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CHARLES D. WALCOTT, DIRECTOR

IRRIGATION NEAR BAKERSFIELD, CALIFORNIA

BY

CARL EWALD GRUNSKY

WASHINGTON
GOVERNMENT PRINTING OFFICE
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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, July 1, 1898.

SIR: I have the honor to transmit herewith a manuscript entitled Irrigation near Bakersfield, California, prepared by Mr. C. E. Grunsky, and to recommend that it be published in the series of pamphlets on Water Supply and Irrigation. This paper is the first of three relating to San Joaquin Valley, the others being entitled, respectively, Irrigation near Fresno, California (No. 18 of the series), and Irrigation near Merced, California (No. 19 of the series), these titles being somewhat arbitrarily given to indicate the relative geographic position of the areas described. These papers taken collectively are intended to exhibit the character of the development of irrigation in the southern part of the great valley of California, and to give the methods there employed and the results of the experience acquired through many years.

In this, the first paper, some space has been devoted to a general description of San Joaquin Valley as a whole, and of the irrigation districts which have been organized within it, the history of these being briefly outlined. There is also added a description of the methods of irrigation commonly employed, as this has especial interest in connection with the more detailed statements regarding the individual canals and ditches. Following these more general matters Kern River is taken up, its drainage basin is discussed, and each of the numerous systems of water supply depending upon the river is described at some length. Then the creeks lying to the north, Poso and Deer, are decribed, as well as Tule River.

Although a relatively high degree of development of irrigation has been reached in this part of the arid region, yet the results are far below the possibilities. By means of better methods of water conservation and distribution, and more effective modes of intensive agriculture, the population and wealth of San Joaquin Valley may be almost indefinitely increased.. A full discussion, therefore, of this interesting area has value not only as showing what may be, to a certain extent, accomplished elsewhere, but also as illustrating the fact that great progress can still be made in this area.

Very respectfully,
F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

IRRIGATION NEAR BAKERSFIELD, CALIFORNIA.

By C. E. Grunsky.

INTRODUCTION.

The historical and descriptive treatment of irrigation in San Joaquin Valley as here presented is based largely upon information collected by the State engineering department of California ten years ago. That department ceased to exist in independent form in 1888. Its work was to be completed by the State mineralogist, who during the next two years was ex officio State engineer, and it was expected that a final report would be published, covering irrigation in central portions of the State, to supplement the two volumes already issued.[1] But the third volume of the final report has not appeared, and much of the collected material has been lost or is in unserviceable form, and none of it is conveniently accessible. Under these circumstances the writer, who, as chief assistant State engineer from 1882 to 1887, had charge of the collection of irrigation data in the field now under consideration, and of its preliminary arrangement for publication, believes it timely to give to the public at least such benefit as may result from a delayed publication of a portion of the collected information. To this end use has been made of what is left of official records, notebooks, sketches, and fragmentary manuscript (principally of the writer's own preparation), taking therefrom and grouping whatever seemed of sufficient importance to justify publication.

The facts obtained from this source have been supplemented by the results of subsequent personal experience in the field, and by accounts of irrigation works and of experience obtained from persons of local prominence, as well as by information secured on a special trip through the region under discussion, made in the spring of 1897.

It remains to be said that portions of the river descriptions and kindred matter have been taken from the report of the Examining Commission on Rivers and Harbors,[2] frequently without credit, as the writer was a member of that commission and author of its descriptive chapters.

[1] Irrigation Development, History, Customs, Laws, etc., in France, Italy, and Spain, by Wm. Ham. Hall, C. E., State Engineer, Sacramento, California, 1886; and Irrigation in California (Southern), Part 2 of Report of Wm. Ham. Hall, C. E., State Engineer of California, 1888.

[2] Report Examining Commission on Rivers and Harbors to the Governor of California; C. F. Reed, C. E. Grunsky, J. J. Crawford, commissioners; 1890.

It will be made apparent in these papers that irrigation development has been most rapid in those sections of the valley where rainfall is less than 10 inches a year and where water diversion from the streams is readily accomplished. There has been comparatively little irrigation in the great central valley northward from Merced River. This is due primarily to the greater natural fertility of the soils, resulting from more rainfall than in the upper or southern portions of the valley, but also to the fact that the principal rivers are considerably depressed below the general upland level, making the diversion of water for upland irrigation often difficult and always expensive. Vineyards and orchards in the lower portion of San Joaquin Valley and throughout Sacramento Valley yield fairly well without irrigation, and the standard crop, wheat, is rarely a complete failure. Protests have therefore at times been loud and emphatic against attempts to make water for irrigation available at general expense in this part of the great central valley of the State. Notwithstanding the active opposition which becomes manifest whenever the construction of comprehensive irrigation systems, such as would compel a modification of the present use of lands, is suggested, the spirit of unrest, discontent, and a desire to change conditions preponderates in many sections of the northern portion of the great central valley. This was demonstrated when opportunity was afforded to organize irrigation districts under the Wright law ten years ago. Seven out of eight districts proposed to the northward of Merced River were speedily organized. This desire to change from dry farming to the more intense cultivation of the soil made possible by irrigation is evidenced, too, by the success of a number of small irrigation works in and adjacent to Sacramento Valley. Among these are the irrigation ditches from Cache Creek, near Woodland, Moore Canal, Capay Ditch, and Adams Ditch. Thermalito, Palermo, and Orangevale may be cited as localities where the growth of citrus fruits is stimulated by the use of water. There is some irrigation from Stony Creek. Deer Creek supplies water for the great vineyard at Vina. Putah Creek is drawn upon for pump irrigation of a number of orchards and vineyards, and both stream and wind assist in raising ground water to the surface near Florin for the irrigation of orchards, vineyards, and gardens. It is not within the scope of this paper, however, to enumerate or describe the irrigation works of Sacramento Valley, and they are referred to merely as illustrating the gradual growth of sentiment in favor of the irrigated farm. The backset which irrigation has received by the unsatisfactory operation of the irrigation-district law will, it is hoped, be only a temporary check of healthful development under extensive systems of canals that should make much of the water of our best rivers, now flowing unused to the sea, do duty as an aid to agriculture.

The author desires to express his appreciation of the many courtesies extended to him in all parts of the valley in the work of collecting data,

and to thank those who have kindly contributed their knowledge of facts or have otherwise aided him or contributed material for this publication.

SAN JOAQUIN VALLEY.

San Joaquin Valley is the southern and larger portion of California's great central valley which lies between the Sierra Nevada on the east and the Coast Range on the west. Its length, measured along the axis of the valley, from near Stockton at its lower end to the base of the Tejon Mountains at its upper end, is 250 miles. The average breadth of the valley is over 40 miles. It is naturally divided into an east-side plain and a west-side plain, which slope with remarkable uniformity and smoothness of surface from the base of the hills upon either side toward the valley trough. Of these plains, that upon the east side of the valley, at the base of the Sierra Nevada, is by far the more extensive and the more important.

In their original condition the uplands of the valley were almost treeless. A few groves of oaks, some of considerable extent, were confined to the lands watered by Calaveras and Mokelumne rivers and lesser streams near Stockton; to the black land near Merced, principally to that watered by Bear and Mariposa creeks; and to the deltas of Kings, Kaweah, and Tule rivers. Some timber, too, was found on the river bottoms and on the submersible plain near the trough of the valley. Except where cottonwoods, willows, and occasional oaks or sycamores mark the course of the principal west-side creeks, all the unirrigated lands of the west-side plain and the abutting hills of the Coast Range are bare of trees.

The area of San Joaquin Valley is 11,500 square miles, which may be classified as follows: East-side plain, 7,700 square miles; west-side plain, 1,850 square miles; lands covered with water and lands subject to occasional inundation, about 1,950 square miles, of which 300 to over 900 square miles, according to the stage of Tulare Lake, are lake surfaces.

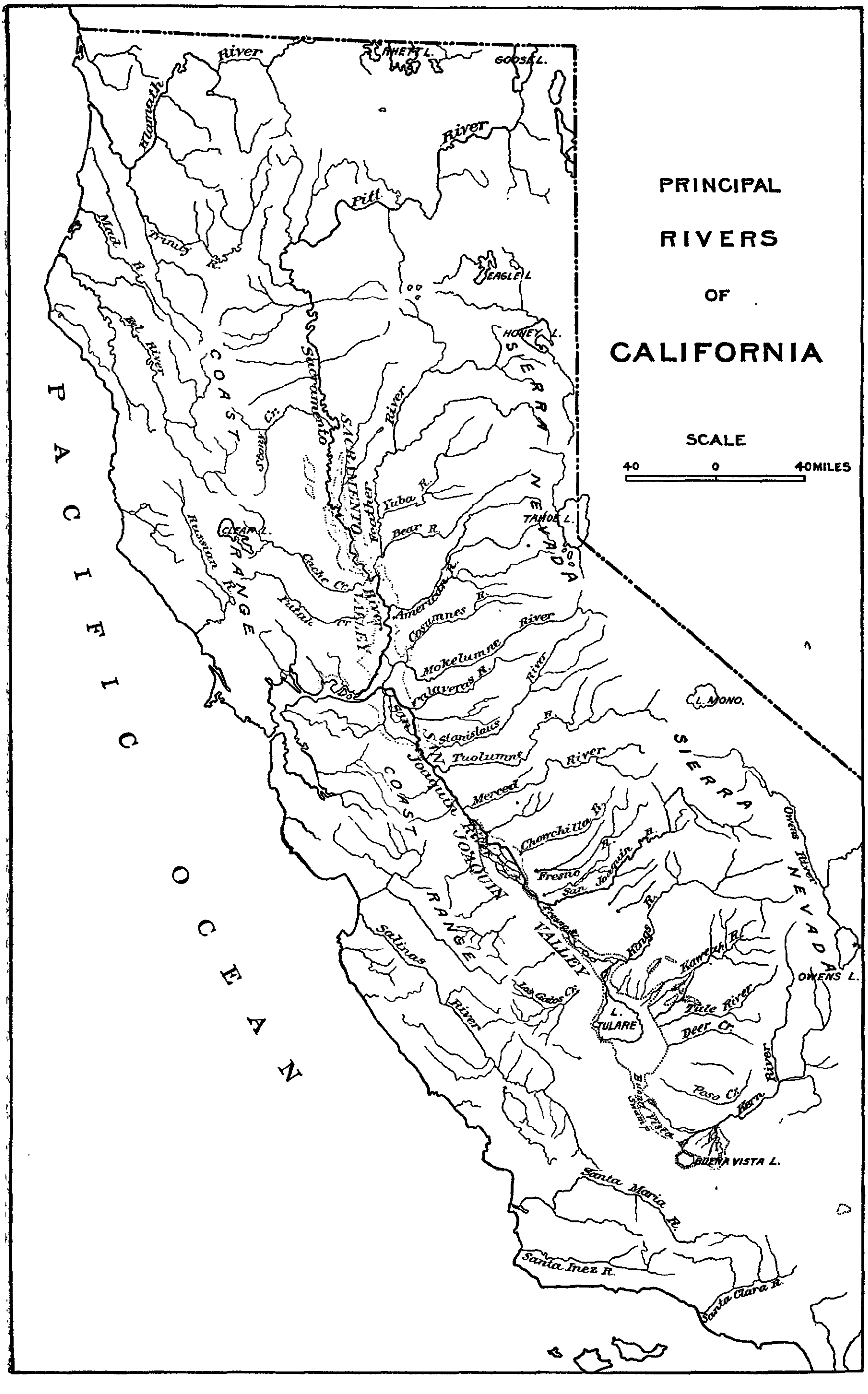
The mountain watershed tributary to the valley, including Cosumnes River, is 20,400 square miles in extent, of which less than one-fifth lies on the west, in the Coast Range, more than four-fifths being to the east, in the Sierra Nevada. Large rivers of perennial flow enter the valley from the east and cross the broad east-side plain, but on the west the numerous small creeks and gulches have no summer flow, and their channels are lost before they reach the main valley drain.

The valley may be considered as again divided into three portions by low, flat ridges built of silt deposits made by two of the principal east-side rivers, Kern River and Kings River, but the lines of demarcation are not features of any prominence. In both cases there has been a gradual pushing forward of the river deltas until basins or depressions have been formed above the crest line of each, thus giving rise to the Kern and Buena Vista lake basins in the one case and to the Tulare Lake basin in the other.

The former of these basins has never been one of sufficient capacity to prevent the annual outflow of Kern River waters toward the north by way of Buena Vista Swamp into Tulare Lake. The latter, however, repeatedly and for many years at a time, even before there was any diversion of water from tributary rivers for irrigation, has been so insufficiently supplied with water that it failed to overflow. During such periods the entire drainage basin above Tulare Lake, including ordinarily a portion of the flow of Kings River, is not tributary to San Joaquin River, whose watershed area is then reduced to about 19,000 square miles, of which about 7,500 square miles are valley lands, from which there is ordinarily little or no run-off.

Tulare Lake has frequently been under discussion as a source of water supply for irrigation. The following facts with reference to the fluctuations of its water surface will be of interest in connection with its availability for this purpose: In 1853, after several wet seasons, the lake was full, though probably not so high as subsequently, in 1862 or in 1868. From 1853 until 1861 there was a gradual subsidence of the low-water stage of the lake. The rate at which this occurred can not now be determined. In the fall of 1861 the water surface of the lake was at the elevation 204 feet above sea level (low water of Suisun Bay), if the testimony of residents at the lake at that time, in reference to the rise of water the following winter, can be relied upon. The unusually heavy rainfall of the winter of 1861–62 caused the lake to rise to the highest known stage—220 feet. Its area was increased from about 300 to about 800 square miles, and 300 billion cubic feet, or 6,885,000 acre-feet, of water were added to its contents. It continued to overflow at least until the spring of 1863, but then rapidly fell to about 11 or 12 feet below its highest stage, which was its condition in the fall of 1867. The inflow of water during the wet winter of 1867–68 again brought the lake nearly, if not quite, to the high-water stage of 1861–62.

The water surface fluctuated between 211 and 217 feet in the years 1872 to 1876, then receded rapidly to the lowest known stage—192 feet—in November, 1883. From that time to this the lake has not received sufficient water to cause it to overflow. It is generally believed that the diversion of water for irrigation purposes from Kern, Tule, Kaweah, and Kings rivers has been the cause of the decrease of water volume in the lake, but this is not true. Although such diversion must produce some effect on the lake, the evidence that protracted low stages preceded the low stage of 1883 is conclusive. On the northeastern shore of the lake, close by the mouth of Mussel Slough, there is a group of tree stumps at an elevation of about 200 feet. These were found at the water's edge in 1882. They presented the appearance of having been broken off at a height of 3 to 4 feet above ground. They were


PRINCIPAL
RIVERS
OF
CALIFORNIA
SCALE
40 0 40 MILES
PACIFIC
OCEAN
Klamath
River
Pitt
Mad R.
Trinity R.
Eel River
COAST
RANGE
Stony Cr.
Sacramento
SACRAMENTO
VALLEY
Feather River
Yuba R.
Bear R.
American R.
Cosumnes R.
Mokelumne River
Calaveras R.
Stanislaus R.
Tuolumne River
Merced
Chowchilla R.
Fresno R.
San Joaquin R.
SAN JOAQUIN
VALLEY
Kings R.
Kaweah R.
Tule River
Deer Cr.
Poso Cr.
Kern River
Buena Vista Swamp
BUENA VISTA L.
L. TULARE
Los Gatos Cr.
Salinas River
Santa Maria R.
Santa Inez R.
Santa Clara R.
Russian R.
Cache Cr.
Putah Cr.
CLEAR L.
EAGLE L.
HONEY L.
TAHOE L.
L. MONO.
OWENS L.
Owens River
GOOSE L.
RHETT L.
SIERRA NEVADA

The Division of Hydrography of the United States Geological Survey has maintained a number of gaging stations in San Joaquin Valley, and has published some of the results.[1]

The important streams which flow into San Joaquin Valley are all Sierra Nevada streams. They appear in small capital letters in the following list of rivers and creeks which are tributary to the valley:

	Area drained, in square miles.
From Tejon Mountains:	
Tejon Creek	64
Tecuya Creek	40
Arroyo Plata	32
San Emidio Creek	69
From the Sierra Nevada:	
Caliente Creek	423
KERN RIVER	2,345
Poso Creek	289
White River	90
Deer Creek	110
TULE RIVER	437
KAWEAH RIVER	619
KINGS RIVER	1,742
SAN JOAQUIN RIVER	1,637
Fresno River	272
Chowchilla River	268
Mariposa Creek	122
Bear Creek	166
MERCED RIVER	1,076
TUOLUMNE RIVER	1,501
STANISLAUS RIVER	1,051
Calaveras River	491
MOKELUMNE RIVER	657
Dry Creek	283
COSUMNES RIVER	580
From the Coast Range:	
Los Gatos Creek	441
Cantua Creek	52
Big Panoche Creek	289
Little Panoche Creek	106
Arroyo Ortigalitos	64
Los Banos Creek	151
San Luis Creek	88
Romero Creek	24
Quinto Creek	29
Las Garzas Creek	57
Orestimba Creek	142
Arroyo de la Puerta	77
Arroyo de los Piedras	20
Hospital Creek	30
Corral Hollow Creek	73
Marsh Creek	54

[1] Twelfth Ann. Rept. U. S. Geol. Survey, Part II, 1891, pp. 316–323, Pls. LXXX–LXXXVIII; Bulletin No. 131, 1895, pp. 78–86; Bulletin No. 140, 1896, pp. 256–314; Eighteenth Ann. Rept. U. S. Geol. Survey. Part IV, 1897, pp. 371–396; Water-Supply and Irrigation Paper No. 11, 1897, pp. 90–92; Water-Supply and Irrigation Paper No. 16, 1898, pp. 187–192.

WATER APPROPRIATION AND IRRIGATION DISTRICTS.

It is provided in the constitution of the State of California adopted in 1878 that "the use of all water now appropriated, or that may hereafter be appropriated, for sale, rental, or distribution," is a public use, subject to regulation and control by the State, and that water rates are to be fixed annually by the governing bodies of counties and municipalities.

The civil code of the State says: "The right to the use of running water flowing in a river or stream or down a canyon or ravine may be acquired by appropriation." But this right ceases when the water ceases to be applied to some useful or beneficial purpose. As between appropriators, the one first in time is the first in right.

The method of making an appropriation and of giving notice of the water claim is thus prescribed:

> . . . person desiring to appropriate water must post a notice, in writing, in a conspicuous place, at the point of intended diversion, stating therein: (1) That he claims the water there flowing to the extent of (giving the number) inches, measured under a four-inch pressure; (2) the purposes for which he claims it, and the place of intended use; (3) the means by which he intends to divert it, and the size of the flume, ditch, pipe, or aqueduct in which he intends to divert it. A copy of the notice must, within ten days after it is posted, be recorded in the office of the recorder of the county in which it is posted.

But the mere posting and recording of this claim to water confers no right upon the appropriator unless, within sixty days after the notice is posted, the construction of works is commenced and diligently prosecuted to completion. In that event, and in that only, are rights acquired, which then relate back to the time the notice was posted. Moreover, the water right secured under the notice and by construction of works should not be considered to be that defined in the notice, wherein the amount named is often absurdly exaggerated, or may be wholly unintelligible; but regard is to be had to the works and their capacity as actually constructed in interpreting the language of the claim.

Whole volumes have been filled in some of the counties of this State with records of claims to water, but there is no department of record—except the courts in cases of conflict—in which the facts relating to date of ditch or canal construction, location, dimensions, and capacity are or can be preserved. Where the recollection of the oldest inhabitant is often the only source of information, it is extremely difficult to trace the history of irrigation works, and information obtained from owners must be treated with some caution.

This condition of public records in the matter of water appropriation should be remedied at once. The State needs a permanent department whose duty it will be to determine the necessary facts, as well as may be, with reference to every water appropriation and to define the rights of the several appropriators. There are, of course, many other duties with which such a department might be charged, but it is not proposed to enlarge upon the matter at this time.

After defining the method of appropriating water, as above explained, it was until 1887 further provided in the civil code that "the rights of riparian proprietors are not affected by the provisions of this title." Notwithstanding the repeal of this particular section of the code, all appropriations of water must necessarily remain subject to whatever rights are vested in the bank-land owners.

The first attempt to combine ownership of land and control of water for irrigation in corporations with municipal functions appears in an act to promote irrigation, which was approved by the governor of California on April 1, 1872. This act was a precursor of the irrigation-district law now in force, and provided for the formation of irrigation districts on petition of land owners, and for the construction of works with money secured by assessment of benefits upon the lands in the districts. The affairs of the districts were to be managed by boards of trustees.

This law was restricted in its operation to a part of the State, and remained practically inoperative. Four years later a special law was passed authorizing the formation of the "West Side irrigation district," for which elaborate surveys and studies were made and which was to have been largely dependent upon Tulare Lake as a source of supply. Notwithstanding the recommendation of its engineers and of the commissioners in charge of the matter, the project failed, and district control of water for irrigation purposes was again deferred until the Wright law (named after its author, Mr. C. C. Wright, of Modesto) was passed, in 1887. Much has been hoped from this new law authorizing the formation of irrigation districts. The prime object of the law is to unite ownership of land and water. It is provided that, upon a petition of landowners, lands susceptible of irrigation by the same system of works may be included within the boundaries of a district, which, upon ratification by a vote of the electors therein, is endowed with municipal functions for the specific purpose of securing and distributing water for irrigation.

The affairs of each district are managed by a board of directors, one of whom is elected from each of the five divisions into which the district is ordinarily divided, and until recently amended the law required that each director must be a resident of the particular division of the district by which he was elected. These requirements have recently been modified to the extent that, on the basis of the petition for the formation of the district, only three divisions may be formed, and that the election of the directors may be at large. This was done to overcome difficulties encountered in finding suitable persons to serve as directors in sparsely settled districts. Powers are conferred upon the directors to do everything that may be necessary to carry out the intent of the law and to secure and distribute the water required for their respective districts. As soon as the probable cost of the works is determined they fix the amount of bonds necessary to be issued, and the question of bond issue is submitted to the qualified electors of the district. Work on district canals is ordinarily done by contract, but may also be done by day labor. It was originally prescribed by law that bonds should not be sold at less than 90 per cent, and as the law now stands no sales are to be made at less than par. The bonds may also be used in paying for completed canals and for water rights and rights of way, but are not to be used for defraying expenses of operation and management.

Difficulties were soon encountered in the application of this law. Almost at the outset it was found that when the exterior boundaries had been fixed by the county supervisors on petition of landowners and the testimony of volunteer witnesses, there was no certainty that correct conclusions had been reached, and the irrigation project assumed to be feasible in advance of an engineering investigation might still be grievously at fault. When taxes were to be collected to meet expenses of examination and surveys, active opposition often became manifest and payments were in many cases greatly delayed. The validity of the law was called into question and was passed upon repeatedly by State courts, and finally by the Supreme Court of the United States, which only recently rendered the decision which conclusively established its validity.

Meanwhile many of the districts which commenced operations under favorable auspices had adopted plans and issued bonds which had been offered for sale with more or less success. The hope that full confidence in the successful operation of the law would be speedily established and that the 6 per cent bonds would soon sell above par was not realized, and despite favorable decisions in the superior courts, confirmatory of the proceedings in individual districts, and favorable action by the supreme court of the State, the bonds did not sell readily. The districts that had been most active in pushing the work on their canals then found themselves in a somewhat peculiar position. The construction funds maintained by the proceeds of bond sales were depleted, the canals and structures were incomplete and of no use until completed, and to current expenses had been added the annual interest and sinking fund account on bonds already sold.

It is hardly surprising that, pending a final decision by the highest tribunal of the country—a decision which was not secured until nine years after the enactment of the law—every resource was exhausted by some of the district managements to continue operations and to derive benefit from completed or nearly completed works. The law requiring bonds to be sold at 90 per cent or more was, in some instances, evaded by selling without requiring the purchaser to guarantee that bonds would be taken as offered. Contracts were then awarded, often without more than nominal competition, and at rates far in excess of cash value, it being generally understood that the money paid in for any block of bonds quickly returned to the contractors, in exchange for warrants for work performed or material furnished. In other cases ditches were built under supervision of the district engineer by private parties, and after completion were bought by the irrigation district for bonds, which were thus legally disposed of without a direct sale. The cost of works under such conditions necessarily became greater than if all could have been constructed for cash. Sometimes, too, first estimates of cost were too small to complete the system of works even under ordinary conditions, so that supplemental bond issues had to be resorted to, or will yet be necessary, to complete and put the irrigation systems into service.

It is found, too, that the introduction of water into a new district generally brings disappointment. The farmer is not prepared to make immediately full use of the water. Its mere presence in the main canals and laterals is not a guaranty of good crops, and he is often slow to adapt himself to the new methods of farming that become necessary. So the burden put upon the farmer in the shape of increased taxation brings no quick return, and, even under comparatively favorable conditions, dissatisfaction is likely to result.

In the light of ten years' experience the conclusion seems justified that, though endeavoring to establish a correct principle, the law has not been uniformly successful in its operation. State supervision by a competent board of public works, which has the confidence of the people, is a first requirement. This supervision should not be a mere nominal one, but district boundaries and preliminary plans of works should emanate from a department of that character, and no plans should be finally adopted without its approval. Such board should serve the several districts at least in an advisory capacity when required to do so, thereby guaranteeing, as far as may be possible, an adequate source of water supply and an adequate canal system. The bonds of every district should be guaranteed by the State, and all bond sales should be made by the State, so that district construction work may always be done on a cash basis.

Bond issues, after being declared necessary by the directors of any district, are voted upon by the qualified electors of the district. Operations under the law would have been safer and would have commanded greater confidence if the right to vote on all questions involving the expenditure of money or the incurring of an indebtedness could have been restricted to the landowners or the taxpayers of each district. The question of material benefit would in most cases be safer in their hands than if left to a popular vote, which, as the law now stands, is often largely cast by a floating population.

Under the district law the operating expenses are raised either by the levying of an assessment (which must be ratified by a vote) or by charges established by the directors for the use of the water.

There are several irrigation districts in San Joaquin Valley in which canal systems have been brought into actual service, but, as above intimated, the operation of the system does not give general satisfaction. The irrigation districts of the great central valley of California are here briefly enumerated. Those of San Joaquin Valley will again be taken up and treated more fully in connection with the irrigation works dependent upon a common source of supply.

Kraft irrigation district.—This is the most northerly of the several districts in Sacramento Valley, and is situated on the north side of Stony Creek. It was organized in 1888. Its area is 13,500 acres. Stony Creek was to be the source of supply, and bonds to the extent of $80,000 were voted. No bonds were sold, all debts were paid, and no further action under the law is contemplated.

Orland South Side irrigation district.—This district, in Sacramento Valley, was organized in 1888 and is situated on the south side of Stony Creek, directly opposite Kraft district. It has an area of about 26,000 acres and was to be dependent upon Stony Creek for a water supply. No bonds were sold, although $100,000 had been voted. The district organization is dead.

Central irrigation district.—This is the most important district in Sacramento Valley. It extends southerly from near Stony Creek for a distance of about 40 miles, being situated on the west side of the valley, between the base of the Coast Range foothills and the valley trough, and having an average width of about 4 miles. Its area is 156,550 acres. Sacramento River is the contemplated source of supply. The district was organized in 1887. Estimated cost of works, not including rights of way or litigation, was $538,000. Bonds were issued to the extent of $750,000, of which about $200,000 remain unsold. No work has been done since 1891.

Colusa irrigation district.—This is a Sacramento Valley irrigation district, which has remained inactive. It was organized in 1888, on the west side of Sacramento River, intermediate between the river and Central district. Its area is about 100,000 acres, and the bonds voted were $600,000, but no bonds were sold. The proposed source of water supply was Sacramento River, it being intended to use the upper section of a main canal in common with Central irrigation district.

College City irrigation district (proposed).—This was to be a third district, dependent upon the canal which was to divert water from Sacramento River for Central district. Its organization was under contemplation in 1889, but it failed. It was practically a proposed southward extension of Central district.

Browns Valley irrigation district.—This irrigation district, organized in 1888, is situated in the foothills of the Sierra Nevada, on the east side of Sacramento Valley. It has an area of 43,000 acres. Water for its irrigation is diverted from Yuba River. The bonds voted and sold amount to $110,000. The irrigation system was completed and is in service.

Modesto irrigation district.—This district is situated in San Joaquin Valley, between Stanislaus and Tuolumne rivers. It was organized in 1887 with an area of about 120,000 acres. To cut down cost of works necessary for its irrigation this area was reduced to 81,500 acres by omitting high uplands in the northeastern portion of the original district. After protracted conferences with Turlock district an arrangement was entered into whereby the two districts were to construct a great masonry weir or diverting dam in Tuolumne River in common, the cost of which was to be apportioned to the two districts in equal shares. The district voted bonds to the amount of $800,000 in 1888, which have all been disposed of. A further bond issue of $350,000 has been voted to complete the main canal and to construct distributaries.

Turlock irrigation district.—This irrigation district is situated on the south side of Tuolumne River and embraces the greater portion of the upland or east-side plain of San Joaquin Valley between Tuolumne and Merced rivers, of which the former is to be the source of water supply. It has an area of 176,000 acres. Bonds to the amount of $600,000 were voted soon after the organization of the district, in 1887, and construction work was actively pushed. A second issue of bonds, to the amount of $600,000, was found necessary, and the main canals will probably be completed within a reasonable time.

Madera irrigation district.—This district, organized in 1888, is situated on the east side of San Joaquin Valley to the north of San Joaquin River. Its area is 305,000 acres. San Joaquin River was to supply water for the district. Bonds to the amount of $850,000 were voted, but none were sold. After much litigation it was finally decided to abandon all further proceedings under the district organization.

Selma irrigation district.—The lands watered by Fowler Switch and Centerville and Kingsburg canals have been united in Selma irrigation district. They are situated on the east-side San Joaquin Valley plain, on the north side of Kings River. It was proposed to acquire by purchase the two canals mentioned. The district was organized in 1890. Bonds were to be issued to the amount of $1,000,000, but this bond issue was twice defeated.

Alta irrigation district.—This district is situated on the south side of Kings River, and has an area of 130,000 acres. It was organized in 1888, and bonds to the amount of $675,000 were voted, of which $410,000 were paid for the "Seventy-six" canal system, which has thus become the district canal. Its water comes from Kings River. Permanent head works and a number of distributing canals are yet to be constructed.

Tulare irrigation district.—This district lies in the delta of Kaweah River, encompassing the town of Tulare. It was organized in 1889, and

FLUME ACROSS ST. JOHNS CHANNEL, TULARE IRRIGATION DISTRICT.

has an area of 39,200 acres. Bonds to the amount of $500,000 were voted, of which about $300,000 were paid for existing canals, reservoir site, and water rights, and the remainder went toward the construction of branch canals. Kaweah River is the source of water supply.

Tule River irrigation district.—This district is situated in the delta of Tule River. Bonds were originally voted to the extent of $90,000, and a second issue of $10,000 soon followed. This district was organized in 1891. It has an area of about 22,000 acres and takes water from Tule River.

Tipton irrigation district.—This district is situated to the south of Tule River, from which it was to be supplied with water. The bonds voted amount to $50,000. These bonds and unpaid warrants to the amount of $15,000 were necessary to complete a canal system, which is temporarily out of service by order of the court.

Poso irrigation district.—This is another of the east-side San Joaquin Valley districts. It is situated in Kern County, northward from Kern River, on the north side of Poso Creek, which is its source of water supply. It has an area of 40,000 acres, and bonds were voted to the amount of $500,000. It is one of the districts in which land is almost valueless without irrigation. Its sparse population is indicated by the fact that only 24 votes were cast on the question of district organization, and only 35 on the bond issue. Works are still incomplete, though a portion of the district has water. All bonds have been disposed of.

Kern and Tulare irrigation district.—This district lies in Kern and Tulare counties. It was organized in 1890, and was to have been supplied with water diverted from Kern River. Its area is 84,300 acres. The bonds voted amounted to $700,000. Although about $40,000 were expended in preliminary work, there has been no canal-construction work done by the district.

Huron irrigation district.—This is a west-side district, situated near the base of the Coast Range foothills, to the northwest of Tulare Lake. The district was organized in 1891, and was to be irrigated with water developed largely from the subsurface flow of Los Gatos Creek. It has sold no bonds, and no construction work has been done.

Sunset irrigation district.—This is a very large district, embracing a long, narrow strip of land on the west side of San Joaquin Valley. It extends northward from Tulare Lake about 60 miles, and has an area of 363,400 acres. It was organized in 1889. Bonds were voted to the amount of $2,000,000, and some of these have been issued in return for water rights and rights of way. A contract has been let aggregating $1,500,000 for the construction of its works, and operations under it were to begin soon after a favorable decision on the district law by the Supreme Court of the United States. It is understood that the contractor is now ready to proceed under his contract.

METHODS OF IRRIGATION.

Although water was used for the irrigation of mission gardens in California more than one hundred years ago, irrigation may still be regarded as a new art in this State. Irrigation development was not rapid until within the last twenty years, and methods of irrigation are the result in most cases of attempts to adapt to local conditions the methods in use elsewhere. There was no incentive at the outset to prevent waste, so that the method adopted was very often determined by first cost of land preparation. As the duty of water was gradually raised and the supply allotted per acre of land became smaller, more attention was given to the method of use, and particularly to the reduction of waste. The degree of attention which the suppression of waste receives depends also upon the value of the products of the soil. This has led to the introduction of extensive pipe systems in southern counties of the State for water distribution to irrigators, as well as its delivery on individual tracts at the exact spots where wanted for use. But in San Joaquin Valley, where the volumes of water under control are larger and cultures are generally on a lower scale of value than farther south, the use of pipes is still out of the question. The methods here adopted are more or less perfectly adapted to the peculiarities of climate, soil, and physical features of the tracts irrigated, but vary within wide limits according to the caprice of the individual irrigators.

The methods of irrigation in San Joaquin Valley may be classified as follows:

Irrigation by flooding.
Irrigation from furrows.
Irrigation by saturation of subsoils.
Irrigation from subsurface conduits.

Cereals are generally irrigated by flooding or by saturation of subsoils, sometimes by the furrow method; alfalfa is irrigated by flooding or by saturation of subsoils; fruits and vines are irrigated by any of the methods enumerated; and vegetables, generally from furrows.

Wild flooding.—Water is made to escape over the banks of small ditches constructed on the highest ground, and is controlled in its flow over the surface to be irrigated by attendants. The supply ditch is either at the highest margin of the tract to be irrigated or follows along ridge summits. Water is turned from it into irrigating ditches, which are usually very shallow depressions with flat embankments on their lower sides, over which the water flows in a thin sheet. It is controlled as much as possible by attendants, who try to force it over the entire surface intermediate between irrigating ditches. Surplus water accumulates in the lower ditches and is used again. The preparation of the ground for irrigation by wild flooding is very inexpensive, but the cost of applying the water, owing to constant attendance required, is relatively great. One attendant is expected to irrigate from 1 to 2 acres a day. The irrigating ditches and their embankments are usually so flat that they do not interfere with farming operations. This method of irrigation is to be regarded as somewhat primitive and is used but little.

Flooding in contour checks.—The land to be irrigated is divided into compartments or checks, each of which is entirely surrounded by embankments of earth. The principal embankments follow contour lines, the vertical distance from one contour levee to the next being uniform. The contour interval usually selected is 6 to 9 inches, rarely so great as 1 foot. It depends in all cases upon the surface slope of the ground to be prepared for irrigation, and should be less than 6

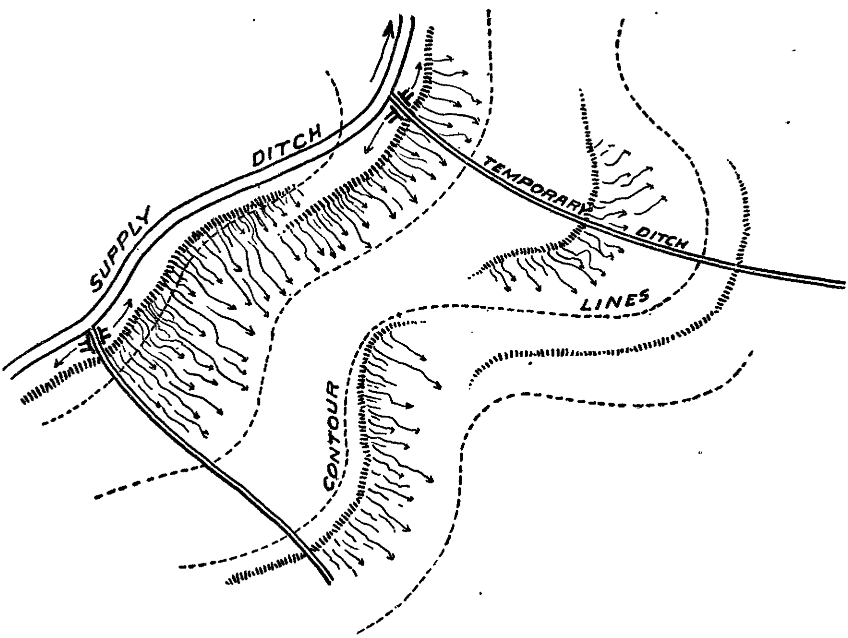


Fig. 2.—Wild flooding.

inches if the ground is sufficiently flat to permit such an arrangement without making the individual checks too small. For ground on a slope that would require levees more than 1 foot apart in elevation some other method of irrigation should be adopted. The strips of land between the contour levees are subdivided by cross levees into compartments of convenient size, which are generally called "checks." Their area should vary according to the volume of water available, a good rule for porous soils being not to exceed one-fourth of an acre for each second-foot when a large head of water is available, and to make half an acre per second-foot the limit for a small supply.

Water is supplied to the several checks in turn from highest to lowest in each series between cross levees. The irrigating ditch which leads off from the supply canal is usually carried in the direction of greatest slope, cutting the several contour levees nearly at right angles. Irrigation commences by turning a full head of water into the upper check upon one side of the irrigating ditch. This should be filled in from one to six hours. In the full check water should be barely over the highest portion of the ground, but 6 inches to 1 foot deep in the lowest portion of the check, according to contour interval. The contour levee should have its top about half a foot above the water surface of a full check. When the upper check is entirely submerged, gates are opened from the irrigating ditch into the next lower check, those admitting water to the upper check are closed, and one or more

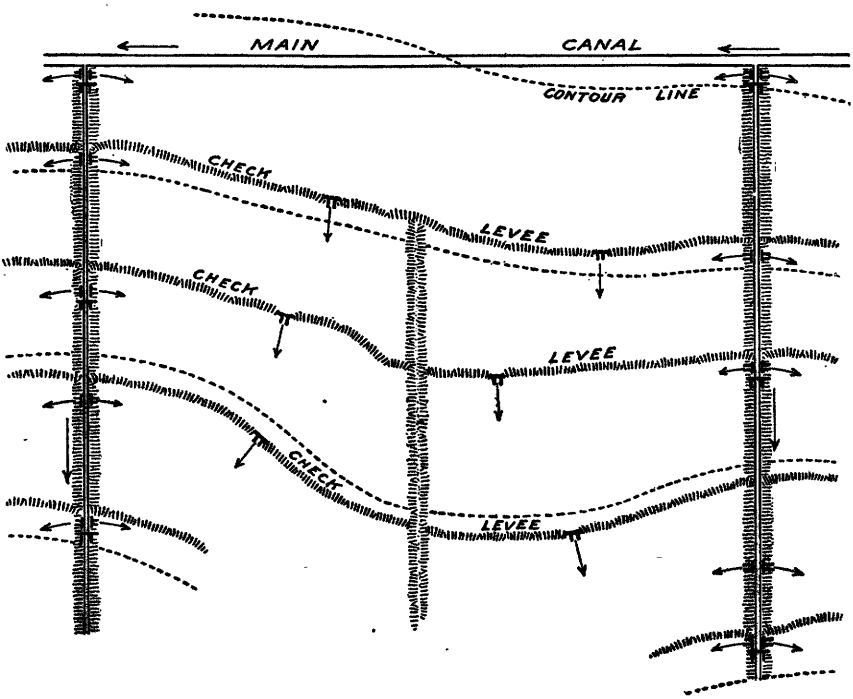


FIG. 3.—Flooding in contour checks.

gates in the contour levee between the two checks are opened to permit the surplus water from the first to drain into and assist in submerging the second one. This will require less time to fill than the first, because the supply of water from the ditch is augmented by the run-off from the upper check.

The irrigating ditches frequently replace cross levees, so that water can be admitted to a check from both sides at once.

When the average time required to fill checks on sandy soils exceeds three hours, it may generally be assumed that water is wasted; either the checks are too large or there is not enough water turned in. Heavy soils, however, do not take up water rapidly, and, aside from requir-

IRRIGATION BY CHECKS IN SAN JOAQUIN VALLEY.

ing more time to absorb water, they do not permit its flow to subsoils so readily as do sandy soils, consequently more time may be allowed to fill a check in clayey soil without undue waste. Twenty-four hours should be regarded as the permissible limit.

Checks are occasionally very large. One was found in service under the Calloway Canal having an area of 60 acres. The water supplied to it was reported to have been as great as 250 second-feet. Such areas in one check are never advisable and are merely temporary features of a growing system. Eight to 10 acre checks are large, and those of 2 to 5 acres are generally preferred.

Embankments around the checks may be either permanent or temporary. The latter are rare. Permanent check levees are made of two types, either with very steep sides and narrow tops, so as to occupy as little space as possible, or very broad and flat, so as not to interfere with farming operations. The flat embankment becomes a part of the cultivated area and generally is the most productive part of the irrigated field. It is constructed by scraping up material from a broad area on both sides if the ground is nearly level, or from the lower side only if the ground is comparatively steep. The cost of preparing land for this method of irrigation in permanent checks ranges from $2.50 to $5 per acre, the cost of the necessary distributing canals, ditches, and structures from $3 to $5 per acre. These figures, of course, may be greatly exceeded if the ground has too great a slope or is very much broken by hogwallows, or swales and ridges. Irrigation by this method is much less expensive than by wild flooding. The only work required of attendants is the opening and closing of gates and the guarding of the check levees. When ground is well prepared for this method of irrigation and the supply of water is abundant, the cost of each application of water will range from 3 to 30 cents per acre. The best examples of irrigation by this method are found on Kern Island; under Calloway Canal; on Buena Vista farm, watered by the Kern Valley Water Company's canals; near Borden and Madera; on the Riverside, Columbia, and Chowchilla ranches, irrigated by the Chowchilla Canal; on the west side of the San Joaquin, under the San Joaquin and Kings River Canal; and at various other points.

Flooding in rectangular checks, not level.—The subdivision into compartments of the land to be irrigated is carried out on straight lines, and levees are built on these lines. The subdivision may be planned with some regard to the direction of the contour lines and lines of greatest slope, or these may be entirely ignored. The advantage of this system over subdivision or contour lines is better conformity with property limits and culture borders, but it has many disadvantages when the surface of the ground is not very smooth. Levees are not uniform in dimension, as is the case with the principal levees under the contour system. It is difficult to avoid leaving low spots, which interfere with thorough drainage, and the first cost of land preparation is generally somewhat greater than when contour levees are used. The method of applying water is substantially the same as in the case of contour-check irrigation. Flooding progresses in the direction from highest to lowest ground.

A good example of this method of irrigation is to be seen on the Kohler, West & Minturn tract, near Minturn. The soil is a light, sandy loam, underlain by a hardpan, which is near the surface at the eastern limit of the tract, but which dips westward. The soil water is about 14 feet below the surface. When irrigation is in progress with a full head of water (about 16 second-feet is so considered by its owners), six men are required to manipulate gates and guard check levees. These attendants work in two shifts of three, each for twelve

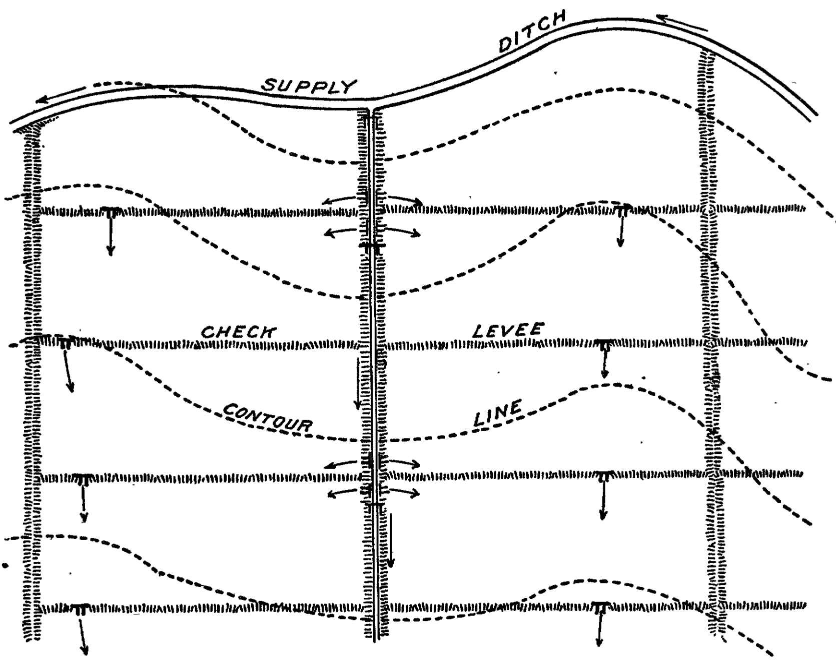


FIG. 4.—Flooding in rectangular checks, not level.

hours. The progress made is at the rate of about 20 acres a day. On the same tract some land is subdivided on the contour plan. Where this is the case the rate of progress is nearly twice as great, but this difference in the duty of water is not to be ascribed solely to the method of irrigation; the rectangular checks are in the western portion of the tract, where soil is lightest and deepest, and where duty of water is naturally least.

Flooding in level checks.—The surface of the ground in each compartment is made perfectly level and smooth. In such cases the check levees are low. Checks are made small to reduce cost of land preparation. The amount of material to be moved when the original surface is smooth increases with the square of the dimension of the checks in the direction of greatest slope. All checks are usually made rectangular. Land preparation for this method of irrigation is always expensive, but where the surface needs special treatment, as in the case of the knolly or "hogwallow" lands, the excess of cost over other methods is inconsiderable. The first irrigators near Fresno adopted this method, and it has long remained in favor in that locality. The first application of water was often accompanied by peculiar phenomena, notably in the nature of an irregular surface settlement, due in part to a copious flow from the surface into subsoils, which often caused a general breaking down of the surface. In refilling the depressions caused by the first wetting a level plane was established for each check, regardless of the nature of the crop to be irrigated, and this system of leveling the ground in each check has become a characteristic feature of irrigation near Fresno.

The area of the checks is made small, generally less than 1 acre, usually one-quarter to one-half acre. Water is admitted to the several checks from small irrigating ditches, and is shut off as soon as it has spread over the whole surface of each. There is ordinarily no drainage from level checks. All water admitted to each is allowed to sink into the soil. Not more than three hours should be required to fill a check with water, soil being ordinary sandy loam. If more time is required the supply of water should be increased or the size of the check should be reduced.

In 1882 an irrigator near Fresno was observed irrigating four small checks of alfalfa. His water supply was small, only 2.26 second-feet. Instead of turning all the water in turn into the several checks, he apportioned it to the four, and the time to fill them was ten hours, whereas not more than an hour apiece would have been required had they been filled one after the other.

The cost of preparing land for this method of irrigation, including the necessary small ditches and gates, ranges from about $15 to $50 per acre. The cost of applying water is inexpensive. The attendant in charge usually has time for other work, it being ordinarily only necessary to turn the water off and on.

Flooding between parallel levees.—This is a recent modification of the primitive system of wild flooding, especially adapted to such cultures as alfalfa and growing cereals. Low parallel embankments, generally 50 to 100 feet apart, are constructed in the direction of the land's greatest slope. Water is delivered, at the upper end of a strip of land between two of these embankments, into a ditch whose downstream bank is usually raised slightly above the general surface of the ground, and is made level. Enough water is admitted to this ditch to cause an overflow of 1 to 2 inches over this bank, and this overflow is maintained until water reaches the lower end of the strip of land. Ordinarily the water will spread from levee to levee. If it shows too great tendency to concentrate on fixed lines, and fails to spread, it is intercepted with other ditches or depressions similar to the one at the head of the strip of land, and the flow from levee to levee again becomes uniform.

All embankments are ordinarily very low and flat, so that farming operations will not be interfered with. The cost of land preparation for this method is about $5 to $10 per acre.

Furrow irrigation.—The method of irrigation by running water in furrows or small temporary ditches made with the plow is a common one in San Joaquin Valley. It is the method generally adopted for the irrigation of fruits, vines, vegetables, hops, or other cultures usually arranged in parallel rows. Water is allowed to flow in furrows, from which it sinks into the soil, being most readily absorbed by the upper layers which have been loosened by plowing. Occasionally drainage is combined with furrow irrigation; more frequently, however, no attention is paid to drainage, the aim being to supply to each furrow only the amount of water that will be absorbed by the soil. The flooding of portions of the ground's surface, as by the furrow methods, compacts the soil, thereby facilitating the return of moisture from below the surface, where it evaporates. To destroy the capillary action of the surface layer, it is necessary to use the hoe or some other implement before it becomes too dry and baked.

Furrow irrigation of cereals.—Cereals are not ordinarily irrigated by the furrow method, but this method of rapidly supplying moisture to a grain field not specially prepared for irrigation has often been resorted to when conditions seemed to justify a special effort to save a parching crop. Sometimes, too, land is wet in the fall of the year, before sowing, by this method.

If the slope of the ground's surface be not too great the furrows, which are generally deep, single plow furrows, are run in the direction of the slope. They are placed 8 to 12 feet apart, according to the porosity of the soil. Water is admitted into them from small ditches, generally crossing them at intervals of 100 to 200 yards. The irrigation commences at the highest part of the field. Water is admitted into a number of furrows at the same time, and the flow is checked or aided in each by an attendant, so as to keep progress uniform and to accomplish a general soaking of the ground's surface. This system of irrigation involves much labor and careful watching. It is relatively expensive. Should the surface of the ground have too great slope, the plow furrows are drawn across the direction of greatest slope on predetermined grade lines. As soon as irrigation is complete the furrows are plowed in, so that they may not interfere with farming operations.

Furrow irrigation of permanent cultures.—The usual method of irrigating trees, vines, or plants set out in rows is to allow water to flow between the rows in plow furrows or small ditches. When rows are far apart, two or more furrows are drawn between rows; ordinarily, however, one deep furrow between each two rows is preferred. The

A. FURROW IRRIGATION OF VINES.

B. FURROW IRRIGATION OF ORCHARD.

direction of furrows is not always restricted to that of rows of trees, etc., but may be determined by other considerations, such as slope of the ground's surface. Small ditches surrounding individual trees or plants are sometimes connected with the irrigation furrows. It is better to prevent the water from standing around trunks of trees, but no rigid rule can be laid down; the spacing of irrigation furrows is governed by the character of the soil to be irrigated, and is determined for each locality by experience.

Water is usually turned into a number of the irrigation furrows at the same time. At the lower end it may be received into a drain ditch which carries it off for further use. The time required for irrigation from each furrow is somewhat indefinite, but the endeavor is always made not to let water flow longer than may be necessary to give a reasonable supply to the soil. The several furrows are generally less than 300 feet long. Irrigation progresses from highest to lowest portion of the tract to be irrigated. This method of irrigation is in general use without regard to character of soil, but gives particularly good results on comparatively heavy soils which do not absorb water rapidly. When soils are porous and take water from the furrows freely, the furrows are kept shorter than in heavier soils.

Furrow irrigation in level checks.—When, a few years ago, it was feared that the ravages of the phylloxera might extend into the vineyards of Fresno County, it was deemed advisable by some vineyardists to set out all vines in checks which could be completely submerged. Fortunately such submersion, to combat the phylloxera, has never become necessary. But the preparation of the ground for flooding in checks led to a new method of applying water to the land. From a supply ditch, water is admitted into a small ditch upon one side of each check, and from this small ditch it enters deep horizontal furrows which have been drawn between each two rows of vines. As soon as water has filled all the furrows irrigation is complete, and the accumulated water is allowed to sink into the ground. No drainage is combined with this method of applying water.

Furrow irrigation of vegetables.—Where irrigations are to be frequently repeated, as in the case of such products as vegetables, berries, etc., each row of plants is generally set on a ridge a few inches to a foot in height. The length of the rows is varied according to slope of the ground in their direction. The depression between each two rows is utilized as a furrow, which generally receives very little or no fall from end to end. Water is supplied to one end of a set of such parallel depressions, and rises in these to near the height of intervening ridges. It is generally allowed to soak into the ground without drainage.

Irrigation by filling subsoils with water.—The success of farming with irrigation in the Mussel Slough country has attracted particular attention to this method of irrigation. As soon as water was introduced in the canal systems of these very flat lands of the Kings River delta, it was found that spots quite remote from the canals and ditches became moist, and that it was not necessary, as in other portions of the valley, to apply water to the surface of the ground. This wetting of the lands was attributed to lateral percolation. Soils were supposed to possess some peculiar property which facilitated the transmission of moisture horizontally, and it took a number of years to make clear to the irri-

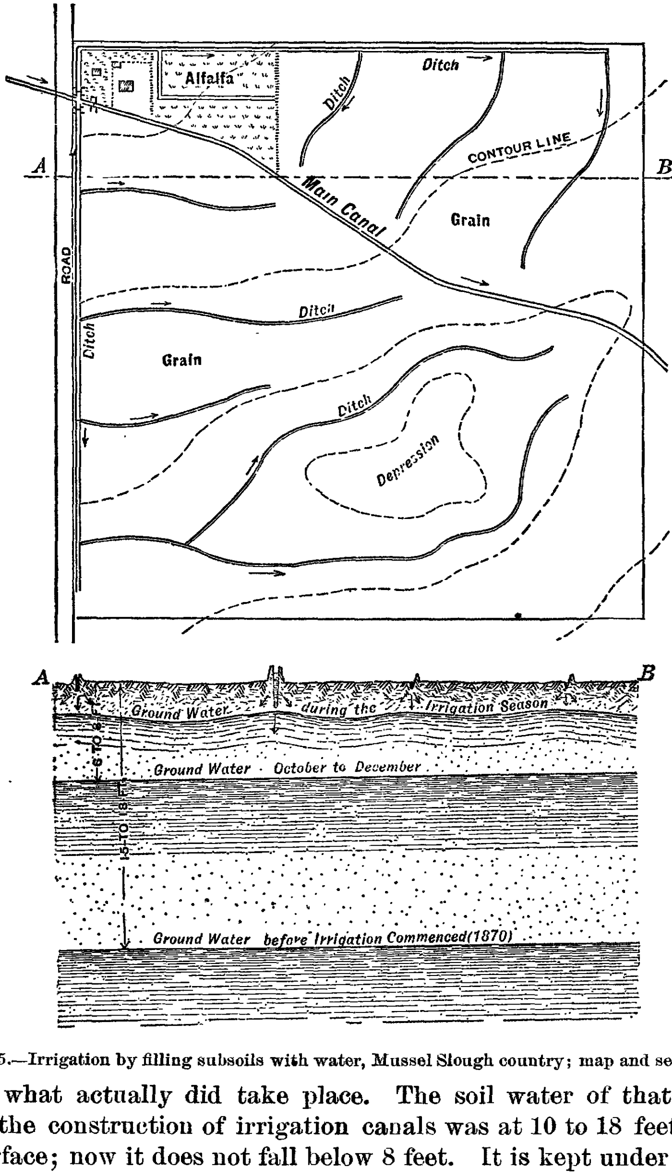


FIG. 5.—Irrigation by filling subsoils with water, Mussel Slough country; map and section.

gators what actually did take place. The soil water of that region before the construction of irrigation canals was at 10 to 18 feet below the surface; now it does not fall below 8 feet. It is kept under control by regulation of the supply in the irrigation ditches and by a natural subsurface drainage, which, as indicated by the slope of the ground-water plane, may be into Tulare Lake.

FURROW IRRIGATION OF GROVE.

This system of irrigation involves but little more than the introduction of water into irrigating ditches in the spring, when the supply is most abundant in river and canals. Irrigating ditches for this purpose are generally constructed about an eighth of a mile apart. They are either permanent or only temporary features of the irrigation system. They receive a very light grade, in order that they may be maintained full, with water flowing sluggishly.

The water sinking from main canals and distributaries and from the irrigating ditches causes a general rise of the ground waters to within 2 or 3 feet of the surface. This occurs late in April or early in May, and as soon as moisture can be detected in the low spots of any field its irrigation for the season is complete.

Careful inquiry in the Kings River delta established the fact that before 1870—that is, before the construction of irrigation works in that section of the valley—the depth to ground water was very generally 15 to 18 feet. It approached to within 10 feet only at a few points nearest the valley trough. It is now kept fluctuating between the limits already indicated, approaching to within 2 to 4 feet of the surface in spring and then settling down to about 8 feet late in the fall.

Irrigation by this method can not be restricted to particular tracts of land; its benefits may extend far beyond any individual tract to be irrigated, and it has frequently happened that lands lying between irrigated farms have derived the full benefit of irrigation without contributing to its cost.

The preparation of land for this method of irrigation is inexpensive, the only necessary cost being the construction of the small ditches. Very little attendance during irrigation is required. Alfalfa lands are sometimes prepared for flooding in order that gophers may be killed, when necessary, by a complete submersion of the cultivated tracts.

The advantages already indicated for this method of irrigation are offset by a decided disadvantage. The rising water brings to the surface alkaline salts, which gradually accumulate and may render unfit for cultivation soils that were originally entirely free from an excess of objectionable salts. Something has been said on this subject in treating of irrigation works in the Mussel Slough country (see page 17).

It remains to be added that the rise of the water table near Fresno has been so pronounced, as a result of the extension of the irrigation systems, that many of the tracts which were originally prepared for irrigation by some other method are now so wet that they are in need of drainage. On many others the application of water to the surface has ceased.

Subirrigation, or irrigation from subsurface conduits.—This method of applying water to land has not been so satisfactory as was hoped, but, having been introduced in some localities on a large scale, it should not be passed without notice.

The intent of this method of irrigation is to supply a moderate quantity of water directly to those parts of the soil where moisture is needed without wetting the surface of the ground. Thereby it was hoped to economize water, to greatly simplify its control and distribution, to cheapen irrigation, and to avoid baking of soil and the necessity of breaking up its surface after each application of water.

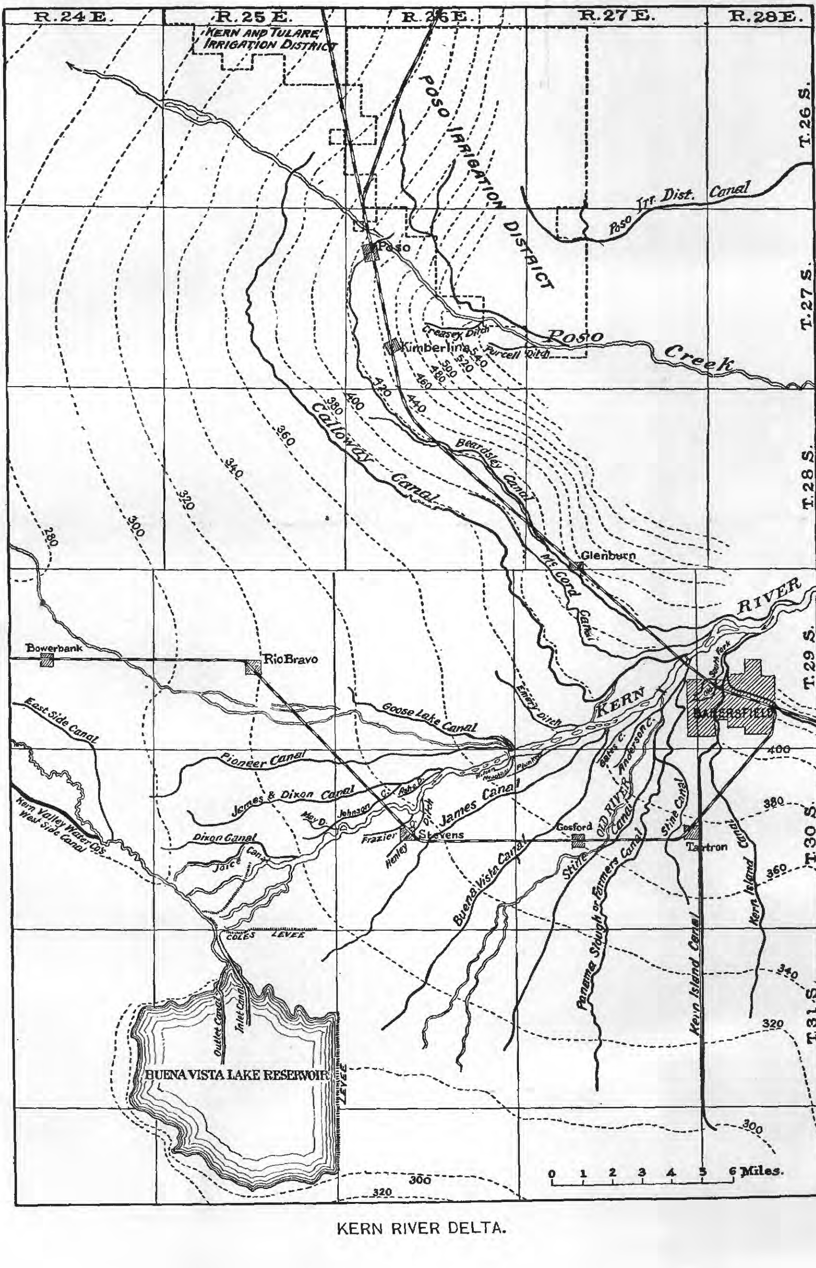
Water is distributed to all parts of the land to be irrigated in cement pipes, from which it escapes through perforated plugs of wood. It is admitted into these pipes under a low pressure, sufficient to insure the escape of some water even in the highest parts of the land to be irrigated. The system is applicable only to smooth-surfaced tracts having but slight slope.

The final distributing pipes are constructed by a peculiar machine. They are made in place and are continuous. The diameter of their bore is 2 inches. At intervals, corresponding to the distance between trees or vines, they are perforated from above, and a wooden plug with a hole about one-sixteenth inch in diameter, lengthwise through it, is inserted in the perforation. This plug is protected by means of a hollow cap, or earth guard, resting loosely upon the pipe over it. The pipe is placed 20 inches or more below the surface of the ground, so as not to interfere with plowing, cultivation, etc. Water is conducted to the 2-inch pipes—which may be laid between each two rows if the rows be far apart, as in the case of trees, or between alternate rows if they be close together, as in the case of vines—by means of a system of 6-inch and 4-inch pipes, which in turn receive water from a main supply pipe, generally about 8 inches in diameter. At all points where the 8-inch and 6-inch pipes branch, vertical cylinders, opened at the top—so-called hydrants—are introduced, by means of which the water may be shut off from one line or the other of pipe. This is accomplished by holding the inlet pipe higher in the cylinder than the outgoing pipe, and providing a seat for a disk to be inserted between the two.

When water is being supplied to any part of a vineyard or orchard, it will escape through the plugs into the ground, and its quantity must be sufficient to keep the stand in the hydrants everywhere above the highest parts of the 2-inch pipe system, so that there may be no doubt that water is escaping from every plug in the tract under irrigation.

Under favorable conditions it will cost about $50 per acre to prepare ground for irrigation by this method. The roots of trees and plants will, notwithstanding every precaution to prevent it, find their way into the lines of pipes at exposed points, and may in time seriously interfere with their successful use.

Until irrigators are required to be very much more economical in the use of water for irrigation than at present, the matter of expense alone will interfere with any extended use of this system of irrigation.



KERN RIVER DELTA.

KERN RIVER.

HYDROGRAPHY.

Kern River is the most southerly of the large streams descending from the slopes of the Sierra Nevada into San Joaquin Valley. It breaks through an outlying spur of the main range in a deep, rocky gorge, which terminates abruptly about 10 miles east of Bakersfield. For a distance of 18 miles from the canyon mouth the river flows westerly between high, gravelly bluffs, in which the adjacent rolling lands and mesas terminate. Occasional low, level tracts border it. From between the flanking hills and uplands the river emerges upon the plains of San Joaquin Valley just northeast of Bakersfield. Thence the main stream has a southwesterly course, flowing in a shallow bed 300 to 800 feet wide nearly 20 miles, to a point within a few miles of the trough of the valley; thence southerly into Buena Vista Lake, now used as a reservoir for irrigation purposes.

Year after year the sandy material eroded by the river from its mountain watershed has been deposited in San Joaquin Valley below the point at which the river emerges upon the plain. New channels have been constantly forming while old ones were being obliterated, and the delta region thus built up extends 20 to 25 miles toward the south and west, terminating in a great semicircle formed by Kern and Buena Vista lakes and the upper portion of Buena Vista Swamp. The central portion of this delta is generally referred to as Kern Island. The flow of water in many of the delta channels is now under control, and they are classed as canals.

Principal among these delta channels are: South Fork, or Old South Fork, which has a southerly course from its head, about 2 miles northeast of Bakersfield, to its outfall into Kern Lake; Old River, which has a southwesterly course from its head, about a mile and a half west of Bakersfield, toward a point between Kern and Buena Vista lakes; and Buena Vista Canal Slough, also flowing southwesterly, which leaves the new channel of Kern River about 2 miles below the head of Old River. Of these channels South Fork was the main channel of the river until 1862. Old River then became the main water way, and remained so until New River was formed by the freshets of 1867–68.

Kern River enters San Joaquin Valley with a total mountain drainage area of 2,345 square miles. By far the greatest portion of the region drained lies in the high Sierra Nevada. Precipitation in the highest portions of the river's drainage basin is generally in the form of snow. But an occasional heavy rain falling on large deposits of snow causes great freshets, generally early in the spring. Ordinarily the river is at a low stage from September to January, inclusive. It is at a high stage from April to July, and at a medium stage in February and March, and in August.

The discharge of the river has been estimated by the State engineering department for the six years 1878 to 1884. According to the results of this estimate, which is based on many measurements and an imperfect record of rise and fall of the river, the average amount of water supplied by Kern River was about 430 second-feet for the months November to January (inclusive); 800 second-feet for February to April; 2,450 second-feet for May to July; and 570 second-feet for August to October. The average annual flow of the river for that period was rated at 1,110 second-feet.[1] The discharge of the river as here noted refers to the State engineering department gaging station,

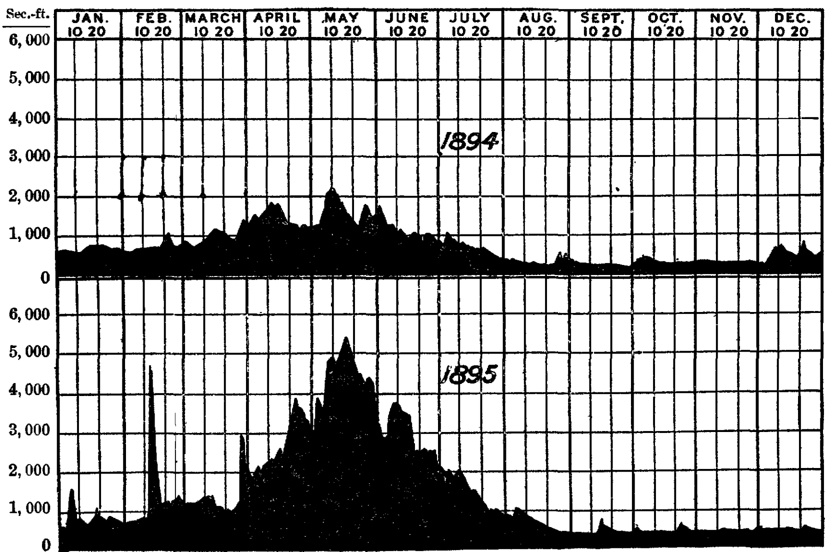


FIG. 6.—Discharge of Kern River, California, 1894–95.

about 3 miles below the point where the river breaks from its mountain gorge and enters upon its course across porous alluvial deposits.

Measurements made by Mr. A. K. Warren, under the direction of Mr. Walter James, chief engineer of the Kern County Land Company, show the facts indicated in the following table and accompanying diagram in regard to the discharge of Kern River for the four years from 1894 to 1897.[2]

[1]See Physical Data and Statistics of California, collected and compiled by the State Engineering Department of California, Sacramento, 1886, pp. 410, 470–472, 476–477.

[2]Bull. U. S Geol. Survey No. 140, 1896, pp. 267–274. For further information concerning the flow of Kern River see Twelfth Ann. Rept. U. S. Geol. Survey. Part II, 1891, p. 319, Pl. LXXX; Bull. U. S. Geol. Survey No. 131, 1895, p. 79; Eighteenth Ann. Rept. U. S. Geol. Survey, Part IV, 1897, p. 395.

Estimated monthly discharge of Kern River at Bakersfield, California.

[Drainage area, 2,345 square miles.]

Month.	Discharge.			Total.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth.	Per square mile.
1893.	*Second-feet.*	*Second-feet.*	*Sec.-feet.*	*Acre-feet.*	*Inches.*	*Sec.-feet.*
October	554	517	534	32, 861	0. 26	0. 23
November	559	467	518	30, 827	.24	.22
December	590	430	516	31, 757	.25	.22
1894.						
January	741	762	661	40, 644	.32	.28
February	1, 114	604	717	39, 817	.32	.30
March	1, 443	762	1, 001	61, 541	.65	.43
April	1, 892	1, 209	1, 495	88, 952	.71	.64
May	2, 208	1, 228	1, 607	98, 798	.79	.69
June	1, 719	871	1, 085	64, 557	.51	.46
July	1, 051	400	700	43, 036	.34	.30
August	549	256	335	20, 565	.16	.14
September	382	172	248	14, 756	.12	.11
October	363	224	279	17, 178	.14	.12
November	268	230	244	14, 500	.11	.10
December	805	234	470	28, 908	.23	.20
Per annum	2, 208	172	737	533, 252	4. 40	.31
1895.						
January	1, 616	473	809	49, 762	.40	.34
February	4, 762	675	1, 252	69, 536	.55	.53
March	3, 004	987	1, 374	84, 437	.67	.59
April	3, 897	1, 911	2, 724	162, 076	1. 29	1. 16
May	5, 384	3, 100	4, 369	268, 608	2. 14	1. 86
June	3, 721	2, 174	2, 906	172, 919	1. 37	1. 24
July	2, 063	867	1, 482	91. 113	.73	.63
August	1, 073	354	629	38, 665	.31	.27
September	676	290	344	20, 469	.17	.15
October	612	276	327	20, 106	.16	.14
November	436	308	346	20 588	.17	9. 15
December	447	368	403	24, 779	.20	.17
Per annum	5, 384	276	1, 413	1, 023, 058	8. 16	.60
1896.						
January	3, 101	377	747	45, 931	.37	.32
February	798	559	617	35, 489	.28	.26
March	2, 089	652	951	58, 475	.47	.41
April	1, 262	766	972	57, 838	.46	.41
May	3, 370	934	1, 401	86, 144	.69	.60
June	3, 611	1, 244	2, 476	146, 142	1. 17	1. 05
July	2, 210	741	1, 346	82, 762	.66	.57
August	741	353	486	29, 883	.24	.21
September	473	234	304	18, 089	.14	.13
October	425	223	267	16, 417	.13	.11
November	416	288	355	21, 124	.17	.15
December	426	313	347	21, 336	.17	.15
Per annum	3, 611	223	854	619, 630	4. 95	.36
1897.						
January	832	350	373	22, 935	.18	.16
February	2, 306	516	809	44, 930	.36	.35
March	2, 044	688	923	56, 753	.45	.39
April	4, 410	1, 094	2, 914	173, 395	1. 38	1. 24
May	5, 342	4, 054	4, 580	281, 613	2. 25	1. 95
June	4, 352	1, 289	2, 308	137, 395	1. 09	.98
July	1, 536	644	1, 006	61, 857	.49	.43
August	671	338	469	28, 838	.23	.20
September	363	260	295	17, 554	.14	.13
October	441	278	340	20, 906	.17	.15
November	447	289	355	21, 124	.17	.15
December	1, 023	327	422	25, 948	.21	.18
Per annum	5, 342	260	1, 234	893, 248	7. 12	.53

1894. Maximum discharge, May, 2,208 second-feet; minimum discharge, September, 172 second-feet; average for the year, 737 second-feet.

1895. Maximum, May, 5,384 second-feet; minimum, October, 276 second-feet; average for the year, 1,413 second-feet.

1896. Maximum, June, 3,611 second-feet; minimum, October, 223 second-feet; average for the year, 854 second-feet.

1897. Maximum, May, 5,342 second-feet; minimum, September, 260 second-feet; average for the year, 1,234 second-feet.

The gaging station of the State engineering department was located on the Rio Bravo Ranch, about 3 miles below the termination of the river's granite canyon, a short distance below the point where in 1879 the material of which the river bed was composed changed in character from bowlders and cobbles to gravel and sand. The several measurements made subsequent to that time, and until the close of the work of the State engineering department, showed a gradual erosion of the river bed, resulting in a downstream movement of the upper end of the gravel and sand bars, which led to inquiry concerning conditions in preceding years and to the conlusions that a few years subsequent to the great freshet of 1861–62 the sand and gravel bars were at a much higher level than in 1879; that erosion had continued from year to year, though at a somewhat irregular rate, until 1884 and was then still in progress; that the aggregate erosion during the five years covered by observations was 5.3 feet, and that at some time preceding the freshet of 1861–62 the river had for a long period occupied a bed fully as low as that of 1883. A row of trees planted at the water's edge at a mean stage of the river about 1868, and now well above the reach of the water, has been pointed to as evidence of a former higher position of the river bed. On the other hand, deep, well-worn depressions made by the Indians in grinding food materials in the tops of great granite bowlders, barely projecting above the low-water stage of the river in 1883, gave evidence of a preceding protracted low position of the river bed. It seems reasonable to expect, therefore, that other great freshets may again temporarily fill the river bed with sand and gravel, and that in years of ordinary flow, such as the entire series of seasons since 1867–68, the river will have a tendency to continue its erosive action.

Due allowance for the changes in actual elevation of the river bottom were, of course, made in interpreting results at the gaging station.

The original course of Kern River waters, westerly and southerly across its delta, widely dispersed in numerous channels, has by natural agencies, aided by the operations of man, been modified to the extent that now at high stages all water in excess of the capacity of the irrigating ditches and canals is kept under reasonable control in one main channel having a direct southwesterly course toward Buena Vista Lake.

Buena Vista Lake has been shut off at the east from its connection with Kern Lake by means of a high levee, which has a north-south course, following the line between Rs. 25 and 26 E. for a distance of over 5 miles.

A. KERN RIVER, LOOKING DOWNSTREAM FROM CANYON.

B. KERN RIVER, TWO MILES BELOW CANYON, LOOKING UPSTREAM.

Thus Kern River water is prevented from reaching Kern Lake, the bed of which is now dry, arable land, and Buena Vista Lake is converted into a large reservoir, the capacity of which is said to be about 150,000 acre-feet. From the northwestern margin of Buena Vista Lake an outlet canal leads into Buena Vista Slough and thence to canals proper of the Kern Valley Water Company, of which the westernmost one, located near the western margin of Buena Vista Swamp, has been planned large enough to afford passage for the outflow waters from the lake when the reservoir is full and the river is high. This canal, therefore, for a long distance takes the place of Buena Vista Swamp, which was the original water way, conducting the outflow from Buena Vista Lake into Tulare Lake. The three lakes which have been or are the recipients of water from Kern River are very flat depressions, without well-defined banks. The beds of Kern and Buena Vista lakes are at an elevation of about 285 feet above sea level; the bed of Tulare Lake is at an elevation of about 175 feet. The area covered by Kern and Buena Vista lakes combined (before the spread of water was restricted artificially) was about 80 square miles when the lakes were full, at which stage the maximum depth of water in either did not probably exceed 14 feet. The area of Tulare Lake fluctuates between 195 and 760 square miles, but the lake water has not spread to the extreme limit of the full lake since 1868.

The lands of the east side of the San Joaquin Valley plain, commanded by the Kern River canals, are very smooth surfaced. Those of the river delta slope uniformly toward the west and south at the rate of 6 to 7 feet to the mile. The only surface inequalities on Kern Island are due to the land-building tendency of the river, which has left broad, low ridges of sand to mark the alignment of channels of former epochs in its history. On the north side of Kern River the delta lands merge almost imperceptibly into the granitic sandy lands of the general valley plain, and the gentle westerly slope from the base of the foothills of the Sierra Nevada is almost unbroken to Buena Vista Swamp.

SOILS AND RAINFALL.

Near the base of the foothill belt, northward as well as southward from the river, the soil is a coarse granitic sandy loam, showing an occasional growth of cactus, and rather forbidding in appearance, yet very productive with water. To the southeast of Kern Lake a large area of fine sandy loam, known as the Weed Patch, marks the sink of Caliente Creek. The soils of the eastern portion of Kern River delta are generally loams, ranging from those rich in clay to soils of a peaty character and to soils of almost pure sand. Different kinds of soil are here frequently found close together, and it is often remarked that probably no single square mile of land could be found whose soil would not have to be put into several classes. Toward the south and west on Kern Island the soil becomes heavier, and near the high-water line of the lakes it is strongly impregnated with alkali. It has a peaty character in the swamp-land areas adjacent to the lakes, also northwestward from Buena Vista Lake throughout the broad tract known as Buena Vista Swamp, which extends about 40 miles northwesterly toward Tulare Lake. These swamp lands were originally covered with a dense growth of reeds—"tules." Their soil is generally a light black vegetable loam or mold, underlain by a dark-colored clay. Eastward from these swamp lands, which mark the trough of San Joaquin Valley, is a long parallel strip of alkali land of inferior quality, which lies to the west of a narrow strip of fertile land flanking the Goose Lake Slough channel. Farther eastward are the sandy loams and coarse granitic soils of the main east-side plain. These generally have a substratum of dry, fine yellow clay, sometimes of sufficient hardness to be called hardpan. This is usually found at a depth of 3 or 4 feet.

The southern or upper end of San Joaquin Valley, in which lie the lands commanded by the Kern River waters, is a region of very light rainfall. The annual average fall is about 5 inches. Profitable cultivation of the soil without the aid of other water to supplement the scant rainfall is not possible.

Kern River water is used to a small extent for irrigation in the valley of South Fork far up in the mountains, also for the irrigation of relatively small areas of bank and mesa lands within the foothill section of the river's course; but the region of principal use is the river delta and a broad expanse of country extending far northward from the river and lying below the base line of the foothills.

CANALS AND DITCHES.

Rio Bravo Ranch canals.—Kern River crosses the foothill belt in a valley, generally one-half mile to a mile in width, with occasional strips of bottom land on one bank or the other. These are frequently backed by higher terraces or mesas with rich, black loamy soil, beyond which the hills rise in irregular disconnected ranges. The Rio Bravo Ranch lies just below the point where the river breaks out of its canyon. Several small ditches have here been built for local irrigation. A water-wheel was first made use of. It was constructed in 1879 by Mr. John Barker, and was intended to lift water 28 feet. The wheel is reported to have delivered the quantity of water expected, but the land required more than was anticipated; consequently the wheel was soon abandoned as a source of supply, and a direct diversion into a ditch constructed along the base of a high bluff on the south side of the river was resorted to. The river, however, for a series of years was there deepening its channel, rendering necessary frequent extensions of the head of the ditch upstream, and making ditch maintenance expensive. Its cost has probably been somewhat in excess of $3,000.

A. HEAD OF KERN ISLAND CANAL, LOOKING UPSTREAM.

B. HEAD OF KERN ISLAND CANAL, LOOKING DOWNSTREAM.

To irrigate lands on the north side of Kern River, in the same locality, the Pierce & Barker Ditch has been constructed. It came into use several years after the Barker Ditch on the south side of the river. This ditch lies at the base of the north-side hills, and for some distance is cut into an almost vertical bluff. There is also a "Pierce & Barker" ditch on the south side of Kern River, but its source of supply is Cottonwood Creek, a tributary of the river, from which diversion is made near its confluence with the main stream. This ditch has a length of 4½ miles. It was constructed in 1885. All of these ditches are small and for private use only.

Another small ditch just below the Rio Bravo Ranch on the north side of the river is the Barker & Wilson Ditch, constructed about 1884, which commands a narrow strip of land along the northern bank of the stream.

The principal crop cultivated by irrigation from these ditches in the foothill section of the river is alfalfa.

Kern Island Canal.—As early as 1864, when there were but a few white families in the vicinity of Bakersfield, Colonel Baker constructed a levee northeasterly from the present town site and placed a gate in the delta channel known as South Fork, at the point where this channel was crossed by the river levee. Subsequent freshets filled the approaches to Panama Slough and to South Fork with sand, and the river cut out a new channel farther to the north and west. The settlers who had already become dependent upon the older water courses as sources of water supply for irrigation and for stock, at once made organized efforts to reopen the head of South Fork, but with indifferent success.

In 1869 Messrs. H. P. Livermore and Julius Chester, having determined that an artificial channel was necessary to replace the upper portion of South Fork, constructed a ditch 25 feet wide, the head of which was a short distance above the present head gate of the Kern Island Canal. This ditch was carried along the base of the hills on the south bank of Kern River and terminated in South Fork a short distance below its original head.

At the same time a number of Mexican settlers made a diversion of water from South Fork in a southerly direction, commencing at a point about a mile below the head of that channel. The ditch constructed by them is known as the "Arujo" Ditch, and its lower portion is still in use as a branch of the Kern Island Canal. This small ditch seems to have suggested the idea of the Kern Island Canal, for the construction of which a company was organized in 1870. It was proposed to unite in one system the entire delta area of the river known as Kern Island, as well as a broad belt of higher land lying to the east of the delta. A combination was effected with the owners of the swamp lands of this region, which had recently been sold by the State, conditioned upon reclamation, whereby the new canal company became the successor in interest of the reclamation district that had already been formed. The canal company was therefore formed with the avowed purpose of protecting from overflow and of supplying with water for agricultural, domestic, and manufacturing purposes a territory of about 120,000 acres. The Kern Island Canal Company acquired the ditch and water rights of Messrs. Livermore and Chester, as well as some of the other private rights vested or supposed to be vested in some of the settlers on South Fork. The construction of the "Mill" section of the Kern Island Canal was at once commenced, and extended southward about 2 miles, part of the distance following the alignment of the Arujo Ditch. Above this section of the canal the South Fork channel was enlarged, and some systematic effort was made to keep up the supply of water from the river. For the settlers on South Fork, who had not transferred their rights to the canal company, water was turned down that channel free of expense. About 1877 the upper portion of the South Fork channel was entirely abandoned, being replaced by a canal at higher level—an extension of the Livermore-Chester Ditch, located between the old water way and the base of the bluff south of the river. This new canal section was extended to the head of the "Mill" section, where water was dropped about 6 feet to the original level of that canal branch. Meanwhile the various branches of the Kern Island Canal had been extended southward as demand for water increased, and had reached the vicinity of Kern Lake. In 1875 the Kern Island Canal Company was granted franchises for the distribution of water in Bakersfield, where actual delivery of water through its ditch system commenced in May, 1875.

At the time of the formation of the Kern Island Canal Company the swamp lands to be protected by it against inundation were already considered safe, their reclamation in the sense of preventing overflow being regarded as complete. It was claimed, however, that the State had no right to appropriate the money to the credit of this land in the swamp-land fund to any other purpose than its reclamation, and that reclamation should be construed to mean the making of the land productive. The canal company therefore demanded and received from the State the money to the credit of the lands in question as a contribution toward the cost of the irrigation system. The amount of money thus contributed by the State was between $12,000 and $14,000.

The method of constructing the main branch of the Kern Island Canal, which extends from a point on South Fork about a mile south of Bakersfield southerly to Kern Lake, is not without interest. A 5-foot plow drawn by 40 yoke of oxen was used in breaking ground for this canal. The loosened earth was then spread to right and left by means of a V-shaped scraper, also of monstrous proportions, being some 30 feet long and 12 to 15 feet wide. As soon as sufficient water way was thus created to afford some erosive effect, water was turned into the partial excavation and it rapidly cut out an ample water way.

A. KERN ISLAND CANAL REGULATOR AND WASTE GATE, LOOKING UPSTREAM.

B. KERN ISLAND CANAL REGULATOR AND WASTE GATE, LOOKING ACROSS THE CANAL.

The excessive grade, 6 to 7 feet to the mile, of the finished canal soon caused the erosion to extend beyond desirable limits and threatened disastrous results by persistent encroachment on the canal banks. It therefore became necessary to reduce the gradient of the canal by means of check weirs or drops (as shown in Pl. X, *A*), which were placed one-half mile apart. These check weirs were constructed according to designs proposed by Mr. F. H. Colton, at that time superintendent in charge of the canal, and although very simple in arrangement, they proved to be efficient and satisfactory. Weir boards, generally of 1-inch material, were supported by inclined rafters, usually 4 by 6 inches. The rafters were placed at such angle, preferably flatter than 45°, as would best fit the spacing of the vertical posts supporting the sides of the weir box. The rafters transmitted water pressure by means of inclined supports, 4 inches square, to the floor timbers. The rafters were toed into the sill at the upper edge of the floor of the weir box. The floor itself was constructed of 1-inch material nailed to sills of 4 by 6 inch timber, 4 feet apart, which in turn rested upon mud sills, also about 4 feet apart. The floor of the weir box was placed 1½ feet below the downstream-grade height of the canal bottom, and light sheeting was driven along the upper and lower edges of the floor to depths varying, according to character of soil, from 1½ to 4 feet. Wings were carried into the canal banks at right angles to the direction of the canal. They were supported in part by upright posts, in part by timbers across the top of the structure, which at both ends were allowed to project well into the bank. The length of the wings varied according to depth of canal. Weir boards were permanently nailed to the rafters to the height of the grade of canal bottom above the structure. All other weir boards were loose and could readily be moved by hand. Spaces between rafters were usually 4 feet. A plank across the structure, supported by the ends of the rafters, made a convenient footbridge and afforded access to the several sections of the weir. The cost of these check weirs on the Kern Island Canal is reported to have been about $200 each.

The canal head gate is constructed on substantially the same plan. It has a clear width of 48 feet. A waste gate has been placed in the right bank of the canal just above the head gate.

The diversion of water from the river into the canal is accomplished by an inexpensive extension of the right-bank canal levee upstream for nearly half a mile, and its projection in the form of a very low sand-and-brush dam diagonally across the southern portion of the very flat, sandy river bed.

The aggregate cost of the Kern Island canal system has been about $200,000.

The canal has a right to 300 second-feet of water, conceded to it by riparian owners, and taking precedence over all other diversions. Its capacity is reported to be 500 second-feet.

Old South Fork.—The delta stream of Kern River known as South Fork supplied water to a few settlers some years before the construction of the Kern Island Canal was thought of. When Colonel Baker, in 1864, undertook the construction of a levee for protection against overflow, a gate was put into the South Fork channel for the control of its flow of water. The freshets of 1867–68, which produced marked changes in the character and alignment of the main channel of Kern River, filled the head of South Fork with sand. Organized effort was necessary to reestablish a connection of the upper end of the South Fork channel with the river. It is reported that from thirty to forty persons contributed time and labor to this work, the result of which was not, however, entirely satisfactory. The river channel had been deepened; the new cut to the river was nearly half a mile below the original head of South Fork, and great difficulty was experienced in

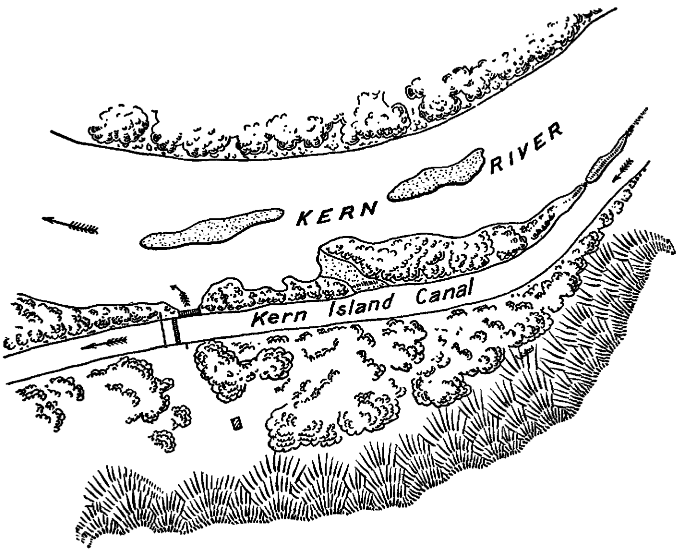


FIG. 7.—Head of Kern Island Canal.

maintaining an artificial barrier at the head of the new channel to turn river water into it. This difficulty led to the construction of the Livermore-Chester Ditch, as already explained, and for a number of years the supply of water to South Fork was through this ditch. About 1877 the use of the upper portions of South Fork was abandoned by the Kern Island Canal Company, and the delivery of water by this company to the irrigators from South Fork ceased. The users of water from South Fork and from Panama Slough resumed control of its head works, and have since maintained this channel as an independent irrigation ditch. A new connection with the river was established near the original head of South Fork, and with more or less trouble it has been kept in efficient service. The management was almost without system, and corporate organization of the owners was not effected until 1885.

A. CHECK WEIR OR DROP ON KERN ISLAND CANAL.

B. KERN RIVER AT HEAD OF SOUTH FORK.

Through the upper portion of South Fork water can be supplied to the lower levels of the Kern Island Canal; Panama Slough is fed with water from South Fork, and as the lower portion of Panama Slough is used as a water way by the Farmers' Canal, there is such interdependence between these several canals, complicated by the fact that many irrigators hold rights to water from two or more of them, that segregation of areas dependent upon any one of them is out of the question.

The principal distributaries of South Fork water are the Jewett Ditch, the Cotton Ranch Ditch, and smaller ditches of landowners in the immediate vicinity of Bakersfield. The capacity of South Fork is generally stated at 50 to 75 second-feet, and the amount annually expended for maintenance is about $1,250. The first cost of the irrigation works can be stated only approximately. It is likely that $3,000 to $4,000 have been expended on construction work.

Farmers Canal.—In 1873 a canal about 50 feet wide and 3 feet deep was excavated from a point on the south bank of Kern River just above the Southern Pacific Railroad, in a southeasterly direction, to a connection with a natural channel known as Cotton Ranch Slough or Skyles Slough. This canal is known as the Farmers Canal. Its water, delivered into Cotton Ranch Slough, flows therein 1½ miles to Panama Slough, and is distributed by a number of small branch ditches throughout the central and southern portions of Kern Island. The canal proper is only about a mile in length. It has recently become of considerable importance as a source of supply for the Stine and Anderson canals, which formerly received their full supply directly from Kern River at the head of Old River, about 3 miles west of Bakersfield.

In 1880 Messrs. Celsus Brower and Walter James estimated the total cost of construction of this canal and its branches at $18,800.

Panama Slough.—Panama Slough hardly deserves separate enumeration among the irrigation works from Kern River, because it is now supplied with water through the head of South Fork. It was, however, in use as an independent source of supply before permanent connection between it and the South Fork channel was established by the freshets of 1867–68. Irrigators dependent upon the flow of water in Panama Slough united with those on South Fork in 1868, when it became necessary to reestablish a connection of these streams with the main channel of the river. All of that portion of Panama Slough below Bakersfield is used jointly by the irrigators who depend upon the Farmers Canal for their supply and by those who hold rights as original users of water from the slough itself.

The principal distributary of the Panama Slough water is the Panama Ditch, the cost of which Mr. Celsus Brower in 1880 reported as having probably exceeded $6,000. The main distributing ditch and branches were then reported to have an aggregate length of 8 miles. Its width was given as 10 feet and its depth of channel as 2 feet.

Castro Ditch.—A comparatively unimportant irrigation ditch which for many years diverted water from the south banks of Kern River at the head of Old River is known as the "Castro" or "Mexican" Ditch. It is reported to have been in use as early as 1859, at that time supplying water to the lands of a few Mexican settlers. This ditch is about 16 feet wide, 2 feet deep at its head, and about 5 miles long. Its capacity is generally rated at about 15 to 20 second-feet, and there may have been expended upon it from $2,000 to $3,000. The head works of the canal, or rather the point of diversion from the river, has within the last few years been extended upstream about a quarter of a mile from the original intake.

Fisher & Abley Ditch.—About 1869 a small ditch known as the Fisher & Abley Ditch was constructed, paralleling the Castro Ditch, and delivering water into Reeder Slough, thence into Panama Slough, from which it was again diverted, a few miles below, for use upon several small farms. That portion of the ditch above Reeder Slough has been abandoned and the lower portion has become dependent upon the Farmers Canal for its supply of water.

Stine Canal.—This name has been applied to portions of Old River and several distributing canals since 1873. In that year the settlers along this river channel united in the construction of a weir about 175 feet long across the head of Old River, and two main branches of the canal were subsequently diverted from this stream. The first one of these, in order downstream, is known as the Call Branch, or Branch No. 1. It has its head about three-quarters of a mile below the head of Old River, is 20 feet wide for about a mile, then 30 feet wide, gradually contracting again to 25 feet. The original depth was intended to be 3 feet, but the channel was made somewhat deeper. One of its branches connects with a branch of the Kern Island Canal. Branch No. 2 of the Stine Canal is diverted from Old River about 5 miles below its head. It is about 6 miles long. The diversion of water from the channel of Old River into these branches is accomplished by means of weirs or regulating gates that serve to control water elevation.

The water passing the head of Branch No. 2 flows on toward the lakes and is occasionally used for wild flooding of grass lands. Recently the diversion of water for the Stine Canal was made through the head of the Farmers Canal and delivered to the former through a canal section called the extension of the Stine and Anderson canals. The capacity of the Stine Canal is claimed to be about 200 second-feet.

The cost of the works, including repairs, was estimated for the principal owners in 1880 at $87,000. This does not include the extension to the Farmers Canal, which was made subsequent to that time.

Anderson Canal.—This canal, which is also called the "Baker & Noble Canal," was constructed, in part, at least, in 1872. The diversion of water for it was originally made from the south bank of New Kern River, about one-quarter of a mile below the head of Old River; but as ownership of a number of canals became centered in the same group of owners, it was thought desirable to establish common head works for this canal together with the Stine and Castro canals, at the head of Old River. It was therefore extended to this point, and for many years one system of works served to divert water for all three of these canals. Within the last few years a further consolidation of canal head works has been effected, and the water for the Stine and Anderson canals is now diverted from the river through the upper section of the Farmers' Canal, as already explained. The Bellevue property, one of the many possessions of the Kern County Land Company (J. B. Haggin, principal owner), is the locality where the water of the Anderson Canal is used.

Gates Canal.—This canal is reported to have been constructed in 1872 and 1873. It was enlarged in 1874 from a bed width of 9 feet to 12 feet. Its water is used only on the Bellevue Ranch. Its diversion is made about three-quarters of a mile below the head of Old River. It is only 2 to 3 miles long, and its capacity is 30 to 40 second-feet.

Buena Vista Canal.—This name has been given to one of the delta channels of Kern River, together with its system of distributary ditches. The natural water course referred to broke out from the south bank of Kern River about 2 miles below Old River. It was provided with a head gate 26 feet wide in 1870, and a new connection with the river was established. For some years thereafter the settlers along this slough, which had a southerly course, and along its main branch, Button Willow Slough, made use of the water thus admitted under control, for irrigation purposes. Diversion from the sloughs was effected by means of temporary brush dams. In 1875 the canal proper was constructed. The slough was permanently closed about a mile below its head, and its lower section was replaced by the artificial channel of Buena Vista Canal. The capacity of the canal is probably between 100 and 150 second-feet. The cost of works and repairs to 1880 was estimated for the owners by Mr. W. R. Macmurdo at $26,000. A weir of the ordinary light flashboard type is maintained in Kern River just below the head of the James Canal to force water into the Buena Vista and James canals.

James Canal.—This canal was constructed for the irrigation of the odd-numbered sections of land westward from Old Kern River on Kern Island. The construction work commenced late in 1871. The diversion of water from the river is made a few rods below the head of Buena Vista Slough. As originally constructed the canal was 100 feet wide for about 1,000 feet, thence 20 feet wide for a distance of 300 to 400 feet, and 30 to 40 feet wide throughout the rest of the first three-quarters of a mile of its course. Its fall in this distance is 2 feet, and it is intended to carry water 3 feet deep. The length of the main canal is about 18 miles, but its lower portions have fallen into disuse on account of the abandonment of Lake Ranch, where an unsuccessful attempt was made to irrigate strongly alkaline land. Mr. W. R. Macmurdo, about 1879, estimated the total expenditure on the canal at $16,000. The river weir at the head of the James Canal serves to force water into this canal as well as into the Buena Vista Canal. It is in type similar to the Pioneer weir.

Plunkett Ditch.—This ditch was constructed in 1873. It diverted water for the river about three-quarters of a mile below the head of Buena Vista Slough, and had a southwesterly course. It was made 12 feet wide and 2 to 2½ feet deep, and its length was about 4 miles. Some years later a connection with the James Canal was established, and the Plunkett Ditch may now be regarded as a branch of the larger canal.

Meacham Canal.—The Meacham Canal is one of the small ditches taking water from the south side of Kern River just above the Pioneer Bridge, about 6½ miles west of Bakersfield and about 5½ miles below the head of Old River. It was constructed in 1873. Its length was only 3 to 4 miles and its width 8 to 10 feet. The depth of water to be carried was 2 to 3 feet. The canal is now arranged to deliver its water into the James Canal, with which it has been connected.

Wilson Canal.—The head of this ditch, which was constructed in 1874, was originally located about one-quarter of a mile below the Pioneer Bridge, but in 1875 the ditch was extended upstream to a point alongside the head of the Meacham Canal, just above the bridge. The ditch is only 1 to 2 miles long, about 5 feet wide, and 2½ feet deep.

Henley and Frazier ditches.—These are two small diversions from the south side of the river, about 4 miles below the Pioneer Bridge. The former was constructed in 1874, the latter in 1873. Each is about 2 miles long. Their combined capacity was probably less than 20 second-feet. No information is available as to whether they are still in use.

Beardsley Canal.—The head of Beardsley Canal is about 1½ miles above the head works of Kern Island Canal, on the north side of Kern River. It is the uppermost of the Kern River canals which divert water from this river for the irrigation of portions of the main east-side plain of San Joaquin Valley. The construction of the canal extended through several years, commencing late in 1873. Its course for about 100 feet near its head is along the base of an almost vertical bluff of cemented gravel, and about 2 miles below its head it lies in an extensive cut, 8 or 9 feet deep, through a second bank of cemented gravel. This cut is nearly half a mile long. Otherwise the canal is located on ground favorable for canal construction. The canal was planned to follow a grade line skirting the southwestern base line of the Sierra Nevada foothills, and in this respect differed materially from the works on the other side of the river, which, except the upper section of the Kern Island Canal, were all constructed in the direction of the greatest fall of the land, thus occupying positions which are usually assigned to laterals. The Beardsley Canal was originally made 15 feet wide and 2 to 2½ feet deep, but owing to the light grade on which it was constructed—0.8-foot fall per mile—it was found difficult to keep it reasonably free from obstruction by the rapidly growing vegetation, and it became necessary to enlarge the canal to make its fall more effective. A timber weir of the open flashboard type is maintained across the river at the head of Beardsley Canal. For many years the full length of this canal was about 8 miles, but as it, with the majority of the other Kern River canals, came into possession or under control of the same owners, the Kern County Land Company, it was extended northward to and across Poso Creek, and now has a total length of about 25 miles. Its laterals frequently extend westward to a connection with the McCord Canal and to the Calloway, so that surplus waters are readily delivered to these lower canal systems. The territory commanded by this canal, lying between it and the Calloway, is about 33,000 acres, which includes between 6,000 and 7,000 acres formerly served by the McCord Canal.

McCaffery Ditch.—The mention of the McCaffery Ditch as an independent irrigation work is merely historical. It is a small ditch diverting water from the south side of the slough known as McCaffery or Calloway Slough, which has been made a part of the well-known Calloway Canal. The ditch is several miles long, 7 to 8 feet wide, and 2 to 3 feet deep. It was constructed in 1873, and is still in use as a distributary of the Calloway Canal water. The use of its water is confined to the island lying between Calloway Slough and the main channel of the river.

McCord Canal.—This canal, which has a position intermediate between the Beardsley and Calloway canals, was built, in part at least, in 1875 and 1876. A diversion of water was made from the north side of Kern River, about 2 miles below the head of the Kern Island Canal, into a natural high-water channel, and from this natural channel the canal proper was carried 3 or 4 miles northward. In 1879 the canal was reported to be about 4¼ miles long, with three branches, aggregating 10 miles in length. Its bed width was noted at 20 feet and its depth at 2 to 3 feet.[1] The canal was provided with a new head gate in 1882 and was extended northward. The main canal had a total length of about 12 miles. The district commanded by the canal is now served with water from the Beardsley Canal, and no attempt is made to maintain the McCord Canal as an independent work.

Calloway Canal.—This is the principal canal for the irrigation of lands on the north side of Kern River. Its purpose was primarily to supply water for the reclamation of lands entered as desert claims. Almost as soon as the notice of intention to make the diversion of water for this canal had been posted at the head of McCaffery Slough, in the spring of 1875, all individual rights were assigned to the Calloway Canal Company, known on the records as the Kern River Land

[1] See Rept. State Engineer, Wm. Ham. Hall, 1880, Appendix to Part IV, p. 77.

and Canal Company, and no time was lost in commencing construction, which was pushed forward rapidly until Poso Creek had been crossed by the main line of the canal. The diversion from the river was effected at the head of McCaffery or Calloway Slough, which was corrected in alignment so far as necessary and cut to a uniform width of 120 feet. The upper 2½ miles of the slough were thus appropriated for canal purposes. Thence an artificial channel 60 feet wide on the bottom was cut in a northerly direction. At between 2 and 3 miles from

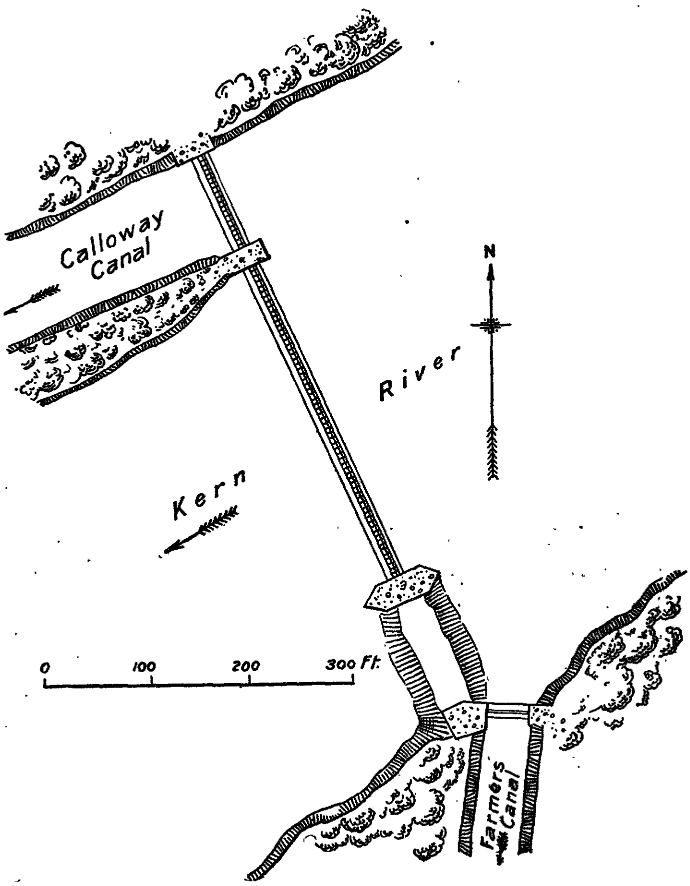


FIG. 8.—Head of Calloway Canal.

the slough the width of the canal was increased to 80 feet on the bottom, and it retained this width to Poso Creek. To the north of Poso Creek the canal extension is 60 feet wide. The canal has a fall of 0.8 foot to the mile northward from the point where it leaves McCaffery Slough for a distance of about 15 miles; thence to and beyond Poso Creek the fall per mile is only 0.4 foot. The total fall from the head of McCaffery Slough to the point where the canal proper leaves the slough is about 10 feet. The inflow into what is ordinarily called

WEIR AND REGULATOR, HEAD OF CALLOWAY CANAL.

the head of the canal, being the original head of McCaffery Slough, is controlled by a head gate or regulator. Where the canal proper leaves the slough a check weir, serving the purpose of a waste gate, closes the latter and affords convenient control of the water-surface elevation at that point. A second regulator is put into the head of the artificial channel, which leaves the slough just above the check weir. Sands accumulating in the slough channel above the lower barrier are readily sluiced out by removing the loose flashboards of the weir and permitting a free flow through the lower section of the slough back to the river.

The distribution of water from the Calloway Canal is effected by means of branch ditches or laterals, which are generally carried westward in the direction of the greatest slope of the valley plain. Their position is usually determined by that of gentle swells or ridges, which afford the best command of the lands to be irrigated. These laterals are ordinarily about 16 feet wide. Their banks are made high, so that inundation of adjacent territory can readily be accomplished. The natural fall of the valley surface in the direction of the laterals is 7 to 20 feet to the mile. This is reduced by means of check weirs or drops to less than 2 feet, effective, to the mile. Tenants of land to be irrigated from these laterals are reported to have frequently taken contracts for their construction as low as 5 cents per cubic yard of earthwork.

Late in 1879 Mr. F. R. Fillebrown, engineer in charge of canal construction, reported an expenditure of $78,165 on the main canal, and $49,460 on about 64 miles of laterals. The area covered by the 64 miles of laterals was reported at 16,160 acres, and the cost of laterals, with gates complete, per acre under ditch was $4. The cost of constructing check levees in this district for irrigation by flooding was given at $2.15 per acre. Water was first turned into the Calloway in 1875, but at that time the principal purpose was to moisten the canal bed and thereby facilitate excavation.

All structures on the canal are extremely simple, but efficient. The head gate or regulator now in use was constructed in 1884, late in the season, after a first freshet had floated the original head gate out of place. The gate was designed and built by Mr. L. F. Colton. While work on it was in progress a large portion of the dam or weir across the river at the head of the canal was washed away, and this was replaced under some difficulty, as the river rose before work was completed and flooded the foundation pit. Much of the flooring had to be nailed under water. The weir or dam across the river is a very light structure, of the open type, resting upon a floor which is the top of a large sand box extending across the river. The weir proper consists of a set of rafters, 4 feet apart from center to center, supported by a set of shores or braces, forming a light framework, and the necessary flash or drop boards for the closing of the spaces between rafters. The rafters were originally inclined at an angle of about 40 degrees, but when it was found desirable to raise the weir crest somewhat they were placed more nearly erect. They are cut off horizontally at the top and afford support to a single-plank footbridge, each plank of which is held in position by a dowel in the top of the weir timber. This arrangement was adopted to secure a proper spacing of the weir timbers at their tops. The drop boards are of light, 1-inch thick material. According to the original design, the entire superstructure was movable. A set of brackets has been attached to the weir frames below the footbridge to support the drop boards, which are out of service. The total length of the weir was originally 500 feet, of which only the northernmost 400 feet was rebuilt in 1884; the rest, extending from a small island in the river to the south bank, has been replaced by a solid earth, or rather sand, fill. This part of the weir had a superstructure of a type different from

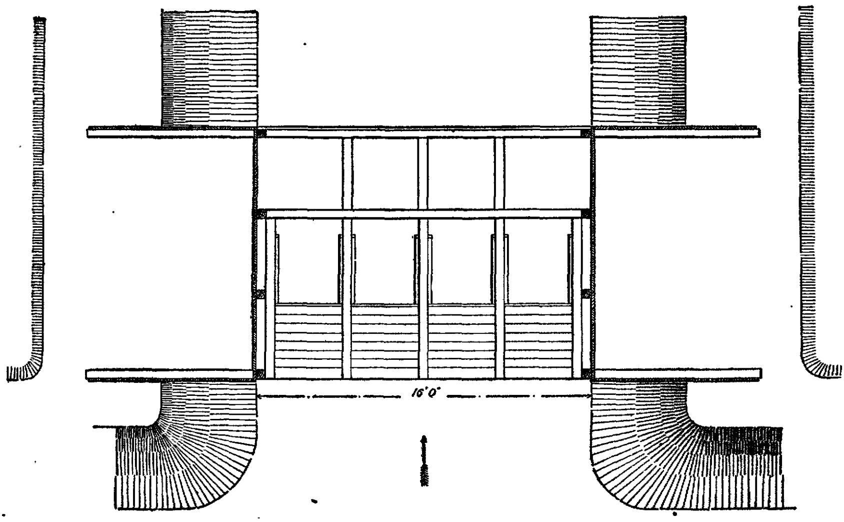


Fig. 9.—Plan of head gate of Calloway Canal.

that of the new weir. Its floor of 2-inch planking rested upon two lines of sheet piling, and the floor joists received additional support from intermediate piles. The river bed at that point, to an unknown depth, is a clean, moderately fine sand, with which all voids under the flooring were compactly filled.

With some variations in detail of construction the river weir is prolonged in a direct line northerly across the head of the Calloway Canal; but the timbers of the Calloway Canal regulator are somewhat heavier than those of the weir. Its frames are not movable. The main timbers are 6 by 8 inches, and have several supports each 6 by 6 inches. The canal regulator is 100 feet long, having 25 openings, or bays, each 4 feet from center to center of gate frames. The drop or flash boards are 1 by 6 inches.

At each end of the Calloway weir and of the canal regulator the banks are protected by timber bulkheads, sheet piling, and brushwork.

A full flow of water is expected in the Calloway Canal during the months February to May, inclusive. At the low stage of the river the canal is entirely dry. The maximum capacity of the canal, estimated some years ago from dimensions below McCaffery Slough, was about 550 second-feet, but the ordinary full flow is 450 to 500 second-feet. More water than this in the canal renders liability of breaks in the banks too great.

The canal laterals have been extended throughout a district having an area of about 60,000 acres, nearly all of which may be considered fully prepared for irrigation and actually irrigated each season. The principal crop irrigated is alfalfa. A view of a large field of this forage crop being irrigated by means of contour checks on the Jackson Ranch is shown in Pl. XII, *B*. No water was sold from the Calloway Canal

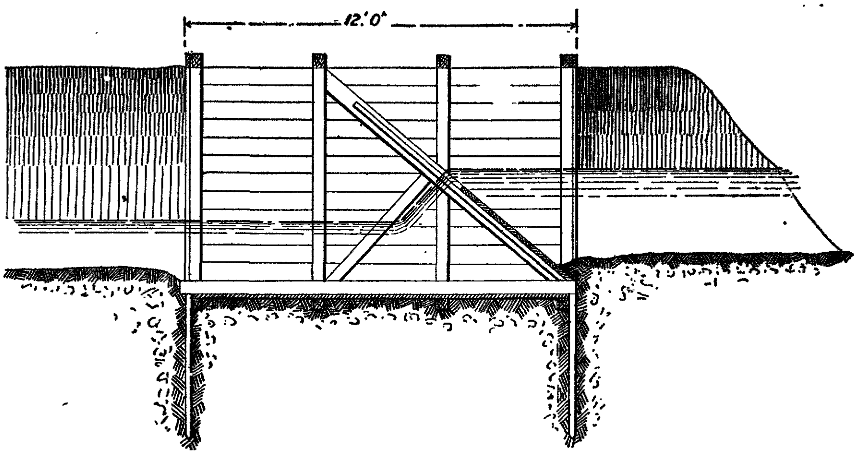


Fig. 10.—Section of head gate of Calloway Canal.

until the sale of lands owned by the Kern County Land Company (J. B. Haggin and Lloyd Tevis) commenced.

Emery Ditch.—This is a small ditch making a diversion of water from the north side of Kern River about 4 miles below the head of the Calloway Canal. It was constructed in 1877 as a private ditch by Mr. R. K. Emery, and was only 3 miles long, 6 to 8 feet wide, and 2 feet deep. The diversion of water was effected by inexpensive brush wing dams, a new one being required after each freshet. Notwithstanding a capacity of 10 to 20 second-feet, but little irrigation was ever accomplished with this ditch. It was difficult to force the necessary water into the ditch even at moderately high stages of the river; the loss of water in transit to lands to be irrigated was considerable, as the route of the ditch was across a sandy region, and the drifting sands made it difficult to keep the ditch open.

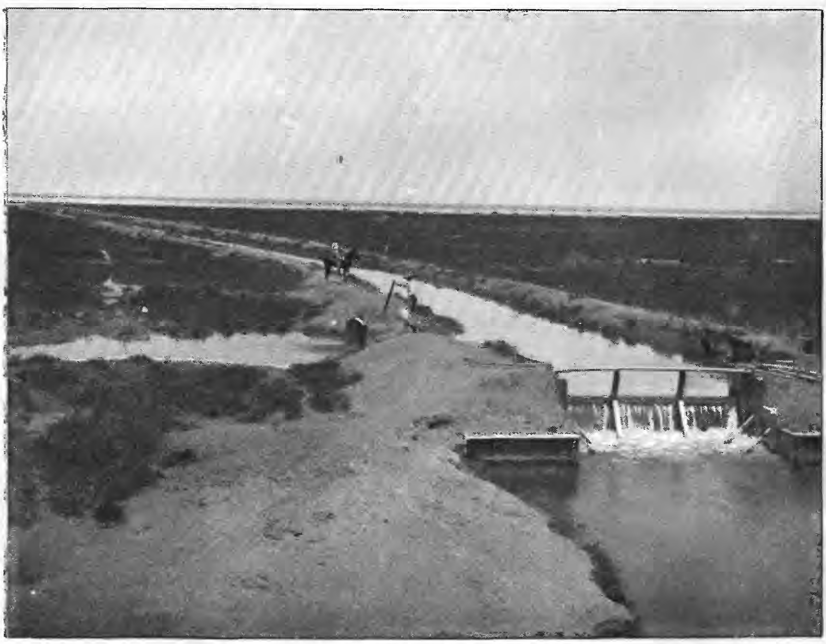
Jones & Tuckey Ditch.—The description of this ditch, like that of a number of the other lesser irrigation works from Kern River, is hardly more than a historical note. The ditch was next below the Emery Ditch, on the north side of the river, and followed a parallel route northward. It was about 10 feet wide and 4 miles long. It was constructed in 1876, but fell into disuse seven or eight years later, when it came under control of the principal owners of the larger canals commanding the same territory. Its rights have been merged with those of the larger canals.

Railroad Canal.—At the head of a natural high-water or overflow channel on the north bank of Kern River, known as Goose Lake Slough, three cuts have been made to afford a greater inlet capacity to the head of the slough. The uppermost of these is known as the Railroad Canal. It is about one-half mile long and 25 to 30 feet wide on the bottom. This canal, if such a designation may be applied to the diversion, was constructed late in 1875, and a light timber barrier 40 feet wide (8 bays, each 5 feet) was placed across its head for the control of its flow. The water diverted from the river into this channel was for the irrigation of lands (desert-land entries) near Goose Lake Slough belonging to persons who had failed to secure rights in the Goose Lake or the Wible canals. Very little irrigation was accomplished with it, except the natural wetting of lands adjacent to the slough. Only 320 acres of the lands for which water was claimed through the Railroad Canal are said to be still served with Kern River water.

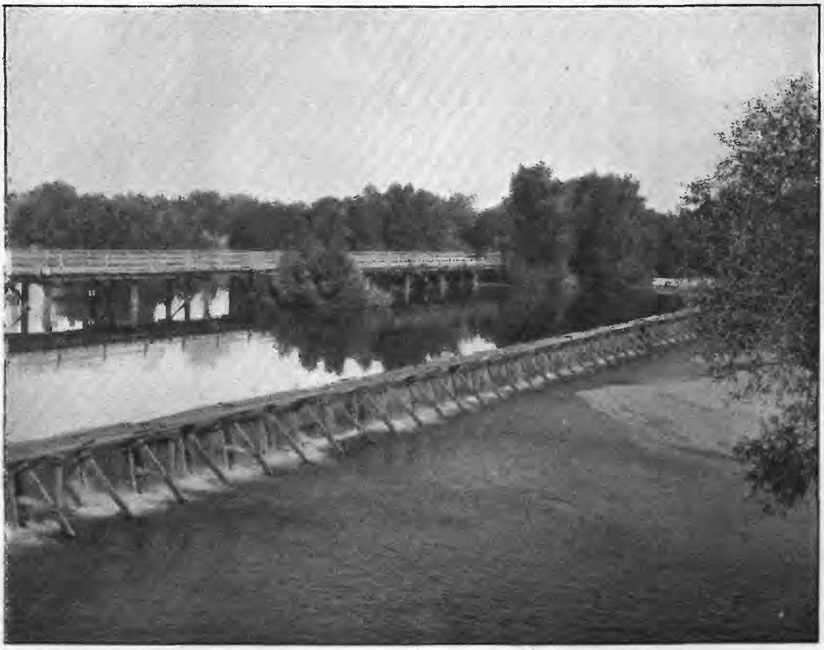
Wible Canal.—Just below the Railroad Canal is another cut from the river to the slough, which was made in the summer of 1875, by another set of persons, who were desirous of using Goose Lake Slough as a main channel to carry water to their lands. This cut was only 1,000 to 1,500 feet long. It was 30 to 35 feet wide on the bottom and about 2 to 3 feet deep. Its head gate was 56 feet wide. The first cost of the canal is reported at $3,500, and the cost of the regulator at $500. Water is apportioned to stockholders without any elaborate system of measurement. Expenses of management, which are light, are apportioned to the consumers of water by mutual agreement.

Goose Lake Canal.—First in the order of time of construction, but third in position, is the enlarged original head of Goose Lake Slough, known as the Goose Lake Canal. This is located on the north side of Kern River just above the Pioneer Bridge, about 7 miles in a direct line west of Bakersfield. In 1874 the head of Goose Lake Slough was cleaned out and enlarged and a regulator was built across it. This regulator is 134 feet wide. The head of the slough was 150 to 160 feet wide. This work has always been under the control of the parties who controlled the principal large canals already enumerated and has not been in use to any considerable extent for systematic irrigation.

A. CALLOWAY CANAL.



B. IRRIGATING ALFALFA IN CONTOUR CHECKS.



A. PIONEER CANAL WEIR, KERN RIVER.

B. PIONEER CANAL.

Pioneer Canal.—This canal was constructed in 1873 by settlers upon lands on the north side of the river below the Pioneer Bridge. It was originally made 30 feet wide at its head for a distance of a little over 100 yards; there its width was decreased to 10 or 12 feet. Subsequently, however, the canal was enlarged to a bed width of 30 feet throughout a length of 7 or 8 miles, and its upper sections were still further enlarged in 1879, when the canal was made 60 feet wide. From its head at the Pioneer Bridge the canal has a westerly course, its waters being used principally upon the Kern County Land Company's tract of land. The canal capacity reported for this canal by Mr. W. R. Macmurdo, C. E. (in charge of canal work in 1880), was 450 second-feet, and its cost about $44,000.

The head gate of this canal offers some points of interest. It rests upon sand. A trench was excavated across the canal, 14 feet wide

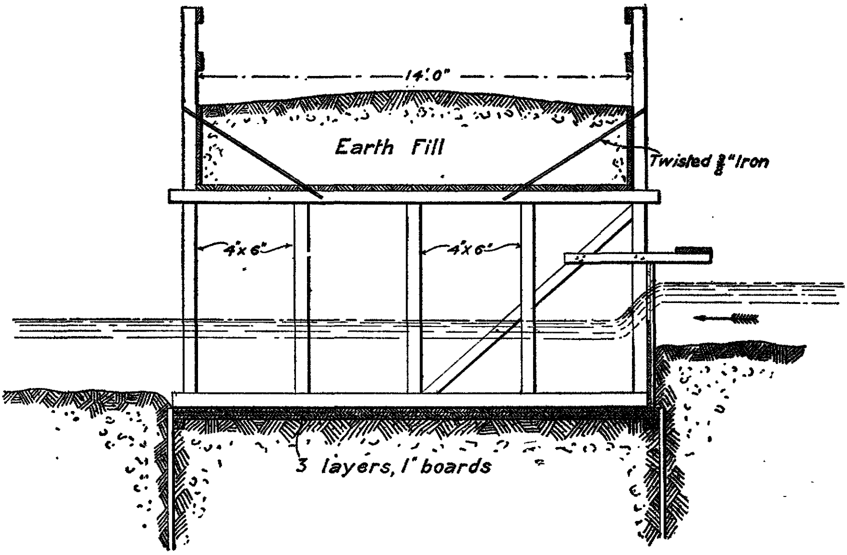


FIG. 11.—Section of Pioneer Canal regulator.

(14 by 60 feet) and 3 feet deep. Light sheet piling was driven on the four sides of this trench 1 foot deep. To the top of the sheet piling were nailed 2 by 4 inch timbers at the height of the canal grade. The trench was then refilled and 1 by 6 inch pine boards were laid across the top of the filling 4 feet apart, in the direction of the canal axis. Floor boards 2 inches thick were thereupon nailed to the pine strips and extended over the side walls of the trench. They were laid across the axis of the canal. On this floor sills 4 by 6 inches were placed on edge, 4 feet apart, for the support of 4 by 6 inch posts, which serve as bridge posts. The bridge floor is 2 inches thick and covered with an earth fill 3 feet thick, which serves to give weight and stability to the entire structure. The sides of the bridge, acting as retaining walls for the earth fill, are tied to the floor joists by means of three-eighths-inch

iron rods, twisted together for tension. The upper bridge posts support the loose flashboards by means of which the structure is converted into a regulator. This is one of the best examples of a cheap, efficient structure. Its total cost was only $540, including all earthwork. It was built in 1884 by the engineer in charge, Mr. Walter James. The weir in the river at the head of the Pioneer Canal was originally a combination structure. The weir posts supported a bridge, toward the construction of which a money contribution was made by Kern County. The original weir has been replaced by a late structure, crossing Kern River just below the Pioneer Bridge. This is very similar in arrangement to the one at the head of the Calloway Canal. It controls the water-surface elevation in the river for a number of canals and ditches besides the Pioneer Canal, including the Goose Lake Slough system on the north side of the river, and the Wilson and Meacham ditches on its south side.

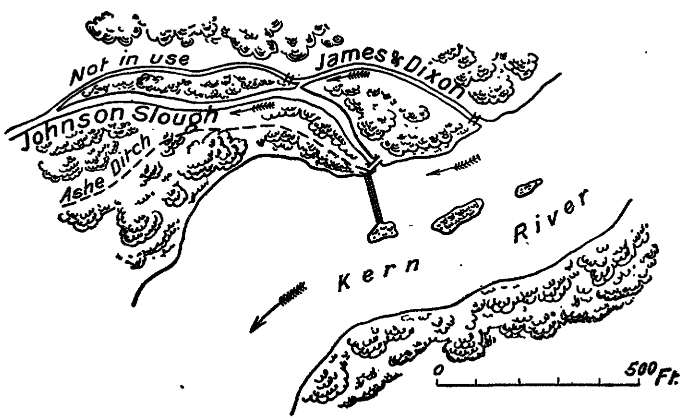


FIG. 12.—Head of James & Dixon Canal.

Edwards Ditch.—This ditch, whose head is about a mile below the Pioneer weir, is to be classed with those of lesser importance. It was constructed in 1875. Work may have commenced late in the preceding year. The ditch was about 2 miles long, and 10 to 12 feet wide on the bottom. It fell into disuse in 1879, but was reopened in 1885. It was then in use by several persons, but received water only at high stages of the river.

James & Dixon Canal.—This name has been applied to a cut about 2½ miles below the Pioneer Bridge, from Kern River into Johnson Slough (one of the river's north-side delta channels). This cut was excavated in 1872 and 1873. It was less than half a mile long, and was originally made 30 feet wide on the bottom. In 1884 it was connected, at a point about 200 yards below its head, with the Johnson Cut, a second opening from the river into Johnson Slough. The water delivered into the slough by the James & Dixon Cut is for use on portions of the McClung Ranch and on the Buena Vista Ranch. The slough is used in common by the owners of the two canals for about a mile below the point where their waters are mingled. The Johnson Canal water is there taken out of the south side of the slough for distribution to irrigators, while the James & Dixon Canal water flows on down the slough channel.

About 1882 it became necessary to establish a better control of the flow of water into Johnson Slough. To this end a reasonably permanent wing dam was constructed just below the Johnson Cut, and a new head gate, or regulator, was placed in that cut. The wing dam was in the form of a timber weir extending halfway across the river channel and resting against a small island. The space between its end and the south bank of the river was closed annually at the low-water stage by an inexpensive sand dam. The water was thus forced over the weir and brought under control. The control at high stages was not essential. This work was carried out under the direction and management of the owners of the James & Dixon Canal, and a proportional part of the cost—$2,200 out of a total of $4,700—was contributed by the owners of the Johnson Canal. The water supply for both canals was thereafter drawn through the same regulator.

The original purpose for which the James & Dixon Canal was constructed was to supply water for irrigation to the Buena Vista Ranch, then owned by Mr. James Dixon, and to lands in its vicinity. The canal and the lands to be irrigated by it have long since become a part of the property under control of the Kern County Land Company.

The combined capacity of the James & Dixon and the Johnson canals has been estimated at 400 to 450 second-feet. The head works of the James & Dixon Canal are now out of service, because it has been found more convenient to supply water to the lower section of the canal through a branch of the Pioneer Canal.

Johnson Canal.—Several hundred feet below the original head of the James & Dixon Canal is the cut from the river to Johnson Slough known as the Johnson Canal, which is owned by the Lower Kern River Irrigating Company. It was constructed in 1873 and is about one-eighth mile long. It was described by Mr. James D. Schuyler, in his report to the State engineer, as being 10 feet wide on the bottom, 3 feet deep, with bank slopes of 1 on 2; but greater original dimensions are claimed for it by resident engineers of Kern County. The canal water, as already noted, flowed about a mile in Johnson Slough and was then taken out for delivery to irrigators. The separation of its water from that of the James & Dixon Canal was effected and controlled by means of regulators, one being placed in the slough, another in the artificial channel. There was no sale of water to consumers. The canal owners took water as they needed it, and expenses of canal management were apportioned. The cost of maintaining head works at the river was borne in part by the owners of the James & Dixon Canal. Water is now delivered to the lands served by the Johnson Slough Canal through branches of the Pioneer Canal, and the use of the canal head works has been abandoned.

Ashe Ditch.—This ditch, which fell into disuse about 1882, was a small one, belonging to a private owner, and was constructed about 1874 or 1875. Its head was on the north side of the river, just below the Johnson Canal. It had a westerly course, was about 1 mile long, 8 feet wide on the bottom, and 2 feet deep. Its mention is merely historical.

May Ditch.—This ditch was in use for several years subsequent to 1874. Its length was 2 miles, its course westerly, its width about 8 feet, and its depth 2 feet. Its head works were 4 to 5 miles below those of the Johnson Canal. Whether it is now in use is not known.

Joice Canal.—There is some confusion among names applied to the ditches of Lower Kern River which were intended in whole or in part to supply water to the Buena Vista Ranch. In 1873 the lands known by this name were owned by the late W. C. Ralston, and were under the management of James Dixon. The first diversion made for their irrigation was in that year, from a minor north-side delta channel of the river known as Gage Slough. The ditch was 12 feet wide, and was intended to carry water about 2 feet deep. To increase the flow of water in that branch of Kern River upon which Gage Slough was dependent, a dam of brushwork was constructed across the most southerly of two channels into which the river separated a short distance above the head of Gage Slough. Still later, in the same year, a second ditch was constructed from the north side of the river above the slough, and this was connected with the first ditch. The head of Gage Slough was then closed permanently.

Two years later a private ditch was constructed as a branch of the Joice Ditch, commencing about 2 miles below the head of the latter. This was known as the Dixon Ditch, and has led to the use of the name Joice & Dixon Ditch for that part of the original Joice Ditch above the Dixon Ditch. The uncertainty as to amount of water covered by recorded claims, and the procedure in Kern County leading to the granting of a canal franchise, are well illustrated by the Joice Canal. A notice was posted on April 28, 1873, in sec. 21, T. 30 S., R. 25 E., Mount Diablo meridian, by Messrs. E. V. Joice and James Dixon, of a claim to 10 cubic feet of the water of Kern River, measured under a 4-inch pressure. On May 26 of the same year the same persons posted another notice of claim to 20 feet of water, measured under a 4-inch pressure. These claims were followed in 1878, on October 7, by another by Mr. William B. Carr, posted on sec. 23 at the head of Joice Canal, to 6,250 inches of water, measured under a 4-inch pressure. He was on the following day granted a franchise by the supervisors of Kern County, acting in the capacity of water commissioners, to construct a new canal 30 feet wide on the bottom, 2 feet deep, and having a cross-sectional area of 72 square feet, or to enlarge any canal acquired by him to these dimensions for the purpose of diverting the amount of water named in his claim. The franchise then obtained was transferred a few days later to the Joice Canal Company.

From a report made in 1879 by Mr. W. R. Macmurdo, one of the engineers in charge of canal work, to Messrs. Haggin & Carr it is learned that the cost of irrigation with water of this ditch, after ditches and checks were all constructed, was as low as 10 cents per acre. The lands commanded by the canal can also be supplied with water from the Pioneer Canal and from the James & Dixon Canal, as has been already explained. The Joice Canal receives water only during comparatively high stages of Kern River. A timber weir extending partially across the river was maintained for a number of years, but it has recently been found more convenient to abandon the canal head works and to supply it with water from the Pioneer Canal.

Dixon Canal.—Two years after the construction of the Joice Canal the branch known as the Dixon Canal was carried in a northwesterly direction, for the irrigation of a small tract of land on the margin of the lands segregated as swamp and overflowed, and thereafter the upper portion of the Joice Canal, about 2½ miles long, was regarded as the common head of the two ditches. The ditch was described by Mr. James D. Schuyler in 1880, in his report to the State engineer, as being 2½ miles long, 6 to 8 feet wide on the bottom, and 1½ feet deep.

Kern Valley Water Company's canals.—For the reclamation of the lands in the upper or southeastern portion of Buena Vista Swamp two large canals were constructed, one upon either side of the long, narrow trough of the valley through which the overflow waters of Kern and Buena Vista lakes took a northwesterly course toward Tulare Lake. Of these two canals, the one on the west side was intended as a recipient of the flood flow, and was therefore given magnificent dimensions. The other canal was to serve more particularly as a source of supply for irrigation water. Both of these canals were connected with Buena Vista Slough, a natural channel of irregular alignment and variable dimensions, which has a northwesterly course from Buena Vista Lake for a distance of about 8 miles to the vicinity of the canal head works, near which point its channel becomes more or less indefinite.

At the time these canals were constructed, about 1875, it was proposed by their projectors to convert Kern and Buena Vista lakes into great storage basins of water to serve for the irrigation of lands to the northwest. But this proposition met with opposition. Other claims to the lakes were advanced. The lake beds were claimed as swamp and overflowed land subject to reclamation by drainage. Long litigation ensued, involving among other things the question of riparian ownership in the waters of Kern River, as it was manifestly to the advantage of the owners of lands in Buena Vista Swamp to prevent diversions in the upper sections of the river, so as to augment the flow through natural channels into Buena Vista Lake and thence into the channels from which the lower canals were fed. As a result of this litigation it was definitely determined that the doctrine of riparian rights prevails in this State; and, more directly bearing upon the questions at issue, it led to an agreement between the conflicting interests according to which the use of lake surface for reservoir purposes was restricted to Buena Vista Lake, and some definiteness was given to the rights of the various canals to make diversions of the Kern River water.

As soon as this result was reached, in 1891, work progressed rapidly on the structures necessary to dam off Buena Vista Lake toward the east and to control the outflow of its waters toward the north. The storage capacity of the lake is represented to be 150,000 acre-feet, being presumably the amount actually available for irrigation purposes when the lake is full. The alignment of the principal channel of Kern River in its course toward the lake has been corrected, and it is separated by means of high embankments from a return channel correspondingly correcting the alignment of Buena Vista Slough. With-

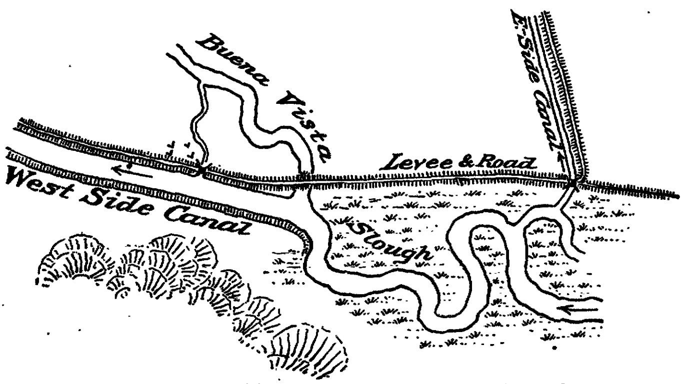


FIG. 13.—Head of Kern Valley Water Company's canals.

out any definite information concerning the cost of these works, it is not unreasonable to suppose that it has exceeded $250,000, in addition to over $300,000 for original canals.

The west-side canal was made 125 feet wide on the bottom and was planned to carry water 7 feet deep. The position of the canal along the western border of the swamp gave it a fall of about 4 to 5 feet to the mile, which was reduced by means of check weirs or drops. Four of these were constructed, but three were washed out, and but a single one remains to serve as a regulator. The canal has a length of 24 miles, covering more than one-half the distance toward Tulare Lake, and discharging at its lower end upon the lower portion of Buena Vista Swamp. The east-side canal is 25 feet wide and has a depth of 3 to 5 feet. A regulator has been placed in it where it is crossed by the road embankment, which serves as a barrier against flood waters of the river or slough from the south. The regulator is a combination of a bridge with earth fill on top and a gate. The gate is of the ordinary vertical flashboard type.

Where water is to be drawn from the main west-side canal for irrigation purposes it is admitted to distributing ditches by means of wooden box culverts placed under the canal levee.

Maintenance of the works has involved frequent bank protection on the main canal, the bottom of which below its regulator has been irregularly eroded.

Flood waters have frequently made dangerous inroads upon banks and levees where the canal lies in the light alkaline soils of the west side, which do not afford much resistance to the erosive action of the water.

The irrigation from this canal system is still confined to the alfalfa fields at the head of Buena Vista Swamp between the two main canals. Here about 20,000 acres of alfalfa, in one continuous tract and under one ownership and management, represent the extent of the water's use.

The system of irrigation is the contour-check system. The contour levees have usually 6 inches difference in elevation, or a little more. The soil is a black vegetable mold, 4 to 6 inches deep, under which is a heavy clay subsoil. Checks are generally 8 to 10 acres in area. Small checks are preferred, and some of the larger ones are being subdivided. Some drainage of the land after flooding is necessary and drain ditches are provided for the purpose. The cost of preparing the land for irrigation, including the cost of small ditches, was about $10 per acre.

KERN AND TULARE IRRIGATION DISTRICT.

No work of actual construction was done on the proposed canal system for this irrigation district, now disorganized, but as the contemplated source of water supply was Kern River the project requires mention. The district was located on the east-side valley plain surrounding Delano, in Kern and Tulare counties, about 25 miles northward from Kern River. It had an area of 84,000 acres. The proposed main canal was to have a bed width of 40 feet, a water depth of 4 feet, a fall of 9 inches to the mile, and a total length of about 55 miles. The diversion from the river was to be made about 8 miles above the head of the Beardsley Canal, on the north side of Kern River, and the route of the canal was to be westward along the bluffs and broken slopes of the hills for about 7 miles, to where it emerged upon a comparatively smooth plain at the base of the hills, thence northerly across Poso Creek and Dyers Gulch, to and across White River. The estimated cost of the main canal was $426,000 and of the necessary distributaries $195,000. The district was organized in 1890, and a bond issue of $700,000 was intended to cover cost of works.

WATER SUPPLY, DISTRIBUTION, AND MEASUREMENT.

The breadth and shallowness of the bed of Kern River, whose banks are only 3 to 6 feet high, facilitate diversion of its water. The lands irrigated have already been described.

Diversions are numerous both toward the north and toward the south, and are usually effected by the use of light, movable, open-work timber weirs, above which water is forced into the head of a ditch or canal. The flow in the canals is controlled by gates or regulators, usually of the inclined or vertical flashboard type.

The canals on the north side of the river have an aggregate capacity of several thousand second-feet; those on the south side, between 1,000 and 2,000 second-feet.

Most of the Kern River canals were constructed for the irrigation of particular tracts of land, and therefore received alignments as direct as possible from the point of diversion to the land to be irrigated. Their location in a position to command as much land as possible is exceptional. The Kern Island, Beardsley, McCord, and Calloway canals are among the exceptions. On Kern Island the course of the canals is generally in the direction of the greatest slope of the ground's surface. As this slope is represented by a fall of about 7 feet to the mile, and the soil is generally easily eroded, check weirs or drops are necessary to check the flow of water in the canals and to render diversion into laterals possible. Such structures are about one-half mile apart on the principal original branches of the Kern Island Canal. There are 25 of them in the main channel of the Stine Canal, and about the same number on the Buena Vista Canal. The James Canal has 14.

Despite the various names assigned to the Kern River canals and to the corporations which own them, the conflicting interests thereby indicated do not all exist. Almost the entire canal and ditch system of this river has passed into the control of the two great proprietary firms, Haggin & Tevis and Miller & Lux, and contentions as to water apportionment are usually restricted to broad questions affecting whole districts rather than individual diversions. Until a satisfactory allotment of the low-water flow of the river was agreed to by these firms, comparatively little attention was paid to perfecting a system of water apportionment either from the river or from the several canals. It was the rule for each irrigator to use water as he required it, so long as water was available. The only canal from which water was sold until within the last few years was the Kern Island Canal.

The plan of apportionment of water in the case of the Beardsley and the other canals owned by joint stock companies, stock being held by landowners, gave to each stockholder a part of the water in the canal proportional to the amount of stock owned, but the distribution was based on approximation, without attempting measurement of the water delivered.

The allotment of water to the irrigators from the Kern River canals is in charge of canal superintendents, who are assisted by ditch tenders, locally called "zanjeros." The canals are inspected daily, and the water applied for by irrigators is delivered into their irrigating ditches. Water is sold by measurement, being delivered through measuring boxes.

Before 1875 water was furnished free of charge from the Kern Island Canal to irrigators, in order to encourage its use. During the years 1875 to 1877 it was sold at 1¼ cents per 24-hour inch (miner's inch, supposed to be under 4-inch pressure, equivalent to about 0.02 second-foot), aggregating about $1.50 per acre per annum, as then used for the various crops cultivated. In 1878 the rate was increased to 1½ cents per 24-hour inch. In 1879 the Kern Island Canal Company charged the following rates for water:

For general farming: April to November (inclusive), 1½ cents per inch under a 4-inch pressure, for twenty-four hours. December to March (inclusive), 1 cent per 24-hour inch.

For market gardens: For 12-inch stream and upward for not less than one half month, 2 cents per inch per day of twenty-four hours. For 48-inch stream and upward for one day or more, 2 cents per inch per day of twenty-four hours.

For house lots and gardens: 12 inches for one day of twelve hours, or 24 inches for one-half day of six hours, $1; 12 inches for one night of twelve hours, 75 cents; 12 inches for one-half day of six hours, or 24 inches for three hours, 75 cents; 24 inches for one day of twelve hours, $1.50; 24 inches for one night, $1.25; 24 inches for one hour, 50 cents.

The prices now charged vary somewhat for the different canals, being adjusted according to operating expenses. They range from about 30 to 75 cents per second-foot for twenty-four hours, and in exceptional cases have been below the lowest rate named.

The original measuring box was so constructed that a uniform head, over an aperture which could be adjusted to the number of inches called for, could be maintained. The area of the aperture was controlled by means of a horizontal sliding board. It was 4 inches in height, and the surface of water above the aperture was maintained at 4 inches above its top. Water had an unobstructed outfall through the aperture.

This gate was superseded by a well-constructed overfall weir. Water is admitted to a chamber above the weir by means of a gate which affords control of the water elevation. The depth of overfall is determined by measurements to the water surface above the weir from a carefully set "level-board." The cubic foot per second, or second-foot, has recently been substituted for the inch as the unit of measurement. At the present time gates with submerged orifice are preferred and are coming into general use.

On the South Fork Canal no system of measurement has been introduced. Each consumer takes what he requires when there is an abundant flow in the canal. When water becomes scarce, a canal superintendent is employed to apportion the water to the canal stockholders.

The same lack of system in water measurement prevailed for a long time on the Pioneer, the Beardsley, and many other canals before they passed entirely into the ownership or under the control of the large water corporations.

METHODS OF IRRIGATING AND DUTY OF WATER.

Alfalfa and cereals are still the principal crops irrigated with Kern River water, although during a few years orchard and vineyard areas increased rapidly in the colony tracts north of the river. The demand for water for the large areas represented by the alfalfa and wheat fields has led to special effort to minimize the expense of applying water to the soil. The system of wetting the soil for these crops is generally by flooding, which is accomplished in various ways. The most primitive system, rapidly falling into disuse, is that of spreading water over the surface from small temporary ditches, sometimes mere plow furrows, located on high ground, and controlling the overflow from these. Skill is required to cover the whole surface with water; the progress of irrigation is slow and the system is expensive because much labor is required to control the water. The only advantage of this system is that its first cost is small.

Irrigation by flooding in rectangular checks is confined to occasional orchards and vineyards and small tracts of alfalfa. The favored method of applying water is by flooding in contour checks. Low, flat embankments, generally 1½ feet in height, rarely 2 feet, are thrown up, which closely follow contour lines, and the spaces between these are divided into compartments or checks by means of cross levees. The areas of these checks range from less than 1 acre to 60 acres. When a tract of land checked in this way is to be irrigated, water is admitted to the highest checks first, and as soon as the flooding of a highest check is complete its water is drawn off through suitable gates to the one next below, into which the irrigating stream is turned at the same time.

The labor attached to this system of irrigation is much less than that required by the method of wild flooding, but the first cost of preparing land is considerable. The cost of land preparation will of course depend upon the smoothness of the surface and its slope; also upon the character of the levees between compartments. The best form of these levees has a base 16 to 24 feet in width and slopes so flat that any kind of farming implement may cross them in any direction.

The following example of cost of land preparation and ditching under the Calloway Canal has been taken from notes by Mr. James D. Schuyler:[1]

The average cost per acre of 5,956 acres prepared in this way was as follows: Earthwork, $1.64; waste or drainage gates, $0.51; total, $2.15. The average cost of lateral canals, including necessary regulators and side gates to supply the land, was $4 per acre, making the total cost of preparation of ground $6.15 per acre.

These check levees are built upon 1-foot contours with about 20 feet base; the lateral canals are from one-fourth to one-half mile apart, and the checks range from ten to fifty acres in area. From 15 to 20 miles of check levees are required per square mile of land, and a mile of levee contains 3,080 cubic yards. The soil is a sandy loam, easily worked, and the cost of preparation shown above is probably less than the average cost of such works elsewhere.

The laterals can supply water to the checks between them at a rate generally between 100 and 200 second-feet, the amount of water ordinarily admitted at one time into a check being about 50 to 70 second-feet from each of the laterals between which it lies. The contours on which the levees are constructed are from 0.5 to 1 foot apart in vertical elevation. One foot was first adopted as the vertical distance between contours, but experience has proved it to be better to reduce this distance, thereby making the water more controllable and at the same time reducing the area of the checks.

In filling large checks water stands long on the lowest ground. It is customary to draw it off into the next check as soon as the whole surface is submerged. But it is found that the portion of the check submerged for the shortest period of time produces a crop equally as good as that from any other portion. All percolation in localities where water stood more than the minimum time allowed for the high places is therefore a waste of water. This waste in large checks is frequently so great that a check can hardly be filled, as water is lost by percolation almost as fast as supplied. Economy of time and water would therefore seem to demand checks smaller than those in common use at present to the north of Kern River, where the average area of checks is about 8 to 10 acres. Moreover, the use of lower check levees reduces the obstructions offered by the check system to farming operations.

It can be shown by mathematical demonstration that there is considerable loss of water and of time when porous soils are irrigated in large checks, but an example will suffice.

The irrigation of a 60-acre check of alfalfa with water from the Calloway Canal commenced at 5 o'clock p. m. on May 12, 1885. All parts of the check were covered and irrigation was complete about 8 a. m. on the following day. No accidents causing loss of water had occurred. The amount of water entering the check was stated to have been about 250 second-feet (one-half the amount then flowing in the Calloway Canal). This is presumed to be an overestimate, and it will be safe to say that at least the maximum amount ordinarily delivered from two

[1] Rept. State Engineer of California, 1880, Part IV, App., p. 85.

laterals was entering the check. This amount would be about 150 second feet.

During the time required to accomplish the irrigation of these 60 acres the amount of water entering the check was sufficient to have covered it to a depth of over 3 feet, while the amount in the check when its irrigation was complete, and which was in part available for irrigation in lower checks, had an average depth of about 0.75 foot. The total amount absorbed was therefore over 2.25 feet, and it must be presumed that much more water sank into the ground in those parts of the check which were lowest and had water standing on them fifteen hours than in those parts which were highest and were submerged only from two to three hours.

For economic irrigation the volume of water applied and the areas of the checks should be so adjusted that no portion of the check will be under water more than twice as long as the period of desirable inundation. In porous soils the full head of water can generally be allowed to flow into a check until irrigation is complete. In heavy soils there is less danger of excessive waste, absorption by the soil is less rapid, and the head of water may be reduced as soon as the whole surface of the check is submerged. A rapid delivery of the surplus water from an irrigated check into the one next below it is essential to economic irrigation by the contour-check method.

Irrigation from the Calloway Canal in May, 1885, was progressing at the rate of 200 to 400 acres per day. The flow of the canal was 450 to 475 second-feet. In other words, the irrigated tracts were receiving water at the enormous gross rate of 130,000 cubic feet per acre, equivalent to an average depth of about 3 feet over all lands irrigated.

A new system of irrigation by flooding has recently been tried on some of the land commanded by the Calloway Canal. This system consists in the construction of parallel levees which follow lines of greatest slope at short intervals. These levees are low, not over 1 foot high, and are placed 50 to 200 feet apart. There is between each two a long, narrow strip of land, crossed at intervals by a levee at right angles to the embankment on each side. These cross levees have along their bases distributing ditches with gates on their lower sides, so arranged that water can be admitted into the compartment between the levees lying next below. Flooding is accomplished by admitting water in large quantities to a compartment at its upper end and allowing it to flow in a broad, shallow sheet to the lower end. Water not absorbed in thus passing through a check is collected at the upper base of the lower cross levee and is allowed to find its way back into the distributing canals for use at points below. Only land with a smooth surface and of very slight slope can be irrigated in this way. The system is better adapted for alfalfa fields than for grain land, because in the former the surface of the soil is more compact and the plants offer more resistance to the flowing water.

The following examples of irrigation, illustrating the duty of water, are in part taken from Mr. James D. Schuyler's report to the State engineer in 1880.[1] The latter ones are from unpublished data collected and prepared for the use of the State engineer in his final publication, which has not been issued.

In the following table the quantity of water used by some Chinese vegetable gardeners in 1879 from the Kern Island Canal, near Bakersfield, is noted. The data on which the table is based are reliable.

Quantity of water used by gardeners in 1879 from the Kern Island Canal, near Bakersfield.

Name of irrigator.	Area of land irrigated.	Total water used.	Average depth of water used on land.	Cost of water per acre.	Period of irrigation.
	Acres.	*Cubic feet.*	*Feet.*		
Sin Mon	30.0	5,320,800	4.07	$1.97	Dec., Feb. to June (incl.).
Ah Cow	.8	1,331,840	38.20	20.00	Feb., Mar. to June (incl.).
Ah Gee	50.0	6,375,600	3.00	1.42	Jan., Mar. to June (incl.).
Ah Song	3.2	2,751,200	19.70	10.00	Jan. to June (incl.).
Ah Lung	3.2	2,322,432	17.00	6.17	Feb. to June (incl.).
Sing Lee	10.0	1,658,880	3.80	1.92	Apr. to June (incl.).

The smaller of the gardens irrigated have a stream of 6 to 12 inches (0.12 to 0.24 second-foot) running continuously, day and night.

On secs. 1 and 2, T. 30 S., R. 27 E., 2 miles south and west of Bakersfield, along Panama Slough, where the land receives the percolation of several channels, natural and artificial, a field of 50 acres of alfalfa is irrigated in six days and nights with a stream equal to 1½ second-feet, and an orchard of 20 acres is irrigated in two days and one night with the same amount. The discharge would be equivalent to a depth of 0.36 and 0.37 foot, respectively, over the land irrigated. The soil is an alluvial loam. The orchard is irrigated once a month, and the alfalfa field once or twice a year, or more, when it is used as a pasture.

SE. ¼ sec. 30, 6½ miles south of Bakersfield, was irrigated first in 1878. Four acres can be irrigated in twenty-four hours with 7 second-feet. Allowing a loss of 1 second-foot in transit from canal to lands, this amount would be equal to a depth of 3 feet over the whole area. The soil is a sandy loam. Surface water is at a depth of 6 feet, rising to 3 feet after irrigation and subsiding again. The crops irrigated are wheat, barley, beans, sweet potatoes, alfalfa, and orchard and small fruits. The water used in 1878 cost $1.03 per acre, and in 1879 it cost 81 cents per acre.

On SW. ¼ sec. 31, 7½ miles south of Bakersfield, a first irrigation of 40 acres in May and June, 1879, was effected with 1,209,600 cubic feet of water, equivalent to a depth of 0.7 foot over the whole area. The land was thoroughly soaked in the spring by a break in the canal, and received the benefit of constant percolation. Cost per acre of the only

[1] Report of W. H. Hall, State Engineer of California, 1880, Part IV, App., p. 86 et seq.

irrigation given was 25 cents. The soil is a sandy loam containing decayed vegetable matter. Crops, cereals.

On sec. 32, 7½ miles south of Bakersfield, from July 23 to 29, inclusive, six days, 40 acres were thoroughly saturated with a discharge of 7.73 second-feet, equivalent to a depth of 2.3 feet over the whole area. The land had been irrigated but once before this season—the first week of May. It was dry to a depth of 6 inches, while surface water stood at a depth of 3.75 feet below surface. The land was first irrigated in the spring of 1878, when surface water stood at a depth of 17.5 feet. After first irrigation it rose to 12 feet; after first irrigation in 1879 it rose to 3.75 feet, where it remains. The soil is an alluvial sandy loam, mixed with partially decayed tule roots to a depth of 17 feet, and underlain by a stratum of clay 12 to 14 inches thick. The crops are wheat, barley, alfalfa, and corn. The average number of irrigations during the season is about one and a half. The average cost of water per acre is 70 cents. The average cost of labor (Chinese) per irrigation is 8 to 10 cents. A part of the land is irrigated by the check system, and a part by the small ditch or wild flooding system.

On sec. 5, T. 31 S., R. 28 E., 8½ miles from Bakersfield, adjoining the last-named section, with similar soil, and cultivated the same length of time, a record was kept of the quantity of water used for the second irrigation of a tract of 150 acres of corn. The total discharge in twenty-one days was 16,004,736 cubic feet, sufficient to have covered the land to a depth of 2.45 feet. The land had been irrigated in February or March for wheat, but it was so late that only weeds sprouted. In June the land was irrigated again to prepare it for corn, and the last irrigation noted above was from July 23 to August 12. The total cost of labor employed for the last irrigation of corn was $80.50, or 53.67 cents per acre. The total cost for water and labor was $1.20 per acre. The total cost of water used on the section during the season for 350 acres of wheat and 150 acres of corn was $452.32, or 90.5 cents per acre.

On sec. 7, T. 31 S., R. 28 E., the first irrigation of 50 acres of corn (the land having been wet before plowing in May) was accomplished in ten days—July 21 to 30—with an average discharge of 7.2 second-feet, equivalent to a depth of 2.86 feet over the whole area. The total cost for water was 31 cents per acre. The total cost of water for the season for irrigation of 90 acres of wheat and barley, 50 acres of corn, and 70 acres of alfalfa was 55 cents per acre. The soil was in part black, stiff loam, almost adobe in texture, in part loam mixed with sand, and in part coarse sand underlain by quicksand. Most of the land under cultivation was irrigated this year for the first time. The ranch could nearly all be subirrigated, but the owner preferred the small ditch system. He thinks that next year his land will absorb not more than one-half the water it has this year.

On secs. 21, 28, and 33, T. 31 S., R. 28 E., and sec. 4, T. 32 S., R. 28 E., 12 miles from Bakersfield, in the vicinity of Kern Lake, 800 acres of wheat, corn, and alfalfa were irrigated once, 250 acres irrigated twice, and 100 acres three times. The entire acreage required a total of 66,450,000 cubic feet of water during the season—equivalent to a depth of 1.33 feet at each irrigation. The average cost of water was 50 cents per acre for the season. The soil is a stiff, black loam, 1 to 2½ feet thick, underlain by yellow clay 2 to 4 feet thick, beneath which surface water is abundant in a stratum of sand. Moisture is also found above the clay, maintained by drainage of lands above.

On sec. 4, T. 31 S., R. 27 E., in one experiment 3⅓ acres, prepared with care, leveled, and checked with proper levees, were covered in fifteen hours with an average discharge of 2⅝ second-feet, equivalent to a depth of 0.87 foot over the whole area. The land lies adjacent to Panama Slough, from which it receives moisture by percolation. The soil is a sandy loam of considerable depth. The surface water is 8 feet below the surface. The land had been irrigated four or five years.

At Livermore Ranch (Greenfields), secs. 18, 20, 29, 30, 31, 32, T. 31 S., R. 29 E., and sec. 5, T. 32 S., R. 29 E., the average number of waterings required is 1½—one general irrigation and a second irrigation on the drier spots. The average cost per acre for labor of irrigation is 12 to 15 cents. The average cost for the season for labor and water is $1.50 per acre. The water was shut off from March 17 till May 15, causing the failure of 300 acres of barley and 600 acres of wheat that had been sown. No data could be obtained as to the quantity of water used per acre. The ranch being at the terminus of the main canal and the central branch, the supply fluctuates according to the demands from the lands above.

Mr. Schuyler says: "These examples are all taken from lands requiring comparatively little water, as they are all subject to percolation from numerous sources. Most of the lands referred to are irrigated from the Kern Island Canal. This being the only canal in the county from which water is sold by measurement, the data afforded regarding the cost of irrigation and the quantity consumed are more definite and reliable than any that could be obtained elsewhere."

A few other examples may be given as approximately correct to illustrate the thirstiness of other classes of soils.

On Bellevue Ranch, T. 30 S., R. 27 E., no exact data as to volume of water used could be obtained. The average number of irrigations required for cereals is two to three, one being sometimes sufficient in seasons of favorable rainfall. For alfalfa three or four irrigations are generally needed; for corn two are sufficient. The soil is sandy, with streaks of heavy loam marking the course of old sloughs.

On McClung Ranch, secs. 3, 4, and 5, T. 30 S., R. 26 E., and sec. 1 in township adjoining, the first year of irrigation (1874) a ditch, described as "12 feet wide on bottom, 2 feet deep, with a good average flow," was discharged for seven months upon 100 acres before the land was saturated. If this be true, such a ditch, with side slopes 1 to 1 and grade of, say, 2 feet per mile, would have discharged enough water in that time to cover the land 166 feet deep. The water was, of course, not confined to the immediate neighborhood of the tract upon which it was discharged, but spread for miles in underground channels, filling up the loose porous soil to a depth of several feet. The average head of water which one man can conveniently handle in irrigating on the McClung Ranch is what will pass through a gate 4 feet wide with a depth of overfall of about 1 foot, equivalent to about 13 second-feet, and with this from 1 to 6 acres per day (of twelve hours) can be irrigated. This discharge is sufficient to cover the land from 2 to 13 feet deep. The land has been irrigated from three to four years, and absorbs a trifle less each year; but if irrigation be suspended for one season the surface moisture drains away, and the following year much more would be required than would have sufficed the previous year. This is the case, to a greater or less extent, in all parts of the valley of Kern River. On the lands cited in this example one thorough soaking is sufficient to produce a crop of cereals, with enough rainfall to sprout the grain. With no rain two irrigations are required—one to prepare the land, the other to mature the crop. Alfalfa requires three to four waterings through the season to maintain a vigorous growth. The soil is a coarse sand and sandy loam of great depth.

In sec. 13, T. 29 S., R. 27 E., on a strip of bottom land between the McCord Canal and Calloway Slough, 80 acres of alfalfa have been irrigated in four days and nights with a discharge of about 6 second-feet, sufficient to have covered the ground to a depth of 0.6 foot. The land had been irrigated for two or three years. The soil is an alluvial loam having an elevation of but 5 or 6 feet above the river, and receiving constant moisture from below by percolation. The crop was irrigated twice during the season prior to August 1.

On sec. 14, T. 29 S., R. 27 E., with a discharge equal to about 2 second-feet 2 acres of corn can be covered in a day of twelve hours, equivalent to a depth of about 2 feet over the whole area. This example was given as the fourth and last irrigation of the tract in the season, the land having been wet once before seeding and three times after. The land had been irrigated several years. The soil is a brown sandy loam 1 to 6 feet deep, underlain by hardpan not wholly impervious.

On sec. 8, T. 29 S., R. 27 E., alfalfa is said to require irrigation twice a month. Wheat is irrigated once before and twice after planting. Corn requires five irrigations, the first of which is given before seeding, in May, the last in the latter part of July. The soil is a sandy loam 2 feet deep, underlain by 2 feet of yellow hardpan. No data as to quantity of water required at each irrigation were obtained.

On sec. 27, T. 28 S., R. 26 E., the first irrigation was in 1879. Wheat required three or four irrigations, one prior to sowing. The land was irrigated by the check system, by which two men could water 160 acres in four days, at a cost of about 10 cents per acre per irrigation for labor. The soil is similar in character to that cited in the foregoing example.

At Poso Ranch, sec. 9, T. 27 S., R. 25 E., a test was attempted to ascertain, if possible, the quantity of water absorbed by the desert lands on the plains north of Kern River, now supplied by the Calloway Canal. A check containing 3¾ acres was prepared and water was admitted in as great quantity as was expedient for the safety of the newly built banks about the gates. An hourly record of the head was kept, the discharge being from 4 to 9 second-feet. Eleven hours were required to fill the check sufficiently to barely cover the highest ground, when the water was shut off. Next morning all the water had soaked away. The quantity discharged was sufficient to have covered the whole area to a depth of 1.75 feet. A portion of the area doubtless absorbed five times as much as the higher spots, as the percolation seemed to be entirely downward, and not in a lateral direction. Three weeks later the check was filled in four hours and twelve minutes, with an average discharge of 13.35 second-feet, the ground being covered to an average depth of 1.25 feet. Some time between these two experiments the land was flooded by the breaking of a check above. The total quantity absorbed by the three waterings was probably not less than 4 to 5 feet. The soil is a brown sandy loam, of unknown depth, but probably greater than 20 feet to hardpan.

All of the above examples, illustrating at once the practice of irrigation and the amount of water required, are the result of inquiries and experiments made in 1879. To these the following can now be added.

On sec. 30, T. 30 S., R. 28 E., in August, 1881, water from the Kern Island Canal was used for five days to the extent of 3.63 second-feet for the irrigation of 30 acres of corn. The amount of water was equivalent to 1.21 feet over the entire area. The water was applied by the furrow system of irrigation. The soil is very variable, generally light and loamy. Its character ranges from pure sand to black adobe. Soil water is at a depth of 8 or 9 feet.

On the same section as the last, 60 to 70 acres of wheat were irrigated by flooding in checks lying between contour lines. The surface of the ground is smooth but not level. Water was used for eleven days in December, January, and February, at the rate of 3.61 second-feet, equivalent to a depth of 1.21 feet over the whole surface. It was again used for eight days in March, at the rate of 3.26 second-feet, equivalent to a depth of 0.97 feet over the entire surface. The ground received another irrigation between April 1 to 5, four days in all; water was used at the rate of 5.20 second-feet, and the equivalent average depth of water over the entire surface was 1.37 feet. The whole amount of water consumed in the irrigation of the wheat was therefore equivalent to an average depth of 4.18 feet of water over all. Alfalfa was irrigated on the same section to the extent of 50 to 60 acres. The water used for it prior to the end of May, 1882, was 5.20 second-feet for fourteen days in

March, and 7.36 second-feet for fifteen days in May. The amount of water which the alfalfa field received in these two irrigations was equivalent to a depth of 6.61 feet. It was proposed to give it, and it probably received, two more irrigations subsequent to the two here noted.

Sec. 31, T. 30 S., R. 28 E., has a loamy soil which does not crack or bake in drying, contains a small excess of alkali, and ranges in texture from sand to black adobe. In 1881 wheat to the extent of 125 acres was irrigated by flooding in checks. The surface of the ground is smooth but not level. The ground was wet before plowing in January. The amount of water it received at that time was equivalent to a layer 5.01 feet thick. It received a subsequent irrigation equivalent to a depth of 0.69 foot of water. The total average depth of water delivered to the land was therefore 5.70 feet.

On the same section, in 1882, a wheat field of 350 acres was supplied with water for sixteen days in the first part of January. Water was used at the rate of 3.26 second-feet, equivalent to an average depth of 0.30 foot. It received water again, at the rate of 7.41 second-feet, from April 1 for seventeen days, equivalent to 0.76 foot in depth over the whole area. For fourteen days, from April 25 to May 8, it again received water, at the rate of 8.60 second-feet, equivalent to a depth of 0.66 foot over the whole area. The aggregate average depth of water received by this whole tract in 1882 was therefore 1.72 feet.

On sec. 6, T. 31 S., R. 28 E., having soil of the same character as that described above for sec. 31, 120 acres of corn land were irrigated, from April 18 to 24, in 1882. This irrigation was preparatory to the planting, and was equivalent to a depth of 0.78 foot over the whole surface of the land. The corn received one more irrigation.

On sec. 32, T. 30 S., R. 28 E., whose soil is mostly a sandy loam, but ranges from pure sand to a dark vegetable loam, 130 acres of wheat were irrigated in March and April, 1881. The head of water used was 9.91 second-feet. The depth to which it would have covered the ground averaged 2.34 feet. Ground water is at about 17 feet below the surface.

On the same section, in May, June, and July, 1881, 80 acres of corn received water to the extent of an average depth over all of 6.35 feet. The head of water was 9.91 second-feet. On the same section a 6-acre orchard was irrigated in August and September, 1881, and received water enough to cover the 6 acres 4.53 feet deep. The water used was 4.56 second-feet. On the same section, in March, 1882, an old alfalfa field of 100 acres was irrigated and absorbed water equivalent to a depth of 2.52 feet. The head of water used was 12.10 second-feet. On the same section, in March, 1882, newly sown alfalfa was irrigated; its area was 120 acres. It received water at the rate of 12.10 second-feet. The total amount of water it received was equivalent to a depth of 2.52 feet over the whole area. It was again irrigated in May, receiving 8.60

second-feet for eight days, or sufficient water to cover it 0.98 foot deep. It was proposed to give the newly sown alfalfa one more irrigation in 1882.

On sec. 7, T. 31 S., R. 28 E., whose soil varies from a light sandy loam to a black sandy vegetable mold, with ground water at from 4 to 10 feet below the surface, 300 acres were sown to wheat in 1882; alfalfa was sown with the wheat. The ground was not irrigated before sowing. The irrigation of this tract commenced on February 25 and was completed on April 6; water was used for forty-one days at the rate of 8.21 second-feet. The total amount consumed in irrigating the 300 acres was equivalent to a layer 2.22 feet thick over all. The wheat did not require any further irrigation. The young alfalfa was irrigated again after the wheat had been harvested.

IRRIGATION FROM POSO CREEK.

Poso Creek is a small foothill stream just northward from Kern River, which flows for several months each year. Its drainage basin has an area of about 289 square miles. The creek has not been used to any considerable extent for irrigation, because there is but little land that can be commanded with its water except at considerable expense, and because its brief irregular flow did not seem to justify works to benefit large sections. It was not, therefore, until the irrigation-district law went into effect that a combination of interests led to the projection and partial execution of works of considerable magnitude. Several small private ditches were in use before the organization of the Poso irrigation district, but no complete list of these is available. One of them is the Purcell Ditch, which takes water from the south side of Poso Creek, about 8 miles above Poso. The ditch was made 12 feet wide and 2 feet deep, and was in use in 1885 for the irrigation of about 400 acres of alfalfa, immediately below the head of the ditch and adjacent to the creek. Another ditch, on the south side of the creek, is the Creasey Ditch, constructed in 1885 for the irrigation of 300 acres of land about 4 miles above Poso. The head of the ditch is about 2 miles below the head of the Purcell Ditch. It was made 16 feet wide on the bottom. The Rhymes and Hughes ditches are small ones, somewhere in the foothill section drained by the creek, concerning which nothing definite is known except that they were in use for many years.

POSO IRRIGATION DISTRICT.

This district was organized in 1888. Its bond issue is $500,000. It has an area of about 40,000 acres, located to the north of Poso Creek, at the western base of the Sierra Nevada foothills, in Kern County. The contemplated works for the irrigation of the district are far advanced, though not yet completed. Much work on them was done by day's labor before it was decided to be advantageous to let contracts.

Water for the district lands is to be obtained from a system of reservoirs in the drainage basin of Poso Creek, which are to supplement the creek's natural flow. The first reservoir, now constructed, is formed by means of an earthwork dam to be raised to a maximum height of 70 feet, but now only half finished. Its capacity when completed will be about 7,000 acre-feet. From it water flows in the channel of Poso Creek about 7 or 8 miles to a point where it is diverted into a flume by means of a granite dam, whose greatest height is about 16 feet. The flume shown in Pl. XIV, *A* and *B*, is about 3 miles long and delivers its water into an apparently well-constructed hillside ditch which has a length of about 30 miles before reaching the district. Two other flumes are in use on the canal line to carry the water over deep ravines. The flumes have a width of 8 feet and are planned to carry water 4 feet deep. Water was sent through the canal for the first time this season, but only for the purpose of testing the work. This upper district canal is supplemented by a lower canal which leaves the creek about 10 miles above Famosa and commands the western portion of the district. This lower canal is in service, but irrigation is extending very slowly.

IRRIGATION FROM DEER CREEK.

Deer Creek is a small stream draining about 110 square miles of Sierra Nevada foothill lands lying southward from the Tule River basin. It flows into San Joaquin Valley during several months of the year; rarely, however, as late as July. Its water ordinarily sinks within 10 or 12 miles of the foothills, but occasional freshets have sent it as far as Tulare Lake. The summer flow of the creek, which is very small, does not reach the San Joaquin Valley lands.

Winfield Ditch.—This is a small ditch on the south side of Deer Creek, having its head about 4 miles above the point where the creek breaks out upon the main valley plain. It was constructed in 1858, is between 3 and 4 miles long and 3 to 4 feet wide, and supplies water to several hundred acres of creek bottoms. It has been in use continuously since its construction. The entire low-water flow of the creek is taken into the ditch.

Carothers Ditch.—The head of this ditch is on the north side of Deer Creek, about a mile above the point where the creek reaches the border of San Joaquin Valley. It was constructed in 1885, but takes its name from an older ditch (constructed in 1868) which had for many years been out of service. It has a westerly course, and is about 5 miles long and 4 feet wide on the bottom.

Deer Creek Consolidated Ditch (*Sausalito Ditch*).—This is the principal irrigation work on Deer Creek. The head of the ditch is on the south side of Deer Creek, about 12 miles in a direct line above Belleville and about 3 miles below the head of Carothers Ditch. The ditch is carried

A HEAD FLUME, POSO IRRIGATION DISTRICT.

B. HEAD FLUME, POSO IRRIGATION DISTRICT.

along the south side of Deer Creek, close to the creek channel, for a distance of nearly 8 miles; thence its course is diagonally across the creek bed to its north side. From this point the course of the ditch is westerly and southwesterly, in a number of branches, which deliver water to lands lying to the east and northeast of Belleville. The crossing of the sandy bed of Deer Creek is effected between embankments of sand, which are sure of destruction during freshets, but which are quickly restored. The lower portion of this ditch system was constructed in 1875 and 1876. Two sets of farmers commenced operations independently, but soon found it advantageous to unite their interests and construct a ditch in common. It was soon found necessary to substitute an artificial channel on firm ground for the porous creek bed from the foothills to the head of the original ditch, and this led to the construction of the upper section of the ditch in 1878. The main ditch has somewhat irregular dimensions. Its bed width is generally about 10 feet. Its capacity has been estimated at 40 second-feet. The capacity of the lower section of the ditch, on the north side of the creek, is about 30 second-feet. The cost of this irrigation system, which furnishes water to 3,000 acres of land, was about $20,000.

When the consolidation of interests by those desiring to use water near Belleville was effected, it was determined to establish water rights that should become appurtenant to specified tracts of land. This plan could not be adhered to, however, owing to insufficiency of the water supply from the creek, which made it impossible to deliver water to many of the tracts westward from Belleville for which water was wanted. It was found necessary to confine the delivery of water to consumers near and above (east of) Belleville, and these have become the stockholders in the company which owns and manages the ditch.

During the irrigating season (generally November to the end of June) a ditch superintendent is in charge of water distribution. Water is delivered to the several branches in proportion to the number of shares of stock for which each is to receive water. As soon as the water becomes insufficient to meet the demands of irrigators the ordinary system of using it in rotation is adopted. Eight hours is usually fixed as the time of a run per share. No water is sold, and all expenses are assessed upon the stockholders. Management and repairs cost about $1,000 per annum. About one-third of the area irrigated is alfalfa; the rest is orchard, vineyard, summer crops, and some grain. Irrigation is accomplished by flooding in small rectangular checks. The preparation of the ground to receive water was inexpensive, its original surface having been very smooth. The soil is a sandy loam. At about 3 feet below the surface is a stratum sufficiently hard to be called hardpan. As usual in irrigated districts on the plains, irrigation has produced a permanent effect upon the elevation of ground water. This was originally found at a depth of 17 feet below the surface; it is now at 9 to 12 feet.

TULE RIVER.

HYDROGRAPHY.

Tule River enters San Joaquin Valley at Porterville, with a drainage area above that point of 437 square miles. The river has a perennial flow throughout its mountain and foothill portions, but not at points below Porterville, near where the last remnant of its water during very low stages sinks into its sandy bed. During the months of May and June the flow of the river, as estimated for the six years, 1878 to 1884, was over 1,000 second-feet. Its mean flow for that entire period was about 450 second-feet. From November to January the mean flow was 130 second-feet. It was 636 second-feet from February to April, 941 second-feet from May to July, and 139 second-feet from August to October.[1]

Below Porterville this water flows in several channels, one of which, Porter Slough, has its head on the north side of Tule River, about 3 miles above Porterville. The water not in this slough remains in the main channel for about 10 miles, then separates into a network of channels having a general westerly course, and is finally delivered into Tulare Lake. The main stream crosses the Southern Pacific Railroad about 2½ miles north of Tipton. Water rarely flows in this part of the river more than four months of the year.

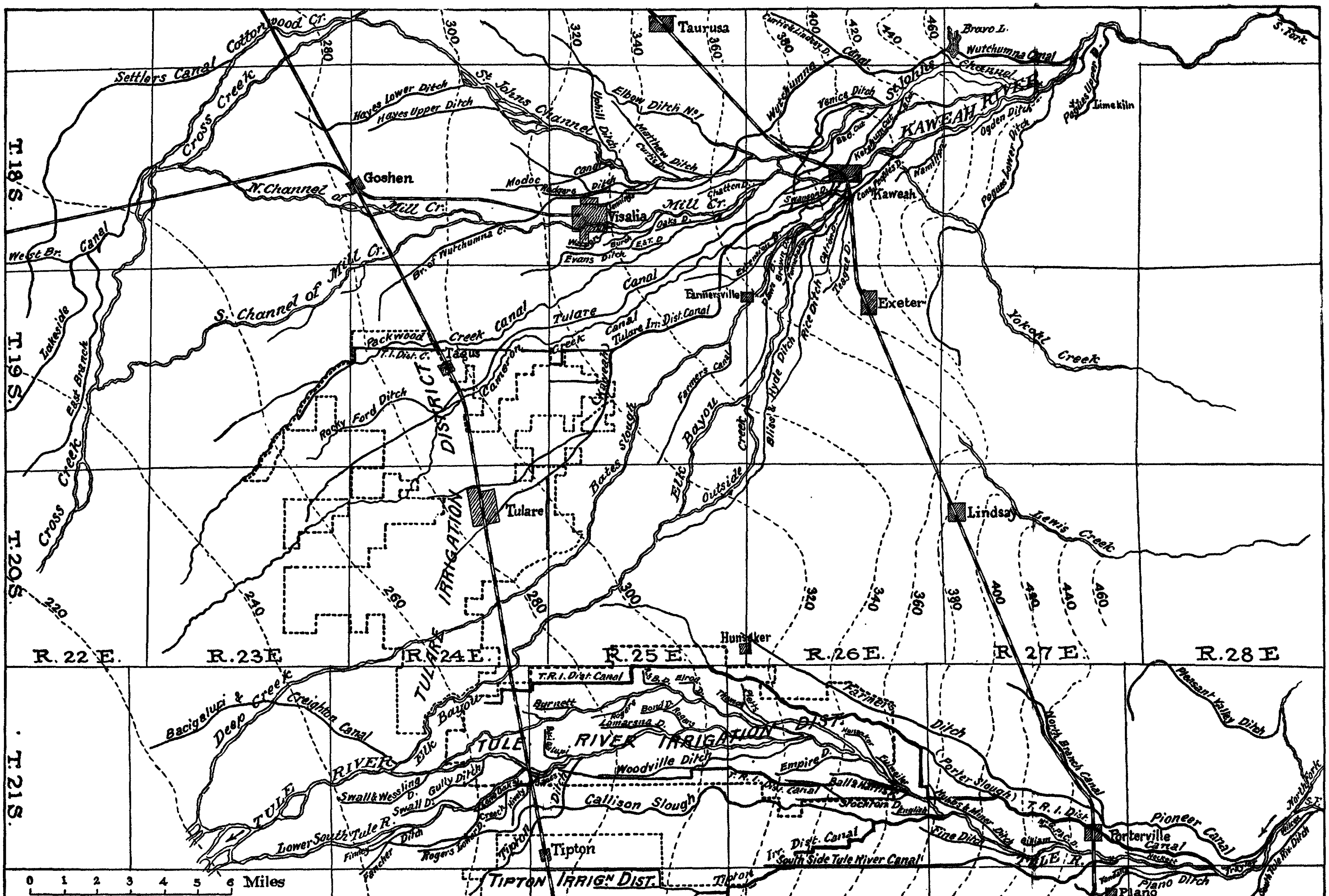
The Tule River channels are barely of sufficient capacity to pass ordinary freshets. This is particularly noticeable westward from Woodville on all the many channels into which the river is subdivided. The resulting bank-land inundations are of considerable extent and are an important supplement to artificial irrigation. The ready overbank escape of the freshet waters of the river and the very smooth surface of the delta lands greatly facilitate the diversion of water into ditches and canals, which have become very numerous. Many of these are, however, mere cuts into the bank, into which water flows when the river is high and which become dry soon after the river recedes from its highest stage.

Where there are so many small, relatively unimportant diversions as from the several channels of Tule River, a minute description of each work will not be attempted, and in many cases a mere mention of name, general position, and time of first use must suffice.

CANALS AND DITCHES.

South Tule River Ditch.—This (sometimes called Campbell Ditch) is the uppermost ditch on the south side of Tule River, though by no means the first in time of construction. The diversion of water from the river is made at the head of an older ditch, known as the Wilcox, at a point about 8 miles above Porterville. The ditch skirts the base

[1] California Physical Data and Statistics, Wm. Ham. Hall, State Engineer, pp. 458 and 476.



CANALS FROM TULE AND KAWEAH RIVERS.

of the hills, commanding a narrow strip of valley land which lies between the hills and the river. It is about 6 feet wide on the bottom, and has irrigated but a few acres. Its construction was commenced in 1879.

Wilcox Ditch.—The diversion of water into the Wilcox and South Tule River ditches is accomplished by means of an inexpensive wing dam of cobbles and brushwork. One channel in common is utilized for the water of both ditches for about a quarter of a mile. The Wilcox Ditch lies between the South Tule River Ditch and the river. It was constructed about 1855 for the irrigation of a small tract of land 2 miles below its head. The ditch is about 3 feet wide on the bottom.

Plano Ditch.—For the irrigation of lands in the vicinity of Plano, a small settlement on the south side of Tule River, directly opposite Porterville, a small ditch was constructed in 1863. It takes water from the south side of the river, about 3 miles in a direct line from Plano. It gradually withdraws from the river, crossing the river bottoms to the base of the hills, and skirts the base of "Sugarloaf" just to the east of Plano. Thence its course is southwesterly through Plano to a termination about 1 mile west of the village. The dimensions of the ditch are irregular; its capacity is about 16 second-feet. It supplies water to about 400 acres of orchard, alfalfa, and vegetables.

Vandalia Ditch.—This is another small ditch on the south side of Tule River. It takes water from the river a mile above Plano, has a capacity of about 3 second-feet, and irrigates about 100 acres. It was constructed in 1861.

Rose Ditch.—This is another of the small private ditches near Plano. Its head is several hundred yards below the head of the Vandalia Ditch. It was constructed in 1862. The land it irrigates was before that time supplied with water from a ditch known as the Somers Ditch, but the freshets of 1861–62 cut the irrigated district in two by the formation of a new channel for the river, and the Rose Ditch was built to supply water to a few acres of the original irrigated district left on the south side. It irrigates 10 to 20 acres.

Mitchell, Springer & Rose Ditch.—The head of this ditch was a short distance above the bridge on the road southward from Porterville. It was less than a mile long and about 4 feet wide on the bottom. The point at which water was taken from the river was frequently changed, and various tracts of land were irrigated with its water. It was one of the old-time ditches which now seems to have fallen into disuse. The extent of irrigation from it a few years ago was less than 20 acres.

South Side Tule River Canal.—This canal, which was for many years referred to as the "Big Ditch," and is also known as the "Poplar Canal," was constructed in 1875 by an organization of farmers whose lands were located on the main San Joaquin Valley plain, south of Tule River. The head of the canal is just above the bridge southward from Porterville. The canal regulator has been placed about a quarter mile below the bridge. The ditch has a bed width of 20 feet, and is intended to carry water 2 to 3 feet deep. The course of the canal is westerly. It is about 11 miles long. In seasons of ordinary rainfall there is no trouble in keeping the canal well supplied with water during the spring months. At other times, and often when water is most needed, the supply is scant. The flow of the main canal is usually apportioned to one or more of the distributaries, or district ditches, as they are called, and the entire flow of each of these is used in turn by the irrigators. The length of time that an irrigator may use the water is determined by the number of shares of stock held by him.

The use of the canal has been interfered with considerably by litigation. Riparian land owners have been successful in throwing legal obstacles into the way of water diversion for this canal, and court decisions against canal interests have been enforced to some extent. The area irrigated has, therefore, remained small—probably less than 1,000 acres. The cost of the canal was about $20,000, but under good management would have been less. Check weirs were placed in the

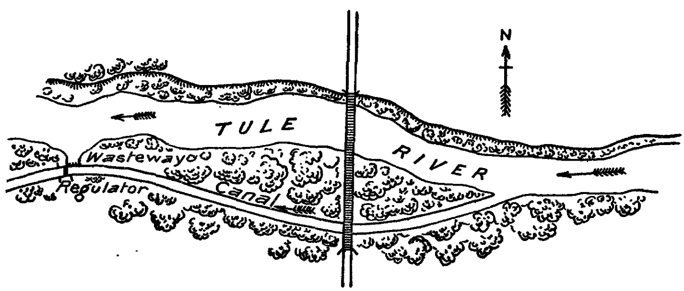
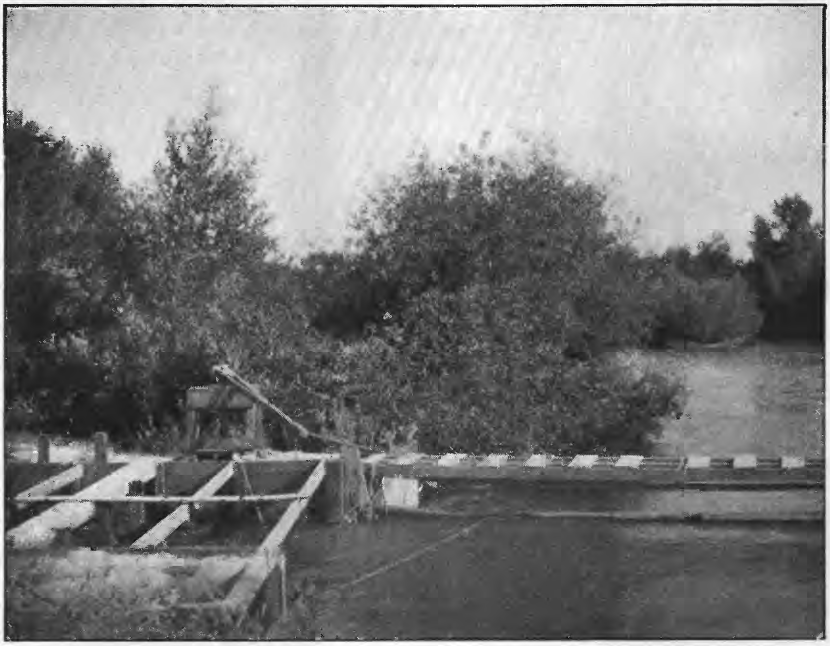


FIG. 14.—South Side Tule River Canal.

canal every half mile, but did not serve long. They were soon washed out of place. Their purpose was to prevent excessive erosion (the fall in the direction of the canal being about 15 feet per mile) and to facilitate diversion into branch ditches. After the first set of these structures was gone the expense of placing a weir in the main canal at the head of a distributary was thrown upon the owners of the latter, but the canal management reserved the right to approve the design and to supervise its construction. The original check weirs were of the flashboard type. The bays had a width of 4 feet. The timbers supporting the flashboards were inclined. The principal defect seems to have been the placing of the floor of the structure at, and not below, the grade height of canal bottom.

Fine Ditch.—The head of the Fine Ditch is about 3 miles below the head of the South Side Canal. It commands a district intermediate between Tule River and the lands irrigated with water from the South Side Canal. The ditch was built and is owned in common by a number of farmers, who apportion its water among themselves. It is about 7 miles long.



A. REGULATOR AND WASTE WAY OF SOUTH SIDE TULE RIVER CANAL.

B. REGULATOR OF PIONEER CANAL, LOOKING UPSTREAM.

Callison Slough.—Callison Slough (Woods Central Ditch) is a high-water escapeway from the south side of Tule River, about 5 miles due west from Porterville. It was probably one of the many new channels formed by the freshets of 1861–62. Water enters the head of this slough under control of a regulator at the high stages of the river, and at lower stages the flow is increased by means of a temporary wing dam of sand, which is extended farther and farther upstream as the river falls. The flow of the slough has been under control for irrigation since 1878, in which year a company was organized for this purpose, under the name of the Woods Central Irrigating Ditch Company. The head gate was made 18 feet wide. About $1,560 was expended in converting the slough into a serviceable ditch. Several small distributing ditches have been constructed from the slough to the lands of irrigators, and about 1,000 acres represent the extent of annual actual wetting.

When the Tipton irrigation district was organized, in 1891, arrangements were made by its directors for the use of Callison Slough in com-

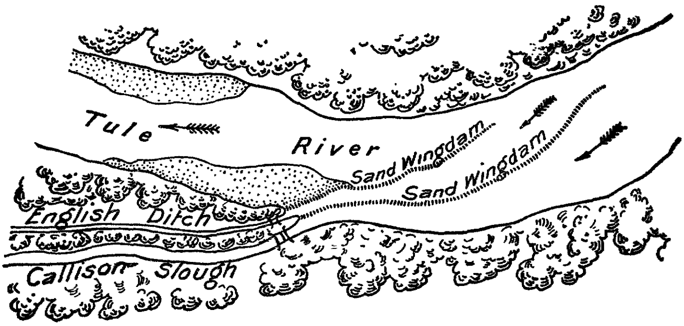


FIG. 15.—Head of Callison Slough and English Ditch.

mon with the Woods Central Irrigating Ditch Company. A new regulator was soon afterwards put into the head of the slough. It was made 30 feet wide, it being understood that 10 feet of its width was to serve the original users of slough water, and the other 20 feet the irrigation district. The district canal is out of service at the present time.

Old English Ditch.—The head of this ditch is immediately below the head of Callison Slough, and its water is used on several small farms between Callison Slough and the river. The ditch was constructed about 1869. It is about 8 feet wide on the bottom, 2 miles long, and annually irrigates between 100 and 200 acres. Whenever it is desirable to use water after the high stage of the river, a long temporary wing dam of sand is constructed at its head, just below, and almost parallel with, that at the head of Callison Slough.

Stockton Ditch.—This ditch takes its name from a small private ditch which was in use for a few years preceding 1871. It was built in 1874 by a company composed of eight farmers who desired a common source of supply. It leaves the south side of Tule River about midway between Porterville and Woodville, and has a westerly course to the vicinity of the latter settlement. The ditch is about 6 miles long, and is 15 feet wide at its head. Water is ordinarily available for it from February to June. No restriction is placed upon the locality where each stockholder may use his water. The water is delivered in turn to each person entitled to its use, the time of a "run" per share of stock being fixed annually by the directors, usually at forty-eight or twenty-four hours per share. The lands irrigated by this ditch have in part been included in the Tule River irrigation district, and are to become dependent upon its works for their water supply.

Ball & Harris Ditch.—About one-half mile below the head of Stockton Ditch a small ditch, irrigating several hundred acres of land, leaves the river. It is known as the Ball & Harris Ditch (or the Markham, or Pierce & Markham, or Pierce, Markham & Booth Ditch). It was built about 1871, and is reported to have been in continuous use after 1874. The ditch is only 3 to 5 feet wide on the bottom. Its regulator has a width of 6 feet. This is one of the ditches whose rights have been merged with those of the Tule River Irrigation Ditch Company.

Empire Ditch.—The head of this ditch (also called Pheil & Otto, Stover, or Lower Pioneer Ditch) is on the south side of Tule River, 3 miles east of Woodville, at a point known as the Forks of Tule River. Its course is westerly; it is 3 miles long and irrigates several hundred acres of land in the immediate vicinity of Woodville. Its width is 2 to 3 feet on the bottom, and its estimated capacity is about 5 second-feet. The lands served by this ditch are in part in the Tule River irrigation district.

Woodville Ditch.—This ditch has its intake on the south side of the river about 1½ miles northeast of Woodville. Its course is westerly; its length is about 7 miles, and its width in the upper sections about 10 feet on the bottom. The regulator has a width of 12 feet. The ditch was constructed in the years 1883 to 1885. It is one of the few ditches constructed and managed on the principle of proportional assessment of stockholders to meet those expenses only which are incurred on the ditch above the point where water is delivered to each irrigator. This is another of the small ditches whose rights have been merged with the Tule River Irrigation Ditch Company.

Tipton Ditch.—This ditch (also called Mitchell Ditch) was constructed for the irrigation of lands near Tipton. Its builders agreed to contribute to the cost of construction and maintenance of so much of the main ditch as was above the upper limits of their lands in proportion to their respective interests in the canal water. The construction of the ditch commenced in 1881, but it was not completed for several years. The head of this ditch is on the south side of Tule River, about 3½ miles northeast of Tipton. The ditch has a southwesterly course, is 6 to 7 miles long, about 20 feet wide near its head, and is planned to deliver a relatively large amount of water to the area dependent upon it during the short period (about February 1 to June 15) when water is ordinarily available.

Janes Ditch.—This is a very small private ditch, the head of which is about a quarter mile below the head of Tipton Ditch. It follows the river bank, crossing Lone Oak Slough and South Tule River to a small tract of land irrigated with its water.

Lone Oak Slough.—This is a small high-water channel breaking out of the south side of Tule River due north from Tipton, about a half mile above the railroad crossing. It has a southwesterly course, and supplies water to several independent small distributaries known as the Hively, the Creech, and the Rogers Lower ditches. The flow of water in the slough is controlled by a regulator, put in about 1891.

Hively Ditch.—This is a small private ditch, about a mile long, receiving water from Lone Oak Slough just to the west of the railroad crossing.

Creech Ditch.—This is another small private ditch, about a mile long, leading from the south side of Lone Oak Slough.

Rogers Lower Ditch.—This ditch also receives water from Lone Oak Slough. It is a mile below the Creech Ditch, and is about 2 miles long.

The combined irrigation from Lone Oak Slough ditches probably does not exceed 200 acres.

Fancher Ditch.—Another of the Tule River ditches, owned in common by four or five irrigators, is the Fancher Ditch, which for several years prior to 1884 is reported to have received its water from the river at the point where Callison Slough unites with South Tule River. A weir was constructed in the river channel and the diversion was made from the slough channel. About 1884 it was found necessary to extend the ditch upstream about half a mile to a new head, where for some time water was admitted without control. The ditch has a southwesterly course, is about 2 miles long and 12 feet wide, and usually irrigates several hundred acres.

Finney Ditch.—On the north side of South Tule River, near the last-mentioned diversion, is a small private ditch, known as the Finney or Berry Ditch. Its head is a quarter of a mile below the head of Fancher Ditch. Water is there diverted into a small natural depression, in which it flows about half a mile to points where it is used by several irrigators. This ditch came into use in 1884.

Swall Ditch.—Another small private ditch, on the north side of South Tule River, is the Swall Ditch. Its use dates back to 1875. Its head is 2½ miles below the head of the river channel called South Tule River. It is about 2 miles long, and has a westerly course.

Gully Ditch.—This ditch receives water from the south side of the main channel of Tule River, 1½ miles below the head of South Tule River. It has a southwesterly course, is about 2½ miles long, and, in common with the Swall Ditch, supplies water to several hundred acres. It was constructed in 1875.

Swall & Wessling Ditch.—This is a small ditch on the south side of the main channel of Tule River, about a mile long, which connects this channel with a small natural water course. Its head is 3½ miles below the head of South Tule River. It has been in use since about 1884.

Great American Ditch.—Before the Tule River Indian Reservation, above Porterville, was thrown open to settlement the construction of a small hillside ditch for the irrigation of lands intermediate between the north-side hills and the river had been commenced. This ditch had its head on the west side of North Fork about 8 or 9 miles above Porterville, and was intended solely for the use of the Indians. This work was subsequently to have been completed by a corporation which seems to have been organized principally for speculative purposes. There is but little left of the enterprise except the name.

Pleasant Valley Ditch.—This is a diversion from the west side of North Fork of Tule River, about 2½ miles above its junction with Middle

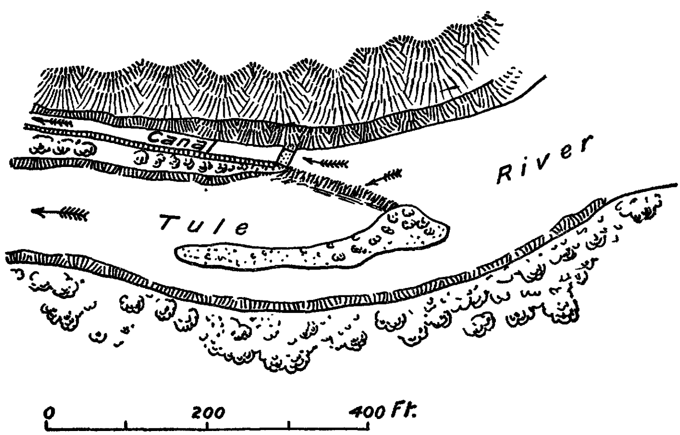


FIG. 16.—Head of Pioneer Canal.

Fork. The ditch has a southerly course for over 5 miles, thence a northwesterly course for 5 miles, and thence a southerly course for over 2 miles. It commands Pleasant Valley lands. Its bed width is about 6 feet for several miles, thence 4 feet. The ditch was constructed in 1889 by the Pleasant Valley Ditch Company, organized as a corporation the previous year by farmers requiring water for stock and irrigation purposes.

Pioneer Canal—This canal, controlled by the Tule River Pioneer Water Ditch Company, is the most important of the several irrigation works receiving water from Tule River. It was constructed and first came into use about 1867. Its head was then located three-quarters of a mile below the junction of North and South forks of Tule River. The freshets of 1877–78 destroyed the upper section of the canal and at the same time cut a high-water channel near the base of the hills at the northern border of the bottom lands. This new channel was at once utilized for the canal water. A regulator was put in its head and has been maintained. The canal proper terminates at the flour mill at Porterville, to which it supplies power. Its course is along the base of the hills on the north side, and generally half a mile to 2 miles from the river. The bottom lands thus commanded above Porterville are very productive. The canal has a length of about 7 to 8 miles. Its fall is somewhat irregular, generally 6 to 7 feet to the mile. Its bed width is 8 to 12 feet, and the depth of water carried 2 to 3 feet. Its regulator is of the box or culvert type. A loose-rock fill on top of the structure gives it weight to prevent its being undermined. Three vertically sliding gates control the inflow of water. The width of the regulator between side walls is 18 feet. The capacity claimed for the Pioneer Canal is 72 second-feet.

Before a reorganization of the canal company was effected, several years ago, the canal water was delivered to stockholders in proportion to the amount of stock owned by each. Stockholders were permitted to take their water at any convenient point through a suitable outlet gate, constructed and maintained by the user of the water taken. No water was sold by the canal company, and all expenses of management and repairs were assessed to the stockholders. The result of this system of operation was the union of interests by groups of irrigators, who then made a common diversion of water from the main ditch and built distributing ditches, which are managed much the same as independent ditches.

The most notable branch of this character was the Farmers Ditch. It received water from the Pioneer Canal at the mill, and, passing to the east and north of Porterville, had a course a little north of west, skirting the southern border of Old Tule River Swamp. Its length was about 12 miles. It was owned by an organization formed in 1875, ownership being represented in 12 shares. Each share of stock entitled its holder to a proportional interest in the canal down to a point where he diverted or intended to divert his water from the main canal. The company did not sell any water. Water was used from the canal in rotation, the duration of a run per share of water being mutually agreed upon.

The cost of construction was apportioned to each member in proportion to his interest in the canal. Each member bore a proportional part of all expenses incurred along the canal above the point at which he was to receive his water, and did not contribute toward the construction of the canal below that point. Expenses of maintenance and repairs were apportioned on the same basis to those actually using water. As the canal had a total length of 12 miles, and some of its water was used within 3 or 4 miles of its head, these expenses were about four times as great for the most distant irrigator as for the one nearest the head of the canal.

Farmers Ditch in its upper sections was also known as the Old State

Ditch, being one, or on the line of one, of the ditches that was intended to divert the flow of flood waters from the Old Tule River swamp lands, and which had been constructed with money from the State swamp-land fund. This ditch, in somewhat altered alignment, together with the North Branch of Pioneer Canal (which might also be called the North Side State Ditch), has become one of the principal distributaries of the reorganized Pioneer Canal Company.

Water is still delivered to stockholders in proportion to stock owned, but without actual measurement. A change is to be made at once, according to which water is to be sold to stockholders on the basis of 1 miner's inch per share of stock. The canal capacity, 50 second-feet, is equivalent to 3,600 miner's inches under 4-inch pressure, and there are 3,600 shares of stock in the corporation. The price to be charged for water is to be fixed at 5 cents per 24-hour miner's inch.

The area of citrus fruits dependent upon this canal for water has within the last few years rapidly grown to 1,000 acres. About 900 acres of other orchards are also irrigated by this canal. The orchard lands for the most part lie to the north and east of Porterville.

The wetting of orchard land is generally accomplished by allowing small streams of water to flow in a number of furrows between rows of trees, usually four, and to harrow the surface as soon after the application of water as possible.

On the lower section of the Farmers branch of the canal alfalfa and grain are irrigated in rectangular checks. Land there is smooth surfaced and comparatively level, consequently the cost of preparation for irrigation is small. It is said to have been as low as 50 cents per acre for ditching and checking.

The value of water stock at the present time is said to range from $200 to $300 for stock entitling to water above the Porterville Mill, and $50 to $100 for stock entitling to water below the mill. This difference in price is due to the fact that most of the flow of the canal must be delivered at the mill for power purposes, and that water for diversion from the canal by irrigators above the mill is therefore limited.

Traylor Ditch.—This is a small private ditch having its head on the north side of Tule River half a mile below the head of the Pioneer Canal. It has a course about midway between the larger ditch and the river, is about 2 miles long, and irrigates a few acres of river bottom land.

Porter Slough.—Porter Slough breaks through the north bank of Tule River about 4 miles above Porterville. It was made the principal channel of Tule River by the freshets of 1861–62, but within a few years contentions arose as to the apportionment of water to this channel and to that which afterwards became the main channel of the river. Obstructions placed in the head of Porter Slough were repeatedly removed by settlers along the slough. It is claimed that such obstructions, in part at least, caused the rapid enlargement of the other channel of the river by the freshets of 1867–68, and that ever since that time some work at the head of Porter Slough is annually necessary to put water into it at ordinary stages of the river.

Since the construction of the works for the irrigation of lands in the Tule River irrigation district, water is turned into the head of Porter Slough through an artificial channel or cut 700 feet long, in the head of which a regulator is maintained. This regulator has a total width of 36 feet, divided into nine spaces, of which seven are separated from the other two by a longitudinal partition. The water passing through the larger portion of the gate is for the irrigation district, the rest is for the Hubbs & Miner Ditch, which formerly received its water through an independent head some miles below Porterville. The actual flooding of lands with water from the slough before its use by the Tule River irrigation district was not very extensive, but the presence of water in the channel accomplished much wetting of adjacent agricultural land.

Hockett Ditch.—This is one of the small ditches which was constructed immediately after the freshets of 1861–62 to replace Somers Ditch, which was destroyed by the high waters. Its head is on the north side of Tule River, about 1½ miles below the head of Porter Slough. It supplies water for several hundred acres of land between Porter Slough and the main channel of the river southward from Porterville. The Somers Ditch, whose water rights are claimed for the Hockett Ditch, is reported to have been constructed in 1858, and it is probable that some of its original owners had attempted to make diversions of water as early as 1854.

Wallace Ditch.—The head of the Wallace Ditch is immediately below that of the Vandalia Ditch. Although the diversion of water for this ditch is made on the south side of the river, it is at once carried over to the north side in a small flume, and its use is entirely on the north side. It is a small private ditch, occupying a position between the Hockett Ditch and the river and supplying water to a few acres in the same vicinity as Hockett Ditch.

McGee, Putnam & Caldwell Ditch.—This is another small north-side ditch, having its head about 1¼ miles below the bridge south of Porterville. It commands lands between the river and Porter Slough just west of those covered by Hockett and Wallace ditches. It is said that the use of water through this ditch commenced about 1863.

Gilliam Ditch.—This ditch leaves the river about a quarter mile below the McGee, Putnam & Caldwell Ditch. It is a small private ditch which is also known as the Gillis Ditch, or the Gilliam & McGee Ditch. It was probably constructed in 1862 and commands a portion of the district originally irrigated by the Somers Ditch.

Hubbs & Miner Ditch.—This is a north-side ditch supplying water to eight or ten farmers, whose interests in the ditch are represented by shares of stock. The head of the ditch was about 2 miles below the

Porterville road bridge until, in 1893, a combination with the Tule River irrigation district was effected, according to which a common head or new inlet from the river to Porter Slough was constructed. Of the water diverted from the river, the surplus not required by the irrigation district goes to the lands dependent upon the Hubbs & Miner Ditch for water.

Fulweiler and Hunsaker ditches.—The next north-side ditch has its head about 6 miles below Porterville. It is known as the Fulweiler Ditch. Its construction was commenced by an organized association of farmers, but work was soon abandoned. One of the owners subsequently commenced operations again, and was joined in 1884 by several other farmers. The ditch was about 1½ miles in length, having a northwesterly course to a point where a junction was effected with another small ditch, known as the Hunsaker Ditch, whose head is half a mile below the head of Fulweiler Ditch. The Hunsaker Ditch had a length of about 2 miles. Its central section was used in common by the two ditches—an arrangement effected to overcome right-of-way difficulties which were encountered by the owners of the Fulweiler Ditch. The Hunsaker Ditch was constructed in 1871. About 400 acres were irrigated from the two ditches. All of the lands served by the Hunsaker Ditch and part of those served by the Fulweiler Ditch are now in the Tule River irrigation district and are dependent upon its canals for water.

Pletts Ditch.—This is a small ditch receiving water only during high stages of the river. It has been in use since 1872, but has ordinarily irrigated only about 10 acres of alfalfa and orchard land. Its head is just below the country road leading northward from Porterville.

Thomas Ditch.—Less than a quarter of a mile below the head of the Pletts Ditch, also on the north side of Tule River, is the Thomas Ditch. It is also called the Walker Ditch. It was constructed about 1871 or 1872. Like other high-water diversions from Tule River, it has had no regulator at its head. The extent of actual flooding with its water has been about 25 acres. The lands it watered are now served by the Tule River irrigation district canals.

Elrod Ditch—This is one of the same class of small ditches just enumerated. It is a reconstruction of an older ditch which was known as the Lewis & Walker, about 2 miles below the Thomas Ditch. The original ditch came into use in 1871. The lands irrigated by it are now a part of the Tule River irrigation district.

Ray & Brown Ditch.—This was an insignificant ditch on the north side of the river about 5 miles east of Bayou, which affords water for the flooding of a few acres at flood stages of the river. Like the other small ditches named, it has been absorbed by the Tule River irrigation district.

M. M. Burnett Ditch.—This is a small high-water ditch from the north side of Tule River, a mile southeast of Tagus. It is about a mile long, has a bed width of 5 feet, and cost about $100. It was constructed in 1886.

Bond Ditch.—This is a small ditch which carries water southwesterly three-fourths of a mile from a point on the north channel of Tule River at the head of Schoolhouse Branch. It unites with Rogers Ditch for the irrigation of the same lands. This ditch was constructed in 1871.

Rogers Upper Ditch.—This is a diversion from the north side of the Stadtmüller Branch of Tule River, made in 1880. It has a northwesterly course for nearly a mile, to its junction with the Bond Ditch. The two ditches belong to the same owners.

Rogers Middle Ditch.—This is a ditch from the lower end of the Schoolhouse Branch of North Tule River. It is a short ditch 6 feet wide, having a southerly course, and drops its water into a natural channel, whence it is again taken for the irrigation of several small tracts. It was constructed in 1880.

Klein Ditch.—This ditch was practically duplicated by the Rogers Middle Ditch. The diversion was made from the same point, but in a ditch located a few feet farther east, and the same natural channel was used to convey water about a mile to its place of use. The mention of the ditch is merely historical; it went out of use about 1880.

Lamarsna Ditch.—This is another of the very small high-water ditches which abound in the Tule River country. It was constructed in 1878 or 1879, to supply water to several farms lying between the main channels of Tule River about 3 miles southeastward from Bayou. It has been in actual use very little, and but a few acres of alfalfa have been dependent upon it for water.

Bacigalupi Ditch.—Southward from Bayou, on the north side of the main channel of Tule River, is another high-water ditch, which has been in use more or less since about 1882. It is a short private ditch which supplies water for use on several hundred acres of land.

Bacigalupi & Creighton Canal.—This canal was constructed, in part at least, in 1877. It is really a diversion from Elk Bayou, the southernmost delta channel of Kaweah River, but as Lower Elk Bayou may also be considered a Tule River channel, receiving water from Porter Slough and being the main channel of Old Tule River, it will not be out of place to enumerate this canal among the Tule River ditches, particularly as the flow of Main Tule River into the lower end of Elk Bayou is chiefly relied upon as a source of supply for this ditch. The head of the ditch is on the north side of the bayou, about a quarter of a mile above its junction with the main channel of Tule River. The canal has a northwesterly course for about 4 miles, thence a southwesterly course for a like distance to near the eastern margin of Tulare Lake. It was built primarily for the reclamation of land entered as a desert claim. The regulator built in the head of the canal was soon washed out of place and the upper end of the original canal was considerably enlarged by erosion. The upper part of the canal was originally about 8 feet wide on the bottom, but a width of 12 feet on the bottom, with a water depth of 2 to 3 feet, is claimed for most of its course. So far as can be learned, there has been but little systematic irrigation in the territory commanded by this canal.

Tulare Lake Canal.—This canal, which was built in 1890, takes water from Tule River at a point 10 miles due west from Tipton. It has a bed width of 40 to 50 feet and a depth reported at 4 to 5 feet. It lies within the extreme high-water limit of Tulare Lake. Its course is due south and its length is 3 miles. It commands the lands westward to the present lake margin. Water is expected to be available in this canal from about February to July. It is reported to have supplied water this season to 7,000 acres of grain land. At the head of the canal structures of the ordinary open flashboard type are in use for the diversion and control of the water. The cost of the canal head works is said to have been $3,000, and the cost of the main canal and 10 to 15 miles of branch ditches, including the head works, was about $10,000.

TULE RIVER IRRIGATION DISTRICT.

In no portion of the State has the necessity for harmonizing conflicting claims to water and adequate control of its diversion and use been greater than on Kaweah and Tule rivers, and it is on these rivers that the successful operation of the irrigation-district system was to be anticipated. It seemed as though all irrigators could only gain, and none lose, by bringing the many small independent ditches under one management, as authorized by the district law. And, in fact, no difficulty was encountered in forming on Tule River two irrigation districts, both of which have constructed canal systems, but in both of which there is now much dissatisfaction with the operation of the law and with the results thus far achieved. Of course the disappointments and failures are, in part at least, due to the general depression of the farming industry; but with an increasing tax rate as a burden upon those who meet their district obligations, and with probable confiscations of the property of those who continue delinquent, the problem of district management becomes difficult of solution.

The Tule River irrigation district was organized in September, 1891. A bond issue of $90,000 was soon followed by a second of $10,000. The district has an area of about 22,000 acres—practically all the lands within or immediately adjacent to the delta of Tule River. The district has a greatest length in the direction of the river of 13 miles, its eastern limit being about 6 miles west of Porterville, and a breadth of about 4 miles. Some of the land within exterior boundaries has been excluded.

The entire bond issue has been expended in completing the canal system. The bonds could not be sold readily and were finally, through the hands of a nominal purchaser, turned over to the contractors, who carried on operations by hypothecating them. The canal system consists of a main water way to and into the district—Porter Slough—and two principal laterals, one on each side of Tule River. At the head of Porter Slough a cut 700 feet long has been made from the river into the slough. In this cut a regulating gate 36 feet wide has been placed, which is intended to serve the irrigation-district canal as well as the Hubbs & Miner Ditch. Of its 9 bays or openings, 7 are for the district and 2 for the other ditch. After flowing in Porter Slough for 7 or 8 miles the district water is taken into a large canal whose head is 3 miles west of Porterville, and which has a westerly course for 2½ miles to a point near the north bank of Tule River. The water is there separated into two canals, of which one has a northerly course back to Porter Slough and the other drops its water into Tule River, from which it is again reclaimed half a mile below. Porter Slough is the main north-side lateral for 6 or 7 miles; thence an artificial canal continues westward to near the western limit of the district. The south-side main lateral has a course almost due west for 11 to 12 miles, holding a position within one-half mile to a mile of the south boundary of the district. The older ditches within the district and smaller laterals complete the distributing system. The dropping of the south-branch water into Tule River is only a temporary arrangement, it being proposed to carry this water over the river in a flume.

Water is expected in the district canals from about March 1 to July 1. The irrigators are this season allowed to take water as they please, canal operation being blocked by litigation. It was at first proposed to meet operating expenses by levying an assessment upon the property of the district. This was done one season, and cost of operation was about $2,000. The following year, 1896, water was sold at 20 cents per irrigating head per hour, the head of water being understood to mean the amount which would pass over a clear overfall 4 feet long and 1 foot deep. This year, as already stated, water is taken by irrigators as they can get it.

TIPTON IRRIGATION DISTRICT.

The Tipton irrigation district is a second district dependent upon Tule River for its water supply, but its right to make a diversion extends only to the flood flow of the river. This district was organized in 1891. It contains 17,040 acres, located on the south side of Tule River, south of the lower portion of the Tule River irrigation district. A first issue of bonds of $50,000 was followed by a second to the amount of $20,000, but the second series has never been disposed of.

The district receives water through Callison Slough, the southernmost delta channel of Tule River. Arrangements were made with the Woods Central Irrigating Ditch Company whereby a regulating gate was to be placed and maintained for common use in the head of the slough. This was done. The gate was made 30 feet wide, 20 feet for the irrigation district, and 10 feet for the Woods Irrigating Ditch. The main district canal was taken out of the slough about 2½ miles below its separation from the river. It reached the district by a course a little south of west, and four principal laterals were extended from it westward into the district.

The canal system cost the district $50,000 in bonds and an additional $11,000 represented by outstanding warrants. Here, as in other districts, bonds did not sell readily for cash at or above the limit prescribed by law, and here too the bulk of them went to the contractors of ditch work through a nominal purchaser.

The tax collector of the district has been temporarily enjoined from selling property for delinquent taxes. The residents of the districts do not seem able to pay the irrigation tax, which has been from 3 to over 4 per cent per annum. The operating expenses, including salaries of all officials and employees, were about $3,000 while the district was still in operation. Irrigation has therefore been extended very little, if any, under the district system, so that on the whole the outlook for this district is not encouraging.

METHODS OF IRRIGATION.

Irrigation from Tule River, with its many channels of slight depth, is very readily accomplished; so easily, in fact, that most of the farmers along its banks have in the past drawn its water through small ditches, generally owned in common by several irrigators. Small high-water ditches, frequently without head gates, are numerous, and there are but few irrigation works on a large scale. The dams in use to divert the water into the heads of the ditches are usually temporary structures of sand and brush. The only ones which are expected to withstand the freshets are those at canal heads above Porterville. The banks of Tule River are so low that but little cutting is required to carry water from the point of diversion away from the river banks. Only the lands near and above Plano and Porterville, and those along the Farmers' Canal, are favored with water for irrigation during more than the spring months.

Crops cultivated above Porterville are principally fruits, including citrus fruits, for which this section is famed, vegetables, and other summer crops. Below Porterville the most important crop irrigated is alfalfa. Most of the irrigated land near Porterville and Plano, where not in the river bottom, is a moderately dark loam. Water is applied to trees, vines, and vegetables in furrows run between rows. The slope of the ground in the region just indicated is ordinarily too great to permit of irrigation by any of the systems of flooding in checks, as elsewhere practiced. When irrigating in furrows, the water is delivered into a number of these at the same time from a small distributing ditch. The quantity of water admitted into each is so small that it does not cause erosion. As soon as the loose soil between furrows is thoroughly wet, irrigation is complete and water is turned off.

This system of irrigation was observed on a hillside about 1 mile east of Porterville. Water was diverted from a branch of the Pioneer Canal into a small distributary lying along the upper edge of the orchard to be irrigated. The amount used as an irrigating head was about half a second-foot. From the distributing ditch the water was diverted at regular intervals through small tubes of tin, stuck through short boards and placed temporarily into the side of the ditch; thence it found its way into the furrows. The grade of the furrows was about 1 foot in 20. The water was allowed to flow in thirty furrows at the same time and required the attention of one man. Constant attendance was required, but the labor was very light. This system of irrigation can be practiced to advantage only in the daytime. The furrows were about 3 feet apart; there were three furrows between each two rows of trees.

By means of this system of irrigation the ground was wet to a depth of 3 feet or more. After a few days the ground was well cultivated, in order to reduce the loss of water from the surface by evaporation. The soil of the tract thus irrigated is a light black loam, a dry bog, which becomes very soft and sticky when wet. The proprietor gave his vines and trees only one irrigation per annum. The average annual rainfall in this vicinity is about 11 inches. It is less at points farther west, being only about 7 inches along the central line of San Joaquin Valley at points opposite Porterville.

Lands along Tule River west of Porterville are for the most part level and have a smooth surface. Irrigation is generally accomplished by flooding in checks having an area of only a few acres each. Alfalfa is irrigated every four to six weeks while water is available; orchards and vineyards, once or twice a season, according to water supply; corn land, ordinarily once before seeding; and vegetables, almost continuously during the time water is available. Every ditch owner tries to keep water in his ditch as long as possible, because it is useful for stock purposes when not required for irrigation. The soil along the river is generally a sandy loam, usually resting on firm clay, called hardpan, found at a depth of 1 to 6 feet. Ground water near the river is about 14 feet; it is to some extent affected by the flow of water in the river and in ditches and its use in irrigation; but the time between irrigation periods is so long that the water table has not been permanently raised in consequence of irrigation. Irrigation has produced no marked changes in the character of the soil, though it is occasionally claimed to have been the cause of an increase of alkali at the surface of some of the lands irrigated. Fevers are, and always have been, prevalent to some degree along Tule River, and it is not possible from the limited data collected to determine to what extent the healthfulness of the country has been affected by the practice of irrigation.

Private ownership of ditches has been the rule on Tule River. The sale and measurement of water is now, however, about to become an established fact on the Pioneer Canal, and has already been introduced in the Tule River irrigation district; but it practically amounts only to systematizing water distribution, compelling economic use, and putting the burden of canal maintenance upon the irrigator alone, the sale being restricted either to holders of canal stock or to taxpayers in a district.

PUMP IRRIGATION AT LINDSAY.

The water development by means of artesian wells in San Joaquin Valley is a subject of considerable interest, but can not be dealt with fully in this paper, owing to lack of detailed information concerning recent developments. But the use of water secured by pumping from a subsurface source has been so successful, in at least one portion of the field under consideration, that a brief reference to it will not be out of place.

Lindsay is a new settlement on the east-side valley plain, about 10 miles northwest of Porterville. It was at first proposed to bring water into that locality from Kaweah River, but before the difficulties in the way of canal construction were overcome it was found that a layer of sand at about 60 to 65 feet below the surface afforded a fair supply of water. Centrifugal pumps have been brought into service to develop this water supply. The pumps are placed in pits about 30 feet deep, near the surface of the ground water, and water is delivered by them through pipes to the place of use. Both steam and gasoline engines are in use to supply power. The irrigation is confined almost exclusively to citrus fruits, the cultivation of which commenced in this locality about five years ago. The water surface in the wells is lowered during pumping from 10 to 27 feet, according to pump capacity. The total height water is raised, including friction in pipes, is said to exceed in some cases 70 feet. One irrigator, with 2¼ cords of oak wood at $4 a cord, and one pump, claims to be able to irrigate from 20 to 25 acres of orchard land per day, according to distance from pump. The method of irrigation is by multiple furrows between rows of trees. The soil is a rather stiff, chocolate-colored loam.

There are four steam pumping plants and about six gasoline pumping plants now in that vicinity.

Irrigation is continued throughout the summer months from about May 1 to October 1. Trees over one year old receive water every five to six weeks; younger trees more frequently.

INDEX.

1895.

Sixteenth Annual Report of the United States Geological Survey, 1894–95, Part II, Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Big Horn Range and Big Horn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar year 1893–94, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in a number of counties in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895–96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers, on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett; and "Preliminary report on the artesian areas of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo. 230 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896–97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton; and "Reservoirs for irrigation," by J. D. Schuyler.

1898.

Nineteenth Annual Report of the United States Geological Survey, 1897–98, Part IV, Hydrography, 1898; octavo, — pp.

Contains a "Report of progress of stream measurements for the calendar year 1897," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton; and "Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

Water-Supply and Irrigation Papers, 1896–1898.

This series of papers is designed to present in pamphlet form the results of stream measurements and of special investigations. A list of these, with other information, is given on the outside (or fourth) page of this cover.

Survey bulletins can be obtained only by prepayment of cost, as noted above. Postage stamps, checks, and drafts can not be accepted. Money should be transmitted by postal money order or express order, made payable to the Director of the United States Geological Survey. Correspondence relating to the publications of the Survey should be addressed to **The Director, United States Geological Survey, Washington, D. C.**

WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phœnix, Arizona, by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colorado, by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1898.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Water resources of southeastern Nebraska, by Nelson Horatio Darton, 1898.
13. Irrigation systems in Texas, by William Ferguson Hutson, 1898.
14. New tests of certain pumps and water lifts used in irrigation, by O. P. Hood, 1898.
15. Operations at river stations, 1897, Part I, 1898.
16. Operations at river stations, 1897, Part II, 1898.
17. Irrigation near Bakersfield, California, by C. E. Grunsky, 1898.

In press:

18. Irrigation near Fresno, California, by C. E. Grunsky.
19. Irrigation near Merced, California, by C. E. Grunsky.
20. Experiments with windmills, by Thomas O. Perry.

In addition to the above, there are in various stages of preparation other papers relating to the measurement of streams, the storage of water, the amount available from underground sources, the efficiency of windmills, the cost of pumping, and other details relating to the methods of utilizing the water resources of the country. Provision has been made for printing these by the following clause in the sundry civil act making appropriations for the year 1896-97:

Provided, That hereafter the reports of the Geological Survey in relation to the gauging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed 100 pages in length and 5,000 copies in number; 1,000 copies of which shall be for the official use of the Geological Survey, 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered to the House of Representatives, for distribution. (Approved, June 11, 1896; Stat. L., vol. 29, p. 453.)

The maximum number of copies available for the use of the Geological Survey is 1,000. This number falls far short of the demand, so that it is impossible to meet all requests. Attempts are made to send these pamphlets to persons who have rendered assistance in their preparation through replies to schedules or donation of data. Requests specifying a certain paper and stating a reason for asking for it are attended to whenever practicable, but it is impossible to comply with general requests, such as to have all of the series sent indiscriminately.

Application for these papers should be made either to Members of Congress or to

THE DIRECTOR,

UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C.