqueduct in Owens Valley. The Water and Forest Association isohyets as amended by Duryea appear on Plate VII as solid lines, and revisions proposed by the writer are represented by dotted lines. The geographic distribution of precipitation as thus presented on Plate VII covers the Sierra Nevada and adjacent valley from Lake Tahoe to the Mohave Desert.

The relation of precipitation and topography is exhibited most strikingly by studying observations made along cross sections of the Sierra Nevada laid out at right angles to the trend of the range. Two

[1] Irrigation development, pt. 2, Irrigation in California, 1886.
[2] Lippincott, J. B., California hydrography: Water-Supply Paper U. S. Geol. Survey No. 81, 1903.

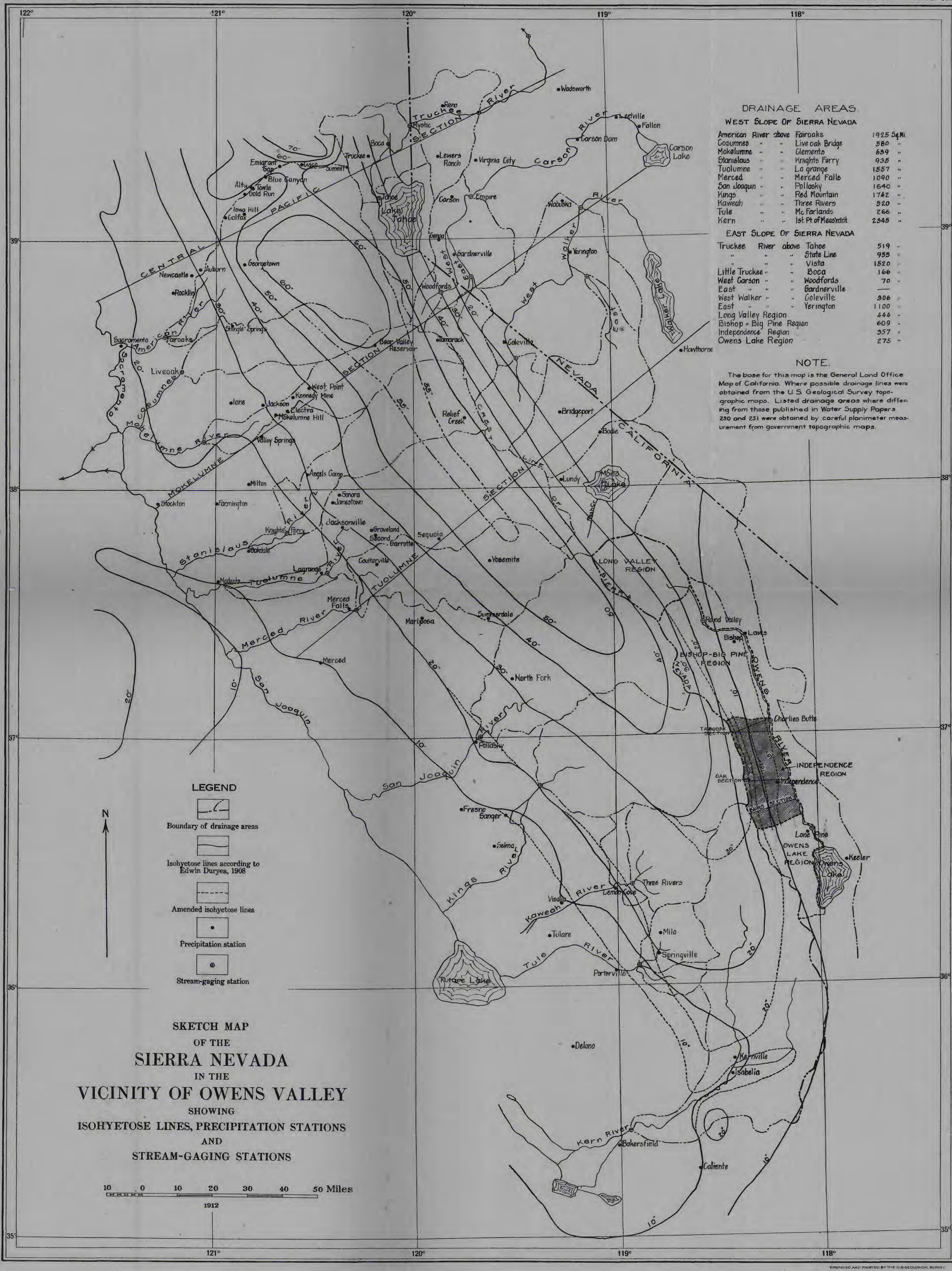
such sections made near elevated stations are indicated on Plate VII as the Central Pacific and Mokelumne sections. In Tables 19 and 20 will be found listed the stations chosen in each section, their elevation, distance from Great Valley station in miles, length of observed record, observed and computed long-term annual mean precipitation, and station upon whose record computed long-term means are based. The computed long-term means represent periods of 40 years for the Central Pacific group of gages and 28 years for the Mokelumne group. The computations of the means were made in a similar way to those described in connection with base-station records for drainage areas and give values that are more strictly comparable than the observed means. In the Central Pacific group Sacramento, Newcastle, Iowa Hill, Reno (1888–89 to 1909–10), and Wadsworth (1890–91 to 1909–10)[1] are Weather Bureau stations. The others are maintained by the Southern Pacific Railroad. The railroad stations are equipped with 3-inch gages, and observations are made by station agents and reported to William Hood, chief engineer. All the stations in the Mokelumne group are maintained by the Weather Bureau.

The relations of precipitation, altitude, topographic position, and profiles of ground surface are shown graphically for the two groups in diagrams 1 to 6 on Plate VIII by platting the values presented in Tables 19 and 20. The marked similarity in the curves for the two sections indicates that the amount of precipitation at points in a transverse section of the range conforms to some general law. Elevation is obviously not the controlling factor, for above the 5,000-foot level the precipitation decreases with increase in altitude. The slope of the ground surface appears to be the most important element involved, as is seen from Plate VIII, diagrams 2, 3, 5, and 6. The phenomenon is rather complex, however, and has been recognized by meteorologists only during recent years. Briefly, it results from the condensation of aqueous vapor due to adiabatic cooling of masses of moist air driven up the slope of a mountain range by the prevailing winds. The region of maximum precipitation is at the lower cloud limit on the windward slope of the range, and above this the latent heat liberated by condensation raises the temperature above the dew point, resulting in decreased precipitation. After crossing the summit of a high range the descending mass of air contracts in volume, thereby raising the temperature rapidly above the dew point and resulting in marked decrease of precipitation.

The phenomenon was first observed by S. A. Hill[2] in studying rainfall in the northwest Himalayas of India, and he developed for that region the empirical formula $R = 1 + 1.92h - 0.40h^2 + 0.02h^3$, in which R represents the amount of rain and h the relative height in units of

[1] Station removed to Fernley in 1907.

[2] Lippincott, J. B., op. cit., p. 354.


DRAINAGE AREAS
WEST SLOPE OF SIERRA NEVADA
American River above Fairoaks 1925 Sq.Mi
Cosumnes " " Live oak Bridge 580 "
Mokelumne " " Clements 639 "
Stanislaus " " Knights Ferry 935 "
Tuolumne " " La grange 1557 "
Merced " " Merced Falls 1090 "
San Joaquin " " Pollasky 1640 "
Kings " " Red Mountain 1742 "
Kaweah " " Three Rivers 520 "
Tule " " Mc Farlands 266 "
Kern " " Ist. Pt. of Meas'm'nt. 2345 "
EAST SLOPE OF SIERRA NEVADA
Truckee River above Tahoe 519 "
" " " State Line 955 "
" " " Vista 1520 "
Little Truckee " " Boca 166 "
West Carson " " Woodfords 70 "
East " " " Gardnerville —
West Walker " " Coleville 306 "
East " " " Yerington 1100 "
Long Valley Region 444 "
Bishop - Big Pine Region 609 "
Independence Region 357 "
Owens Lake Region 275 "
NOTE.
The base for this map is the General Land Office Map of California. Where possible drainage lines were obtained from the U. S. Geological Survey topographic maps. Listed drainage areas where differing from those published in Water Supply Papers 250 and 251 were obtained by careful planimeter measurement from government topographic maps.
LEGEND
Boundary of drainage areas
Isohyetose lines according to Edwin Duryea, 1908
Amended isohyetose lines
Precipitation station
Stream-gaging station
SKETCH MAP
OF THE
SIERRA NEVADA
IN THE
VICINITY OF OWENS VALLEY
SHOWING
ISOHYETOSE LINES, PRECIPITATION STATIONS
AND
STREAM-GAGING STATIONS
10 0 10 20 30 40 50 Miles
1912
Truckee River
Carson River
Walker River
CENTRAL PACIFIC
NEVADA
CALIFORNIA
LONG VALLEY REGION
BISHOP-BIG PINE REGION
INDEPENDENCE REGION
OWENS LAKE REGION
Owens River
San Joaquin River
Kings River
Kern River
Sacramento
Stockton
Modesto
Merced
Fresno
Bakersfield
Yosemite
Bishop
Independence
Lone Pine
Owens Lake
Tulare Lake
Mono Lake
Lake Tahoe
Reno
ENGRAVED AND PRINTED BY THE U.S.GEOLOGICAL SURVEY

DIAGRAMS SHOWING THE INFLUENCE OF ALTITUDE AND TOPOGRAPHIC LOCATION ON PRECIPITATION, AS ILLUSTRATED BY THE SIERRA NEVADA, CALIFORNIA

NOTES: Observations on Central Pacific and Mokelumne groups of gages by United States Weather Bureau. Observations on Taboose, Oak, and Bairs groups of gages by City of Los Angeles. For location of gages see Plates I and VII. The season is from September 1 to August 31.

1,000 feet above an assumed plane which is itself 1,000 feet above sea level. This equation, when platted, gives a curve very similar to that shown in diagrams 1 and 4 of Plate VIII, the plane of maximum rainfall being 4,160 feet above sea level. The equation does not apply to conditions on the leeward slope of a range, however, to judge by the discontinuity at the crest line shown on the Sierra Nevada curves. F. Pockels has investigated the subject theoretically and concludes that there is a zone of maximum precipitation on the windward slope of a mountain range and that the inclination of the earth's surface is of more importance in determining precipitation than absolute elevation.[1] His theoretical curves correspond in form with those shown in diagrams 2 and 5 of Plate VIII. The straight-line relation between precipitation and elevation often assumed in engineering computations has a very limited use and is at best a rough approximation.

A knowledge of the conditions of precipitation on the leeward or eastern slope of the Sierra Nevada is the goal of the foregoing general discussion. In addition to the two Sierra Nevada sections already mentioned records are available for parts of three others which cross the Independence region and are indicated on Plates I, VII, and VIII as the Taboose, Oak, and Bairs sections. The stations in these groups were maintained by the Los Angeles Aqueduct, as previously described. The elevations and distances of the gages from the Sierra crest will be found in Table 5 and the observed precipitation for the seasons 1908–9 and 1909–10 in Tables 6 and 7. In Table 21 are computed values for the mean seasonal precipitation at each gage based on a 26-year record at Independence. The expansion of a 2-year record into a 26-year mean is a recognized weakness in these studies, but it gives the best estimates available from the data at hand, and the results are uniform and consistent, as will appear by an inspection of diagrams 7 to 15 of Plate VIII. The similarity of all the curves is very marked, not only for the Owens Valley sections but for the Central Pacific and Mokelumne sections.

The upper points on the Owens Valley curves need some explanation. As already noted, it was not practicable to make observations of precipitation above the 6,500-foot level. An attempt has been made, however, to arrive at an approximate value for precipitation at the Sierra crest by computations based on measured stream flow. The data available for these computations were the true run-off from mountain canyons and studies of the relation of rainfall to run-off on the west slope of the range. These data are presented and discussed in the section on stream flow (pp. 31–48). It will be sufficient here to state that the mean seasonal discharge to the square mile of the drain-

[1] Monthly Weather Review, U. S. Weather Bur., 1901, p. 153.

age areas cut by the Taboose and Oak sections is 1.75 second-feet and of those cut by the Bairs section 1.36 second-feet; the run-off factor for Kings River, which is adjacent to these areas on the west, is 0.59. By basing computations on a run-off factor of 0.75, the average precipitation over the drainage areas cut by the Taboose and Oak sections is found to be 31.7 inches in depth, and over the Bairs section areas 24.6 inches in depth. An inspection of Plate I shows that in general outline many of these areas are isosceles triangles with apexes up the canyon mouths and bases lying along the Sierra crest. Assuming a uniform rate of change of precipitation from crest to canyon mouth, as indicated by the observations in the Central Pacific and Mokelumne sections, we find that the average precipitation over a whole area equals the actual precipitation at a point, measuring from the crest, one-third of the distance from the crest to the mouth of the canyon. The observed precipitation at the canyon mouth being available, it is a matter of simple proportion to compute that at the crest. The values resulting therefrom, 40.8 inches for the Taboose and Oak sections and 32.7 inches for the Bairs section, are platted as the upper points on the diagrams, and they appear to be reasonably consistent with the observed values.

Precipitation in the Independence region is therefore primarily dependent on topography, for consistent and similar variation is to be observed with both altitude and slope of ground surface. The relation of precipitation and altitude seems to be constant from the Sierra crest to the 5,000-foot contour, and the decrease in precipitation ranges from 0.47 inch for each 100-foot drop in altitude along the Taboose section to 0.34 inch along the Bairs section. Below the 5,000-foot level the precipitation decreases less rapidly with decrease in altitude. Furthermore, precipitation and slope of ground surface exhibit similar characteristics with regard to horizontal distance from the Sierra crest, a very rapid decrease occurring in the first 3 or 4 miles, followed by a consistently less rapid decrease beyond this point out into the valley. In general, precipitation from Independence northward is about 41 inches along the Sierra crest, decreasing to about 14 inches at the base of the mountains (6,500-foot level) and to 5 or 6 inches at the upper edge of the grassland. South of Independence it is 33 inches at the crest, 9 inches at the base of the mountains, and 3 or 4 inches at the upper edge of the grassland. East of Independence there is a precipitation of about 3 inches at Owens River.

The relation of precipitation and latitude, though readily apparent, is not of sufficient importance here to be discussed at length. It results from the decrease in intensity of the north Pacific storms as they travel southward down the coast. The isohyets on Plate VII show the relation quantitatively for Owens Valley and adjacent areas.

SUMMARY.

Precipitation has very unequal distribution over the Independence region, the average ranging from 3 or 4 inches a year at Owens River to 30 or 40 inches along the Sierra crest.

The total amount of water falling on a definite subdivision of the region during a normal year may be computed from the diagrams on Plate VIII.

In the valley the extreme range of departure for single seasons is from more than 350 per cent to 20 per cent of the normal, and over periods of 12 years the average may be 35 per cent below the normal.

In the high mountain areas the range is from twice to one-third the normal, and periods of three years may occur when the average will be 30 per cent below the normal.

The monthly distribution of precipitation is favorable to maximum percolation from the intermediate mountain and outwash slopes and to maximum snow storage in the mountains.

STREAM FLOW.

SOURCES.

Precipitation upon a drainage area is initially disposed of in three ways—by flowing directly into surface streams, by evaporation into the atmosphere, and by percolation into the ground. There may subsequently, however, be a change from surface to underground water, or vice versa, by such processes as percolation from stream channels and escape of ground water in springs. There may also be losses from streams and lakes by evaporation, and from underground water by transpiration and evaporation from damp soil.

The general sources of stream flow in the Independence region are direct surface run-off and springs. For Owens River, in particular, there should also be included the residual surface water which reaches it from tributary drainage areas. No direct measurements of any of these sources were available at the commencement of the investigations. The stream-gaging work carried on by the United States Geological Survey in Owens Valley since 1903 was planned for the purpose of determining the amount of water available for irrigation diversion. Its scope and the location of the gaging stations did not conform to the requirements of this study, which made it necessary to carry on considerable additional stream-gaging work to supply the data lacking. The field methods employed were those practiced by the Geological Survey, an acoustic meter being used for small streams and a small Price meter for ordinary work.

SURFACE RUN-OFF.

CHARACTERISTICS.

The portion of the precipitation which finds its way directly into stream channels as surface run-off varies widely, depending largely on the porosity and depth of superficial material overlying bedrock. The bare, impervious granite surfaces of the Sierra Nevada yield a maximum run-off and the porous gravel of the outwash slopes a minimum; the clay soils of the valley floor are between these extremes. The four general subdivisions of the region are each consistent in their run-off characteristics and will be considered separately.

The clay soils of the valley floor occasionally yield a small run-off during and following winter precipitations of 1 inch or more in 24 hours, or warm rain falling upon old snow. Frost does not enter the ground uniformly, nor to sufficient depth to prevent natural percolation. This water gathers and passes off into Owens River within a few hours by way of four waste channels. It usually carries in solution much alkali which has been leached from the surface of the soil, and by contact with vegetation it acquires a dark-brown color. Inspection of Tables 46 and 47 shows that during 1909 and 1910 the surface run-off from precipitation amounted to 4 second-feet continuous flow. Such conditions usually occur every second year, so that the average total run-off from precipitation on the valley floor is about 2 second-feet continuous flow.

The outwash slopes yield no appreciable surface run-off, on account of the porous gravel formation and the great depth to ground water. This fact has been established by repeated observations during and after rainstorms and thaws, including the storm of December 31, 1909, and January 1, 1910, and is confirmed by the noticeable absence of recent drainage channels or washes, except those of streams that derive their water from high mountain drainage areas.

The intermediate mountain slopes yield a small run-off during the months of May and June, when the temperature at that level is sufficient to melt the accumulated winter snow, but the small streams do not advance far over the outwash slopes before they are entirely absorbed. If the precipitation of the preceding winter is below normal the snow melts before the hot weather comes and is absorbed at once. (See Pl. IV, *B*, p. 14.) If precipitation for the year is normal or above normal, the run-off of three of these areas reaches adjacent living streams, namely, Charlies Canyon between North and South forks of Oak Creek, Lime Fork of Little Pine Creek, and North Fork of Symmes Creek. This results from the shallow depth of the loose material overlying bedrock across which these small streams flow when they leave the mountains. Springs are common along the lower borders of these slopes, the source being the melted snow absorbed by the porous material above and brought to the surface where it comes into contact with impervious formations. In only a few places does such water find its way into living streams.

The high mountain drainage areas have an abundant run-off, and perennial streams flow from all but one of them, that one being Dry Canyon, between Goodale and Division creeks. The source of this water is precipitation in the form of snow and rain which falls within the drainage areas and to a small extent snow dust carried over the summits by the prevailing west and northwest winds of winter and spring. For all practical purposes the average discharge at the mouth of the canyon represents the average precipitation within the drainage area minus losses by evaporation from exposed snow surfaces. This statement assumes that the gain through windblown snow balances the loss by evaporation of water from summer rainstorms. The underflow from these areas is negligible.

Stream discharge is at a minimum from September to April. The flow during these months is remarkably uniform and is entirely uninfluenced by the current storms, though 70 to 80 per cent of the annual precipitation occurs between November 1 and March 31. The low-water flow is derived from springs and from the slow melting of the snow layer exposed to the earth's latent heat. Streams are usually frozen over by November, and as late as April they flow nearly to the mouths of the canyons in tunnels under the snow. Absolute minimum flows occur in December, in the absence of early snow; otherwise in January or February. Between April 1 and 20 air temperatures increase sufficiently to melt the snow at lower elevations and the streams begin to rise. There is an increase in air temperatures and stream flow from this date until the maximum flood crest is reached, some time between June 15 and July 15, depending on the amount of snow to be melted. Stream flow then decreases until some time in September, after which low water prevails. About 70 per cent of the annual run-off of the streams from Oak Creek to Lone Pine Creek, inclusive, occurs during May, June, July, and August. Goodale and Taboose creeks, however, are more regular in flow, only 56 per cent of their run-off occurring during this period. Stream gagings at the mouths of canyons are not available, so that the values of maximum, minimum, and mean discharges and the run-off were obtained indirectly as outlined in the following pages.

PERCOLATION FROM STREAM CHANNELS.

The United States Geological Survey gaging stations on streams draining the high mountain areas are located at the lower edges of the outwash slopes, just above the division boxes which apportion the water for use on the ranches of the valley floor. After leaving its canyon each stream traverses several miles of channel before reaching the gaging station, and preliminary observations in June, 1908, showed that considerable water (in some streams 50 per cent) disappeared between the two points. It was therefore necessary either to establish regular gaging stations at the canyon mouths and depend on records for short periods or to devise some means of computing the true discharge of the high mountain areas from the existing Government records, which extended over a number of years. The latter method was chosen and the results have proved very satisfactory.

The loss from these stream channels occurs as percolation into the porous formations, direct evaporation from water surface, and transpiration from vegetation growing along the stream borders. Evaporation and transpiration losses are so small, however, that they can not be detected in current-meter work. Many of the streams are completely arched with vegetation, but by assuming open conditions and basing calculations on maximum observed pan-evaporation losses at noonday the maximum evaporation loss on the largest stream studied was calculated as one-half of 1 per cent of the discharge at the canyon mouth during the high-water season and 1½ per cent during low water. The transpiration loss on this stream probably does not exceed this amount, as vegetation covers only a narrow fringe along each bank and consists mostly of small birch trees. The maximum combined loss, therefore, does not exceed 5 per cent of the total flow from the mouth of the canyon; moreover, the maximum occurs during a few days only and then during less than 6 hours out of the 24. Current-meter work in rough mountain streams, even with the exercise of the greatest care, is subject to errors as great as 5 per cent.[1] The problem therefore resolved itself into a study of percolation from stream channels, as the expense of installing and maintaining weirs was prohibitive.

There are three factors to be considered in a study of this subject—the rate of percolation, the area through which percolation occurs (the wetted perimeter), and the period of time during which a given unit of water is exposed (velocity of flow). The rate of percolation depends on (1) the character of the channel lining and the medium surrounding the channel as regards size of pores and porosity; (2) the pressure gradient, depending on the difference in level of the surface of the water in the channel and the ground-water surface; and (3) the temperature of the water. The effects of these factors on the rate of percolation are too obvious to need explanation, although Table 22 is instructive in showing the relation of temperature and percolation.

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[1] Hoyt, J. C., and Grover, N. C., River discharge, New York, 1907, pp. 102–104.

The effect of an increase in the wetted perimeter, other conditions being the same, is obviously to increase the percolation, but such change is accompanied by a proportionally larger increase in the velocity of flow, which reduces the time of exposure of a given volume of water. The net result, considering the total flow, is therefore a proportionally smaller percolation, although this effect may be counteracted to a certain extent by the scouring of a nonporous channel lining due to the increased carrying power of the stream. The whole matter is affected by so many indeterminate conditions that a general mathematical analysis is impossible, but with these ideas in view a study was made of each channel to determine the ordinary range of temperature and discharge.

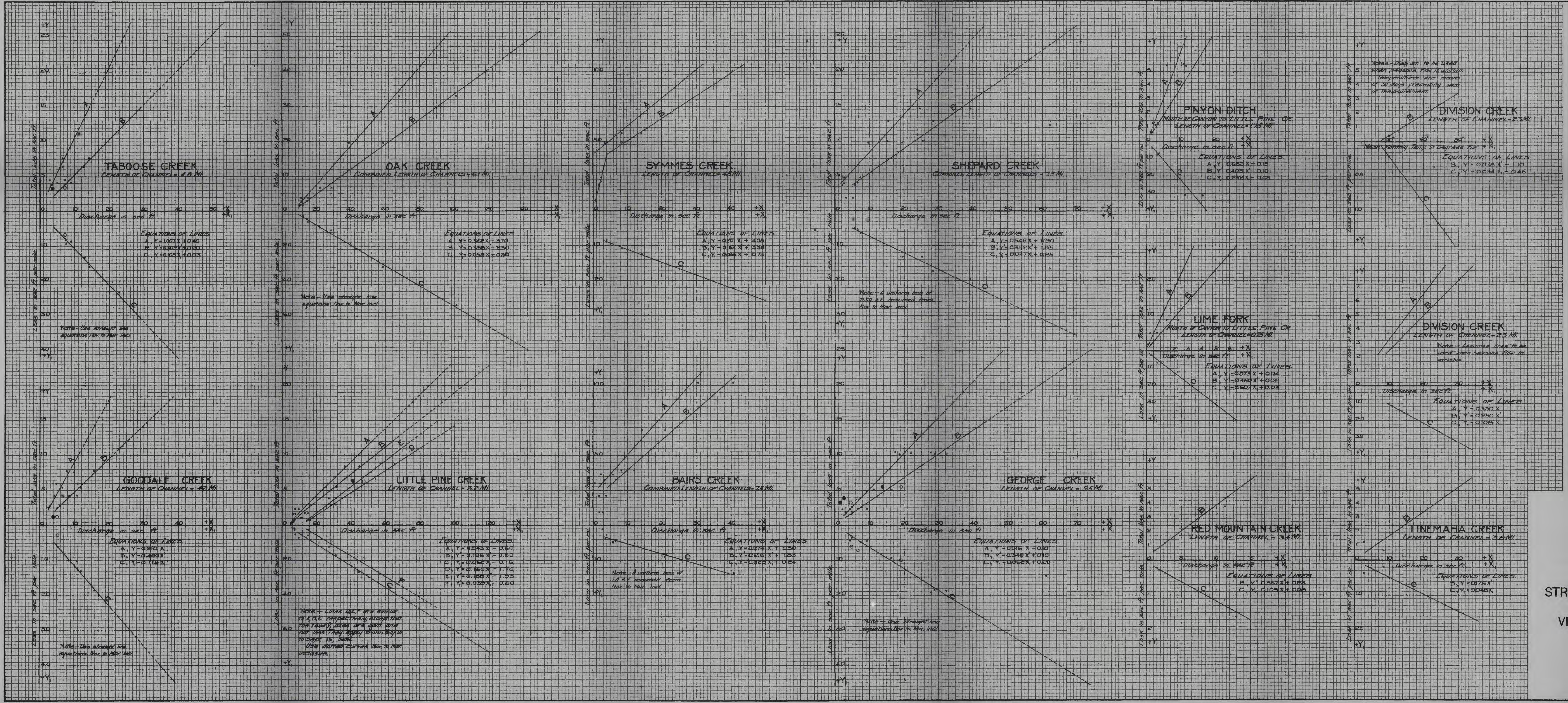
The field work consisted of making comparative current-meter measurements at upper and lower stations on each creek, giving proper allowance of time for the passage of water between the two points. The measurements were made at intervals of six weeks to two months and extended over the period from June 15, 1908, to September 15, 1909, including the high-water periods of wet and dry seasons. Although it is difficult to do very accurate meter work at high-water stages on these swift-flowing streams with rough channels, it is believed that on the whole the results are reliable. Permanent gaging stations were established at the mouth of the canyon on each creek. Estimates of the time required for the passage of water between stations were based on actual trial with aniline dye in Division Creek. The average velocity maintained by a flow of 8 second-feet over a 2.3-mile course with an average slope of 687 feet to the mile was 1.06 miles an hour. Very little fluctuation in discharge has been observed in any of the creeks between 8 a. m. and 5 p. m., even in the high-water period.

The creek channels studied are listed and described in Table 23, and their locations are shown on Plate I. The "mouth of canyon" may be described as the point where percolation commences and is usually where the stream channel passes from bedrock to the alluvial cone. Above this point the bedrock is generally covered with alluvial débris, but the percolation is negligible. Where impervious dikes bring the underflow to the surface below the mouth of the canyon, gaging stations are located just below such dikes and described as at "mouth of canyon." Elevations and distances are taken from the topographic map of the Mount Whitney quadrangle made by the United States Geological Survey, the locations of gaging stations being established by field surveys where necessary. The lava formations mentioned are sheet flows which in recent geologic time spread out over the upper slopes of the cones and in some places extended well out into the valley. They are fissured and porous and have a greater capacity for carrying percolating waters than the alluvial material.

A complete list of discharge measurements, with time, date, and temperature of water, is given in Table 24. It will be noted that the temperature of the water as it issues from the canyons varies from 35° to 42° in winter and from 48° to 53° in summer In winter the temperature does not increase much as the water travels toward the valley. After leaving the protecting cover of the snow in the canyons during December and January the water actually becomes colder, ice prevailing for several weeks. In summer there is an average increase of 10° between the mouth of canyon and the Survey stations. The data embodied in Table 24 were the basis for office study.

Several methods were attempted for generalizing the results, but the most satisfactory was the graphic method, in which losses were platted as abscissas and stream discharges as ordinates with rectangular coordinates (Pl. IX). It was found that for each channel a straight line expressed the relation of these two quantities from April to October, inclusive. During the remaining five months the relation is not clear, but the total loss is then so small that it can be obtained by inspection without affecting the accuracy of the computed discharge at mouth of canyon. Total losses are platted on the basis of discharge both at lower and upper stations, so that in correcting the Government records to obtain true yield from high mountain drainage areas the quantity desired can be obtained at once by entering on the x axis the discharge at the lower or Government station. It is also possible at the same time to read loss in second-feet to the mile from the straight line below the x axis.

There are some interesting conclusions to be drawn from these diagrams. In general, the amount of water percolating from the channels studied varies with the time of year and with different channel conditions. Variation with the time of year is due to the combined effects of temperature, area of wetted perimeter, and velocity of flow. These work more or less in harmony during April to October, inclusive, and produce the straight-line relation of total loss and discharge. From November to March, inclusive, discharges remain practically constant, showing that variations are largely controlled by temperature. Discharges are then so small, however, that errors of measurement are appreciable and losses by evaporation have greater weight, so that the true relation of loss and temperature does not appear. A possible relation between total loss and temperature is suggested by the results on Division Creek, where the discharge at the mouth of the canyon was practically uniform during the period of study. Using as ordinates the mean air temperature at Independence for the 30 days preceding each date of measurement, we obtain a straight line which crosses the x axis at about 35°. A line supported



NOTES

These diagrams have been prepared for the purpose of computing (1) seepage losses above United States Geological Survey gaging stations and (2) actual yield of high mountain drainage areas.

FIELD DATA. Discharge measurements were made with small Price current meters during the period from June, 1908, to August, 1909, inclusive, covering a season of small run-off and one of large run-off. The accuracy is up to the standard for streams of this type. Measurements of medium and high stages are difficult on account of the rough sections and very high velocities

GAGING STATIONS. The upper station on each stream is at the mouth of the canyon or below impervious dikes forcing seepage water to the surface. The average elevation is 6000 feet. The lower station is that used by the United States Geological Survey (unless otherwise noted), situated above diversion, at an average elevation of 4100 feet. Below the lower station is half a mile or more of channel suffering a large seepage loss which is not included.

LENGTH OF CHANNEL was obtained by scaling from Mount Whitney quadrangle, and for Taboose, Red Mountain, and Tinemaha creeks from a triangulation survey. Elevations were obtained similarly.

USE OF DIAGRAMS. The unbroken portions of the lines indicate the relation that applies from April to October, inclusive, during which time temperature and discharge vary similarly. The dashed portions are not supported by field data and are to be used with judgment. From November to March, inclusive, temperature is the only effective variable, and arbitrary values for loss have been selected.

Line A expresses the relation of total loss to discharge at United States Geological Survey station; line B the same to discharge at mouth of canyon; line C the loss per mile to discharge at mouth of canyon. The diagrams are so arranged that all the four values involved can be obtained by entering any one of them.

PERCOLATION DIAGRAMS
FOR
OUTWASH-SLOPE CHANNELS
OF
STREAMS DRAINING HIGH MOUNTAIN AREAS
IN THE
VICINITY OF INDEPENDENCE, CALIFORNIA

●○ Measurements made in spring of 1910

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

by additional data might cross nearer 32°, the temperature at which water freezes and percolation becomes physically impossible.

The character of the surrounding medium was the only channel condition which noticeably affected percolation. The loss from a channel crossing fissured lava, even where the lava was covered by a thin sheet of alluvium, was 30 per cent greater than that in coarse alluvium. Many other channel conditions are probably effective, but this is the only one noted from these studies.

This discussion and the accompanying diagrams (Pl. IX) outline sufficiently the method devised for computing stream discharges from high mountain areas from the existing Government records.

RUN-OFF STUDIES IN ADJACENT DRAINAGE AREAS.

The available records of stream flow in the Independence region cover the seasons 1904–5 to 1909–10, but as the longer records both of precipitation and stream flow for the west slope of the Sierra Nevada show a preponderance of wet years during this period it would not be safe to depend entirely on these 6-year records. A possible method of arriving at a knowledge of true average conditions for streams of this region is by comparison with the streams of the adjacent west slope for which long records are available. Such a comparison would not be reliable for periods of a year or even two years, because of the relatively large ground and snow storage of creeks tributary to Owens Valley. It is justified for longer periods, however, by similarity in variation of the annual precipitation which falls on both slopes (fig. 2, p. 24). As a basis for such comparison there will be presented here data regarding the seasonal variation in flow of west-slope streams and a discussion of the relation of rainfall to run-off for these drainage areas.

The stream best adapted for such a comparison is Kings River, because of the location of its drainage area (Pl. VII) and the length of the available record of its flow. Discharge measurements of this stream have been made at Red Mountain, about 18 miles east of Sanger, Fresno County, for a period of 21 years, from November, 1878, to October, 1884, by the California State Engineering Department, and from September, 1895, to the present time by the United States Geological Survey. A summary of these measurements is given in Table 25. The discharge per square mile and the depth of run-off in inches are computed for an area of 1,742 square miles, as published by the Geological Survey, and all values are given for the run-off year September 1 to August 31. From the last column of this table it will be observed that the run-off for the period 1904–5 to 1909–10 is 18 per cent above the 21-year mean and that the season 1909–10 is very slightly below the normal.

Other streams to the north and south of Kings River having available records of various lengths are also of interest, and mean seasonal discharges and variations from 20-year means for five such streams are presented in Table 26. Named in order from north to south these are Tuolumne, Merced, Kaweah, Tule, and Kern rivers. Computed 20-year means for Merced, Kaweah, and Tule rivers are based on the Kings River record. The progressive decrease in the discharge per square mile for each stream from north to south is to be expected from the decrease in the rainfall. The similarity of variation in run-off for different streams from year to year is marked, especially for the more northerly streams. These percentages have been platted on Plate VI, an examination of which will show the general agreement in seasonal variation of both run-off and precipitation for each drainage area. There is a tendency, however, for variations in precipitation to be exaggerated by the run-off. The extreme variations in run-off of single seasons for the six Sierra streams considered seem to be from more than half to twice the mean. The minimum run-off observed for a period of three consecutive years on Tuolumne River is 32 per cent below the normal, on Kings River 39 per cent below the normal, and on Kern River 59 per cent below the normal. It should be noted, however (see Pl. VI), that run-off records are not available during periods when most severe or most protracted shortages in precipitation have occurred except on Kern River, and that even on this stream records of precipitation are not available during periods when most severe droughts have occurred farther north. It is therefore possible that greater extremes of run-off may have been experienced on these six Sierra Nevada streams than the records indicate.

Southern California streams, of which Santa Ana River is typical, are of interest in this connection. Variations in precipitation and run-off for this stream are platted on Plate VI, from which it will be seen that run-off records are available for the most protracted and severe drought which has occurred since the season 1872–73. Precipitation ranges from a little more than twice to two-fifths of the mean; seasonal run-off varies from almost three times to about one-third of the mean, and for a period of three years the minimum has been two-fifths of the mean. There are thus greater extremes of annual run-off on this stream than on the Sierra streams, although the range of annual precipitation is no greater. This may be due to dissimilarity of drainage areas with regard to elevation, geology, and vegetation, as well as to the occurrence of a period of exceptional drought. There is little doubt, however, that the minimum seasonal run-off for Kings River is less than one-half the mean for periods of a year and possibly as low as one-half the mean for periods of three years.

Conditions are very favorable for the natural regulation of run-off on Sierra streams tributary to Owens Valley, so that variations from the mean are probably not as great on these streams as on Kings River. The run-off for the season 1907–8, for example, averaged 45 per cent below the normal on all Sierra streams of the west slope but was only 10 per cent below the normal in Owens Valley, owing to the storage of water in snowbanks and in glacial material during the two preceding wet years. The available records are too short, however, to say with any degree of certainty what the extremes might be for this region. Periods of drought extending over three years are possible, during which the average precipitation may be 30 per cent below the normal, but the shortage in stream flow would probably not be very severe until the third year. Precipitation at Owens Valley stations does not provide a means of determining extreme conditions, as can be seen by reference to Plate VI, for the reason that the conditions of precipitation existing in northern and central California prevail over the high mountain drainage areas of Owens Valley streams, whereas Great Basin conditions strongly influence precipitation in the open valley. In general, annual variations in run-off for Owens Valley streams agree with those of Kings River, although they do not have as great extremes.

Computations of the run-off factor (ratio of run-off to total precipitation upon a drainage area) for the six Sierra streams just considered has been attempted as outlined in Table 27. In brief, the method was for each season to multiply the average precipitation in inches for each drainage area by the percentage the precipitation bore to the mean for that area and divide the measured run-off in inches by the result. The average precipitation over each drainage area was obtained from the isohyets of Plate VII, by estimating the average precipitation between them, multiplying it by the included area, and dividing the total of such products by the total area. The locations of the State Engineering Department and United States Geological Survey gaging stations are not the same on Tuolumne and Kaweah rivers. The territory drained and therefore the average precipitation differs. The seasonal percentages for precipitation are those platted on Plate VI. Measured stream flow in inches was computed from the values for seasonal discharge in second feet per square mile given in Table 26. It will be observed that Tuolumne, Kings, and Kaweah rivers have an average run-off factor of about 0.55; Merced River comes next with 0.44; and Tule and Kern rivers last with 0.39 and 0.32, respectively. Tuolumne and Kings rivers have an extreme seasonal range of 0.75 to 0.40; Kaweah River varies from 0.94 to 0.29, Merced River from 0.63 to 0.31, Tule River from 0.58 to 0.19, and Kern River from 0.50 to 0.17. Thus for the three northern streams the maximum run-off factor for individual seasons is twice and for the three southern streams three times the minimum, the difference in range being due to the different precipitation and physical characteristics of the drainage areas.

The run-off factor for streams of the Independence region probably corresponds more closely with that for Kings River than with those for other west-slope streams. Many conditions favor a larger factor for the drainage areas of these small streams, however, among them being their high altitude, the nonporous character of the bedrock in which they are carved, the universal occurrence of deep cirques and canyons which favor the collecting of snow in protected drifts, the snow dust carried over the Sierra crest from the west into the cirque basins by prevailing winds, and the absence of lake surfaces or much vegetation. All these characteristics tend to increase the run-off factor by decreasing losses through evaporation and percolation and increasing the available snow supply in excess of that falling as direct precipitation. It is thought that in view of these conditions a value of 0.75 is not too great for the average run-off factor for streams draining the east slope of the Sierra.

The depth of snow evaporation from these drainage areas is approximately 7.7 inches of equivalent water a year. (See p. 50.) As already stated the average run-off from drainage areas cut by the Taboose and Oak rain-gage sections is 1.75 second-feet to the square mile, or 23.8 inches in depth. If to this is added the 7.7 inches lost by evaporation, a value of 31.5 inches is obtained for the average precipitation on these areas. With a run-off factor of 0.75, an average precipitation of 31.7 inches would produce a run-off of 23.8 inches, indicating the approximate correctness of the assumed run-off factor.

RUN-OFF COMPUTATIONS FOR HIGH MOUNTAIN DRAINAGE AREAS OF INDEPENDENCE REGION.

Sufficient data have been presented regarding losses by percolation from stream channels and character with respect to normal conditions of the years for which records are available to make it possible to compute the average total yield of the high mountain drainage areas. In brief, the method was as follows: United States Geological Survey records were so corrected by use of the diagrams for percolation loss as to represent true discharge at the canyon mouths; values for the few missing seasons were estimated to give complete six-year records on all streams; and the long-term average discharge was obtained by comparison with the Kings River record.

The Geological Survey records as published[1] are reproduced in Tables 28 to 33 as monthly means, arranged by run-off seasons from

[1] Water-Supply Papers 100, 134, 177, 213, and 251.

1904–5 to 1909–10, for creeks from Tinemaha to Lone Pine, inclusive. The estimated values are determined from occasional meter measurements and by comparison with the hydrographs of adjacent streams. Tinemaha and Lone Pine creeks are not within the boundaries of the Independence region but are included because of their instructive characteristics. The corresponding values, corrected for percolation losses and representing discharge at the canyon mouths of the various streams, are presented in Tables 34 to 39. They are obtained by entering the monthly mean discharge at Geological Survey stations on the x axis of the proper percolation loss diagram (Pl. IX), moving up parallel with the y axis to the a line, across to the b line, and down to the desired value on the x axis. For creeks where the straight lines do not apply during the winter months the average value stated on the diagram is used. Special cases arise for Division and Little Pine creeks. The discharge of the former is so uniform throughout the year that except in years when stream flow is well above the normal, temperature is the dominant element causing variation in percolation from the channel. For periods of uniform flow the temperature curve was used and for periods of variable flow other curves were used as noted in the tables. Little Pine Creek exhibited the unexpected phenomenon of increased flow between the mouth of the canyon and the Geological Survey station. This seemed to occur for a short period only, following an exceptional high-water stage of the creek, but enough measurements were obtained to determine the seepage-gain curves D and E. It is probably caused by the draining of the gravel prisms which are saturated during the high-water stage, although why this is not accomplished by percolation, as on other creeks, is not apparent. The seepage-gain curves were used on this creek for the periods following very high stages, as noted in the tables.

It will be seen that stream-flow records are not available on some creeks for the entire six seasons 1904–5 to 1909–10 and are lacking altogether for some of the smaller creeks. The determination of the total amount of surface water entering the region from high mountain drainage areas involves these missing values, and for the purpose of estimating them an analysis of available records has been made and is presented in Tables 40 to 42. The total discharge from the several drainage areas is reduced to the more comparable unit discharge per square mile; the observed 6-year means and computed 21-year means are then obtained; and finally the percentages which seasonal discharges bear to the 6 and 21 year means are computed.

A study of the discharge per square mile from the several drainage areas showed a general agreement in values, and among adjacent areas having similar exposures there was a remarkable agreement. This observation led to the classification of drainage areas indicated in Table 40, according to the proportion of their area above an elevation of 10,000 feet and their geographic position with respect to the Kings-Kern divide. The 10,000-foot contour is approximately the lower boundary of the open cirque floors and glacial-lake benches. A drainage area having 60 per cent or more of its area above this contour has considerable flat open country near the summit of the range and a long crest exposure, conditions both of which are favorable to large precipitation and run-off. On the other hand, a drainage area with less than 60 per cent above the 10,000-foot contour has steep upper slopes and short crest exposure, and therefore small precipitation and run-off. The Kings-Kern divide is an elevated ridge lying between Kings and Kern rivers west of the crest, which it leaves at right angles from a point about 2 miles south of the northwest corner of the Shepard Creek drainage area. (See Pl. I.) North Pacific storms in their movement southward lose much of their moisture in crossing this divide, at the expense of the Sierra Nevada to the south, and as a result there is a marked difference in precipitation and run-off north and south of the junction of the ridge with the Sierra crest. This condition is noticeable from the observations of precipitation in the Bairs section, as well as from stream flow. The four classes A, B, C, and D include all streams characterized by these various run-off conditions. Class E includes only Sawmill Creek, which for some unrecognized reason has a much smaller discharge than the streams of class C, with which it would otherwise be listed.

Six-year records are available on Taboose, Goodale, Division, Oak, Little Pine, and Lone Pine creeks, and the percentage which each season's discharge bears to the 6-year mean is given for these creeks in Table 41. Percentages for the season 1904–5, the records for which are missing for Shepard, George, Bairs, and Sawmill creeks, are assumed to correspond with those for adjacent streams. Six-year means are computed from the available records, the average ratio of mean seasonal discharge for the period 1905–6 to 1909–10 to that for the period 1904–5 to 1909–10 being accepted as 1.07. In a similar manner the 6-year mean for Symmes Creek was computed, the ratio for the period 1905–6 to 1909–10 to the 6-year period being 1.04. The values in parentheses in Table 41 were thus obtained, and the 21-year means of Table 42 were computed by dividing the 6-year means by the ratio 1.18, derived from the Kings River record.

The observed 6-year mean discharges in second-feet per square mile for streams north and south of the divide having 60 per cent or more of their drainage area above 10,000 feet is 2.06 and 1.61, respectively, and for streams with less than 60 per cent above 10,000 feet 1.39 and 1.10; but Sawmill Creek has a mean discharge of only 0.86 second-foot. The 21-year means are respectively 1.75, 1.36, 1.18, 0.93, and 0.73 second-feet per square mile. Thus the yield per square mile from areas of class A exceeds that of Kings River, and that from areas of class B exceeds that of Kaweah River; both of these relations are to be expected. It is also to be noted that while the general variations from year to year of the creeks in the Independence region and of Kings River correspond, the former do not show as great extremes as the latter.

The streams for which records are entirely lacking are still to be considered. These are Dry Canyon and Thibaut, Pinyon, and Hogback creeks. As indicated by the name, Dry Canyon is a drainage area from which no surface flow escapes. It is, however, an area of class A, and is so small and so choked with glacial débris that there has never been sufficient water flowing from it at any time to cut out a channel. As a result the yield passes directly into the valley fill without appearing permanently upon the surface. The assumed 21-year mean seasonal discharge for this area was obtained by averaging those of Goodale and Division creeks, which lie to the north and south of it; the assumed seasonal percentages are those of Goodale Creek. For Thibaut Creek a 21-year mean of 0.55 second-foot per square mile, with Sawmill Creek percentages, was assumed. Values for the other creeks were obtained similarly.

From the values thus obtained for discharge in second-feet per square mile for all high mountain drainage areas tributary to the region for the six seasons 1904–5 to 1909–10, and from the areas in square miles embraced by each as shown in Table 2, Table 43 was prepared, giving the total seasonal discharge in second-feet from each area. Red Mountain and Tinemaha creeks, although entering the region from the mountains, discharge their waters northward into the Bishop-Big Pine region across a low saddle in the Poverty Hills barrier. Only such water as percolates from their outwash-slope channels becomes part of the ground-water supply of the Independence region. The average total contribution of surface water from the 17 mountain canyons from Taboose Creek to Hogback Creek was 153 second-feet during the 6-year period of observation and 130 second-feet during a 21-year period, which represents practically normal conditions. Table 44 presents all observed seasonal discharges at United States Geological Survey stations. It is interesting to note that only 65 per cent of the discharge leaving the mountains is available for measurement at the lower stations and that on several streams the amount is barely 50 per cent.

SPRINGS.

The occurrence of springs in the region is due to the reappearance of water which originally fell within its boundaries as precipitation and percolated into the ground. There are in general three types of springs which give rise to surface streams—those which derive their supply from precipitation upon the intermediate mountain slopes and appear at the base of these slopes, those which derive their supply from precipitation and stream percolation and appear along the upper edge of the grassland, and those which derive their supply from precipitation on lava flows and appear at the lower borders of the flows.

The springs of the first of these types are not deep seated and represent the drainage from the superficial deposits lying upon the triangular mountain slopes between canyons. The temperature of their water is about 47° or 48° F., and the flow of many of them increases in early summer and decreases during late summer and autumn. The water from most of these springs sinks into the porous gravels of the outwash slope and need not be considered in this discussion.

Springs Nos. 1 and 2, on Division Creek, and a group of springs feeding the South Fork of Oak Creek opposite the mouth of Sardine Canyon, discharge a considerable volume of water into living streams. The springs on Division Creek are located north of the creek at the crest of the alluvial cone. No. 1 has a discharge of about 0.5 second-foot, a part of which reaches the creek. Spring No. 2 discharges 2 second-feet, most of which formerly reached the creek. Its flow is now diverted into the penstock of the aqueduct power plant on this creek. These springs were considered in making measurements of percolation and in computing the surface yield from the mountain canyon. All Geological Survey measurements on Division Creek include that portion of the flow of these springs which was not lost by percolation. The steady flow and large volume of spring No. 2 indicates a source other than precipitation upon the mountain slope above, but none has yet been recognized.

The springs at the mouth of Sardine Canyon derive most of their supply from the run-off of the drainage area, which sinks into porous gravel deposits in the lower canyon. There is also a contribution from ground storage in accumulations of slide material on the mountain face to the south of the canyon. The flow from this group varies from about 3 to 1½ second-feet and is discharged directly into the South Fork of Oak Creek. In computations of run-off these springs were assumed to represent the yield of the drainage area.

The line of springs along the upper edge of the grassland represents the intersection of the natural surface of the ground and the surface of ground water. The water has penetrated rather deeply into the gravel fill and issues with a temperature of about 62° F., which is 5° higher than the mean annual temperature at Independence and 1° lower than that of water flowing from artesian wells in the same location. The flow of these springs is variable, being least in late summer and greatest in early spring, with regular fluctuation between these dates evidently depending on ground-water stages within the grass area. Only during the winter months is the discharge sufficient to be the source of surface streams which flow any considerable distance, and even then there are only a few of such streams which reach Owens River. Most of the yield of these springs is lost by evaporation and transpiration. The winter discharge of individual springs varies from 0.5 second-foot down to an amount that is only enough to fill small pools of standing water from which evaporation equals the yield. The total winter discharge from all these springs is about 4 second-feet.

The springs issuing from the lava formations are unique in having uniform discharges throughout the year and a temperature of 57° F. The water is probably derived from precipitation upon the lava surface, absorbed by the porous rock, and, by reason of the peculiar formation, gathered and delivered at the lower margin of the flow. The largest of these springs is Blackrock Springs (Pl. I), situated 9 miles north of Independence. It has a discharge of 23 second-feet; which flows out across the valley floor in two sloughs, each emptying into a series of shallow lakes. From November to March, inclusive, an average flow of about 7 second-feet reaches Owens River, but during the remainder of the year all the water is lost by seepage, evaporation, and transpiration. The water is apparently discharged into the basin at the spring under a low head, for by varying the elevation of water surface 2 or 3 feet the discharge can be varied as much as 20 per cent. Variations of 5 to 10 per cent occur, depending on whether or not Division Creek is allowed to flow out into the lava above the spring. Hines Spring is situated 3 miles north of this spring, and has a continuous yield of about 4 second-feet. Approximately 1 second-foot finds its way into Owens River during the winter, but is lost during the remainder of the year. Campbell Spring is situated east of Owens River, 1 mile north of Aberdeen. It has a yield of about 0.5 second-foot, and discharges directly into the river. Upper and Lower Seeley springs are situated, respectively, just above and just below Charlies Butte and discharge directly into Owens River. The upper spring has a flow of 9.5 second-feet, which is included in measurements of Owens River at the Butte. The lower spring has a flow of 1.5 second-feet.

OWENS RIVER.

Owens River forms the eastern boundary of the Independence region for a distance of 29 miles, although the actual length of its channel is possibly 20 per cent greater, owing to its sinuosity. It is the drainage outlet for the waste surface water of the region, including the run-off from the valley floor, the yield of springs, and a small portion of the run-off from high mountain drainage areas. In order to account for all escaping surface waters and determine the condition of the river channel with regard to seepage, daily measurements of river discharge were made near the north and south boundaries of the region, and measurements of discharge into and diversion from the river channel were made between these two points.

The upper river station is at Charlies Butte (Pl. I), a lava mound situated 3½ miles above the Los Angeles aqueduct intake. It is equipped with a cable and car and a staff gage. Observations of river stage are made daily and current-meter measurements of discharge are obtained each month. The section is fairly stable and a good station rating curve has been constructed covering the period from January, 1907, to May, 1911. The lower river station was established in June, 1908, at Mount Whitney bridge, east of Lone Pine. Observations of river stage were made daily on a staff gage spiked to one of the bridge piles. Current-meter measurements from the bridge were always unsatisfactory in high water, however, and in January, 1911, a cable station was installed 1,000 feet below the bridge. In early February, 1911, a series of measurements were made covering a high stage in the river, and from these a satisfactory station rating curve based on the gage heights at the bridge was constructed for all river stages. Mean monthly discharges at each station for the period May, 1908, to December, 1910, will be found in Tables 45 to 47.

There are four well-established channels (Pl. I) by which waste surface water reaches the river. The most northerly enters about 6 miles north of Citrus bridge and carries part of the flow of Blackrock Springs and occasional run-off from the valley floor. This is dry about seven months of the year. Another channel enters less than a mile above Citrus bridge and carries the surplus flow of Little Pine, Oak, and Sawmill creeks, a portion of the flow of Blackrock Springs, and occasional surface run-off. This is dry not more than five months of the year. South of Citrus bridge waste from Shepard Creek has an outlet into the river, and still farther south the combined waste from Bairs and George creeks enters. Both of these channels also carry occasional surface run-off. Lower Seeley Springs and Campbell Springs discharge directly into the river. Current-meter measurements of the amount of water passing through these channels were made as often as possible, and mean monthly discharges for the period May, 1908, to December, 1910, will be found in Tables 45 to 47. The Stevens ditch and the Lower and Upper East Side canals divert water from the river above Citrus bridge for irrigation, and their mean monthly flows computed from gage-height readings and current-meter measurements are also given in the tables.

Surplus creek water reaches Owens River in appreciable quantities only during the high-water season. An inspection of the tables shows that in the dry year 1908 there was no such discharge into the river; in the normal year 1910 there was about 3 second-feet during one month; and in the wet year 1909 the total discharge in June was 147 second-feet, in July 135 second-feet, and in August 11 second-feet, which is equivalent to an average daily flow during the three months of 98 second-feet, or 12 per cent of the total discharge from high mountain drainage areas during the run-off season 1908–9. Thus only a very small portion of the tributary mountain drainage ever reaches Owens River. The run-off from the valley floor and the yield of springs has already been considered.

The amount of seepage into the channel of Owens River depends entirely on the adjacent ground-water level. North of Citrus bridge the water in ordinary stages occupies a narrow trench of moderate depth which winds back and forth in a wide grassy flood plain. South of the bridge the flood plain is narrow and bluffs rise almost from the water's edge. Just north of the Alabama Hills the sand bluff recedes, and for a distance of 2 miles the flood plain is over a mile in width. This area is known as "The Island" and is subject to overflow in high river stages. South of it the channel is again closely confined between the bluffs. The ground-water level of the valley in the vicinity of the river is several feet above low-water stage but is below high-water level. Seepage losses are therefore to be expected in high-water stages and seepage gains during low water. The actual conditions are shown in the last columns of Tables 45 to 47, the positive sign indicating gain and the negative sign loss. It will be seen that during flood stages the flood plain and dry sand bluffs absorb water which during the following low-water periods drains back into the river. The 10 second-feet excess of annual loss is the result of evaporation and transpiration between Charlies Butte and Mount Whitney bridge. The source of any seepage water entering this portion of Owens River is therefore not within the region and has no relation to the local ground-water problem.

SUMMARY.

The total average surface run-off from various portions of the Independence region is 132 second-feet, of which 2 second-feet is derived from the valley floor and 130 second-feet from the high mountain drainage areas.

The extreme range of departure of single seasons is from about twice to one-half the average, and periods of three years are possible when the mean run-off will be 35 per cent below normal.

The run-off factor for high mountain drainage areas of the Independence region is approximately 0.75.

The average yield per square mile of high mountain areas north and south of the Kings-Kern divide which have more than 60 per cent of their area above 10,000 feet is 1.75 and 1.36 second-feet, respectively, and that of areas which have less than 60 per cent above 10,000 feet 1.18 and 0.93 second-feet.

The portion of the run-off from high mountain areas reaching Owens River does not exceed 3 second-feet continuous flow or 2½ per cent of the total.

Seepage gains by Owens River are balanced in the long run by seepage losses.

The discharge from numerous springs in various parts of the region must be considered in ground-water computations.

EVAPORATION.

CONTROLLING FACTORS.

A portion of the precipitation falling upon a drainage area returns to the atmosphere through evaporation. This not only occurs immediately after a storm but also extends over a period whose duration depends on the character of the surface and underground storage of the drainage area. The latter consideration also largely determines the proportion of the total precipitation which will be lost by evaporation from two drainage areas whose climatic conditions are similar. The process of evaporation is controlled by complicated and rapidly varying conditions, which scientific research has not yet satisfactorily analyzed and formulated. In general, however, it depends on the temperature and the quantity of moisture already in the immediately surrounding atmosphere. The latter factor depends not only on the amount of moisture in the air generally but also on the action of wind in removing accumulated water vapor from above the evaporating surface. Warm arid regions have a greater annual loss through evaporation than those which are either cool and arid or warm and humid. Of the two controlling factors probably temperature is the more important in determining the amount of evaporation, but over short periods wind may have a relatively greater influence. Owens Valley, although characterized by aridity, has a temperature somewhat modified by the proximity of the elevated Sierra Nevada, and evaporation in the valley is in general less than in the desert areas to the east and south but greater than in the more humid San Joaquin Valley.

Evaporation may occur from water as it lies in the form of snow or ice, from free water surfaces, from bare ground, and indirectly from the soil by transpiration through vegetation. All these avenues for the passage of water as vapor from the earth's surface into the atmosphere are present in Owens Valley. An extensive snow-covered area exists in the higher mountains from December until June or July; mountain lakes and streams, Owens River, small lakes and flooded areas in the valley floor, and especially Owens Lake furnish free water surfaces; and the whole ground surface at various times is in a moist condition favorable for the process of evaporation.

EVAPORATION FROM SNOW.

Evaporation from snow occurs, not alone from the general snow surface, but also from the particles of snow dust that during the late winter and spring months are carried by the fierce winds from exposed ridges and northwest slopes and collect in drifts in the shelter of canyons or cirques. The only observations which are known to have been made under conditions at all similar to those prevailing on the east slope of the Sierra were made by the Arrowhead Reservoir Co. at Little Bear Valley, in the San Bernardino Mountains, at an elevation of about 5,100 feet, in the drainage area of Santa Ana River.[1] An ordinary 8-inch cylindrical rain gage was filled with snow, either by exposure during a storm or by inverting it and pressing it down into the snow as it lay on the ground. It was then adjusted on a stand so that the general snow surface was several inches above the cylinder rim and the space between the cylinder and the surrounding snow was filled. By means of a false bottom the snow level in the cylinder was raised to the general level and kept there constantly. The evaporation was obtained by removing and weighing the cylinder and contents every 24 hours. (See Table 48.) From the results it is seen that the average depth of equivalent water which evaporated from the snow surface daily during the month of March was 0.10 inch. This figure is probably too large to represent evaporation from the Sierra snow fields, for they lie at greater elevations and do not completely cover the surface on account of the rugged topography. The effect of altitude upon evaporation from water is well shown in figure 4, prepared from the results of observations by the Office of Experiment Stations, United States Department of Agriculture, on the eastern slope of Mount Whitney.[2] The rate decreases rapidly from the valley floor at 4,000 feet elevation to 10,000 feet but very slowly above that level. The snow lies on the Sierra as far down as 7,000 feet from December to April or May and above

[1] Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1898, p. 620.
[2] Eng. News, Sept. 19, 1907, p. 305.

10,000 feet from December to June. Figure 4 shows that the average evaporation from water from the 7,000-foot to the 10,000-foot level is 73 per cent of that at 5,100 feet, and from 10,000 to 14,000 feet 64 per cent of that at 5,100 feet. The areas between these contours bear the ratio of 4 to 5, that above 10,000 feet being the larger. The average evaporation from water over the whole area is therefore 68 per cent of that at 5,100 feet. On the assumptions that at the 5,100-foot level in Owens Valley evaporation from snow is equal to that observed at Little Bear Valley, and that evaporation from water and from snow vary similarly with altitude, the average daily

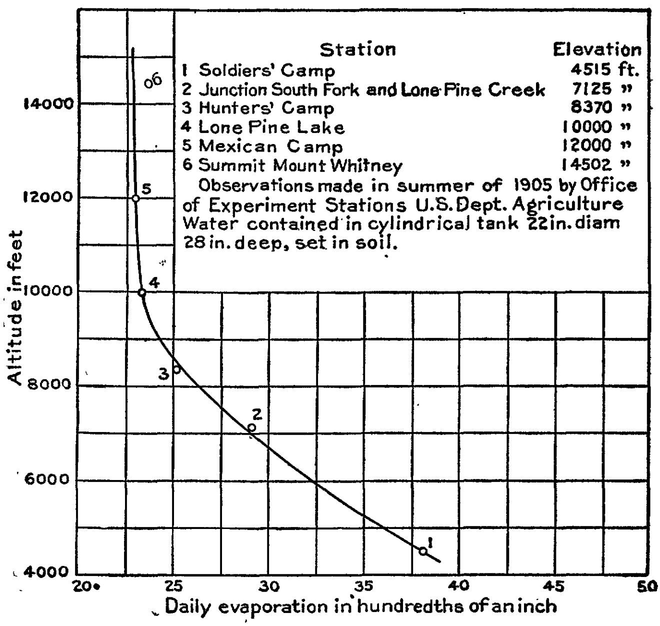
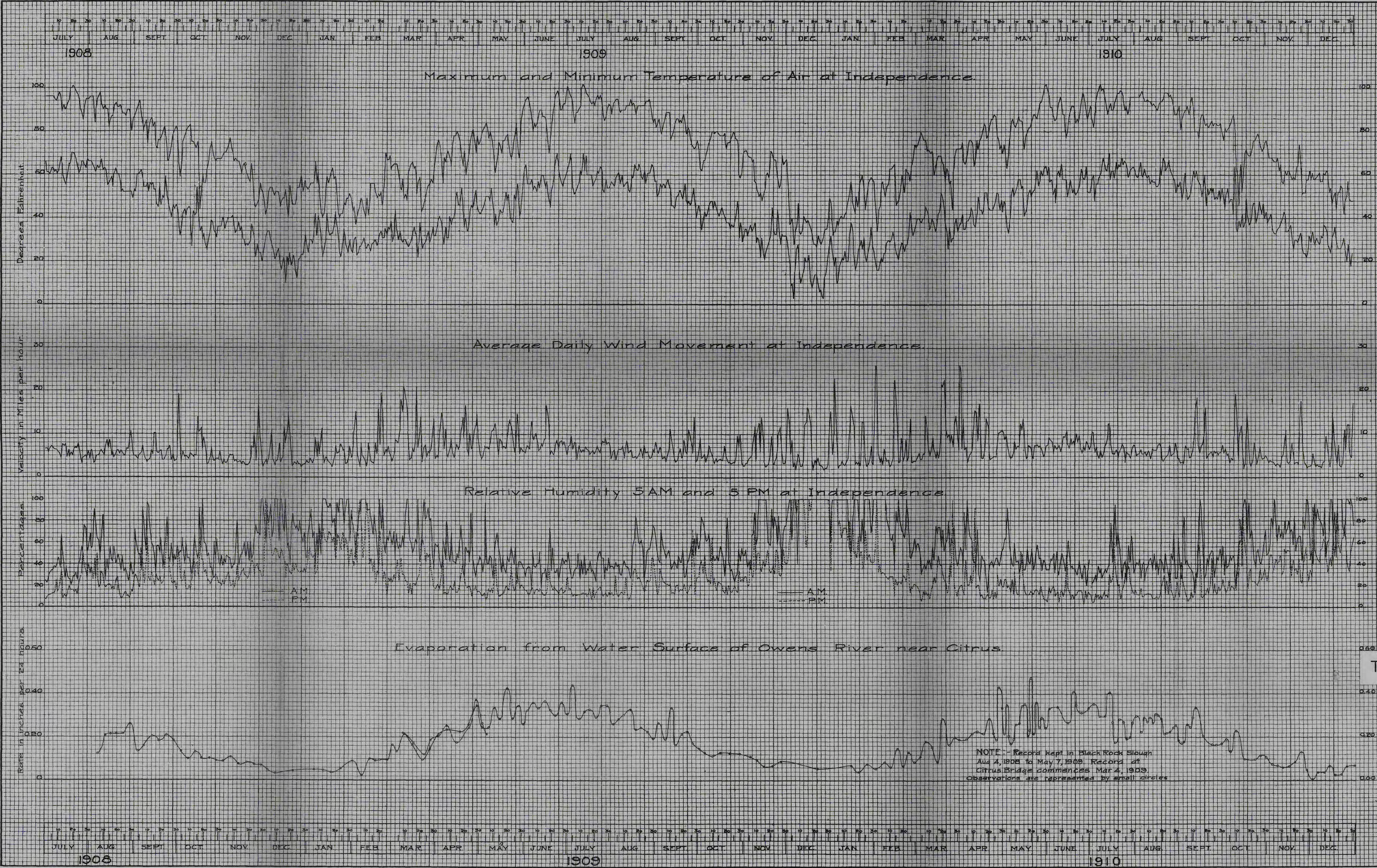


FIGURE 4.—Influence of altitude on evaporation on the east slope of Mount Whitney.

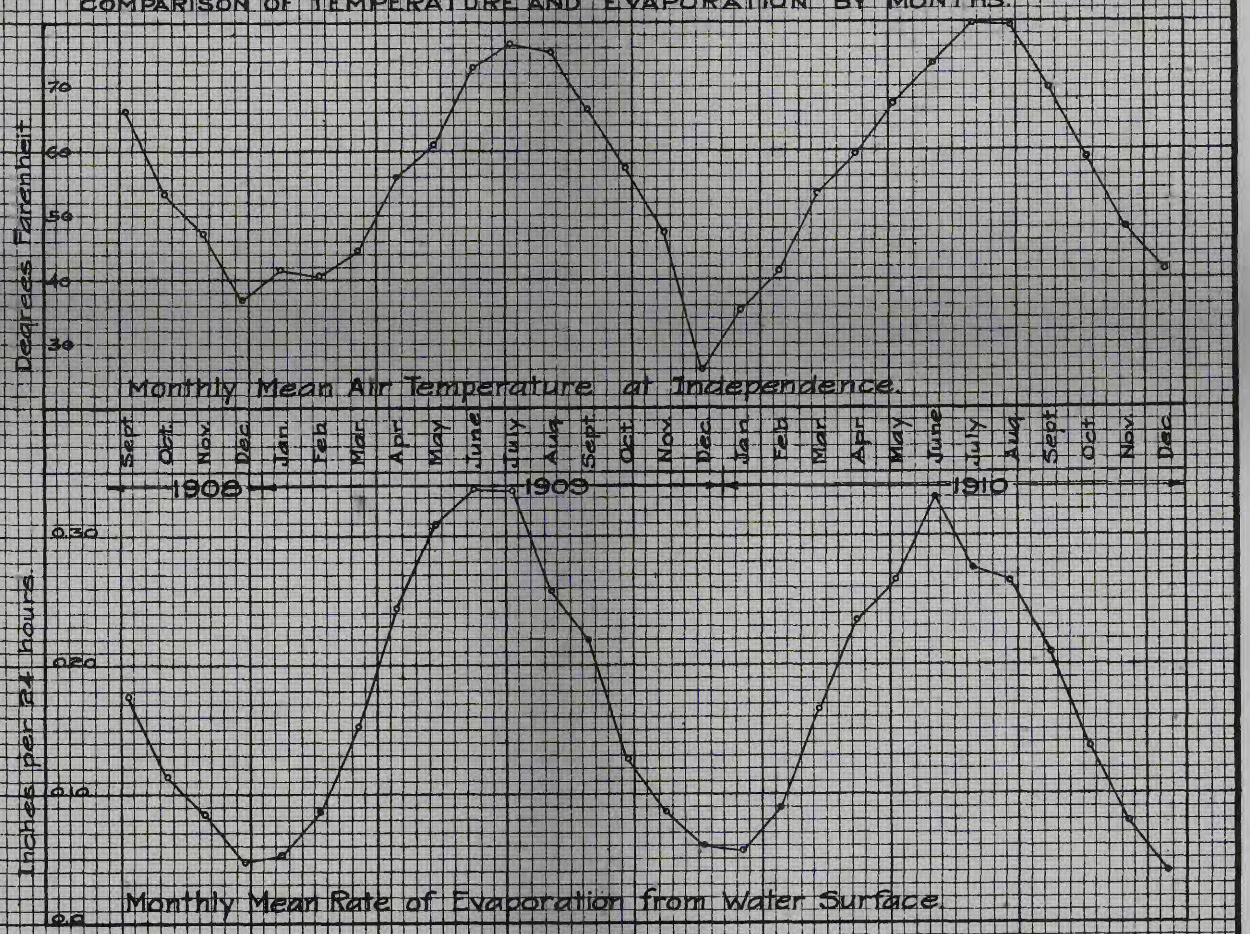
evaporation rate during March from the Sierra snow fields would be 0.068 inch for unbroken covering, and, say, 75 per cent of this, or 0.05 inch, under actual conditions. The average evaporation rate from water in the Owens Valley during the period December 1 to May 15 is about 25 per cent less than that in March, and during the period December 1 to June 15 about 10 per cent less. The average depth of equivalent water lost by evaporation from the snow fields of the high mountain areas would thus amount to 7.7 inches a season. This figure, though not accepted as correct, is yet very useful in connection with studies of stream-flow data.



MONTHLY MEAN AIR TEMPERATURE AT INDEPENDENCE 1895 to 1910.

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1895	37.8	45.5	49.2	57.3	65.8	71.5	78.1	76.1	68.3	60.0	48.3	37.8	58.0
1896	43.2	47.0	—	—	—	—	—	—	—	—	—	—	—
1898	—	—	—	61.8	62.1	74.3	80.5	80.1	71.7	60.1	48.1	39.7	—
1899	40.3	46.5	50.5	59.3	60.0	74.2	80.3	72.7	74.5	55.5	49.4	43.1	58.9
1900	46.6	48.1	54.9	52.0	65.7	75.4	79.4	72.4	63.5	58.8	50.4	43.4	59.2
1901	37.7	43.6	50.0	55.2	62.8	71.6	80.2	76.9	68.1	61.4	52.1	45.3	58.7
1902	39.4	43.6	44.6	55.9	61.7	75.5	77.0	74.9	72.9	60.2	45.3	40.5	57.6
1903	44.5	37.6	48.0	54.1	64.3	75.0	76.7	78.5	70.1	63.5	53.2	44.2	59.1
1904	42.4	48.5	50.9	56.3	67.6	74.6	78.1	77.9	69.0	59.2	51.4	41.3	59.8
1905	42.4	45.1	50.7	56.6	59.4	72.1	79.8	78.2	70.1	58.3	46.8	39.4	58.2
1906	43.0	48.9	48.6	54.1	61.6	70.9	79.9	75.6	68.3	58.3	45.2	42.1	58.0
1907	33.6	48.6	46.6	59.1	61.2	67.1	76.7	76.5	66.3	57.7	47.7	42.4	57.0
1908	37.8	40.4	49.9	57.1	58.2	68.5	79.1	74.3	66.1	53.4	47.1	36.7	55.7
1909	42.0	40.3	44.3	56.1	60.7	72.8	76.5	75.3	66.1	57.4	47.0	26.0	55.4
1910	35.6	41.3	53.6	59.8	57.5	73.4	77.9	77.2	69.7	58.6	48.0	41.6	58.6
Average	40.4	44.6	49.4	56.8	62.8	72.6	78.6	76.2	68.9	58.7	48.6	40.2	58.1

COMPARISON OF TEMPERATURE AND EVAPORATION BY MONTHS.



DIAGRAMS SHOWING

TEMPERATURE, WIND MOVEMENT, RELATIVE HUMIDITY AND EVAPORATION FROM WATER SURFACE IN THE INDEPENDENCE REGION, CALIFORNIA

JULY, 1908, TO DECEMBER, 1910

EVAPORATION FROM WATER SURFACE.

In the course of these investigations measurement of evaporation from free water surface has been made under three conditions—from a pan floating in a body of water, from a pan placed in the soil, and from a deep tank placed in the soil. The first two were designed to furnish data regarding evaporation from reservoir surfaces and from areas of shallow flood water, respectively. The third was desired for purposes of comparison with records of evaporation from soil. The pans, which were of the pattern used by the Reclamation Service, were 3 feet square and 10 inches deep and were made of sheet galvanized iron. Observations were made by replacing the amount evaporated with a cup whose capacity was equal to a depth of 0.01 inch in the pan. The initial height of the water surface was such that a pin projecting from the center of the pan and remaining at a fixed height, 2 inches below the rim, was just submerged. The deep tank was circular, 3½ feet in diameter and 4 feet deep, and observations were made in a stilling well with a hook gage and vernier scale reading to 0.01 inch. The records were all kept near Independence, and observations were made every second day in summer and every fourth day in winter.

The record for the pan in water is available from August 4, 1908, to June 1, 1911, with four intervals of a few days each when the pan floated away. The pan was at first located in Blackrock Slough, but was moved to its final location in Owens River at Citrus bridge May 7, 1909. (See Pl. XI, *A*.) Another pan that had been placed at Citrus bridge March 4, 1909, was then removed and used elsewhere. The pan was supported by a timber float which protected it from splashing water. The depth of water beneath the pan varied from 1 to 5 feet, depending on the river stage. The river water had a moderate velocity and varied in temperature from about 75° F. in summer to about 40° F. in winter. The river banks averaged 4 feet high above the water surface and the pan was situated about 30 feet from them. Rain gage No. 18 was located 100 feet away on the river bank and was observed in connection with the evaporation record.

The detail of the record for the pan in water is presented graphically on Plate X, and Table 49 summarizes the results by months. The annual depth of evaporation is about 67 inches, 75 per cent of which occurs between April and September. The difference between the evaporation in summer (April to September) and that in winter (October to March) is about 33 inches. The data presented on Plate X are instructive as regards the effect of temperature, wind movement, and relative humidity on evaporation. The coincidence of the annual maximum temperature, extreme dryness of atmosphere, and maximum rate of evaporation is striking, as is also the immediate change in the rate of evaporation brought about by a windstorm, period of dampness, or hot weather. The most important factor controlling evaporation is evidently temperature. The meteorologic observations were made by the Weather Bureau at Independence, 4 miles west of the evaporation pan, but the general conditions are very similar at the two places.

The record for the pan in soil is broken. It extends from August 1, 1909, to November 30, 1909, and from March 14, 1910, to June 1, 1911. The pan was located in the valley floor at the soil evaporation experiment station about 3 miles east of Independence. It is set in a shallow excavation, and soil is banked up to about half the depth of the pan. (See Pl. XI, *B*.) Water temperatures range from 95° F. in summer to 32° in winter. The surface temperature is about 1° warmer than that for the mixed contents of the pan. Rain gage No. 17 is located 40 feet southwest. Table 50 summarizes the results by months for this pan, and by comparing it month by month with the evaporation from the pan in water an average excess of about 33 per cent is observed. This is probably due to the warmer temperature of the water in the pan in soil during the hours of sunlight.

The deep-tank record extends unbroken from April 16, 1909, to June 1, 1911. The tank is located at the soil evaporation experiment station and is set in the soil with the upper rim flush with the surface. (See Pl. XII, *A*.) The water surface was not allowed to fall more than 4 inches below the rim. The temperature of the surface water varied from 80° in the heat of summer to freezing in winter. Except during freezing weather the average temperature of the contents of the tank was 5° less than that of the surface layer. The presence of the surrounding soil makes the range in temperature less than that for the shallow pan. The record, which is presented in Table 51, indicates an annual depth of evaporation slightly greater than that from the pan in water at Citrus bridge. The monthly distribution is more uniform, there being 70 per cent of the total during the six summer months and a difference of 27 inches between summer and winter evaporation. The effect on evaporation of the modified temperature extremes of the soil is well shown by comparison with the record for the pan in water (Table 49). Temperature conditions for the deep tank agree so closely with those of the surrounding soil that this record may be considered as representing the maximum rate of evaporation from soil.

No other extended series of measurements of evaporation from water have been made in Owens Valley. The Reclamation Service established a standard pan in one of the large irrigation ditches near Bishop and kept a record from January to October, 1904, inclusive. The total evaporation was 55 inches during the ten months, and would probably have been 60 inches for the year. The average tem-

A. EVAPORATION PAN ON OWENS RIVER NEAR CITRUS BRIDGE.

B. EVAPORATION PAN IN SOIL.

A. DEEP WATER EVAPORATION TANK.

B. SOIL EVAPORATION TANK SET, BEFORE INSTALLATION.

perature at Bishop is about 4° lower than at Independence, so this difference in evaporation is to be expected. The annual evaporation from the surface of Owens Lake is approximately 80 inches, as computed from fluctuations in the lake surface and the Government record of stream inflow.[1] The temperature is considerably higher at the lake than at Independence.

EVAPORATION FROM GROUND SURFACE.

Water in the surface layers of the ground is subject to evaporation, either directly from the soil or through vegetation by the process of transpiration. It is available for evaporation in Owens Valley under two conditions—temporarily following a rainstorm or sudden thaw and permanently within areas where the average depth to ground water does not exceed 8 feet. The total evaporation under the first condition is relatively unimportant because of the infrequency of storms and the small amount of precipitation, and no attempt was made to measure it. Under the second condition, however, evaporation is rather large, for not only is soil capillarity able to draw gravity water (see pp. 64–65) to the surface, but roots of vegetation, such as wild grass, penetrate the soil to ground water and become the channels by which a large amount of moisture is conveyed into the atmosphere. Evaporation from bare soil combined with transpiration is in fact the most important element entering into computations relating to ground water for this region.

Owens Valley is an ideal location for carrying on such experiments. In the first place, the source of water available for evaporation may be kept under the complete control of the observer as regards amount and rate of supply. Storms are rare and the total precipitation small, so that little uncertainty exists from this cause regarding the amount of percolation from precipitation upon the surface of a body of isolated soil. Second, the method by which the surface soils of the valley floor are kept moist can be artificially reproduced on a small scale with only a slight departure from natural conditions. The source of supply for soil moisture is a permanent ground-water surface from which water is drawn by capillary forces. This ground water is replenished by percolation from the precipitation and surface water of the intermediate mountain and outwash slopes, which seeps laterally toward the valley floor and lies beneath it under hydrostatic pressure sufficient to maintain a permanent ground-water surface. Similar pressure can be reproduced in the bottom layer of an isolated body of soil, and capillary forces can be depended upon to raise moisture to the surface. Finally, the large annual depth of evaporation makes possible a more accurate determination of its amount

[1] First Ann. Rept. Los Angeles Aqueduct, appendix D.

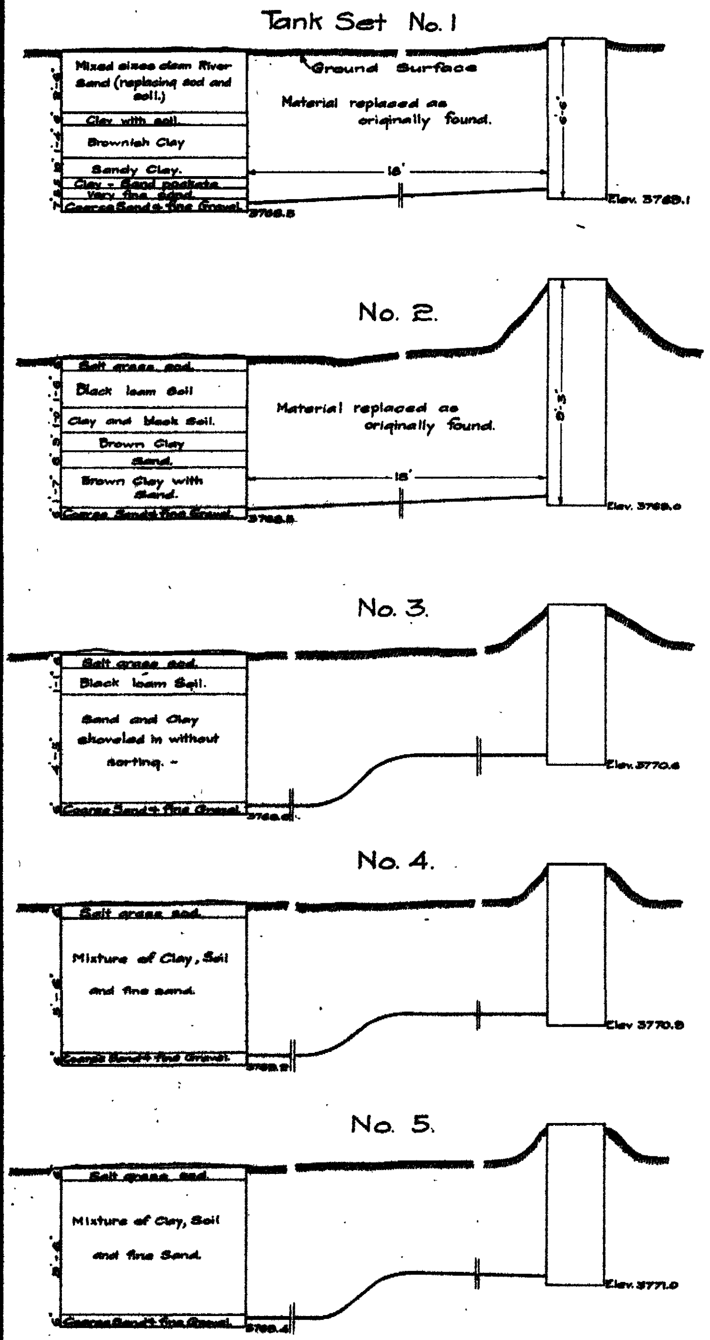
than in a less arid region. Experiments carried on under these conditions have been very satisfactory.

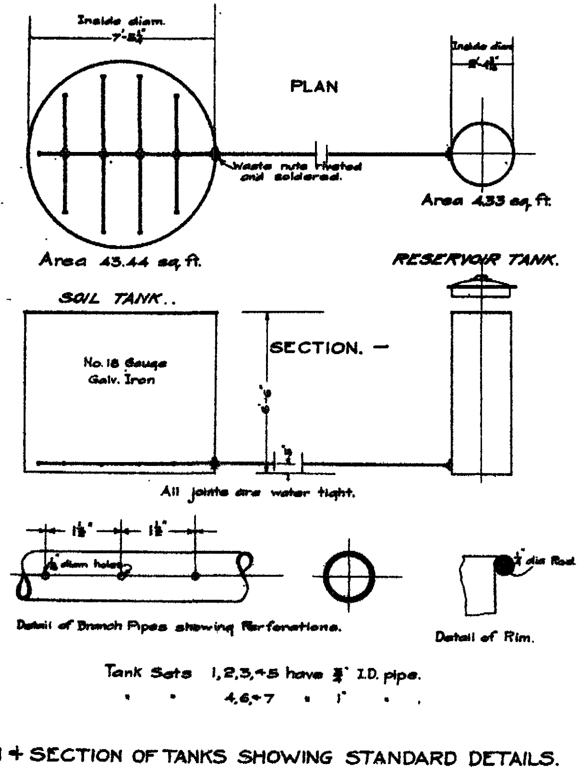
The rate of evaporation from soil depends on the temperature of the air and soil, the quantity of moisture already in the immediately surrounding atmosphere, the amount of moisture in the surface layers of the soil, and the character of the vegetation and other soil covering. The first two of these factors have the same effect on soil evaporation as on that from free water surface—higher air and soil temperatures result in increased evaporation, as does also dryer atmosphere or increased movement of wind. The third factor is directly proportional to the rate of evaporation, because the loss of moisture occurs from soil grains at or very near the surface. The amount of moisture in the soil available for evaporation thus depends upon the character of the soil as regards capillarity and depth to ground-water surface.[1] For example, in a coarse sandy or gravelly soil "gravity water" will be drawn to the surface through the capillary spaces from depths not exceeding 4 feet, while in a fine sandy or clayey soil water will be drawn from depths as great as 8 feet. The last factor, the extent and character of vegetation, affects the evaporation rate both through the activity of transpiration and the effect upon capillarity. Plant roots are continually absorbing water from the soil; this water passes off into the atmosphere through the leaves, and the evaporation losses from soil are greatly increased thereby. The roots of native salt grass will penetrate to a depth of 8 feet in search of water. A further effect of the growth of vegetation is to increase the vertical capillary flow of moisture through soil by way of the many tubes filled with the rotted fiber of dead roots. These tubes are the result of years of growth and penetrate the soil in all directions above the ground-water surface.

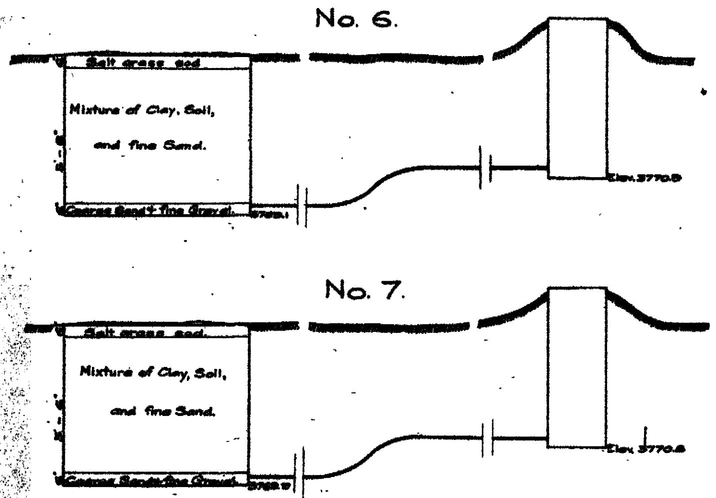
The purpose of the experiments was to obtain data sufficiently complete to compute the total volume of water annually lost by evaporation and transpiration from the valley floor. This involved making observations under the various local conditions which affect soil evaporation. The plan was to reproduce natural conditions in isolated bodies of typical soil and determine the evaporation therefrom for varying climatic conditions, depths to ground water, soils, and vegetation.

The experimental equipment consists of two galvanized iron tanks $6\frac{1}{2}$ feet in depth connected at the bottom by an 18-foot length of galvanized pipe. (See Pls. XII, *B;* XIII.) The smaller tank is 2 feet $4\frac{3}{16}$ inches in diameter and is furnished with a tight-fitting cover. The larger tank is 7 feet $5\frac{1}{4}$ inches in diameter and has a system of branching perforated pipes at the bottom connected with the pipe

[1] Buckingham, Edgar, Studies in the movement of soil moisture: Bull. Bur. Soils No. 38, U. S. Dept. Agr., 1907.

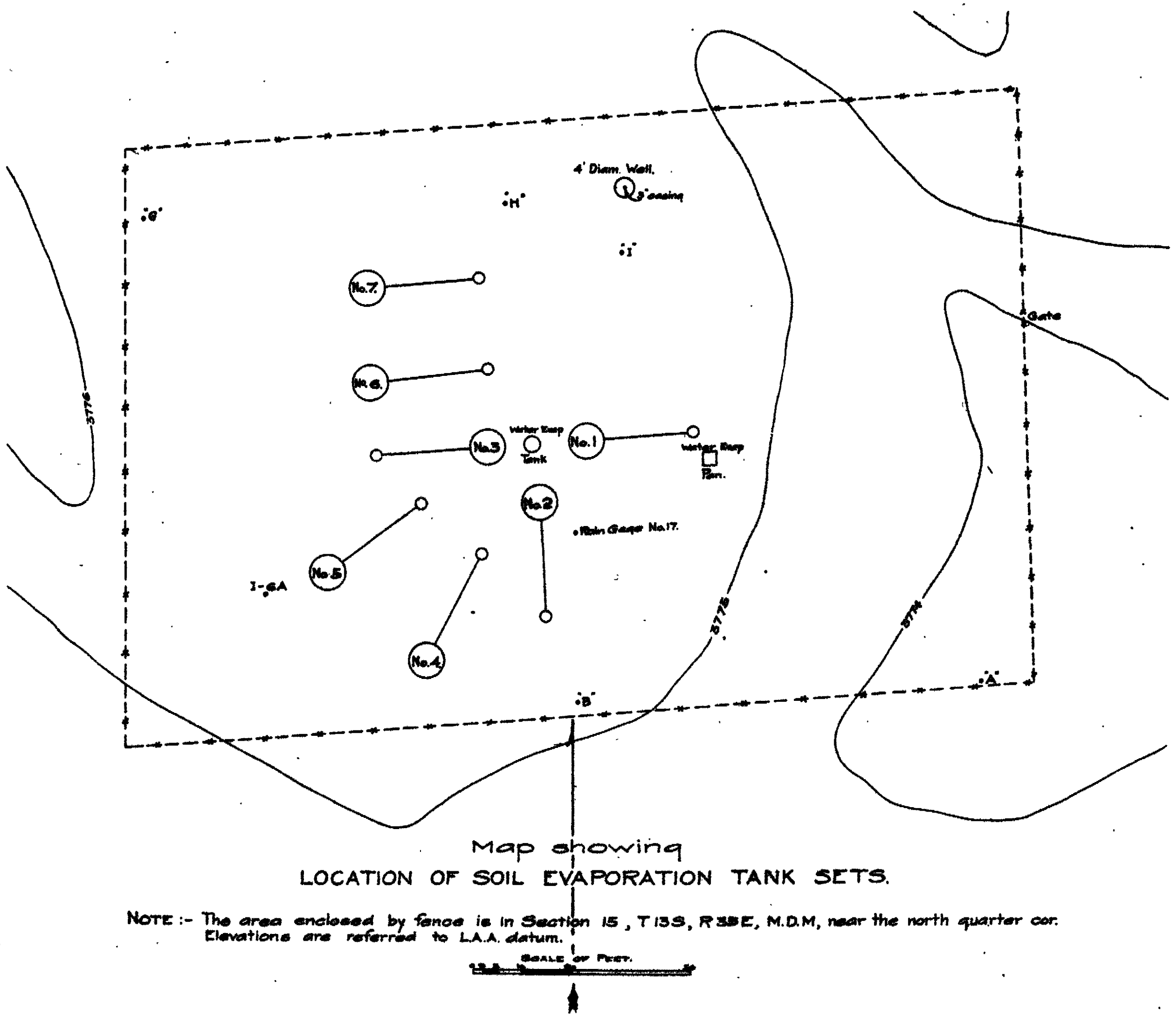






Scale ½" = 1'.

CROSS SECTIONS OF TANK SETS.



Map showing
LOCATION OF SOIL EVAPORATION TANK SETS.

NOTE :- The area enclosed by fence is in Section 15, T 13 S, R 35 E, M.D.M, near the north quarter cor. Elevations are referred to L.A.A. datum.

– NOTES –

The purpose of experiments is to measure the amount of evaporation occuring from ground surfaces in the Independence Region under varying conditions of soil, depth to ground water, vegetation, etc.

The method is to feed the soil in the large tanks from the bottom by supplying water to the reservoir tanks in measured quantities. As soon as capillary action is established, the water is drawn to the surface and evaporates.

Sand in the bottom layer of each soil tank was obtained from Pinyon Wash and all sizes less than 1/16 screened out.

ENGRAVED AND PRINTED BY THE U.S.GEOLOGICAL SURVEY.

MECHANICAL DETAILS OF TANKS AND CROSS SECTIONS AND LOCATION OF TANK SETS USED IN SOIL EVAPORATION EXPERIMENTS NEAR INDEPENDENCE, CALIFORNIA

from the smaller tank. The two tanks and all connections are water-tight, and water poured into the smaller or reservoir tank passes into the larger or soil tank and escapes through the perforations. These two tanks were placed in excavations of proper size to receive them, the soil tank was filled with the excavated soil, and the reservoir tank was filled with water. A 6-inch layer of screened gravel too coarse to enter the $\frac{1}{16}$-inch perforations was laid in the bottom of the soil tank to insure an uninterrupted and well-distributed feeding of water from the reservoir tank into the superimposed soil. As soon as the material became saturated and capillary action established to the surface, the water level in the soil was brought to the desired depth and kept there by supplying water to the reservoir tank in measured quantities. Volumetric measurements of water poured into or withdrawn from the reservoir tanks were made with an ordinary gallon measure. Accumulation or depletion of the supply in the reservoir tank was determined volumetrically by measuring the depth of water with a steel tape. The volume passing out of the reservoir tank during a given period represents the total evaporation from the soil tank during that period.

The position of the ground-water surface in the soil tank was determined by measuring its depth below the ground surface in augur holes of 2-inch diameter bored in the soil to a proper depth. Measurements were made from a fixed point with a steel tape weighted at the end and chalked before each observation. Three holes were placed in each tank halfway between the center and rim on radii 120° apart. For reasons noted below some of the tanks were provided with six holes placed on radii 60° apart. The holes were not bored deep enough to reach the bottom layer of coarse gravel, and the water level in them represented the ground-water surface in the surrounding soil. An average of the observations made at a given time was assumed to represent the general depth to ground water for the tank at that time. The tendency for the sides of the holes to cave in and the bottom to fill with sand was controlled by casing them with 2-inch galvanized sheet-iron pipe generously perforated with $\frac{1}{16}$-inch holes. These pipes were so driven that the top was just flush with the ground surface, and they were closed at the top with wooden plugs. In some of the tanks it was found impossible to bring the ground-water surface to the desired level with the available hydrostatic pressure from the reservoir tanks, and 2-inch holes were bored between the observation holes to the saturated gravel layer. Water usually rose in these holes to the same height as in the reservoir tank and by seeping laterally into the soil built up the ground-water surface. It was found difficult to keep these holes open to the gravel, however, and the water level in most of them eventually represented the ground-water surface.

Three tank sets were installed in the open valley floor east of Independence in February, 1909. (See Pl. XIII.) The surface of soil tank No. 1 (Pl. XIV, *A*) was bare sand; Nos. 2 and 3 (Pl. XIV, *B*) were laid with salt-grass sod. The initial plan formulated for tank sets Nos. 1 and 3 was to hold the ground-water level at various depths below the ground surface for periods of a few weeks during the summer while the climatic conditions were constant, in order to obtain, in a short time and with few tanks, trustworthy results of a general nature. The movement of the water surface from one level to another consumed so much time, however, that winter approached before the experiments on the lower levels were reached, and furthermore, there was no accurate method of determining the volume of evaporated water represented by the differences in depth. The experience of the first year's work with these tanks showed the necessity of maintaining a fixed ground-water level during a complete cycle of climatic changes. In soil tank No. 2 it was at first proposed to hold the ground-water level at or near the ground surface, but so great was the rate of summer evaporation that this plan was found to be impracticable with the equipment available. To remedy the defect the hydrostatic pressure from the reservoir tank was increased by soldering to it a 3-foot extension, but this extension could not be used until late in the season. This experience suggested the desirability of placing the reservoir tanks above the soil tanks and of increasing the size of the feed pipe from three-quarters to 1 inch.

In order to test this plan four additional tank sets were installed in January, 1910. The reservoir-tank outlets were placed about 1.7 feet above the soil-tank inlets, and 1-inch pipe was used throughout. The new soil tanks were laid with salt-grass sod, which grew fairly well. In tank set No. 1 the depth of water in the reservoir tank was held at 6 feet to maintain a uniform hydrostatic pressure in the soil tank, and thus reproduced natural conditions. No attempt was made in this set to control ground-water fluctuations artificially. In tank sets Nos. 2 to 7 water was supplied to reservoir tanks in quantities such that the depths to ground water were respectively 5 feet, 4.5 feet, 4 feet, 3 feet, 2 feet, and 1 foot. Observations were carried on continuously in the seven tanks for one year in order to study the effect of the ordinary range of climatic conditions. By this plan sufficiently complete data were obtained to make computations of evaporation loss from the valley floor.

The details of the observations on soil evaporation for each tank set are shown graphically in Plates XV to XXI. The supply of water available to the soil from the reservoir tank is the element under complete control of the observer, and at the top of each diagram are statements of the purpose governing additions to or withdrawals from this supply during various periods of time. Below this

A. SOIL TANK No. 1 IN OPERATION.

B. SOIL TANK No. 3 IN OPERATION.


RECORD OF OBSERVATIONS
SOIL EVAPORATION EXPERIMENTS.
TANK SET No. I.
SURFACE OF SOIL TANK IS SAND WITHOUT VEGETATION.
One U. S. Gallon = 231 cu in = .01337 cu ft
= .0031 ft depth in reservoir tank
= .0037 in. depth of evaporation from soil tank.
PLAN OF OPERATION
Water supplied reservoir tank to obtain a 1 ft. depth to ground-water surface in soil tank.
Water withdrawn from reservoir tank to obtain a 2 ft. depth to ground-water surface.
Water supplied res. tank to maintain a 2 ft depth to ground-water surface
Water withdrawn from res. tank to obtain a 3 ft. depth to ground-water surf.
Water supplied reservoir tank to maintain a 3 ft. depth to ground-water surface.
Observations discontinued because of freezing temperature.
Water supplied res. tank to obtain a minimum depth to ground-water surface.
Water supplied reservoir tank to maintain a constant pressure from reservoir tank.
Depth to ground-water surface in soil tank allowed to vary without artificial control
DIAGRAM SHOWING FLUCTUATION OF WATER SURFACE IN RES. TANK
DIAGRAM SHOWING AGGREGATE VOLUME OF WATER SUPPLIED RES. TANK
No water supplied Res. Tank Oct. 27, 1909 to Feb. 15, 1910.
Water draining from soil tank into res. tank
Reservoir Tank empty, repairing for leakage.
Assumed 20% of rain reaches G.W. surface = 6 gal.
Assumed 25% of rain reaches G.W. surface = 7 gal.
Assumed 25% of rain reaches G.W. surface = 4 gal.
Assumed 50% of rain reaches G.W. surface in Dec., Jan. & Feb.
Assumed 40% of rain reaches G.W. surface = 8 gal.
MEAN GROUND SURFACE IN SOIL TANK
DIAGRAM SHOWING FLUCTUATION OF WATER SURFACE IN SOIL TANK
Moisture commenced to appear on surface
Surface uniformly moist
Evaporation too great to maintain 1 ft. depth to G.W. surface
Surface commencing to dry
Surface quite dry
Soil tank buried under snow Dec. 5, '09. Sand frozen to a depth of several inches until end of Feb.
Placed 3 ft. lengths of 2 in. perforated casing in observation holes
Aggregate Volume of Water Supplied Reservoir Tank - U.S. Gallons.
Depth of Water in Reservoir Tank - Feet.
Mean Depth to G. W. Surface in Soil Tank - Feet.
April May June July August September October November December January February March April May June July August September October November December January February March April May
1909 1910 1911

RECORD OF OBSERVATIONS, SOIL EVAPORATION EXPERIMENTS, TANK SET NO. 2

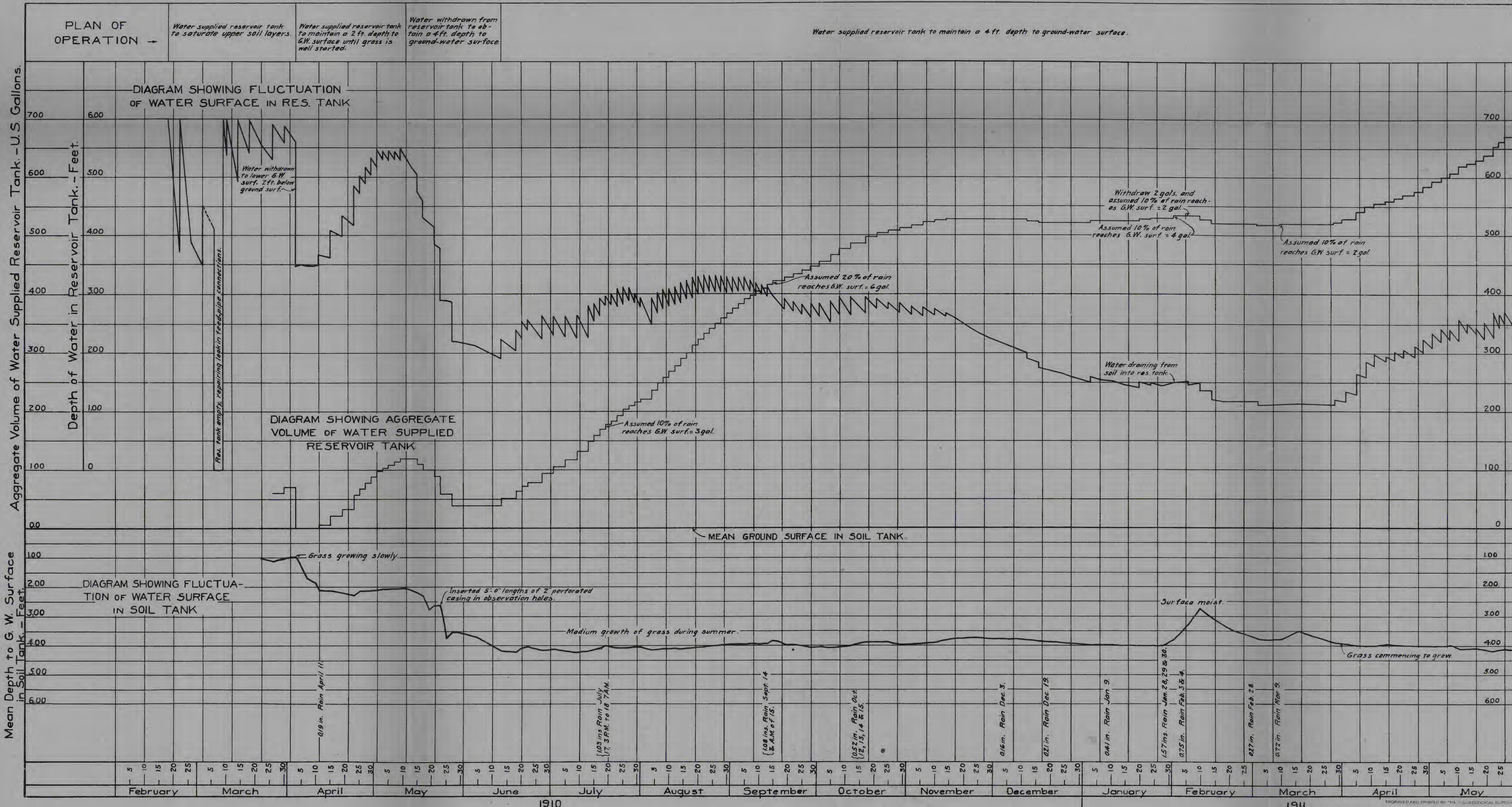
SURFACE OF SOIL TANK IS SOD WITH SCATTERED SALT GRASS

One U. S. gallon=231 cu. in.=0.1337 cu. ft.
=0.031 ft. depth in reservoir tank
=0.037 in. depth of evaporation from soil tank

RECORD OF OBSERVATIONS, SOIL EVAPORATION EXPERIMENTS, TANK SET NO. 3

SURFACE OF SOIL TANK IS SOD WITH VIGOROUS GROWTH OF SALT GRASS

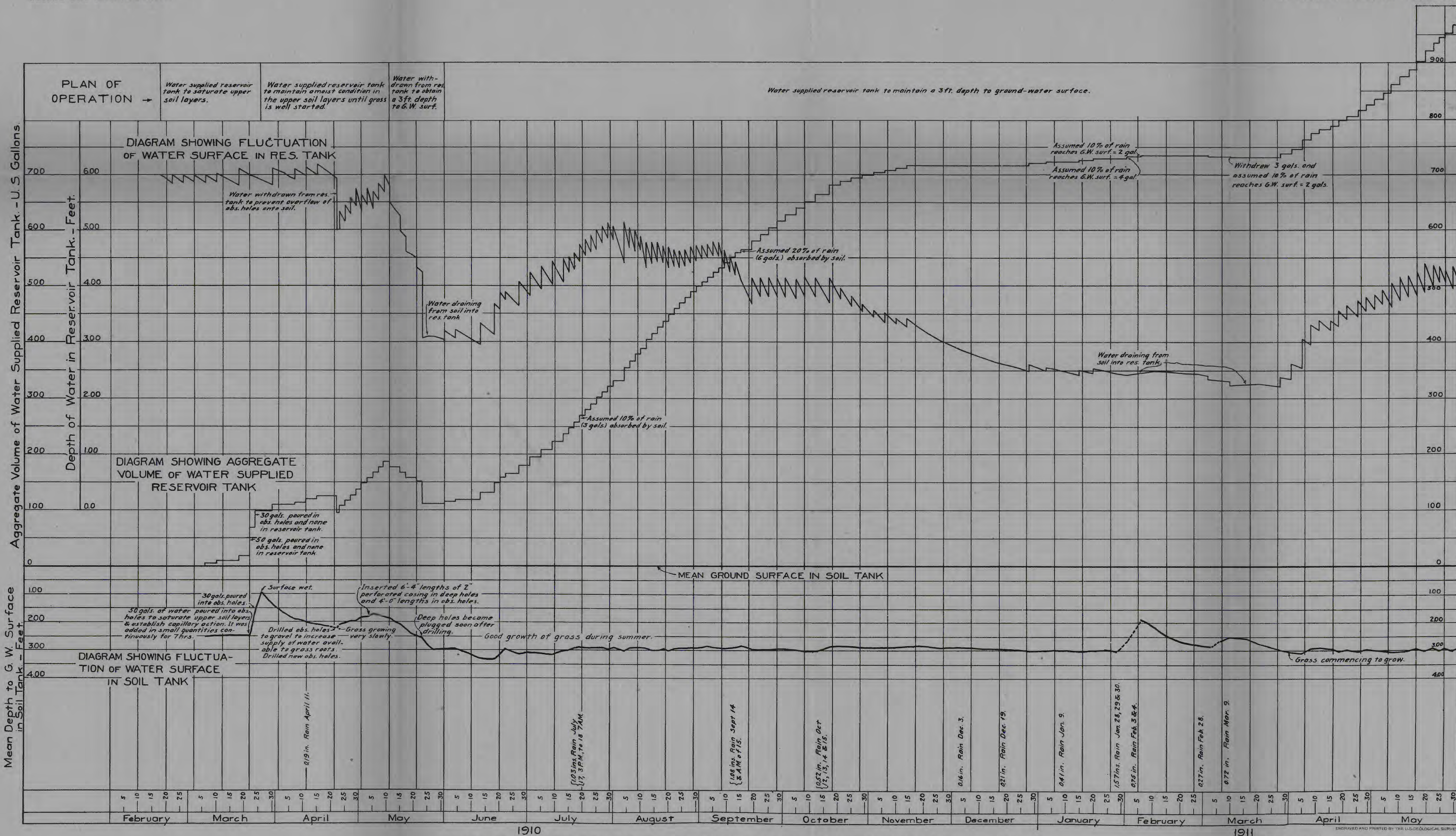
One U. S. gallon = 231 cu. in. = 0.1337 cu. ft.
= 0.031 ft. depth in reservoir tank
= 0.037 in. depth of evaporation from soil tank



One U. S. gallon = 231 cu. in. = 0.1337 cu. ft.
= 0.031 ft. depth in reservoir tank
= 0.037 in. depth of evaporation from soil tank

RECORD OF OBSERVATIONS, SOIL EVAPORATION EXPERIMENTS, TANK SET NO. 4

SURFACE OF SOIL TANK IS SOD WITH MEDIUM GROWTH OF SALT GRASS



RECORD OF OBSERVATIONS, SOIL EVAPORATION EXPERIMENTS, TANK SET NO. 5

SURFACE OF SOIL TANK IS SOD WITH GOOD GROWTH OF SALT GRASS

One U. S. gallon = 231 cu. in. = 0.1337 cu. ft.
= 0.031 ft. depth in reservoir tank
= 0.037 in. depth of evaporation from soil tank

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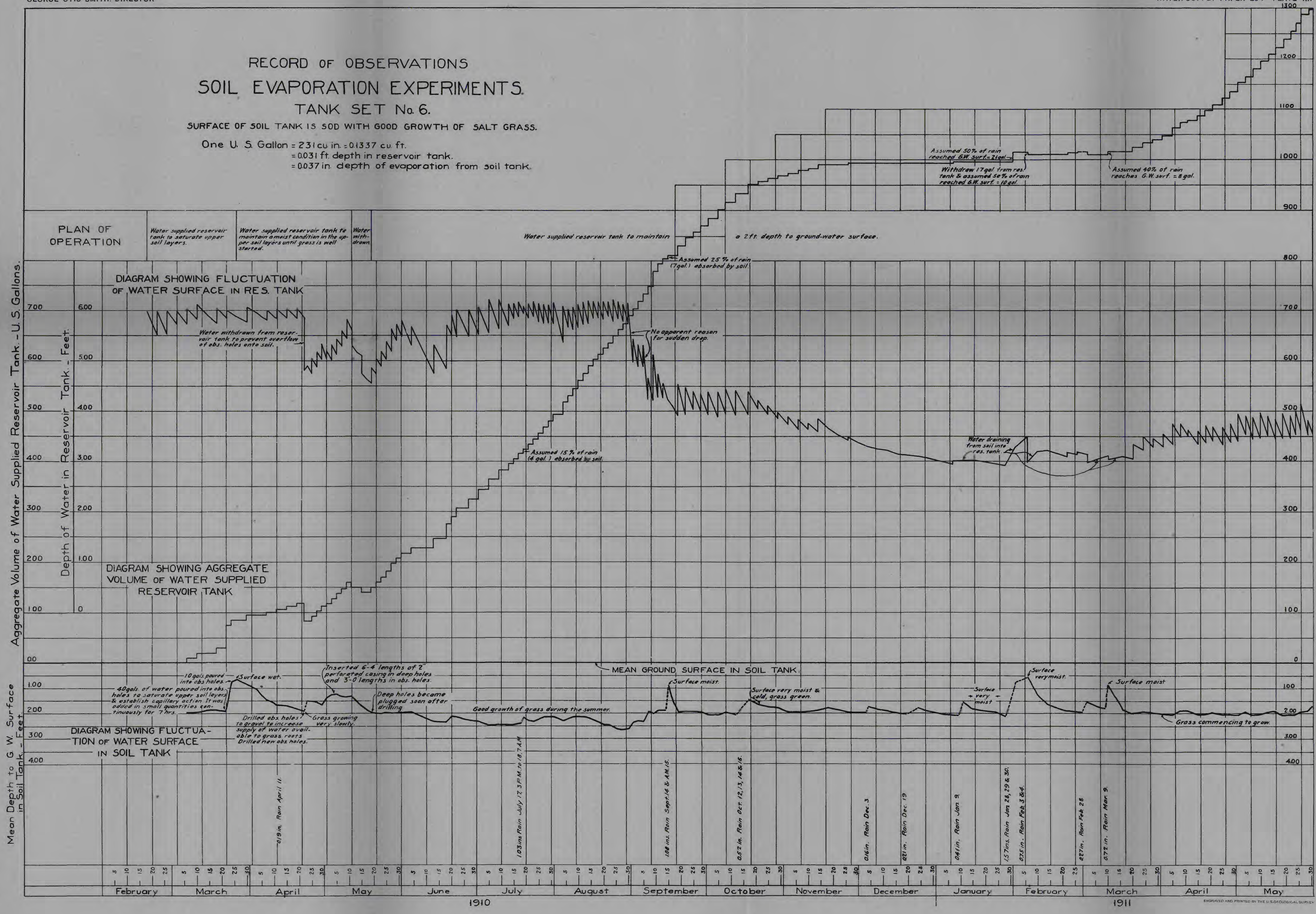
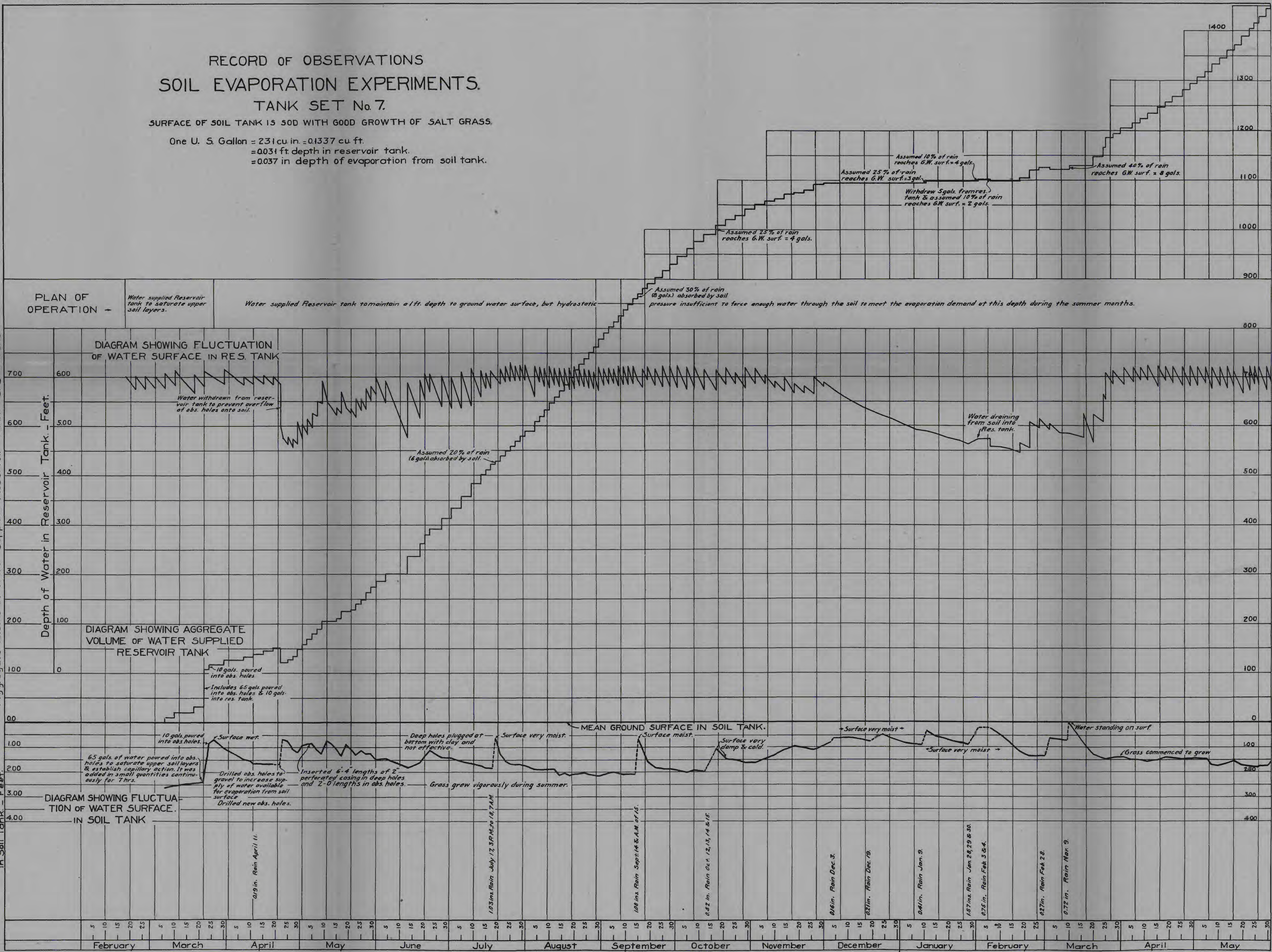

RECORD OF OBSERVATIONS
SOIL EVAPORATION EXPERIMENTS.
TANK SET No. 6.
SURFACE OF SOIL TANK IS SOD WITH GOOD GROWTH OF SALT GRASS.
One U. S. Gallon = 231 cu. in. = 0.1337 cu. ft.
= 0.031 ft. depth in reservoir tank.
= 0.037 in. depth of evaporation from soil tank.
PLAN OF OPERATION
Water supplied reservoir tank to saturate upper soil layers.
Water supplied reservoir tank to maintain a moist condition in the upper soil layers until grass is well started.
Water withdrawn.
Water supplied reservoir tank to maintain a 2 ft. depth to ground-water surface.
DIAGRAM SHOWING FLUCTUATION OF WATER SURFACE IN RES. TANK
DIAGRAM SHOWING AGGREGATE VOLUME OF WATER SUPPLIED RESERVOIR TANK
DIAGRAM SHOWING FLUCTUATION OF WATER SURFACE IN SOIL TANK
Aggregate Volume of Water Supplied Reservoir Tank. - U. S. Gallons.
Depth of Water in Reservoir Tank. - Feet.
Mean Depth to G. W. Surface in Soil Tank. - Feet.
Water withdrawn from reservoir tank to prevent overflow of obs. holes onto soil.
Assumed 15 % of rain (4 gal.) absorbed by soil.
Assumed 25 % of rain (7 gal.) absorbed by soil.
No apparent reason for sudden drop.
Assumed 50 % of rain reached G.W. surf. = 21 gal.
Withdrew 17 gal. from res. tank & assumed 50 % of rain reached G.W. surf. = 10 gal.
Assumed 40 % of rain reaches G.W. surf. = 8 gal.
Water draining from soil into res. tank
MEAN GROUND SURFACE IN SOIL TANK.
40 gals. of water poured into obs. holes to saturate upper soil layers & establish capillary action. It was added in small quantities continuously for 7 hrs.
10 gals. poured into obs. holes
Surface wet.
Drilled obs. holes to gravel to increase supply of water available to grass roots. Drilled new obs. holes.
Grass growing very slowly.
Inserted 6-4 lengths of 2" perforated casing in deep holes and 3-0 lengths in obs. holes.
Deep holes became plugged soon after drilling.
Good growth of grass during the summer.
Surface moist.
Surface very moist & cold, grass green.
Surface very moist
Surface very moist.
Surface moist
Grass commencing to grow.
0.19 in. Rain April 11.
1.03 ins. Rain July 17, 3 P.M. to 18, 7 A.M.
1.08 ins. Rain Sept. 14 & A.M. 15.
0.52 in. Rain Oct. 12, 13, 14 & 16.
0.16 in. Rain Dec. 3
0.21 in. Rain Dec. 19
0.41 in. Rain Jan. 9.
1.57 ins. Rain Jan. 28, 29 & 30.
0.75 in. Rain Feb. 3 & 4.
0.27 in. Rain Feb. 28
0.72 in. Rain Mar. 9.
February March April May June July August September October November December January February March April May
1910
1911
ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY


RECORD OF OBSERVATIONS
SOIL EVAPORATION EXPERIMENTS.
TANK SET No. 7.
SURFACE OF SOIL TANK IS SOD WITH GOOD GROWTH OF SALT GRASS.
One U. S. Gallon = 231 cu. in. = 0.1337 cu. ft.
= 0.031 ft. depth in reservoir tank.
= 0.037 in. depth of evaporation from soil tank.
PLAN OF OPERATION -
Water supplied Reservoir tank to saturate upper soil layers.
Water supplied Reservoir tank to maintain a 1 ft. depth to ground water surface, but hydrostatic pressure insufficient to force enough water through the soil to meet the evaporation demand at this depth during the summer months.
DIAGRAM SHOWING FLUCTUATION OF WATER SURFACE IN RES. TANK
DIAGRAM SHOWING AGGREGATE VOLUME OF WATER SUPPLIED RESERVOIR TANK
DIAGRAM SHOWING FLUCTUATION OF WATER SURFACE. IN SOIL TANK
MEAN GROUND SURFACE IN SOIL TANK.
Aggregate Volume of Water Supplied Reservoir Tank. - U. S. Gallons.
Depth of Water in Reservoir Tank. - Feet.
Mean Depth to G. W. Surface in Soil Tank. - Feet.
Water withdrawn from reservoir tank to prevent overflow of obs. holes onto soil.
Assumed 20% of rain (6 gals.) absorbed by soil.
Assumed 30% of rain (8 gals.) absorbed by soil
Assumed 25% of rain reaches G.W. surf. = 4 gals.
Assumed 25% of rain reaches G.W. surf. = 3 gal.
Assumed 10% of rain reaches G.W. surf. = 4 gals.
Withdrew 5 gals. from res. tank & assumed 10% of rain reaches G.W. surf. = 2 gals.
Assumed 40% of rain reaches G.W. surf. = 8 gals.
Water draining from soil into Res. tank.
10 gals. poured into obs. holes
Includes 65 gals. poured into obs. holes & 10 gals. into res. tank.
10 gals. poured into obs. holes.
Surface wet.
65 gals. of water poured into obs. holes to saturate upper soil layers & establish capillary action. It was added in small quantities continuously for 7 hrs.
Drilled obs. holes to gravel to increase supply of water available for evaporation from soil surface
Drilled new obs. holes.
Inserted 6'-4" lengths of 2" perforated casing in deep holes and 2'-0" lengths in obs. holes.
Deep holes plugged at bottom with clay and not effective.
Grass grew vigorously during summer.
Surface very moist.
Surface moist.
Surface very damp & cold.
Surface very moist
Surface very moist
Water standing on surf.
Grass commenced to grow
0.19 in. Rain April 11.
1.23 ins. Rain July 17, 3 P.M. to 18, 7 A.M.
1.08 ins. Rain Sept. 14 & A.M. of 15.
0.52 in. Rain Oct. 12, 13, 14 & 15.
0.16 in. Rain Dec. 3.
0.31 in. Rain Dec. 19.
0.41 in. Rain Jan. 9.
1.57 ins. Rain Jan. 28, 29 & 30.
0.75 in. Rain Feb. 3 & 4.
0.27 in. Rain Feb. 28.
0.72 in. Rain Mar. 9.
February March April May June July August September October November December January February March April May
1910
1911

is platted a broken line representing the fluctuation of water surface in the reservoir tank, the vertical portions indicating additions to or withdrawals from the reservoir supply made by the observer and the inclined portions indicating the soil-tank draft. There is also platted a mass curve showing the aggregate volume of water supplied to the reservoir tank, which appears as a series of vertical and horizontal lines. At the bottom of each diagram is platted an undulating line representing the fluctuation of ground-water surface in the soil tank, each depth being obtained by averaging the depths recorded in the observation holes.

The small part that precipitation plays in ground-water fluctuations in Owens Valley is well shown by these diagrams. The average annual precipitation at the experiment station is about 4.38 inches the season 1909–10 being normal and 1910–11 well above normal. At the bottom of the diagrams are noted the date and amount of precipitation for each storm. It is seen that even in a wet season percolating water does not penetrate to depths exceeding 2.5 feet, unless more than 1 inch falls within a short period on moist soil. Even then it does not appear to reach depths greater than 4 feet. The problem of percolation from rainfall is therefore practically eliminated from the experiments. When rising ground water was noted in a soil tank after precipitation, the volume of percolating water was estimated from the observed rise and included in the mass curve as noted on the diagrams.

The amount of water evaporated from the soil surface of any tank during a given period can be computed accurately from the diagrams, when the depth to ground water at the beginning and end of the period is the same, by noting from the mass curve the amount of water supplied to the reservoir tank during the period and the accumulation or depletion in the reservoir tank. The sum of these quantities with their proper algebraic sign gives the loss by evaporation. For differing depths to ground water, however, the computations are only approximate, because the proportion of empty space in the soil layer and the amount of moisture it contained initially are both unknown.

A summary of the results for each tank set by months for the year June 1, 1910, to May 31, 1911, is presented in Tables 52 to 58. It will be seen that in tank set No. 1 the draft on the reservoir tank varied as well as the ground-water surface in the soil tank, and that the fluctuations of the latter only partly represent the variation in evaporation rate. The average difference of water level in the two tanks was only 1.2 feet, however, so that the pressure was probably not as great as under natural conditions. The results for this tank are thus not as conclusive as desired. In tank sets Nos. 2 to 6 ground-water level was maintained at the desired depths, but in tank set No. 7 the pressure from the reservoir tank was not sufficient between April and September to hold the water level at the 1 foot depth. The average head of water in the reservoir tanks during the six months from April to September, inclusive, for sets 2 to 7, was 0.22, 0.59, 1.68, 2.02, 2.20, and 2.61 feet, respectively, indicating that a progressively greater pressure is required to maintain the ground-water level at shallower depths. As the average summer depth to ground water in soil tank No. 7 was 1.67 feet, it would require a maximum head of possibly 3.5 feet to supply water in sufficient quantities to meet the evaporation demand from ground-water surface at a depth of 1 foot.

The annual depth of evaporation from the several soil tanks exhibited a consistent decrease with increase of depth to ground water and varied from 43.1 inches for No. 7 to 7.9 inches for No. 2. The depth of summer evaporation varied from 77 to 83 per cent of the annual in the several tanks and averaged 79 per cent. The month of maximum evaporation is August, and minimum evaporation occurs most commonly in February. Examination of Plates XV to XXI, however, shows that the exact dates of maximum and minimum evaporation rates for the several soil tanks occur early in September and late in March, respectively, and follow each other consecutively with greater depth to ground water. The approximate dates of maximum and minimum air temperatures at Independence are July 10 and January 10, respectively, but no measurements were made to determine the lag of corresponding soil temperatures at various depths. The extremes of evaporation from water surface agree in time of occurrence with maximum and minimum air temperatures, however, and the observed lag in soil evaporation is in general consistent with observed lag in soil temperatures in other localities. Hence it is reasonable to conclude that extremes in rate of soil evaporation and soil temperature are concurrent at a given depth.

A graphic study of the data in Tables 52 and 58 for the periods April 1 to September 30 and October 1 to March 31, which are, respectively, periods of increasing and decreasing evaporation rate, is presented in figure 5. There appears to be during each period a straight-line relation between total evaporation and depth to ground water. The limiting depth is apparently 7.5 feet, and the total evaporation when water and ground surface coincide 42.3 inches and 10.2 inches, respectively. The total depth of evaporation in inches being represented by E and the depth to ground water in feet by D, the equations representing variation in evaporation with depth to ground water are $E=42.3-5.64\ D$ and $E=10.2-1.36\ D$. Capillary conditions and plant-root systems have not reached their natural state in most of the tanks, although each year of maintenance brings the equipment nearer perfection, as can be seen by noting that the total evaporation in May, 1911, exceeds that of June, 1910, even though temperatures during early 1910 were above normal and during early 1911 below normal. Tank No. 6 probably represents conditions most nearly normal, because capillary action is strong at that depth, and plant roots have not far to go to reach water. Observations of depth to water in transition zones between meadow and desert land indicate that soil evaporation ceases at a depth of 8 feet instead of

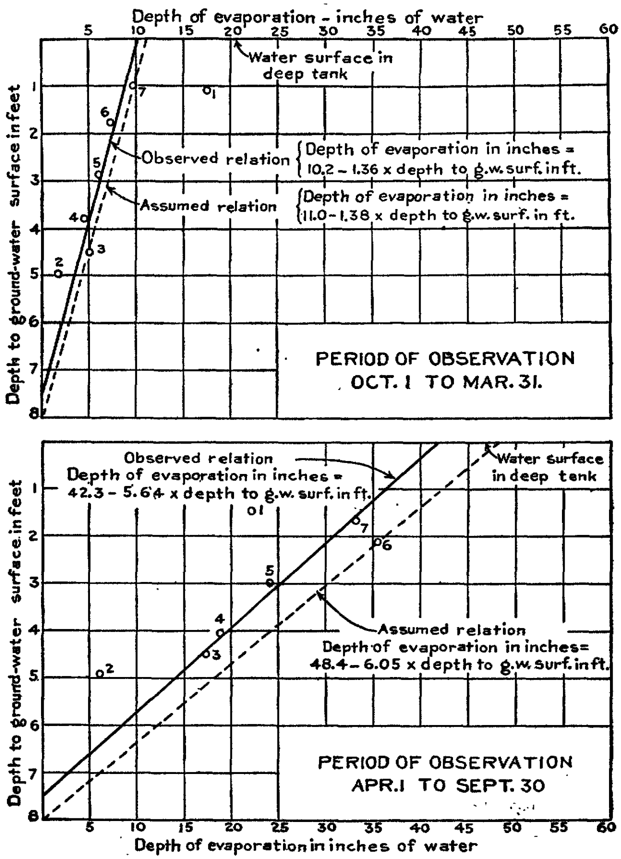


FIGURE 5.—Relations between evaporation, soil, and depth to ground water.

7.5 feet. From these considerations, lines are assumed which it is thought more nearly represent natural conditions, their equations being $E=48.4-6.05\ D$ and $E=11.0-1.38\ D$. It will be noted that the depth of evaporation from the water surface in the deep tank from April 1 to September 30 is practically equal to that obtained by substituting $D=0$ in the first of these equations. Hence, during the summer period evaporation from the deep water tank represents the maximum soil evaporation from meadow land of this type. During the winter, however, the water evaporation is almost twice the maximum soil evaporation.

The great difficulty in carrying on experiments relating to evaporation from soil is in reproducing natural conditions as regards atmospheric exposure of the isolated body of soil, its temperature, means of acquiring moisture, plant growth, and capillary state. It is believed that the experimental equipment employed in these investigations when operated with fixed ground-water level will, for all practical purposes, duplicate natural conditions by the end of two seasons' observations. The first year's results are regarded as being too small, because of insufficient development of plant-root systems and incomplete establishment of channels for the rise of water by capillarity. The cost of the tank equipment and installation is greater than that of the kind used by the Department of Agriculture,[1] but the operation is much simpler and less expensive and the results are fully as reliable.

TRANSPIRATION.

A considerable portion of the water evaporating from soil is absorbed by plant roots and carried upward through the stem and into the foliage, whence it escapes in the process of transpiration. This process continues as long as the plant has life, but is most active during the growing period. Transpiration differs in different species of plants and even in the same species when existing under different conditions of light, atmospheric pressure, soil texture, and available moisture in the soil. King's experiments indicate that humidity does not affect transpiration.[2] For a species growing in a definite locality, light and available soil moisture are the controlling factors.

The process of transpiration and respiration in plants is similar to the breathing of animals. Both plants and animals inhale air and exhale from the respiratory organs large quantities of water. The lungs of animals are intended primarily to provide a means for the entrance of oxygen into the body and for the escape of carbon dioxide, but they can not perform their functions unless the interior lining of the air cells is kept moist. Similarly the breathing surface of a plant must be kept moist, and, as a protection from too rapid evaporation, this surface is within the plant structure, principally in the foliage. Plant leaves are inclosed in a relatively impervious skin or epidermis in which are small breathing pores or stomata which automatically open or close, depending on the needs of the plant for a greater or less amount of air. When exposed to light the food-manufacturing processes of a green plant are stimulated and require a continually changing volume of air in contact with the breathing surface. The

[1] Fortier, Samuel, Evaporation losses in irrigation and water requirements of crops: Bull. Office Exper. Sta. No. 177, U. S. Dept. Agr., 1907.

[2] King, F. H., Irrigation and drainage, New York, 1899.

stomata open proportionally to the light intensity. Should the water supply in contact with the roots be insufficient, the breathing surface may become dry, and when that happens the stomata automatically close until the proper amount of air is admitted for the plant to do its work under the new conditions. The stomata therefore control the amount and rate of loss of water from plants by transpiration.

There is a marked diurnal periodicity in the rate of transpiration which investigators are led to believe is largely the result of varying

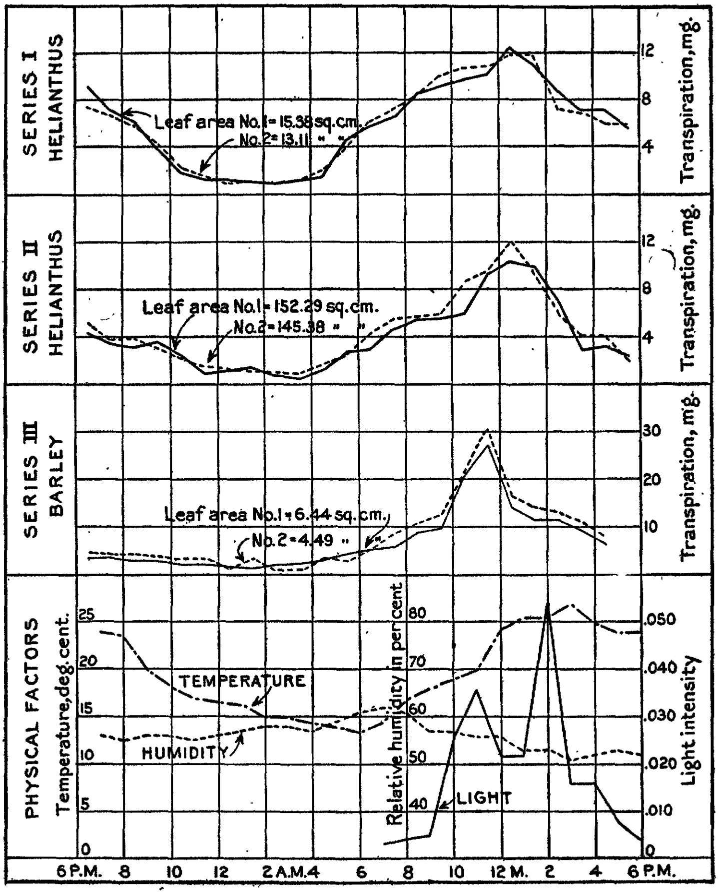


FIGURE 6.—Relation of transpiration to intensity of light.

intensity of light. This periodicity is well illustrated by observations made under the direction of Frederick E. Clements, State botanist of Minnesota, and reproduced in figure 6.[1] Measurements of transpiration were made hourly from 6 p. m. February 16 to 6 p. m. February 17, and the physical factors were observed between the hours. The day was cloudy throughout, so that variation in temperature and

[1] Sampson, A. W., and Allen, L. M., Influence of physical factors on transpiration: Minnesota Bot. Studies, pt. 1, vol. 4, 1909, p. 42.

humidity was slight. The diagrams show very strikingly the response of transpiration to changes in intensity of light.

The amount of water required by the common types of vegetation has been variously estimated by investigators working under differing climatic conditions and by differing methods. The German experiments especially are well known, and King, at Madison, Wis., has obtained valuable data. Table 59, summarizing a portion of the results of his experiments, is reproduced from King's book "Irrigation and drainage." The experiments were carried on in the field, where natural conditions could be reproduced.

No measurements of transpiration that have been made under conditions similar as regards altitude and aridity to those in Owens Valley are available. It is unnecessary in the present study to know separately the transpiration from wild grasses and evaporation from bare soil, because the area of the latter is relatively small. The experiments on soil evaporation were therefore planned to give the combined loss from these two causes. It is desirable, however, to know the amount of transpiration from field crops, to aid in computing the amount of percolation from irrigation. Observations for such crops were confined to alfalfa.

The method of measurement was based on the assumption that the rate of loss of water from freshly cut plants would correspond closely with that before cutting. The plants were rapidly cut from a measured area, weighed, and spread out on paper to cover the same area as before cutting. At short intervals they were reweighed until there was no further appreciable loss. No noticeable wilting occurred during the first 15 minutes, and the rate of loss during this period was used as a basis for calculations.

The results of the measurements are shown graphically in figure 7. Four average samples were cut, at 8.45, 9.15, and 10.30 a. m., and 2.02 p. m. The initial weights of the samples were 3 pounds 15½ ounces, 4 pounds 7 ounces, 5 pounds 5 ounces, and 4 pounds 7 ounces. In Table 60 are given the losses from each sample in ounces to the square yard for various periods during the first two hours.

The rapid decrease in the rate of loss is very noticeable. Inspection of figure 6 will show that the rates of transpiration at 8.45, 9.15, and 10.30 a. m., and 2.02 p. m., expressed as percentages of the average rate for 24 hours, are respectively 128, 141, 177, and 197, an average of 161 per cent. If a similar relation is assumed the average loss in a 24-hour day from the four alfalfa samples would be 366 ounces to the square yard of field area, or 0.49 inch in depth. This figure appears rather large at first glance, for the rate of evaporation for that day from the pan in Owens River was 0.30 inch, and that from the shallow pan in the soil was 0.38 inch. The results obtained by German investigators [1] indicate the loss from sod during

[1] Bull. Forest Service No. 7, U. S. Dept. Agr.

the growing season to be 92 per cent greater than from water surface, and that from cereals to be 73 per cent greater. Furthermore, the humidity of the air after passing over an alfalfa field is very noticeably greater than after crossing a body of water. The result obtained in the experiment here described is therefore within reason.

The growing season for alfalfa in the vicinity of Independence is marked by an entire absence of cloudiness. It extends from about April 15 to September 30, during which time three crops mature, the yield being about 5 tons of dry matter to the acre. The samples used for the experiments were almost ready for the second cutting.

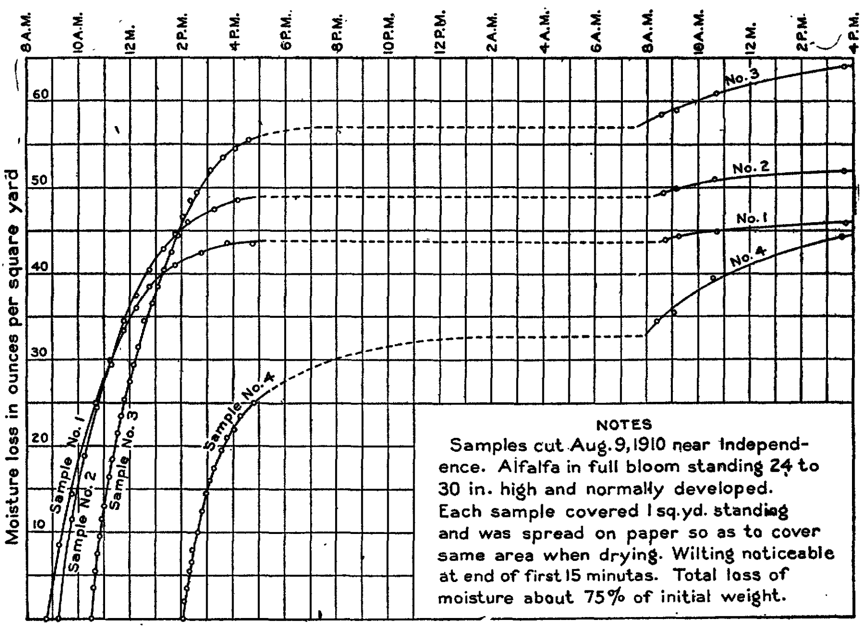


FIGURE 7.—Rate of loss of water by transpiration from freshly cut alfalfa.

On the assumption that the average area of transpiring surface during the entire growing season was 50 per cent of that on the day of the experiment, the total loss of water during the season would amount to 41 inches, or 3.43 feet in depth. With a production of dry hay amounting to 5 tons to the acre there would therefore be 1 pound of dry matter for every 93.5 pounds of water lost by transpiration. These results, though apparently large, are regarded as approximately correct and are used as a basis for further computation.

SUMMARY.

The depth of evaporation from snow which falls upon the high mountain areas is approximately 7.7 inches annually.

The depth of annual evaporation from the surface of water near Independence in a pan floating in Owens River is 67 inches, in a pan set in soil approximately 85 inches, and in a deep tank set in soil 69 inches. The percentages of these totals occurring between April 1 and September 30 are 75, 77, and 70, respectively.

The depth of combined soil evaporation and transpiration from the grass lands of the valley floor, as experimentally observed, is expressed by the equations $E=42.3-5.64D$ and $E=10.2-1.36D$, the first applying to the period April 1 to September 30 and the second to the period October 1 to March 31. These equations are believed to give results too small. The depth of summer evaporation averages 79 per cent of the annual for the various depths.

The depth of combined soil evaporation and transpiration in irrigation near Independence is about half the depth of water applied.

PERCOLATION.

CONDITION AND MOVEMENT OF WATER IN SOIL.

Water reaching the surface of porous unsaturated ground has a tendency to pass downward to the surface of saturation. This process, known as percolation, is very important in connection with the occurrence of underground water. A short summary of the principles governing the condition and movement of water in the soil is therefore not out of place in this report.

Most of the water contained in a soil exists in either a capillary or a gravitational state. "Capillary water" occupies a thin film surrounding each soil grain and also the space adjacent to points of contact with other soil grains. It is capable of movement in any direction through the soil in response to the force known as surface tension, but it will not leave the soil except by evaporation. When equilibrium has been established in soil containing water, capillary movement can occur only as a result of evaporation or a change in surface tension. When evaporation occurs the movement is toward the region of depletion. A change in surface tension may be brought about by the introduction of soluble salts or foreign liquids, such as oil, and it results in either an increase or decrease of the proportion of void space occupied by capillary water. If an increase, more water will be drawn upward from the surface of saturation, or, if there is no capillary connection with a body of saturated soil, there will be a contraction of the region containing capillary water; if a decrease, water will drain downward to the surface of saturation, or there will be an expansion of the capillary region. The extent of capillary action is greater in moist than in dry soils, as is also the rate of advance of water.

"Gravity water" occupies the void spaces in soil which are not capillary in nature, and it is free to drain away under the pull of gravity. The relative amount of capillary and gravity water in a saturated soil depends on the texture and structure of the soil, the surface tension of the soil water, and the length of soil column considered. For example, in very fine clays the interstitial space is entirely capillary, and even when saturated water will not drain from it. In coarse-grained soils, however, the capillary space is relatively small and a portion of the contained water will drain off readily. With a given sample of soil, changes in surface tension or the position of the surface of saturation will cause variation in the relative amounts of capillary and gravity water.[1]

The amount of water which reaches the surface of saturation and becomes a permanent addition to the ground-water supply of a region depends on the amount of water entering the soil and the rapidity with which it passes beyond the reach of capillary forces tending to bring it back to the surface. The amount entering the soil depends on the total volume of water at the surface, the texture and structure of the surface soil and subsoil, the rate of evaporation, and the slope and smoothness of the surface. The rapidity of its descent depends on the amount of moisture already in the soil, the texture and structure of the soil, and the depth to the surface of saturation. Percolation is favored by coarse and loosely arranged soil grains, a moist soil, large precipitation or surface flooding, low rate of evaporation, a gently sloping and uneven surface, and a depth to the surface of saturation greater than the limit of capillarity.

A permanent body of ground water exists in the void spaces of the porous material filling the closed rock basin of the Independence region. The source of this ground water is percolation from precipitation and from other water which occurs upon the surface of the valley fill, the latter being derived from surface streams, irrigation water, and surplus water from mountain streams which occasionally flood portions of the valley floor. The total amount of this percolation may be estimated from data already presented.

PERCOLATION FROM PRECIPITATION.

All portions of the region receive precipitation, but there is wide local variation in the amounts that enter the ground and percolate downward to the surface of saturation. The impervious rock surfaces of the high mountain drainage areas shed all precipitation which they receive except that lost by evaporation, but accretions to the ground water from precipitation on the remaining areas of the region are of considerable importance.

Conditions are exceptionally favorable for percolation on the intermediate mountain slopes. As has been stated, the formation is very

[1] Briggs, L. J., Mechanics of soil moisture: Bull. Bur. Soils No. 10, U. S. Dept. Agr., 1897, p. 5.

porous (Pl. III, p. 13) and practically none of the run-off reaches living streams. All precipitation but that lost by evaporation can therefore be considered as percolating downward to the surface of saturation and becoming a permanent addition to the ground-water supply. Snow is practically all melted before May 15, so that the period of direct exposure to evaporation is not as long as at higher levels, although the rate is greater. Evaporation losses from the moist soil are very small. Before it is melted the snow blanket protects the soil surface, and by its gradual and uninterrupted melting it fills the capillary spaces to considerable depth, so that gravity water passes downward rapidly. When the snow disappears the rapid drying of the soil surface soon interrupts upward capillary movement, thus preventing further evaporation loss and allowing the percolating water to reach the surface of saturation. In view of these facts, the percolation factor is regarded as being about 0.75 for the more elevated areas receiving approximately 20 inches of precipitation. Less-favored areas were assigned smaller factors after a study of their individual characteristics.

The results of computations of the total amount of percolating water yielded by the intermediate mountain slopes are shown in Table 61. The method was to determine the mean seasonal precipitation at the center of area of each triangular subdivision, multiply this by the area in square miles, and apply a percolation factor. The area of each subdivision and the horizontal and vertical position of its center were obtained from Table 3. Diagrams Nos. 7, 8, 10, 11, 13, and 14 on Plate VIII were used in determining the depth of precipitation. The values differed slightly as read from the altitude and distance diagrams and the average was adopted as the most reliable. The total volume of precipitation upon the 29.4 square miles of intermediate mountain slope is 27,580 acre-feet, of which 19,700 acre-feet is a permanent addition to the underground water supply of the region. Expressed as a continuous flow, the total percolation from this area is 27 second-feet, and the yield per square mile ranges from 1.07 second-feet in the vicinity of Taboose Creek to 0.72 second-foot near Bairs Creek, with an average of 0.92 second-feet.

The outwash slopes yield to the underground supply a much smaller volume of water, which is derived principally from slopes above the 5,500-foot contour. Precipitation occurs as snow less often here than on the higher slopes and usually melts within a few days after falling. The capillary water in the upper layers of the soil thus has opportunity to evaporate after each storm and it is only when several storms occur in succession that there is enough percolating water to penetrate the ground beyond possibility of return. The long dry summer and the desert conditions draw all moisture from the ground to considerable depths, however, and the progress of percolating waters is slow because the capillary spaces must be refilled. Test pits dug in the region of the 4,500-foot contour 10 days after a series of storms showed a penetration of capillary water to a depth of 4 feet and the entire absence of gravity water. The total precipitation from these storms at this point was about 3.5 inches, which, with a 28 per cent available pore space, would represent 1 foot of completely saturated soil. (See Pl. XXVIII, p. 82, test pit No. 11.) Considering the evaporation losses it is not surprising that there was no gravity water within the depth of penetration observed. Observations made at higher elevations showed gravity water in considerable quantity at a depth of 12 feet. Percolation factors varying from zero to 0.60 were assigned to the several zones of the outwash slope as a result of these field observations.

The results of computations for the total amount of percolating water yielded by the outwash slopes are shown in Table 62. The whole area of 165 square miles was divided into zones lying between contours at 500-foot intervals from about 4,000 to 6,500 feet and the zones in turn were divided into groups corresponding with the precipitation gages. The method of computation was to average the precipitations for adjacent contours obtained from diagrams Nos. 7, 8, 10, 11, 13, and 14 of Plate VIII. These averages represented the average precipitation for each zone in each group and, when multiplied by the area and the percolation factor, gave the amount of percolating water which reached the permanent ground-water level. The total annual precipitation on the outwash slopes is 62,000 acre-feet, of which 16 per cent, or 9,800 acre-feet, is effective percolating water. Expressed as a continuous flow the volume of percolating water amounts to 13.4 second-feet.

Throughout the valley floor the surface of saturation is so close to the ground surface that capillary connection is maintained during most of the year and percolation from precipitation is rapid. The depth of penetration is usually slight, however, because precipitation in single storms is small. Several storms in succession or a warm rain on snow will result in a rise of ground water, but the total average ground-water supply from this source does not exceed 4 second-feet.

Direct percolation from precipitation therefore furnishes a continuous flow of 44 second-feet to the underground supply of the region.

PERCOLATION FROM STREAM CHANNELS.

The most important source of underground water in a desert region is percolation from stream channels. This process is continuous from perennial streams, although it varies with the discharge of the stream and the temperature, as previously indicated. Beneath each stream channel as it crosses the outwash slope is a "ridge" of ground water rising from the general plane of saturation. The inclination of the slopes of this ridge and the breadth of its base vary periodically with the stage of the creek and the time of year. There is complete saturation within its slopes and a movement of gravity water toward the general ground-water surface. A considerable amount of water also percolates from intermittent streams.

Percolation from stream channels in the Independence region is confined to the creeks draining mountain canyons. It begins where the stream leaves its canyon to cross the outwash slope and continues to and in some streams beyond the edge of the valley floor. There are 17 of these streams, 11 of which are perennial throughout their channels, 5 perennial over the upper portion of their channels only, and 1 (Dry Canyon) entirely an underground stream. The surface flow of the two most northerly of these streams, Tinemaha and Red Mountain creeks, discharges northward across the Poverty Hills into the Bishop-Big Pine region, but the percolation from their channels is tributary to the Independence region. This region receives both the surface and the underground flow of the creeks from Taboose to Hogback, inclusive. The channels of these streams are continuous from their canyons to the United States Geological Survey gaging stations, below which they divide, irrigation ditches carrying all the flow except during the high-water period of wet years, when the excess passes down the natural channels. The problem is thus divided into the determination of percolation above and below the Government gaging stations. The first subject has already been discussed at length and need not be considered here in detail. An inspection of Tables 43 and 44 shows that for the creeks from Taboose to Hogback, inclusive, the total 21-year average discharge at the mouths of the canyons is 130 second-feet and at Government gaging stations 84 second-feet. If the flow of 2 second-feet from spring No. 2 on Division Creek is included with the canyon discharge, the percolation loss above the Government gaging stations is 48 second-feet. To this should be added 6 second-feet, as indicated by the diagrams, for Tinemaha and Red Mountain creeks, making a total of 54 second-feet.

The amount lost below these stations is not so easily determined on account of the numerous channels and irregular flow. For example, the water diverted from Oak Creek is distributed by seven main ditches whose aggregate length, not including field laterals, is approximately 4 miles. The flow in these ditches varies with the stage of the creek and with the needs of the irrigators. The field work necessary to determine channel losses below the Government stations accurately was so great that it was not attempted. Estimates were made on each creek, however, based on the length of main channel and distributing ditches outside of irrigated areas. The loss per mile was assumed to be the average annual loss per mile for the upper channel of the creek, and the total percolation loss from stream channels below the Government stations was estimated at 25 second-feet continuous flow. This estimate does not include percolation from waste irrigation water or surplus creek water which has passed east of the ranches.

The total addition to the underground supply derived by percolation from stream channels is therefore 79 second-feet continuous flow.

PERCOLATION FROM IRRIGATION.

Irrigation has been practiced throughout this region in connection with farming for at least 30 years and is a permanent factor in the underground water problem. The total area under systematic irrigation is approximately 3,000 acres, divided into a number of isolated ranch groups which depend on the mountain creeks for their supply. Oak Creek, the largest of these streams, supplies about 45 per cent of the whole area. The remaining area is divided among eight creeks and the Stevens ditch, which during the period of observation has been largely supplied by the surplus flow of the creeks. The acreage irrigated from each source is given in Table 63. About 50 per cent of this land was originally desert lying along the lower margin of the outwash slope and is very porous. The remainder lies in the valley floor, where permanent ground water is within reach of plant roots and where clay soils predominate. The location of the several areas is shown on Plate I. Alfalfa and grain are irrigated by flooding and corn by the furrow method. Three crops of alfalfa are raised each year, and the irrigating season extends from about April 15 to October 15, although some farmers irrigate 9 months in the year. Grain is irrigated early in the season and corn late, so that the water is continually employed. In most places the use of water is lavish, and no attempt is made to economize it or even to apply the amount best suited to the crop and soil conditions.

A basis for determining the percolation from irrigation is a knowledge of the duty of water, or the quantity of water used in maturing a given area of crop. This was obtained in 1909 by carefully measuring the amount of water used during the irrigating season on five typical ranches which derived their supply from Oak Creek. Gages were established at permanent sections in the supply ditches near the points of entrance to the ranches, and the amount of water delivered was computed from daily gage readings and weekly current-meter measurements. On ranches where there was a continual waste from irrigation the surplus water was also measured. Areas in crop were obtained from a careful stadia survey of each ranch.

Ranch No. 1 is situated on rather high, well-drained land of a sandy and porous texture. The permanent ground-water level is 10 to 15 feet below ground surface. The irrigators are economical in their use of water. The total area in crop during 1909 was 109 acres, 33 per cent being alfalfa, 30 per cent corn, 28 per cent barley, 4 per cent potatoes, and 5 per cent orchard and vineyard. The observed duty of water was 7.22 acre-feet an acre, which for this type of soil and location represents about the least amount of water which will mature these crops.

Ranch No. 2 is situated east of No. 1, on soil which varies from light sandy to black clayey, the latter predominating. The ground-water level ranges from 10 feet below the surface along the west boundary to about 4 feet in the bottom land. The total area in crop in 1909 was 154 acres, the percentages being as follows: Barley 43; alfalfa, 31; corn, 15; and miscellaneous, 8. The observed duty of water was 2.80 acre-feet an acre, an amount greater than that ordinarily used on the damp bottom land because of the area of sandy land included.

Ranch No. 3 has black clay soil throughout, and the ground-water level averages about 4 feet below the surface. The total area in crop in 1909 was 260 acres, of which 33 per cent was barley, 31 per cent corn, 25 per cent pasture, 4 per cent alfalfa, and 7 per cent miscellaneous. The observed duty of water was 2.34 acre-feet an acre, which represents the average amount used for this type of soil in this locality.

Ranch No. 4 has the well-drained sandy soil of porous texture which characterizes No. 1. Permanent ground-water level is 10 to 15 feet below the surface. Irrigation is carried on in a very lavish and wasteful manner. The total area in crop during 1909 was 49 acres, of which 46 per cent was alfalfa, 40 per cent corn, and 13 per cent barley. The observed duty of water was 15.40 acre-feet an acre, which is about the amount of water ordinarily used on this type of soil throughout the region.

Ranch No. 5 is situated similarly to No. 4 and has experienced a similar lavish use of water. The area in crop in 1909 was 38 acres, of which 87 per cent was alfalfa, 8 per cent potatoes, and 5 per cent miscellaneous. The observed duty of water was 16.40 acre-feet an acre. The methods of irrigation were similar to those practiced on Ranch No. 4, and the results indicate the large demands of alfalfa for water.

With conditions on these typical ranches in mind, an examination was made of all other ranches in the region and values estimated for the duty of water on each. The number of acres irrigated and in crop was also determined approximately by reference to subdivisions of the public survey. From these data the volume of water used for irrigation was computed as shown in Table 63. The total volume used during the six months, April 15 to October 15, is about 26,000 acre-feet, equivalent to a continuous flow during the period of 72 second-feet. When spread out over 3,010 acres this represents an average depth of 8.6 feet. This result probably represents average practice throughout the Owens Valley, for the duty of water measured by the Reclamation Service during the season of 1904 on two typical ranches near Bishop was 7.11 and 9.17 acre-feet an acre.

The distribution of this water as regards evaporation, transpiration, and percolation beyond the reach of plant roots is the next step in computing the ground-water supply from this source. Direct evaporation is relatively small, for the water when spread out over the fields is shaded by the crop and sinks rapidly into the ground. Probably 10 per cent would cover this loss. The transpiration loss from alfalfa during the irrigating season has already been computed as 3.43 feet depth of equivalent water, or 40 per cent of the average volume of water applied to crops. The transpiration loss from corn and small grains is probably less in this locality, but the direct evaporation loss is greater. Therefore 50 per cent, or 4.3 feet depth, represents the amount of water applied in irrigation in this region which is absorbed by the atmosphere. The other 50 per cent is a permanent addition to the ground-water supply and is equivalent to a continuous flow throughout the year of 18 second-feet.

PERCOLATION FROM FLOOD WATER.

The amount of percolation from surplus creek water which spreads out over the valley floor to a greater or less extent is difficult to determine. Of the 84 second-feet average flow at Government gaging stations, 61 second-feet is disposed of in channel percolation and irrigation. Possibly 5 second-feet of the remainder reaches Owens River. This leaves 18 second-feet to be divided between evaporation and percolation in the flats between the ranches and the river. The area flooded averages about 5 square miles during June and July. The loss by evaporation during this period from a shallow pan in soil was about 24.5 inches, and as the conditions are similar this amount represents approximately the loss from shallow flood water. The volume expressed as a continuous flow for two months is 55 second-feet, or for a year 9 second-feet. The other 9 second-feet can be assumed to represent the percolation from this flood water. It is not a permanent addition to the ground-water supply, however, for the surface of saturation is only a few feet below the ground surface in this area, and evaporation from damp soil and transpiration from natural vegetation soon reduce the ground-water surface to its normal position.

SUMMARY.

The four sources of ground water are percolation from direct precipitation, from stream flow, from irrigation, and from flood water in the valley floor.

The first of these yields about 44 second-feet, of which 61 per cent is from the intermediate mountain slopes, 30 per cent from the outwash slopes, and 9 per cent from the valley floor. Percolation from streams yields about 79 second-feet, of which 68 per cent is above Government gaging stations and 32 per cent below. Irrigation yields 18 second-feet and flood waters in the valley floor 9 second-feet.

The total ground water is therefore 150 second-feet, of which probably 75 per cent reaches the deeper strata of the valley fill.

GROUND WATER.

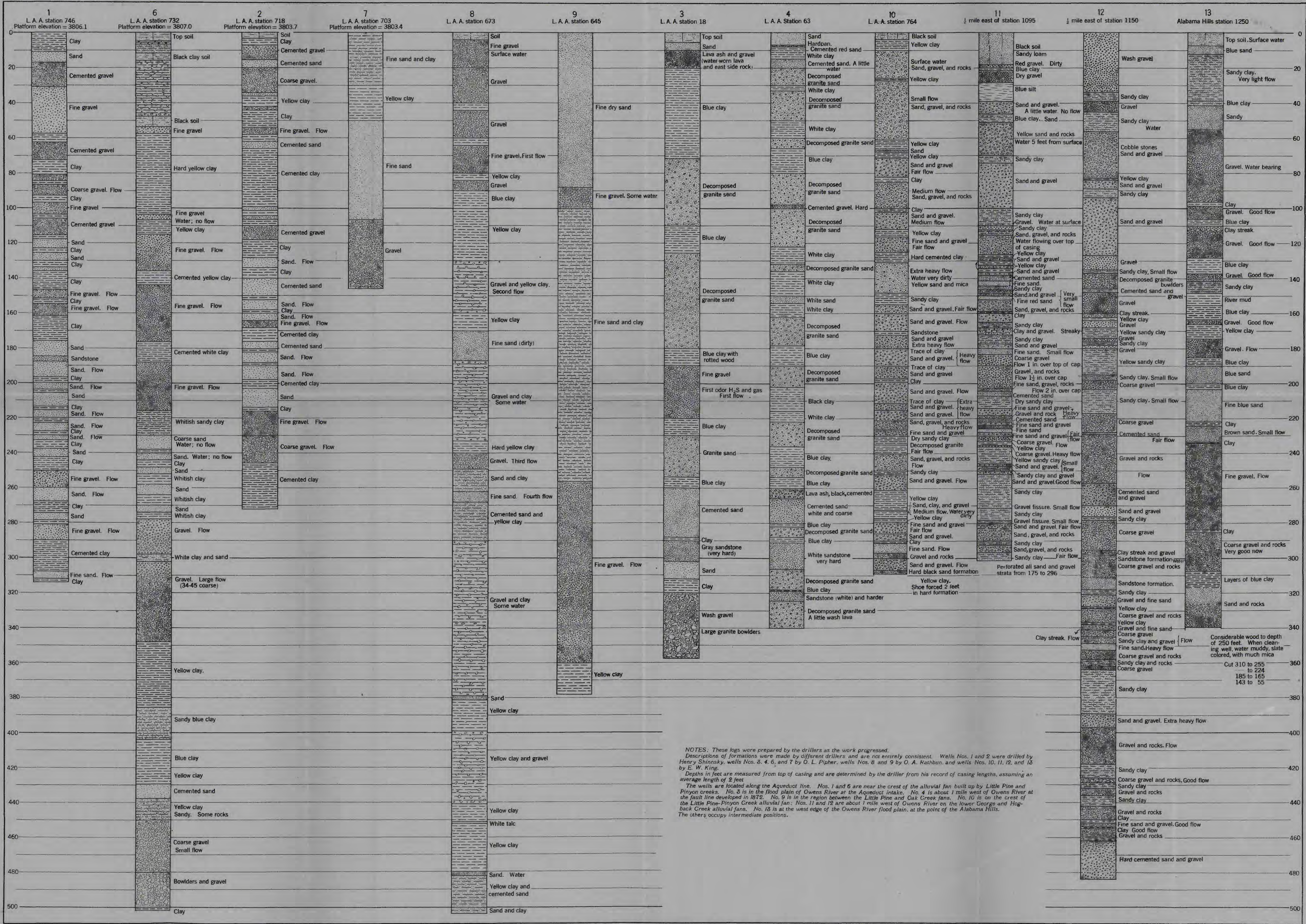
THE UNDERGROUND STORAGE RESERVOIR.

The aggregate voids in the porous alluvial material filling the bottom of the closed rock basin of the Independence region form a great underground storage reservoir whose source of supply is percolation from water occurring upon the surface of the valley fill. There can be found in nature few better opportunities than this for studying the occurrence and behavior of water in such a reservoir. The well-defined sources of supply which it is practicable to measure, the simplicity of the geologic structure, the definite bounds within which ground water is confined, and the ideal climatic conditions for measuring the natural outlets by evaporation are unique when combined as in the region under investigation. The existence of ground water in this reservoir will be considered as regards the formation of the valley fill, the form and fluctuation of the ground-water surface, and the volume and outlets of the overflow.

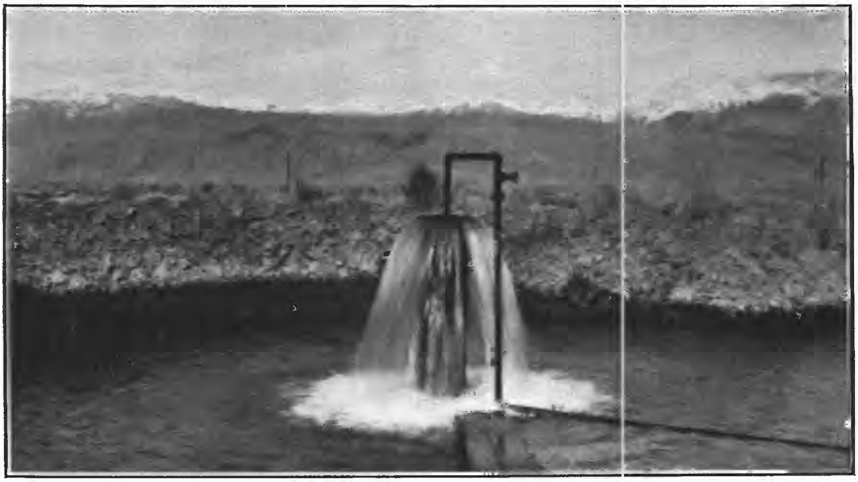
FORMATION OF THE VALLEY FILL.

The alluvial material which forms the valley fill varies in size from large bowlders to fine clay and in arrangement from a thorough mixture of all sizes to layers of well-assorted gravel, sand, and clay. The transporting medium was water, both mountain streams and Owens River taking part in the work. Some of the material was deposited in the beds and on the sides of shifting stream channels and much of the finer sand and clay was deposited from the quiet waters of a large lake which occupied the lower portion of the valley. The structure of the valley fill is therefore complex, and the character of the alluvial material underlying a given locality is difficult to determine without actual examination from borings.

The only deep borings which have been made in the region are those put down by the city of Los Angeles in connection with the



LOGS OF ARTESIAN WELLS DRILLED FOR LOS ANGELES AQUEDUCT IN OWENS VALLEY NEAR INDEPENDENCE, CALIFORNIA



A. ARTESIAN WELL No. 2.

B. SIERRA NEVADA FROM THE VICINITY OF ARTESIAN WELL No. 2.

development of the aqueduct supply. These are of the California or "stovepipe" type[1] and range in depth from 250 to 500 feet. Logs of these wells kept by the drillers as the work progressed are reproduced in Plate XXII. In general the material encountered was in layers of clay, sand, and gravel varying in thickness from a few inches to 150 feet. Reference to Plate XXV (p. 76), on which the geographic location of the wells has been platted, shows that relatively coarse material in thin layers interbedded with clay predominates along the upper edge of the valley floor in the spring belt. All wells located in this belt yield artesian flows of 1 to 2 second-feet. (See Pl. XXIII.) The material is progressively finer and occurs in thicker strata east of this belt, toward the center of the valley, and artesian flows decrease in volume. Near Owens River fine sand and clay in alternate layers is the only material encountered above 300 feet depth, except at the north end of the Alabama Hills. The color of the sands and clays near the river is bluish; those farther west are yellow.

The streams from the Sierra Nevada were by far the most active in the work of building up the valley fill. Their loads were acquired in the mountain canyons and carried out into the valley, where they were dropped in order of size as the velocity of flow decreased. The old lake level stood at an elevation of about 3,790 feet for a long period, as shown by beach lines on the east slope of the Alabama Hills. The present 3,790-foot contour lies near the spring belt, and it is very probable that the fine sands and clays underlying the area between the spring belt and Owens River are lake deposits. The entire absence of coarse material in this area is very significant, for the sudden checking of the velocity of a stream upon entering a body of still water results in the immediate deposition of gravel and coarse sand. The strata of coarse material encountered at the north end of the Alabama Hills in well No. 13 are derived from Hogback Creek, which flowed around the hills on a steep grade and entered the lake at this point. The barrier formed by the saturated lake deposits may therefore be the cause of the rise of water in springs and of the artesian flows encountered along the upper edge of the valley floor. Another explanation is the tendency for the coarser material to be deposited near stream channels and at points of sudden reduction in velocity due to flattening of the grade, while the finer material is carried out into the more level valley and into the regions between the alluvial cones.

Two cross sections of the valley showing the probable geologic structure of the region were constructed along the Thibaut and Independence sections (Pl. XXIV). The topography for these sections was obtained from the Geological Survey's map of the Mount Whitney

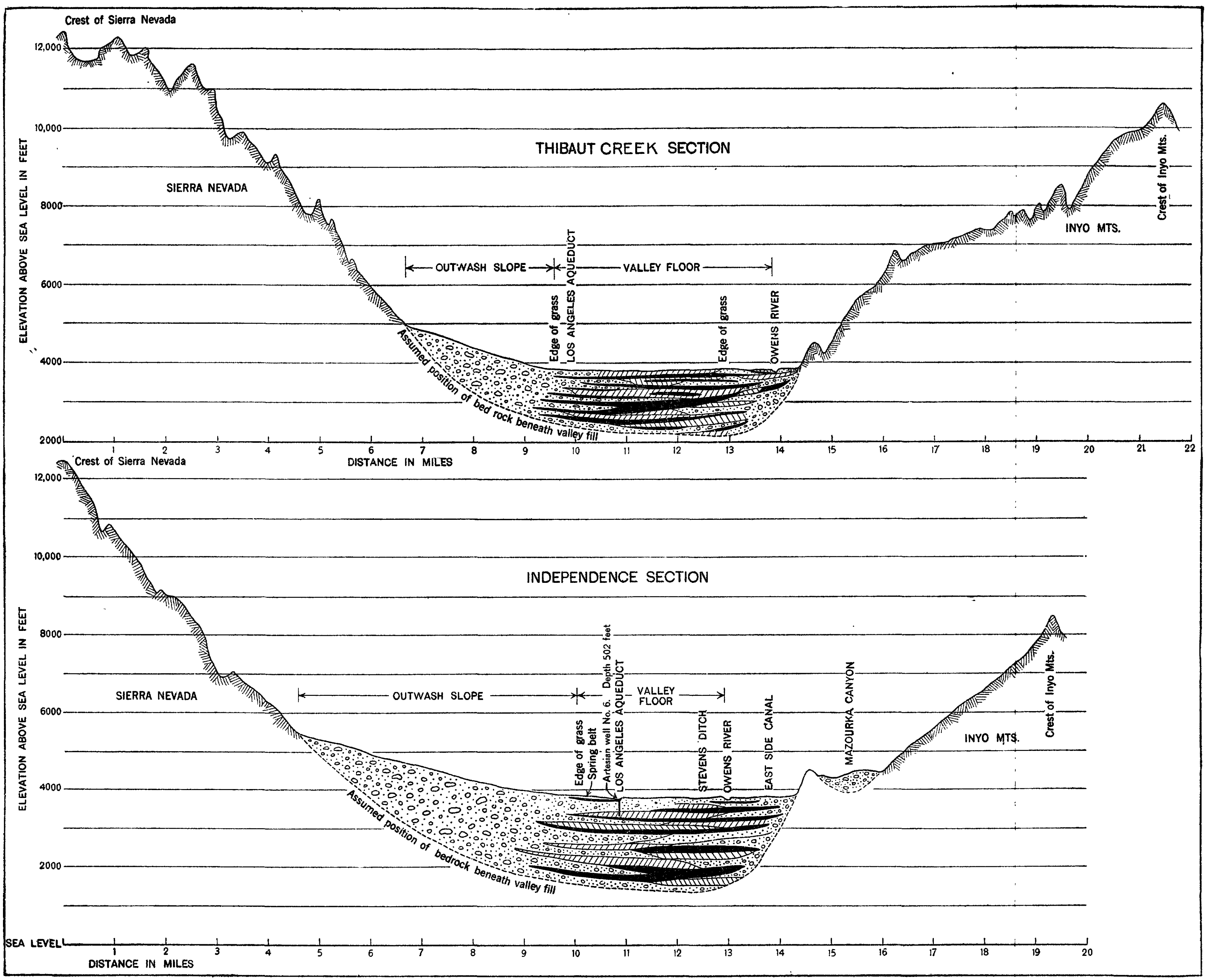
[1] Slichter, C. S., Field measurements of the rate of movement of underground waters: Water-Supply Paper U. S. Geol. Survey No. 140, 1905, pp. 98-103.

quadrangle and the character of surface material was determined by field inspection. The exposed slopes of bedrock on either side of the valley were joined beneath the valley floor, and the arrangement of the material filling the basin thus formed was represented according to the best available knowledge, the strata of fine material being indicated by solid black. The greatest depth of alluvial filling in the Independence section measures 2,500 feet on the diagram and in the Thibaut section 1,800 feet. Two of the aqueduct wells near the Independence section reached depths of 500 feet in alluvial material, and a well being drilled by the Southern Pacific Co. opposite the Alabama Hills at Lone Pine station has reached a depth of 800 feet, entirely in fine sand. There is no reason to suppose that the gravel filling near Independence is less than 2,000 feet in depth.

The amount of void space, or porosity, of a body of alluvial material of this type is variously estimated by different authorities at 20 to 35 per cent of the total volume.[1] Samples of the mixed gravel, sand, and silt of the outwash slopes west of Independence were removed to a depth of 4 feet without disturbing the natural arrangement of the particles and weighed dry and after saturation. The results of these tests, as shown in Plate XXVIII (p. 82), indicate a porosity of 28 per cent for these samples. The presence of very coarse gravel and bowlders in this material would reduce the porosity, and for the valley fill as a whole 25 per cent is probably nearer correct.

An interesting feature of the valley fill of the Independence region is its total storage capacity for water. Its surface as represented by the outwash slopes and valley floor has an area of 230 square miles. On the assumption of an average depth of 1,000 feet of saturated alluvial débris beneath this area and a porosity of 25 per cent, the void space filled with water is 10.9 cubic miles, or 37,000,000 acre-feet. A portion of this water is capillary and not available for recovery from the ground. If one-fifth the total volume is assumed to be gravity water, there would be approximately 7,000,000 acre-feet which could be extracted from the underground reservoir, or a continuous flow of 3,200 second-feet for three years. This calculation has little practical bearing, however, for the average amount of water recovered from an underground reservoir with a well-planned and well-operated system of development would not exceed the natural overflow and also because of the prohibitive cost of constructing the necessary works.

[1] Mendenhall, W. C., Preliminary report on the ground waters of San Joaquin Valley, California: Water-Supply Paper U. S. Geol. Survey No. 222, 1908, p. 27. Hamlin, Homer, Underflow tests in the drainage basin of Los Angeles River: Water-Supply Paper U. S. Geol. Survey No. 112, 1905, pp. 29, 30, 31, 52.



CROSS SECTIONS OF OWENS VALLEY, SHOWING GEOLOGIC RELATIONS.

FORM OF THE GROUND-WATER SURFACE.

The general form of the ground-water surface corresponds with that of the surface of the valley fill, although the slopes are less steep and the irregularities are not so pronounced. In the valley floor the depth to ground water is only a few feet. It becomes progressively greater toward the mountains and probably lies 200 or 300 feet beneath the outwash slope at about the 5,000-foot contour. Near the base of the mountains the alluvial material is shallow and ground water lies at moderate depths. Superimposed upon the general ground-water surface are sharp "ridges" beneath stream channels and "mounds" under irrigated fields. The surface of water in the underground reservoir is therefore not a level plain but has a varied topography.

There are two reasons for this condition—the action of gravity tending to equalize inequalities in the ground-water surface, and the resistance which the ground offers to lateral motion of water through its interstices. Percolating waters enter the valley fill from the upper edge of the outwash slope, from stream channels crossing the outwash slope, and from irrigated fields. The valley floor is the lowest portion of the valley fill and also the ground-water outlet. The force of gravity therefore tends to draw percolating water which has reached the surface of saturation to the level of the valley floor. This can occur only by a lateral movement of water from the outwash slope toward the valley floor, but the resistance of the porous material is so great that a steep gradient is necessary to maintain even a very low velocity. Hence there is the steep slope of the ground-water surface from the mountains toward the valley and laterally from stream channels and irrigated fields. The lateral movement of water is so slow that percolating water entering at the upper edge of the outwash slopes during a series of wet or dry years would not reach Independence for at least two years.

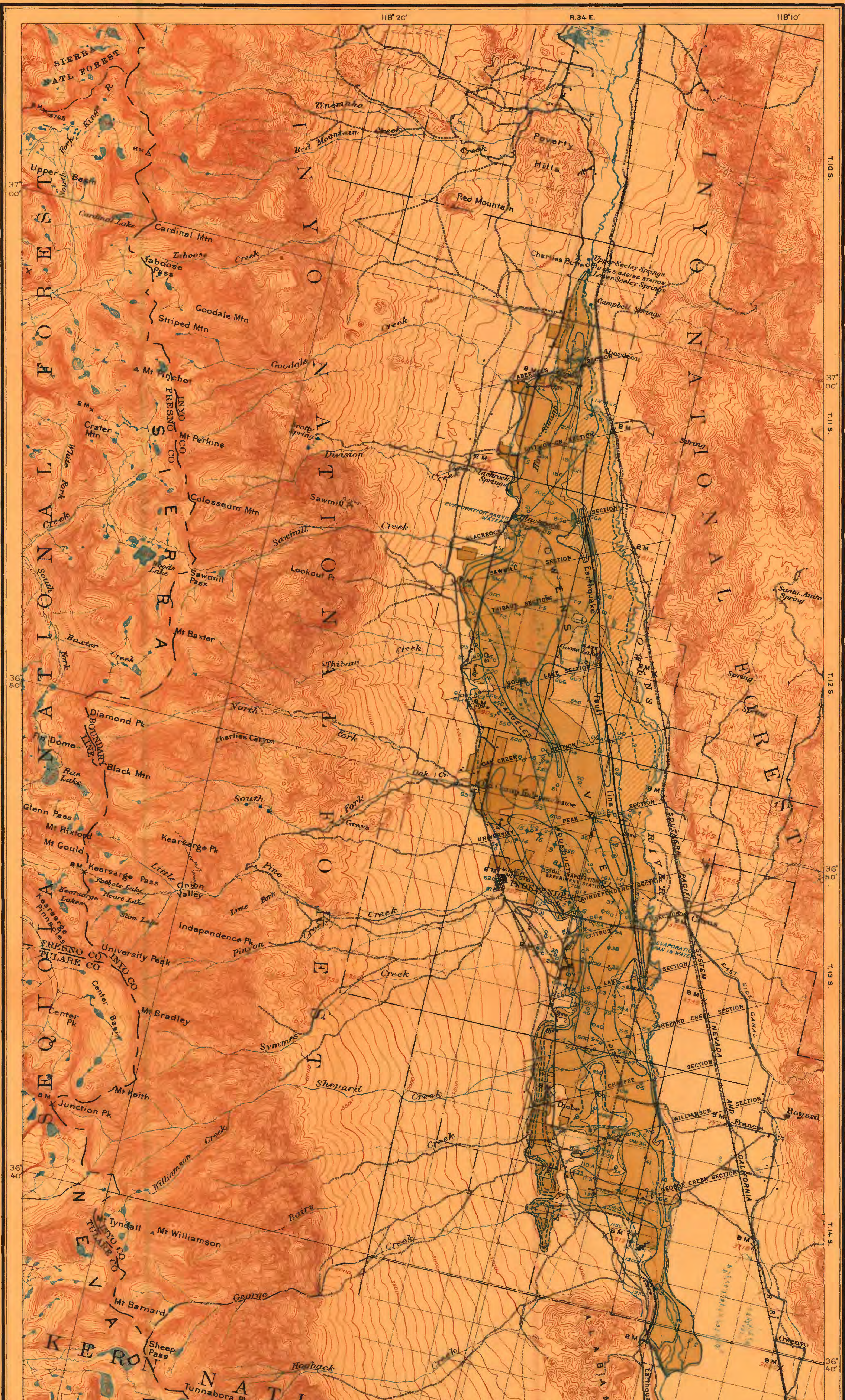
The position of the surface of water in a well, when there are no disturbing conditions, such as pumping, registers the position of the surface of ground water in the surrounding soil. In order to outline this surface definitely, all existing domestic wells in the region were located and many additional observation wells drilled where the cost was not prohibitive. The region contains 27 domestic wells, 12 of which are located on the valley floor and 15 on the outwash slopes. There were drilled 142 observation wells, all but two being located on the valley floor. These wells were sufficient to define the ground-water surface over about 60 square miles of the region. They are listed and described in Table 64 and their location is shown on Plate XXV.

The general arrangement of the wells is in parallel lines spaced from 1 to 2 miles apart and transverse to the axis of the valley.

Where such wells did not sufficiently outline the ground-water contours they were supplemented by intermediate wells. There are 15 of these lines, or sections, each designated by name and containing from 3 to 17 wells. The wells are designated by the initial letter of the name of the section and numbered consecutively, beginning with No. 1 at the west or east end of the section. The intermediate wells are numbered from 1 to 64, inclusive, without regard to location. In Table 64 the wells are arranged from north to south, and in each section or group of intermediate wells from west to east. The location of wells with respect to the land net was determined by reference to existing fence lines or by stadia surveys. The elevations of ground surface and bench mark at each well were determined with an engineer's level. The descriptions of surface conditions in Table 64 were prepared in the field during August, 1908, and represent permanent conditions, except for surface alkali, which varies during the year.

Observation wells described as "test holes" in Table 64 are 2-inch holes drilled with a specially designed spoon auger fitted with extensible handle. In the clay soil of the valley floor these holes stand indefinitely without caving and are practical to depths of about 10 feet. The type of auger used brings out a true sample of the material encountered, so that accurate logs of each hole could be kept. Bench marks consisted of two stakes on opposite sides of the hole driven nearly flush with the ground surface. Measurements of depth to water surface were made from a cleat laid across the stakes. Observations of depth to water were made by lowering a chalked steel tape, weighted at the end, from the bench mark until the weight was submerged. Readings were to feet and hundredths.

The cross sections of the valley in Plate XXVI define the form of the ground-water surface below the 4,000-foot contour on September 20, 1909. The elevations of ground surface in these sections were obtained with an engineer's level, and the distances by the stadia method. The ground-water surface was outlined by the methods just described. In the sections the vertical scale has been greatly exaggerated to bring out the detail. The ground-water surface as it approaches the valley floor from the west has an average slope of 90 feet to the mile. The corresponding slope of the ground surface is steeper, varying from 150 to 110 feet to the mile. At the upper edge of the grass land the two surfaces are about 8 feet apart, and a short distance beyond they intersect in the spring belt. From this belt to Owens River the distance to ground water varies from 4 to 12 feet beneath the gently sloping or level valley floor. This sudden break in the slope of the ground-water surface at the spring belt is caused by the change from coarse to fine material in the region of the old lake shore. The fine material acts somewhat like a dam, raising



LEGEND

VALLEY FLOOR

- Cultivated land
- Grass land
- Alkali land
- Desert land
- Depth to ground water
- Test hole or shallow dug well
- Artesian well
- Spring

ENGRAVED AND PRINTED BY THE U.S.GEOLOGICAL SURVEY

MAP OF INDEPENDENCE REGION, INYO COUNTY, CALIFORNIA, SHOWING TEST HOLES, ARTESIAN WELLS, DEPTH TO GROUND WATER, AND SURFACE CHARACTERISTICS

E.M.Douglas, Geographer.
R.B.Marshall, in charge of section.
Topography by G.R.Davis, C.L.Nelson and S.N.Stoner.
Triangulation by C.F.Urquhart.
Surveyed in 1905.

Scale $\frac{1}{125000}$

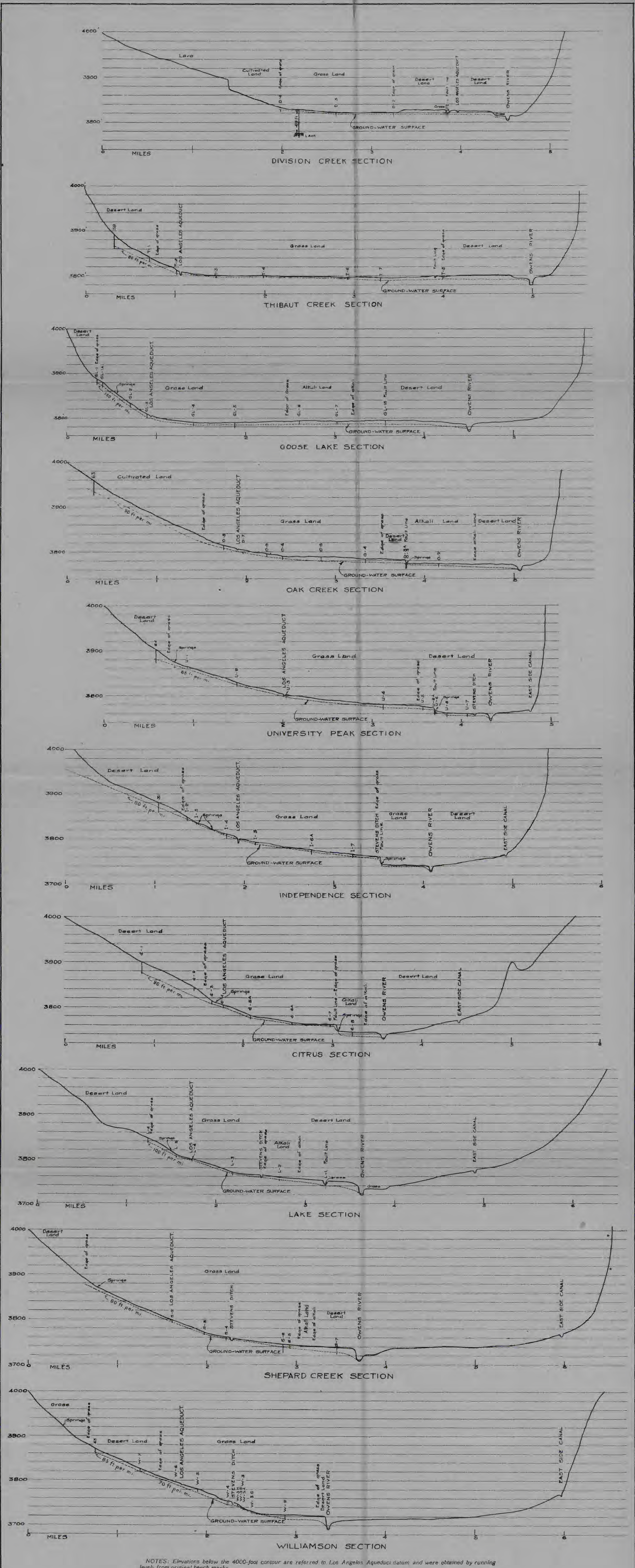
1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.

Datum is mean sea level.

1912



NOTES: Elevations below the 4000-foot contour are referred to Los Angeles Aqueduct datum and were obtained by running levels from original bench marks.
Elevations in the complete sections are referred to the United States Geological Survey datum and were taken from the map of the Mount Whitney quadrangle.
Distances were scaled from a copy of the Mount Whitney map upon which the location of wells had been plotted.

CROSS SECTIONS OF OWENS VALLEY, INDEPENDENCE REGION, CALIFORNIA, SHOWING PROFILE OF GROUND-WATER SURFACE BELOW 4000-FOOT CONTOUR ON SEPTEMBER 20, 1909 a portion of the ground water to the surface in springs and retarding the lateral movement of the remainder.

Ground-water contours for the valley floor showing lines of equal average depth to ground water have been worked out on Plate XXV. They represent the average position of the surface of saturation between the extreme levels indicated in Table 65. The data are sufficient to determine the 3, 4, and 8 foot contours with reasonable accuracy. The sudden approach of ground water toward the surface at the upper edge of the grass land is shown, and also the general proximity of ground water to the surface throughout the valley floor. The total area between the westerly 8-foot contour and Owens River is 67 square miles. The average depth to ground water is between 4 and 8 feet over 40 per cent of this area, and between 3 and 4 feet over 28 per cent. It exceeds 8 feet over 14 per cent of the area and is 3 feet or less over 18 per cent. The area of the valley floor is 66.4 square miles (Table 1) and its west boundary practically coincides with the 8-foot contour. The nonirrigated area within the 3-foot contour is 11.89 square miles, between the 3 and 4 foot contours 17.66 square miles, and between the 4 and 8 foot contours 25.04 square miles.

There is a very striking relation between vegetation and depth to ground water. On the outwash slopes the vegetation consists of various stunted desert shrubs. In approaching the valley floor at about the 20-foot contour, sagebrush (*Artemisia*) begins to predominate and has a luxuriant growth as far east as the 12-foot contour, where it is replaced by greasewood, rabbit brush, and coarse bunch grass. In the vicinity of the 8-foot contour salt grass (*Distichlis spicata*) begins to appear, and farther east, near and within the area inclosed by the 4-foot contour, it grows luxuriantly. Within the 3-foot contour fresh-water grasses thrive where there is sufficient surface water to leach out and carry away most of the alkali, but the salt grass grows well even where the soil is alkaline. In various portions of the valley floor rabbit brush and greasewood are found where the average depth to ground water is 4 feet or more, but grass predominates east of the 8-foot contour. In areas where the alkali is excessive there is practically no vegetation. In general, grass does not grow where the depth to ground water exceeds 8 feet, so the 8-foot contour tends to coincide with boundaries between meadow and desert lands.

A fault plane in the valley floor (Pl. XXV), along which vertical and horizontal movement of the earth's crust occurred during the earthquake of 1872, gives rise to some interesting local ground-water conditions. A permanent result of these movements was the formation of a crack extending in a generally straight line parallel with Owens River from a point 1½ miles north of Citrus bridge to the river opposite Aberdeen. Along this crack there still remain sunken areas and bluffs. The sunken areas form closed basins whose bottoms are either intermittently or permanently below ground-water surface and hence are flooded with seepage water. The deeper basins are permanent lakes without surface inlet or outlet, but the shallower basins contain water only during highest ground-water stages and are green meadows at other times. These lakes and meadows are in marked contrast to the immediately surrounding country, over most of which the depth to ground water exceeds 8 feet and desert conditions prevail. Goose Lake is an example of a permanent ground-water lake; the lake south of Citrus bridge in the lake section is intermittent.

The bluffs range from slight breaks in the surface to steep banks 12 feet in height. At the bases of these bluffs there are numerous

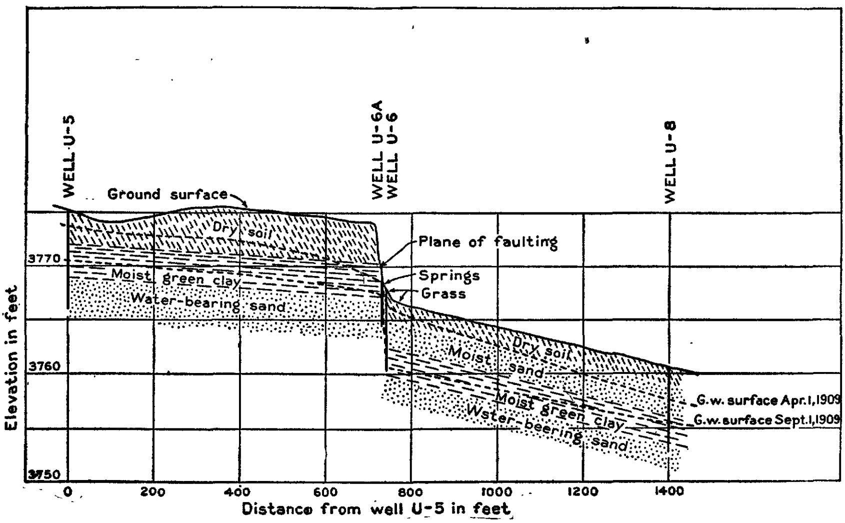


FIGURE 8.—Ground-water conditions at intersection of the University Peak section in the earthquake rift of 1872.

springs, and seepage water appears in sufficient quantity to keep green a narrow strip of meadow grass. This condition results from the exposure of the broken edge of a water-bearing stratum, as shown in figure 8. The crossings of the fault line with the Oak, Independence, and Citrus sections are similar to that of the University Peak section shown in the diagram.

FLUCTUATIONS OF THE GROUND-WATER SURFACE.

The surface of ground water is continually fluctuating. Both the amount and character of this fluctuation vary widely in different localities and at different times, depending on the proximity to ground-water sources or outlets and the relative rates of ground-water accretion and depletion. Three pronounced types are to be observed in the Independence region—(1) broad irregular fluctuations of varying amplitude in the outwash-slope area; (2) slightly irregular periodic fluctuation with wide fixed limits in and near irrigated areas; and (3) a regular periodic fluctuation with comparatively narrow and fixed limits in the valley floor. Special characteristics are also exhibited by wells within certain limited areas, as the result of local ground-water conditions.

These fluctuations were determined and studied from well observations made by the methods already described. Readings obtained at intervals of two to four weeks were sufficient to establish accurately the position of the ground-water surface at all times, as the fluctuations are characterized by exceptional regularity. Most of the wells listed in Table 64 were observed from August 15, 1908, to November 15, 1909, and on 26 of the most typical wells observations were continued to May 1, 1911. The fluctuation of the surface of the lake south of Citrus bridge was observed from August 15, 1908, to November 15, 1909, and of Goose Lake from August 15, 1908, to May 1, 1911.

The type of fluctuation peculiar to wells located on the outwash slope is shown in Plate XXVII by wells Nos. 31, 64, 25, 26, and 59 and Citrus No. 1. Water stands 10 feet or more below the surface in all these wells, the vegetation of the surrounding area is limited to desert shrubs, and there are no alkali deposits on the surface. With knowledge of the sources and movement of ground water beneath the outwash slopes, the assigned cause for this type would be annual variation in the amount of water supplied by percolation from precipitation on the intermediate and outwash slopes and from stream channels. This is confirmed by the observations. For example, well No. 31, which is situated 7 miles from the base of the Sierra and 500 feet south of the old channel of Pinyon Creek, exhibits a persistent downward tendency which was partly checked during the summer months of 1909 and 1910. The maximum effect of the very wet years 1906 and 1907 evidently reached this well in 1908 and early 1909. During the following years the water had a tendency to return to its normal level. This was twice opposed by percolation from the channel of Pinyon Creek, which carried flood water during a few weeks in June and July, 1909, and for a very short period in 1910. Citrus well No. 1, which is about three-quarters of a mile south of well No. 31, has similar fluctuations, but in this well the maximum effect of seepage from Pinyon Creek is registered six weeks later in 1909 and in 1910 is much smaller in amount. Well No. 64, situated similarly with respect to the mountains, but north of Little Pine Creek, has the same downward tendency, which is temporarily checked during the summer by irrigation in an adjacent alfalfa field and a small garden at the well. Well No. 59, which is 2 miles from the base of the Sierra and half a mile south of Sawmill Creek, had an upward tendency during 1909, due to the percolation from precipitation of the wet winter 1908–9. In 1910 the water level fell in response to the normal winter 1909–10. Seepage from Sawmill Creek does not affect this well appreciably. Wells Nos. 25 and 26 exhibit the general tendencies of well No. 59, but they are situated in the transition zone between the outwash slope and valley floor, where there is a periodic backwater effect from the annual rise of ground water in the grassland.

Wells Nos. 61 and 62 illustrate the type of fluctuation characteristic of the irrigated areas of the region. They are located in irrigated gardens in the town of Independence. The form of the curve is periodic, with sharp crests and troughs, the former in July, the latter in January or February. The amount of fluctuation in such wells ranges from 10 to 20 feet in different portions of the region. Irregularities superimposed upon the broad periodic curve are the result of irregularity in the application of irrigation water. The general form of the curve, however, corresponds to the average intensity of irrigation.

The fluctuation of ground-water surface in various parts of the valley floor, other than at eight wells already mentioned, is shown by 48 typical well records in Plate XXVII. Most of these wells are located where the average depth to ground water is less than 8 feet. The adjacent ground surface is more or less crusted with alkali, and where the alkali is not too concentrated several species of wild grass grow vigorously. (See Table 64.) The two lakes and wells Nos. C-3 and 43 are located in areas where the average depth to ground water exceeds 8 feet and desert conditions prevail.

The character of the fluctuations observed in all the valley-floor wells is remarkably uniform. When platted the observations give smooth and regular lines of the sine-curve type, with an annual periodicity. The average time of occurrence of crests for wells situated in grass or alkali areas is March 15; the troughs occur September 15, six months later. Heavy winter precipitation or the proximity of springs advances the crests into January or February, but in the desert areas the crest lags into April or May. (See Tables 64 and 65.) The amount of fluctuation between maximum and minimum levels in normally situated wells ranges from 1.5 to 4 feet. Wells situated near or below springs in the vicinity of intermittently occurring surface water have a greater range, which may reach 7 feet. The average amount of fluctuation for 1908–9 as observed in 122 wells distributed generally over the valley floor is 3.14 feet. (See Table 65.) This average represents normal conditions.

Fluctuation of this type is due to evaporation from the soil and transpiration, processes which are active wherever there is capillary connection between the surface of saturation and the ground surface or wherever gravity water or capillary water is within reach of plant

DIAGRAMS SHOWING FLUCTUATION OF GROUND-WATER SURFACE IN TYPICAL OBSERVATION WELLS IN INDEPENDENCE REGION, CALIFORNIA

NOTES: For description of observation wells see Table 64, "Statistics of Observation Wells." Permanent bench marks were established at each well and test hole from which measurements to water surface could easily be made with a steel tape.
Before observing, a weight is fastened at the end and the tape is chalked. The end of the tape is then submerged and the difference between the reading at the bench and at the water surface is the depth. Corrections are made in the office when the bench is not at ground surface. Readings are in feet and hundredths

roots. Two general conditions have led to this conclusion—(1) the area characterized by capillary connection between ground-water surface and ground surface and by accessibility of ground water to plant roots is coincident with the area exhibiting this type of periodic fluctuation; and (2) the combined rates of evaporation from soil and transpiration as observed experimentally increase and decrease concurrently and in the same ratio with the fall and rise of the ground-water surface.

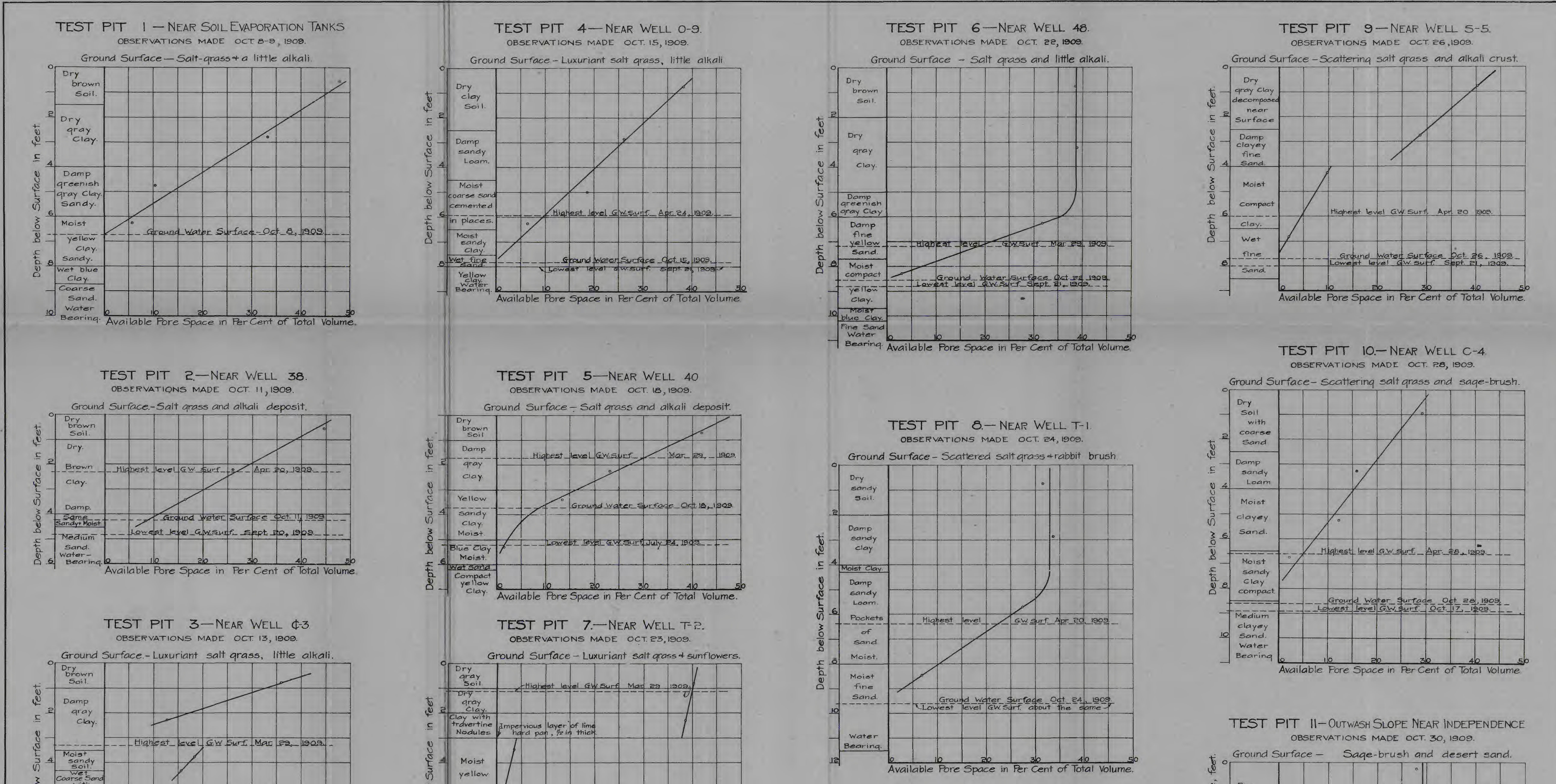
The first of these conditions is indicated by the following facts. Surface incrustations of alkali are now known among investigators to be an indication of evaporation from the soil, and a growth of natural grasses certainly shows the presence of water within reach of plant roots. These manifestations are both strictly confined to valley-floor areas within which the periodic fluctuation is observed. There are valley-floor areas, however, within which the periodic fluctuation occurs but which have a loose sandy surface devoid of alkali and vegetation. An examination of such areas shows that they are surrounded or bordered by meadow and alkali-crusted land, and further that maximum and minimum ground-water levels exhibit a lag in time of occurrence which varies with the distance from these adjacent lands. (See Pl. XXVII, well C-3 and Goose Lake.) The fluctuations in these desert areas do not originate within the areas themselves but in the adjacent lands, from which they are propagated as annual waves. In general, average depths to ground water exceed 8 feet in desert areas but are less than 8 feet in meadow or alkali lands.

Studies of the available pore space in the soil above the ground-water surface are of interest in this connection (Pl. XXVIII). In October, 1909, about a month after the period of minimum ground-water level, a number of samples of soil in various parts of the valley floor and at various depths were tested to determine their capacity for absorbing water. The samples were about one-eighth cubic foot in volume and were taken at intervals of 1 to 2 feet from the ground surface to the surface of saturation, the depth below ground surface being measured to the center of gravity of the samples. Samples which would hold together under water were cut into squared blocks 6 inches on an edge; those which showed signs of disintegrating were taken out in a sheet metal ring 8 inches in diameter and 6 inches long provided with a cutting edge, and the open ends squared off. In the process of submerging the samples, they are placed on sheet-metal plates and cylindrical samples were not removed from the casing. The samples were weighed to ounces immediately after removal from the ground and were then submerged in water until completely saturated, when they were weighed again. The difference in weight expressed as an equivalent volume of water divided by the measured volume of the sample was assumed to give the percentage of available pore space. The results of this study are presented in Plate XXVIII for each test pit and include a description of surface conditions, the material encountered in the excavation, the existing ground-water level and its maximum and minimum positions, and the relation of depth below ground surface and available pore space. The diagrams show unmistakably the phenomenon observed by King in studying the distribution of moisture in saturated soil columns after long standing, namely, that there is a uniform decrease of moisture from the surface of saturation to the upper limits of capillary action.[1] They show further that where the average depth to ground water does not exceed 8 feet the upper limits of capillary action are near the ground surface, but that where it is greater than 8 feet the connection with the surface is broken and the upper limits of capillary water fall to a level below the surface. (See results for test pits Nos. 6 and 9.) This fact explains the occurrence of alkali crusts only where the depth to ground water is less than 8 feet, and also supports the observation made in connection with the experiments on evaporation from soil that evaporation does not occur from ground water where the depth exceeds 8 feet.

The second condition—that variations of soil evaporation and transpiration are similar to ground-water fluctuations—is indicated by the results of the experiments on evaporation from soil. The maximum rate of soil evaporation occurs between September 1 and 15 and the minimum between March 15 and 30. Lowest ground-water level occurs about September 15 and highest level on March 15 (Pl. XXIX). Thus critical points in curves of soil evaporation and ground-water fluctuation are practically coincident as regards time. Furthermore, although the curves are inversely related, their form is remarkably similar. The natural conclusion is that ground-water fluctuations in nonirrigated portions of the valley fill are the result of evaporation from the soil and transpiration.

Variations from the normal periodic curves occur for three causes—large precipitation, seepage from springs, and seepage from standing or flowing surface water. The infrequency of precipitation sufficient to raise the ground-water surface is shown on Plates XXVII and XXIX. It is practically a negligible factor in ground-water fluctuations. The springs at the upper edge of the outwash slope affect ground-water conditions in their vicinity by stimulating the annual rise and maintaining the ground-water level at a maximum during several months prior to March. (See Pl. XXVII, wells Nos. 46, U–6A, and I–4.) This results from the decrease in the rate of soil evaporation which allows accumulation of their discharge in the sur-

[1] King, F. H., Sixteenth Ann. Rept. Wisconsin Exper. Sta., 1899, p. 24.

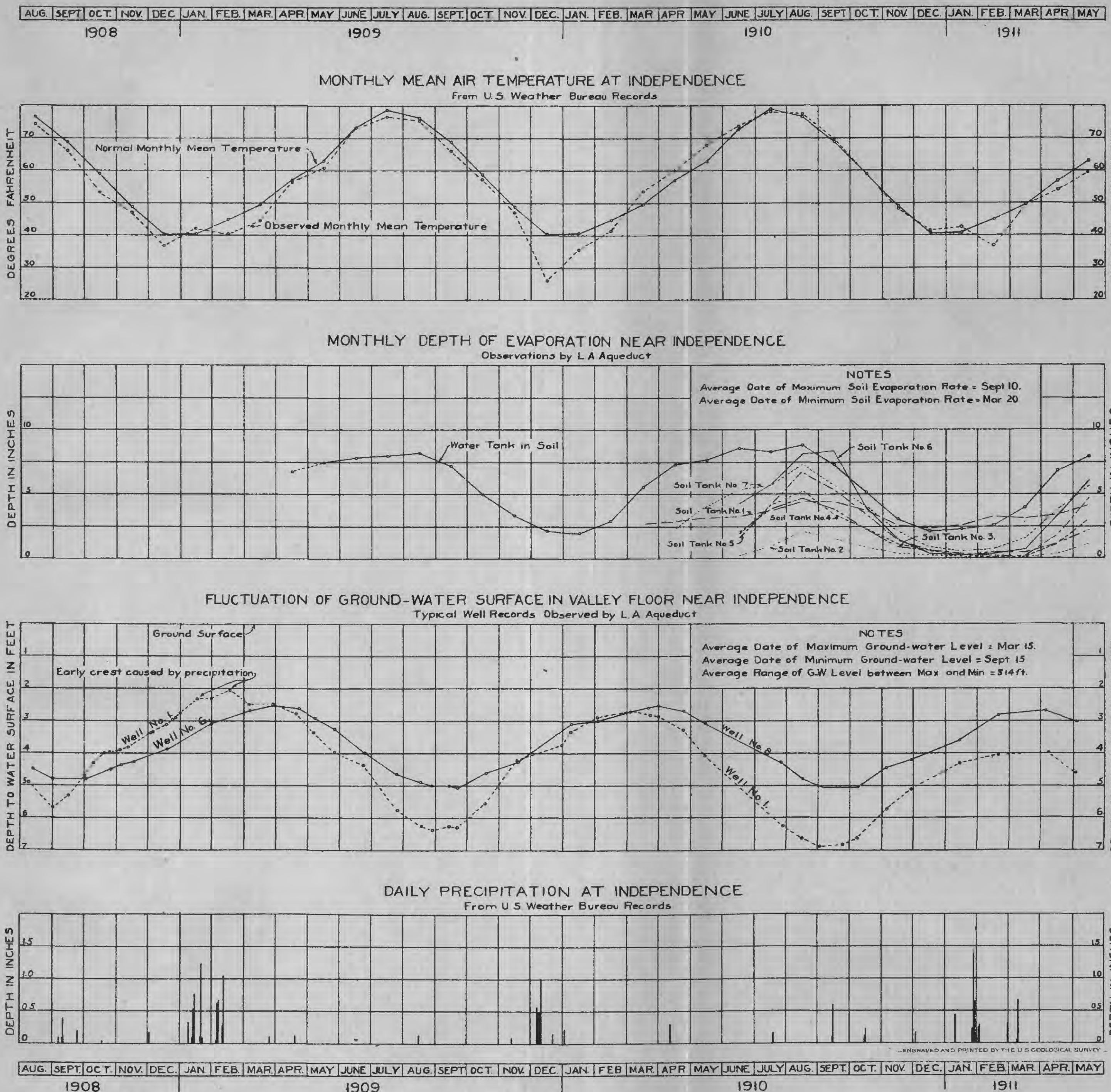


NOTES: The method of obtaining the field data was as follows: Samples of soil about 1/8 cu. ft. in volume and cubical in shape were taken at intervals from 1 to 2 feet from the ground surface to the surface of saturation. These were weighed. submerged in water until saturated. and then weighed again. The difference in weight, expressed as equivalent volume of water, divided by the measured volume of the sample gave the per cent of available pore space in the soil tested. Samples which held together under water were cut into squared blocks. Others were cut out with an 8" length of 8" well casing. sharpened at one end. the open ends squared off. and the sample submerged without removing the casing.

The observations were made about three weeks after the date of lowest ground water and ten weeks after the maximum rate of evaporation from water surface, so that the soil immediately above the ground-water surface had probably commenced to accumulate capillary water.

Depth below surface of ground was measured to center of volume of sample

DIAGRAMS SHOWING AMOUNT OF AVAILABLE PORE SPACE ABOVE THE SURFACE OF LOWEST GROUND WATER IN VALLEY-FLOOR LANDS OF INDEPENDENCE REGION, CALIFORNIA



TEMPERATURE, EVAPORATION FROM SOIL, PRECIPITATION, AND FLUCTUATION OF GROUND-WATER SURFACE IN VALLEY FLOOR NEAR INDEPENDENCE, CALIFORNIA

rounding soil at a greater rate than in adjacent areas where the rate of supply of underground water is less. Surface water has its source in large springs, waste from irrigation, and flood waters of mountain streams. It occurs at various times and places and can not be considered as a permanent factor in ground-water fluctuations. (See Pl. XXVII, wells Nos. 4, 38, 39–A, 32, and GL–1.) The irregular fluctuations of ground water on the outwash slope do not appear in the valley floor because of the relief afforded by the escape of water in springs at the upper edge of the grassland.

The volume of water represented by the annual rise and fall of the surface of saturation in the valley floor is of interest in a study of the ground-water yield. The area of the valley floor, exclusive of irrigated land, within which the periodic fluctuation is observed is 63.8 square miles, of which 9.18 square miles is desert land. The average amount of fluctuation in ground-water level observed over the 63.8 square miles is 3.14 feet, which is equivalent to 3.67 feet over the evaporating area of 54.6 square miles. The depth of water represented by this fluctuation depends on the available pore space in the soil layer, which is alternately filled and drained. At maximum ground-water level this layer is saturated, but at minimum level it is drained of gravity water and capillary spaces are shrunken. It is therefore necessary to know the amount of available pore space in the layer at lowest ground-water level in order to compute the depth of water represented by the observed rise. The diagrams of Plate XXVIII show this percentage at various depths five weeks after the lowest level of 1909. The available pore space in the region of fluctuation then varied from 5 to 15 per cent and averaged about 10 per cent. On the assumption that at lowest ground-water level the average was 25 per cent, the depth of water represented by a fluctuation of 3.67 feet is 11 inches. The average depth to ground water in the area of the valley floor (exclusive of irrigated land) from which evaporation occurs is 4.2 feet. Figure 5 (p. 59) shows the difference between summer and winter evaporation at this depth to be 14 inches. The true value is therefore probably close to 12 inches.

GROUND-WATER YIELD.

Ground-water fluctuations within the valley floor consist primarily of the regular annual rise and fall produced by variation in the rate of evaporation. This is indicated by actual observations extending over three years and confirmed by the persistency of various perennial plant species. Hence there must be overflow of ground water from the valley fill of the region in general equal to inflow by percolation. The possible outlets would seem to be underflow southward through the valley fill, underflow by way of deep fissures, seepage, and spring flow into the channel of Owens River, evaporation from spring waters, evaporation from damp soil, and transpiration from vegetation. The first two of these are eliminated by the geology of the region. The slope of the ground-water surface in the valley fill opposite the Alabama Hills does not exceed 8 feet to the mile, and the material is fine sand and clay, as indicated by the Southern Pacific Co.'s well at Lone Pine station. Even if there is a movement of ground water southward from the region, it must be exceedingly slow and it would be entirely intercepted by the alluvial fan of Lone Pine Creek, which has a ground-water surface higher than the valley fill to the north. The swampy land in the valley floor opposite the north end of the Alabama Hills is also proof that underflow southward is negligible. The granitic formation of the Sierra Nevada and the granite core of the Inyo Mountains are complete barriers against the escape of underground waters through any formation but the valley fill. It has already been shown that there is no seepage flow into Owens River from the water supply of the region, and the outlets by evaporation, transpiration, and spring discharge into Owens River are all that remain to be considered.

Soil evaporation and transpiration will be discussed first for irrigated lands and second for the general grass and alkali area of the valley floor (Pl. XXX). The amount of water used in irrigating the 3,011 acres under cultivation in the region is about 72 second-feet continuous flow for six months (Table 63), which is equivalent to a depth of 8.6 feet over the whole area. The depth of transpiration from alfalfa during the irrigating season has already been computed as 3.43 feet, or 40 per cent of the total volume used. There is also a small loss through evaporation from the soil during and immediately after irrigations, say 0.85 foot, or 10 per cent of the total. The total loss by evaporation from the soil and transpiration from irrigated areas is therefore 4.3 feet in depth, or 18 second-feet continuous flow.

The bases for computing the evaporation and transpiration loss from grass and alkali land are the soil-evaporation equations of figure 5 and the ground-water contours of Plate XXV. The equations were developed for fixed ground-water surface, but they cover the periods October 1 to March 31 and April 1 to September 30, which practically coincide with the observed periods of rising and falling ground water. Hence, to cover the natural conditions of fluctuating ground-water surface, average annual depth to ground water at a given point can be substituted in the equations instead of fixed ground-water depths. The average annual depth to ground water in feet and the depth of evaporation as determined from the equations applying during the season 1910–11 are given in Table 66 for the nonirrigated areas inclosed by the 3-foot contour and between the 3 and 4 foot and 4 and 8 foot contours. The volume annually

VIEW OF VALLEY FLOOR, SHOWING GRASS AND ALKALI LANDS FROM WHICH EVAPORATION HAS TAKEN PLACE.

evaporating from the whole area inclosed by these contours is equivalent to a continuous flow for the year of 93 second-feet. The total volume evaporating from this area as computed by use of the assumed equations is 114 second-feet. The first of these quantities is believed to be too small, and it is possible that the second is too large.

The water of Blackrock and Hines springs and of the small springs along the upper edge of the valley floor spreads out in many shallow lake basins before reaching Owens River. The loss by evaporation from the surface of these lakes is large. Estimates based on the area of water surface exposed and the evaporation from water in the shallow pan in soil indicate that about 50 per cent of the flow of these springs thus escapes into the atmosphere. As the combined flow is 31 second-feet, the loss by evaporation from free water surface is 15 second-feet. The remaining portion which does not flow into Owens River percolates into the soil and escapes by evaporation from the soil and transpiration.

Two springs deriving their waters from percolation discharge directly into Owens River; these are Upper and Lower Seeley springs. Their combined average flow is 11 second-feet. In addition the Blackrock Springs discharge an average of 7 second-feet into the river during the months November to March, inclusive, which is equivalent to a continuous flow of 3 second-feet. The total discharge into the river from springs is therefore 14 second-feet.

The total ground-water yield is thus greater than 140 second-feet and equal to or less than 161 second-feet. In the opinion of the writer experiments extending over the calendar year 1911 would establish the value as 155 second-feet.[1]

SUMMARY.

1. The structure of the valley fill is favorable for the underground storage of water.

2. The ground-water surface lies within a few feet of the ground surface throughout the valley floor. West of the spring belt it rises with a slope of about 90 feet to the mile, which is less than the slope of the ground surface.

3. Fluctuations of the ground-water surface are caused by variations in ground-water supply in the outwash-slope area and in irri-

[1] The results of experiments on evaporation from the soil for the calendar year 1911, which have become available since the foregoing was written, show an increase of about 17 per cent over the evaporation observed for the period June 1, 1910, to May 31, 1911. This increase is probably due to the fact that the conditions in the soil tanks during 1911 were more nearly as they are in nature. A further though smaller increase is to be expected during 1912. The results of the observations during 1911 indicate that the evaporation and transpiration from grass and alkali land areas of the Independence region was equivalent to a continuous flow of 109 second-feet. It appears therefore that the total ground-water yield of this region is approximately 155 second-feet.

gated portions of the valley floor. In nonirrigated portions of the valley floor they are caused primarily by variations in natural ground-water yield.

4. The total ground-water yield is 155 second-feet, distributed as follows: Soil evaporation and transpiration from grass and alkali lands of the valley floor, between 93 and 114 second-feet; soil evaporation and transpiration from irrigated land, 18 second-feet; evaporation from spring flow, 15 second-feet; and discharge of springs into Owens River, 14 second-feet.

5. The available data indicate the equality of ground-water supply and yield.

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TABLES.

TABLE 1.—*Subdivisions of Independence region.*

Subdivision.	Area.		Boundary.		Slope.	Vegetation.	Character of surface.
	Square miles.	Per cent of total.	Upper.	Lower.			
High mountain drainage.	95.8	27	Sierra crest..	Mouth of canyon.	Precipitous to gentle.	Isolated forest trees.	Bare granite and fragmental rock accumulations.
Intermediate mountain slope.	29.4	8	Canyon drainage.	6,500-foot contour.	2,000 to 3,000 feet to the mile.	Desert bushes and nut pine.	Fragmental and finely disintegrated rock accumulations.
Outwash slope...	165.3	46	6,500-foot contour.	Grassland.	300 to 600 feet to the mile.	Desert bushes.	Bowlders, sand, and gravel.
Valley floor:							
Cultivated...	4.7	1	....	....	Gentle......	Alfalfa, etc....	Soil.
Meadow.....	45.1	13	....	....	Gentle to level.	Salt grass, etc.	Do.
Alkali.......	2.7	1	....	....	Level.......	None..........	Do.
Desert.......	13.9	4	....	....	.....do......	Desert bushes.	Fine sand.
	356.9	100					

TABLE 2.—*High mountain drainage areas of Independence region.*

Creek.	Area.		Elevation.		Shape.	Length of Sierra crest drained.	Remarks.
	Total.	Per cent above 10,000 feet.	Head of canyon.	Mouth of canyon.			
	Sq. mi.		*Feet.*	*Feet.*		*Miles.*	
Taboose..........	6.99	60	12,000	6,500	Triangular..	3.34	Morainal deposits; regulated run-off.
Goodale..........	4.97	69	12,500	6,500	.....do.......	2.67	Do.
Dry Canyon......	2.48	65	12,000	6,500	.....do.......	1.21	Morainal deposits; no surface run-off.
Division..........	3.88	51	12,000	6,000	Rectangular.	1.88	Morainal deposits.
Sawmill..........	7.64	44	12,000	5,000	.....do.......	2.75	
Thibaut (N. Fk.).	2.25	20	11,500	6,000	Irregular....	0.0	
Thibaut (S. Fk.)..	2.62	55	12,000	6,000	.....do.......	0.0	
Oak (N. Fk.).....	8.08	65	12,500	6,000	.....do.......	5.17	Morainal deposits; regulated run-off.
Oak (S. Fk.)......	7.28	57	12,500	6,000	.....do.......	1.06	
Little Pine.......	8.42	74	13,000	6,500	Triangular..	4.60	
Pinyon...........	4.29	47	13,000	6,500	Irregular....	1.09	
Symmes..........	4.22	43	13,000	6,300	Triangular..	1.59	
Shepard..........	12.29	66	13,500	6,500	.....do.......	7.95	5.68 miles of crest south of Kings-Kern divide.
Bairs (N. Fk.)....	4.01	43	13,500	6,300	Irregular....	0.0	Lies on east face of Mount Williamson.
Bairs (S. Fk.)....	2.90	41	13,000	6,300	.....do.......	0.0	Do.
George...........	9.10	74	13,500	6,500	Triangular..	3.89	
Hogback.........	4.38	58	13,000	7,000	Irregular....	0.67	
	95.80	55	....	....	....	37.87	

TABLE 3.—*Intermediate mountain slopes of Independence region.*

Adjacent high mountain drainage areas.	Area.	Elevation.			Distance from Sierra crest to center of area.	Remarks.
		Apex.	Center of area.	Lower border.		
	Sq. miles.	*Feet.*	*Feet.*	*Feet.*	*Miles.*	
Tinemaha	2.17	(11,000)	8,000	6,500	3.0	
Red Mountain	2.37	(12,000)	8,300	6,500	3.0	
Taboose	3.94	12,200	8,000	6,500	3.3	
Goodale	2.29	11,800	7,200	6,500	2.6	Does not include Dry Canyon.
Division	.95	9,500	7,500	6,500	3.5	
Sawmill	1.32	10,200	7,500	6,500	3.2	
Thibaut (North Fork)	.53	10,500	7,500	6,500	3.1	
Thibaut (South Fork)	.07	7,000	6,700	6,500	4.0	Charlies Canyon yields run-off in normal and above normal years.
Oak (North Fork)	3.62	12,600	7,100	6,500	4.2	
Oak (South Fork)	1.03	10,600	7,100	6,500	3.8	
Little Pine	2.02	11,800	7,400	6,500	3.8	Lime Fork yields run-off in normal and above normal years.
Pinyon	2.89	11,500	7,600	6,500	2.7	
Symmes	.42	9,200	7,400	6,500	3.2	North Fork similar to Lime Fork.
Shepard	.97	9,900	7,200	6,500	4.5	
Bairs (North Fork)	.48	9,100	7,100	6,500	5.0	
Bairs (South Fork)	1.21	10,300	7,800	6,500	4.6	
George	2.09	11,200	8,100	6,500	3.5	
Hogback (one-half)	1.08	10,800	7,900	6,500	4.1	
	29.45	....	....	....	....	

TABLE 4.—*Precipitation in inches at Independence, Cal.*

[1865–1877, U. S. War Dept., Fort Independence, elevation, 3,930 feet; 1892–1895, and 1898–1910, U. S. Weather Bur., Independence, elevation, 3,920 feet.]

Season.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1865–66	......	......	0	0.65	2.42	0	0	0.16	......	......	......	......	......
1866–67	0	0.32	0	2.27	0	1.63	4.76	.53	0.76	0	0.01	1.15	11.43
1867–68	0.07	.32	0.21	12.19	5.46	0	0	.40	.71	0	.10	0	19.46
1868–69	0	.74	.44	1.17	.16	0	.32	.11	.36	0	.03	0	3.33
1869–70	0	0	.14	0	.20	1.36	0	.21	.27	0	.35	.10	2.63
1870–71	0	1.10	0	1.00	0	1.28	0	0	0	0.30	0	0	3.68
1871–72	0	0	.65	4.70	0	.30	.28	.55	.18	0	.28	.12	7.06
1872–73	0	0	0	1.18	0	.40	0	0	0	0	0	.05	1.63
1873–74	.10	0	0	3.40	2.40	1.00	0	0	0	.01	.15	0	7.06
1874–75	.40	.80	.40	0	1.73	0	0	0	0	0	0	0	3.33
1875–76	.01	0	.66	.62	1.51	.70	.87	0	0	.15	.19	.56	5.27
1876–77	.16	.26	0	0	.76	0	0	.59	.69	0	0	0	2.46
1891–92	......	......	......	......	......	......	.62	......	.96	.07	Tr.	Tr.	......
1892–93	0	.35	.23	1.61	1.51	2.91	.98	.02	Tr.	0	.77	Tr.	8.38
1893–94	Tr.	0	.10	.75	.12	.42	.09	.02	.10	.11	.12	.51	2.34
1894–95	Tr.	0	0	1.89	1.24	1.18	.12	Tr.	.01	Tr.	Tr.	.04	4.48
1895–96	Tr.	.83	.67	.08	1.67	0	......	......	......	......	......	......	......
1897–98	......	......	......	......	......	......	0	.16	.23	Tr.	Tr.	.11	......
1898–99	.20	0	.10	.20	.54	Tr.	.01	.02	.03	.37	.01	.06	1.54
1899–1900	Tr.	.30	.85	.56	.31	.05	.67	.62	.22	.04	.08	Tr.	3.70
1900–1901	.75	.01	1.34	.13	2.81	.64	.05	Tr.	.36	0	.10	.32	6.51
1901–2	0	.65	.22	.06	.04	1.69	1.05	.17	.04	.01	.17	.13	4.23
1902–3	Tr.	.08	.41	.04	.71	.27	.34	.19	Tr.	.02	0	0	2.06
1903–4	Tr.	.42	Tr.	0	Tr.	1.20	.95	Tr.	.02	0	Tr.	.07	2.66
1904–5	.32	.06	0	Tr.	.54	.73	2.08	Tr.	.25	0	0	Tr.	3.98
1905–6	.25	0	.43	Tr.	2.89	.13	1.86	.36	.42	.10	.31	.04	6.79
1906–7	0	0	.02	.84	.95	.56	1.10	.14	.01	.55	Tr.	0	4.17
1907–8	0	2.12	Tr.	.42	1.63	.98	.14	Tr.	Tr.	Tr.	.26	.46	6.01
1908–9	.84	.03	.01	.20	3.27	2.73	.16	.12	Tr.	Tr.	0	.25	7.61
1909–10	.07	.01	.19	3.90	.25	Tr.	.10	.31	0	0	.27	0	5.10
26-year mean	.12	.29	.25	1.43	1.12	.77	.61	.17	.17	.06	.12	.15	5.26

TABLE 5.—*Los Angeles aqueduct precipitation stations near Independence, Cal.*

[For location of gages see Plate I, p. 10.]

No. of gage.	Group.	Elevation of gage above sea level.	Distance to gage from crest of Sierra.	Topographic location of gage.	Dates of record (inclusive).
		Feet.	*Miles.*		
1	....	3,820	8.0	On valley floor	Oct., 1908–Apr., 1909
1A	....	3,880	7.5	.....do	Sept., 1909–Aug., 1910
2	Taboose	4,070	8.1	Edge of valley floor	Oct., 1908–Aug., 1910
3	...do	4,460	6.9	On outwash slope	Oct., 1908–Aug., 1910
4	...do	5,040	5.5	.....do	Oct., 1908–Aug., 1910
5	...do	5,550	4.7	At base of mountain	Oct., 1908–Aug., 1910
6A	...do	6,190	4.2	On ridge south of Taboose Creek	Oct., 1908–Feb., 1909
6	...do	6,190	4.2	On slope of mountain	Jan., 1909–Aug., 1910
18	Oak	3,735	13.8	Bank of Owens River	Sept., 1909–
17	...do	3,775	12.5	On valley floor	Apr., 1909–
7	...do	3,940	9.6	Edge of valley floor	Oct., 1908–
8	...do	4,300	8.4	On outwash slope	Oct., 1908–Aug., 1909
8A	...do	4,500	8.0	.....do	Sept., 1909–
9	...do	5,030	6.6	.....do	Oct., 1908–
10	...do	5,590	5.7	.....do	Oct., 1908–
11	...do	6,120	4.8	At base of mountain	Oct., 1908–
12	Bairs	4,100	10.2	Edge of valley floor	Oct., 1908–Oct., 1910
13	...do	4,500	9.0	On outwash slope	Oct., 1908–Oct., 1910
14	...do	5,000	7.7	.....do	Oct., 1908–Oct., 1910
15	...do	5,500	6.6	.....do	Oct., 1908–Oct., 1910
16	...do	6,100	5.7	At base of mountain	Oct., 1908–Oct., 1910.
19	....	4,700	7.2	On outwash slope	Sept., 1909–
20	....	4,420	5.2	.....do	Sept., 1909–

TABLE 6.—*Precipitation, in inches, at Los Angeles aqueduct stations near Independence, Cal., 1908–9.*

[Figures in parentheses estimated by C. H. Lee.]

Gage No.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1	(0.84)	0.14	Tr.	0.16	3.51	3.00	0.23	0.22	0	0	0	(0.20)	8.30
2	(.85)	.06	(Tr.)	.15	4.52	3.22	.24	Tr.	0	0	0	(.05)	9.09
3	(.85)	.04	(Tr.)	.27	4.85	4.02	.28	.04	0	0	0	(.05)	10.40
4	(.90)	.05	(Tr.)	.26	6.32	3.77	.37	.02	0	0	0	(.05)	11.74
5	(.95)	.12	(0.10)	.28	8.93	5.23	.80	.02	0	0	0	(.10)	16.53
6	(1.00)	(.17)	(.15)	(.12)	(12.69)	7.49	1.42	.05	0	0	0	(.15)	23.24
7	(.85)	(.04)	Tr.	.19	3.44	2.52	.12	.02	0	0	0	.04	7.22
8	(.85)	(.05)	Tr.	.21	4.65	3.06	.36	0	0	0	0	.06	9.24
9	(.90)	(.06)	Tr.	.25	5.89	3.49	.71	0	0	0	0	.05	11.35
10	(.95)	(.10)	.08	.25	7.69	4.62	.71	0	0	0	0	.07	14.47
11	(1.00)	(.15)	.23	.31	11.49	6.61	1.08	.02	0	0	0	.15	21.04
12	(.85)	Tr.	(Tr.)	.22	1.53	1.53	.15	Tr.	0	0	0	Tr.	4.28
13	(.85)	Tr.	(Tr.)	.26	2.67	2.06	.15	0	0	0	0	.10	6.09
14	(.90)	Tr.	(Tr.)	.27	3.48	2.56	.29	0	0	0	0	.13	7.63
15	(.95)	.14	(.10)	.29	5.05	4.36	.63	Tr.	0	0	0	.15	11.67
16	(1.00)	.28	(.15)	.29	6.43	4.98	1.00	.07	0	0	0	.14	14.34

Table 7.—*Precipitation, in inches, at Los Angeles aqueduct stations near Independence, Cal., 1909–10.*

[Figures in parentheses estimated by C. H. Lee.]

Gage No.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1A	0.00	0	0.05	3.14	1.03	0	0.00	0.50	0	0	(1.00)	0	5.72
2	.00	0	.13	3.24	1.39	0	.00	.64	0	0	(1.25)	0	6.65
3	.00	0	.24	3.29	2.15	0	.00	.43	0	0	(1.50)	0	7.61
4	.07	0	.50	3.39	2.64	0	.00	.34	0	0	(1.75)	0	8.69
5	.08	0	.90	3.75	2.50	0	.00	.28	0	0	(1.75)	0	9.26
6	.11	0	1.20	6.39	3.00	0	.00	.24	0	0	(2.00)	0	12.94
18	.03	0	.01	2.20	.14	0	.05	.12	0	0	.60	0	3.15
17	.07	0	.26	2.50	.16	0	.04	.19	0	0	1.03	0	4.25
7	.01	0	.17	2.99	.60	0	.00	.44	0	0	.21	0	4.45
8A	.10	0	.27	3.20	.88	0	.03	.35	0	0	.44	0	5.27
9	.12	0	.40	3.60	1.20	0	.02	.23	0	0	.85	0	6.42
10	.13	0.	.59	(3.95)	1.58	0	.06	.14	0	0	1.22	0	7.67
11	.18	0	1.24	(4.85)	2.30	0	.18	.16	0	0	1.28	0	10.19
12	.02	0	.02	3.08	.40	0	.03	.00	0	0	.19	0	3.74
13	.10	0	.04	2.68	.55	0	.03	.05	0	0	.18	0	3.63
14	.11	0	.09	3.97	.82	0	.03	.10	0	0	.22	0	5.34
15	.27	0	.27	(3.66)	1.11	0	.06	.26	0	0	.31	0	5.94
16	.18	0	.41	(4.19)	1.39	0	.11	.40	0	0	.56	0	7.24
19	.05	0	.22	4.19	.82	0	.12	.36	0	0	.50	0	6.26
20	.06	0	.34	6.68	.18	0	.07	.34	0	0	1.87	0	9.54

Table 8.—*Precipitation, in inches, at Bishop, Cal.*

[Elevation, 4,450 feet.]

Season.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1894–95	(0.00)	(0.00)	(0.00)	(3.00)	2.60	0.38	0.47	0.18	0.03	0.12	0.12	0.01	(6.91)
1895–96	.01	.19	.21	.03	1.52	.0	.93	.17	.04	.05	.61	.36	4.12
1896–97	Tr.	Tr.	.04	.48	.32	1.67	1.75	.0	.12	Tr.	.01	.05	4.44
1897–98	.09	.39	Tr.	.49	.05	.13	Tr.	.21	.23	Tr.	Tr.	.0	1.59
1898–99	.41	.0	.21	.11	1.65	.0	Tr.	.64	.02	.0	.0	.05	3.09
1899–1900	.0	.14	.05	1.05	.49	.01	.54	.60	.34	.12	Tr.	.0	3.34
1900–1901	.39	.03	2.69	.17	4.89	1.01	Tr.	.50	1.29	Tr.	.0	.39	11.90
1901–1902	.0	.81	.61	.12	.07	.55	1.53	.61	.06	0.	Tr.	.12	4.48
1902–1903	.05	.28	.97	.03	.46	.20	.35	.14	Tr.	.20	.0	.0	2.68
1903–1904	Tr.	.21	.0	.0	Tr.	1.65	2.39	.04	.06	Tr.	.39	.67	5.41
1904–1905	1.67	.64	.0	.10	.46	1.18	2.13	.04	.40	.02	.0	.0	6.64
1905–1906	.41	.0	.50	.05	2.34	.14	3.69	.74	.46	.19	.01	.51	9.04
1906–1907	.0	.0	.30	2.15	1.80	.15	1.41	.0	.14	Tr.	.0	Tr.	5.95
1907–1908	.0	2.59	.0	.74	1.58	1.65	.18	Tr.	.0	Tr.	.08	.15	6.97
1908–1909	(1.20)	(0.05)	(.0)	.42	3.77	1.47	.20	.42	.0	Tr.	.0	.0	7.53
1909–1910	Tr.	.27	......	......	......	......	......	......	......	.19	......	(.0)	......
15-year mean.	.28	.36	.37	.60	1.47	.68	1.04	.29	.21	.05	.08	.19	5.61

Table 9.—*Precipitation, in inches, at Laws, Cal.*

[Elevation, 4,113 feet.]

Season.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1883–84	0.12	0.11	0.00	0.38	0.62	0.64	0.94	0.05	0.00	0.00	0.00	0.00	2.86
1884–85	.0	.0	.0	1.00	.0	.0	.67	.14	.0	.0	.0	.0	1.81
1885–86	.0	.02	0.35	.0	1.03	.0	.50	.38	.0	.0	.0	.0	2.28
1886–87	.0	.0	.0	.20	.65	1.58	.0	.35	0.55	0.35	.0	.0	3.68
1887–88	.15	.15	.05	1.10	1.37	.47	.05	.0	.0	.35	0.20	.0	3.89
1888–89	.0	.0	1.72	.40	.10	.50	1.46	.12	.30	.0	.0	.0	4.60
1889–90	.0	.03	.35	1.20	4.75	.30	.0	.0	.0	.0	.0	0.50	7.13
1890–91	.69	.0	.0	1.00	.0	3.70	.28	.0	2.90	.0	.0	.03	8.60
1891–92	.19	.0	.0	3.52	.10	.70	1.10	.0	.25	Tr.	.0	.0	5.86
1892–93	.0	.20	1.42	2.27	1.22	1.12	.15	.0	.0	.0	1.05	Tr.	7.43
1893–94	.19	.0	.10	.49	.30	.75	.09	.05	Tr.	.35	Tr.	.23	2.55
1894–95	Tr.	.0	.0	1.18	1.10	.50	.22	.29	.15	.11	.21	.07	3.83
1895–96	Tr.	.16	.15	Tr.	1.07	.0	.60	.05	.03	.0	.57	.06	2.69
1896–97	.05	Tr.	Tr.	.16	......	......	......	......	......	......	......	......	......
13-year mean.	.10	.05	.30	.98	.95	.79	.47	.13	.32	.09	.16	.07	4.40

TABLE 10.—*Precipitation, in inches, at Keeler, Cal.*

[Elevation, 3,622 feet. Figures in parentheses estimated from Lone Pine record.]

Season.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1883-84	......	......	......	......	......	......	......	0.20	1.60	0.80	0	0.20	....
1884-85	0	0	0	0.70	0	0	0.12	.82	0	.08	0	.11	1.83
1885-86	0	0.25	0.65	.36	0.49	0.14	.60	.40	0	0	0.14	.08	3.11
1886-87	0	.01	.08	0	Tr.	.93	0	1.14	.04	Tr.	.52	0	2.72
1887-88	1.08	.84	.01	.48	.70	1.21	.30	.12	.30	.20	.17	.10	5.51
1888-89	.06	0	1.68	.82	.04	Tr.	.52	.12	.06	.01	0	Tr.	3.31
1889-90	.08	.56	.05	.56	.42	.01	Tr.	.10	.20	0	Tr.	1.71	3.69
1890-91	.93	.03	.12	.22	0	1.00	2.01	0	.37	.30	.06	.02	5.06
1891-92	.19	.04	0	.31	.26	.19	.32	0	.56	Tr.	0	0	1.87
1892-93	Tr.	.81	.11	.54	.71	.75	1.50	0	Tr.	0	1.41	Tr.	5.83
1893-94	Tr.	Tr.	.03	1.48	Tr.	.29	.01	Tr.	Tr.	Tr.	.11	0	1.92
1894-95	0	0	0	1.05	.35	1.15	Tr.	.25	Tr.	Tr.	Tr.	Tr.	2.80
1895-96	Tr.	0	0	Tr.	.45	0	Tr.	Tr.	.15	Tr.	.25	1.42	2.27
1896-97	.50	Tr.	0	.25	.10	.27	.13	0	Tr.	0	0	.19	1.44
1897-98	.14	.15	Tr.	Tr.	0	0	0	.05	0	0	0	0	.34
1898-99	Tr.	0	Tr.	.30	.40	.45	0	.01	Tr.	.50	Tr.	Tr.	1.66
1899-1900	0	Tr.	1.75	Tr.	Tr.	0	.16	1.25	.23	Tr.	.10	Tr.	3.49
1900-1901	.35	.09	.45	0	.75	.25	0	Tr.	.40	0	0	.90	3.19
1901-2	0	.50	0	0	Tr.	.25	1.25	0	0	0	Tr.	Tr.	2.00
1902-3	Tr.	0	.50	.10	0	.10	Tr.	Tr.	Tr.	Tr.	0	0	.70
1903-4	0	0	0	0	Tr.	.70	.50	0	0	0	Tr.	1.00	2.20
1904-5	.55	.75	0	0	.90	1.00	3.30	Tr.	1.10	0	0	0	7.60
1905-6	0	0	.50	0	1.05	.20	(.90)	.85	0	0	......	0	(3.50)
1906-7	......	0	.30	.10	1.55	.33	1.12	0	0	1.00	0	0	4.40
1907-8	0	1.94	0	0	.91	1.08	0	0	.25	0	.50	.58	5.26
1908-9	2.75	0	0	0	......	......	......	......	......	......	......	......	....
24-year mean.	.14	.25	.26	.30	.38	.43	.53	.21	.15	.09	.14	.26	3.15

TABLE 11.—*Precipitation, in inches, at Lone Pine, Cal.*

[Elevation, 3,728 feet. Figures in parentheses estimated from Independence record.]

Season.	Sept.	Oct.	Nov	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1904-5	......	......	(0)	(0)	0.60	0.86	3.51	0.16	1.19	0	0	0	....
1905-6	0.15	0	0.63	0	1.00	.11	1.11	.23	.18	Tr.	Tr.	0.01	3.42
1906-7	0	0	.20	0.62	2.21	.31	1.42	.28	Tr.	0.04	Tr.	Tr.	5.08
1907-8	Tr.	2.71	Tr.	.26	1.57	2.18	.10	0	0	0	Tr.	.29	7.11
1908-9	1.12	.18	0	.10	.89	2.22	.23	Tr.	0	Tr.	0	.23	4.97
1909-10	.36	Tr.	Tr.	2.92	Tr.	0	.63	.20	0	.07	.18	0	4.36
5-year mean.	.33	.58	.17	.78	1.13	.96	.70	.14	.04	.02	.04	.11	4.99

TABLE 12.—*Observed precipitation, in inches, at base stations selected for Tuolumne River drainage area.*

Season (Sept. 1 to Aug. 31).	Modesto (elevation, 90 feet).	La Grange (elevation, 293 feet).	Sonora (elevation, 1,825 feet).	Second Garotte (elevation, 2,714 feet).	Crockers (elevation, 4,452 feet).
1868-69	....	18.16	....	....	....
1869-70	....	12.84	....	....	....
1870-71	....	10.46	....	....	....
1871-72	12.71	20.48	....	....	....
1872-73	7.65	14.35	....	....	....
1873-74	11.36	14.63	....	....	....
1874-75	7.40	10.29	....	....	....
1875-76	13.52	25.87	....	....	....
1876-77	4.12	5.74	....	....	....
1877-78	11.51	18.90	....	....	....
1878-79	8.48	11.54	....	....	....
1879-80	12.88	19.50	....	....	....
1880-81	8.40	15.12	....	....	....
1881-82	6.64	14.51	....	....	....
1882-83	10.03	15.98	....	(29.00)	....
1883-84	12.87	25.01	....	52.61	....
1884-85	6.40	11.89	....	29.50	....
1885-86	12.79	24.09	....	46.50	....
1886-87	5.72	11.01	....	27.00	....
1887-88	6.58	11.43	21.75	25.00	....
1888-89	7.61	14.43	25.66	27.25	....
1889-90	16.40	30.34	67.39	67.25	....
1890-91	7.49	....	32.29	36.02	....
1891-92	10.35	....	30.40	32.25	....
1892-93	14.17	19.37	43.76	47.25	....

TABLE 12.—*Observed precipitation, in inches, at base stations selected for Tuolumne River drainage area*—Continued.

Season (Sept. 1 to Aug. 31).	Modesto (elevation, 90 feet).	La Grange (elevation, 293 feet).	Sonora (elevation, 1,825 feet).	Second Garotte (elevation, 2,714 feet).	Crockers (elevation, 4,452 feet).
1893-94	11.40	22.77	37.53	37.25	....
1894-95	16.40	22.36	45.95	52.00	....
1895-96	10.60	14.71	31.17	32.05	....
1896-97	11.63	19.80	38.23	37.79	63.44
1897-98	3.87	10.57	21.04	20.25	31.37
1898-99	9.35	12.83	32.81	29.29	42.43
1899-1900	11.91	....	33.14	35.22	48.40
1900-1901	14.62	....	46.79	55.75	75.04
1901-2	10.10	....	28.42	(30.50)	48.63
1902-3	12.23	....	33.03	....	55.35
1903-4	8.85	....	34.47	....	55.19
1904-5	15.64	....	32.83	....	48.73
1905-6	12.55	....	(51.16)	....	83.54
1906-7	19.04	....	(49.77)	....	66.51
1907-8	9.79	....	....	....	31.79
1908-9	11.16	....	35.98	....	61.20
1909-10	10.93	15.26	29.86	....	55.54
Number of seasons observed	39	30	22	20	14
Mean of seasons observed	10.64	16.47	36.52	37.48	54.80
Computed long-term mean (1871-1910)	10.64	10.64	33.48	33.48	51.40

TABLE 13.—*Observed precipitation, in inches, at base stations selected for Merced River drainage area.*

Season (Sept. 1 to Aug. 31).	Merced (elevation, 173 feet).	Crockers (elevation, 4,452 feet).	Summerdale (elevation, 5,270 feet).	Yosemite (elevation, 4,063 feet).
1872-73	12.21	....	....	....
1873-74	6.94	....	....	....
1874-75	10.00	....	....	....
1875-76	12.85	....	....	....
1876-77	3.03	....	....	....
1877-78	11.81	....	....	....
1878-79	5.83	....	....	....
1879-80	11.89	....	....	....
1880-81	11.59	....	....	....
1881-82	8.58	....	....	....
1882-83	9.81	....	....	....
1883-84	22.08	....	....	....
1884-85	7.18	....	....	....
1885-86	13.43	....	....	....
1886-87	6.20	....	....	....
1887-88	7.08	....	....	....
1888-89	7.80	....	....	....
1889-90	17.81	....	....	....
1890-91	8.92	....	....	....
1891-92	9.64	....	....	....
1892-93	10.98	....	....	....
1893-94	10.86	....	....	....
1894-95	12.63	....	....	....
1895-96	12.55	....	....	....
1896-97	11.36	63.44	53.50	53.38
1897-98	5.76	31.37	29.39	....
1898-99	7.82	42.43	39.77	....
1899-1900	11.25	48.40	49.56	....
1900-1901	11.42	75.04	85.47	....
1901-2	9.98	48.63	45.83	....
1902-3	11.89	55.35	49.83	....
1903-4	8.36	55.19	49.78	[a] 41.87
1904-5	13.20	48.73	49.84	36.00
1905-6	17.76	83.54	84.84	....
1906-7	16.38	66.51	71.77	55.64
1907-8	8.41	31.79	42.22	21.26
1908-9	14.38	61.20	66.55	49.48
1909-10	10.19	55.54	50.22	40.42
Number of seasons observed	38	14	14	7
Mean of seasons observed	10.79	54.80	54.90	42.58
Computed long-term mean (1872-1910)	10.79	51.40	52.40	39.77

[a] Computed value for December, 1903, is 1.97 inches.

TABLE 14.—*Observed precipitation, in inches, at base stations selected for Kings River drainage area.*

Season (Sept. 1 to Aug. 31).	Merced [a] (elevation, 173 feet).	Fresno (elevation, 293 feet).	Sanger (elevation, 371 feet).	Selma (elevation, 311 feet).	Visalia [a] (elevation, 334 feet).	Summerdale [a] elevation, 5,270 feet).
1872-73	12.21					
1873-74	6.94					
1874-75	10.00					
1875-76	12.85					
1876-77	3.03					
1877-78	11.81					
1878-79	5.83					
1879-80	11.89					
1880-81	11.59					
1881-82	8.58	6.60				
1882-83	9.81	9.84				
1883-84	22.08	18.71				
1884-85	7.18	7.20				
1885-86	13.43	19.45				
1886-87	6.20	8.47		7.79		
1887-88	7.08	6.73		5.71		
1888-89	7.80	7.99		7.35	10.68	
1889-90	17.81	13.01	17.24	14.43	14.22	
1890-91	8.92	8.25	6.23	6.96	9.15	
1891-92	9.64	9.93	9.68	7.48	12.31	
1892-93	10.98	11.10	8.91	8.65	10.27	
1893-94	10.86	8.59	9.69	5.91	7.80	
1894-95	12.63	14.67	15.58	10.95	13.41	
1895-96	12.55	8.42	9.43	6.72	7.89	
1896-97	11.36	10.32	12.18	8.73	10.79	53.50
1897-98	5.76	4.96	6.66	3.96	5.53	29.39
1898-99	7.82	7.84	9.29	6.91	9.07	39.77
1899-1900	11.25	10.28	11.28	9.34	9.83	49.56
1900-1901	11.42	11.33	14.77	9.16	12.88	85.47
1901-2	9.98	6.15	6.49	6.48	8.83	45.83
1902-3	11.89	8.50	7.19	7.82	7.56	47.83
1903-4	8.36	8.04	8.88	7.57	6.74	49.78
1904-5	13.20	12.09	13.76	12.83	11.49	49.84
1905-6	17.76	13.52	17.79	15.23	13.85	84.84
1906-7	16.38	10.84	15.93	12.26	11.85	71.77
1907-8	8.41	7.65	7.36	8.27	[b] 9.01	42.22
1908-9	14.38	9.88	10.23	12.13	[c] 13.28	66.55
1909-10	10.19	10.99	5.83	9.83	8.87	50.22
Number of seasons observed	38	29	21	24	22	14
Mean of seasons observed	10.79	10.05	10.69	8.85	10.24	54.90
Computed long-term mean (1872-1910)	10.79	9.70	10.03	8.72	9.73	52.40

[a] Merced and Summerdale are in the Merced River area and Visalia in the Kaweah River area, but the stations are used on account of scarcity of rainfall stations within the Kings River area.
[b] Computed value, October, 1907, 0.86 inch; December, 1907, 0.83 inch.
[c] Computed value March, 1909, 1.33 inches.

TABLE 15.—*Observed precipitation, in inches, at base stations selected for Kaweah River drainage area.*

Season (Sept. 1 to Aug. 31).	Fresno (elevation, 293 feet).	Visalia (elevation, 334 feet).	Tulare (elevation, 274 feet).	Lemon Cove (elevation, 600 feet).	Milo (elevation, 1,600 feet).
1881-82	6.60				
1882-83	9.48				
1883-84	18.71				
1884-85	7.20				
1885-86	19.45				
1886-87	8.47				
1887-88	6.73				
1888-89	7.99	10.68			
1889-90	13.01	14.22			
1890-91	8.25	9.15			
1891-92	9.93	12.31			
1892-93	11.10	10.27			
1893-94	8.59	7.80	5.99		
1894-95	14.67	13.41	10.47		
1895-96	8.42	7.89	5.85		

TABLE 15.—*Observed precipitation, in inches, at base stations selected for Kaweah River drainage area*—Continued.

Season (Sept. 1 to Aug. 31).	Fresno (elevation, 293 feet).	Visalia (elevation, 334 feet).	Tulare (elevation, 274 feet).	Lemon Cove (elevation, 600 feet).	Milo (elevation, 1,600 feet).
1896-97	10.32	10.79	7.99		
1897-98	4.96	5.53	5.13		
1898-99	7.84	9.07	8.09		
1899-1900	10.28	9.83	9.65		
1900-1901	11.33	12.88	10.92		
1901-2	6.15	8.83	6.92		18.08
1902-3	8.50	7.56	6.63	12.89	19.76
1903-4	8.04	6.74	6.70	11.09	14.49
1904-5	12.09	11.49	13.14	19.71	22.39
1905-6	13.52	13.85	13.97	27.20	42.11
1906-7	10.84	11.85	11.73	20.58	[a] 27.19
1907-8	7.65	[b] 9.01	10.80	13.34	19.11
1908-9	9.88	[c] 13.28	12 17	13.97	33.43
1909-10	10.99	8.87	8.34	13.22	23.79
Number of seasons observed	29	22	17	8	9
Mean of seasons observed	10.05	10.24	9.09	16.50	24.48
Computed long-term mean (1872-1910)	9.70	9.73	9.13	15.72	24.40

[a] Computed value, November, 1906, 0.59 inch.
[b] Computed value, October, 1907, 0.86 inch; December, 1907, 0.83 inch.
[c] Computed value, March, 1909, 1.33 inches.

TABLE 16.—*Observed precipitation, in inches, at base stations selected for Tule River drainage area.*

Season (Sept. 1 to Aug. 31).	Porterville (elevation, 461 feet).	Tulare (elevation, 274 feet).	Milo (elevation, 1,600 feet).	Hot Springs (elevation, 3,300 feet).
1889-90	12.78			
1890-91	8.11			
1891-92	8.58			
1892-93	9.77			
1893-94	5.56	5.99		
1894-95	10.97	10.47		
1895-96	6.37	5.85		
1896-97	9.66	7.99		
1897-98	6.11	5.13		
1898-99	7.96	8.09		
1899-1900	9.24	9.65		
1900-1901	12.76	10.92		
1901-2	9.33	6.92	18.08	
1902-3	8.24	6.63	19.76	
1903-4	7.47	6.70	14.49	
1904-5	11.86	13.14	22.37	
1905-6	17.90	13.97	42.11	
1906-7	13.44	11.73	[a] 27.19	
1907-8	11.70	10.80	19.11	20.49
1908-9	14.95	12.17	33.43	38.59
1909-10	10.00	8.34	23.79	20.05
Number of seasons observed	21	17	9	3
Mean of seasons observed	10.13	9.09	24.48	26.38
Computed long-term mean (1881-1910)	10.36	9.46	21.76	22.37

[a] Computed value November, 1906, 0.59 inch.

TABLE 17.—*Observed precipitation, in inches, at base stations selected for Kern River drainage area.*

Season (Sept. 1 to Aug. 31).	Bakersfield (elevation, 404 feet).	Porterville (elevation, 461 feet).	Kernville (elevation, 2,600 feet).	Isabella (elevation, 2,600 feet).
1889-90	5.70	12.78		
1890-91	3.97	8.11		
1891-92	5.51	8.58		
1892-93	5.42	9.77		
1893-94	2.77	5.56		
1894-95	6.44	10.97	14.73	
1895-96	5.90	6.37	10.27	
1896-97	6.00	9.66	12.41	
1897-98	3.20	6.11	15.60	4.10
1898-99	2.80	7.96	5.38	5.38
1899-1900	5.23	9.24	5.69	6.62
1900-1901	(6.17)	12.76	13.03	13.72
1901-2	4.51	9.33	10.47	10.50
1902-3	4.98	8.24	7.56	6.73
1903-4	4.46	7.47	5.98	7.42
1904-5	8.27	11.86	11.29	12.54
1905-6	8.72	17.90	16.36	16.14
1906-7	4.85	13.44	8.77	10.91
1907-8	3.31	11.70	8.37	8.33
1908-9	7.39	14.95	21.17	23.70
1909-10	6.19	10.00	9.85	10.57
Number of seasons observed	21	21	16	13
Mean of seasons observed	5.32	9.09	11.06	10.51
Computed long-term mean (1881-1910)	5.44	10.36	10.88	10.61

TABLE 18.—*Variation in seasonal precipitation at Owens Valley stations.*

Season.	Percentage of 26-year mean at various stations.					Average.[b]
	Bishop.	Laws.[a]	Independence.	Lone Pine.	Keeler.	
1866-67			217			217
1867-68			370			370
1868-69			63			63
1869-70			50			50
1870-71			70			70
1871-72			134			134
1872-73			31			31
1873-74			134			134
1874-75			63			63
1875-76			100			100
1876-77			47			47
1883-84		65				65
1884-85		41			58	41
1885-86		52			99	52
1886-87		84			86	84
1887-88		88			175	88
1888-89		104			105	104
1889-90		162			117	162
1890-91		195			161	195
1891-92		133			59	133
1892-93		169	159		135	164
1893-94		58	44		61	51
1894-95	96	87	85		89	89
1895-96	57	61			72	59
1896-97	61				46	61
1897-98	22				11	22
1898-99	43		29		53	36
1899-1900	46		70		111	58
1900-1901	165		124		101	145
1901-2	62		80		64	71
1902-3	37		39		22	38
1903-4	75		51		70	63
1904-5	92		76		241	84
1905-6	125		129	77	111	110
1906-7	82		79	115	140	92
1907-8	97		114	161	167	124
1908-9	104		145	112		120
1909-10			97	99		98

[a] 13-year observed mean.

[b] Keeler not included.

TABLE 19.—*Description and mean precipitation for stations in Central Pacific group.*[a]

Gage No.	Station.	Elevation.	Distance from Sacramento.	Length of record.	Observed mean seasonal precipitation.	Computed mean seasonal precipitation.			Observed precipitation, 1909–10.
						Base station.	Number of years covered.	Precipitation.	
		Feet.	*Miles.*	*Years.*	*Inches.*			*Inches.*	*Inches.*
1	Sacramento	71	0	61	19.50	Sacramento	40	19.36	12.18
2	Rocklin	249	18.9	8	28.45	Auburn	40	24.65	21.06
3	Newcastle	956	26.3	15	32.32	do	40	28.20	26.92
4	Auburn	1,363	30.0	40	34.93	do	40	34.93	36.12
5	Colfax	2,421	42.1	40	49.01	Colfax	40	49.01	49.69
6	Iowa Hill	2,825	46.8	31	52.64	do	40	50.53	50.68
7	Gold Run	3,222	48.8	11	54.49	Alta-Towle	40	43.05	48.34
8	Towle (Alta)	3,612	52.8	40	49.15	do	40	49.15	53.02
9	Blue Canyon	4,695	58.5	11	72.82	do	40	57.55	64.11
10	Emigrant Gap	5,230	61.7	30	53.50	Cisco	40	54.50	56.28
11	Cisco	5,939	67.9	40	51.96	do	40	51.96	58.85
12	Summit	7,017	78.6	39	48.00	do	40	47.60	37.00
13	Truckee	5,820	85.8	39	27.65	Truckee	39	27.65	25.01
14	Boca	5,531	92.0	38	20.47	Boca	38	20.47	25.93
15	Reno	4,484	110.1	39	7.05	Reno	39	7.05	7.52
16	Wadsworth (Fernley).	4,084	138.4	35	4.59	Wadsworth	35	4.59	5.17

[a] Stations 1 to 12 inclusive, seasonal totals (Sept. 1 to Aug. 31); stations 13 to 16 inclusive, calendar year totals, except last column.

TABLE 20.—*Description and mean precipitation for stations in Mokelumne group.*

Gage No.	Station.	Elevation.	Distance from Stockton.	Length of record.	Observed mean seasonal precipitation.	Computed mean seasonal precipitation.			Observed precipitation, 1909–10.
						Base station.	Number of years covered.	Precipitation.	
		Feet.	*Miles.*	*Years.*	*Inches.*			*Inches.*	*Inches.*
1	Stockton	23	0	60	15.31	Stockton	28	14.82	13.81
2	Farmington	111	13.0	33	16.47	Farmington	28	16.73	15.91
3	Ione	287	33.0	32	21.03	Ione	28	21.33	20.39
4	Valley Springs	673	31.2	22	24.71	Stockton	28	24.18	23.28
5	Jackson	1,200	40.0	20	33.19	Jackson	20	33.19	....
6	Mokelumne Hill.	1,550	41.0	28	32.53	Mokelumne Hill.	28	32.53	32.93
7	West Point	2,800	52.8	16	42.50	do	28	41.15	39.56
8	Bear Valley Reservoir.	5,800	72.5	7	63.35	do	28	57.65	....
9	Tamarack	8,012	89.5	11	57.23	do	28	54.73	48.94
10	Gardnerville	4,830	108.5	11	8.93	do	28	9.08	16.57
11	Wabuska	4,347	141.5	7	3.70	....	....	....	3.49

TABLE 21.—*Computed mean precipitation, in inches, at Los Angeles aqueduct stations, based on 26-year observed mean at Independence.*

Taboose group of gages.

Gage No.	Observed precipitation.		Computed mean seasonal precipitation based on—		
	Season 1908–9.	Season 1909–10.	Season 1908–9.	Season 1909–10.	Average.
2	9.09	6.65	6.27	6.86	6.56
3	10.40	7.61	7.17	7.85	7.51
4	11.74	8.69	8.10	8.96	8.53
5	15.53	9.26	11.40	9.55	10.48
6	23.24	12.94	16.03	13.34	14.69
Oak group of gages.					
18	....	3.15	....	3.25	3.25
17	....	4.25	....	4.38	4.38
7	7.22	4.45	4.98	4.59	4.78
8	9.24	....	6.37	....	6.37
8A	....	5.27	....	5.43	5.43
9	11.35	6.42	7.83	6.62	7.22
10	14.47	7.67	9.98	7.91	8.94
11	21.04	10.19	14.51	10.51	12.51
Bairs group of gages.					
12	4.28	3.74	2.95	3.86	3.40
13	6.09	3.63	4.20	3.74	3.97
14	7.63	5.34	5.26	5.51	5.38
15	11.67	5.94	8.05	6.12	7.08
16	14.34	7.24	9.89	7.46	8.68
Miscellaneous gages.					
1	8.30	....	5.72	....	5.72
1A	....	5.72	....	5.90	5.90
19	....	6.26	....	6.45	6.45
20	....	9.54	....	9.84	9.84

TABLE 22.—*Relative flow of water through a porous medium at various temperatures, assuming the rate of flow at 32° F. as unity.*[a]

[By L. G. Carpenter, Fort Collins, Colo.]

Temperature.	Velocity.	Temperature.	Velocity.
°*F.*		°*F.*	
32	1.000	72	1.860
42	1.195	82	2.109
52	1.403	92	2.372
62	1.624	102	2.649

[a] Eng. News, June 30, 1898, p. 422.

TABLE 23.—*Creek channels studied for percolation losses.*

Stream.	Points of measurement.				Length of channel.	Average slope.	Description of channel.
	Upper station.		Lower station.				
	Location.	Elevation.	Location.	Elevation.			
		Feet.		*Feet.*	*Miles.*	*Feet per mile.*	
Tinemaha Creek	Mouth of canyon	6,470	Cabin at spring west of Jeru Ranch.	4,665	3.60	502	Coarse alluvial deposit; luxuriant tree growth.
Do	Cabin at spring	4,665	U. S. Geol. Survey station	(4,150)	2.50	(206)	Coarse alluvial deposit; vegetation scattered.
Red Mountain Creek	Mouth of canyon	6,565	Point of departure from Tinemaha Creek.	4,875	3.40	497	Coarse alluvial deposit; luxuriant tree growth.
Taboose Creek	do	5,730	U. S. Geol. Survey station	3,970	4.80	367	Fissured lava; luxuriant tree growth.
Goodale Creek	do	5,900	do	3,980	4.20	457	Do.
Division Creek	do	6,000	Los Angeles aqueduct power house No. 2.	4,420	2.30	687	Fissured lava covered with wash; luxuriant tree growth.
Sawmill Creek	do	4,900	U. S. Geol. Survey station above road.	4,450	0.50	900	Coarse alluvial deposit; luxuriant tree growth.
Do	do	4,900	U. S. Geol. Survey station at road.	3,900	2.00	500	Do.
Oak Creek, North Fork	do	5,600	Junction with South Fork	4,350	2.60	480	Do.
Oak Creek, South Fork	do	5,800	Junction with North Fork	4,350	3.00	483	Coarse alluvial deposit; vegetation scattered.
Oak Creek, main channel	Junction of forks	4,350	U. S. Geol. Survey station	4,200	0.50	300	Coarse alluvial deposit; luxuriant tree growth.
Little Pine Creek	Mouth of canyon	5,900	Junction of Pinyon ditch	5,300	1.20	500	Do.
Do	Junction Pinyon ditch	5,300	Second pine tree	4,700	1.40	430	Coarse alluvial deposit; medium tree growth.
Do	Second pine tree	4,700	U. S. Geol. Survey station	4,150	1.80	305	Do.
Pinyon ditch	Mouth of canyon	6,200	Junction Little Pine Creek	5,350	1.75	486	Coarse alluvial deposit; no vegetation.
Do	Heading of Pinyon ditch	5,700	Heading of Davis ditch	4,200	4.25	353	Do.
Do	Heading of Davis ditch	4,200	Citrus road	3,900	1.00	300	Fine alluvial deposit; no vegetation.
Lime Fork of Little Pine Creek.	Mouth of canyon	6,500	Junction of Little Pine Creek.	5,800	0.75	935	Do.
Symmes Creek	do	6,300	U. S. Geol. Survey station	4,500	4.50	400	Coarse alluvial deposit; no vegetation.
Symmes Creek, North Fork	do	6,800	Junction of Symmes Creek	5,000	....	....	Do.
Shepard Creek	do	6,400	Point of branching	4,430	4.75	415	Do.
Shepard Creek, North Branch.	Point of branching	4,430	U. S. Geol. Survey station	4,000	1.50	286	Do.
Shepard Creek South Branch.	do	4,430	do	4,050	1.25	304	Do.
Bairs Creek, North Fork	Mouth of canyon	6,100	Junction with South Fork	4,800	2.60	500	Coarse alluvial deposit; luxuriant tree growth.
Bairs Creek, South Fork	do	6,300	Junction with North Fork	4,800	3.00	500	Do.
Bairs Creek, main channel	Junction of forks	4,800	U. S. Geol. Survey station	4,200	1.90	316	Coarse alluvial deposit; occasional trees.
George Creek	Mouth of canyon	6,450	do	4,200	5.50	409	Coarse alluvial deposit; luxuriant tree growth.

TABLE 24.—*Discharge measurements on which studies of stream percolation are based.*

Stream and gaging stations.	Date of measurement.	Discharge at— Upper station. Time.	Discharge at— Upper station. Temperature of water (°F.).	Discharge at— Upper station. Discharge (second-feet).	Discharge at— Lower station. Time.	Discharge at— Lower station. Temperature of water (°F.).	Discharge at— Lower station. Discharge (second-feet).	Loss. Total (second-feet).	Loss. Second-feet per mile.	Remarks.
Tinemaha Creek, mouth of canyon to old cabin.	Apr. 8, 1909	10.30 a. m.	40	2.73	4.00 p. m.	58	1.43	1.30	0.36	
	May 13, 1909	10.15 a. m.	43	8.45	2.00 p. m.	52	7.73	.72	.20	Loss appears too small.
	Aug. 4, 1909	9.50 a. m.	47	26.10	2.00 p. m.	57	21.50	4.60	1.28	
Tinemaha Creek, old cabin to U. S. Geol. Survey station.	Apr. 8, 1909	4.00 p. m.	58	1.43	5.10 p. m.	60	3.51	− 2.08	....	Gain is from springs and irrigation seepage.
	May 13, 1909	2.00 p. m.	52	7.73	3.00 p. m.	57	11.40	− 3.67	....	Do.
	Aug. 4, 1909	2.00 p. m.	57	21.50	3.10 p. m.	64	24.50	− 3.00	....	Do.
Red Mountain Creek, mouth of canyon to departure from Tinemaha Creek.	Apr. 8, 1909	12.50 p. m.	42.5	2.58	3.15 p. m.	59	1.33	1.25	.37	
	May 13, 1909	11.15 a. m.	43	11.24	1.15 p. m.	52	7.35	3.89	1.14	
	Aug. 4, 1909	11.15 a. m.	49	12.90	1.00 p. m.	59	7.40	5.50	1.62	
Taboose Creek, mouth of canyon to U. S. Geol. Survey station.	June 29, 1908	12.00 m.	....	12.80	5.00 p. m.	....	6.40	6.40	1.33	
	Sept. 27, 1908	1.00 p. m.	....	9.00	6.00 p. m.	....	4.90	4.10	.86	
	Nov. 14, 1908	10.15 a. m.	41	7.26	3.10 p. m.	48	3.36	3.90	.81	
	Apr. 6, 1909	10.45 a. m.	44	7.31	3.25 p. m.	55	2.81	4.50	.94	
	May 14, 1909	10.15 a. m.	45	14.21	2.30 p. m.	54	6.55	7.66	1.60	
	Aug. 5, 1909	10.50 a. m.	50	22.90	2.45 p. m.	61	11.70	11.20	2.34	
Goodale Creek, mouth of canyon to U. S. Geol. Survey station.	June 26, 1908	3.30 p. m.	....	10.80	2.00 p. m.	....	4.80	6.00	1.25	Upper station one-half mile above regular at 6,400-foot level.
	June 29, 1908	3.00 p. m.	....	10.70	5.45 p. m.	....	6.40	4.30	1.02	
	Sept. 27, 1908	4.00 p. m.	....	8.37	6.30 p. m.	....	4.10	4.27	1.00	
	Nov. 14, 1908	12.00 m.	42.5	5.13	3.30 p. m.	45	2.61	2.52	.60	
	Apr. 6, 1909	12.45 p. m.	44	5.75	4.15 p. m.	50	2.97	2.78	.66	
	May 14, 1909	12.15 p. m.	46	11.90	3.20 p. m.	54	6.45	5.45	1.30	
	Aug. 5, 1909	12.45 p. m.	52	15.60	3.45 p. m.	61	7.80	7.80	1.86	
Division Creek, mouth of canyon to Los Angeles aqueduct power house No. 2.	June 27, 1908	10.30 a. m.	....	9.13	11.45 a. m.	....	6.44	2.69	1.17	Upper station, discharge includes 2 springs 2.5 second-feet.
	Sept. 27, 1908	10.30 a. m.	....	8.76	11.45 a. m.	....	7.92	.84	.36	Do.
	Nov. 13, 1908	2.00 p. m.	42	8.55	4.00 p. m.	45	7.29	1.26	.55	Do.
	Feb. 24, 1909	12.00 m.	41	8.17	12.00 m.	44	7.69	.48	.21	No change in gage height 2 p. m.; includes springs.
Sawmill Creek, mouth of canyon to U. S. Geol. Survey station above road.	June 26, 1908	10.30 a. m.	....	4.22	11.00 a. m.	....	3.80	.42	.84	
	Nov. 13, 1908	10.15 a. m.	43	4.86	11.15 a. m.	43	4.95	− .11	.00	

Oak Creek, North Fork, mouth of canyon to junction of South Fork.	Sept. 28, 1908	1.00 p.m.	....	10.20	3.00 p.m.	....	8.90	1.30	.50	
	Oct. 8, 1908	1.25 p.m.	....	8.32	12.00 m.	....	7.52	.80	.31	
	Nov. 15, 1908	10.15 a.m.	40	7.10	12.00 m.	43	7.39	− .29	....	Stream from Charlies Canyon not included.
	Apr. 9, 1909	1.30 p.m.	46	8.39	3.45 p.m.	51	8.89	− .50	....	Do.
	May 12, 1909	10.00 a.m.	42	18.60	1.15 p.m.	46	22.20	− 3.60	....	Do.
	June 10, 1909	11.30 a.m.	....	36.30	3.00 p.m.	....	38.40	− 2.10	....	Charlies Canyon and McGann ditch measured.
	July 30, 1909	9.45 a.m.	48	27.70	11.30 a.m.	55	21.00	6.70	2.58	Measurement same as June 10; upper section very poor.
	Sept. 13, 1909	8.45 a.m.	44	14.20	11.15 a.m.	52	10.40	3.80	1.46	
Oak Creek, South Fork, mouth of canyon to junction of North Fork.	Oct. 8, 1908	10.00 a.m.	....	6.64	11.30 a.m.	....	4.32	2.32	.77	
	Nov. 15, 1908	10.30 a.m.	....	5.10	12.30 p.m.	45	3.52	1.58	.53	
	Apr. 9, 1909	9.45 a.m.	45	5.93	12.45 p.m.	59	3.68	2.25	.75	
	May 12, 1909	9.30 a.m.	44	15.20	2.00 p.m.	51	12.40	2.80	.93	
	July 30, 1909	10.00 a.m.	....	30.90	11.45 a.m.	59	21.00	9.90	3.30	
	Sept. 8, 1909	11.30 a.m.	53	17.00	3.00 p.m.	63	10.40	6.60	2.20	
Oak Creek main channel, junction of forks to U. S. Geol. Survey station.	Oct. 8, 1908	12.00 m.	....	11.84	3.15 p.m.	....	11.14	.70	1.40	
	Nov. 15, 1908	12.00 m.	44	10.91	1.00 p.m.	45	10.59	.32	.64	
	Apr. 9, 1909	3.30 p.m.	56	12.13	4.15 p.m.	54	11.42	.71	1.42	
	May 12, 1909	1.30 p.m.	48	34.60	3.00 p.m.	48	31.80	2.80	5.60	
	June 10, 1909	3.00 p.m.	....	58.50	4.00 p.m.	....	49.00	9.50	19.00	
	July 30, 1909	11.30 a.m.	57	42.00	1.15 p.m.	59	38.90	3.10	6.20	
Oak Creek, combined channels, mouth of canyon to U. S. Geol. Survey station. For subsequent dates, see above.	Aug. 20, 1906	....	....	101.00	....	....	68.00	33.00	5.40	
	June 25, 1908	12.00 m.	....	28.70	2.00 p.m.	....	22.00	6.70	1.10	
	Sept. 28, 1908	1.00 p.m.	....	14.00	3.30 p.m.	....	13.10	.90	.15	Not plotted; measurement on South Fork questioned.
	June 24, 1908	12.00 m.	....	31.40	1.30 p.m.	....	25.90	5.50	1.72	Pinyon Creek measured at mouth of canyon.
	Sept. 12, 1908	11.00 a.m.	....	15.20	3.00 p.m.	....	13.40	1.80	.56	Subsequent measurements just below junction.
Little Pine Creek, junction of Pinyon ditch to U. S. Geol. Survey station.	Oct. 5, 1908	1.30 p.m.	....	9.88	5.00 p.m.	....	7.55	2.33	.73	
	Oct. 31, 1908	1.00 p.m.	44	7.96	3.30 p.m.	45	6.27	1.69	.53	
	Dec. 11, 1908	12.15 p.m.	....	6.05	2.30 p.m.	....	5.68	.37	.12	
	Jan. 18, 1909	10.45 a.m.	41	7.26	2.30 p.m.	46	6.49	.77	.24	
	Jan. 29, 1909	10.30 a.m.	33	6.91	2.00 p.m.	38	6.39	.52	.16	
	Mar. 13, 1909	10.00 a.m.	39	5.20	3.00 p.m.	50	5.10	.10	.00	
	Apr. 23, 1909	12.10 p.m.	52	11.90	2.30 p.m.	55	10.87	1.03	.32	
	May 11, 1909	10.30 a.m.	47	44.80	5.00 p.m.	48	36.30	8.50	2.66	
	June 4, 1909	2.00 p.m.	52	95.20	4.00 p.m.	55	90.40	4.80	1.50	Upper measurements poor; very high velocity.
	July 22, 1909	1.30 p.m.	57	56.70	5.00 p.m.	60	65.50	− 8.80	− 2.75	
	Aug. 9, 1909	9.00 a.m.	53	28.60	1.15 p.m.	63	31.60	− 3.00	− .94	
	Aug. 23, 1909	11.00 a.m.	57	27.50	2.30 p.m.	64	31.40	− 3.90	− 1.22	
	Sept. 11, 1909	8.00 a.m.	50	15.50	11.30 a.m.	57	16.40	− .80	− .25	
	Oct. 27, 1909	9.30 a.m.	43	7.20	1.30 p.m.	51	5.80	1.40	.44	
Little Pine Creek, mouth of canyon to junction of Pinyon ditch.	Oct. 5, 1908	10.30 a.m.	....	8.11	1.30 p.m.	....	8.19	.08	.00	Loss negligible.
	Oct. 31, 1908	10.00 a.m.	39	5.40	1.00 p.m.	44	5.76	− .36	.00	Do.
Little Pine Creek, junction of Pinyon ditch to second pine tree.	Oct. 5, 1908	1.30 p.m.	....	9.88	3.30 p.m.	....	7.82	2.06	1.47	
	Oct. 31, 1908	1.00 p.m.	44	7.96	2.30 p.m.	44	5.71	2.25	1.60	
	Dec. 11, 1908	12.15 p.m.	....	6.05	1.30 p.m.	....	5.12	.93	.66	

TABLE 24.—*Discharge measurements on which studies of stream percolation are based*—Continued.

Stream and gaging stations.	Date of measurement.	Discharge at— Upper station. Time.	Upper station. Temperature of water (°F.).	Upper station. Discharge (second-feet).	Lower station. Time.	Lower station. Temperature of water (°F.).	Lower station. Discharge (second-feet).	Loss. Total (second-feet).	Loss. Second-feet per mile.	Remarks.
Little Pine Creek, second pine tree to U. S. Geol. Survey station.	Oct. 5,1908	3.30 p. m.	....	7.82	5.00 p. m.	....	7.55	0.27	0.15	
	Oct. 31,1908	2.30 p. m.	44	5.71	3.30 p. m.	45	6.27	− .56	....	
	Dec. 11,1908	1.30 p. m.	....	5.12	2.30 p. m.	....	5.68	− .56	....	
	May 15,1909	1.00 p. m.	49	11.23	3.00 p. m.	52.5	5.83	5.40	3.10	No waste down old channel.
	July 22,1909	10.30 a. m.	52	16.30	2.00 p. m.	55	10.80	5.50	3.14	4.7 second-feet waste down old channel.
Pinyon ditch, mouth of canyon to junction of Little Pine Creek.	Aug. 9,1909	10.30 a. m.	51	3.80	11.45 a. m.	60	2.60	1.20	.68	7.10 second-feet waste down old channel.
	Aug. 23,1909	9.30 a. m.	51	3.29	10.45 a. m.	60	1.96	1.33	.76	4.87 second-feet waste down old channel.
	Sept. 10,1909	10.30 a. m.	50	1.86	11.25 a. m.	62	1.19	.67	.38	4.16 second-feet waste down old channel.
Pinyon Creek, heading of Pinyon ditch to heading of Davis ditch.	June 15,1909	10.15 a. m.	49	24.70	5.00 p. m.	62	11.80	12.90	3.04	Upper measurements poor; very high velocity.
	July 2,1909	10.30 a. m.	....	23.50	3.00 p. m.	....	18.10	5.40	1.27	
Pinyon Creek, heading of Davis ditch to Citrus road crossing.	June 15,1909	5.00 p. m.	62	11.20	5.30 p. m.	65	9.30	1.90	1.90	
Lime Fork of Little Pine Creek, mouth of canyon to junction of Little Pine Creek.	May 15,1909	2.00 p. m.	53	2.30	2.30 p. m.	55	1.41	.89	1.19	
	June 4,1909	1.00 p. m.	55	4.90	1.30 p. m.	63	2.60	2.31	3.06	
	July 2,1909	12.30 p. m.	....	.76	1.00 p. m.	....	.25	.51	.68	
	July 22,1909	9.30 a. m.	59	.29	10.00 a. m.	70	.10	.19	.25	
Symmes Creek, mouth of canyon to U. S. Geol. Survey station.	June 24,1908	4.45 p. m.	....	8.43	7.00 p. m.	....	3.53	4.90	1.09	
	Sept. 22,1908	12.30 p. m.	....	2.08	....	....	.0	2.08	....	Flow 1 mile above and still advancing at 2.30 p. m.
	Dec. 7,1908	1.30 p. m.	35	1.78	5.30 p. m.	35	.0	1.78	.40	Flow just reached U. S. Geol. Survey station.
	Feb. 4,1909	1.15 p. m.	36	1.89	....	45	.0	1.89	....	Flow 0.8 mile above and still advancing at 3,00 p. m.
	Mar. 13,1909	12.30 p. m.	48	2.36	....	....	.0	2.36	....	Do.
	Apr. 6,1909	3.30 p. m.	51	3.77	5.00 p. m.	....	.0	3.77	.84	Flow just reached U. S. Geol. Survey station.
	May 11,1909	1.00 p. m.	48	22.50	3.30 p. m.	55	18.80	3.70	.82	North tributary discharging. Loss too small.
	June 15,1909	1.00 p. m.	53	40.50	3.30 p. m.	62	30.50	10.00	2.22	North tributary discharging.
	July 29,1909	11.45 a. m.	53	14.10	3.30 p. m.	69	8.50	5.60	1.24	North tributary dry.

Symmes Creek, North Fork, mouth of canyon to junction of Symmes Creek	May 5, 1909	1.00 p. m.	49	4.39	3.15 p. m.	67	1.84	2.55	.57	
	June 4, 1909	12.00 m.	52	6.40	9.15 a. m.	....	5.50	.90	.20	"Loss" in error; time not right.
Shepard Creek, mouth of canyon to point of branching.	Nov. 11, 1908	10.30 a. m.	36	7.23	1.40 p. m.	....	5.04	2.19	.46	Ice melting; results in error.
	Apr. 2, 1909	9.45 a. m.	41	6.59	1.15 p. m.	57	5.89	.70	.14	
	May 11, 1909	1.20 p. m.	44	28.40	3.45 p. m.	48	26.80	1.60	.34	
Shepard Creek, North Branch, point of branching to U. S. Geol. Survey station.	Nov. 11, 1908	1.40 p. m.	....	2.15	10.00 a. m.	....	.56	1.59	1.06	Do.
	Apr. 2, 1909	1.30 p. m.	57.5	4.94	3.15 p. m.	65	2.18	2.76	1.84	
	May 11, 1909	4.30 p. m.	48	21.20	....	....	9.61	11.59	7.70	
Shepard Creek, South Branch, point of branching to U. S. Geol. Survey station.	Nov. 11, 1908	1.40 p. m.	....	5.04	10.00 a. m.	....	1.94	3.10	2.48	Ice melting; results in error.
	Apr. 2, 1909	1.30 p. m.	57.5	.95	2.30 p. m.	66	.49	.46	.37	
	May 11, 1909	4.30 p. m.	48	5.63	....	....	7.18	−1.55	....	
	June 15, 1909	2.00 p. m.	60	11.90	3.00 p. m.	63	9.70	2.20	1.76	
Shepard Creek, combined channel, mouth of canyon to U. S. Geol. Survey station.	July 1, 1908	11.00 a. m.	....	25.30	10.00 a. m.	....	15.30	10.00	1.33	Lower measurements in four channels.
	Sept. 22, 1908	10.30 a. m.	....	19.50	1.30 p. m.		9.70	9.80	1.31	Lower measurements in two channels.
	Nov. 11, 1908	10.30 a. m.	36	7.23	10.00 a. m.	....	2.50	4.73	.63	
	Feb. 4, 1909	10.45 a. m.	35	5.18	3.00 p. m.	44	3.35	1.83	.24	
	Apr. 2, 1909	9.45 a. m.	41	6.59	3.00 p. m.	66	2.67	3.92	.52	
	May 11, 1909	1.20 p. m.	44	28.40	....	....	15.50	12.90	1.72	
	June 15, 1909	10.15 a. m.	50	62.10	3.30 p. m.	64	49.70	12.40	1.65	
	July 29, 1909	10.30 a. m.	50	39.30	3.00 p. m.	65	24.60	14.70	1.96	
Bairs Creek, North Fork, mouth of canyon to junction with South Fork.	Sept. 21, 1908	2.30 p. m.	....	2.41	4.00 p. m.	....	1.92	.49	.19	
	Nov. 12, 1908	2.15 p. m.	37	1.70	3.50 p. m.	43	1.25	.45	.17	
	Feb. 2, 1909	2.20 p. m.	35	1.67	4.00 p. m.	41	.91	.76	.29	
	Apr. 3, 1909	1.45 p. m.	40	3.57	3.30 p. m.	52	1.53	2.04	.78	
	May 10, 1909	12.30 p. m.	47	10.49	2.15 p. m.	52	7.82	2.67	1.03	
	June 14, 1909	2.15 p. m.	49	23.20	4.30 p. m.	53	19.00	4.20	1.61	
	July 28, 1909	3.00 p. m.	52	7.20	4.15 p. m.	57	6.10	1.10	.42	
	Sept. 9, 1909	10.20 a. m.	51	4.94	11.45 a. m.	57	2.36	2.58	.99	
Bairs Creek, South Fork, mouth of canyon to junction with North Fork.	Sept. 21, 1908	1.15 p. m.	....	1.42	3.45 p. m.	....	.42	1.00	.33	
	Nov. 12, 1908	1.10 p. m.	38	.99	3.45 p. m.	48	.58	.41	.14	
	Feb. 2, 1909	1.05 p. m.	34	1.75	3.45 p. m.	43	.12	1.63	.54	
	Apr. 3, 1909	12.30 p. m.	45	2.28	3.10 p. m.	61	.95	1.33	.44	
	May 10, 1909	11.00 a. m.	43	10.39	2.30 p. m.	54	10.33	.0	.0	Possible error in measurement.
	June 14, 1909	1.00 p. m.	48	17.40	4.00 p. m.	54	15.90	1.50	.50	
	July 28, 1909	2.00 p. m.	53	4.80	4.00 p. m.	63	3.40	1.40	.47	
	Sept. 9, 1909	9.40 a. m.	53	1.54	11.30 a. m.	65	.53	1.01	.34	
Bairs Creek, main channel, junction of forks to U. S. Geol. Survey station.	Sept. 21, 1908	4.00 p. m.	....	2.34	4.30 p. m.	....	1.68	.66	.35	
	Nov. 12, 1908	3.45 p. m.	46	1.83	4.20 p. m.	....	1.75	.08	.0	
	Feb. 2, 1909	4.00 p. m.	42	1.03	3.30 p. m.	43	.41	.62	.33	
	Apr. 3, 1909	3.20 p. m.	56	2.48	4.10 p. m.	59	2.17	.31	.16	
	May 10, 1909	2.30 p. m.	53	18.15	3.15 p. m.	56	14.08	4.07	2.14	
	June 14, 1909	4.15 p. m.	54	34.90	3.50 p. m.	57	30.40	4.50	2.37	
	July 28, 1909	4.00 p. m.	60	9.50	5.00 p. m.	62	8.10	1.40	.74	
	Sept. 9, 1909	11.30 a. m.	61	2.89	12.45 p. m.	67	3.22	−.33	....	
Bairs Creek, combined channel, mouth of canyon to U. S. Geol. Survey station.	July 1, 1908	2.00 p. m.	....	9.79	12.30 p. m.	....	4.62	5.17	.69	

TABLE 24.—*Discharge measurements on which studies of stream percolation are based*—Continued.

Stream and gaging stations.	Date of measurement.	Discharge at—						Loss.		Remarks.
		Upper station.			Lower station.					
		Time.	Temperature of water (°F.).	Discharge (second-feet).	Time.	Temperature of water (°F.).	Discharge (second-feet).	Total (second-feet).	Second-feet per mile.	
George Creek, mouth of canyon to U. S. Geol. Survey station.	Oct. 30, 1906	....	....	4.80	....	....	3.10	1.70	0.31	
	July 1, 1908	5.00 p. m.	....	27.90	2.15 p. m.	....	17.40	10.50	1.91	
	Sept. 12, 1908	11.20 a. m.	....	9.10	2.30 p. m.	....	6.70	2.40	.44	
	Nov. 12, 1908	11.00 a. m.	37	4.85	3.10 p. m.	....	3.00	1.85	.34	
	Feb. 2, 1909	11.15 a. m.	37	4.34	3.00 p. m.	....	2.03	2.31	.42	
	Apr. 3, 1909	10.15 a. m.	42	7.64	3.00 p. m.	65	5.01	2.63	.48	
	May 10, 1909	9.30 a. m.	42	32.30	2.30 p. m.	50	22.00	10.30	1.87	
	June 14, 1909	11.15 a. m.	46	61.00	2.45 p. m.	53	53.00	8.00	1.45	Upper measurements poor; very high velocity.
	July 28, 1909	11.30 a. m.	49	28.90	3.00 p. m.	57	18.70	10.20	1.86	
	Sept. 7, 1909	10.30 a. m.	49	16.30	1.30 p. m.	58	11.20	5.10	.93	

TABLE 25.—*Seasonal discharge of Kings River at Red Mountain for 21 years.*

[Drainage area, 1,742 square miles.]

Season (Sept. 1 to Aug. 31).	Discharge in second-feet.						Run-off.		Variation from mean (per cent).
	Maximum.	Minimum.	Highest monthly mean.	Lowest monthly mean.	Mean.	Mean per square mile.	Depth in inches.	Acre-feet.	
1878–79	....	....	5,090	290	1,620	0.93	12.62	1,172,600	−39
1879–80	....	....	9,540	270	2,760	1.58	21.44	2,001,100	+ 4
1880–81	....	....	8,220	220	2,580	1.48	20.09	1,868,400	− 3
1881–82	....	....	9,190	230	2,050	1.18	16.01	1,487,400	−22
1882–83	....	....	6,730	320	1,770	1.02	13.84	1,283,900	−33
1883–84	....	....	17,600	220	4,590	2.63	35.69	3,330,100	+73
1895–96	22,100	250	12,700	328	2,580	1.48	20.09	1,870,700	− 3
1896–97	22,700	310	14,500	350	2,890	1.66	22.53	2,097,900	+ 9
1897–98	8,350	215	3,550	320	1,230	.70	9.50	888,100	−54
1898–99	20,200	145	6,080	204	1,700	.98	13.30	1,227,800	−36
1899–1900	12,700	180	5,880	215	1,760	1.01	13.71	1,280,200	−34
1900–1901	43,900	215	14,400	301	4,310	2.48	33.66	3,128,600	+63
1901–2	26,400	320	8,060	440	2,160	1.24	16.83	1,566,700	−18
1902–3	17,300	215	9,550	265	2,340	1.34	18.19	1,692,500	−12
1903–4	15,700	130	10,400	183	2,360	1.35	18.32	1,714,800	−11
1904–5	9,800	280	6,450	354	2,010	1.15	15.61	1,457,800	−24
1905–6	26,600	150	17,100	174	5,220	3.00	40.72	3,801,900	+98
1906–7	15,600	330	10,400	397	3,840	2.20	29.86	2,786,100	+45
1907–8	6,900	265	3,580	363	1,420	.82	11.13	1,034,200	−46
1908–9	32,800	265	14,100	312	3,860	2.21	29.99	2,789,400	+45
1909–10	41,800	280	7,810	401	2,485	1.43	19.41	1,803,800	− 6
Mean	21,523	237	9,568	293	2,645	1.52	20.60	1,918,300	....

TABLE 26.—*Seasonal discharge of five Sierra Nevada rivers.*

Season (Sept. 1 to Aug. 31).	Tuolumne River.[a]			Merced River.[b]			Kaweah River.[c]		
	Discharge.		Per cent of 20-year mean.	Discharge.		Per cent of 20-year mean.	Discharge.		Per cent of 20-year mean.
	Second-feet.	Second-feet per square mile.		Second-feet.	Second-feet per square mile.		Second-feet.	Second-feet per square mile.	
1878–79	2,004	1.18	66	....	....	....	299	0.43	36
1879–80	3,615	2.14	120	1,718	1.58	108	954	1.38	117
1880–81	2,915	1.73	97	1,800	1.65	112	555	.80	68
1881–82	2,233	1.32	74	1,132	1.04	71	578	.83	70
1882–83	2,050	1.21	68	1,381	1.27	86	384	.55	47
1883–84	3,313	1.96	110	2,488	2.28	155	1,513	2.18	185
1895–96	2,209	1.42	80	....	....	....	....	....	....
1896–97	3,439	2.21	124	....	....	....	....	....	....
1897–98	1,357	.87	49	....	....	....	....	....	....
1898–99	1,924	1.24	70	....	....	....	....	....	....
1899–1900	2,319	1.49	84	....	....	....	....	....	....
1900–1901	3,782	2.43	137	....	....	....	....	....	....
1901–2	2,229	1.43	80	1,154	1.06	72	....	....	....
1902–3	2,726	1.75	98	1,342	1.23	84	....	....	....
1903–4	3,631	2.33	131	1,507	1.38	94	503	.97	82
1904–5	2,424	1.56	88	1,267	1.16	79	478	.92	78
1905–6	4,821	3.10	174	2,791	2.56	174	1,482	2.85	242
1906–7	5,180	3.32	187	2,941	2.70	184	831	1.60	136
1907–8	1,511	.97	54	725	.65	44	349	.67	57
1908–9	3,168	2.04	115	2,053	1.88	128	1,108	2.13	180
Observed mean	2,842	1.78	....	1,715	1.57	....	753	1.28	....
Computed 20-year mean	2,842	1.78	....	1,600	1.47	....	700	1.18	....

[a] Drainage area above gaging station—1,691 square miles, California Eng. Dept.; 1,557 square miles, U. S. Geol. Survey.

[b] Drainage area above gaging station—1,090 square miles.

[c] Drainage area above gaging station—694 square miles, California Eng. Dept.; 520 square miles, U. S. Geol. Survey.

TABLE 26.—*Seasonal discharge of five Sierra Nevada rivers*—Continued.

Season (Sept. 1 to Aug. 31).	Tule River.[a]			Kern River.[b]		
	Discharge.		Per cent of 20-year mean.	Discharge.		Per cent of 20-year mean.
	Second-feet.	Second-feet per square. mile.		Second-feet.	Second feet per square mile.	
1878–79	107	0.24	27	582	0.25	54
1879–80	558	1.28	145	1,073	.46	100
1880–81	339	.78	89	1,339	.57	124
1881–82	368	.84	95	660	.28	61
1882–83	308	.70	80	642	.27	59
1883–84	1,096	2.51	285	2,352	1.00	217
1893–94				834	.36	78
1894–95				1,399	.60	130
1895–96				864	.37	80
1896–97				1,221	.52	113
1897–98				413	.18	39
1898–99				458	.20	44
1899–1900				435	.19	41
1900–1901				1,188	.51	111
1901–2	156	.59	67	798	.34	74
1902–3	154	.58	66	770	.33	72
1903–4	96	.36	41	640	.27	59
1904–5	101	.38	43	761	.32	70
1905–6	458	1.72	195	2,464	1.05	228
1906–7	215	.81	92	(1,550)	(.66)	143
1907–8	114	.43	49			
1908–9	395	1.49	169	2,382	1.02	222
Observed mean	319	.91		1,087	.46	
Computed 20-year mean	306	.88		1,087	.46	

[a] Drainage area above gaging station—437 square miles, California Eng. Dept.; 266 square miles, U. S. Geol. Survey.
[b] Drainage area above drainage station—2,345 square miles.

TABLE 27.—*Computation of run-off factor for drainage areas of Sierra Nevada streams.*

[Based on isohyets of Plate VII, p. 28.]

Season (Sept. 1 to Aug. 31).	Kings River.					Merced River.					Tuolumne River.				
	Average precipitation (from isohyets).	Season's precipitation.		Measured stream flow.		Average precipitation (from isohyets).	Season's precipitation.		Measured stream flow.		Average precipitation (from isohyets).	Season's precipitation.		Measured stream flow.	
		Per cent of mean.	Inches.	Inches.	Per cent of precipitation.		Per cent of mean.	Inches.	Inches.	Per cent of precipitation.		Per cent of mean.	Inches.	Inches.	Per cent of precipitation.
1878–79	33.5	54	18.1	12.6	70	41.6					42.5	75	31.9	16.0	50
1879–80	33.5	110	36.9	21.4	58	41.6	110	45.8	21.4	47		120	51.0	29.0	57
1880–81	33.5	107	35.9	20.1	56	41.6	107	44.5	22.4	50		86	36.6	23.5	64
1881–82	33.5	74	24.8	16.0	65	41.6	80	33.3	14.1	42		75	31.9	17.9	56
1882–83	33.5	96	32.2	13.8	43	41.6	91	37.9	17.2	45		86	36.6	16.4	45
1883–84	33.5	200	67.0	35.7	53	41.6	205	85.3	30.9	36		138	58.6	26.6	45
1895–96	33.5	91	30.5	20.1	66						45.3	92	41.7	19.3	46
1896–97	33.5	108	36.2	22.5	62						45.3	113	51.2	30.0	59
1897–98	33.5	55	18.4	9.5	52						45.3	55	24.9	11.8	47
1898–99	33.5	82	27.5	13.3	48						45.3	85	38.5	16.8	44
1899–1900	33.5	104	34.8	13.7	39						45.3	100	45.3	20.2	45
1900–1901	33.5	128	42.9	33.7	79						45.3	142	64.3	33.0	51
1901–2	33.5	79	26.5	16.8	63	41.6	92	38.3	14.4	38	45.3	89	40.3	19.4	48
1902–3	33.5	89	29.8	18.2	61	41.6	104	43.3	16.7	39	45.3	107	48.5	23.8	49
1903–4	33.5	84	28.1	18.3	65	41.6	96	39.9	18.7	47	45.3	98	44.4	31.6	71
1904–5	33.5	124	41.5	15.6	38	41.6	101	42.0	15.7	37	45.3	113	51.2	21.2	41
1905–6	33.5	160	53.6	40.7	76	41.6	163	67.8	34.7	51	45.3	144	65.2	42.1	65
1906–7	33.5	137	45.9	29.9	65	41.6	140	58.2	36.6	63	45.3	152	68.9	45.1	65
1907–8	33.5	83	27.8	11.1	40	41.6	69	28.7	8.8	31	45.3	77	34.9	13.2	38
1908–9	33.5	123	41.2	30.0	73	41.6	126	52.4	25.5	49	45.3	110	49.8	27.7	56
1909–10	33.5	94	31.5	19.4	62	41.6	100	41.6	18.2	44	45.3	98	44.4		
Mean		104	34.8	20.6	59		113	47.1	21.1	44		103	45.7	24.2	52

TABLE 27.—*Computation of run-off factor for drainage areas of Sierra Nevada streams*—Continued.

Season (Sept. 1 to Aug. 31).	Kaweah River.					Tule River.					Kern River.				
	Average precipitation (from isohyets).	Season's precipitation.		Measured stream flow.		Average precipitation (from isohyets).	Season's precipitation.		Measured stream flow.		Average precipitation (from isohyets).	Season's precipitation.		Measured stream flow.	
		Per cent of mean.	Inches.	Inches.	Per cent of precipitation.		Per cent of mean.	Inches.	Inches.	Per cent of precipitation.		Per cent of mean.	Inches.	Inches.	Per cent of precipitation.
1878–79	25.6	(54)	13.8	5.8	42	...	...	...	...	...	18.8	(54)	10.2	3.4	33
1879–80	25.6	(110)	28.2	18.7	66	...	...	...	...	...	18.8	(110)	20.7	6.2	30
1880–81	25.6	(107)	27.4	10.9	40	...	...	...	...	...	18.8	(107)	20.1	7.7	38
1881–82	25.6	68	17.4	11.3	65	...	...	...	...	...	18.8	(80)	15.0	3.8	25
1882–83	25.6	101	25.9	7.5	29	...	...	...	...	...	18.8	(91)	17.1	3.7	22
1883–84	25.6	193	49.4	29.6	60	...	...	...	...	...	18.8	(205)	38.5	13.6	35
1893–94	...	...	...	...	...	...	...	...	...	...	18.8	52	9.8	4.9	50
1894–95	...	...	...	...	...	...	...	...	...	...	18.8	120	22.6	8.1	36
1895–96	...	...	...	...	...	...	...	...	...	...	18.8	88	16.5	5.0	30
1896–97	...	...	...	...	...	...	...	...	...	...	18.8	106	19.9	7.1	36
1897–98	...	...	...	...	...	...	...	...	...	...	18.8	75	14.1	2.4	17
1898–99	...	...	...	...	...	...	...	...	...	...	18.8	57	10.7	2.7	25
1899–1900	...	...	...	...	...	...	...	...	...	...	18.8	75	14.1	2.6	18
1900–1901	...	...	...	...	...	...	...	...	...	...	18.8	121	22.7	6.9	30
1901–2	...	...	...	...	...	23.2	82	19.0	8.0	42	18.8	92	17.3	4.6	27
1902–3	...	...	...	...	...	23.2	80	18.6	7.9	42	18.8	76	14.3	4.5	31
1903–4	26.5	71	18.8	13.2	70	23.2	70	16.2	4.9	30	18.8	70	13.2	3.7	28
1904–5	26.5	121	32.1	12.5	39	23.2	119	27.6	5.2	19	18.8	122	22.9	4.3	19
1905–6	26.5	156	41.3	38.7	94	23.2	172	39.9	23.3	58	18.8	159	29.9	14.2	48
1906–7	26.5	121	32.1	21.7	68	23.2	126	29.2	11.0	38	18.8	101	19.0	9.0	47
1907–8	26.5	91	24.1	9.1	38	23.2	102	23.7	5.8	24	18.8	82	15.4	...	...
1908–9	26.5	119	31.5	28.9	92	23.2	150	34.8	20.2	58	18.8	174	32.7	13.8	42
1909–10	26.5	95	25.2	...	...	23.2	96	22.2	...	...	18.8	100	18.8	...	...
Mean	...	108	29.0	17.3	59	...	111	25.7	10.8	39	...	101	18.9	6.3	32

TABLE 28.—*Monthly mean discharge, in second-feet, at United States Geological Survey stations, of creeks near Independence for season 1904–5.*

[Estimates and compilations by C. H. Lee, from published data in water-supply papers.]

Creek.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Mean.
Taboose	4	6	4	3	2.5	3	3	2	6	16	12	7	5.7
Goodale	3	5	3	2.5	2	2.5	2.5	2	5	9	6	4.5	3.9
Division [a]	4	5	4	3.5	3	4	4	3	4	5	4	3	3.9
Oak	10	14	11	10	8	9	9	7	15	30	20	13	13.0
Little Pine	4.5	7	5	4	3.5	4	4	3	15	44	23.5	[b] 10.9	10.7
Lone Pine	6	8	6	4	3	4	4	2.5	12	33	25	11	9.9

[a] United States Geological Survey station at upper road. Length of seepage channel, 4 miles.
[b] United States Geological Survey measurement.

TABLE 29.—*Monthly mean discharge, in second-feet, at United States Geological Survey stations, of creeks near Independence for season 1905–6.*

[Compiled from published data in water-supply papers.]

Creek.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Mean.
Taboose	[a] 4.5	[a] 4.5	[a] 3.8	[a] 4.5	3.7	2.9	3.3	5.8	10.4	21.8	46	26	11.4
Goodale	[a] 3	[a] 3	[a] 2.5	[a] 3	[b] 2.5	[b] 2.5	[b] 2.5	3.5	6.3	11.2	19.0	6.4	5.4
Division [c]	[a] 3	[a] 3	[a] 4	[a] 5	6.7	5.1	6.1	6.0	7.3	8.4	17.2	14.3	7.2
Sawmill	[a] 3	[a] 3	[a] 2.5	[a] 3	[b] 3	2.7	3.7	3.4	4.3	7.6	16.3	12.6	5.4
Oak	[a] 10	[a] 9	[a] 11	[a] 8	[b] 6	7.3	7.8	11.9	28	70	140	74	31.8
Little Pine	4.6	3.2	3.6	3.6	4.0	2.8	4.8	8.0	29.6	96	127	54	28.5
Shepard	[a] 2	[a] 1	[a] 2	[a] 2	[b] 2	[b] 2	[b] 2	9.0	26	62	104	63	23.1
Bairs	[a] 0.5	[a] 0.5	[a] 0.5	[a] 1	[b] 1	[b] 1	[b] 1	3.2	12.5	31	30	13	8.0
George	[a] 2	[a] 1	[a] 1	[a] 1	[b] 1	[b] 1	[b] 2	10.3	21.1	53	87	42	18.6
Lone Pine	[a] 4	[a] 3.5	[a] 4	[a] 4	[b] 3	2.9	3.8	7.2	28	74	129	68	27.6

[a] Estimated by C. H. Lee.
[b] Estimated by United States Geological Survey.
[c] Station at upper road.

TABLE 30.—*Monthly mean discharge, in second-feet, at United States Geological Survey stations, of creeks near Independence for season 1906–7.*

[Compiled from published data in water-supply papers.]

Creek.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Mean.
Tinemaha	[a] 12.0	[a] 6.8	[a] 6.2	[a] 5.9	4.9	4.4	4.0	5.3	11.0	18.0	39.0	20.0	11.4
Taboose	15.0	3.7	3.6	3.5	2.3	2.3	7.3	12.0	23.0	21.0	18.0	12.0	10.8
Goodale	5.9	5.6	5.3	4.3	3.9	3.6	3.3	5.1	7.0	10.2	15.1	10.3	6.6
Division [b]	10.9	12.6	11.5	10.1	10.6	10.8	11.2	10.1	9.7	11.1	12.4	10.1	10.9
Sawmill	9.8	6.7	[c] 5.0	[c] 5.0	[c] 5.2	[c] 5.4	[c] 5.0	[c] 5.0	[c] 8.0	[c] 17.0	[c] 12.0	[c] 7.0	7.6
Oak	32	20.5	11.8	11.3	10.8	10.4	12.2	18.8	27	42	57	33	23.9
Little Pine	22.9	12.4	6.1	5.2	5.5	3.5	4.9	14.9	26	62	70	36	22.5
Symmes	[c] 1.0	[c] 0	[c] 0	[c] 0	[c] 0	[c] 0	[c] 0	[c] 0.6	[c] 6.8	[c] 14.5	[c] 12.0	[c] 2.0	3.1
Shepard	12.0	2.6	[c] 0.5	[c] 3.0	2.0	2.4	3.4	8.1	14.0	26	37	21.0	11.0
Bairs	4.3	2.0	[c] 1.0	[c] 0.5	[c] 1.0	[c] 1.0	3.0	7.0	9.6	12.2	11.7	4.4	4.8
George	21.0	7.7	2.6	[c] 1.7	2.0	2.5	5.0	11.0	17.0	19.0	28.0	13.0	10.9
Lone Pine	27	14.0	8.0	8.0	8.2	6.5	8.8	19.5	[c] 30.0	45	62	40	23.1

[a] Estimated by C. H. Lee.
[b] Station at upper road, except from August 18 to September 18, when it was at Rickey ranch
[c] Estimated by United States Geological Survey.

TABLE 31.—*Monthly mean discharge, in second-feet, at United States Geological Survey stations, of creeks near Independence for season 1907–8.*

[Compiled from published data in water-supply papers.]

Creek.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Mean.
Tinemaha	6.1	5.4	5.5	5.7	6.0	5.8	4.4	4.3	4.4	8.5	32	21.0	9.1
Taboose	5.0	4.2	3.6	3.2	3.0	2.3	2.3	3.1	4.9	6.0	10.9	8.2	4.7
Goodale	3.9	2.8	2.8	2.8	3.0	2.6	2.6	2.7	4.4	5.8	7.3	5.0	3.8
Division [a]	9.9	10.0	9.0	7.7	[b] 7.0	6.7	5.9	5.8	7.0	7.2	7.2	7.7	7.6
Sawmill	[c] 6.5	[c] 6.5	[c] 6.0	[c] 5.5	[c] 4.0	[c] 4.0	[c] 4.0	[c] 4.5	[c] 4.0	[c] 3.5	[c] 5.5	[c] 5.5	5.0
Thibaut, S. Fork	1.0	1.0	1.0	0.9	[c] 1.0	[c] 1.0	[c] 1.0	[c] 1.0	[c] 0.5	[c] 0.6	[c] 0.6	[c] 0.5	0.8
Oak	20.4	14.5	13.0	13.0	[b] 10.0	9.2	9.3	12.3	15.8	21.0	29	22.5	15.8
Little Pine	16.7	6.6	7.6	6.9	4.3	2.4	3.4	7.4	15.7	21.5	29	19.9	11.8
Symmes	0.5	0	0	0	[c] 0	[c] 0	[c] 0	[c] 0	[c] 2.0	[c] 2.5	[c] 3.0	[c] 1.5	0.8
Shepard	4.7	5.1	4.7	2.9	[c] 1.3	[c] 1.3	1.3	2.6	6.2	13.4	22.0	21.0	7.2
Bairs	1.1	1.7	2.1	1.5	[c] 1.0	[c] 0	[c] 0	1.2	3.0	4.0	4.5	4.0	2.0
George	4.0	5.2	3.8	2.3	2.7	1.9	2.2	5.3	8.0	11.0	18.0	14.0	6.5
Lone Pine	11.5	19.6	16.2	8.5	[c] 8.0	7.7	8.2	11.3	17.4	32	44	58	20.2

[a] Station moved from upper road to intake of power plant No. 1, May 1. Length of seepage channel to old station, 4 miles.
[b] Estimated by United States Geological Survey.
[c] Estimated by C. H. Lee.

TABLE 32.—*Monthly mean discharge, in second-feet, at United States Geological Survey stations, of creeks near Independence for season 1908–9.*

[Compiled from published data in water-supply papers.]

Creek.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Mean.
Tinemaha	9.8	5.5	5.0	5.3	4.7	9.5	6.0	3.0	9.8	45.9	45.7	24.2	14.5
Taboose	6.4	4.5	4.0	5.5	4.3	4.0	2.7	4.9	8.7	25.7	22.6	10.2	8.6
Goodale	4.1	3.3	3.0	3.0	2.3	2.4	2.4	3.8	8.6	18.7	16.5	8.8	6.4
Division [a]	7.7	7.5	7.7	7.6	7.2	6.9	7.3	7.9	8.0	16.7	16.4	15.6	9.7
Sawmill	[b] 3.5	[b] 3.0	[b] 4.5	[b] 4.0	4.1	5.0	4.9	6.6	7.3	14.1	17.8	13.1	7.3
Thibaut, South Fork	[b] .4	[b] .2	[b] 0	[b] 0	0	0	0	1.8	2.6	2.8	2.0	1.0	.9
Oak	15.5	13.0	11.6	10.5	11.4	10.8	11.1	15.9	36.3	100.0	98.0	35.7	30.8
Little Pine	8.3	9.0	6.6	6.3	6.3	5.5	5.4	9.9	41.1	94.2	82.2	34.5	25.8
Pinyon [c]	1.8	2.0	2.0	1.5	1.9	1.7	1.7	4.0	8.0	5.0	9.5	2.4	3.5
Symmes	[b] 0	[b] 0	[b] 0	[b] 0	0	0	0	3.0	21.0	31.0	15.4	5.2	6.3
Shepard	9.6	5.7	2.6	[d] 2.0	4.7	3.0	2.5	8.8	14.8	37.9	42.4	20.6	12.9
Bairs	1.6	[d] 1.4	[d] 1.2	[d] 1.0	1.0	.5	1.5	7.7	13.0	24.0	15.2	5.0	6.1
George	8.1	6.0	3.2	3.0	2.8	2.3	3.2	11.4	19.4	43.7	38.4	14.7	13.0
Lone Pine	24.0	11.3	7.6	6.3	7.2	8.4	6.4	11.9	31.5	102.0	81.1	41.4	28.3

[a] United States Geological Survey station at intake of power plant No. 1.
[b] Estimated by C. H. Lee.
[c] Measured at junction of Pinyon ditch and Little Pine Creek by city of Los Angeles.
[d] Estimated by U. S. Geological Survey.

TABLE 33.—*Monthly mean discharge, in second-feet, at United States Geological Survey stations, of creeks near Independence for season 1909–10.*

[Compiled from published data in water-supply papers.]

Creek.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Mean.
Tinemaha	12.9	8.5	6.9	10.0	9.6	8.2	7.0	6.8	15.3	26.3	24.4	17.7	12.8
Taboose	5.7	4.0	3.6	5.7	4.9	3.1	3.5	3.9	7.2	12.1	10.6	7.0	5.9
Goodale	5.6	4.1	4.0	4.9	3.7	3.1	3.8	4.4	7.3	10.0	8.0	4.7	5.3
Division [a]	14.8	13.4	12.2	11.2	10.0	9.0	8.0	8.5	8.5	8.5	7.0	7.3	9.9
Sawmill	10.6	9.0	8.7	8.0	8.0	6.5	6.5	5.0	6.0	7.0	6.0	4.5	7.2
Thibaut	[b] .5	0	0	0	0	0	0	[b] .6	[b] .8	[b] .6	.3	.15	.25
Oak	19.6	15.0	15.6	14.0	12.0	11.0	11.6	15.4	27.8	34.1	30.4	14.4	18.4
Little Pine	16.1	7.2	9.5	10.2	8.4	7.0	6.1	13.6	32.5	45.7	35.5	14.2	17.2
Pinyon [c]	1.5	2.0	[b] 1.5	[b] 1.0	1.0	[b] 1.0	[b] 2.0	[b] 2.0	3.5	[b] 4.0	[b] 2.5	[b] 1.5	2.0
Symmes	[b] 2.0	0	0	0	0	0	0	.1	3.0	5.0	2.5	.8	1.1
Shepard	11.0	4.7	3.0	3.0	2.0	1.5	2.0	4.0	11.6	17.0	22.0	11.0	7.7
Bairs	3.9	1.2	1.0	1.0	.5	.15	.2	.9	8.7	6.3	3.9	1.4	2.4
George	8.7	3.5	2.0	1.9	1.5	1.2	3.0	5.8	16.3	17.2	13.6	6.4	6.8
Lone Pine	19.6	8.6	7.8	7.9	6.2	8.3	6.1	10.4	24.5	32.5	34.8	21.4	15.7

[a] United States Geological Survey station at intake of power plant No. 1.
[b] Estimated by C. H. Lee.
[c] Measured at junction of Pinyon ditch and Little Pine Creek.

Table 34.—*Monthly mean discharge, in second-feet, at mouth of canyon, of creeks near Independence for season 1904–5.*

[Obtained from discharges at United States Geological Survey stations by use of percolation-loss diagrams.]

Creek.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Mean.
Taboose	8.6	13.0	8.6	6.5	5.6	6.5	6.5	4.6	13.0	31.0	24.0	15.0	11.9
Goodale	5.8	9.5	5.8	5.0	3.8	5.0	5.0	3.8	9.5	17.0	12.0	8.5	7.6
Division [a]	7.6	9.5	5.9	4.8	3.6	4.6	4.8	5.9	7.6	9.5	7.6	5.9	6.4
Oak	12.0	18.0	13.0	12.0	9.2	10.0	10.0	8.0	20.0	43.0	28.0	17.0	16.7
Little Pine [b]	5.0	8.5	5.5	4.0	3.5	4.0	4.0	3.5	18.0	54.0	29.0	13.0	12.7
Lone Pine	6.0	8.0	6.0	4.0	3.0	4.0	4.0	2.5	12.0	33.0	25.0	11.0	9.9

[a] Includes flow from springs No. 1 and No. 2, 2 second-feet.
[b] Includes discharge of Pinyon ditch, 2 second-feet at junction.

Table 35.—*Monthly mean discharge, in second-feet, at mouth of canyon, of creeks near Independence for season 1905–6.*

[Obtained from discharges at United States Geological Survey stations by use of percolation-loss diagrams.]

Creek.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Mean.
Taboose	9.5	9.5	8.5	9.5	8.0	6.4	7.2	12.0	21	37	61	41	19.2
Goodale	5.8	5.8	5.0	5.8	5.0	5.9	5.0	6.8	12	22	29	12	9.9
Division [a]	4.0	4.0	5.8	6.0	7.0	5.8	7.3	7.2	10	12	24	20	9.4
Sawmill	...	...	...	...	...	...	...	...	...	...	...	...	6.5
Oak	12.0	11.0	13.0	9.2	6.0	8.0	8.5	14.0	40	106	180	112	43.3
Little Pine [b]	5.0	3.4	3.6	3.6	4.0	2.8	4.8	9.5	36	108	[c] 109	[c] 48	28.1
Shepard	6.0	4.5	4.5	4.5	4.5	4.5	4.5	17.0	44	80	122	81	31.4
Bairs	2.8	2.8	1.5	2.0	2.0	2.0	2.0	6.3	18	42	41	19	11.8
George	3.0	2.0	1.0	1.0	1.0	1.0	3.0	16.0	32	68	102	57	23.9
Lone Pine	4.0	3.5	4.0	4.0	3.0	2.9	3.8	7.2	28	74	129	68	27.6

[a] Includes flow from springs No. 1 and No. 2, 2.5 second-feet.
[b] Includes discharge of Pinyon ditch, 3.5 second-feet at junction.
[c] Seepage gain curve used.

Table 36.—*Monthly mean discharge, in second-feet, at mouth of canyon, of creeks near Independence for season 1906–7.*

[Obtained from discharges at United States Geological Survey stations by use of percolation-loss diagrams.]

Creek.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Mean.
Tinemaha [a]	11.0	5.8	5.2	4.9	3.9	3.4	3.0	4.3	8	15	39	20.0	10.3
Taboose	30.0	7.8	7.6	7.5	5.5	5.5	15.0	25.0	38	36	33	25.0	20.5
Goodale	11.0	10.0	10.0	8.5	7.3	7.0	6.3	9.8	13	20	25	20.0	12.3
Division [b]	21.0	15.0	13.0	11.0	11.0	11.0	12.0	11.0	13	15	17	14.0	13.7
Sawmill	...	...	...	...	...	...	...	...	...	...	...	...	9.1
Oak	47.0	28.0	15.0	14.0	13.0	12.0	15.0	26.0	39	63	86	48.0	33.8
Little Pine [c]	28.0	15.0	7.0	5.9	6.1	3.5	5.1	18.0	32	74	[d] 62	[d] 32.0	24.0
Symmes	5.2	4.0	2.0	2.0	2.0	2.0	2.5	4.5	12	22	19	6.6	7.0
Shepard	22.0	7.1	3.0	5.5	4.5	4.9	5.9	16.0	24	43	55	36.0	18.9
Bairs	7.8	4.8	2.0	1.5	2.0	2.0	4.0	11.0	14	18	17	8.0	7.7
George	32.0	12.0	4.0	2.0	3.5	3.9	7.7	16.0	26	29	42	20.0	16.5
Lone Pine	27.0	14.0	8.0	8.0	8.2	6.5	8.8	19.5	30	45	62	40.0	23.1

[a] United States Geological Survey discharges are corrected for combined seepage loss from channel and gain from irrigation waste and springs.
[b] Includes flow from springs No. 1 and No. 2, 2.5 second-feet.
[c] Includes discharge of Pinyon ditch, 3.5 second feet at junction.
[d] Seepage gain curve used.

TABLE 37.—*Monthly mean discharge, in second-feet, at mouth of canyon, of creeks near Independence for season 1907–8.*

[Obtained from discharges at United States Geological Survey stations by use of percolation-loss diagrams.]

Creek.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Mean.
Tinemaha [a]	5.1	4.4	4.5	4.7	5.0	4.8	3.4	3.3	3.4	6.5	32.0	21.0	8.2
Taboose	10.0	8.9	7.6	6.9	6.5	5.2	5.2	6.7	10.0	12.0	22.0	17.0	9.8
Goodale	7.4	5.2	5.2	5.2	5.8	5.0	5.0	5.1	8.4	11.0	14.1	9.5	7.2
Division [b]	12.3	12.5	10.8	8.8	7.6	7.0	7.3	7.2	8.8	9.0	9.9	11.2	9.4
Sawmill [c]	8.5	8.0	7.0	6.0	4.0	4.0	4.0	4.5	4.5	4.0	6.0	6.0	5.5
Oak	28.0	19.0	17.0	17.0	12.0	11.0	11.0	16.0	21.0	29.0	42.0	32.0	21.2
Little Pine [d]	20.0	8.0	9.0	8.0	4.3	2.4	3.4	9.0	19.0	26.0	35.0	24.0	14.0
Symmes	4.8	2.0	2.0	2.0	1.5	1.0	1.5	2.0	6.7	7.2	7.7	5.8	3.7
Shepard	10.0	11.0	7.5	5.4	3.8	3.8	3.8	7.0	13.0	24.0	37.0	36.0	13.5
Bairs	3.5	4.5	3.1	2.5	2.0	1.0	1.0	3.5	6.0	7.5	8.0	7.5	4.2
George	6.0	8.0	6.0	3.5	4.2	2.5	3.5	8.0	12.0	16.0	27.0	21.0	9.8
Lone Pine	11.5	19.6	16.2	8.5	8.0	7.7	8.2	11.3	17.4	32.0	44.0	58.0	20.2

[a] United States Geological Survey discharges are corrected for combined seepage loss from channel, and gain from irrigation waste and springs.
[b] Includes flow from Springs No. 1 and No. 2, 2.5 second-feet.
[c] Estimated by C. H. Lee.
[d] Includes discharge of Pinyon ditch, 2 second-feet at junction.

TABLE 38.—*Monthly mean discharge, in second-feet, at mouth of canyon, of creeks near Independence for season 1908–9.*

[Obtained from discharges at United States Geological Survey stations by use of percolation-loss diagrams.]

Creek.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Mean.
Tinemaha [a]	8.8	4.5	4.0	4.3	3.6	8.6	5.0	2.1	7.0	43	45.7	24.2	13.4
Taboose	13.2	9.5	8.4	11.4	9.0	8.4	6.0	10.0	17.8	40	37.4	20.9	16.0
Goodale	7.8	6.3	5.7	5.7	4.6	4.6	4.6	7.3	16.3	29	26.6	16.7	11.2
Division [b]	10.9	10.0	9.2	8.6	7.4	7.5	7.8	[c]8.0	8.0	20	19.0	18.0	11.2
Sawmill	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7.3
Oak	20.4	16.5	14.3	12.6	14.4	13.5	14.0	21.0	54.0	140	138.0	52.0	42.6
Little Pine [d]	9.8	10.7	7.6	6.9	7.0	5.6	5.5	12.0	50.0	116	[e]71.8	[e]31.0	27.8
Pinyon	2.6	3.1	3.1	2.3	2.7	2.5	2.5	6.4	13.3	[f]35	[f]25.0	[f]11.1	9.2
Symmes [g]	[f]2.0	[f]2.0	[f]2.0	[f]2.0	[f]2.0	[f]1.8	[f]2.5	7.9	30.0	42	23.2	10.5	10.7
Shepard	17.9	11.9	5.1	4.5	7.2	5.5	5.0	16.6	25.8	56	60.0	35.0	20.9
Bairs	4.4	4.2	2.2	2.0	2.0	1.5	2.5	12.0	19.0	33	21.7	8.7	9.4
George	12.3	9.1	4.8	4.6	4.1	3.7	5.0	17.1	29.3	59	53.0	22.2	18.7
Lone Pine	24.0	11.3	7.6	6.3	7.2	8.4	6.4	11.9	31.5	102	81.1	41.4	28.3

[a] United States Geological Survey discharges are corrected for combined seepage loss from channel and gain from irrigation waste and springs.
[b] Includes flow from springs No. 1 and No. 2, 2.5 second-feet.
[c] Power plant No. 2 put in operation and No. 1 shut down. No. 2 carried 6 second-feet.
[d] Includes discharge of Pinyon ditch, 3.5 second-feet at junction.
[e] Seepage-gain curve used.
[f] Obtained by interpolation between mouth of canyon measurements.
[g] Includes discharge of North Fork, seasonal mean, 0.5 second-foot.

TABLE 39.—*Monthly mean discharge, in second-feet, at mouth of canyon, of creeks near Independence for season 1909–10.*

[Obtained from discharges at United States Geological Survey stations by use of percolation-loss diagrams.]

Creek.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Mean.
Tinemaha [a]	11.9	7.5	5.9	9.0	8.6	7.2	6.0	5.8	14.3	23.3	24.4	17.7	12.0
Taboose	12.0	8.6	7.7	12.0	10.2	6.6	7.5	8.3	14.8	24.5	21.7	14.4	12.4
Goodale	10.6	8.0	7.8	9.5	7.0	5.8	7.2	8.5	14.0	19.0	15.4	9.0	10.2
Division [b]	19.3	17.6	[c]15.0	12.2	10.0	9.0	8.5	10.0	10.4	11.0	10.0	10.6	12.0
Sawmill	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7.2
Oak	27.0	19.5	20.5	18.2	15.0	13.5	14.5	20.2	39.5	48.4	44.0	18.8	25.0
Little Pine [d]	[e]15.0	8.8	[c]10.0	[c]10.0	10.2	8.1	6.5	16.2	39.2	56.0	[e]31.0	[e]13.0	18.7
Pinyon	[f]5.0	[f]3.5	[f]2.0	[f]1.0	[f]1.6	[f]1.6	[f]2.6	[f]2.6	[f]5.0	[c]10.0	[c]5.0	[c]2.0	3.5
Symmes [g]	6.7	[c]4.0	[c]4.0	[f]3.0	[f]2.0	[f]2.0	[f]2.0	4.2	7.8	10.4	7.2	5.0	4.9
Shepard	20.0	10.3	5.5	5.5	4.5	4.0	4.5	9.1	21.0	29.2	37.0	20.2	14.2
Bairs	7.2	3.8	2.0	2.0	1.5	1.2	1.2	3.3	13.4	10.4	7.2	4.0	4.8
George	13.4	5.6	3.2	3.0	2.2	1.6	4.6	9.0	25.0	26.0	20.5	9.6	10.3
Lone Pine	19.6	8.6	7.8	7.9	6.2	8.3	6.1	10.4	24.5	32.5	34.8	21.4	15.7

[a] U. S. Geological Survey discharges are corrected for combined seepage loss from channel and gain from irrigation waste and springs.
[b] Includes flow from springs No. 1 and No. 2, 2.5 second-feet.
[c] Estimated by C. H. Lee.
[d] Includes discharge of Pinyon ditch, 2.0 second-feet at junction.
[e] Seepage-gain curve used.
[f] Obtained by interpolation between mouth of canyon measurements.
[g] Discharge of North Fork, 0 second-foot.

TABLE 40.—*Seasonal discharge, in second-feet per square mile, at mouth of canyon, of creeks near Independence.*

[Figures in parentheses are assumed.]

Creek.	Year beginning Sept. 1—						Observed 6-year mean.	Compnted 21-year mean.	Assumed 21-year mean.
	1904	1905	1906	1907	1908	1909			
Class A.									
Tinemaha	....	....	1.97	1.56	2.56	2.29	2.09	1.92	....
Taboose	1.70	2.74	2.92	1.40	2.29	1.77	2.14	1.81	....
Goodale	1.53	1.99	2.47	1.45	2.26	2.05	1.96	1.66	....
Dry Canyon	....	....	....	....	....	....	....	....	1.70
Division	(1.13)	1.78	2.89	1.78	2.24	2.45	2.04	1.73	....
Oak	1.09	2.81	2.20	1.38	2.77	1.63	1.98	1.68	....
Little Pine	1.27	2.92	2.44	1.42	2.88	1.98	2.15	1.82	....
Average	1.34	2.45	2.48	1.50	2.50	2.03	2.06	1.75	....
Class B.									
Shepard	(0.90)	2.56	1.54	1.10	1.70	1.15	1.49	1.26	....
George	(.90)	2.62	1.81	1.08	2.06	1.13	1.60	1.36	....
Lone Pine	.83	2.31	1.94	1.69	2.37	1.31	1.74	1.47	....
Average	.88	2.50	1.76	1.29	2.04	1.20	1.61	1.36	....
Class C.									
Pinyon	....	....	....	....	2.14	0.82	....	....	1.11
Symmes	....	....	1.66	0.88	2.42	1.16	(1.47)	1.25	....
Average	....	....	1.66	.88	2.28	.99	(1.39)	1.18	....
Class D.									
Bairs	(0.62)	1.71	1.11	0.61	1.36	0.69	1.02	0.86	....
Hogback	....	....	....	....	....	....	....	....	1.00
Class E.									
Sawmill	(0.52)	0.85	1.19	0.72	0.96	1.02	0.86	0.73	....

Class A, north of Kings-Kern divide, 60 per cent or more of area above 10,000 feet.
Class B, south of Kings-Kern divide, 60 per cent or more of area above 10,000 feet.
Class C, north of Kings-Kern divide, less than 60 per cent of area above 10,000 feet.
Class D, south of Kings-Kern divide, less than 60 per cent of area above 10,000 feet.
Class E, small run-off for unknown reason, less than 60 per cent of area above 10,000 feet.

TABLE 41.—*Seasonal discharges at mouth of canyon, expressed as percentages of observed 6-year mean, for streams near Independence.*

[Figures in parentheses are assumed.]

Class A.

Stream.	Year beginning Sept. 1—						Average.
	1904	1905	1906	1907	1908	1909	
Tinemaha	....	....	94	75	123	110	100
Taboose	79	128	136	65	107	83	100
Goodale	78	102	126	74	115	105	100
Division	(55)	87	142	87	110	120	100
Oak	55	142	111	70	140	82	100
Little Pine	59	136	114	66	134	92	100
Average	65	119	120	73	122	99	100

TABLE 41.—*Seasonal discharges at mouth of canyon, expressed as percentages of observed 6-year mean, for streams near Independence*—Continued.

[Figures in parentheses are assumed.]

Class B.

Stream.	Year beginning Sept. 1— 1904	1905	1906	1907	1908	1909	Average.
Shepard	(60)	172	103	74	114	77	100
George	(56)	164	113	68	129	71	100
Lone Pine	48	133	112	97	136	75	100
Average	57	156	109	79	126	74	100
Class C.							
Pinyon	....	....	....	....	....	....	....
Symmes	....	....	113	60	165	79	104
Average	....	....	113	60	165	79	104
Class D.							
Bairs	(61)	168	109	60	133	68	100
Class E.							
Sawmill	(60)	99	138	84	112	109	100
West slope of Sierra Nevada.							
Kings	64	167	122	46	123	79	100
Merced	68	149	157	38	109	78	100

TABLE 42.—*Seasonal discharges at mouth of canyon, expressed as percentages of computed 21-year mean, for streams near Independence.*

[Figures in parentheses are estimated.]

Class A.

Stream.	Year beginning Sept. 1— 1904	1905	1906	1907	1908	1909	Average.
Tinemaha	....	....	104	83	135	121	111
Taboose	94	151	161	77	127	98	118
Goodale	92	120	149	87	136	124	118
Division	65	103	167	103	129	142	118
Oak	65	167	131	82	165	97	118
Little Pine	70	160	134	78	158	109	118
Average	77	140	141	85	142	116	117
Class B.							
Shepard	(71)	202	122	87	135	91	118
George	(66)	193	133	79	151	83	118
Lone Pine	56	157	132	115	161	89	118
Average	64	184	129	94	149	88	118

TABLE 42.—*Seasonal discharges at mouth of canyon, expressed as percentages of computed 21-year mean, for streams near Independence*—Continued.

[Figures in parentheses are estimated.]

Class C.

Stream.	Year beginning Sept. 1—						Average.
	1904	1905	1906	1907	1908	1909	
Pinyon							
Symmes			133	70	194	93	122
Average			133	70	194	93	122

Class D.

Bairs	(72)	199	129	71	158	80	118

Class E.

Sawmill	(71)	116	163	99	132	129	118

West slope of Sierra Nevada.

Kings	76	197	145	54	145	94	118
Merced	79	174	184	45	128	92	117

TABLE 43.—*Seasonal discharge, in second-feet, at mouth of canyon, of creeks tributary to Independence region.*

[Figures in parentheses are estimated.]

Creek.	Year beginning Sept. 1—						Observed 6-year mean.	Computed 21-year mean.
	1904	1905	1906	1907	1908	1909		
Taboose	11.9	19.2	20.4	9.8	16.0	12.4	15.0	12.7
Goodale	7.6	9.9	12.3	7.2	11.2	10.2	9.8	8.3
Dry Canyon	(3.9)	(5.1)	(6.3)	(3.7)	(5.7)	(5.2)	5.0	4.2
Division	(4.4)	6.9	11.2	6.9	8.7	9.5	7.9	6.7
Sawmill	(4.0)	6.5	9.1	5.5	7.3	7.2	6.6	5.6
Thibaut	(1.9)	(3.1)	(4.4)	(2.7)	(3.5)	(3.4)	3.2	2.7
Oak	16.7	43.2	33.8	21.2	42.6	25.0	30.4	25.8
Little Pine	10.7	24.6	20.5	12.0	24.3	16.7	18.1	15.3
Pinyon	(3.6)	(8.9)	(6.6)	(4.2)	9.2	3.5	6.0	4.8
Symmes	(3.5)	(8.8)	7.0	3.7	10.2	4.9	6.2	5.3
Shepard	(11.1)	31.4	18.9	13.5	20.9	14.1	18.3	15.5
Bairs	(4.3)	11.8	7.7	4.2	9.4	4.8	7.0	5.9
George	(8.2)	23.8	16.5	9.8	18.7	10.3	14.6	12.4
Hogback	(2.8)	(7.8)	(5.7)	(4.2)	(6.8)	(3.7)	5.2	4.4
	94.6	211.0	180.4	108.6	194.5	130.9	153.3	129.6

TABLE 44.—*Seasonal discharge, in second-feet, at United States Geological Survey stations, of creeks tributary to Independence region.*

[Figures in parentheses are estimated.]

Creek.	Year beginning Sept. 1—						Observed 5-year mean.	Computed 21-year mean.
	1904	1905	1906	1907	1908	1909		
Taboose	(5.7)	11.4	10.3	4.7	8.6	5.9	8.2	6.5
Goodale	(3.9)	5.4	6.6	3.8	6.4	5.3	5.5	4.3
Dry Canyon	0	0	0	0	0	0	0	0
Division	(3.9)	7.2	10.9	7.6	9.7	9.9	9.1	7.2
Sawmill	....	5.4	(7.6)	(5.0)	7.3	7.2	6.5	5.1
Thibaut	(0.5)	(1.0)	(1.0)	.8	.9	.2	.6	.5
Oak	(13.0)	31.8	23.9	15.8	30.8	18.4	24.1	19.0
Little Pine / Pinyon	(10.7)	28.5	22.5	11.8	25.8	17.2	21.2	16.7
Symmes	....	(2.8)	3.1	.8	6.3	1.1	2.8	2.2
Shepard	....	23.1	11.0	7.2	12.9	7.7	12.5	9.8
Bairs	....	8.0	4.8	2.0	6.1	2.4	4.7	3.7
George	....	18.6	10.9	6.5	13.0	6.8	11.2	8.8
Hogback	(0)	(1.0)	(.5)	(0)	(.5)	0	.4	.3
	....	144.2	113.1	66.0	128.3	82.1	106.7	84.0
Per cent of totals at mouth of canyon	....	68	63	61	66	63	65	65

TABLE 45.—*Analysis of flow of Owens River between Charlies Butte and Mount Whitney bridge, 1908.*

[Figures in parentheses are estimated.]

Month.	Discharge into river channel.						Diversions.		Discharge of Owens River at Mount Whitney bridge.		Seepage gain or loss.
	Owens River at Charlies Butte.	Slough near Goose Lake. *a*	Slough at Lake ranch. *b*	Shepard Creek.	Bairs and Georges creeks.	Miscellaneous. *c*	East Side canal.	Stevens ditch.	Computed.	Measured.	
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
January	....	....	....	....	....	....	....	....	....	....	....
February	....	....	....	....	....	....	....	....	....	....	....
March	....	....	....	....	....	....	....	....	....	....	....
April	....	....	....	....	....	....	....	....	....	....	....
May	58	0	0	0	0	2	15	10	35	(52)	+17
June	57	0	0	0	0	2	15	15	29	(53)	+24
July	187	0	0	0	0	2	15	15	159	164	+ 5
August	266	0	0	0	0	2	15	15	238	234	4
September	172	0	0	0	0	2	15	15	144	145	+ 1
October	290	0	0	0	0	2	10	10	272	284	+12
November	382	(1)	(5)	0	0	2	10	7	373	374	+ 1
December	392	(3)	(13)	0	0	2	2	0	408	396	−12

a Portion of Blackrock Springs and occasional surface run-off.
b Includes discharge of Little Pine, Oak, and Sawmill creeks, surplus flow of Blackrock Springs, and occasional surface run-off.
c Includes waste of Seeley and Campbell springs and of Red Mountain and Taboose creeks.

TABLE 46.—*Analysis of flow of Owens River between Charlies Butte and Mount Whitney bridge, 1909.*

[Figures in parentheses are estimated.]

Month.	Discharge into river channel.						Diversions.		Discharge of Owens River at Mount Whitney bridge.		Seepage gain or loss.
	Owens River at Charlies Butte.	Slough near Goose Lake.[a]	Slough at Lake ranch.[b]	Shepard Creek.	Bairs and Georges creeks.	Miscellaneous.[c]	East Side canal.	Stevens ditch.	Computed.	Measured.	
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
January	612	(10)	(18)	0	0	2	1.0	6.0	635	571	− 64
February	544	(6)	(18)	0	0	2	1.5	6.0	562	590	+ 28
March	394	(4)	(7)	0	0	2	10.7	6.9	389	401	+ 12
April	309	(2)	0	0	0	2	20.3	14.0	279	312	+ 33
May	140	(0.5)	0	0	0	2	20.5	9.5	112	127	+ 15
June	901	0	72	27	36	14	17.0	6.0	1,027	836	−191
July	958	0	80	22	22	13	23.8	3.0	1,068	1,056	− 12
August	284	0	9	1.6	0.3	2	18.9	0	278	280	+ 2
September	211	0	0	0	0	2	14.8	0	198	214	+ 16
October	311	0	0	0	0	2	14.8	0	298	318	+ 20
November	438	(1)	(7)	0	0	2	15.0	0	433	450	+ 17
December	525	(3)	(10)	0	0	2	14.5	0	526	519	− 7
Mean.	469	2.2	18.4	4.2	4.8	3.9	14.4	4.3	484	473	− 11

[a] Portion of Blackrock Springs.
[b] Includes discharge of Little Pine, Oak, and Sawmill creeks, surplus flow of Blackrock Springs, and occasional surface run-off.
[c] Includes waste of Seeley and Campbell springs and of Red Mountain and Taboose creeks.

TABLE 47.—*Analysis of flow of Owens River between Charlies Butte and Mount Whitney bridge, 1910.*

[Figures in parentheses are estimated.]

Month.	Discharge into river channel.						Diversions.		Discharge of Owens River at Mount Whitney bridge.		Seepage gain or loss.
	Owens River at Charlies Butte.	Slough near Goose Lake.[a]	Slough at Lake ranch.[b]	Shepard Creek.	Bairs and Georges creeks.	Miscellaneous.[c]	East Side canal.	Lower East Side canal.[d]	Computed.	Measured.	
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
January	655	12.5	27.7	0	0	2	0	(2.9)	694	713	+ 19
February	499	3.0	19.4	0	0	2	0	9.0	514	487	− 27
March	510	2.0	5.9	0	0	2	4.6	9.0	506	475	− 31
April	164	1.0	1.9	0	0	2	16.0	.8	152	184	+ 32
May	254	.3	.2	0	0	2	24.4	23.4	208	196	− 12
June	428	0	0	(2)	(1)	2	(23.0)	(30.0)	380	349	− 31
July	272	0	0	0	0	2	(23.0)	(30.0)	221	218	− 3
August	145	0	0	0	0	2	(20.0)	(20.0)	107	110	+ 3
September	110	0	0	0	0	2	(15.0)	(15.0)	82	95	+ 13
October	289	0	0	0	0	3	(15.0)	(15.0)	262	247	− 15
November	418	(1)	(5)	0	0	4	(15.0)	0	413	388	− 25
December	468	(3)	(8)	0	0	5	(15.0)	0	469	442	− 27
Mean.	351	1.9	5.7	0.2	0.1	2.5	14.2	12.9	334	325	− 9

[a] Portion of Blackrock Springs.
[b] Includes discharge of Little Pine, Oak, and Sawmill creeks, surplus flow of Blackrock Springs, and occasional surface run-off.
[c] Includes waste of Seeley and Campbell springs and of Red Mountain and Taboose creeks.
[d] Stevens ditch not diverting from river in 1910.

TABLE 48.—*Comparison of evaporation from snow and water in Little Bear Valley, Cal.*

[Elevation, 5,150 feet.]

Time.	Depth of evaporation from water (inches).	Depth of evaporation from snow—equivalent water in inches.[a] Total.	Daily average.	Ratio of snow to water evaporation.[b]	Precipitation (inches).
March, 1895	1.12	2.48	0.08	2.21	8.82
March, 1896	.94	3.79	.12	4.03	4.21
January, 1897	.57	1.58	.05	2.78	5.16
February, 1897	.24	2.82	.10	11.75	12.05
March, 1897	[c] .48	3.12	.10	6.50	10.17

[a] Snow heavy and wet, reduced to water, 5 to 1.
[b] Variation due to winds from sea or desert.
[c] Estimated.

TABLE 49.—*Depth of evaporation, in inches, from water surface near Independence (pan in water).*

Month.	1908 Total.	1908 Rate per 24 hours.	1909 Total.	1909 Rate per 24 hours.	1910 Total.	1910 Rate per 24 hours.	1911 Total.	1911 Rate per 24 hours.	Average per cent of annual evaporation.
January	......	......	1.60	0.052	1.75	0.056	1.65	0.053	2
February	......	......	2.40	.086	2.50	.089	2.35	.084	4
March	......	......	4.70	.152	5.15	.166	3.70	.119	7
April	......	......	7.30	.243	7.05	.235	6.25	.208	11
May	......	......	9.60	.310	8.29	.267	8.01	.258	13
June	......	......	10.10	.337	9.90	.330	......	......	15
July	......	......	10.40	.335	8.50	.274	......	......	14
August	[a] 4.90	0.222	8.00	.258	8.20	.264	......	......	12
September	5.30	.176	6.60	.220	6.30	.210	......	......	10
October	3.50	.113	3.90	.126	4.20	.135	......	......	6
November	2.50	.083	2.60	.087	2.36	.079	......	......	4
December	1.50	.048	(1.85)	.060	1.24	.040	......	......	2
	......	......	69.05	.189	65.44	.179	......	......	100

[a] Aug. 10 to 31, inclusive.

TABLE 50.—*Depth of evaporation, in inches, from water surface near Independence (pan in soil).*

Month.	1909 Total.	1909 Rate per 24 hours.	1909 Per cent of evaporation from pan in water.	1910 Total.	1910 Rate per 24 hours.	1910 Per cent of evaporation from pan in water.	1911 Total.	1911 Rate per 24 hours.	1911 Per cent of evaporation from pan in water.
January	......	......	......	......	......	......	2.25	0.073	138
February	......	......	......	......	......	......	2.25	.080	95
March	......	......	......	[a] 4.25	0.236	......	4.80	.155	130
April	......	......	......	9.50	.316	135	8.12	.271	130
May	......	......	......	10.61	.342	128	10.25	.330	128
June	......	......	......	11.95	.398	121	......	......	......
July	......	......	......	12.55	.405	148	......	......	......
August	10.70	0.345	134	11.80	.381	144	......	......	......
September	8.50	.283	129	8.80	.293	140	......	......	......
October	5.80	.187	149	5.60	.180	133	......	......	......
November	3.80	.127	146	2.85	.095	121	......	......	......
December	......	......	......	1.60	.052	129	......	......	......
	......	......	......	......	......	133	......	......	......

[a] Mar. 14 to 31, inclusive.

TABLE 51.—*Depth of evaporation, in inches, from water surface near Independence (deep tank in soil).*

Month.	1909			1910			1911			Per cent of annual evaporation.
	Total.	Rate per 24 hours.	Per cent of evaporation from pan in water.	Total.	Rate per 24 hours.	Per cent of evaporation from pan in water.	Total.	Rate per 24 hours.	Per cent of evaporation from pan in water.	
January	....	....	....	2.00	0.064	114	2.30	0.074	139	3
February	....	....	....	2.90	.104	116	2.55	.091	108	4
March	....	....	....	5.00	.180	109	3.95	.127	107	8
April	[a] 2.90	0.193	....	7.40	.246	105	6.80	.226	84	11
May	7.50	.242	78	7.71	.248	93	7.90	.254	77	11
June	7.80	.260	77	8.60	.287	87	....	....	....	12
July	7.90	.254	76	8.30	.268	98	....	....	....	12
August	8.20	.264	102	8.80	.284	107	....	....	....	13
September	7.20	.240	109	7.30	.243	116	....	....	....	11
October	5.00	.161	128	5.15	.166	123	....	....	....	7
November	3.30	.110	127	3.10	.103	131	....	....	....	5
December	(2.20)	.071	119	2.15	.069	173	....	....	....	3
	....	....	....	69.01	.188	106	....	....	....	100

[a] Apr. 16 to 30, inclusive.

TABLE 52.—*Depth of evaporation from ground surface near Independence, tank set No. 1.*

Month.	Volume of water supplied reservoir tank (gallons).	Depth of water in reservoir tank (feet).		Accumulation or depletion of water in reservoir tank (gallons).	Volume of water evaporated.			Average depth to ground-water surface in soil tank (feet).
		Beginning of month.	End of month.		Total (gallons).	Depth (inches)	Rate in inches per 24 hours.	
1910.								
June	85	5.82	5.80	−1	86	3.18	0.102	1.55
July	98	5.80	5.80	0	98	3.62	.117	1.47
August	121	5.80	5.91	+4	117	4.33	.140	1.45
September	113	5.91	5.73	−6	119	4.40	.147	1.23
October	103	5.73	5.82	+3	100	3.70	.119	1.26
November	67	5.82	5.72	−3	70	2.59	.086	1.04
December	68	5.72	5.83	+4	64	2.38	.077	.92
1911.								
January	70	5.83	5.89	+2	68	2.52	.081	1.06
February	87	5.89	5.89	0	87	3.22	.115	1.07
March	79	5.89	5.77	−4	83	3.07	.099	1.16
April	91	5.77	5.80	+1	90	3.33	.111	1.57
May	98	5.80	5.81	0	98	3.61	.116	1.59
Year	1,080	5.82	5.81	0	1,080	39.95	.109	1.28

TABLE 53.—*Depth of evaporation from ground surface near Independence, tank set No. 2.*

Month.	Volume of water supplied reservoir tank (gallons).	Depth of water in reservoir tank (feet).		Accumulation or depletion of water in reservoir tank (gallons).	Volume of water evaporated.			Average depth to ground-water surface in soil tank (feet).
		Beginning of month.	End of month.		Total (gallons).	Depth (inches)	Rate in inches per 24 hours.	
1910.								
June	0	1.49	1.33	−5	5	0.18	0.006	4.70
July	22	1.33	1.32	−3	25	.93	.030	5.01
August	60	1.23	1.36	+4	56	2.07	.067	4.99
September	44	1.36	1.42	+2	42	1.55	.056	4.91
October	17	1.42	1.21	−7	24	.89	.029	4.92
November	7	1.21	1.13	−3	10	.37	.012	4.98
December	5	1.13	1.10	−1	6	.22	.007	4.97
1911.								
January	6	1.10	1.15	+2	4	.15	.005	4.98
February	0	1.15	1.11	−1	1	.04	.001	4.95
March	3	1.11	1.14	+1	2	.07	.002	4.94
April	10	1.14	1.18	+1	9	.33	.011	4.94
May	30	1.18	1.19	0	30	1.11	.036	4.98
Year	204	1.49	1.19	−10	214	7.91	.022	4.94

TABLE 54.—*Depth of evaporation from ground surface near Independence, tank set No. 3.*

Month.	Volume of water supplied reservoir tank (gallons).	Depth of water in reservoir tank (feet).		Accumulation or depletion of water in reservoir tank (gallons).	Volume of water evaporated.			Average depth to ground-water surface in soil tank (feet).
		Beginning of month.	End of month.		Total (gallons).	Depth (inches)	Rate in inches per 24 hours.	
1910.								
June	24	1.19	0.32	−28	52	1.92	0.064	4.50
July	103	.32	.38	+ 2	101	3.74	.121	4.51
August	145	.38	1.01	+20	125	4.63	.149	4.52
September	89	1.01	.53	−15	104	3.85	.128	4.48
October	57	.53	.42	− 4	61	2.26	.073	4.44
November	16	.42	.18	− 8	24	.89	.030	4.43
December	14	.18	.14	− 1	15	.56	.018	4.49
1911.								
January	9	.14	.10	− 1	10	.37	.012	4.53
February	18	.10	.23	+ 4	14	.52	.019	4.59
March	12	.23	.20	− 1	13	.48	.015	4.48
April	40	.20	.54	+11	29	1.07	.036	4.50
May	62	.54	.60	+ 2	60	2.22	.072	4.49
Year	589	1.19	.60	−19	608	22.51	.062	4.49

TABLE 55.—*Depth of evaporation from ground surface near Independence, tank set No. 4.*

Month.	Volume of water supplied reservoir tank (gallons).	Depth of water in reservoir tank (feet).		Accumulation or depletion of water in reservoir tank (gallons).	Volume of water evaporated.			Average depth to ground-water surface in soil tank (feet).
		Beginning of month.	End of month.		Total (gallons).	Depth (inches).	Rate in inches per 24 hours.	
1910.								
June	54	2.16	2.29	+ 4	50	1.85	0.062	4.07
July	128	2.29	2.84	+18	110	4.07	.131	4.11
August	146	2.84	3.03	+ 6	140	5.18	.167	4.08
September	81	3.03	2.62	−13	94	3.48	.116	3.96
October	65	2.62	2.71	+ 3	62	2.29	.074	3.99
November	16	2.71	2.22	−16	32	1.18	.038	3.84
December	− 6	2.22	1.53	−22	16	.59	.019	3.84
1911.								
January	7	1.53	1.49	− 1	8	.30	.010	3.97
February	− 8	1.49	1.18	−10	2	.07	.002	3.36
March	3	1.18	1.19	0	3	.11	.004	3.74
April	62	1.19	2.15	+31	31	1.15	.038	4.00
May	96	2.15	2.57	+14	82	3.04	.098	4.06
Year	644	2.16	2.57	+14	630	23.31	.064	3.92

TABLE 56.—*Depth of evaporation from ground surface near Independence, tank set No. 5.*

Month.	Volume of water supplied reservoir tank (gallons).	Depth of water in reservoir tank (feet).		Accumulation or depletion of water in reservoir tank (gallons).	Volume of water evaporated.			Average depth to ground-water surface in soil tank (feet).
		Beginning of month.	End of month.		Total (gallons).	Depth (inches).	Rate in inches per 24 hours.	
1910.								
June	69	3.04	3.88	+27	42	1.56	0.052	3.11
July	151	3.88	5.09	+39	112	4.15	.134	3.00
August	169	5.09	4.73	−12	181	6.70	.216	2.97
September	117	4.73	3.90	−27	144	5.33	.177	2.92
October	83	3.90	3.56	−11	94	3.48	.112	2.94
November	17	3.56	2.95	−20	37	1.37	.046	2.89
December	4	2.95	2.55	−13	17	.63	.020	2.96
1911.								
January	8	2.55	2.43	− 4	12	.44	.0 4	3.01
February	6	2.43	2.42	0	6	.22	.008	2.47
March	3	2.42	2.36	− 2	5	.18	.006	2.73
April	88	2.36	3.65	+42	46	1.70	.057	2.99
May	141	3.65	4.09	+14	127	4.70	.151	3.01
Year	856	3.04	4.09	+33	823	30.46	.084	2.92

TABLE 57.—*Depth of evaporation from ground surface near Independence, tank set No. 6.*

Month.	Volume of water supplied reservoir tank (gallons).	Depth of water in reservoir tank (feet).		Accumulation or depletion of water in reservoir tank (gallons).	Volume of water evaporated.			Average depth to ground-water surface in soil tank (feet).
		Beginning of month.	End of month.		Total (gallons).	Depth (inches).	Rate in inches per 24 hours.	
1910.								
June	119	5.50	5.65	+ 5	114	4.22	0.141	2.15
July	156	5.65	5.76	+ 4	152	5.62	.181	2.31
August	209	5.76	5.50	− 8	217	8.04	.259	2.36
September	180	5.50	4.07	−46	226	8.36	.278	1.93
October	99	4.07	3.86	− 7	106	3.92	.126	1.85
November	25	3.86	3.38	−16	41	1.52	.051	1.89
December	0	3.38	3.03	−11	11	.41	.013	1.85
1911.								
January	12	3.03	3.19	+ 5	7	.26	.008	1.92
February	9	3.19	3.17	− 1	10	.37	.013	1.31
March	24	3.17	3.32	+ 5	19	.70	.023	1.70
April	94	3.32	3.53	+ 7	87	3.22	.107	2.00
May	163	3.53	3.54	0	163	6.03	.195	1.99
Year	1.090	5.50	3.54	−63	1,153	42.67	.117	1.94

TABLE 58.—*Depth of evaporation from ground surface near Independence, tank set No. 7.*

Month.	Volume of water supplied reservoir tank (gallons).	Depth of water in reservoir tank (feet).		Accumulation or depletion of water in reservoir tank (gallons).	Volume of water evaporated.			Average depth to ground-water surface in soil tank (feet).
		Beginning of month.	End of month.		Total (gallons).	Depth (inches)	Rate in inches per 24 hours.	
1910.								
June	139	5.62	5.50	− 4	143	5.30	0.177	1.47
July	166	5.50	5.91	+13	153	5.67	.183	1.57
August	198	5.91	5.98	+ 2	196	7.26	.234	2.03
September	152	5.98	5.91	− 2	154	5.70	.190	1.82
October	111	5.91	6.01	+ 3	108	4.00	.129	1.70
November	50	6.01	5.79	− 7	57	2.11	.070	1.18
December	3	5.79	5.07	−23	26	.96	.031	.63
1911.								
January	3	5.07	4.70	−12	15	.56	.018	.73
February	31	4.70	5.08	+12	19	.70	.025	.81
March	67	5.08	5.90	+26	41	1.52	.049	.98
April	102	5.90	5.96	+ 2	100	3.70	.123	1.46
May	151	5.96	5.92	− 1	152	5.62	.181	1.64
Year	1,173	5.62	5.92	+ 9	1,164	43.10	.118	1.34

TABLE 59.—*Average amount of water used by several plants in Wisconsin in producing a ton of dry matter.*

Crop.	Number of trials.	Water used per ton of dry matter (tons).	Water used (inches).	Dry matter produced per acre (tons).	Acre-inches of water per ton of dry matter.
Barley	5	464.1	20.69	5.05	4.096
Oats	20	503.9	39.53	8.89	4.447
Maize	52	270.9	15.76	6.59	2.391
Clover	46	576.6	22.34	4.39	5.089
Peas	1	477.2	16.89	4.01	4.212
Potatoes	14	385.1	23.78	7.00	3.399
Average	....	446.3	23.16	5.99	3.939

TABLE 60.—*Loss in weight of newly cut alfalfa, in ounces per square yard of field area.*

Period.	Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.	Average.
First 15 minutes	(4.5)	(7.0)	7.5	5.5	6.1
Second 15 minutes	(4.0)	(4.5)	5.5	4.0	4.5
Third 15 minutes	(3.5)	(3.5)	4.5	3.5	3.8
First 30 minutes	8.5	11.5	13.0	9.5	10.6
Second 30 minutes	6.0	7.5	8.5	6.0	7.0
Third 30 minutes	4.5	5.5	6.0	4.0	5.0
First hour	14.5	19.0	21.5	15.5	17.6
Second hour	10.5	10.5	11.7	6.5	....

TABLE 61.—*Percolation from precipitation upon intermediate mountain slopes of Independence region.*

[Mean seasonal values.]

Taboose group of precipitation gages.

Adjacent high mountain drainage area.	Depth of precipitation on center of area (inches).[a]			Volume of precipitation on area (acre-feet).	Percolation factor.	Amount of percolation.	
	A.	B.	Average.			Volume in acre-feet.	Discharge in second-feet.
Tinemaha	22.2	17.8	20.0	2,320	0.75	1,740	2.4
Red Mountain	23.6	17.8	20.7	2,620	.75	1,970	2.7
Taboose	22.2	16.5	19.4	4,080	.75	3,060	4.2
Goodale	18.5	20.0	19.2	2,350	.75	1,760	2.4
Division	19.9	15.5	17.7	900	.70	630	.9
	....	....	....	12,270	....	9,160	12.6

Oak group of precipitation gages

Sawmill	18.2	18.4	18.3	1,290	0.70	900	1.2
Thibaut, North Fork	18.2	18.9	18.6	530	.70	370	.5
Thibaut, South Fork	14.5	15.0	14.8	60	.60	40	.1
Oak, North Fork	16.4	14.2	15.3	2,950	.60	1,770	2.4
Oak, South Fork	16.4	15.8	16.1	880	.70	620	.9
Little Pine	17.7	15.8	16.8	1,810	.70	1,270	1.8
Pinyon	18.7	20.8	19.8	3,050	.75	2,290	3.2
	....	....	....	10,570	....	7,260	10.1

Bairs group of precipitation gages.

Symmes	13.4	17.0	15.2	340	0.70	240	0.3
Shepard	12.7	12.4	12.6	650	.65	420	.6
Bairs, North Fork	12.4	10.8	11.6	300	.65	200	.3
Bairs, South Fork	14.8	12.0	13.4	860	.70	600	.8
George	15.8	15.8	15.8	1,760	.70	1,230	1.7
Hogback	15.2	13.6	14.4	830	.70	580	.8
	....	....	....	4,740	....	3,270	4.5
Grand total	....	....	....	27,580	....	19,690	27.2

[a] Depth of precipitation as obtained by the precipitation-altitude diagram is given under A; as obtained by the precipitation-distance diagram, under B. The average is taken for use in computations.

TABLE 62.—*Percolation from precipitation upon outwash slopes of the Independence region.*

[Mean seasonal values.]

Taboose group of precipitation gages.

Contours bounding precipitation zones.	Area of zones (square miles).	Depth of precipitation (inches). On contours.	Depth of precipitation (inches). On zone.	Volume of precipitation on zone (acre-feet).	Percolation factor.	Amount of percolation. Volume in acre-feet.	Amount of percolation. Discharge in second-feet.
Grass-4,500	28.07	6.0, 7.7	6.8	10,180	0.00	0	0
4,500-5,000	8.54	7.7, 9.0	8.4	3,830	.10	380	.5
5,000-5,500	8.14	9.0, 10.8	9.9	4,300	.20	860	1.2
5,500-6,000	5.56	10.8, 12.9	11.8	3,500	.35	1,220	1.7
6,000-6,500	3.42	12.9, 15.2	14.0	2,550	.60	1,530	2.1
	53.73			24,360		3,990	5.5
Oak group of precipitation gages.							
Grass-4,500	24.57	4.8, 5.9	5.4	7,080	0	0	0
4,500-5,000	11.78	5.9, 7.3	6.6	4,150	.05	210	.3
5,000-5,500	9.23	7.3, 9.1	8.2	4,040	.15	610	.8
5,500-6,000	5.82	9.1, 11.3	10.2	3,170	.30	950	1.3
6,000-6,500	4.82	11.3, 13.6	12.4	3,190	.50	1,600	2.2
	56.22			21,630		3,370	4.6
Bairs group of precipitation gages.							
Grass-4,500	19.56	3.3, 4.0	3.6	3,760	0	0	0
4,500-5,000	11.68	4.0, 5.2	4.6	2,860	0	0	0
5,000-5,500	9.76	5.2, 6.9	6.0	3,120	.10	310	.4
5,500-6,000	9.23	6.9, 8.6	7.8	3,840	.25	960	1.3
6,000-6,500	5.11	8.6, 10.3	9.4	2,560	.45	1,150	1.6
	55.34			16,140		2,420	3.3
Grand total	165.29			62,130		9,780	13.4

TABLE 63.—*Estimated net volume of water used for irrigation in the Independence region during the year 1909.*

Source of supply.	Area irrigated (acres).[a]	Duty of water per acre for season (acre-feet).[b]	Total volume of water used. Acre-feet.	Total volume of water used. Second-feet for 6 months.
Taboose Creek	(170)	(12)	2,040	5.6
Goodale Creek	(110)	(16)	1,760	4.9
Division Creek	(80)	(16)	1,280	3.5
Sawmill Creek	(90)	(16)	1,440	4.0
Oak Creek, ranch No. 1	109	7.22	790	2.2
Oak Creek, ranch No. 2	49	15.40	758	2.1
Oak Creek, ranch No. 3	155	2.80	435	1.2
Oak Creek, ranch No. 4	260	2.34	609	1.7
Oak Creek, ranch No. 5	38	16.40	623	1.7
Oak Creek	(80)	(16)	1,280	3.5
Do	(100)	(5)	500	1.4
Do	(560)	(3)	1,680	4.6
Little Pine Creek	(300)	(14)	4,200	11.6
Symmes Creek	(160)	(5)	800	2.2
Shepard Creek	(280)	(12)	3,360	9.3
George Creek	(160)	(12)	1,920	5.3
Stevens ditch	(310)	(8)	2,480	6.9
	3,011		25,955	71.7

[a] Areas in parentheses obtained from approximate field observations; other areas obtained by careful field measurement.
[b] Figures in parentheses assumed from observations on Oak Creek ranches.

Table 64.—*Statistics of observation wells in the Independence region.*

Well No.	Location. T.	Location. R.	Location. Sec.	Class of well	Depth of well (feet).	Elevation of ground surface (feet).	Elevation of bench mark (feet).	Description of surface conditions.
A-4	11 S.	34 E.	23	2-inch test hole	7.5	3,850.8	3,850.85	Rabbit brush and bunch salt grass, sandy, no alkali.
A-3	11 S.	34 E.	23	do	7.5	3,843.6	3,843.65	Same as A-4, but surface drier, as there is no irrigation seepage.
A-2	11 S.	34 E.	23	do	6.0	3,835.0	3,835.01	Same as A-4, salt and tule grass, light soil, trace of alkali.
A-2A	11 S.	34 E.	23	do	6.0	3,830.9	3,830.91	Same as A-2, heavier growth of grass.
A-2B	11 S.	34 E.	14	do	7.0	3,824.0	3,823.98	Tule grass, heavy black soil, trace of alkali.
22	11 S.	34 E.	25	do	9.5	3,827.4	3,827.35	Salt grass and little rabbit brush, black soil, trace of alkali.
D-4	11 S.	34 E.	35	do	7.5	3,831.7	3,831.73	Rabbit brush and scattering salt grass, sandy, no alkali.
D-3	11 S.	34 E.	35	do	7.5	3,822.4	3,822.42	Rabbit brush and bunch salt grass, clay soil, white alkali film.
D-2	11 S.	34 E.	36	do	6.5	3,821.6	3,821.28	Scattering bunch grass, clay soil, alkali at grass roots.
D-1	11 S.	34 E.	25	10-foot diameter dug well	8.0	3,817.6	3,817.65	Elevation west of fault, 3,826.8 feet; salt and tule grass; soil alkali crust.
21	12 S.	34 E.	2	2-inch test hole in pit	7.5	3,813.6	3,813.45	Luxuriant salt grass, surface soil puffed with alkali.
20	12 S.	34 E.	2	do	7.5	3,814.3	3,814.77	Scattering salt grass and rabbit brush, clay soil, no alkali.
18	11 S.	34 E.	36	2-inch test hole	6.0	3,816.4	3,816.30	Do.
19	11 S.	34 E.	36	2-inch test hole in pit	5.0	3,819.6	3,818.60	Do.
B-2	12 S.	34 E.	11	2-inch test hole	9.5	3,820.5	3,820.46	Sagebrush and bunch salt grass, clay soil, no alkali.
B-3	12 S.	34 E.	11	do	7.0	3,809.9	3,809.87	Luxuriant salt grass, light soil, trace of alkali.
B-4	12 S.	34 E.	1	do	7.5	3,807.0	3,807.04	Scattering salt grass and sagebrush, clay soil, trace of alkali.
B-5	12 S.	34 E.	1	do	6.0	....	....	Luxuriant bunch salt grass, sandy, thick alkali crust.
B-6	12 S.	34 E.	1	do	7.5	....	....	Salt and tule grass, sandy, alkali crust.
B-6A	12 S.	34 E.	1	do	7.5	....	....	Do.
59	12 S.	34 E.	16	5-foot diameter dug well	25.8	3,869.2	3,869.20	Good growth of sagebrush, desert sand, no alkali.
24	12 S.	34 E.	14	2-inch test hole in pit	4.0	3,811.1	3,811.10	Scattering salt grass, sandy surface, white alkali spots.
24A	12 S.	34 E.	14	2-inch test hole	5.5	3,815.1	3,815.14	Salt grass in mounds, hog-wallow surface, alkali crust.
45	12 S.	34 E.	11	3 by 3 foot dug well	11.5	3,821.5	3,823.33	Sagebrush, desert sand, no alkali.
SM-1	12 S.	34 E.	15	2-inch test hole	7.5	3,842.3	3,842.32	Meadow grass, clay soil, no alkali.
SM-3	12 S.	34 E.	14	do	7.5	3,822.7	3,822.70	Same as SM-1, trace of alkali.
SM-4	12 S.	34 E.	14	do	5.5	3,806.7	3,806.67	Scattering salt grass, sandy, no alkali.
T-1	12 S.	34 E.	22	do	9.5	3,836.8	3,836.75	Bunch salt grass and rabbit brush, sandy, trace of alkali.
T-2	12 S.	34 E.	23	do	7.5	3,813.1	3,813.11	Luxuriant salt grass and sunflowers, black soil, no alkali.
T-3	12 S.	34 E.	23	do	5.0	3,801.4	3,801.37	Scattering salt grass, clay, alkali in spots.
T-4	12 S.	34 E.	23	do	7.0	3,800.4	3,801.66	Do.
T-5	12 S.	34 E.	13	do	7.5	....	....	Luxuriant meadow grass, black soil, no alkali.
T-6	12 S.	34 E.	13	do	6.0	3,796.8	3,796.84	Salt grass and sagebrush on mounds, hog-wallow surface, alkali spots.
T-7	12 S.	35 E.	18	do	9.5	3,794.4	3,794.42	Luxuriant salt grass, clay soil, spots of alkali.
T-8	12 S.	35 E.	18	do	6.0	3,797.4	3,797.41	Scattering salt grass, sandy, alkali in spots.
26	12 S.	34 E.	26	6-inch casing well	18.0	3,849.4	3,851.75	Good growth of sagebrush, desert sand, no alkali.
25	12 S.	34 E.	26	do	19.0	3,847.0	3,848.75	Do.
17	12 S.	34 E.	23	2-inch test hole in pit	8.0	3,811.1	3,809.44	Salt grass, sandy soil, no alkali.
16	12 S.	34 E.	26	do	12.5	3,809.8	3,808.00	Salt grass, gravelly soil, no alkali.
15	12 S.	34 E.	26	2-inch test hole	6.0	(3,806.4)	(3,806.4)	Salt grass, clay, no alkali.
56	12 S.	34 E.	26	do	7.5	3,795.2	3,795.17	Scattering grass, clay, alkali crust.

TABLE 64.—*Statistics of observation wells in the Independence region*—Continued.

Well No.	Location.			Class of well.	Depth of well (feet).	Elevation of ground surface (feet).	Elevation of bench mark (feet).	Description of surface conditions.
	T.	R.	Sec.					
GL-1	12 S.	34 E.	35	4-foot diameter dug well	12.3	3,884.9	3,885.91	Upper edge of meadow.
GL-1A	12 S.	34 E.	35	.....do	13.5	3,882.3	3,882.85	Do.
GL-2	12 S.	34 E.	35	2-inch test hole	7.5	3,834.3	3,834.34	Tule grass and sunflowers, black soil, no alkali.
GL-3	12 S.	34 E.	35	2-inch test hole in pit	7.0	3,804.6	3,803.75	Salt grass, light soil, no alkali.
GL-4	12 S.	34 E.	25	2-inch test hole	6.0	3,788.8	3,788.79	Luxuriant salt and tule grass, clay, no alkali.
GL-5	12 S.	34 E.	25	.....do	4.5	3,792.2	3,792.19	Salt grass, black soil, alkali deposit.
GL-6	12 S.	35 E.	30	.....do	9.5	3,792.5	3,792.54	Salt grass and sagebrush, mounds, hog-wallow surface, alkali crust
GL-7	12 S.	35 E.	30	.....do	7.5	3,791.8	3,791.76	Same as GL-6, less alkali.
GL-8	12 S.	35 E.	19	.....do	4.0	3,781.4	3,781.41	Luxuriant salt grass, black soil, alkali at grass roots.
GL-9	12 S.	35 E.	19	.....do	6.0	3,783.4	3,783.41	Do.
GL-10	12 S.	35 E.	19	.....do	7.0	3,784.1	3,784.11	Do.
GL-11	12 S.	35 E.	19	.....do	7.5	3,785.1	3,785.06	Salt grass, light soil, spots of alkali.
GL-12	12 S.	35 E.	19	.....do	7.5	3,786.4	3,786.36	Do.
GL-13	12 S.	35 E.	19	.....do	7.5	3,786.4	3,786.41	Do.
GL-14	12 S.	35 E.	29	.....do	5.5	3,786.8	3,786.76	Same as GL-11, west of fault.
GL-14A	12 S.	35 E.	29	.....do	7.5	3,786.3	3,786.26	Same as GL-11, east of fault.
GL-15	12 S.	35 E.	29	.....do	7.5	3,789.8	3,789.76	Same as GL-11, some sagebrush.
57	12 S.	34 E.	36	2-inch test hole in pit	7.0	....	....	Luxuriant salt grass, little rabbit brush, no alkali.
55	12 S.	34 E.	36	2-inch test hole	9.0	....	....	Salt grass and rabbit brush, soil puffed with alkali.
54	12 S.	35 E.	....	.....do	8.5	....	....	Luxuriant salt grass, clay soil, little alkali.
O-8	13 S.	35 E.	5	.....do	9.5	3,812.6	3,812.50	Luxuriant salt grass and sunflowers, clay soil, no alkali.
O-7	13 S.	35 E.	5	.....do	9.5	3,803.5	3,803.54	Do.
O-9	13 S.	35 E.	5	....	8.5	3,796.4	3,796.40	Luxuriant salt grass, sandy soil, trace of alkali.
O-6	13 S.	35 E.	5	2-inch test hole	7.5	3,788.8	3,788.66	Salt grass, clay soil, no alkali.
O-5	13 S.	35 E.	5	.....do	9.5	3,788.1	3,787.89	Luxuriant grass and sunflowers, clay soil, no alkali.
O-4	12 S.	35 E.	32	....	9.0	3,784.2	3,783.74	Scattering salt grass and a few sunflowers, sandy, clay, little alkali.
O-3A	12 S.	35 E.	32	2-inch test hole	6.0	3,776.3	3,776.31	Short salt grass, sandy, little alkali.
O-3	12 S.	35 E.	32	.....do	6.0	3,773.4	3,773.35	Elevation west of fault, 3,782.2 feet; surface same as O-3A.
O-2	12 S.	35 E.	33	.....do	7.5	3,772.3	3,772.27	Little sagebrush on mounds, bare hog-wallow land, thick alkali crust.
63	13 S.	34 E.	1	3-foot diameter dug well	23.0	3,947.9	3,947.92	Bare sandy black soil, irrigated land south and east.
53	13 S.	35 E.	5	2-inch test hole	9.0	....	....	Luxuriant salt grass, light clay soil puffed with alkali.
52	13 S.	35 E.	5	.....do	7.5	3,803.1	3,803.10	Luxuriant salt grass and little rabbit brush, deep soil, no alkali.
51	13 S.	35 E.	5	....	7.5	3,787.7	3,787.70	Rabbit brush and luxuriant salt grass, light soil, no alkali.
50	13 S.	35 E.	4	2-inch test hole	9.5	3,782.7	3,782.70	Luxuriant salt grass, clay soil puffed with alkali.
49	13 S.	35 E.	3	.....do	3.5	3,766.2	3,766.20	Sagebrush on mounds, bare hog-wallow land, alkali crust.
U-1	13 S.	35 E.	8	.....do	7.5	3,866.3	3,865.67	Salt grass and rabbit brush, gravelly soil, alkali at roots.
U-1A	13 S.	35 E.	8	.....do	7.0	3,866.3	....	Do.
U-2	13 S.	35 E.	8	.....do	6.5	3,827.6	3,827.16	Same as U-1, sandy soil.
U-3	13 S.	35 E.	9	.....do	7.0	3,802.5	3,802.53	Same as U-1, clay soil.
U-4	13 S.	35 E.	4	.....do	11.5	3,779.0	3,779.00	Salt grass, light clay soil puffed with alkali.
U-5	13 S.	35 E.	3	.....do	7.5	3,775.1	3,775.10	Rabbit brush and scattering salt grass, light clay soil, little alkali.

U-6A	13 S.	35 E.	3	.....do......................	4.0	3,768.4	3,768.40	Green tule grass, hole in face of bank.
U-6	13 S.	35 E.	3	.....do......................	7.5	3,768.0	3,768.00	Elevation west of fault, 3,772 feet; salt grass, light clay soil.
U-8	13 S.	35 E.	3	.....do......................	7.5	3,760.7	3,760.70	Sagebrush on mounds, bare hog-wallow land, alkali in spots.
U-7	13 S.	35 E.	3	.....do......................	6.5	3,759.5	3,759.50	Tule grass in bunches, sandy, no alkali.
62	13 S.	35 E.	17	6-foot diameter dug well.....	30.0	3,922.5	3,922.46	Irrigated garden, formerly sand and sagebrush, sandy black soil.
61	13 S.	35 E.	17	4-foot diameter dug well.....	53.0	3,940.2	3,940.18	Do.
64	13 S.	35 E.	7	4 by 4 foot dug well..........	26.5	3,902.4	3,902.38	Sagebrush, gravel and sand.
35	13 S.	35 E.	9	2-inch test hole..............	5.5	3,831.5	3,831.47	Luxuriant grass, gravelly soil, no alkali.
30	13 S.	35 E.	10	4-inch casing well...........	18.3	3,787.1	3,787.77	Salt grass and rabbit brush, clay soil, no alkali.
36	13 S.	35 E.	9	2-inch test hole..............	7.5	3,779.1	3,779.08	Salt grass, clay soil, no alkali.
48	13 S.	35 E.	3	.....do......................	9.5	3,778.2	3,779.14	Salt grass, dark clay soil puffed with alkali.
I-2	13 S.	35 E.	16	.....do......................	9.5	3,849.6	3,849.60	Salt grass, tule grass and willows, sandy soil, no alkali.
I-3	13 S.	35 E.	16	.....do......................	3.5	3,836.7	3,836.70	Luxuriant salt and tule grass, black soil, little alkali.
I-4	13 S.	35 E.	16	.....do......................	7.5	3,809.4	3,809.40	Scattering salt grass, clay soil, alkali at roots.
I-5	13 S.	35 E.	16	.....do......................	6.0	3,792.0	3,791.48	Rank growth bunch grass, rabbit brush, clay soil, little alkali.
I-6	13 S.	35 E.	15	2 by 4 foot hole..............	3.0	3,774.3	3,773.60	Short salt grass, black soil, no alkali.
I-6A	13 S.	35 E.	15	2-inch test hole..............	9.0	3,775.3	3,775.22	Salt grass, sandy soil, little alkali.
I-6B	13 S.	35 E.	15	4-inch casing well...........	6.0	3,775.2	3,776.93	Do.
I-7	13 S.	35 E.	10	2-inch test hole..............	8.0	3,764.8	3,764.35	Bunch salt grass, bare sandy soil, no alkali.
31	13 S.	35 E.	21	6-inch casing well...........	25.0	3,875.3	3,876.06	Sagebrush, desert sand, no alkali.
1	13 S.	35 E.	21	4 by 4 foot well..............	7.0	3,837.5	3,839.18	Luxuriant salt grass, black soil, no alkali.
2	13 S.	35 E.	16	2-inch test hole..............	7.5	3,803.9	3,803.90	Bunch salt grass, light soil, little alkali.
14	13 S.	35 E.	15	6-foot diameter dug well.....	7.5	3,812.3	3,812.82	Salt grass, sandy soil, alkali at grass roots.
37	13 S.	35 E.	15	2-inch test hole..............	6.5	3,766.4	3,766.48	Salt grass, sagebrush, clay soil puffed with alkali.
37A	13 S.	35 E.	15	.....do......................	5.0	3,766.4	....	Do.
Ȼ-1	13 S.	35 E.	21	4 by 4 foot dug well..........	27.7	3,889.6	3,890.41	Sagebrush, desert sand, no alkali.
Ȼ-3	13 S.	35 E.	22	2-inch test hole..............	6.0	3,812.9	3,812.94	Luxuriant salt grass, sandy soil, a little alkali.
Ȼ-4	13 S.	35 E.	22	3 by 5 foot pit...............	5.5	3,804.3	3,801.87	Luxuriant salt grass, clay soil, alkali crust in spots.
Ȼ-5A	13 S.	35 E.	22	2-inch test hole..............	6.5	3,779.8	3,779.85	Salt grass, clay soil, little alkali.
Ȼ-6	13 S.	35 E.	15	.....do......................	7.5	3,765.7	3,765.72	Bunch salt grass, clay soil, alkali crust.
Ȼ-6A	13 S.	35 E.	22	.....do......................	6.5	3,766.2	3,766.15	Do.
Ȼ-7	13 S.	35 E.	14	.....do......................	6.5	3,762.1	3,761.92	Scattering salt grass and sagebrush, light clay soil, alkali crust.
Ȼ-8	13 S.	35 E.	14	.....do......................	8.0	....	....	Sagebrush, sandy soil, no alkali.
28	13 S.	35 E.	21	6-inch casing well...........	26.3	3,869.0	3,870.33	Scattering salt grass and rabbit brush, desert sand, no alkali.
28A	13 S.	35 E.	21	5 by 5 foot dug well..........	15.0	3,869.1	3,871.01	Do.
13A	13 S.	35 E.	27	2-inch test hole..............	7.5	3,842.6	3,842.64	Scattering salt grass, sagebrush, desert sand, no alkali.
4	13 S.	35 E.	27	.....do......................	6.0	3,803.3	3,803.31	Scattering salt grass, sandy soil, no alkali.
5	13 S.	35 E.	22	3 by 6 foot test hole.........	6.5	3,802.6	3,799.55	Salt grass, black soil, little alkali.
32	13 S.	35 E.	23	4 by 4 foot dug well..........	7.0	3,765.0	3,765.02	Salt grass and sagebrush, clay soil, little alkali.
38	13 S.	35 E.	23	2-inch test hole..............	7.5	3,765.4	3,765.15	Salt grass, clay soil, little alkali.
L-6	13 S.	35 E.	27	.....do......................	9.5	3,848.2	3,848.24	Scattering salt grass and sage and rabbit brush, light clay soil, no alkali.
L-5	13 S.	35 E.	27	.....do......................	7.5	3,810.3	3,810.74	Salt grass, sunflowers, and rosebushes, clay soil, no alkali.
L-4	13 S.	35 E.	27	3 by 6 foot test pit..........	5.5	3,799.0	3,798.90	Luxuriant salt grass, clay soil, alkali at grass roots, and surface caked.
L-3	13 S.	35 E.	27	2-inch test hole..............	4.5	3,768.4	3,768.03	Scattering salt grass, clay soil, no alkali.
L-2	13 S.	35 E.	26	.....do......................	7.2	3,757.0	3,757.03	Scattering salt grass, sagebrush, sandy soil, little alkali.
L-1	13 S.	35 E.	26	.....do......................	5.0	3,741.6	3,741.59	Elevation west of fault, 3,752.5 feet; scattering salt grass, little alkali.
7	13 S.	35 E.	34	3 by 6 foot test pit..........	5.0	3,796.5	3,795.50	Luxuriant salt grass, clay soil, alkali crust.
6	13 S.	35 E.	34	.....do......................	6.0	3,800.3	3,797.60	Do.
46	13 S.	35 E.	34	2-inch test hole..............	7.0	3,772.4	(3,772.4)	Luxuriant salt grass, rosebushes, black soil, no alkali.
40	13 S.	35 E.	35	.....do......................	7.5	3,772.8	(3,772.8)	Salt grass, clay soil puffed with alkali.
39	13 S.	35 E.	26	.....do......................	7.0	3,759.7	(3,759.7)	Salt and tule grass, clay soil, little alkali.

TABLE 64.—*Statistics of observation wells in the Independence region*—Continued.

Well No.	Location.			Class of well.	Depth of well (feet).	Elevation of ground surface (feet).	Elevation of bench mark (feet).	Description of surface conditions.
	T.	R.	Sec.					
39A	13 S.	35 E.	26	2-inch test hole	7.0	3,760.0	(3,759.9)	Salt grass, clay soil puffed with alkali.
S-2	14 S.	35 E.	3	3 by 6 foot pit	6.0	3,797.8	3,797.69	Luxuriant salt grass, alkali crust.
S-3	13 S.	35 E.	35	2-inch test hole	3.5	3,769.8	3,769.80	Luxuriant salt grass, black soil, alkali crust.
S-4	13 S.	35 E.	35	.....do	7.0	3,759.1	3,759.14	Same as S-3, sandy soil.
S-5	13 S.	35 E.	35	.....do	7.5	3,743.2	3,743.24	Scattering salt grass, light soil, alkali crust.
S-6	13 S.	35 E.	36	3-inch cast-iron pipe, 4 by 4 foot well.	19.3	3,740.5	3,737.05	Same as S-5, no alkali.
S-7	13 S.	35 E.	36	2-inch test hole	6.0	....	....	Luxuriant tule grass, black soil, no alkali.
47	14 S.	35 E.	1	.....do	5.5	3,745.2	3,745.16	Scattering salt grass and rabbit brush, sandy soil, alkali crust.
C-3	14 S.	35 E.	11	5-foot diameter dug well	14.3	3,791.6	3,790.26	Sage and rabbit brush, desert sand, no alkali.
C-4	14 S.	35 E.	1	2-inch test hole	9.5	3,760.1	3,760.10	Little sagebrush and bunch salt grass, light clay soil, little alkali.
C-5	14 S.	35 E.	1	.....do	8.0	3,731.8	3,731.77	Little salt grass and sagebrush, sandy soil, no alkali.
29	14 S.	35 E.	15	4 by 4 foot dug well	19.5	3,868.2	3,870.38	Sagebrush and desert sand, irrigation near by.
9	14 S.	35 E.	11	2-inch test hole in pit	12.0	3,796.6	3,788.40	Large sagebrush, desert sand, no alkali.
8	14 S.	35 E.	11	.....do	9.5	3,795.3	3,792.16	Bunch salt grass, sandy soil, no alkali.
W-7	14 S.	35 E.	14	2-inch test hole	7.0	3,821.6	3,821.55	General elevation 400 feet north, 3,826 feet; luxuriant grass, black soil, alkali spots.
W-6	14 S.	35 E.	14	3 by 6 foot pit	5.0	3,794.4	3,793.88	Salt grass and sagebrush, sandy soil, a little alkali.
W-5	14 S.	35 E.	14	2-inch test hole	6.2	3,780.4	3,779.00	Scattering salt grass, sandy soil, no alkali.
W-4	14 S.	35 E.	12	.....do	7.0	3,755.2	3,755.20	Scattering salt grass and sagebrush, sandy soil, little alkali.
W-3H	14 S.	35 E.	12	.....do	4.0	3,747.1	3,747.10	Bunch salt grass, sandy soil, alkali crust.
W-3B	14 S.	35 E.	12	.....do	3.0	3,743.8	3,743.84	Tule grass, black soil, no alkali.
W-3C	14 S.	35 E.	12	.....do	3.5	3,742.6	3,742.55	Do.
W-3A	14 S.	35 E.	12	.....do	3.5	3,740.5	3,740.53	Do.
W-3D	14 S.	35 E.	12	.....do	3.5	3,736.8	3,736.77	Do.
W-3	14 S.	35 E.	12	.....do	5.0	3,735.8	3,735.78	Do.
W-3E	14 S.	35 E.	12	.....do	3.0	3,735.5	3,735.53	East edge of tule grass at sand.
W-3F	14 S.	35 E.	12	.....do	5.5	3,736.3	3,736.26	Sand, very little vegetation.
W-3G	14 S.	35 E.	12	.....do	3.0	3,736.4	3,736.45	Tule grass, black soil, no alkali.
W-2	14 S.	35 E.	12	.....do	9.5	3,722.7	3,722.71	Salt grass, clay soil, no alkali.
43	14 S.	35 E.	14	6 by 6 foot dug well	9.0	3,862.0	3,862.13	Scattering salt grass and rabbit brush, sandy soil, no alkali.
33	14 S.	35 E.	14	3 by 3 foot dug well	5.0	3,834.7	3,834.66	Tule and salt grass, black soil, no alkali.
10A	14 S.	35 E.	14	2-inch test hole	7.5	3,795.5	3,795.47	Scattered salt grass, sage and rabbit brush, sandy soil, little alkali.
11A	14 S.	35 E.	24	.....do	7.0	3,789.0	3,789.02	Do.
12	14 S.	35 E.	24	2.5-foot dug well	12.0	3,796.8	3,799.07	Luxuriant salt grass, no alkali.
34	14 S.	35 E.	13	4-foot dug well	11.0	3,757.6	3,759.90	Elevation west of fault, 3,767.2 feet; bare coarse sand, alkali crust.
41	14 S.	35 E.	13	2-inch test hole	4.0	....	....	Salt grass, light soil, thick alkali crust.
G-3	14 S.	35 E.	24	.....do	7.5	3,767.6	3,767.23	Bunch salt grass and sagebrush, sandy soil, no alkali.
G-4	14 S	36 E.	19	.....do	7.0	3,728.3	3,728.26	Luxuriant salt grass, sandy soil, little alkali.
G-5	14 S.	36 E.	19	4 by 4 foot dug well	6.5	3,698.3	3,701.91	Salt grass, little alkali.
G-6	14 S.	36 E.	19	2-inch test hole	7.0	3,693.6	3,692.48	Sagebrush and salt grass on mounds, hog-wallow land, alkali crust.

Table 65.—*Maximum and minimum ground-water levels in observation wells of the valley floor.*

No. of well.	1908		1909				Amount of fluctuation.		
	Lowest level.		Highest level.		Lowest level.		1908 minimum to 1909 maximum.	1909 maximum to 1909 minimum.	Assumed average.
	Date.	Depth below ground.	Date.	Depth below ground.	Date.	Depth below ground.			
A-4	Sept. 1	7.4			Oct. 19	6.0			4.0
A-3	Oct. 2	5.8	Mar. 10	4.9			0.9	2.5	2.0
A-2A	Aug. —	(4.5)	Mar. 30	1.1	Aug. 26	3.5	(3.4)	2.4	2.9
A-2	Aug. —	(5.2)	Jan. 22	2.3	July 21	4.5	(3.0)	2.2	2.6
22	Oct. 2	8.9	Mar. 30	.8			8.1		6.0
D-4	Aug. —	(7.0)					2.1		2.0
D-3	(Sept. 1)	(5.2)	Jan. 22	2.0	Aug. 27	5.1	(3.2)	3.1	3.2
D-2	(Sept. 1)	(4.1)	Mar. —	(2.4)	Aug. 26	3.9	(1.7)	(1.5)	2.0
D-1	(Sept. 1)	(2.0)	Jan. 22	.6	Sept. 21	1.8	(1.4)	1.2	1.0
21	Sept. 7	7.3	Mar. 11	3.4			3.9		4.0
20	Aug. —	(5.7)	Mar. 10	2.6			(3.1)		3.1
18	Oct. 24	4.3	Mar. —	(2.3)	(Sept. —)	4.2	(2.0)	(1.9)	2.0
19	Sept. 7	6.2	Mar. 11	3.3	Sept. 22	5.1	2.9	1.8	2.2
B-2	Oct. 24	8.7	Mar. 3	(6.0)	Aug. 26	8.6	(2.7)	(2.6)	2.7
B-3	Oct. 24	6.2	Mar. 1	0.9			5.3		5.3
B-4	Sept. 16	5.3	Mar. 10	2.2	Sept. 22	5.6	3.1	3.4	3.2
B-6	Aug. —	(3.0)	Mar. 10	1.4	Aug. 27	3.4	(1.6)	2.0	1.8
B-6A			Dec. 8, '08–Mar. 10, '09	.4	Aug. 27	3.8		3.4	3.4
45			Mar. 7	7.4	Sept. 21	9.3		1.9	2.0
SM-1	Aug. —	(6.5)	Jan. 23	2.6	June 20	4.3	(3.9)	1.7	2.8
SM-3		(5.5)	Mar. 3	.7	Aug. 26	4.4	(4.8)	3.7	4.2
SM-4	Sept. 1	3.2			July 22	3.4			2.5
T-1	Nov. 10	9.7	Apr. 20	6.4	Oct. 20	9.6	3.3	3.2	3.2
T-2	Oct. 4	6.9	Mar. 29	1.1	Sept. 21	6.8	5.8	5.7	5.8
T-3	Oct. 4	4.1	Mar. 28	1.8	Sept. 21	3.9	2.3	2.1	2.2
T-4			Oct. 4, '08–Apr. 1, '09	1.1	May 25	2.6		1.5	1.5
T-6	Aug. —	(5.0)	Mar. 10	1.0	July 21	4.4	(4.0)	3.4	3.7
T-7	Sept. —	7.3	(Mar. 30)	(1.0)	Aug. 27	6.7	6.3	5.7	6.0
T-8			Feb. 27	.6	Oct. 19	5.8		5.2	5.2
17	Sept. 1	8.3							4.0
16	Aug. —	(12.5)	Mar. 29	6.3				6.2	6.0
15			Dec. 7, '08	2.6	Aug. 26	6.4		3.8	3.8
56			Mar. 29	2.5	Sept. 21	6.6		4.1	4.1
GL-1	Aug. 31	9.7	Mar. 29	8.0	May 28	8.5	1.7	.5	1.1
GL-1A	Aug. 31	7.2	Mar. 8	5.6	May 28	6.0	1.6	.4	
GL-2	Aug. —	(6.1)	Nov. 7, '08–Mar. 29, '09	1.7	Sept. 21	7.4	4.4	5.7	5.0
GL-3	Aug. —	(8.5)	Mar. 28	1.8	Oct. 20	7.8	(6.7)	6.0	6.4
GL-4	Aug. 31	5.1	Mar. 8	.2	Sept. 21	6.0	4.9	5.8	5.4
GL-6	Nov. 9	9.3	Apr. 21	5.7	Oct. 18	8.6	3.6	2.9	3.2
GL-7	Dec. 8	6.6	(Apr. 21)	(2.5)	Oct. 18	6.5	4.1	4.0	4.0
Goose Lake	Oct. 24	2.0	Apr. 24	+.3	Oct. 18	2.2	2.3	2.5	2.4
GL-8	Sept. 1	1.1	Jan. 1–June 26.	(a)	Sept. 22	1.7			
GL-9	(Sept. 1)	(3.5)	Apr. 21	.7	Sept. 22	3.9	(2.8)	3.2	3.0
GL-10	(Sept. 1)	(4.3)	Apr. 21	1.2	Sept. 22	4.2	(3.1)	3.0	3.0
GL-11	Sept. 1	4.3	Mar. 30	1.8	July 21	4.2	2.5	2.4	2.4
GL-12	(Sept. 1)	(5.8)	Apr. 21	2.8	Aug. 27	5.6	(3.0)	2.8	2.9
GL-13	(Sept. 1)	(5.3)	Apr. 21	2.6	Sept. 22	5.2	(2.7)	2.6	2.6
GL-14	(Sept. 1)	(4.8)	Apr. 21	2.6	Sept. 22	4.5	(2.2)	1.9	2.0
GL-14A	Sept. 1	(5.0)	Apr. 21	2.6	Sept. 22	5.0	(2.4)	2.4	2.4
GL-15			Apr. 21	5.9	Sept. 22	7.6		1.7	1.7
57			Mar. 29	3.2	Oct. 20	6.2		3.0	3.0
55			Apr. 20	3.3	Sept. 21	6.4		3.1	3.1
O-8	Sept. —	(8.0)	Mar. 29	2.3	Sept. 21	6.2	(5.7)	3.9	4.8
O-7	Sept. —	(9.3)	Mar. 25	2.9	Oct. 16	7.4	6.4	4.5	5.4
O-9	Sept. —	(8.0)	Apr. 24	5.9	Sept. 21	7.8	(2.1)	1.9	2.0
O-6	Aug. —	(7.0)	Apr. 20	3.0	Aug. 25	5.1	(4.0)	2.1	3.0
O-5	Sept. —	(9.4)	Mar. 8	2.7	Oct. 16	9.9	6.7	7.2	7.0
O-4	Oct. 1	8.4	Mar. 29	5.5	Oct. 16	8.2	2.9	2.7	2.8
O-3A	Oct. 24	4.2	Mar. 25	2.4	Oct. 16	4.0	1.8	1.6	1.7
O-3	Oct. 1	3.2	Mar. 8–Apr. 20	1.4	Sept. 22	3.2	1.8	1.8	1.8
O-2	Oct. 25	5.0	Mar. 6	3.6	Oct. 16	5.2	1.4	1.6	1.5

[a] Flooded.

TABLE 65.—*Maximum and minimum ground-water levels in observation wells of the valley floor*—Continued.

No. of well.	1908		1909				Amount of fluctuation.		
	Lowest level.		Highest level.		Lowest level.				
	Date.	Depth below ground.	Date.	Depth below ground.	Date.	Depth below ground.	1908 minimum to 1909 maximum.	1909 maximum to 1909 minimum.	Assumed average.
53	....	....	Mar. 25	2.9	July 24	6.2	....	3.3	3.6
52	....	....	Mar. 16	2.1	Oct. 16	6.4	....	4.3	....
50	....	....	Mar. 4	2.4	Oct. 16	9.6	....	7.2	7.0
49	....	....	Mar. 29	1.7	Oct. 16	3.6	....	1.9	1.9
U-1	Aug. —	(7.2)	Mar. —	(3.0)	Aug. 25	6.5	(4.2)	(3.5)	3.8
U-2	Aug. —	(4.7)	Feb. 20	.6	Sept. 13	4.6	(4.1)	4.0	4.0
U-3	Aug. —	(5.5)	Feb. 20	1.4	Sept. 13	5.0	(4.1)	3.6	3.8
U-4	....	....	Mar. 29	3.2	Oct. 1	5.8	....	2.6	....
U-5	Sept. 1–Oct. 1	4.3	Mar. 29	1.3	Aug. 25	4.7	3.0	3.4	3.2
U-6A	Sept. —	.5	Feb. 1–May 6	Flowing.	Aug. 25	1.1	.5	1.1	.8
U-6	Aug. —	(5.9)	Mar. 29	1.2	Sept. 22	7.3	4.7	6.1	5.4
U-8	....	....	(Mar. 12)	(3.2)	Sept. 22	5.2	....	2.0	2.0
U-7	Dec. 8	5.4	Apr. 20	4.5	Oct. 16	6.0	.9	1.5	1.2
L-6	Sept. —	(10.0)	Jan. 1–Mar. 29	8.9	July 25	9.6	(1.1)	.7	.9
L-5	Aug. —	(4.8)	Mar. 29	.6	Aug. 16	4.8	(4.2)	4.2	4.2
L-4	Sept. 3	2.6	Feb. 16	.7	July 24	2.2	1.9	1.5	1.7
L-3	Aug. —	(4.6)	Mar. 15	2.7	Aug. 27	4.2	(1.9)	1.5	1.7
L-2	Aug. —	(4.7)	Apr. 20	2.6	Aug. 27	5.0	(2.1)	2.4	2.2
L-1	Aug. —	(4.2)	Mar. 27	.4	July 22	3.6	3.8	3.2	3.5
Lake	....	....	Mar. 27	.4	Sept. 8	2.6	....	2.2	2.2
7	Sept. 1	4.1	Mar. 5	.3	July 24	3.8	3.8	3.5	3.6
6	Sept. 18	4.9	Mar. 29	2.5	Sept. 21	5.1	2.4	2.6	2.5
46	....	....	Feb. 16–Mar. 29	.1	Aug. 27	4.2	....	4.1	4.1
40	....	....	Mar. 29	1.7	July 24	5.2	....	3.5	3.5
39A	....	....	Mar. 27	2.6	Sept. 13	5.4	....	2.8	2.8
S-2	Sept. 1	5.3	Mar. 29	1.9	Aug. 31	4.8	3.4	2.9	3.2
S-3	Aug. —	(3.0)	Jan. 30–Mar. 29	.4	Sept. 17	3.5	(2.6)	3.1	2.8
S-4	Aug. —	4.0	Mar. 29	.8	Sept. 21	3.0	3.2	2.2	2.7
S-5	Sept. —	7.4	Apr. 20	6.0	Sept. 21	8.0	1.4	2.0	1.7
47	....	....	Apr. 20	2.1	Oct. 17	6.2	....	4.1	4.1
C-3	Oct. 1	14.6	Apr. 22	12.2	Sept. 21	15.2	2.4	3.0	2.7
C-4	(Sept. 1)	8.8	Apr. 28	6.6	Oct. 17	8.9	2.2	2.3	2.2
C-5	Aug. —	(7.0)	Apr. 20	4.4	Sept. 20	6.2	(2.6)	1.8	2.2
8	Aug. —	(8.7)	Mar. 29	6.2	Sept. 21	8.0	(2.2)	1.8	2.0
30	Sept. —	(4.3)	Feb. 16	.9	Sept. 20	4.5	(3.4)	3.6	3.6
36	Sept. —	(7.0)	Feb. 17	1.5	Oct. 17	5.2	(5.5)	3.7	4.3
48	....	....	Mar. 29	7.2	Sept. 21	8.8	....	1.6	1.6
I-2	Aug. —	(9.0)	Mar. 6	3.9	Sept. 13	5.4	5.1	1.5	3.5
I-3	Aug. —	(3.9)	Dec. '08–Mar. 27	1.1	....	....	2.8	....	2.8
I-4	Aug. —	(5.9)	Jan. 16–Feb. 16	.5	Sept. 20	5.2	5.4	4.7	5.0
I-5	Sept. 1	5.4	Mar. 27	1.7	Sept. —	5.4	3.7	3.7	3.7
I-6A	Sept. 1	(5.3)	Feb. 16	1.3	Aug. 27	4.2	4.0	2.9	3.4
I-6B	....	....	Mar. 27	.2	Aug. 26	3.5	....	3.3	3.3
I-7	Oct. 1	6.2	Apr. 20	4.4	....	....	1.8	....	1.8
1	Sept. 1	5.6	Feb. 16	2.0	Aug. 27	6.3	3.6	4.3	4.0
2	....	....	Mar. 27	.8	Sept. 12	4.1	....	3.3	3.3
14	Sept. 14	6.5	Mar. 27	2.6	Sept. 5	(6.5)	3.9	3.9	3.9
C-3	Aug. —	5.5	Mar. 29	3.3	Sept. 21	5.7	2.2	2.4	2.3
C-4	Sept. 1	4.25	Feb. 16	1.15	Aug. 27	4.6	3.1	3.4	3.2
C-5A	Oct. 9	4.2	Mar. 13	(1.2)	Sept. 5	4.8	3.0	3.6	3.3
C-6A	Oct. 24	3.1	Feb. 16	.7	Aug. 27	3.8	2.4	3.1	2.8
13A	Aug. —	(7.5)	Mar. —	5.0	July 24	6.9	(2.5)	1.9	2.2
4	....	....	Mar. 29	1.9	Sept. 13	4.6	....	2.7	2.7
5	Sept. 1	4.5	Feb. 16	2.4	Aug. 16	4.7	2.1	2.3	2.2
32	Aug. —	(5.2)	Mar. 27	2.6	Sept. 13	4.9	(2.6)	2.3	2.4
38	Sept. —	(6.3)	Apr. 20	2.3	Sept. 20	4.8	(4.0)	2.5	3.2
W-7	Sept. 6	5.6	Mar. 27	.5	....	....	5.1	....	5.1
W-6	Oct. 1	4.7	Apr. 20	2.6	....	....	2.1	....	2.1
W-5	Oct. 2	7.9	Mar. 6–Apr. 20	6.7	Oct. 17	7.9	1.2	1.2	1.2
W-4	....	....	Mar. 6	5.4	Oct. —	(8.3)	....	2.9	2.9
W-3B	Aug. —	(3.0)	Mar. 27	.8	Sept. 20	2.9	(2.2)	2.1	2.1
43	Oct. 25	7.9	Jan. 30	4.1	Sept. 21	7.8	3.8	3.7	3.8
10A	Oct. 25	6.7	June 22	4.4	....	....	2.3	....	2.3
12	Sept. 1	4.1	Mar. 6	1.3	Oct. 17	3.9	2.8	2.6	2.7
G-3	Aug. —	(7.0)	Mar. 15	4.1	Aug. 26	6.5	(2.9)	2.4	2.6
G-6	Aug. —	(7.0)	Apr. 22	3.7	Nov. 21	6.9	(3.3)	3.2	3.2
Average	Sept. 20	....	Mar. 28	....	Sept. 20	....	3.19	2.97	3.14

TABLE 66.—*Total evaporation from grass and alkali lands in the valley floor.*

Inclosing contours	Area (square miles).	Average depth to ground-water (feet).	Annual depth of evaporation (inches).			Equivalent flow (second-feet).
			Summer.	Winter.	Total.	
3 feet	11.89	2.5	28.2	6.8	35.0	31
3-4 feet	17.66	3.5	22.5	5.4	27.9	36
4-8 feet	25.04	5.5	11.4	2.7	14.1	26
	54.59					93

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