DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 18

IRRIGATION NEAR FRESNO, CALIFORNIA.—GRUNSKY

WASHINGTON
GOVERNMENT PRINTING OFFICE
1898

IRRIGATION REPORTS.

The following list contains titles and brief descriptions of the principal reports relating to water supply and irrigation, prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 123 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888–89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 395 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889–90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890–91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 190 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 35, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 25, September 9, 1892; quarto, 22 pp.

Contains tabulations showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a résumé of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891–92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American irrigation engineering"; and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 119 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price, 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892–93, in two parts; Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

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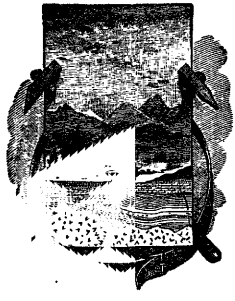
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

IRRIGATION NEAR FRESNO, CALIFORNIA

BY

CARL EWALD GRUNSKY



WASHINGTON
GOVERNMENT PRINTING OFFICE
1898

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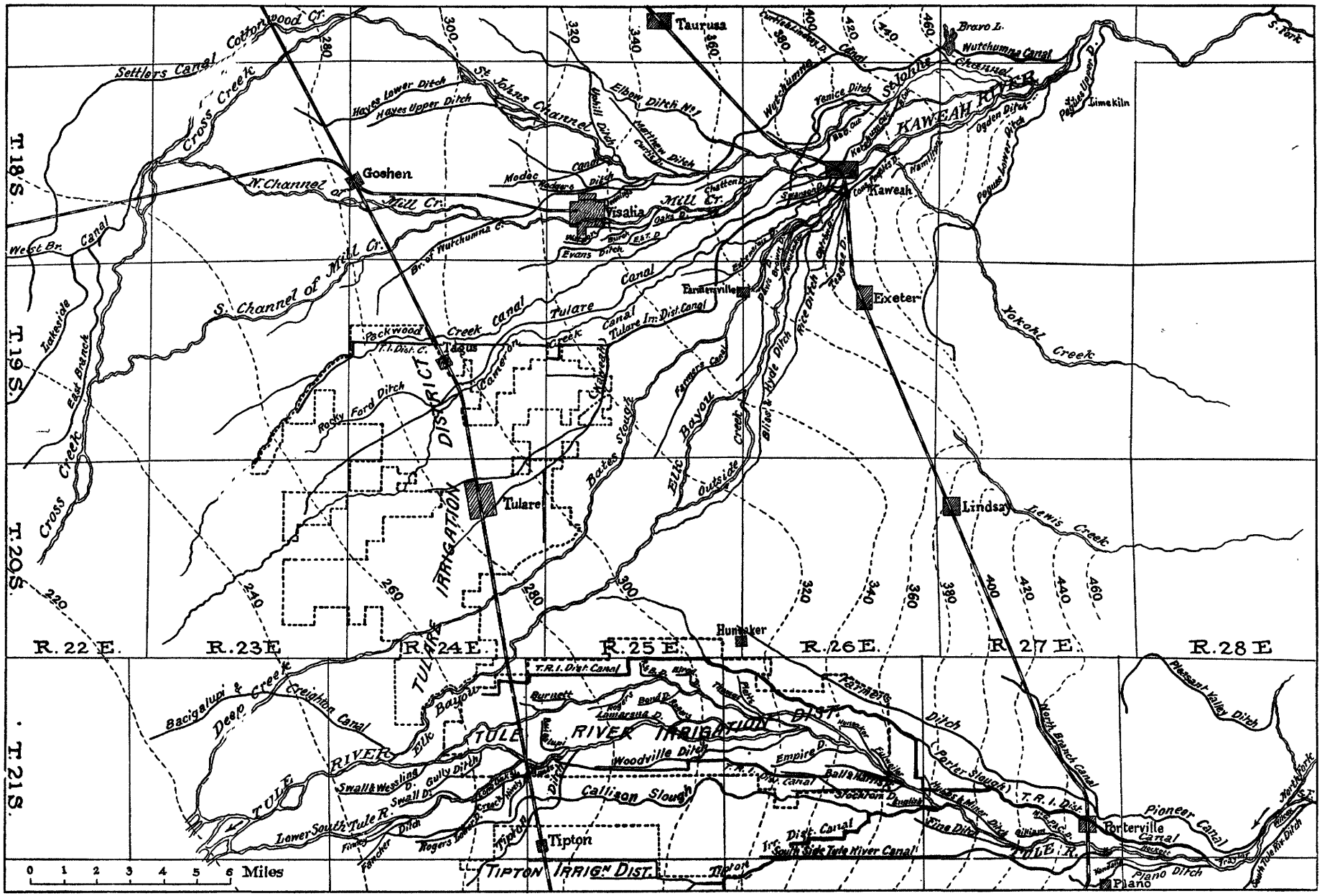
DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, July 6, 1898.

SIR: I have the honor to transmit herewith a manuscript entitled Irrigation near Fresno, California, by Mr. C. E. Grunsky, and to recommend that it be published as one of the series of pamphlets on Water Supply and Irrigation. This is the second of three papers relating to irrigation in San Joaquin Valley, the other two being Nos. 17 and 19 of the series. It relates mainly to the irrigation systems deriving their water supply from Kaweah and Kings rivers, and covering the agricultural lands on the east side of San Joaquin Valley, between Visalia and Fresno.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

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



CANALS FROM KAWEAH AND TULE RIVERS.

IRRIGATION NEAR FRESNO, CALIFORNIA.[1]

By C. E. GRUNSKY.

KAWEAH RIVER.

HYDROGRAPHY.

Kaweah River enters San Joaquin Valley from the east, passing between Dillons Point on the north end and Wutchumna Hill on the south, about 15 miles east of Visalia. Its drainage basin above that point has an area of 619 square miles, mostly low mountain country. The river has a perennial flow, but its flow is comparatively small at low stages, ordinarily about 30 second-feet. The low-water period usually begins in August and continues through January. The river is subject to freshets in the winter months, and is at its highest stages in April, May, and June. Medium stages are expected throughout February, March, and July. The monthly mean flow at the river's highest stage exceeds 4,000 second-feet.[2]

Before the freshets of 1861–62, which have become memorable, the river annually overflowed large areas in its course across the east-side valley plain, and numerous high-water channels carried its waters toward Tulare Lake. The portion of its overflowed district to the east of or above Visalia is generally referred to as Visalia Swamp. Four of the river channels—Elbow Creek, Visalia or Mill Creek, Packwood Creek, and Deep Creek—gave the name of "Four Creek Country" to the vicinity of Visalia. The channel at the northern edge of the overflowed land was known as Canoe Creek above Iron Mountain, and as Elbow Creek below that point. The course of Elbow Creek is north of west to a junction with Cottonwood Creek, a small water course from the northeast, thence southwesterly to a reunion with Kaweah River water in Cross Creek, which name is given to the lower portion

[1] For an account of irrigation in other parts of San Joaquin Valley, see Water-Supply and Irrigation Papers Nos. 17 and 19. These three papers are based largely upon information collected by the State engineering department of California ten years ago, and are intended to supplement the two volumes issued by that department, namely: 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. (See introductory paragraph on page 13 of Water-Supply and Irrigation Paper No. 17.)

[2] Physical Data and Statistics, Wm. Ham. Hall, State Engineer of California, pp. 455, 476.

of St. Johns Channel of the river. Deep Creek was the principal south marginal stream. It received water from the main channel of the river 8 miles east of Visalia and lost its identity about 5 miles southeast of Visalia, where its waters spread and were received into other channels of different names. Visalia Creek and Packwood Creek were the names given to the two water courses into which the main channel of Kaweah River separated 5 miles above Visalia. The course of Visalia Creek was westerly through Visalia, that of Packwood Creek southwesterly. To understand the changes made in the system of principal channels of the river by the high waters of 1862 and the effects of these changes, it is necessary to know that, even preceding that year, irrigation and drainage work had been done in the Kaweah River delta. The Shipp Cut had been made in 1854. It was a small drain ditch from the swamp, near where Rocky Ford now is, southwesterly to a connection with Canoe Creek. A canal had been constructed from Visalia Creek into Visalia to supply power to a flour mill. The Lander Ditch, the Watson Ditch, and a number of other small ditches from Visalia and Packwood creeks had also become dependent upon the flow of water in the river channels at the south of Visalia. The freshets of 1861–62 cut a new channel from a point on Kaweah River about 14 miles east of Visalia in a northwesterly direction toward and along the northern border of Kaweah River Swamp. Shipp Cut and a section of Canoe Creek were enlarged by the flood waters and became a part of this new channel, and finally a connection was established with the Cross Creek channel below Visalia, and thus St. Johns Channel of Kaweah River was permanently established. At the same time a new high-water channel was washed out toward the northeast from a point on Kaweah River 6 miles above Visalia to a connection with this new channel. This is known as Sand Slough, which still remains as a connection between the two river channels at a point where they are only about one-half mile apart. The same high waters caused so much erosion in Landers Ditch that it became a branch of the river, and is generally referred to as Landers Slough. Its upper portion was long in use as the channel through which the Consolidated Peoples Ditch received its water.

The upper sections of the original main channel of Kaweah River were obstructed by the drift and silt deposits of these freshets, and as the low-water period of 1862 approached, it was found that water was scarce for those depending upon Deep Creek, Packwood Creek, and Visalia Creek for their supply, and many projects were proposed for relief. During the years immediately following, a number of ditches were constructed from the St. Johns Channel of the river, near Rocky Ford, southwesterly to the original main channel. Such were Longs Canal, Ketchum Canal, and the Bostwick Cut. All of these were intended to increase the flow in the delta streams at and southward of Visalia. After much contention between settlers on these several streams as to

the apportionment of their scant supply of water, it was agreed, in 1867, that a gate should be constructed in the head of Visalia Creek. This gate was not, however, maintained long. The freshets of 1867–68 were almost equal to those of 1861–62 and effected further enlargement of the St. Johns Channel. They refilled and otherwise destroyed some of the ditches that had been opened as connections between the two rivers. They washed out the gate in the head of Visalia Creek, and partially closed the heads of Packwood and Deep creeks. They enlarged Sand Slough. At the same time the upper portions of the old channel of Kaweah River were further obstructed by drift and silt, and a new head of St. Johns Channel was eroded about a mile above the former point of separation of the two channels.

To overcome the increased difficulties of keeping a good supply of water in those channels of the river reaching the vicinity of Visalia, many ineffectual efforts were made and much money was almost uselessly expended until, in 1877, a contract was entered into with Mr. Samuel Fowler by the Kaweah Canal and Irrigation Company, the Consolidated Peoples Ditch Company being an interested party, to open the old channel of the river. The cut then made, practically following the old channel, was enlarged and deepened by erosion, until a few years thereafter it was again the low-water channel of Kaweah River. Another obstructed section of the old channel near the head of the Consolidated Peoples Ditch, about 10 miles east of Visalia, was improved about the same time by the Kaweah and Mill Creek Water Company, and has since been known as the Visalia Cut or Hamilton Cut.

The obstructed head of Packwood Creek was improved by the Rocky Ford Canal Company, but was not in service long. This creek now receives its principal supply of water through the Bacon & Crossmore Cut from Visalia Creek. It has a southwesterly course, and such of its water as is not used for irrigation is delivered into Tulare Lake.

Cross Creek has already been mentioned as receiving the water of St. Johns Channel, Elbow Creek, and Cottonwood Creek. After approaching within 4 miles of Traver its course becomes southwesterly to a union with some of the old high-water delta channels of Kings River. Its course is thence southerly along the eastern border of this delta to Tulare Lake, which receives its water.

Visalia or Mill Creek separates into two channels soon after passing through Visalia. The course of one of these is a little north of west, that of the other southwest. Both unite with Cross Creek before reaching Tulare Lake.

Cameron Creek is one of the lesser delta channels of Kaweah River. It receives a portion of the flow of Deep Creek at a point about 6 miles due east from Visalia, and has a southwesterly course to Tulare Lake. It passes just to the northward of Tulare. An artificial channel at the head of this water way, constructed to improve its connection with Deep Creek, was closed by an order of court some years ago.

Deep Creek has already been mentioned. Its waters at the spread or sink of the creek were conducted by small artificial channels into Lower Deep Creek and Bates Slough. These artificial channels were soon so enlarged by erosion that the two lower sloughs have become extensions of the Deep Creek channel and conduct its waters onward southwesterly toward Tulare Lake.

Outside Creek has a course along the eastern margin of the Kaweah delta. The creek can not be traced to a direct connection with the present river channels. It may, in fact, be regarded as the extension into the river delta of Yokohl Creek, a small stream draining a portion of the foothill section intermediate between the Kaweah River and Tule River drainage basins; but in times of flood the natural flow of some of the river water was into depressions, reaching a point that may be regarded as the head of Outside Creek, about 9 miles east of Visalia. The creek now receives an occasional inflow of foothill drainage waters from the east and the waste water from some of the branches of the Consolidated Peoples Ditch. The water of Outside Creek is distributed to a number of channels, the most southerly of which is Elk Bayou, which unites southeast of Tulare with the old channel of Tule River, and thence has a southwesterly course to a union with the present main channel of Tule River.

CANALS AND DITCHES.

Wutchumna Canal.—This is the upper north-side diversion of water from Kaweah River. The head of the canal is at the base of the slope of Dillons Point, a foothill spur rising to the northward. Thence it has a westerly course for 4 miles to a flat depression, which its water converts into a lake of about 40 acres, known as Bravo Lake. Leaving Lake Bravo, the westerly course of the canal is maintained 4 miles farther to the northern base of Iron Mountain, and thence 6 miles southwesterly to St. Johns Channel, about 4 miles above Visalia, where its water is carried over the river channel in a flume. The main canal then flows westerly near the south bank of the river about 2 miles to a junction with Old or Lower Wutchumna Ditch, whose branches extend far to the west of Visalia.

The Wutchumna Water Company was incorporated in 1872 for the avowed purpose of effecting a better distribution of water to the several ditches dependent upon Kaweah River for their supply, but various difficulties were encountered which prevented the enterprise from meeting with anticipated success, and it was not until 1880 that a connection between the upper diversion—work on which is reported to have commenced in 1872—and the distributing system of the lower canal was finally established. The lower canal was constructed in 1873 or 1874. Its head is on the south side of the St. Johns Channel of Kaweah River, about 3 miles northeast from Visalia. It established a direct southerly connection between St. Johns River and Visalia Creek,

and for three years its water furnished power for the flour mill in Visalia. The principal branch of the Lower Wutchumna Canal has a westerly course, passing just to the north of Visalia and terminating at a point about 4 miles south from Goshen.

The first work at the head of the Wutchumna Canal seems to have been done by Stephen Barton, who subsequently appears as one of the directors in the Pioneer Canal Company, which was incorporated in 1877, and which during that season constructed a ditch on the line adopted by the Wutchumna Canal as far as Bravo Lake. When the Wutchumna Canal Company, as successor of the Pioneer Company, assumed control, this upper ditch was extended along the route already described.

The canal head gate or regulator has been placed in a rock cut, and, as a result of this location of the head of the canal, expenditures of maintenance became unusually heavy when, a few years after the canal came into use, it became necessary to cut the upper section of the canal 4 feet deeper. This was done at a cost of $6,000. The total cost of canal construction has probably exceeded $60,000. The head gate width is 20 feet, and this may be regarded as the average bed width of the canal throughout its principal section. Its fall is reported to be nearly 7 feet to the mile for 4 miles, thence 2½ feet to the mile. The flume across St. Johns River is 14 feet wide, 2 feet deep, and about 150 feet long. It was built in 1880. The head gate of the Lower Wutchumna Canal is a little over 11 feet wide.

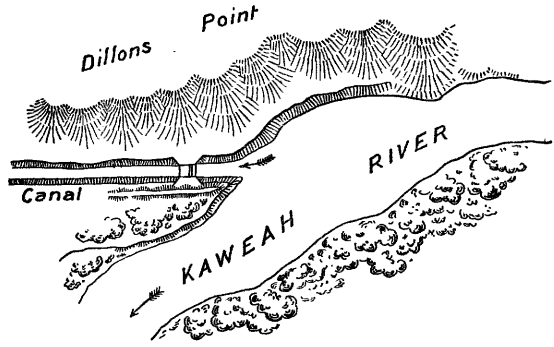


FIG. 1.—Head of Wutchumna Canal.

For a distance of about 4 miles westward from Lake Bravo the canal follows the original alignment of the Curtis & Lindsey Ditch. This ditch was enlarged, and its owners were granted a right to use that section of the Wutchumna Canal.

The canal is owned by an incorporated company whose shares are all in the hands of about thirty persons. All canal expenses are met by assessment of the stockholders. Each stockholder is entitled to a proportional part of the water in the canal, and he may dispose of this at his pleasure. He may lease this to whom he pleases, but not in less amounts than full shares. The distribution of water is in charge of a canal superintendent, who apportions it to the various distributing ditches in proportion to the number of shares represented in each. Although the company owns some of the shares of stock, these are not

for sale, nor will the company lease them or the water which they represent. By retaining these the company increases the proportional part of water represented by each of the other shares. The canal company bears the expense of the necessary structures at the heads of distributing ditches, but does not keep them in repair or replace them if destroyed. This has to be done under direction of the canal superintendent by the parties directly interested in their maintenance.

Curtis & Lindsey Ditch.—This ditch has its head on the north side of St. Johns River, 4 miles below the head of the Wutchumna Canal. It has a northwesterly course for one-half mile to a connection with the Wutchumna Canal, into which it drops its water. Four miles below this point the water dropped into the Wutchumna Canal is again taken out by a ditch 4 miles long having a northwesterly course and terminating on the bottom lands of Cottonwood Creek. The Curtis & Lindsey Ditch was constructed in 1876, and its extension toward Cottonwood Creek was made in the following year. Soon afterwards 4 miles of its course were adopted as the alignment for the Wutchumna Canal, so that the ditch now appears in two sections, of which the lower one may also be considered a branch of the Wutchumna Canal. The ditch is also known as the Curtis, Lindsey & Moffitt Ditch. Its width was about 10 feet on the bottom, and its fall between 2 and 3 feet to the mile, but, so far as known, the extent of irrigation from it has not exceeded several hundred acres.

Venice Ditch.—This, called also North Side Rocky Ford Ditch, is a small north-side ditch which seems to have been first used about 1873. It was extended and enlarged somewhat in 1877. Its head is at Rocky Ford. It has a westerly course to Iron Mountain, thence skirts the eastern and southern base of this mountain, and terminates 2 miles farther west. It is about 6 miles long and 3 to 8 feet wide. Ownership in the ditch is represented by shares held by the farmers who use its water.

Elbow Ditch No. 1.—The flow of Elbow Creek, which leaves St. Johns River at a point about 5 miles above Visalia, is controlled, in a measure at least, by a regulator or head gate 8 feet wide, and is frequently referred to as Elbow Ditch No. 1. The upper part of the creek is an enlargement by erosion of a portion of the ditch known as Shipps Cut, which was constructed in 1854.

Matthew Ditch, or Elbow Ditch No. 2.—This is a small ditch having its head on the north side of St. Johns River, about 2 miles below the head of Elbow Creek. It was constructed in 1855, but with a somewhat different alignment from the present. The freshets of 1861–62 so changed the position and character of Kaweah River that the head of the ditch had to be carried upstream. It is difficult to determine whether the ditch remained in continuous use. The head gate was put into the new ditch in 1875 and was set somewhat lower than [illegible] river. A few years later erosion had progressed in

the river channel to such extent that a wing dam had to be used to divert water into the ditch. The ditch has a northwesterly course, is about 6 miles long, 6 feet wide on the bottom, carries water about 1½ feet deep, and has a grade of about 6 feet to the mile. It irrigates between 200 and 300 acres, of which nearly one-half is alfalfa.

Curtis Ditch.—About 1879 there was a small ditch in use occasionally for the irrigation of a few acres of alfalfa on the north side of St. Johns River about a mile below the head of the Matthew Ditch. It was known as the Curtis Ditch, and has fallen into disuse.

Weston Ditch.—Another abandoned small ditch which was in use for a few seasons prior to 1880 on the north side of the river, about a mile above the head of the Uphill Ditch, was the Weston Ditch.

Uphill Ditch.—This is another north-side ditch. Its head is half a mile above the road leading northward from Visalia. Diversion is made from the river without the use of any permanent weir. The diverted water is led in a cut a few hundred yards northwesterly and is dropped into a natural depression or high-water channel, in which it continues on the same course half a mile. Thence it is taken in the ditch proper northerly about 3 miles to the place of use in the vicinity of Elbow Creek. The head gate is 8 feet wide. It is in the form of a box culvert, and bears a heavy fill of sand on top, intended to give it stability. The sand deposits in the cut to the river above the head gate have made it somewhat expensive to keep the head of the ditch open. The ditch was constructed in 1871. It was made 8 feet wide on the bottom, and was intended to carry water 2 feet deep. Its fall is 20 inches to the mile.

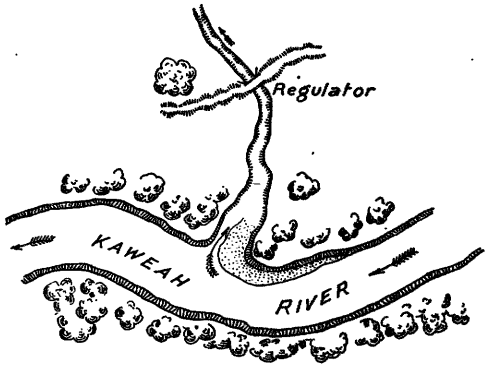


FIG. 2.—Head of Uphill Ditch.

Settlers Ditch.—This is a canal which for many years was of considerable importance as a source of water supply for lands in the eastern part of the Kings River delta. The canal receives water through a branch of Cross Creek. The canal regulator is on the north side of that creek 3 miles south of Traver. The creek channel, there tapped by the canal, is really the extension of Cottonwood and Elbow creeks, but most of its flow comes through a cut, the real head of Settlers Ditch, a quarter of a mile long, leading from the main channel of Cross Creek to its northern branch, at a point about 4 miles above the Settlers Canal head gate. Where the canal is finally diverted from Cross Creek a light timber weir or waste gate has been placed across the

creek channel. The canal regulator is nearly half a mile below the point where the canal leaves the natural channel. The head gate is 32 feet wide. It has eight openings, each 3 feet 6 inches wide in the clear. The gates closing these openings are provided with stems to which power is applied by means of levers.

The canal proper has a bed width at and near its head of 32 feet, and can carry water 2½ feet deep. It has 9 inches fall to the mile, and a capacity of 75 to 80 second-feet. The width of the canal is reduced within 3 miles of its head gate to 24 feet on the bottom, and its fall to 6 inches to the mile. Its course is a little south of west for 5 miles to a point where its water is divided, being carried thence southerly in two channels, of which the easterly branch is about 4½ miles long, and the westerly about 7 miles. The ditch commands a territory of about 8,000 acres, of which as much as 5,000 acres have been benefited by its water in a single season. The canal construction commenced in 1874, and considerable land was irrigated in 1876. Water was available only during the high stages of Kaweah River.

There was but little irrigation with water from this canal at any time to the east of the Kings River delta lands, soils being too alkaline to encourage cultivation. The extent to which this canal is now in use is somewhat problematical, as all the rights to water which it was supposed to have acquired were sold to the Tulare irrigation district, which has made a diversion from the St. Johns River about one-half mile below Rocky Ford. The canal is still in service, and does not appear to have suffered great diminution in its supply of water during the high-water stage of the river. The Settlers Ditch Company, which built the Settlers Canal at a first cost of approximately $35,000, was incorporated in 1874 with a capital stock of $10,000, in 50 shares of $200 each. These were held, at the time of the sale of the canal water rights, by about 50 persons.

All expenses of construction, repairs, maintenance, and management have been met by assessing the stockholders. Each share of stock entitles its holder to a proportional part of the water in the canal. Water is apportioned to each branch and to each distributing canal in proportion to the number of shares for which each draws water. No water is sold by the canal company, nor does the company lease any of the several shares which have reverted to it. Each stockholder, however, is permitted to lease his water to other persons, and can have it delivered to any point of the main canal or its branches which he selects. Water is delivered to irrigators through gates of various forms, generally under pressure. Its equitable distribution depends to a great extent on the judgment of the superintendent. Each share of water is supposed to be sufficient to irrigate 160 acres. The cost of water to the irrigators has averaged about 70 cents per acre per annum.

Lakeside Ditch.—This is another important diversion from the lower

portion of Cross Creek. The head of this canal is 4 miles below the head gate of the Settlers Canal, and 6 miles west from Goshen. The diversion from the natural creek channel is accomplished, as in the case of the Settlers Canal, by means of a weir or waste gate placed in the creek channel below the head of the canal, and a regulator or head gate in the latter about one-half mile below its head. The weir is a light timber structure arranged as a series of gates. It has a total width of 41 feet. Its nine openings between vertical posts are each 4 feet wide in the clear. The canal head gate has a width of 31 feet. The space between side walls is divided by vertical posts into six openings, each about 4½ feet wide in the clear. These openings or spaces between posts are closed with vertically sliding gates, to the stems of which power is applied by means of levers. The canal has a southwesterly course from its head for about 3 miles. In this distance it has a bed width of 30 feet and a fall of 6 inches to the mile. It can carry water about 3 feet deep. Its branches extend in southerly and southwesterly directions to the vicinity of Tulare Lake. The main canal and principal branches have an aggregate length of about 50 miles and command about 20,000 acres of land. The cultures on at least as much as one-half of this area may be considered to have been benefited by irrigation from this canal in a single season. The canal was constructed in 1874 and the years immediately following, at a total first cost of about $35,000.

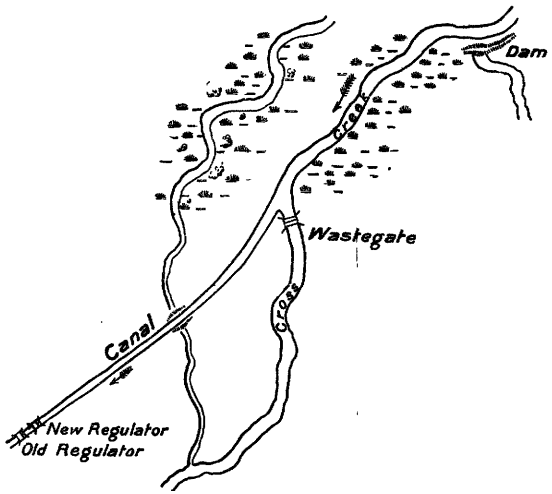


FIG. 3.—Head of Lakeside Ditch.

The canal is owned by the Lakeside Ditch Company, which was incorporated on August 7, 1874, with a capital stock of $10,000, divided into 10,000 shares of $1 each. On February 20, 1875, the capital stock was increased to 30,000 shares of $1 each. These shares were owned by ninety-five persons in 1885. Each share of stock entitles its holder to a proportional share of water in the canal. The canal company does not sell or rent water, not even on the few shares of stock held in the company's name. Each stockholder can have his water delivered at any point of any branch of the company's canal system. He can, if he desires, rent or sell his water for one or more

seasons. The company originally intended to deliver to each stockholder the water to which he was entitled at some point on his own land, but this system of delivery was found to be inexpedient and was abandoned in 1876. The distribution of water is in charge of a canal superintendent, who apportions the water to the various branches of the canal and has control of its delivery to the irrigator. The average annual cost of water from this canal has been about $1.55 per acre.

Jennings Ditch.—This is a small ditch which has its head on the south side of St. Johns River a little more than a quarter of a mile below the head of the Lower Wutchumna Ditch, and sends its branches into the northern portion of Visalia and adjacent territory. The main ditch has a bed width of 10 feet. The diversion of water is accomplished by means of a light wing dam of sand and brush, and the flow of water in the ditch is controlled by means of a simple regulator in the form of a box, 10 feet wide, which can be closed with loose flashboards. Water rights of an old date, preceding the formation of St. Johns River, are claimed for this ditch, whose head has been shifted back and forth between Mill Creek and St. Johns River.

Rodgers Ditch.—This is a small ditch, about 4 feet wide on the bottom, which supplies water to a few acres of land north and west of Visalia. It was constructed about 1875.

Modoc Canal.—This canal or ditch was originally intended to be made a distributary for the Wutchumna Canal water. It was constructed in 1876. Its head is on the south side of St. Johns River, just above the road leading northward from Visalia. Its length is about 4 miles, the course being a little south of west. Its bottom width is about 10 feet, and its capacity about 36 second-feet. Ownership in the ditch is represented by shares of stock. Water is distributed to stockholders in proportion to their interests. The annual expense of maintenance is about $100, which covers the construction of an inexpensive wing dam at the head of the ditch. The area actually irrigated is about 1,000 acres.

Hicks & Weston Ditch.—This is a very small ditch from the south side of St. Johns River, about 200 yards above the Modoc Canal. The ditch is 4 to 5 feet wide on the bottom. It was constructed in 1879. It receives water from the Wutchumna Canal in addition to its independent supply, and is sometimes called the Hicks Branch of Wutchumna Canal.

Hayes Upper Ditch (Goshen Ditch).—This ditch was constructed in 1881 or 1882 to supplement an older small ditch which was constructed in 1874 for the irrigation of lands near Goshen, theretofore considered almost worthless on account of the abundance of alkaline salts in the soil. The upper ditch has its head on the south side of St. Johns River about 4 miles northwest of Visalia. It has a westerly course and is about 4 miles long. Its dimensions are irregular. The pro-

moters of this enterprise constructed a small ditch and gave it an inexpensive, poorly protected head gate. The gate was carried off by the first freshet and the ditch was rapidly enlarged by erosion, so that it became a canal of considerable capacity. The second regulator put into its head was also a very light structure, 18 feet wide. Like many of the structures on Kaweah River, it was arranged as a box culvert, the entrance to which was divided into nine openings by vertical posts. The spaces between posts could be closed with loose flashboards. This ditch and the Lower Hayes Ditch both belong to the same owner, who has supplied some water to his neighbors at agreed rates per acre.

Hayes Lower Ditch.—The head of this ditch is about 1½ miles below the head of the Hayes Upper Ditch. Its course is a little south of west to the same region watered by the Hayes Upper Ditch. The ditch is about 4 miles long and 6 feet wide. Its head gate has a width of 10 feet. This ditch was constructed in 1874 by settlers near Goshen, but soon fell into the hands of the promoters of the Goshen Canal enterprise.

Pogues Upper Ditch.—This is the uppermost south-side diversion from Kaweah River. The head of the ditch is about 4 miles above the head of St. Johns River, a mile above the hill known as Limekiln Point. The ditch, which has a bed width of about 6 feet, skirts the northern and western base of Limekiln Point and commands several thousand acres of fine land lying between projecting spurs of the foothills. The ditch was constructed in 1884. Water is carried in a flume for some distance from the head of the ditch. This ditch now serves the citrus orchards at Lemon Cove, which have been set out within the last four or five years and now have an aggregate area of about 500 acres.

Pogues Lower Ditch.—This ditch was constructed in 1875. It diverts water from the south side of Kaweah River just below Limekiln Point. It has a southwesterly course, a bed width of 6 to 8 feet, and passes to the north and west of Wutchumna Hill, following the eastern border of the main valley and terminating at present at a point about 3 miles southeast of Exeter. Its total length is about 15 miles, and the capacity claimed for it is 30 second-feet. There was but little irrigation from this ditch at the time the second Pogue Ditch was constructed, but demand for water is rapidly increasing. The water is used on the lands set out to citrus fruits at and near Bonnie Brae. The area of citrus fruits now set out, all being dependent on this ditch for water, is 550 acres. Purchasers of land from the owners of this ditch are granted the right to call for water at the rate of 1 miner's inch (about one-fiftieth of a second-foot) to 5 acres. The charge of the water is 8 cents per inch per twenty-four hours. The lands (including the water rights) are sold at $75 per acre.

Ogden Ditch.—This ditch has its head on the south side of Kaweah River, about three-quarters of a mile below the head of Pogues Lower

Ditch. It has a southwesterly course, closely following the river, and terminates near Cottage. It is a very small ditch, about 4½ miles long, and supplies water to a few acres of alfalfa. It is said to be one of the old ditches, the date of its construction being given as 1862. The head of the ditch was not, however, always maintained at the same place, this having been impossible on account of the changes in the alignment and character of the river.

Hamilton Ditch.—This is another small private ditch on the south side of Kaweah River. Its head is about a mile above Cottage. It has a southwesterly course, is about 4 miles long, and about 4 feet wide. It has been in use since 1854. A south-side branch of the Hamilton Ditch is sometimes known as the Dillon Ditch.

Consolidated Peoples Ditch.—The difficulties experienced by irrigators

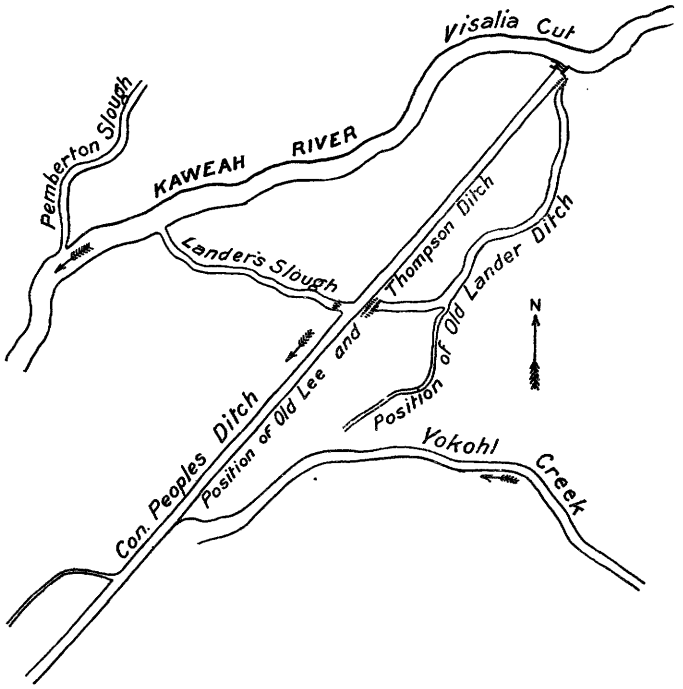


FIG. 4.—Head of Consolidated Peoples Ditch.

dependent for water upon the flow of Deep Creek, Packwood Creek, and Visalia Creek, after the freshets of 1861–62, led to a combination of interests, the direct result of which was the construction of the Peoples Ditch. The outlook for a sufficient supply of water was particularly bad after the winter of 1863–64, in which there was an unusual deficiency of precipitation, and, as a result of a conference with the owners of a number of small irrigation ditches, about one hundred interested persons assembled late in February, 1864, at the point where Landers Slough leaves the river and commenced work on the Peoples

Ditch, the water of which was to be apportioned to a number of ditches which before made independent diversions. The principal ditches that then became dependent upon the Peoples Ditch for water were the Landers, Lee & Thompson, Swanson, Turner, Grubbs, and Rice ditches. The expense of the canal construction was apportioned to the participating farmers according to relative interests. Most of them contributed labor, teams, and supplies. The ditch at its head was made 18 feet wide and 4 feet deep and was to have a fall of about 3½ feet to the mile. Work progressed rapidly and the ditch was considered finished by June 1, 1864. Its estimated cost at that time was $11,000. But owing to the obstructed condition of the old channel of Kaweah River below the head of St. Johns Channel, expectations as to flow of water were not fully realized, and upon petition the water commissioners of Tulare County granted the ditch company a franchise to remove obstructions from the old Kaweah River channel and to enlarge it where necessary to a width of 20 feet. Under the franchise work was done on the old river channel to a point near the present head of St. Johns River, about 4½ miles above the present head of the ditch. The river channel was thus kept open until again filled, in places, with drift and silt by the freshets of 1867–68. These freshets washed out the canal head gate in Landers Slough and considerably deepened and enlarged the upper section of the canal. During the period intervening between that winter and 1877, when the making of the Fowler Cut resulted in the practical reestablishment of the old channel of Kaweah River, water reached the head of the Peoples Ditch through a number of high-water channels leading in a southwesterly direction from the upper section of St. Johns River through Visalia Swamp. When water became scarce at the head of the canal, men would be sent up to St. Johns River to increase the flow toward the south by throwing obstructions into that river channel or by opening a better passage through the swamp. There has been a satisfactory supply of water to the head of the Peoples Ditch ever since the Fowler Cut was made.

This cut was made by Mr. Samuel Fowler under contract with the Kaweah Canal and Irrigation Company, which had entered into an agreement with the management of the Peoples Ditch concerning the apportionment of water. The agreement, which was formally executed on December 21, 1878, but subsequently set aside by a decision of the courts, provided for a joint ownership of the upper portion of the Peoples Ditch and of the water way above the head of that ditch as improved by the Kaweah Canal and Irrigation Company, and conceded to the Peoples Ditch the right at all times to as much water as will flow in a ditch 50 feet wide and 2 feet deep on a grade of 6 inches to the mile. The water of Kaweah River which passes the head of St. Johns Channel separates into two channels, each about a mile long, forming an island about 11 miles above Visalia. The upper portion of the

northernmost of these channels is known as the Hamilton or Visalia Cut. The southernmost is Lander Slough, or the enlarged channel of the Lander Ditch. It is the upper portion of Lander Slough which until 1896 carried water to the point where the flow was brought under final control for the Peoples Ditch. But when the canal regulator failed Landers Slough was closed near its head and an artificial canal was substituted for the Landers Slough section of the Peoples Ditch. A box inlet 20 feet wide and 10 feet deep is maintained in the head of this new canal section, which structure seems to be intended more as a partitioner of the flow of Kaweah River than as a regulating gate in the ordinary sense.

The Consolidated Peoples Ditch has a southwesterly course from Landers Slough for 3 miles to the point where its water was separated from that of the Kaweah Canal, so long as that canal was in service. The main canal extends from that point about 1½ miles farther, to a point known as Dillons Mill, where some of its water is in use to supply power. The section of the canal next below Landers Slough follows the original alignment of the Swanson Ditch for about three-fourths of a mile, following and finally crossing the almost obliterated channel of Yokohl Creek. The occasional flow of this creek is admitted into the canal, and surplus waters are discharged through a waste gate into Outside Creek, which was originally a continuation of the Yokohl Creek channel. The main canal is of somewhat irregular dimensions, much of it having the appearance of a natural channel. Its width is generally 30 to 50 feet and its capacity probably exceeds 400 second-feet.

The consolidation of the interests of the several small ditches and individual irrigators, as already explained, led finally to an incorporation of their organization. This was effected in 1874, and the corporation received the name of the Consolidated Peoples Ditch Company. Its capital stock was fixed at $9,700, in 97 shares of $100 each. Canal expenses are assessed upon stockholders. No water is sold by the canal company. At the time of constructing the canal it was agreed that each person interested in the main canal should contribute toward construction down to the point at which his water was to be delivered into a branch ditch. All branch ditches are under independent management. Water is distributed to the various branch ditches, under the direction of the president of the company, in proportion to the number of shares of stock for which water is to be delivered to each. The apportionment of water between the main canal and a branch ditch is accomplished by constructing a sill or floor at the same elevation in each, the effective width of canal and ditch on each sill being made proportional to the amount of water to be passed. The cost of constructing and maintaining these structures falls upon the canal company. The area of land actually irrigated in a single season with water from the Peoples Ditch has exceeded 5,000 acres. The total expendi-

ture on the main canal chargeable to the construction account has been about $50,000.

Swanson Ditch.—This is a branch of the Peoples Ditch, receiving its water about three-quarters of a mile below the point where the latter leaves Landers Slough. It has a southwesterly course and is about 4 miles long. It is reported to have been in use as an independent ditch as early as 1855. While the supply of water from the Peoples Ditch was somewhat unreliable—preceding 1878—irrigators dependent upon the Swanson Ditch endeavored to keep the head of Packwood Creek open, but with indifferent success. Since that time the ditch is to be regarded merely as a branch of the Peoples Ditch.

Lee & Thompson Ditch.—This was a second old ditch, almost parallel with the Swanson for some distance. Its alignment was adopted for the Peoples Ditch for a considerable distance, and only the lower end of the original ditch remains in use as a small distributary of the Peoples Ditch water.

Rice Ditch.—This is another small ditch, now a branch of the Peoples Ditch, which was in use before the latter was constructed. Its course is southerly from a point near the lower end of the main ditch. It is about 6 miles long, terminating in a branch of Outside Creek used as a distributary of the Peoples Ditch water under the name of the Bliss & Hyde Ditch, and it commands a narrow strip of land lying to the east of Outside Creek.

Catron and Teague ditches.—These are two small branches of the Peoples Ditch, both of which receive water from the south side of the latter through a common head about 2 miles below Landers Slough. Their course is southerly. The former is about 3 miles long, the latter about 4, and both are connected at their lower ends with the Rice Ditch, into which surplus water is dropped.

Bliss & Hyde Ditch.—This is a branch of the Peoples Ditch, receiving its water a quarter of a mile below the head of the Catron and the Teague ditches. At that point a short cut from the south side of the Peoples Ditch drops water for this branch into a natural channel—the eastern branch of Outside Creek—which is the same channel used above that point as a common head for the Catron and the Teague ditches. This channel has a course a little west of south for about 12 miles, to the point where the water of the branch ditch is used, about 6 miles east of Tulare, on both sides of Outside Creek, there known in part as Elk Bayou. Water is diverted from Outside Creek into two irrigation ditches, one upon either side, each of which has a length of about 2 miles.

Davis, Brown, and Pennebaker ditches.—These are three short branches of the Peoples Ditch, all receiving water from it at or near the termination of the main canal, and supplying water to lands near Farmersville.

Extension Ditch.—After the use of a portion of the water of the

Peoples Ditch for power at Dillons Mill, which is at the termination of the main canal, it flows into Outside Creek. The creek channel is closed with an overfall dam of brush, which serves as a waste way for all water not required for the Extension Ditch. This ditch is one of the principal branches of the Peoples Ditch. It has a southwesterly course, and, with its branches, commands the region to the west and northward of Farmersville. It was built by the farmers whose lands it waters. They have formed a corporation known as the Extension Ditch Company, whose shares of stock are in the hands of thirty or more irrigators. The affairs of this company are managed entirely independent of the Peoples Ditch Company, which merely delivers to it the water which its stockholders are entitled to receive from the Peoples Ditch.

Kaweah Canal.—The enumeration of this canal is merely historical.

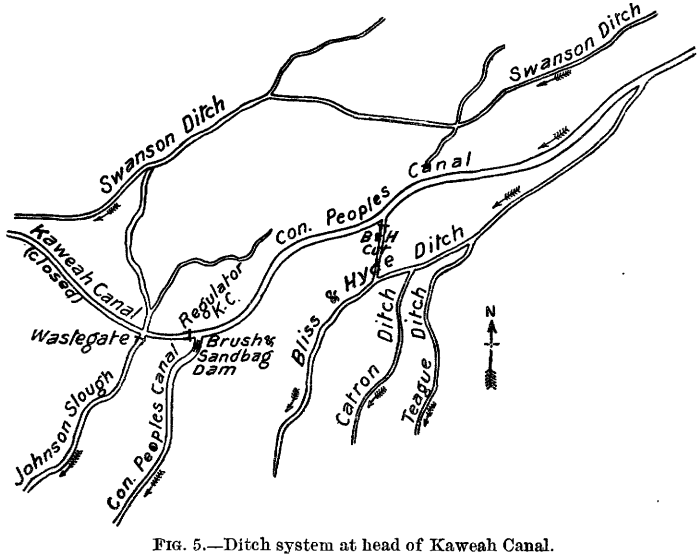


FIG. 5.—Ditch system at head of Kaweah Canal.

It is one of the canals whose successful operation was greatly interfered with by litigation. The canal was constructed in 1877. At that time the Fowler Cut was made for the Kaweah Canal and Irrigation Company, and led to the reestablishment of the original channel of Kaweah River, or of a new channel very nearly coincident with the original one in position. The agreement then made with the Consolidated Peoples Ditch Company gave the new company a right to use the upper sections of the Peoples Ditch for several miles, and below that point a canal was excavated, about 50 feet wide on the bottom and 3 feet deep, which temporarily dropped its water into Deep Creek, in which it flowed to within a few miles of Tulare. The main canal was soon afterwards extended across Deep Creek in a general southwesterly direc-

tion, passing about a mile to the west of Farmersville, until, at a point about 6 miles to the northeast of Tulare, it was separated into two main branches, of which the southerly one commanded the lands in the vicinity of Tulare, including the colony lands toward the west. The northerly branch was extended westerly across Cameron Creek to a connection with the Tulare Canal, and has irrigated a few tracts of land near Tagus. The total length of the main canal, not including the Fowler Cut or the Peoples Ditch, to where it separates into its two principal branches is about 10 miles. Irrigation from this canal has probably exceeded 4,000 acres. The canal was constructed by a corporation known as the Kaweah Canal and Irrigation Company, which was organized in 1877 by farmers who were in need of water for their lands in the vicinity of Tulare. The capital stock was fixed at $50,000, in 500 shares. The expense of canal construction and litigation soon exceeded this sum by at least $10,000. The canal always held its water for sale, but stockholders were entitled to receive it at slightly reduced rates. All expenses in excess of revenue derived from the sale of water were apportioned to stockholders. Water was not sold by measurement; it was delivered to the irrigators from the several canal branches in rotation, and was paid for at fixed rates per acre actually irrigated, generally $1 to $2 per acre. The right of the canal to receive any surplus waters from the Peoples Ditch was disputed in court by farmers who, as riparian owners on Outside Creek, demanded that all flow in the Peoples Ditch in excess of that required for that ditch should be wasted into channels leading into Outside Creek. Their claim having been sustained, the Kaweah Canal for many years received water only by sufferance and only during periods when the river afforded an abundant supply. Its water was no longer taken through the head of the Peoples Ditch, but a cut was made from Kaweah River below Deep Creek to the canal, and the upper half mile of Deep Creek itself was utilized as a source of supply. After the organization of the Tulare irrigation district the canal was sold to the district for $150,000, payment being made in bonds, but with the proviso that the stockholders of the Keweah Canal and Irrigation Company should be preferred takers of one-third of all the water entering the upper section of the canal, at the agreed price of $1.25 per acre per annum.

Farmers Canal.—This canal has its head on the east side of Deep Creek, about 2 miles below Farmersville. It has a southwesterly course, commanding several thousand acres of land between Elk Bayou and Deep Creek channels within 6 miles of the head of the canal. The bed width of the canal for several miles below its head is 14 feet. The head gate or regulator has a width of 18 feet. The water is turned from the creek into the head of the canal by means of a brush dam. The canal was constructed in 1875 by an incorporated company, whose members are the farmers using canal water. The capital stock was

fixed at $20,000, in shares of $100 each. The head of Deep Creek, from which diversion is made for this canal, is about 8 miles, in a direct line, above Visalia, on the south side of Kaweah River. No water flows into Deep Creek from the river during its low stages. Water is generally available from the beginning of March to the end of June. During this time a superintendent is employed to apportion the water to holders of stock. When the supply of water is limited it is used in turn by the irrigators. Each stockholder is permitted to sell or lease the water to which he is entitled. The water represented by a few shares of stock held in the name of the corporation itself is also subject to sale. The estimated cost of canal construction and expenses connected therewith is about $7,000 to $8,000. The annual assessment per share of stock for canal management and maintenance has been about $1. The structures necessary for a delivery of water into branch ditches are constructed and maintained at the expense of those who receive water through each.

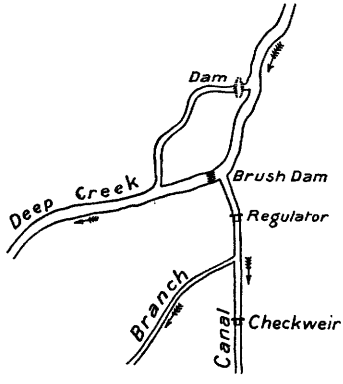
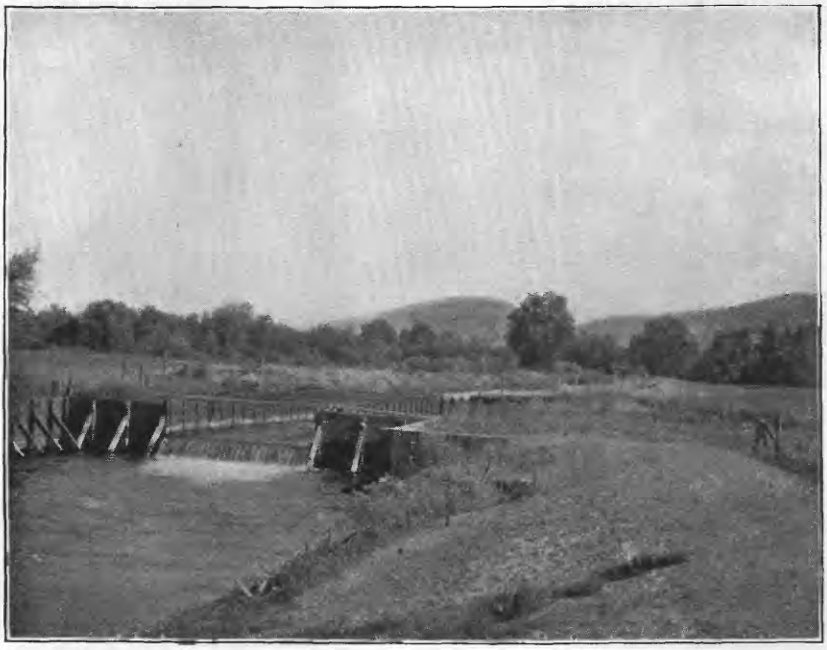


FIG. 6.—Head of Farmers Canal.

Tulare Canal.—This canal was constructed for the irrigation of lands in the vicinity of Tagus and to the northwest of Tulare. Its head is on the south side of Kaweah River, about midway between the head of Deep Creek and the head of Packwood Creek. It has a southwesterly course, is about 15 miles long, and has a bed width of 16 feet. The canal passes about 2½ miles to the south of Visalia and a mile to the south of Tagus, and terminates at the main canal of the Rocky Ford Canal Company. The canal was constructed in 1873. The farmers interested in the enterprise formed a corporation in the following year, known as the Tulare Irrigating Company, whose capital stock was fixed at $40,000, in shares of $100 each. The diversion of water from the river is accomplished by means of a dam or weir of brush, and the inflow into the canal is controlled by a regulator or head gate 16 feet wide. It has been claimed that the Ketchum Cut, one of the several ditches from St. Johns River southwesterly to Kaweah River above the head of the Tulare Canal, has been utilized by the Tulare Irrigating Company to accomplish the diversion of its water direct from St. Johns River, but it has not been possible to verify this claim, or to ascertain whether the canal company has any proprietary interest in the Ketchum Cut.

Before 1885 it was customary to apportion the flow of the canal to the stockholders in the corporation in proportion to their respective interests, but the holders of stock who were not ready to make profitable



A. FLUME OVER TULARE CANAL, THE MAIN CANAL OF TULARE IRRIGATION DISTRICT.

B. MAIN CANAL OF TULARE IRRIGATION DISTRICT.

use of their water demanded a change, and it was at that time decided to permit each stockholder to irrigate free of cost as many acres as he held shares of stock, and to charge $1 per acre for all additional areas.

Rocky Ford Ditch.—This ditch, now a part of the Tulare irrigation district canal system, takes its name from Rocky Ford on St. Johns River, because half a mile above is the head of the Ketchum Cut, which was bought by the Rocky Ford Canal and Irrigation Company, and was supposed to deliver water for the canal from St. Johns River into the Kaweah, from which it was reclaimed for the Rocky Ford Ditch at the head of Packwood Creek. The head of Packwood Creek, which had been almost obliterated by the freshets of 1861–62 and 1867–68, was reopened by this canal company in 1876. A cut 9 feet wide and three-quarters of a mile long, following the channel of Packwood Creek, received the canal water from Kaweah River. The water thus diverted was carried southwesterly in Packwood Creek, and in its south fork about 2½ miles, thence south in a ditch three-quarters of a mile to another natural channel, from which, a half mile below, it was dropped into Cameron Creek, which it followed, still in a general southwesterly direction, to a point about a mile south of Tagus. At that point the water was taken into a system of distributing ditches covering 4,000 to 5,000 acres of land to the southwest of Tagus, between Cameron and Packwood creeks. About $20,000 was expended on this work, besides $3,000 in litigation, but after a few years the company was deprived of the use of the Packwood Creek channel by an order of court, and those dependent upon this canal found themselves without water.

Cameron Creek Company.—This was an unincorporated organization of farmers which may be considered an offspring of the Rocky Ford Ditch Company. The purpose of the organization was to secure water for the Rocky Ford Canal, the head works of which were thrown out of service by orders of the court. There was ordinarily a surplus flow of water in the spring months, which reached Cameron Creek by way of the Deep Creek channels and the Kaweah and Tulare canals. The water thus reaching the Rocky Ford Canal from Cameron Creek was distributed to irrigators under the management and control of the Cameron Creek Company. The owners or lessees of stock in the Rocky Ford Canal Company were the preferred purchasers of water, but if there was sufficient available it was also sold to farmers who held no stock. The apportionment of water was by rotation in the use of the flow of distributaries. The time of use per share of stock was reduced as the supply decreased. The charge for water was at the rate of $1 per year per acre irrigated. The necessity for operations by this company ceased upon the completion of the canal system of the Tulare irrigation district.

Bacon & Crossmore Canal (Packwood Creek Canal).—When, in 1875, it became necessary to improve the flow of Packwood Creek for the supply of water to a large tract of land 6 to 9 miles west from Tulare,

a ditch was constructed from St. Johns River, then the principal channel of Kaweah River, commencing about a hundred yards above Rocky Ford, thence southwesterly about 4 miles, passing to the north and westward of a group of low hills known as the Swamp Angels, to a connection with the old channel of Kaweah River. Water thus turned into this channel was allowed to flow to a point in Visalia Creek about 1¼ miles below the head of Packwood Creek and was there diverted into a canal about 1,000 feet long leading southerly into Packwood Creek. These two ditches, or canals, together with the natural channel of Packwood Creek, are known as the Bacon & Crossmore Canal. The upper portion of this canal has a width of about 16 feet. The width of its head gate or regulator at St. Johns River is 40 feet. The cut for Visalia Creek into Packwood is about 30 feet wide. Its flow is controlled by a gate 30 feet in width. The point of discharge of the canal from St. Johns River into the Kaweah is just below Goads Dam at the head of the Tulare Canal. To enable diversion of water from Visalia Creek into the channel of Packwood Creek by way of the Bacon & Crossmore Cut, a brush dam is maintained in the creek about 60 feet below the head of the cut. The flow of Packwook Creek as thus established is first checked at a point about 4 miles west of Tagus, where distributaries are in use upon either side of the creek channel. Several other diversions are made some miles farther down the creek, and it is claimed that several thousand acres of land are irrigated by this ditch system.

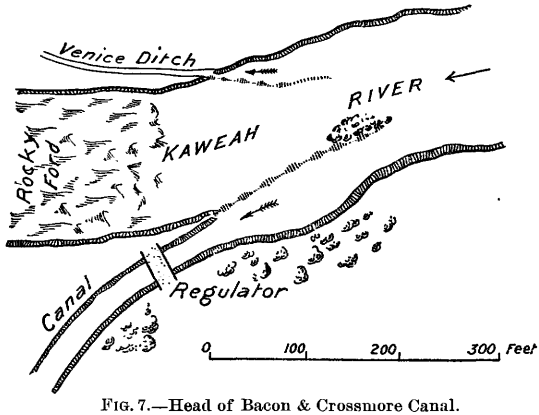


FIG. 7.—Head of Bacon & Crossmore Canal.

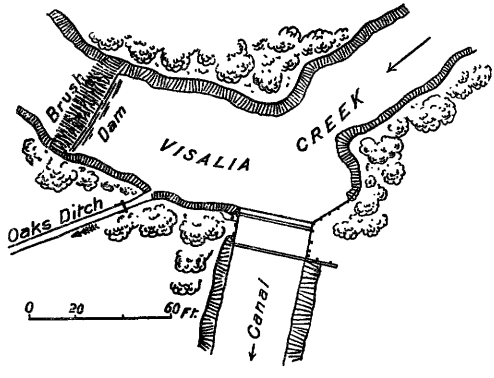


FIG. 8.—Head of Bacon & Crossmore Cut.

Judd Ditch.—This ditch was in use but a short time subsequent to the freshets of 1867–68. An organization of interested farmers known

as the Judd Ditch Company at that time endeavored to keep the head of Packwood Creek open, but owing to controversies with people living near Visalia on Visalia Creek the attempt was soon abandoned.

Cutler & Higgins Ditch (Chatten Ditch).—This is a small ditch between St. Johns River and Visalia Creek. Its head is on the north side of Kaweah River just above the point where it divides into the two channels, Visalia Creek and Packwood Creek. It has a westerly course, is about 2 miles long, 3 to 6 feet wide on the bottom, and belongs to several farmers, who take turns in using its water for the irrigation of a few hundred acres of alfalfa. The ditch has been in use since 1857.

Kaweah and Mill Creek Water Company.—This corporation was organized in 1877 with a capital stock of $10,000, in 200 shares, for the purpose of harmonizing and protecting conflicting interests by maintaining and controlling the flow of water in Mill Creek (Visalia Creek) and distributing it to the canals and ditches entitled to receive it. Its shares of stock were distributed to the owners of the various canals and ditches according to their relative interests, and the superintendent of this company is required to apportion the amount of water available to each ditch and canal in proportion to the number of shares of stock for which water is to be turned into each. A decision of the courts favoring the riparian doctrine has, however, made it difficult for ditch owners along Mill Creek below Visalia to reclaim their water, as the decision interferes with the construction of dams in the creek channel so long as they are objected to by riparian proprietors. To increase the flow of water in Visalia Creek it was found necessary to open the head of Lane Slough. This had been done before, but later freshets had again obstructed its channel near St. Johns River. The Bostwick Cut was the result of the work done by the company at that point. This is a canal leading southerly from St. Johns River, about a mile above Rocky Ford, into the main channel of Lane Slough. Lane Slough was one of the several natural channels having a southwesterly course through Visalia Swamp from near its northern margin to the old channel of Kaweah River above the head of Visalia Creek. It is claimed that this slough was so obstructed with drift and silt by the freshets of 1861–62 that for reclamation purposes it was necessary once before to open it, under direction of State authorities, with moneys from the swamp-land fund. The water company in 1878 also caused a section of the old channel of Kaweah River just below the head of Landers Slough to be reopened. The work there done resulted in the formation of the Hamilton Cut. All expenses of management incurred by the Kaweah and Mill Creek Water Company are raised by assessments levied upon the stock. The principal ditches dependent upon this organization for their water supply are the Oaks, Watson, Burch, Mill, Bahwell, and Fulgham ditches.

Oaks Ditch.—The head of the Oaks Ditch is on the south side of Visalia Creek, just above the dam maintained below the head of the Bacon & Crossmore Cut. It was in use prior to the organization of

the Kaweah and Mill Creek Water Company, from which it now receives its water. It is a small ditch, flowing several miles westerly between Visalia and Packwood creeks, and supplies water to seven or eight small farms. The entire flow of the ditch is usually divided into two irrigating heads.

Evans Ditch.—This ditch, which has also become dependent on the Kaweah and Mill Creek Water Company for its supply of water, has its head on the south side of Visalia Creek about 2 miles above Visalia. Its upper section serves as a common head for three otherwise independent ditches, the other two being the Burch and the Watson ditches. The Evans Ditch is entitled to one-half of the water entering its head, the Watson to one-third, and the Burch to one-sixth. The ditch has a southwesterly course, is about 5 miles long, and supplies water to about 500 acres just to the south of Visalia. Ownership in the ditch is represented by shares of stock, and the distribution of water is made in proportion to the number of shares of stock owned or controlled by each irrigator. Water is generally available for ten months each year, and is used in turn by the irrigators.

Evans & Turner Ditch.—This is a diversion from the west side of Packwood Creek about 2 miles below the Bacon & Crossmore Cut. It has a westerly course, is about a mile long, and drops its water into the Evans Ditch. It is claimed that this ditch was in use as early as 1858, but if so it was out of service for many years preceding its reestablishment, about 1884.

Burch Ditch.—This is another small ditch to which water is supplied under control of the Kaweah and Mill Creek Water Company. Although the ditch was in use before the organization of that company, and then received water direct from Visalia Creek, it has of late years been supplied with water through the head of the Evans Ditch. Its water, together with that for Watson Ditch, is turned out of the west side of Evans Ditch one-half mile below its head. It flows westerly three-quarters of a mile in a channel used in common with the Watson Ditch, and thence a little south of west to the southwestern portion of Visalia. It supplies a number of small farms southeast of Visalia. The head of the ditch was originally on the north side of the creek and its water was brought to the south side in a flume.

Watson Ditch.—This is another of the old irrigation ditches in whose interest the Kaweah and Mill Creek Water Company was organized. This ditch was constructed in 1854, before water was used by the mill in Visalia. Its head was on the south side of the creek about 3 miles east of Visalia, and its water was used near Visalia. It now receives water through a common head with the Evans and the Burch ditches, and is finally separated from the Burch Ditch water about a mile east of Visalia. Ownership in this ditch is represented by shares of stock, of which 100 may be issued. Between 60 and 70 are in the hands of fifteen to twenty farmers, who use its water mostly on small farms to the south and southwest of Visalia. It was originally intended that

each share of stock should represent 17.28 miner's inches of water (about one-third second-foot), and the original price per share was fixed at $5. Stockholders are assessed for all expenses of management and repairs. A superintendent is employed only when necessary, not when water is abundant, nor when there is none at all. Shares of stock not issued are not entitled to water. Holders of stock may sell or lease the water to which they are entitled. When the flow of the ditch is small it is given to the irrigators in turn for eight hours per share of stock. The annual expense of ditch management is about $5 per share.

Mill Ditch.—This is not an irrigation ditch, but it has rights to the use of water from Kaweah River, which make its enumeration among the Kaweah River ditches desirable. Its head is about one-half mile above Visalia, on the south side of Visalia Creek. It has a westerly course into the town, and drops its water back into the creek at the mill. It has been in use since 1854, at which time a brush dam was constructed at its head in Visalia Creek. This is another of the ditches in whose interest the Kaweah and Mill Creek Water Company was organized. The mill owners are stockholders in this corporation and receive the same consideration accorded to irrigators.

Bahwell and Fulgham ditches.—These are two small ditches below Visalia, which were included among those for whose benefit the Kaweah and Mill Creek Water Company was formed. They and a number of other small ditches make use of the freshet flow of Visalia Creek reaching the lower sections of Mill Creek, as well as of the water which is returned to the creek by the Mill Ditch.

Longs Canal.—This exists in name only. It was a canal or reopened slough constructed, some years after the freshets of 1861–62, southwesterly through the upper end of Visalia Swamp, from St. Johns River to Potter Slough, which discharged into Kaweah River. The first work done there was nominally for reclamation purposes—to facilitate drainage of the swamp. The canal was closed by the drift and silt brought down by the freshets of 1867–68, and was again opened at the expense of the Kaweah and Mill Creek Water Company.

Bostwick Cut.—This is a short ditch or canal, southwesterly from St. Johns River about three-quarters of a mile above Rocky Ford, to Lane Slough, which continues in a southwesterly direction to Kaweah River. It was constructed in 1863 or 1864, for drainage purposes, with money from the swamp-land funds. There seems to be no doubt, however, that it would not have been constructed had it not been desirable to increase the flow in Visalia and Packwood creeks for irrigation purposes. The cut was filled with drift and silt by subsequent freshets, and was again opened in 1876 by the same parties who the following year organized the Kaweah and Mill Creek Water Company. It is about 18 to 20 feet wide on the bottom and half a mile long. It is provided with a head gate having a width of 22 feet.

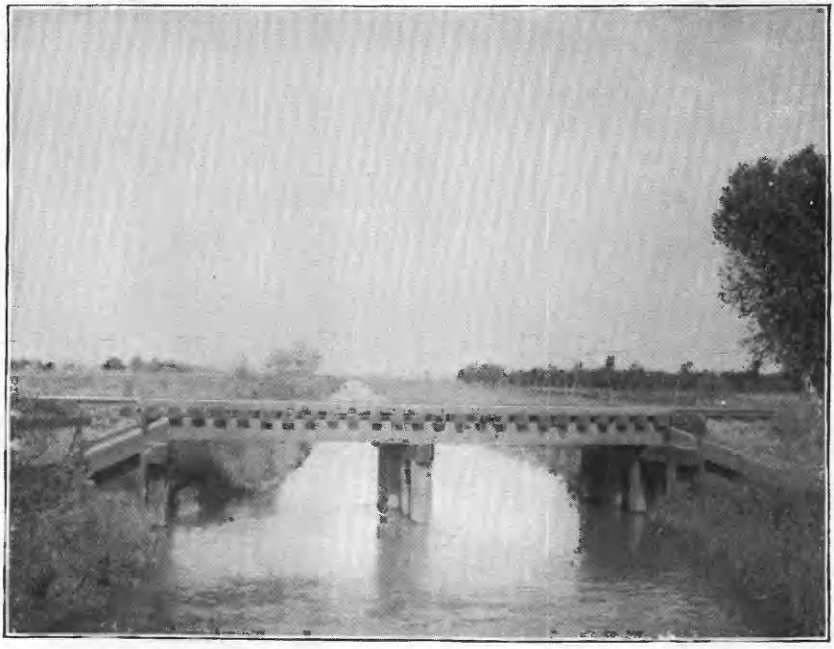
Ketchum Cut.—This is a ditch, about 8 feet wide on the bottom, having its head on the south side of St. Johns River about a half mile above Rocky Ford. Its course is thence southwesterly, skirting the eastern base of the Swamp Angels to Kaweah River, one-half mile above the head of the Tulare Canal. The ditch was constructed, probably about 1864, with money from the State swamp-land funds, ostensibly for drainage purposes. It was originally carried across Kaweah River. The right to use it for irrigation purposes has been claimed by the Rocky Ford Canal Company, and, possibly, also by the Tulare Irrigation Company. It seems to have been in use principally for the irrigation of a few small tracts of land on the north side of Kaweah River. Its flow is controlled by a head gate.

Crowley & Mehrtens Ditch.—To make the enumeration of the old irrigation works complete it is necessary to mention the Crowley & Mehrtens Ditch, which was a small ditch in use for some years on the south side of Kaweah River, westward from Wutchumna Hill. The head of the ditch was near the northwestern base of this hill. There is nothing left of it now except an old cut in rotten granite on the south bank of the river, just below where St. Johns River leaves the Kaweah.

TULARE IRRIGATION DISTRICT.

This district was organized in September, 1889, by landowners in the vicinity of Tulare. Those dependent upon the Rocky Ford Canal and Cameron Creek for their irrigation water seem to have been the prime movers in the matter of district organization. The lands dependent upon Packwood Creek (Bacon & Crossmore Canal) and upon the Kaweah Canal were mostly excluded from the district. The district has an area of 39,200 acres, including the 2,500 acres in the town site of Tulare. After much preliminary work, involving the examination and surveying of a number of feasible canal routes and reservoir sites for water storage, it was decided to purchase the water rights of the Settlers Ditch. This was done for $100,000, in district bonds, through an agent, who at the same time agreed to take an additional block of district bonds amounting to $50,000. The money realized from this bond sale was expended in constructing a canal, 60 feet wide on the bottom, from a point on the north side of St. Johns River about one-half mile below Rocky Ford in a southwesterly direction, nearly parallel with the river, about 2½ miles, to the southern base of Iron Mountain, where the canal water is carried across St. Johns River in a flume 9 feet wide and 4½ feet deep, which is supported by two bridge spans. The course of the canal from St. Johns River is a little west of south to Kaweah River, which is crossed in a similar flume. It then has a course due south to a junction with the Kaweah Canal. Before this entire canal section was completed the available $45,000 had been expended and the district was still without water. The Kaweah and Rocky Ford canals were purchased for $20,000. Contracts were let for the construction of

A. CANAL REGULATOR AT KAWEAH RIVER, TULARE IRRIGATION DISTRICT.



B. LATERAL, ONE MILE SOUTH OF TULARE.

lateral canals and for the enlargement and completion of the main canal, work being practically paid for in bonds which, it was understood, went to the contractor through a nominal purchaser. Main distributaries were carried through the district from northeast to southwest, and smaller ones, generally on land lines from north to south, completed the canal system. The aggregate length of district canals is said to exceed 150 miles, and the main canal capacity is given at 800 second-feet. It should also be said that the completed system of works involves the construction of a storage reservoir at Iron Mountain, to be supplied with water by means of a high line canal with head somewhere near Dillons Point. The reservoir site has in part been purchased. The total bond issue by the district was $500,000, all of which has been disposed of.

The area of land irrigated in the district has been rapidly extended. It is said that from 5,500 to 30,000 acres, principally in alfalfa, cereals, and orchard, have actually been irrigated, the area varying within wide limits, according to amount and duration of the water supply. The inflow of water to the canal is controlled by means of three head gates or regulators, of which the one on the north side of St. Johns River is 60 feet wide, and each of the others 25 feet. They are all of the loose flashboard type, the several openings being about 4 feet, and the drop boards being supported by inclined timbers. A canal superintendent has general charge of water distribution, and he is assisted by ditch tenders. Water is generally available during the four months April to June, inclusive. Operating expenses are met by charging for water, the charge being fixed at 50 cents to $1 per acre for the first irrigation and half price for subsequent wettings. The charge in 1897 was 50 and 25 cents. The tax to meet interest on bonds and cost of its collection has been 1.85 to 1.90 per cent.

WATER SUPPLY, SOILS, AND METHODS OF IRRIGATION.

Prior to the great changes in channel alignment effected by the freshets of 1861–62, the Kaweah River waters spread at high stages over what was known as Visalia Swamp, which commenced at Wutchumna Hill and extended southwesterly about 9 miles, with a width of 1 to 3 miles. The spreading waters were reunited in various channels, as already explained, in and below this swamp. Channel capacity was inadequate to pass flood waters, not only in the swamp, but also below it. It was inexpensive to divert water from a natural channel, or even from a convenient spot in the swamp, into ditches, and the use of water for irrigation commenced soon after the arrival of the first settlers. A number of ditches were thus in use when the regimen of the river was changed by the freshets above mentioned, and entirely new works became necessary in some cases to keep the ditches supplied with water. It was some time before the magnitude of the changes in the river alignment and their ultimate effects were fully realized, and final

relief to those dependent upon the more southerly channels for water did not come until the old channel of Kaweah River was reopened as the Fowler Cut in 1877. Meanwhile there had been a continually increasing demand upon the several river channels for water, and almost every season at the close of the river's high stage there was contention and strife concerning the apportionment of the low-water flow to the different sections of Kaweah delta. Farmers who had settled on Canoe Creek, Elbow Creek, and Cross Creek had become accustomed to regard St. Johns Channel as the principal arm of the river, and dams for its diversion southward into and across Visalia Swamp were not tolerated without protest. When the low-water flow was finally restored to the old channel numerous attempts were made to force it back into St. Johns River, and amicable adjustment seemed out of the question. To avoid the possibility of having a permanent change made at the head of St. Johns River, land was there acquired by the principal south-side ditch companies. A brush dam was then tolerated in the Kaweah River channel, which effected a division of the flow at comparatively low stages, but the exact basis of water apportionment, if any had ever been agreed upon, is not known to the writer. After many years of individual effort some of the settlers were forced into cooperative measures, as already explained, with some degree of success. Had there been greater obstacles to overcome in securing control of water in the first instance, the development of irrigation might have been less rapid, but would probably have been ultimately effected with less friction.

The ditches and canals constructed for the reclamation of Visalia Swamp, as already referred to, were hardly necessary as drain ways, because the increased capacity given the river channels by the freshets of 1861–62 had greatly improved drainage, and they have in a measure become features of the irrigation system of this river.

The surface of the country watered by the many delta channels of Kaweah River has a slope from east to west of about 6 to 7 feet to the mile. The portion of it near Visalia and thence southwest to Tulare, which is generally known as the Four Creek country, is covered, in some places very densely, with a growth of majestic oaks. The soil in the upper portion of Visalia delta is a rich alluvial loam, generally sandy, sometimes heavy. Near the river the soil is deep, resting on sands or gravel. At the base of and between the outlying hills on each side of the river the predominating soil variety is a black loam or dry bog, containing much clay, sometimes gravel, and merges into the heavy red soil of the upper or eastern border of the valley plain. Under the soil of this plain a hardpan layer several feet thick is nearly everywhere found at depths of from 1 to 5 feet. Northward from Kaweah River this valley plain extends in a broad belt along the foothill base. The soil of this belt is of the usual heavy red variety, containing some gravel. Its surface is very generally besprinkled with the low mounds usually known in the West as hog-wallows. The ground water

of this north-side district is from 8 to 30 feet below the surface, depth increasing northward from the river and eastward toward the foothills. Westward from this high east-side plain, and still northward from the river-delta lands, the soil becomes shallower and alkaline salts abound in its surface layers. In the Mill Creek country, 4 or 5 miles westward from Visalia, the hardpan of the higher plain disappears, but the alkaline salts remain present in undesirable quantity.

The soils of the entire delta are generally sandy loams, chocolate colored, deep and strong, without the sublayers of hardpan that are characteristic of the plains. Ground water in the Kaweah (or Visalia) delta is usually at 8 to 12 feet below the surface. Near Tulare and westward from that town the soil is darker than in other portions of the delta. The surface of the soil throughout the delta is smooth and entirely free from the hog-wallows of the adjacent main valley uplands.

Intermediate between the Sierra Nevada foothills and Outside Creek, and southward from Kaweah River, is another belt of country, 3 to 10 miles wide, extending far southward toward Tule River and embracing many acres of excellent, rather heavy soil.

The light average annual rainfall in the Kaweah delta, only about 9 inches, the abundance of natural water courses, and the ease with which water can be diverted into ditches and kept under control, are circumstances which have combined to stimulate ditch and canal construction in this section of the State, but not for speculative purposes. The irrigation works are almost all owned by the farmers who need the water. There are but few irrigators who do not own stock in some ditch company. All irrigation canals in the delta have been carried in the most direct lines from source of water to place of use. They are almost invariably located on lines parallel with the main drainage lines of the country.

The lands watered by Kaweah River are utilized for diversified farming. The natural growth of trees and grasses has always been luxuriant to the limit of the overflow from the delta channels, and the construction of canals and ditches has greatly increased the wet area. Large areas are in use as natural pastures, particularly to the east and north of Visalia. Wheat still remains the staple farm product, but considerable areas have been planted to alfalfa, while the orchard and vineyard and the occasional truck patch give evidence of the rapid movement toward a more intense cultivation of the soil.

The aggregate capacity of the canals, ditches, and water courses whose flow is under the control of ditch companies will probably exceed 2,000 second-feet. There are fortunately many years in which for months at a time, and just when water is most needed, the flow of the river is in excess of this amount. It is difficult to approximate the area irrigated or benefited with water from Kaweah River, because in many instances water is not actually applied to the surface of the land, but reaches the soil indirectly through seepage. There is no way of collecting even imperfect statistics, however, except at great labor in

the field, so that when it is stated that about 50,000 acres are actually irrigated and an additional 40,000 acres are more or less directly benefited with water from this river, too great reliance should not be placed upon the statement.

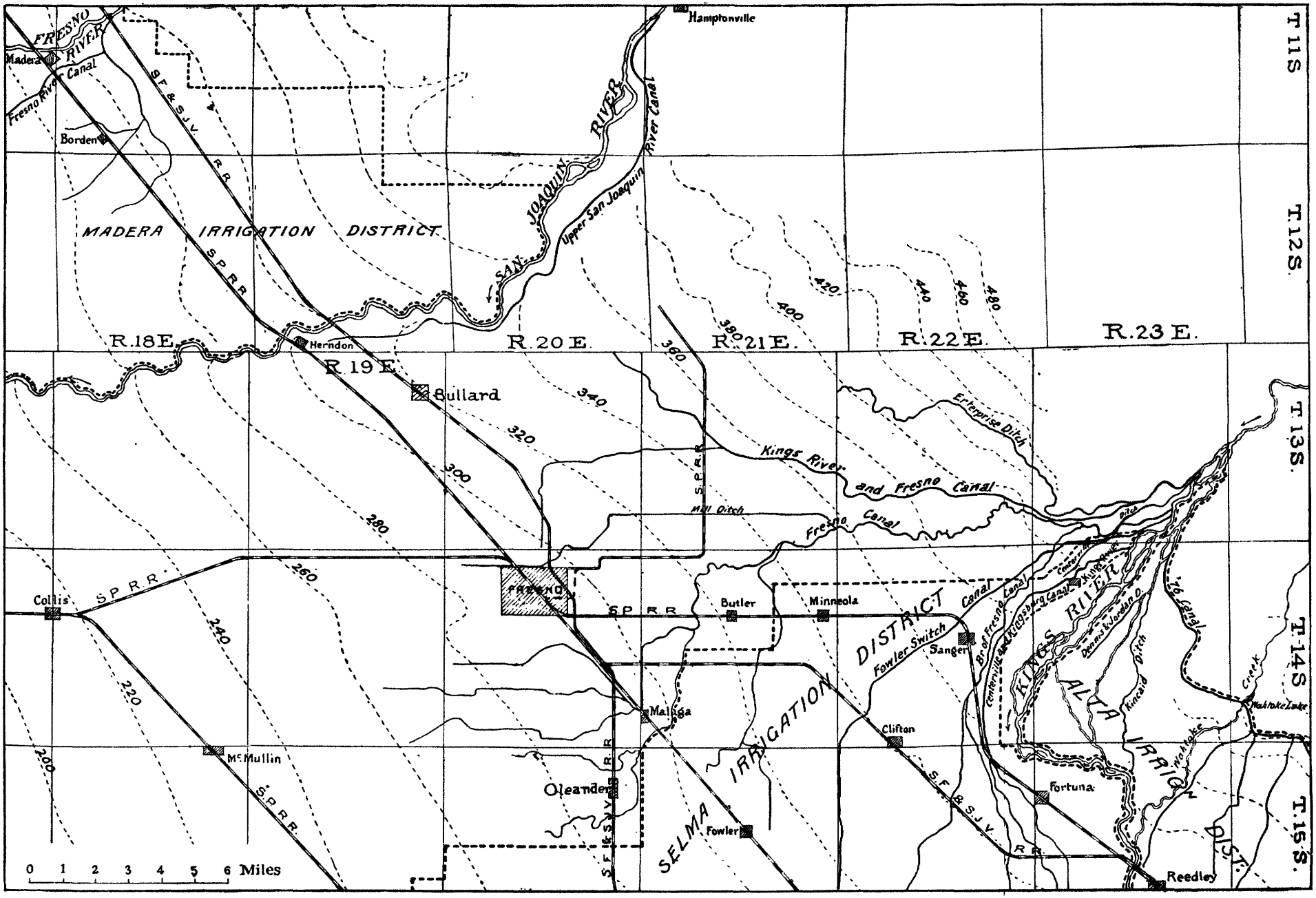
There are very few structures of any kind in the main canals, and but few are required to regulate the grade. Erosion is not undesirable, as the canals are generally long and water is taken from each at comparatively few points; hence the increased cost of providing weirs at points where water is to be diverted is more than offset by the increased capacity resulting from erosion.

All structures for the diversion of water, except dams at the heads of canals, are timber structures; none are of brick or stone. Dams across natural water courses are generally constructed of brush or gravel, and require some annual repairs. No extended observations have been made in this section to determine the loss of water from canals in transit to the lands irrigated; and it is to be remembered in this connection that not all water sinking into the ground from natural or artificial water courses is considered lost, because it is this very loss which fixes the elevation of the plane of subsurface or ground water, and the position of this ground-water plane often has a direct bearing on soil productiveness. Throughout a large part of the Visalia district ground water is within reach of the roots of trees, alfalfa, and other plants, being kept there by the water which sinks from natural and artificial channels in transit to lands irrigated and by the water which sinks into the ground on irrigated lands.

The method of applying water to the lands to be irrigated is generally by flooding, in small compartments or checks. These are adapted to the irregularities of the surface, being made rectangular when the surface is sufficiently level and smooth to permit of this arrangement. Crops cultivated in rows, such as beans, potatoes, and corn, also orchards and vineyards, are generally irrigated by running water in small ditches or furrows between rows. In the case of these products the soil is plowed or cultivated as soon after irrigation as practicable.

Here, as elsewhere in San Joaquin Valley, alfalfa is irrigated after each cutting (about every five or six weeks) so long as water is available. Orchards and vineyards receive water frequently during the spring months, and also in the summer if water holds out. Corn is irrigated once or twice, according to the condition of the ground at the time of planting. Grain is rarely irrigated; vegetables, very copiously and frequently.

No attention has as yet been paid to soil drainage. The many comparatively deep natural channels in the delta have kept ground water so far below the surface that the area in need of drainage is relatively small. As irrigation systems are further expanded throughout the delta it may be that subsurface soils will receive water more rapidly than it can pass off from them, and in such case improved drainage systems will become a necessity.



MAP OF EAST SIDE OF SAN JOAQUIN VALLEY, FROM KINGS RIVER TO FRESNO RIVER.

KINGS RIVER.

HYDROGRAPHY.

The drainage basin of Kings River above the eastern margin of San Joaquin Valley has an area of 1,742 square miles. The river's watershed extends to the main summit of the Sierra Nevada. Less than half of it is to be classed as low mountainous, all the rest being high mountainous country. The snowfall of the winter melts but slowly during the spring months, consequently the river reaches its ordinary high period late in spring or early in summer. The river is generally low from September to the end of January; it is at a medium stage during February, March, and August, and is high from the beginning of April to the close of July. The month of least flow during the six years 1878–1884 was November,[1] the average mean flow having been 313 second-feet, and the least flow for a single month 220 second-feet. The extreme low-water flow of the river has, no doubt, been somewhat below the least monthly mean. At medium stages the river carries 1,000 to 2,000 second-feet of water; during its high stages its monthly mean ranges from 4,000 to over 8,000 second-feet. The maximum flow of the river during the six years above named occurred in June, 1884, the extreme limit having been about 30,000 second-feet.

A gaging station was established on this river September 3, 1895, by the United States Geological Survey. It is located about 15 miles east of Sanger, 3 miles below Jarrett Ranch, and southwest of a hill well named Red Mountain. The station is equipped with a steel cable, car, and tagged wire.[2]

The results of these measurements show for the year 1896 a maximum discharge, which occurred in May, of 22,100 second-feet, and a minimum discharge, occurring in October, of 310 second-feet. The average discharge for that year was 2,582 second-feet. Similar figures for 1897 are as follows: Maximum discharge, 22,730 second-feet, occurring in May; minimum discharge, 250 second-feet, in September, with an average discharge for the year of 2,933 second-feet.

The Southern Pacific Railway Company has maintained gage-height readings at their bridge on the lower Kings River 1 mile from Kingsburg since 1879. The Geological Survey has taken a number of discharge measurements at this point, but owing to the shifting character of the stream it has been found impossible to construct rating tables for same.[3]

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[1] See Physical Data and Statistics, Wm. Ham. Hall, State Engineer of California, pp. 452, 476.

[2] Bull. U. S. Geol. Survey No. 140, 1896, p. 286; Eighteenth Ann. Rept., Part IV, 1897, p. 390; Water-Supply and Irrigation Paper No. 11, 1897, p. 92; Water-Supply and Irrigation Paper No. 16, 1898, p. 191.

[3] Twelfth Ann. Rept. U. S. Geol. Survey, Part II, 1891, p. 320, Pl. LXXXII; Bulletin No. 131, 1895, p. 80, Bulletin No. 140, 1896, p. 284; Eighteenth Ann. Rept., Part IV, 1897, p. 393; Water-Supply and Irrigation Paper No. 11, 1897, p. 920, Water-Supply and Irrigation Paper No. 16, 1898, p. 192.

Estimated monthly discharge of Kings River at Red Mountain, California.

[Drainage area, 1,742 square miles.]

Month.	Discharge (in second-feet).			Total (in acre-feet).	Run-off.	
	Maximum.	Minimum.	Mean.		Depth (in inches).	Second-feet per square mile.
1896.						
January	11,020	390	1,474	90,682	0.98	0.85
February	1,140	728	825	47,477	.51	.47
March	7,020	820	1,710	105,181	1.13	.98
April	4,600	820	1,938	115,349	1.24	1.11
May	22,100	1,140	5,918	363,890	3.90	3.40
June	18,920	5,160	12,737	757,922	8.15	7.31
July	6,680	1,212	3,742	230,110	2.48	2.15
August	1,212	590	795	48,938	.52	.45
September	590	390	491	29,234	.31	.28
October	510	310	350	21,520	.23	.20
November	1,076	390	538	32,043	.35	.31
December	550	470	466	28,659	.31	.27
The year	22,100	310	2,582	1,871,005	20.11	1.48
1897.						
January	624	360	437	26,870	0.29	0.25
February	6,344	1,100	1,631	90,581	.96	.92
March	4,408	1,240	1,884	115,843	1.22	1.06
April	9,380	1,930	5,318	316,442	3.33	2.99
May	22,732	6,344	14,470	889,731	9.40	8.15
June	10,580	2,520	6,145	365,652	3.87	3.45
July	4,040	1,036	2,177	133,859	1.41	1.22
August	1,100	440	739	45,440	.47	.42
September	480	250	329	19,577	.20	.18
October	572	270	394	24,226	.25	.22
November	2,520	360	692	41,177	.44	.39
December	8,348	572	985	60,566	.63	.55
The year	22,732	250	2,933	2,129,964	22.47	1.65

Kings River enters San Joaquin Valley from the east about 20 miles east of Fresno. Before reaching Centerville Bottoms the river flows in a broad bed of cobbles from which the hills rise quite abruptly toward the north and toward the south. The hills retreat from the river somewhat at the upper end of Centerville Bottoms, forming a wedge-shaped valley that opens into the main San Joaquin Valley about 4 miles farther west, at Centerville. The northern portion of this Kings River spur of San Joaquin Valley may be regarded as a second or upper

bottom; the southern portion, lying at a lower level, is the upper division of Centerville Bottoms. These bottom lands, which have a length of about 9 miles, are depressed below the general surface of the San Joaquin Valley plain, being about 10 feet lower than the same at their upper limit and about 60 feet below the same at the Narrows, where the main valley plain drops in abrupt bluffs to the banks of the river as it emerges from these bottoms at their southeastern extremity. From this point southward for about 12 miles the surface of the main valley has greater fall than the river, gradually approaching its level, and near Kingsburg the bluffs upon either side of the river entirely disappear. It is here that the Kings River delta begins.

Through Centerville Bottoms the river flows in numerous channels,

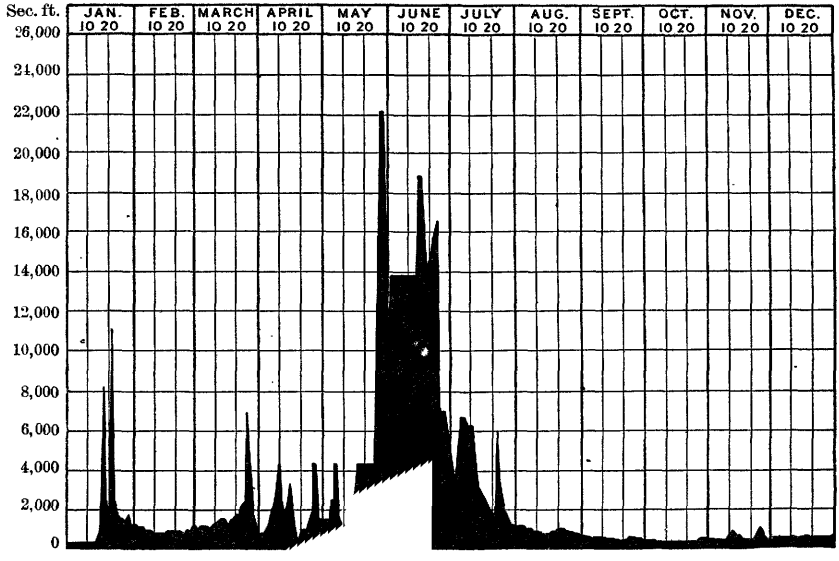


FIG. 9.—Discharge of Kings River at Red Mountain, California, 1896.

the main stream having a length of about 14 miles and a total fall in that distance of about 120 feet. The beds of these streams are for the most part formed of deposits of cobbles, gravel, and sand. Channel banks are rarely high or well defined. Below the Narrows the fall of the river is only 2 feet to the mile, which is maintained with reasonable uniformity to the outfall of the main channel into Tulare Lake.

From the head of Cole Slough, 2 miles south from Kingsburg, the main channel of Kings River has a southwesterly course for a distance of 35 miles to the trough of San Joaquin Valley; its course thence is south about 11 miles to Tulare Lake.

Cole Slough, the uppermost arm of the river thrown off toward the north, has a course nearly parallel with the main channel of the river for some miles, then flows northwesterly and, together with other delta

channels, delivers its water into Fresno Swamp, through which it flows into San Joaquin River. Kings River has but a single tributary below the point where it enters San Joaquin Valley. This is Wahtoke Creek, a small foothill stream which reaches the river from the east at the Narrows. Owing to scant rainfall, there is but little run-off from the lands of the plains, and this is, as a rule, away from the main stream and not toward it.

Canals and ditches from this river are to be divided into two principal groups, of which one embraces those which leave the river at the upper end of Centerville Bottoms and the other those of the delta. For

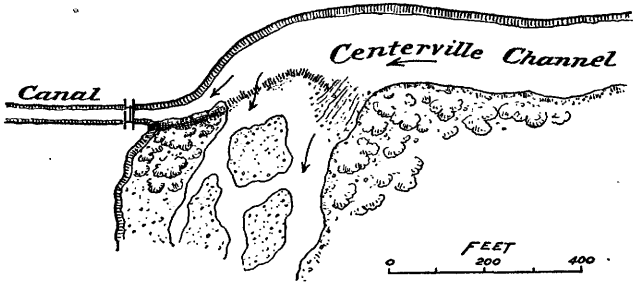


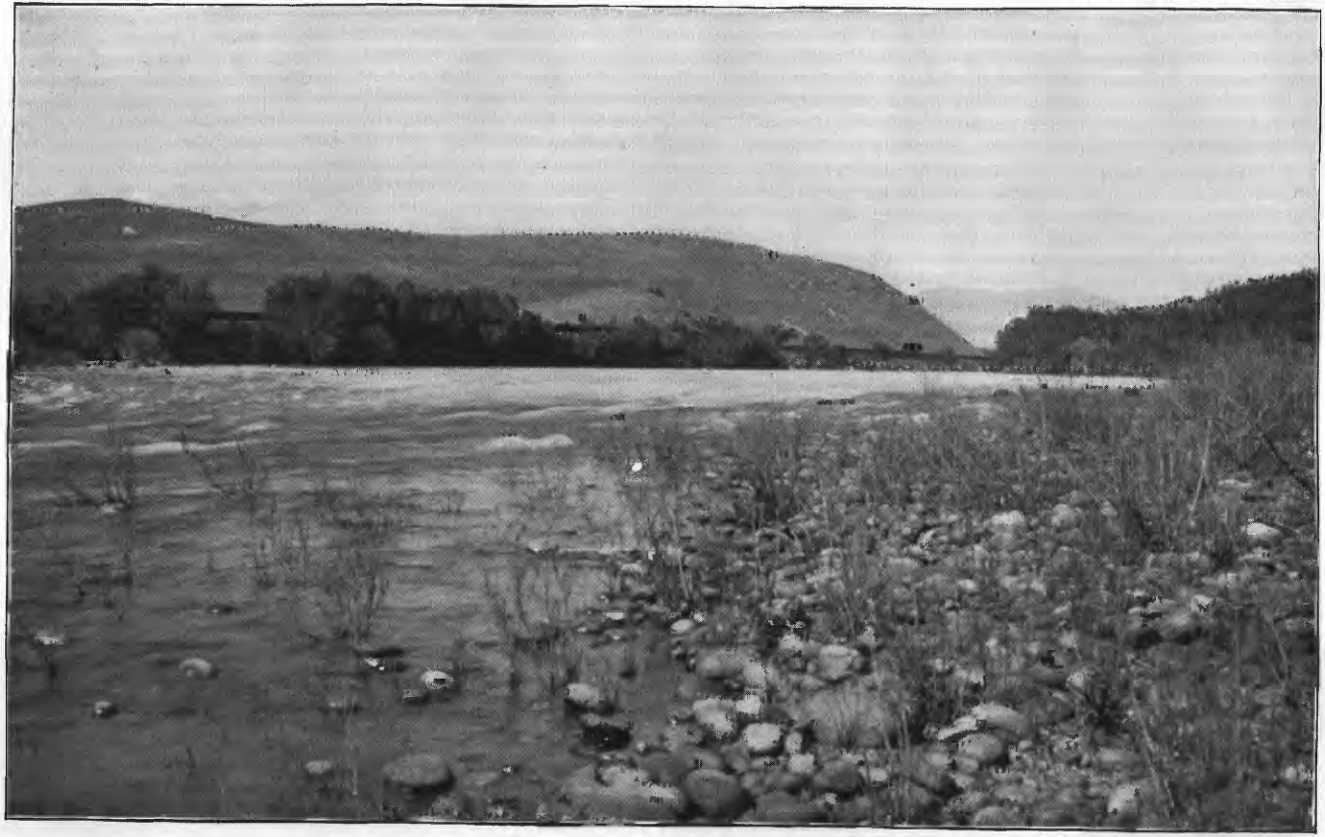
FIG. 10.—Head of Kings River & Fresno Canal.

convenience these groups may be again subdivided according to location of tracts irrigated, and will be treated under appropriate subheadings.

CANALS AND DITCHES.

Kings River & Fresno Canal.—This is the upper north-side canal from Kings River. Its head is 5½ miles above Centerville. The canal receives water through the head of a natural channel or arm of the river which has a position at the base of the low north-side slope that rises from the border of the river bottoms. Within a mile of its head the canal is carried in a cut northwestward out upon the surface of the second bottom, and a half mile beyond its water is dropped into a small natural channel known as Burns Slough. After flowing in this southwesterly for a mile, the water is carried westward in a cut less than one-half mile in length to Kip Slough, from which it is again reclaimed 1½ miles below. The course of the canal, now in an artificial channel, is thence westerly across Fanshaw, Red Bank, and Frolic creeks into the Dry Creek district northeastward from Fresno.

The cut from Centerville Channel of Kings River to Burns Slough has a bed width of about 30 feet. Below that point the canal width is quite irregular, ranging from about 15 to 24 feet. The flumes over creeks are 16 feet wide, with sides 3 feet high. The longest one is that across Red Bank Creek, which has a length of 96 feet. The fall of the main canal is far in excess of what might be considered necessary, its course being almost in the direction of greatest fall of the ground's



KINGS RIVER AT UPPER END OF CENTERVILLE BOTTOMS, LOOKING UPSTREAM.

surface. This results in no injury to bank lands in the upper section of the canal, where a firm substratum sets a limit to erosion, but has made the use of frequent check weirs or drops necessary in its lower sections, particularly at points where water is delivered into branches.

The construction of this canal was commenced in 1872. At that time a regulator was placed in its head at Centerville Channel of Kings River. The following year the cut to Burns Slough was made and the canal was extended westward upon the valley plain. The canal was intended primarily to supply water to landowners who had become stockholders in it, but the sale of water was not restricted to the stockholders. The company's capital stock was fixed at $100,000, in 1,000 shares. Water is sold at rates annually determined, not exceeding $50 per second-foot for stockholders and $75 per second-foot for other irrigators. The sale of water covers all expenses of management and repairs. The first cost of the canal was about $50,000.

As a result of adverse claims to the use of Centerville Channel the canal company was in conflict with the Fresno Canal and Irrigation Company until, in 1875, it was agreed that the water in the regulator of the Kings River & Fresno Canal should be maintained at 1 foot in depth during the low-water period of the river until there was less than 1 foot in depth in the regulator of the other canal, and that thereafter equal depths should be maintained in both regulators.

The distribution of water to ditches of consumers is in charge of a canal superintendent. No system of measurement is in use. Water is delivered to each ditch on the judgment of the superintendent in proportion to the number of second-feet to which each ditch is entitled. No attempt is made to effect actual delivery of the amount of water bargained for. Any number of irrigators may unite and have the aggregate amount to which they are entitled delivered through one gate.

The Enterprise Ditch was the result of such combination of interests. It was constructed about 1885. It received water for a time from the main canal at the point where its waters are dropped into Kip Slough, and takes a westerly course along the base of the north-side foothills. Rounding the point of these about 2½ miles north of Centerville, its course is northerly for 4 miles, thence westerly about 8 miles, generally 3 to 4 miles north of the main canal. This ditch was, a few years after construction, sold to the Fresno Canal and Irrigation Company in consideration of 40 water rights that were issued to its owners.

Fresno Canal.—The head of Fresno Canal is about 1½ miles below the head of the Kings River & Fresno Canal; also on the north side of Centerville Channel. A short artificial channel having a westerly course drops the water of the canal into Chambers Slough, which is a depression at the base of the low bluff at the northern margin of the bottoms. This has been converted into a section of the canal by the construction of a levee along its south bank to a point a little over a

mile from the head of the canal. There the canal enters Long Cut, which extends westward in a direct line a little over one-half mile and carries the canal water into another natural channel, Burns Slough, which connects with Kip Slough a short distance below. Long or Big Cut pierces the rimland which borders Centerville Bottoms on the north. It has a greatest depth of about 10 feet and a width of 65 feet. Kip Slough is utilized for the canal for a little over a half mile. It is thence carried westerly nearly 2 miles in an irregular natural depression, which was converted into a canal by constructing embankments along the south bank of the proposed water way. From this depression an artificial channel only about 500 feet long drops the canal water

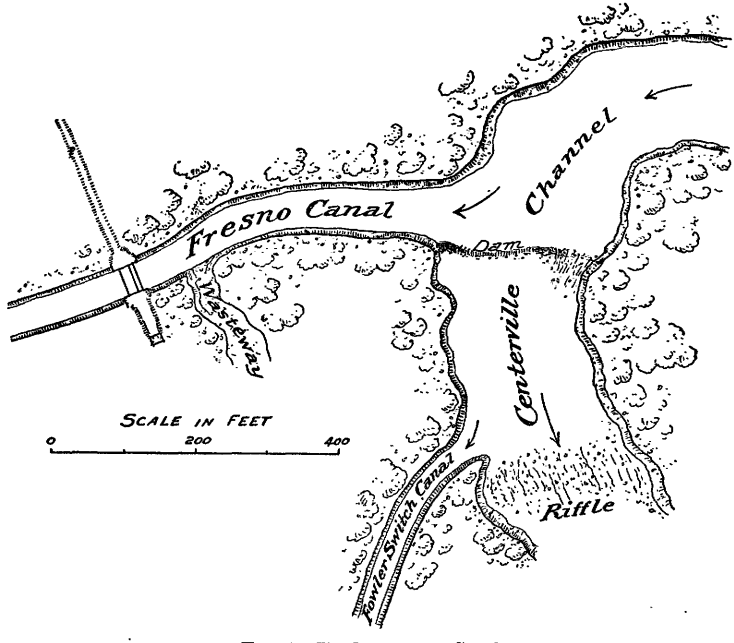


FIG. 11.—Head of Fresno Canal.

into Mud Creek, down which it flows in a southwesterly direction 3 to 4 miles to Fancher (Fanshaw) Creek, which then becomes the main channel of the creek to a point about 3 miles east of Fresno.

Where Fresno Canal leaves Kip or Lone Tree Slough the slough is closed by means of an embankment, in which a gate has been placed, through which water is delivered into the lower section of the slough, which is also known as the Kingsburg branch of Fresno Canal. This branch delivers water to the Highland, the Garfield (which also receives water from other sources), the McCall, and the Selma ditches.

The main canal may be regarded as terminating in the old sink of Fancher Creek, about 3 miles east of Fresno. From that point it sends southward its Washington Colony branch and southwestward

A. REGULATOR ON KINGS RIVER AND FRESNO CANAL.

B. FOWLER SWITCH CANAL NEAR SANGER, LOOKING UPSTREAM.

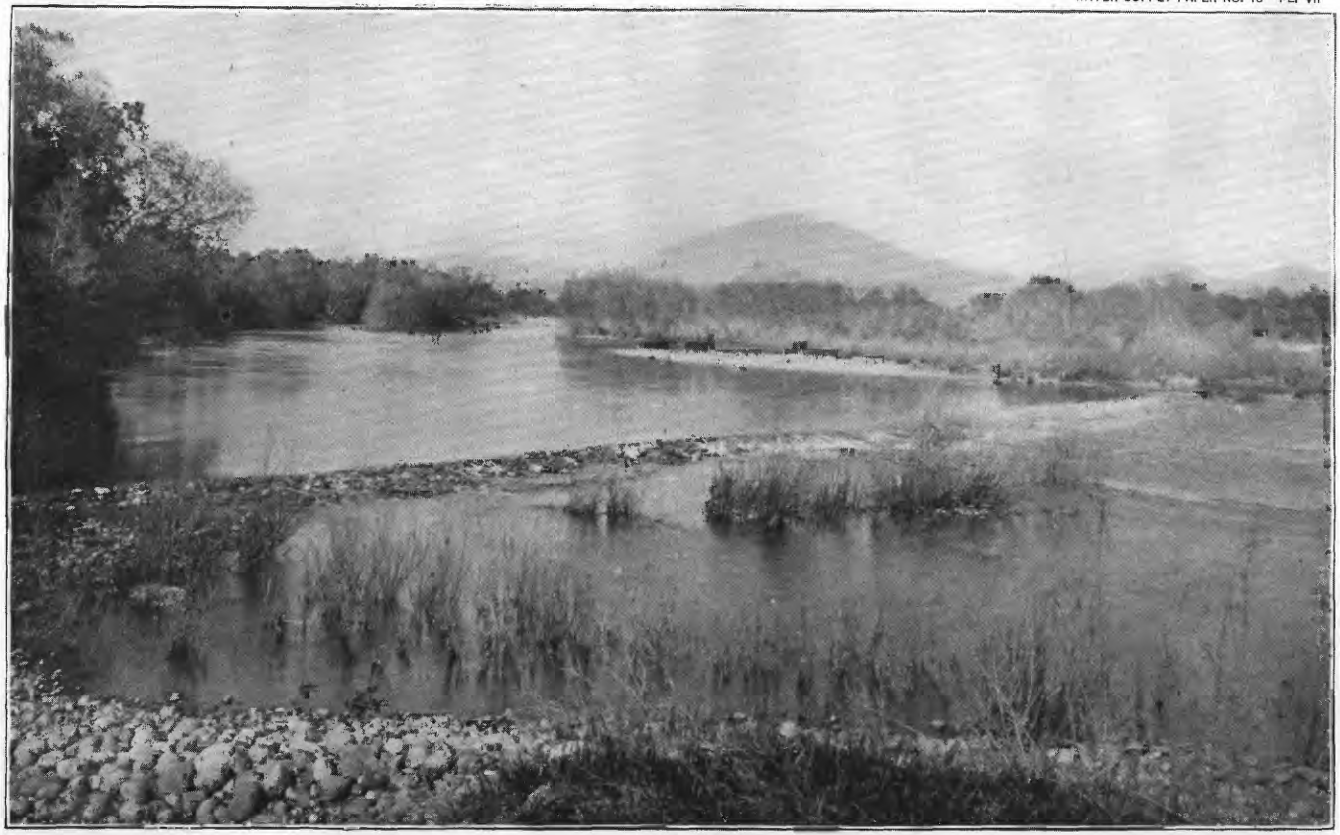
the Central Colony branch, from which there is another branch to Fresno Colony. At the Hobler Dam, about 8 miles east of Fresno, a branch is taken out toward the south and reaches Fowler and the colonies in its vicinity, and another branch is carried westward from the north side of the main canal to portions of the Easterby ranches. Two miles above the Hobler Dam the principal north-side diversion is made. This is known as the Mill Ditch, which for many years furnished power to a flour mill in Fresno, and delivered the water, after use for power, to the colonies southwestward from Fresno. The ditch through Fresno and this north-side branch has become the feeder of the Bank Land Canal, which conveys water northwesterly to a large tract of land northwest of Fresno. Another north-side branch of the Fresno Canal is the Enterprise Ditch, which has already been referred to in describing the Kings River & Fresno Canal (p. 43). This ditch was purchased for 40 water rights.

No attempt will here be made to describe or even to enumerate the many small branches of this canal, particularly as some of these are owned independently and often receive water from other sources as well as from the Fresno Canal. It may be sufficient to state that the aggregate area covered by water rights (each nominally 1 second-foot to 160 acres) exceeds 160,000 acres.

The history of this canal construction is not without interest. Operations on it commenced in 1870 with the posting of a notice of a claim to water "to be taken from Kings River at the upper end of Sweem's Ditch, 20 feet on the bottom, 30 feet on the top, 4 feet deep." This claim was made by Mr. M. J. Church, who a month later acquired a two-thirds interest in the Sweem Ditch. The Sweem Ditch was a small ditch, the construction of which seems to have been commenced in 1870, which was intended to increase the flow of what was then known as the Centerville Ditch. Its upper section was enlarged and became the head section of Fresno Canal. In 1872 a regulator or head gate was constructed in the head of the Fresno Canal, and in the spring of 1874 a small cut on the line of the present Long Cut was completed from the Centerville Ditch to the lower sections of the Fresno Canal, on which work had meanwhile been pushed to the limit of the means of the projector of the work, Mr. M. J. Church. This small connecting ditch is reported to have had a bed width of only 5 feet on a grade of 5 feet to the mile. As the alignment of a part of the older Centerville Ditch was in time to become the alignment of a section of the Fresno Canal, and because it seemed desirable to secure the water rights acquired by the Centerville people, arrangements were made to obtain control of the corporation known as the Centerville Canal and Irrigation Company, and a transfer of their ditch property was made to the Fresno Canal and Irrigation Company. This was in 1874. As soon, however, as the settlers near Centerville realized what their officers were doing the demands for just treatment at the hands of the Fresno Canal and Irrigation Com-

pany were made so emphatic that those who were entitled to water in the older ditch were granted water rights in the new canal for their lands in perpetuity, without limit as to quantity and free from expense assessments. About 1,500 to 2,000 acres of land are thus covered. In 1875 it became necessary to enlarge the cut westward from the Centerville Ditch, and to this end labor was bargained for with farmers who wanted water delivered to their lands through Lone Tree Creek. Thirty-five water rights were issued to farmers, who completed it in June, 1875. Meanwhile other parties besides Mr. Church had become financially interested in the enterprise, notably Mr. P. Y. Easterby, and later Mr. W. S. Chapman. It was not profitable, however, at the outset, and, as the indirect result of overspeculation in wheat by outside parties and failure to increase loans, a transfer of the property in 1876 to the Bank of Nevada became necessary. The management of the property by this bank was expensive and gave no promise of success. It was not long, therefore, before the original projector of the enterprise was sent for and the property was sold to him, on the execution by him of a long-term note, for $28,000. By this time a number of large holdings of land had been subdivided and sold in small tracts and had become dependent upon the canal for water. Notable among these early colonies are Central Colony, 2,640 acres, and Temperance, Church, and Nevada colonies, each 640 acres. These colonies, together with the Pioneer vineyard on the F. T. Eisen tract, soon demonstrated the great productiveness of the Fresno sand plains, and the development of that region was rapid during the next decade. The sale of water rights had progressed steadily, so that in 1884 about 400 had been issued or bargained for, and their price had increased from $200 to $800 each. Later their price was fixed at $1,600 by the canal management.

A water right, as issued by the company, is the right to use one-thousandth part of the flow of the canal, not in excess of 1 second-foot, on a specified tract of 160 acres. The canal company reserves the privilege of issuing 1,000 water rights without enlarging the main canal. Each purchaser of a water right agrees not to use the water, or permit it to be used, on any other land than that for which the right is purchased, nor to permit the water to run off upon contiguous land or in any other way to run to useless waste, and he agrees to return surplus waters back into the main canal or a branch thereof. Each water right remains subject to an annual expense assessment, which ranges from $80 to $100. Water is delivered without any attempt at measurement to each irrigator at any point on the company's ditch system that he may select. No transfer of a water right can be made except with the land which it covers. Each purchaser of a water right grants to the canal company the right of way for ditch and canal purposes through any lands lying in the same township as the tract for which water is bought, and concedes to the company the right to use his private ditch provided the company does not use it so as to



COBBLESTONE AND BRUSH DAM OF FRESNO CANAL, KINGS RIVER.

interfere with the delivery of his water. The purchaser of a water right further obligates himself to pay to the canal company annually an agreed sum (this has usually been $100), and in default of payment for thirty days to forfeit his water right. The water-right agreement further sets forth that the company shall not be responsible for deficiency in water supply caused by drought, insufficiency of water in the river, hostile diversion or obstruction, forcible measures or temporary damage by floods or other accidents, but that it shall use and employ all due diligence at all times in restoring and protecting the flow of water in its canals.

The structures on the canal do not deserve extended notice. They are all made of timber. The original regulator has been replaced by a second one, constructed about 1884, shown in Pl. VIII, *A* and *B*. It consists of a substantial framework of heavy timbers, spaces between vertical posts being closed by vertical sliding gates. From the head gate an embankment of cobblestones, gravel, and sand extends northward across Centerville Bottoms to a connection with high land, and prevents destruction of the upper section of the canal during freshets. The diversion of water into the head of the canal is effected by means of a brush-and-cobblestone dam, as shown in Pl. VII, the maintenance of which in the past has not been expensive. Along the line of the canal, wherever necessary to prevent excessive erosion, or where required to turn water into a branch ditch, light timber weirs are in use. Most of these consist of two side or bulkhead walls and a floor, usually placed a little below the grade of the canal, and a line of vertical posts supported by braces from below. Spaces between posts are closed to the desired height either by fixed horizontal boarding or by movable drop timbers or boards.

The impression which the whole work gives is that of haphazard management, the result of which is not, however, entirely unsatisfactory.

The control of the canal long ago passed out of the hands of Mr. Church, who effected a profitable sale of the property. It is now managed by parties who also own controlling interests in the Kings River and Fresno Canal Company and who have acquired the property known as Rancho Laguna de Tache. It remains to be added that these parties as owners of the rancho, which is located on lower Kings River, have entered into a contract with the Sunset irrigation district under the terms of which, in consideration of a reservoir site, a right of way for a canal, and a waiver of riparian rights, the irrigation district has paid to the owners of the rancho $250,000 in bonds and has agreed to make no demand for water until 3,500 second-feet of water are available for the Fresno Canal and the canal of the rancho.

Centerville Ditch.—This is at present a branch of the Fresno Canal. It was constructed in 1868 and 1869 by settlers near Centerville (now Kings River). They organized a company known as the Centerville

Canal and Irrigation Company, which was incorporated in August, 1868. This company seems to have been the successor in interest to all rights acquired by some of the settlers whose first steps to secure water were taken in 1865. The canal was constructed southwesterly from a point near where the head of the Kings River & Fresno Canal now is about 2½ miles to Burns Slough; thence this slough was utilized for about a mile to a point a short distance below the Long Cut, and thence the ditch was extended southwesterly about 3 miles farther to lands at and west of Centerville. The canal property was transferred to the Fresno Canal and Irrigation Company in 1874, by those who had secured control of the stock, and the opposing minority interests were finally placated by the issuance of perpetual, unassessable water rights in the newer canal to stockholders who owned lands near Centerville.

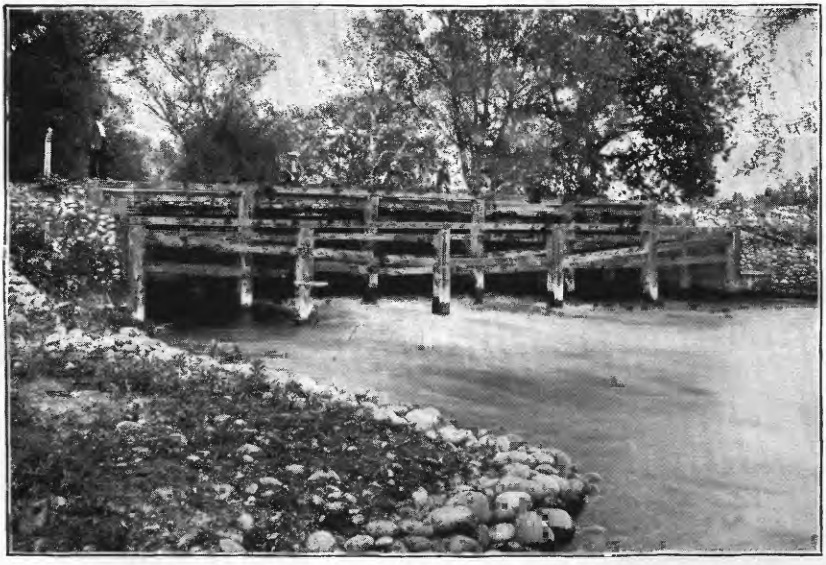
Sweem Ditch.—This ditch was never completed. Its construction was commenced in 1870 from a point near the present head of the Fresno Canal, practically on the alignment subsequently adopted for that canal. Its purpose was to increase the delivery of water into Burns Slough for the Centerville Ditch. It was sold before completion to the parties who were at work on the Fresno Canal project, and within a few years it was transformed into a large canal, as already explained.

Fowler Switch Canal.—The head of the Fowler Switch Canal is in Centerville Bottoms, about 100 yards below the head of the Fresno Canal. Its course is southwesterly for 1½ miles in Centerville Bottoms, thence westerly for 2 miles across the second bottoms to near the channel of Lone Tree Creek, thence southwesterly 10 miles and southerly 5 miles to a point about midway between Fowler and Selma, thence southwesterly 5 miles, thence northwesterly into the district southward from the Washington Colony. The canal is said to have been built to carry 1,500 second-feet. Its bed width is about 45 feet, its depth variable. The gradient is very irregular, being that of the natural surface of the ground in its upper sections, where a quite firm hardpan formation is relied upon to check excessive erosion of the canal bed. Near the lower end of the canal it was given a fall of 1.92 feet to the mile.

It was proposed to use no check weirs to reduce the fall, which for short distances was as great as 12 feet to the mile, and to put lateral ditches at a lower elevation than the main canal, so as to reduce the necessary structures to a minimum. It was soon found, however, that weirs would be necessary at some points to check erosion and at most points where water was to be diverted.

Among the branches of the Fowler Switch Canal may be mentioned the Cleveland Ditch, about 5 miles long, which delivers water to lands midway between Malaga and Fowler; the Western Canal, which supplies water to lands adjacent to and immediately south of the Sierra

A. REGULATOR OF FRESNO CANAL ON KINGS RIVER, AS SEEN FROM ABOVE.



B. REGULATOR OF FRESNO CANAL ON KINGS RIVER, AS SEEN FROM BELOW.

Park and Washington Colony; the Grant Ditch, which has a westerly course for 4 or 5 miles from near the end of the main canal; and the Elkhorn Canal, which has a southwesterly course and delivers water to the western portion of the Wildflower region. The entire canal system gave promise of being one of considerable importance to the prosperity of the district it commanded; but hopes have not been fully realized. The canal has not been permitted to take river water without protest, and unfavorable court decisions have thrown some doubt upon the reliability of this canal as a source of supply.

This canal was constructed in 1883. Farmers in the vicinity of Fowler who wanted water for their own lands formed a corporation,

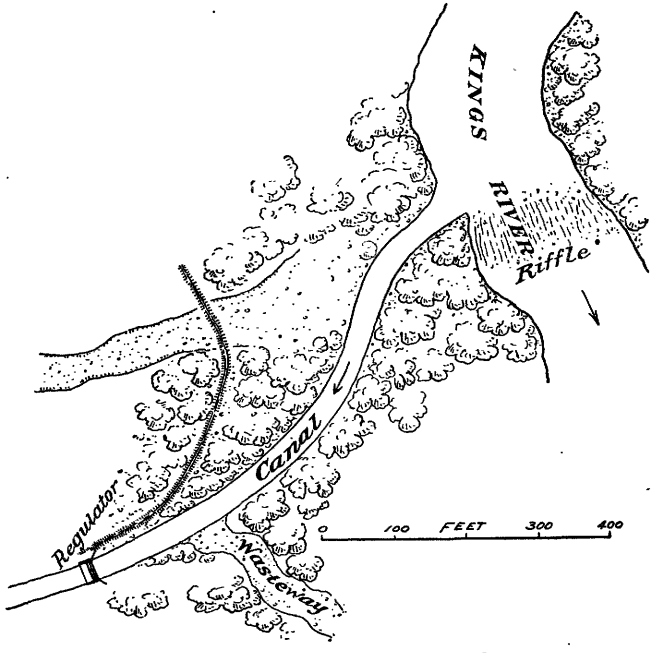


FIG. 12.—Head of Fowler Switch Canal.

the capital stock of which was fixed at $450,000, divided into 1,500 shares, of which 300 were subscribed for. It was agreed that in payment for each share labor and material might be contributed to the extent of $200, the remainder to be paid in coin. It was soon found, however, that the first issue of shares would not cover the cost of canal construction, and it was followed by a second issue of 300 shares, which were taken by the same persons who held the first issue. About $110,000 were expended on canal construction in the first two years.

The water in the canal is apportioned to the stockholders, who may ask for the delivery of their water at any point on the main canal. This has led to the construction of a number of branch ditches under

independent management, which receive their water from the main canal. One of the principal branches of this sort is the Elkhorn Ditch. It is owned by a company in which thirty shares are represented. Some of the stockholders in the Elkhorn Ditch Company are not holders of Fowler Switch stock. In such cases they are required to buy their water from some stockholder. The use of the Elkhorn Ditch is restricted to its owners, no water being sold.

The water represented by the stock of the Fowler Switch Canal Company is at the disposal of the individual stockholders to the extent that it may be leased or sold and its delivery may be called for through any branch ditch. No system of water measurement or special design of gate has been prescribed. All gates in distributing ditches are constructed by the consumers. The delivery of water through these gates is in charge of a canal superintendent. The canal company itself does not sell any water. All expenses are met by assessing the stockholders.

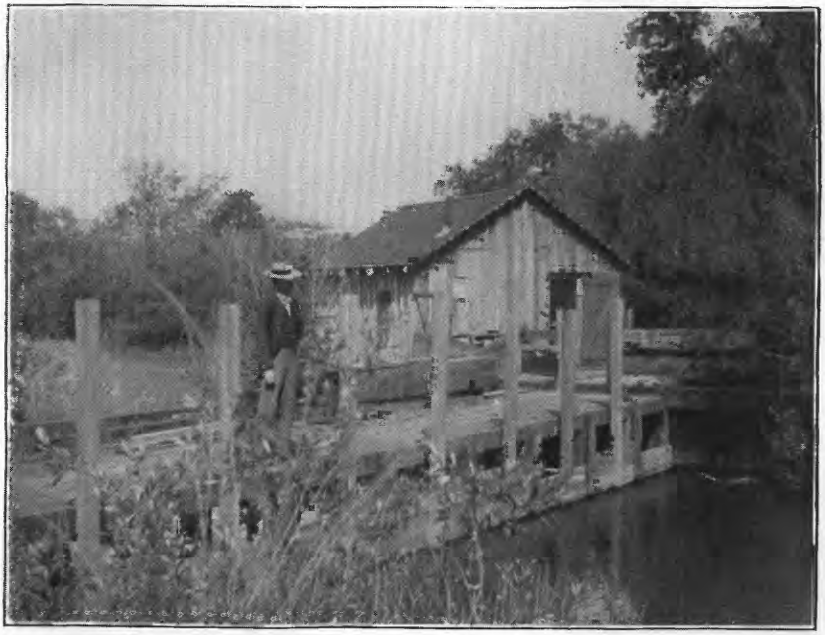
The structures on the canal do not merit extended notice. They are all of very light construction. The check weirs or drops are V-shaped, upper and lower faces being permanently sheathed with light boarding. There is no diverting dam at the head of the canal, which has been located just above a natural cobblestone-and-bowlder riffle.

Centerville & Kingsburg Canal.—This is another of the important north-side canals from Kings River belonging to the upper group of canals. Its head is about 2 miles in a direct line northeast of Centerville, and about the same distance by river below the head of the Fowler Switch Canal. Its course is westerly for nearly half a mile, directly toward the northwestern margin of Centerville Bottoms. Its second half mile has a southwesterly direction, along the slope from higher plains to the bottoms; thence on the higher level it holds a course southwesterly and southerly for about 8 miles, practically parallel with the bluff, 20 to 30 feet high, which drops from the valley plain to Centerville Bottoms. This portion of the canal is frequently within a few rods of the edge of the bluff, and is rarely more than half a mile distant therefrom.

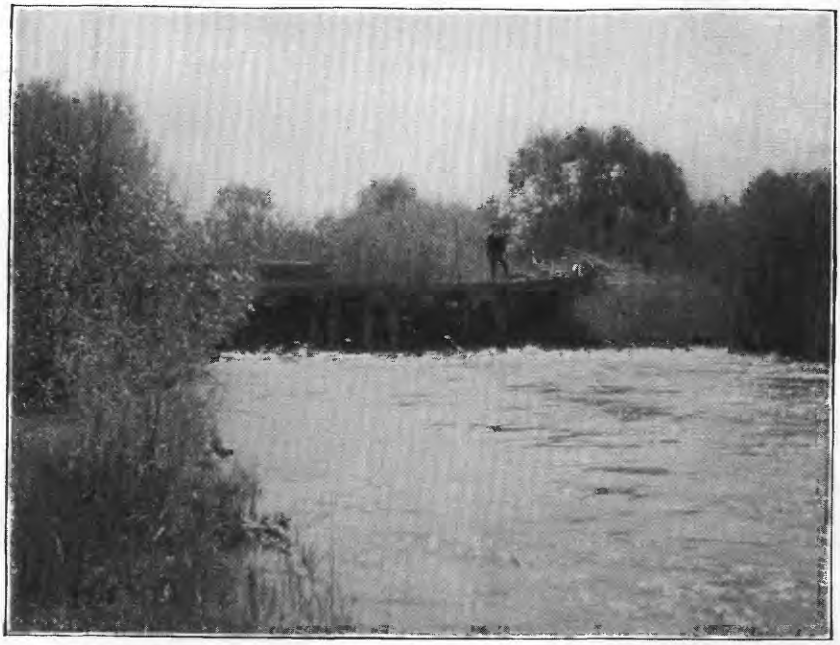
About 9 miles below its head the canal is separated into a number of branches, which radiate throughout the district westward from Kings River below the Narrows, extending southeastward to lands east and south of Sanders, southward to the vicinity of Kingsburg, and southwestward beyond Selma and well into the Wildflower country.

The main canal has irregular dimensions, its bed width being generally about 30 to 35 feet. It has been allowed to cut deep into the friable surface soils in the upper sections of its course, where but little attempt has been made to reduce its gradient below that of the natural surface of the ground. The length of main canal is about 18 miles. The length of its three principal branches is reported at about 26 miles.

The diversion from the river is effected by means of a brush-and-cobblestone dam, in which a small gate serves as waste way and sand



A. REGULATOR ON FOWLER SWITCH CANAL, AS SEEN FROM ABOVE.



B. REGULATOR ON FOWLER SWITCH CANAL, AS SEEN FROM BELOW.

sluice. The canal regulator is close to the river and is of a type very common on Kings River canals. Three rows of posts rising from a plank floor extend across the canal from one bulkhead wall to the other. They support a platform loaded with cobbles and gravel to give stability to the structure. The spaces between upper posts are closed by means of vertically sliding gates, each of which has a stem extending above the platform, to which power is applied when the gate is to be opened or closed. The cost of the regulator was about $1,000. The first cost of the canal was about $35,000.

This canal was constructed in 1877 and 1878. It was built by a company organized by farmers who owned lands near Kingsburg and Selma. The capital stock of the corporation which they formed was originally fixed at $12,500, but was subsequently increased to $35,000, being divided into fifty shares. The upper 2 miles of the canal were constructed by day labor. The rest of the main canal was divided into

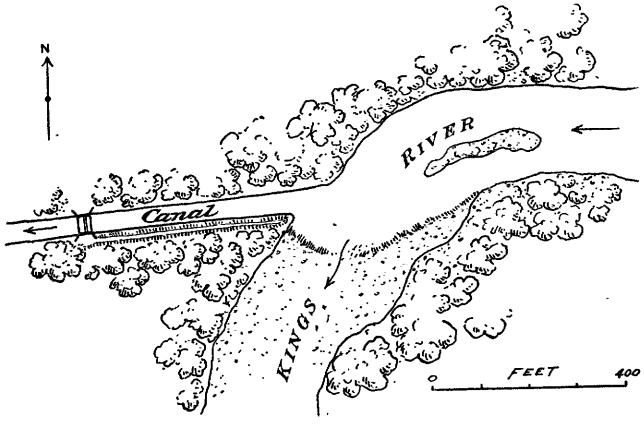


FIG. 13.—Head of Centerville & Kingsburg Canal.

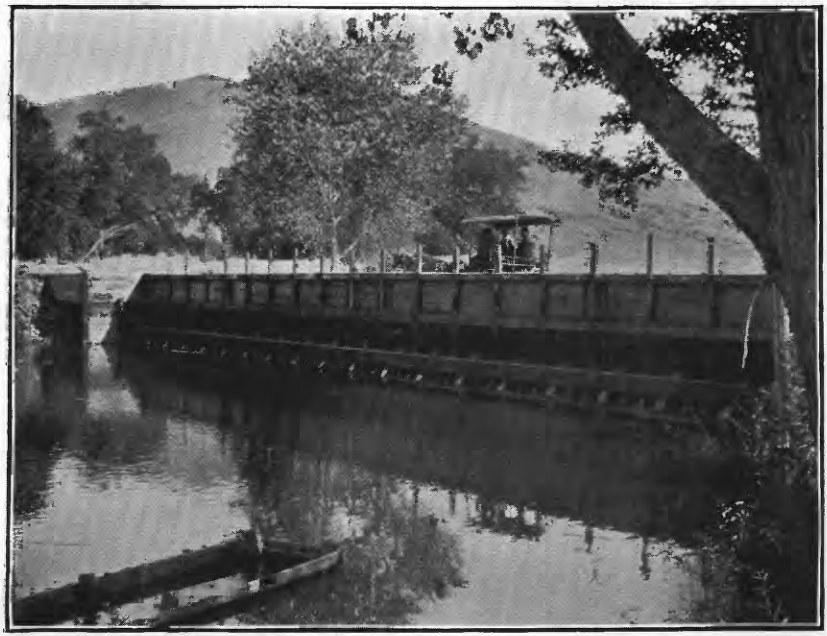
sections, each of which represented one share of stock, and was assigned to some stockholder, who was required to complete it. A few unlimited, unassessable rights to water from the canal have been granted to settlers near Centerville, in consideration of rights of way. Each stockholder is entitled to the delivery of a proportional part of the water remaining available for distribution; but each stockholder, or the corporation when in possession of any shares of stock, may lease the shares. The price of a share per month in 1882 was $6. Shares were at that time valued at about $1,500. Each share of stock is supposed to represent "3 feet of water;" an expression of quantity which seems as vague as the amount named in the franchise of the company—"150 cubic feet of water under a 4-inch pressure." In fact, however, each share of stock entitles its holder to a proportional part of the water varying somewhat according to the number of shares in actual use, but not in excess of three times the amount which would flow 4 inches deep

over a clear overfall 12 inches long. Water is apportioned on the judgment of a canal superintendent, generally through gates of like construction. When the amount of water per share of stock in the canal exceeds three units, each indicated by a clear overfall of 4 inches on a length of 12 inches, then all surplus water is held for sale, by the directors of the company, at fixed rates per month per unit. The cost of canal management, maintenance, and repairs is assessed upon the stockholders. The annual expense assessment is now about $80 per share of stock. The works required to divert water from the main canal into private ditches, including weirs in the main canal, are constructed by the consumers of water, subject to approval of the canal company.

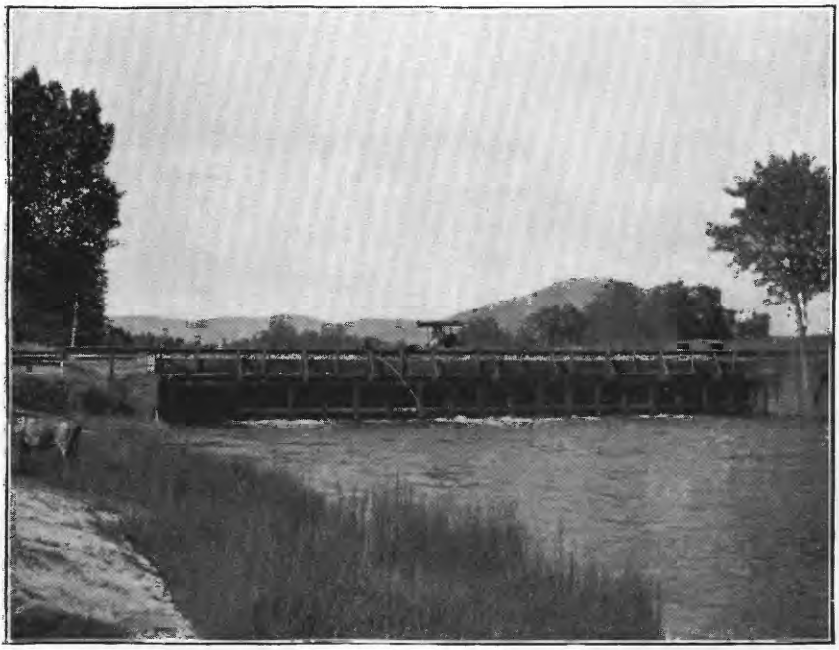
Satisfactory use of this canal has been interfered with to no little extent by litigation, generally involving the right of the canal to receive water from the river, and, as in the case of other canals from Kings River, its permanent efficiency as a source of supply has been thrown somewhat into doubt by adverse decisions of the courts.

Selma irrigation district.—This irrigation district is situated on the north side of Kings River, in Fresno County, and embraces within its limits the lands now watered by the Fowler Switch and the Centerville & Kingsburg canals. It was organized in 1890 with an area of 271,000 acres. For the purchase of existing canals and the construction of new works, it was proposed to issue bonds to the amount of $1,000,000; but the bond issue was twice defeated at the polls, and it seems to be generally conceded that there is small probability of a continuation of operations under the district law.

Alta irrigation district (76 Canal).—The canal which supplies water to the Alta irrigation district is known as the 76 Canal. It belongs to the upper group of Kings River canals. Its head is on the south side of the river, about 1½ miles above the head of the Kings River & Fresno Canal, if the point at which the uppermost work for the direction of water toward the canal regulator may be termed its head. At that point a branch of the river has been enlarged somewhat and otherwise improved, and the water diverted from the main stream through this natural channel is carried in a succession of depressions or high-water channels along the southeastern margin of Centerville Bottoms about 3 miles, to the point where the canal cuts out upon the higher plain lying to the east of Centerville Bottoms. The natural depressions of the upper coal section have in large part been converted into a canal by building up, along their low western banks, embankments of cobblestones and bowlders, which were taken from their beds for their enlargement. Where the canal turns away from Centerville Bottoms a cut 9 feet in depth was necessary. From this point the canal has a general southeasterly course, following a grade line with 18 inches fall to the mile, that skirts the western foothill base. At 6 miles below the regulator the canal is carried across Wahtoke Creek, and its southeasterly



A. REGULATOR ON SEVENTY-SIX CANAL, AS SEEN FROM ABOVE.



B. REGULATOR ON SEVENTY-SIX CANAL, AS SEEN FROM BELOW.

course is maintained about 22 miles farther, to near Cottonwood Creek. The main canal has been made the eastern boundary of the Alta irrigation district.

The bed width of the canal throughout the first 9½ miles below the regulator is 100 feet. Its capacity, with a depth of 5 feet of water, is about 1,200 second-feet. From the main canal numerous branches extend southwesterly and southerly into the heart of the district. The principal of these is the Traver branch, which has been given a bed width of 60 feet. It leaves the main canal about 1½ miles below Wahtoke Creek, and, as its name indicates, delivers water to lands in the vicinity of Traver. Branch canals are for the most part located across the valley plain on lines of its greatest slope. They have generally been given positions on high ground intermediate between gentle depressions, though in some instances, as in the case of the Traver

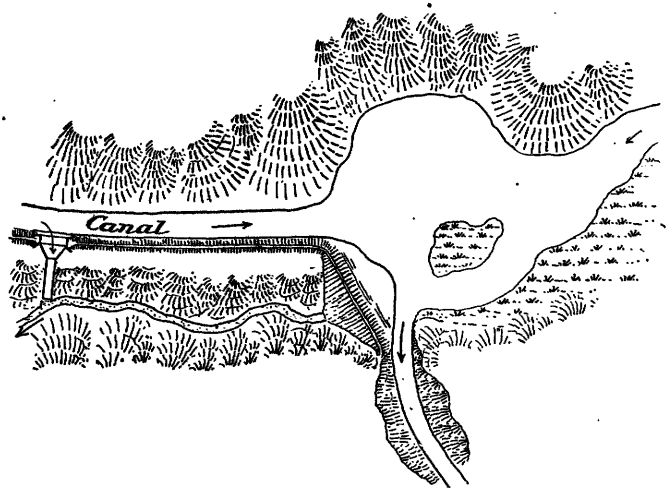


FIG. 14.—Wahtoke Reservoir, on 76 C nal.

branch, natural water courses have been in large part substituted for expensive canal work.

The inflow of water from the upper canal section into the second section of the main canal is controlled by means of a regulator or head gate. Above the regulator in the west canal bank is a spillway through which surplus waters are dropped into Patterson Slough, one of the Kings River channels in Centerville Bottoms. The regulator rises from a plank floor constructed of two layers of 3-inch planking, the dimensions of which are 100 feet in the direction across the canal by 30 feet along its axis. The surface of the floor is at grade of the canal bottom. Along its upper and lower edges are two lines of sheet piling, not driven, but constructed in trenches, which extend to a depth of 5 feet. The bottom ends of the sheeting planks are nailed to a horizontal plank 3 by 12 inches, which adds to the effectiveness of the sheeting. Trenches were

refilled with carefully selected material well tamped into place. Three rows of posts, with necessary brace timbers, rise from this floor, the post rows being 8 feet apart. They support a platform which serves as a bridge. Between the upper posts are the gates, twenty in all, which slide vertically in grooves formed by spiking additional timbers to the upper faces of the posts. Each gate has a stem to which power is applied by means of a lever. Every fourth gate is provided with two vertical revolving shutters, so connected with it that when closed they will not interfere with the free movement of the gate. These shutters are intended to be used when the water pressure on the gates is so great as to interfere with their being raised. The cost of the head gate was $3,000. Lumber at the gate costs $28 per thousand feet, board measure. About 60,000 feet of lumber were used in its construc-

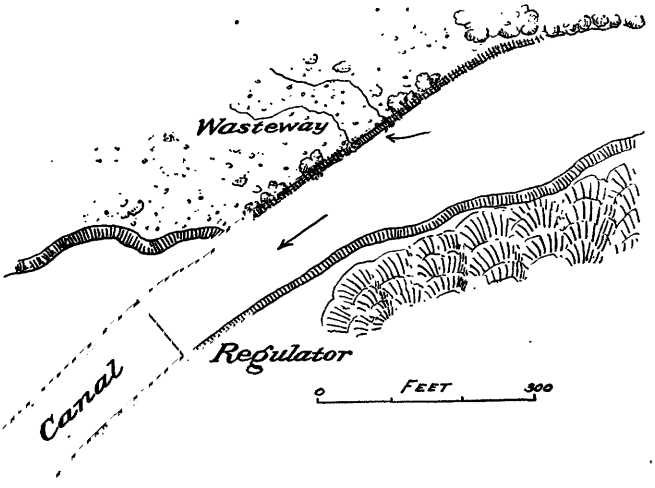


FIG. 15.—Head of 76 Canal.

tion. The check weirs in use on this canal system (there are nine on the Traver branch within 7½ miles above Traver) are simple but serviceable structures. They are of the flashboard type. Spaces between posts 4 feet apart, which rise from a plank floor, are closed by loose boards sliding in grooves. The cost of a check weir across a canal 60 feet wide is reported to have been $275.

Occasionally a firm hardpan layer that would not yield readily to blasting or plowing had to be broken up into long, narrow strips with gads. A spur of rotten granite was crossed at one point, and the maximum cut through it was 28 feet. Throughout 5 miles below the regulator large cobbles—some 1 foot in least diameter—had to be removed from the material loosened by the plow before scraper work could commence. The ground containing these cobbles was first trenched with large road plows drawn by 12 to 16 mules. The plows were steadied by means of long saplings extending out on either side.

Along the base of Campbells Mountain, throughout the 3 or 4 miles above Wahtoke Creek, the surface soil into which the canal was cut is dry bog—a dark-colored, light soil, which contracts, cracks, and crumbles in drying. When wet this soil is soft and sticky. This material had to be used in many places for the canal embankment, which often crossed depressions, and when water reached these it rapidly permeated the spongy bank and often found vents that led to the speedy destruction of the embankment. It cost about $6,000 to get the water in the canal as far as Wahtoke Creek.

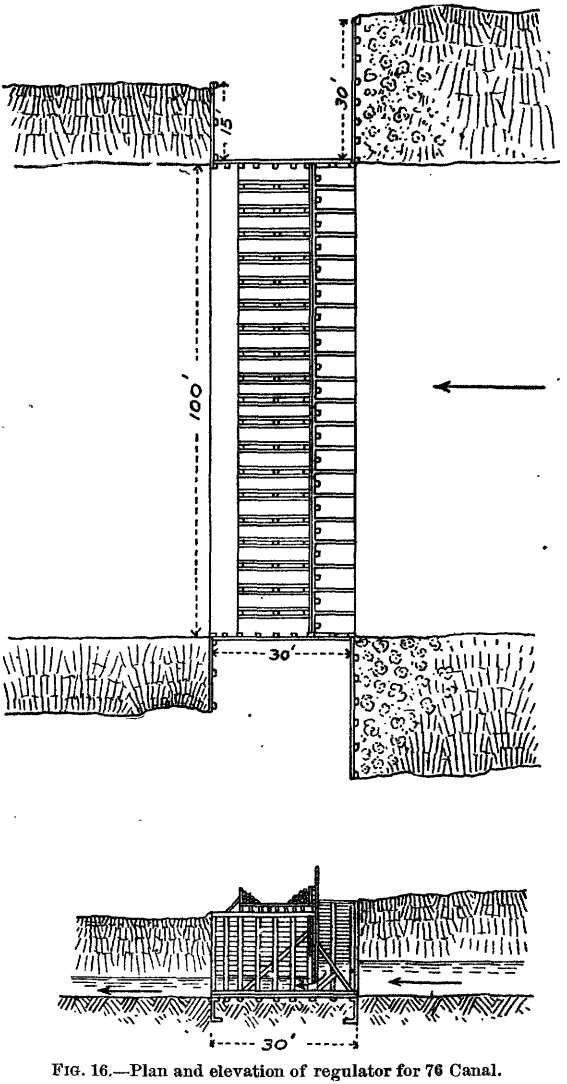


FIG. 16.—Plan and elevation of regulator for 76 Canal.

The canal was constructed in 1882. This was before the enactment of the irrigation-district law. Its construction was undertaken by a private corporation, on a plan which was very satisfactorily carried out. As soon as the feasibility of making the diversion of water from the river was assured, about 40,000 acres of land on the plains to be commanded by the canal were bought for the corporation at prices less than $10 per acre. These lands were offered for sale as soon as the canal came into service, at prices somewhat in excess of the added cost of canal construction. It was proposed to establish each year a schedule of prices to be adhered to for a year, but demand for land was so great at the prices fixed during the first few years that the lands were

repeatedly withdrawn from sale. The expenditure of less than $300,000 in four years thus created and increased values to an estimated amount of over $800,000, not including increased values of properties in which the canal company had no direct interest.

Before the canal was sold to the Alta irrigation district, water rights were issued to purchasers of all lands sold by the canal company and were for sale to others owning land in the district commanded. A water right was defined as 40 miner's inches of water, and was located upon some particular 40-acre tract of land, of which it became an appurtenance. Each full water right was made liable to an assessment of $16 per year to cover expenses of canal management. The price of a water right was fixed at $200.

The Alta irrigation district was formed in 1888 and was made to include the lands to be irrigated with the 76 Canal. It extends southerly from Kings River to and even beyond Cottonwood Creek and westerly to within a mile of the eastern border of the Kings River delta, and has an area of 130,000 acres. Two years later the district purchased the canal and its branches, paying therefor $410,000 in bonds of the district. This covered the repayment to holders of water rights of the amounts which they had paid for them.

The northern apex of the Alta irrigation district is at the western base of Tchoenimne Mountain, where a second river bottom, 10 to 20 feet higher than Centerville Bottoms, lies below the 76 Canal. From the second bottom, which is long and narrow, having an area of nearly 7,000 acres, there is an abrupt rise of 20 to 35 feet to the upland or main east-side San Joaquin Valley plain. The surface of this plain drops away gently from the base of the hills southwestward toward the valley trough. Its slope is at first about 10 feet to the mile, but this becomes gradually less and is only 6 feet to the mile near Traver. The only notable break in the surface of this portion of the valley plain is made by Wahtoke Creek, which, in its southwesterly course from the foothills of the Sierra Nevada, passes to the east and south of Campbells Mountain and discharges into Kings River at the Narrows. It flows in a wide, deep gorge from foothill base to the river.

Southward from Wahtoke Creek are several minor creek channels, which carry water only in very wet seasons and sink or spread before reaching Cross Creek.

After the purchase of the 76 Canal system, in 1890, more branch canals were necessary. These were constructed, under the direction and supervision of the district engineer, by private parties, from whom they were then bought, payment being made with irrigation-district bonds. About 150 miles of branch ditches were thus constructed, at a total cost in bonds of $133,000. The entire district is now covered with branch canals, which are rarely more than 2 to 3 miles apart.

The area of land to whose surface water is now actually applied is estimated by the district officers at 40,000 acres. The distribution of

A. FURROW IRRIGATION FOR CITRUS FRUITS.

B. CHECK WEIR IN ALTA IRRIGATION DISTRICT, IN LATERAL ABOUT TWO MILES WEST OF TRAVER.

water is in charge of a canal superintendent and seven assistants, called "ditch tenders."

The soil of this region is for the most part a sandy loam, with coarse, clayey sands near the eastern border of the district, and finer, lighter sands toward the west. Much alkali is in the soil to the west and southwest of Traver. Hardpan subsoils are common at 2 to 5 feet below the surface. Ground water before 1883 was at 20 to 60 feet. It was nearest the surface in the southern and western portions of this district. Irrigation is causing the water table to rise, particularly near Traver.

Water is usually available for irrigation from February until the end of July. Where used on a small scale, land is occasionally prepared for it by subdivision into small rectangular checks. This was the preferred system when water was first introduced into the vicinity of Traver. Now the contour-check method of irrigation is finding more favor. The reason for this preference seems to be due, not only to reduced first cost, but also to the fact that it requires less cutting down of surface soils than the level-check method of irrigation. The uncovered subsoils are often found to be relatively barren. Orchards, vineyards, and summer crops are quite generally being irrigated by the furrow method. Grain land, if wet at all, is irrigated by spreading water over the surface from small ditches or furrows, usually before sowing.

Morrow Ditch.—This was one of several small private ditches south of the main channel of the river which were in use for the irrigation of small tracts of land in Centerville Bottoms. It was constructed about 1865.

Dennis & Jordan ditch.—This is another private ditch, now having the appearance of a natural arm of the river. Its course is southwesterly from Patterson Slough, from which it takes water about 1½ miles below the regulator of the 76 Canal.

Kincaid Ditch.—This name is applied to an eastern arm of Patterson Slough, the head of which is about one-half mile below the head of the Dennis & Jordan Ditch. It supplies water to the Dennis Ditch and to Finks Branch.

Glenn and Barton ditches.—These are two other small private ditches, which seem to have been in use about 1879 on lands of Centerville Bottoms, but which have probably been abandoned.

Emigrant Canal.—This canal may be classed as almost out of service. It was the uppermost of the north-side Kings River canals of the lower group. It took water from the north side of Cole Slough about 2 miles below the head of that arm of Kings River. Its course was southwesterly, nearly parallel with Cole Slough, for about 3 miles, thence northwesterly to and beyond Wildflower. The canal was constructed by an organization of farmers who wanted water for their lands, and was to be managed for mutual benefit. They formed a cor-

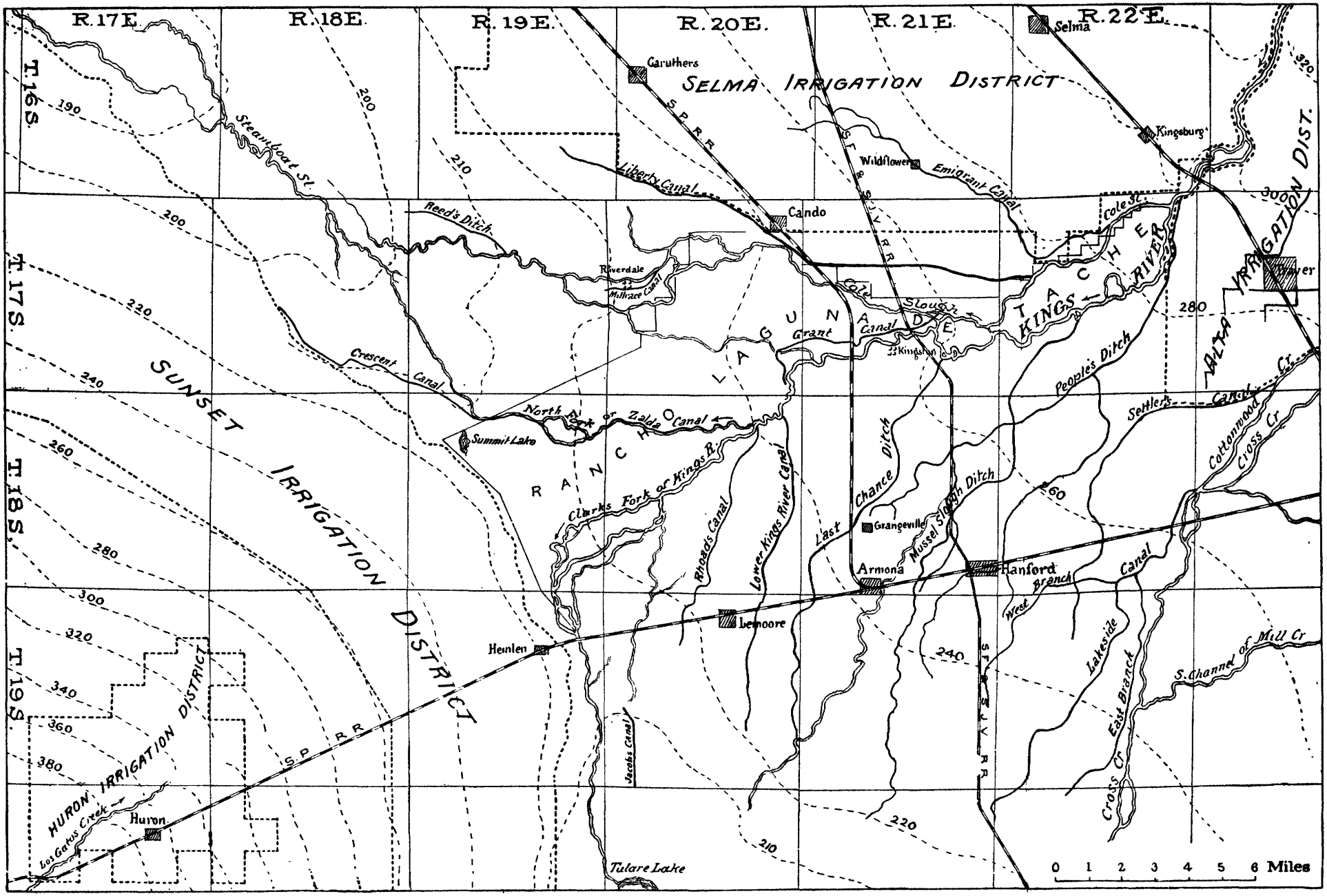
poration late in 1875, with a capital stock of $20,000, in shares of $1,000 each. All expenses of construction, maintenance, and management were met by assessing stockholders. Each stockholder was entitled to the use of canal water in proportion to amount of stock owned. He was allowed to sell or rent his water at pleasure. Each consumer of water was required to build his own delivery gate, subject to the approval of the directors. The distribution of water was in charge of a canal superintendent, which office was annually let to the lowest bidder. The canal had a bed width of about 16 feet, and delivered its water to a number of branches, which covered about 7,000 acres. The canal company became involved in litigation and failed to maintain control of its head works, so that finally it received water only during high stages of the river, and generally for such short periods of time that those dependent upon it soon found it to their advantage to secure additional water from the Centerville & Kingsburg or the Fowler Switch canals.

Liberty Canal.—This is a canal which was constructed about 1882 from the north side of Murphy Slough, its head being about 5 miles above Riverdale. After experiencing much trouble in obtaining a satisfactory supply of water from Murphy Slough, which is the extension of Cole Slough, the original head of the canal was abandoned several years ago, and it was extended easterly about 7 miles to a connection with a high-water escape way from Cole Slough known as the Sutherland Canal. The inflow into the canal is controlled by a regulator placed in the Sutherland Canal about one-eighth mile from Cole Slough. The canal is about 15 miles long, has a westerly course for 7 miles and thence a northwesterly course, is about 20 feet wide, and its branches cover about 5,000 acres to the north of Riverdale.

Millrace Canal.—Where Murphy Slough leaves the grant known as the Rancho Laguna de Tache, about 1½ miles above Riverdale, two gates or flashboard weirs have been built across the two channels of the slough. These force its water through a short canal into another natural channel, known as the Old North Channel, from which it is reclaimed half a mile below and is carried westward and thence northward in the Millrace Canal. This canal is used for the irrigation of lands near Riverdale and westward thereof. It is essentially a high-water canal. The canal proper is about 6 miles long. It has a bed width of about 14 feet.

Reeds Ditch.—One of the old ditches on Kings River is the Reeds Ditch, whose head is on the north side of Murphy Slough, about 4 miles below Riverdale. It is a small private ditch, having a course a little north of west. Its bed width is about 5 feet; its length about 4 miles. It irrigates a few acres of land near Elkhorn.

Laguna de Tache Canal (Grant Canal).—The "River Ranch," which includes the Rancho Laguna de Tache, has an area of about 68,000 acres, embracing within its boundaries nearly all of the delta lands



LOWER KINGS RIVER CANAL SYSTEM.

of Kings River northward from the main stream. A main canal has been constructed for the irrigation of the greater part of this rancho, and this is known either as the Laguna de Tache Canal or the Grant Canal. A large portion of this rancho is annually submerged during the high stages of Kings River. The area subject to such flooding has, however, been considerably reduced by the construction of a north-side river levee along a portion of the ranch frontage. There are a number of north-side delta channels which break out from the main stream within this rancho, most of which have westerly courses toward the valley trough. The history of these, as related by local residents, is not without interest. The present head of Cole Slough is a water way made by the freshets of 1861–62. It was enlarged and deepened by subsequent high waters. Cole Slough is the principal north-side delta channel. Its waters are carried westward by the several branches of Murphy Slough, and finally reach the upper portion of Fresno Swamp, through which they are carried in a network of channels, as frequently found in tule swamps, to Fresno Slough and San Joaquin River, many miles northwestward.

Before 1862 Cole Slough received water from the river through a channel known as the Arroyo de Hotansas, the head of which was about a quarter of a mile below the present head of the slough. This channel was about 3 miles long.

Until 1869 Cole Slough occupied a channel which at a point about 3 miles in a direct line above Kingston was less than a quarter of a mile from Kings River, but in that year Mr. St. John, one of the owners of the rancho, made a small ditch westward from the north slough bank about 6 miles below its head. This ditch was enlarged by the next high water; it lost the appearance of a ditch, and is now called St. Johns Channel or New Cole Slough. It reunites 3 miles below its head with the original slough channel at a point also known as the head of Murphy Slough.

A small ditch, constructed in 1868 by a settler known as Dutch John, connecting Kings River with Cole Slough at the point where the two channels were nearest together, had meanwhile also been converted into a capacious water course and has since been known as the Dutch John Cut. In the same winter, 1868–69, the river broke through the barrier separating it from Murphy Slough at a point about 3 miles (by river) below the Dutch John Cut and formed Reynolds Slough, which is about one-half mile long.

The Grant Canal was constructed in 1873. Water was diverted for it from Murphy Slough, near Reynolds Slough, which latter was permanently closed by means of a dam. Two years later, by permission of the owners of the Grant, a new connection between Cole Slough, half a mile above the head of Grant Canal, and Murphy Slough, nearly the same distance below the canal, was made by settlers who were desirous of increasing the flow of water in the channels

reaching the vicinity of Elkhorn. Its projectors subsequently filed a claim to water and incorporated under the name of the Vanderbilt Canal Company. Settlers in the vicinity of Riverdale and Elkhorn claim that the original cut was entirely artificial, while owners of the Grant Canal claim that the cut is merely the result of cleaning out the head of a natural water course. After the Vanderbilt Cut had become one of the channels for Cole Slough water, the Grant Canal was extended upstream across Murphy Slough to the Vanderbilt Cut, from which it has ever since taken its water. The turning of the flow of Cole Slough into the Vanderbilt Cut is accomplished by means of a dam of earth across the old south channel. From the cut water is turned into the head of the canal by means of a second earth dam, and, flowing in the canal, it crosses Murphy Slough between two dams, of which the lower or westerly one is an overfall dam of brush work, serving as an escape

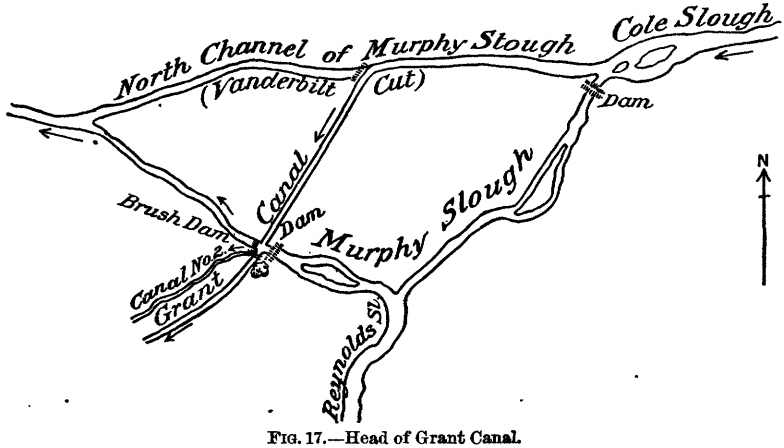


FIG. 17.—Head of Grant Canal.

way for surplus waters and feeding the lower sections of Murphy Slough.

The Laguna de Tache Canal has a westerly course along the northern bank of the main channel of Kings River, from which it is generally less than one-half mile distant. At 5½ miles below its head it crosses a water course known as the James Canal, on an earthen dam, and its direction becomes southerly. It reaches the river bank within a mile and closely follows it southerly for about a mile farther on its course, crossing and closing the head of another delta channel of Kings River known as Old North Fork.

The upper section of the main canal for a distance of about 4 miles from its head has a bed width of about 30 feet and carries water 2 to 2½ feet deep. The distributaries from the main canal are for the most part natural channels, many of which have long ago ceased to serve as delta channels and are mere swales on the tops of low ridges. The James Canal is a channel of more recent formation, which has been

utilized as a distributing ditch. By permission of the owners of the Grant a gate for the control of its flow was put into this channel in 1880. It was washed out by the next freshets and was replaced in 1881, but was again destroyed. Thereupon the owners of the Grant permanently closed this channel with the embankment of earth on which the canal is carried across.

The head of Old North Fork, which is another distributary of canal water, was closed as early as 1865 by Messrs. Sutherland and Mann. One of the most important of the lower-river north-side delta channels is the Zalda Canal, which, throughout its lower sections, is generally known as the North Fork of Kings River. It is claimed that the head of this channel is the enlargement by flood waters of a ditch constructed in 1872 by settlers living to the west of the Grant. This channel was reported closed for a time by a dam at the river about 1885. It was at that time proposed to utilize this channel as one of the distributaries of water from the Grant Canal. The course of North Fork is westward in a very direct line toward Summit Lake, but before the lake is reached its main channel swerves northward into Fresno Swamp. The portion of the Kings River delta between the main river on the south and the Zalda Canal on the north marks the very flat summit between Tulare Lake and Fresno Swamp. In the trough of the valley near and to the south of Summit Lake the general elevation of the ground's surface on this summit, the lowest point on the border of Tulare Lake, is about 211 feet above mean sea level. During the last high stage of the lake, in 1868, the depth of water over the general surface of the country at this point was about 6 feet.

The lands of the Rancho Laguna de Tache have always been so well watered that the irrigation works which have been constructed may be regarded as serving primarily to establish a convenient control of the water rather than as works intended to increase the supply. To prevent excessive natural inundation it has been found necessary to erect embankments along the river, also to construct numerous drain ditches from low tracts into natural channels to facilitate drainage. The main irrigation canal supplies water to a large number of distributaries, frequently natural channels, and these in turn to small irrigating ditches, usually 200 to 450 yards apart. As the entire irrigation system lies within the limits of the rancho there has been less study of methods of controlling and distributing water than would have been the case if a large number of consumers had to be supplied, and water measurement has been entirely out of the question.

The Rancho Laguna de Tache has within the last few years become the property of the same parties who control the Fresno Canal. The future of both properties was kept in mind when the owners of the Grant sold Kings River water to the Sunset irrigation district, to be diverted by way of Cole Slough into the enlarged Grant Canal, thence across the Zalda Canal (North Fork) to a proposed reservoir near Summit Lake.

According to the terms of this agreement the district is given a right of way and a reservoir site, and water is sold to it to the extent of 3,500 second-feet, subject to the prior rights of the owners of the rancho and of the Fresno Canal to the extent of 3,000 second-feet, and subject also to the proviso that, for use on the ranch, 500 second-feet may be taken out of the main canal of the district. The price paid by the irrigation district was $250,000 in district bonds, and the aggregate amount of land in reservoir sites and right of way for the canal was not to exceed 2,200 acres.

Crescent Canal.—This canal was constructed in 1885 and 1886, and came into use in 1887 for the irrigation of lands on the western edge of the extreme southern portion of Fresno Swamp. The head of the canal is on the south side of North Fork, about a mile to the north of Summit Lake. The canal, which is about 8 miles long, has a westerly course for about 1½ miles, thence northwesterly, following a grade line with a fall of 6 inches to the mile. It was originally made 50 feet wide near its head; it was 25 feet wide several miles below, and 50 feet wide in its lower sections. The narrow section was cut to the full width in 1892. It was planned to carry water 3 feet deep. A regulator is maintained in the head of the canal. This is a simple structure. Twelve light gates of 1-inch boards close the 4-foot openings between vertical posts which rise from a plank floor. The total width of the regulator between side walls is 50 feet. Its height is about 6 feet. It is weighted on top with a filling of earth. The canal supplies water to several thousand acres of land, most of which lies within the limit of overflow.

The canal is owned by an incorporated company, whose capital stock was fixed at $75,000, in 150 shares. The cost of the canal works has been about $5,000. The canal was constructed for the supply of water to lands owned by its stockholders and not for the sale of water. Each irrigator is required to own one share of stock for each quarter section of land (160 acres) which he wishes to irrigate. All distributing ditches are constructed by the irrigators, who take water from the main canal at the most convenient points.

Peoples Ditch.—This is a canal of the lower group whose head is on the south side of Kings River, about one-half mile above the head of Cole Slough. Kings River at this point flows in a broad, sandy bed to which there is a steep descent of about 15 feet from the level of the main valley plain on the south. The canal follows the margin of this plain for some distance southwesterly as it recedes from the river, and is gradually brought out upon the surface of the plain about 3 miles below its head. At about 4 miles below its head the distribution of its water to its branches commences. The diversion of water from the river is effected at low stages by means of a dam of brush and sand, which is annually repaired or renewed at considerable expense. Until within the last few years the inflow into the canal was controlled by

A. BRUSH DAM AT TIME OF HIGH WATER, PEOPLES DITCH.

B. REGULATOR IN PEOPLES DITCH, AS SEEN FROM ABOVE.

two regulators, one of which was within a quarter of a mile of the river bank, the other about 2 miles below. These were 24 feet in width and were of the ordinary culvert type with vertically sliding gates.

There is a new regulating gate now in service within several hundred yards of the head of the canal. This is a massive, well-built structure, 38 feet wide between side walls, which supports an earth fill about 2 feet thick, serving as a roadway over the canal. The space between side walls is subdivided by 10-by-10-inch posts into ten bays or openings, each of which is closed by means of a vertically sliding gate. Power is applied to the gate stems by means of a lever, the end of which engages between the teeth of a rack.

The canal has a fall of only about one-half foot in the first 2 miles of its course. The effective fall is increased somewhat by keeping the brush dam at a good height. The canal as originally constructed was 24 feet wide on the bottom, and was intended to carry 4 feet of water.

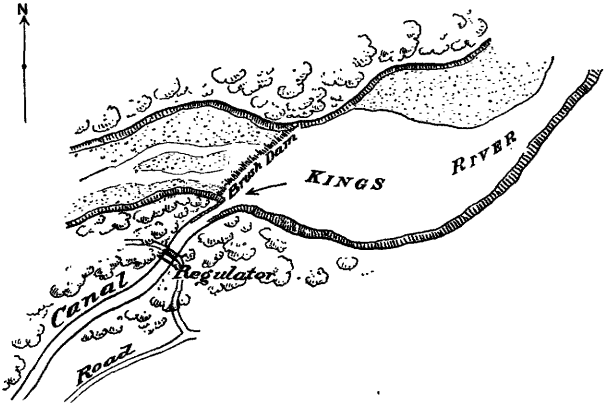


FIG. 18.—Head of Peoples Canal, on Kings River.

Its estimated capacity was about 220 second-feet. Below the second regulating gate the width of the canal increases to 30 feet, and the depth of water to be carried is only 3 feet. These dimensions are maintained for about 4 miles, still in a southwesterly direction and extending well into the northeastern extremity of that portion of the Kings River delta usually referred to as the Mussel Slough country. The canal has three principal branches: West Fork, which terminates near Grangeville; Middle Fork, which passes just to the westward of Hanford; and East Fork, which passes through the southern portion of Hanford and extends to points 4 miles farther south. The aggregate length of the main canal and its principal branches is about 37 miles. This canal was constructed by the Peoples Ditch Company in 1873 and the following years. The first notice of a claim to water was posted late in 1872. The company, formed by settlers who wanted water for their own lands, was finally incorporated in 1873. Its capital stock, originally fixed at $10,000, was soon increased to $35,000, and

later to $100,000. The first cost of the canal was about $50,000 to $60,000. The total cost of canal construction and annual expense account had reached $120,000 in 1881. About $4,000 to $6,000 are annually expended on the dam. The total annual expenditure for management, maintenance, and repairs is about $10,000.

Of the 100 shares into which the company's capital stock is divided about one-third have reverted to the corporation. The remaining shares are in the hands of irrigators, to whom water is delivered in amounts proportional to their holdings of stock. The stockholders are permitted to sell the water to which they are entitled and to ask for its delivery through any of the canal branches. Its use is not restricted to any particular tract of land. The delivery of water to irrigators is usually through gates 1 to 4 feet wide. It is discharged under pressure, the endeavor being to make amounts delivered proportional to stock which it represents, without any attempt at actual measurement. A canal superintendent, with necessary assistants, has charge of the delivery of water. Its equitable distribution depends largely on the judgment of the canal superintendent.

During the years 1883 and 1884 the experiment was tried of selling water to stockholders at $200 per share of stock per year; to those not holding stock an equivalent amount at $300 per year; but it did not prove satisfactory. All stockholders are assessed to meet the annual expenses. The area of land actually irrigated or benefited by the water of this canal is about 25,000 acres.

Mussel Slough Ditch.—This canal, which is now out of service, took its name from one of the delta channels of Kings River which has been utilized for the distribution of water. The canal, unlike the other canals of the Kings River delta, was constructed for speculative purposes. It was proposed to turn a large volume of water from the river into the slough and to derive a revenue from its sale to irrigators. The head of the canal was on the south side of Kings River, about 7 miles below the head of the Peoples Ditch. A narrow cut, the original bed width of which was about 10 feet, was made from that point southerly into and thence southwesterly along the upper portion of the channel of Mussel Slough. The bottom of this cut throughout a little more than a mile from its head was made level, being at an elevation a little below that of the river bed at the head of the canal. The upper portion of this cut, near the river, is over 14 feet in depth. As the canal leaves the river it grows wider, and at about 3 miles from its head the natural channel of Mussel Slough afforded ample capacity for its waters.

Mussel Slough and its principal branches, Sand Slough and Lone Oak Slough, have a general southwesterly course through the delta lands, passing to the west of Handford and extending to the high-water line of Tulare Lake.

To what extent the canal has been in use in the last few years is not

known. It is now out of service, and was not in use for three years preceding 1886. Its head was closed with an embankment of earth in 1884, because at that time the river threatened to destroy the canal head gate and cause inundation of the upper and central portions of the delta.

The canal head gate or regulator was placed in the deepest portion of the cut, near the bank of the river. It was made 24 feet wide, the space between its walls being divided into a number of openings by vertical posts, between which gates slid vertically. The structure had the usual upper platform loaded with earth, making a roadway 20 feet wide. Its floor length was 40 feet. Sheet piling 8 feet deep was used on the upper floor line and for 12 feet under each wing; sheet piling was also driven 6 feet deep across the canal, on the middle line of the floor and at its lower edge.

Throughout the length of the natural channels utilized for the water of the Mussel Slough Ditch, check weirs or gates were constructed with which to hold the water surface at or above the surface of the ground. Irrigation was to be accomplished by subirrigation on a large scale. The charge for water ranged from 31¼ to 62½ cents per acre per year. There was little or no restriction as to the amount of water to be used by individual takers of water, and the principal duty of the canal superintendent seems to have been to prevent those from taking water who had no intention of paying for it.

The total cost of the canal works connected therewith was about $50,000 to $60,000.

This canal was constructed in 1875. Its promoters formed a corporation with a capital stock fixed at $500,000, divided into 10,000 shares, all of which remained in the hands of a few persons. The canal capacity was about 200 to 300 second-feet.

Last Chance Ditch.—One of the most important of the Kings River delta canals is the Last Chance Ditch, whose head is on the south side of the river about 2½ miles by river above Kingston. The course of the canal and its branches is southerly. It commands a district 3 to 4 miles wide, extending from near the river southerly to near the high-water line of Tulare Lake. Grangeville lies at the eastern border of this district and Armona well within it. Lands along its eastern border are commanded jointly by this canal and the Peoples Ditch. A natural cut through the south bank of the river, known as Leinberger Slough, has been utilized for the head of the canal. This slough is really one of the lower delta channels of the river. The canal is cut from its south bank about 150 feet from the river. The canal regulator is about 800 feet below its head. The water entering the head of the slough is divided, a portion flowing down the natural channel, the rest entering the head of the Last Chance Ditch. The canal has a bed width of 25 feet, and was designed for a 4-foot depth of water. Its course is a little west of south for 7 miles to a point half a mile west of

Grangeville, where it is divided into two principal branches. One of these has a southwesterly course and at the end of 3 miles drops its water into a natural channel which has a southerly course and connects with Mussel Slough. The other branch within a mile is again divided, forming a middle and an eastern branch, both of which extend far toward the south. These main branches were all made 16 feet wide on the bottom and were planned to carry water $2\frac{1}{2}$ feet deep. The gradient of the canal is about 1 foot to the mile.

The original canal regulator, which was in service from 1874 to 1880, was made 18 feet wide between side walls and is reported to have cost $5,600. It was replaced by a second one, 20 feet wide, at a cost of $3,000. The removal of sand from the canals, which had been swept in by high waters during the period when there was no gate at the head of the canal, is said to have cost $3,000. The regulator is of the

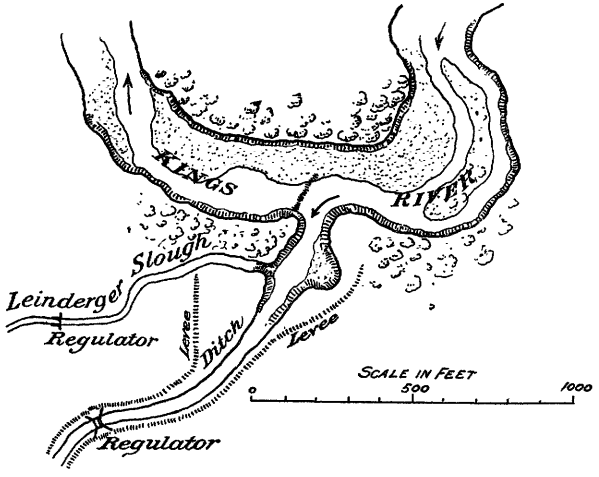


FIG. 19.—Head of Last Chance Ditch, on Kings River.

ordinary box type. From a floor 30 feet wide and 36 feet long (in the direction of the canal) side walls rise to a height of 14 feet. Between them are posts which support a platform or bridge that affords convenient access to the gates. The gateposts divide the space between side walls into six openings, each of which is closed with planking permanently from the top down to about 5 feet from the floor. The remaining open space is controlled by sliding gates having a long stem or standard to which power is applied by means of a lever engaging in the teeth of a rack. The gateposts are braced from below. Long wings extend diagonally into the canal banks above and below the gate. The upper ones are 14 feet high; the lower ones about 4 feet. Tongued and grooved 4-inch sheet piling was driven 10 feet deep along the upper edge of the floor and under the upper wings. Along both sides of the floor, across the canal at its lower end and well out under

A. LAST CHANCE CANAL REGULATOR, AS SEEN FROM UPPER SIDE

B. LAST CHANCE CANAL REGULATOR, AS SEEN FROM BELOW

the lower wings, 3-inch tongued and grooved sheet piling was driven 8 feet deep. Piles were driven to a depth of 12 feet under the braces to gateposts. Floor sills, piles, and main posts were 8 by 8 inches; side wall posts, 4 by 8 inches. The floor is of 3-inch planking, covered by 1-inch boards. Side walls are of 2-inch material, also covered with 1-inch boards. Back filling was selected sand. The bed of the canal below the gate was protected by a layer of brush, pinned down with stakes 6 to 8 feet long.

The Last Chance Ditch was constructed in 1873 and 1874 by a company known as the Last Chance Water Ditch Company, which was organized and incorporated by the farmers to whose lands it was to supply water. The original 30 shares into which a capital stock of $30,000 was divided were a few years later increased to 60 shares, and the capital stock was also doubled. Only about two-thirds of these shares are in the hands of stockholders. Until 1886 all operating and repair expenses, about $4,000 per year, were assessed upon the stockholders, and water was delivered to these without charge in proportion to amount of stock owned or controlled. Since that time water has been charged for at rates fixed annually, generally $1.50 per acre, in order to make actual users of water bear an increased portion of the canal expenses.

There has been no system of water measurement introduced. Water is delivered to irrigators through a great variety of gates; generally, however, through openings under pressure. A canal superintendent and an assistant have charge of its distribution. During the high-water period an attendant is kept constantly at the head gate. The canal ordinarily flows from the beginning of February to the end of July. About 20,000 acres of land are dependent upon it for water.

Lower Kings River Canal.—This is another south-side canal in the Kings River delta. Its head is about 6 miles below Kingston. Its course is southerly, and the district it commands lies just westward of that of Last Chance Ditch and has Lemoore in its center. The canal is cut southerly from the river, and at the end of its first mile reaches Leinberger Slough, into which its water is dropped. It is reclaimed from this slough less than half a mile below that point, and thence has a southerly course to within about 3 miles of Lemoore. Two principal branches, each about 16 feet wide on the bottom, extend toward the south from this point. Near the river the main canal crosses high-water sloughs fed by the over-bank flow from Kings River. These natural channels have been closed by dams on the lower or west side of the canal. Their water, together with other water escaping from Kings River above the head of this canal, is received by the canal and carried to Leinberger Slough. At the point where the canal leaves this slough a waste way 260 feet long is maintained, through which surplus waters are discharged. This is a very light timber structure, which is reported to have rendered good service. Some years ago it was proposed to

supplement it with a second waste gate, 200 feet long, nearer the head of the canal. The main canal regulator or head gate has been set close to the river bank. A secondary regulating gate is just below the Leinberger Slough waste gate. Each gate is about 40 feet wide between side walls. The head gate is arranged similarly to that described for the Last Chance Ditch. The main canal is about 40 feet wide. It was built on a very light grade. The bottom of the canal, commencing at the same elevation as the river bottom, was reported level throughout the first 5 miles of its course. The effective gradient slope of water surface when full is reported at 4 inches to the mile, with a $2\frac{1}{2}$-foot depth at the forks of the canal. Work on this canal commenced in 1870. Twenty-seven persons joined in an agreement under which the canal was to be constructed, and which provided that each person was to bear a proportional part of "all expenses above" his "further boundary." It was at first made 18 feet wide on the bottom near its head, and 10 feet wide at 5 miles below its head. It was enlarged in 1873. The first head gate was constructed in 1872 and is reported to have had a width of 18 feet. It was washed out the following winter and was at once replaced by another, which was in use till 1876. After this second regulating gate was swept away the canal was operated without an upper gate until 1879, when the third regulator, 40 feet wide, was built, at a cost of about $3,000.

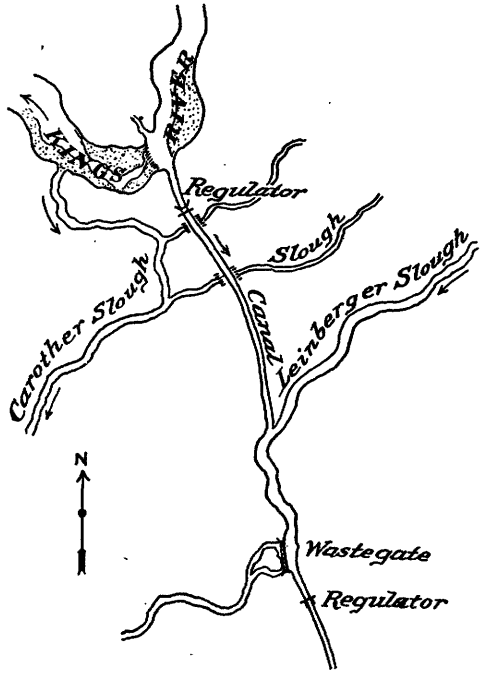


FIG. 20.—Upper section of Lower Kings River Canal.

The canal was built and is owned by those to whom it supplies water. Its owners, who had organized as a company, formed a corporation in 1873, with a capital stock fixed at $30,000, in 100 shares.

The water in the canal is supposed to be represented by those shares of stock which have been issued, which is a little more than one-half of the full number of shares of capital stock. It is sold by directors of the company, but only to the extent of the shares which have been issued. Each of these represents a proportional part of the flow of the canal until such part exceeds 144 miner's inches. Water in excess of

this amount is at the further disposal of the company. Stockholders are preferred purchasers of water to the extent of the shares owned by each, and provided the application for water is made preceding a fixed date. Each share of stock is supposed to represent sufficient water for 320 acres. The annual cost of canal management and repairs is about $1,500 to $2,000. The first cost of the canal was about $30,000. For a number of years after organization all expenses were assessed upon the stockholders, but, this proving unsatisfactory, the plan of selling water was introduced, with good result. The extent of irrigation from this canal may be noted at about 10,000 acres.

Rhoads Canal.—Lands to the west of Lemoore to the extent of 3,000 or 4,000 acres are dependent in large measure upon the flow of the Rhoads Canal for irrigation water. This canal in its upper section has the appearance of a natural high-water channel. From a point on the south side of Kings River about 1½ miles below the head of the Lower Kings River Canal, this channel has a southwesterly course for 2 miles to Carother Slough. It is known as Wrights Cut, and is claimed to be the enlargement of a small ditch constructed many years ago. The Rhoads Canal is carried southward from the termination of this cut at Carother Slough about 7 miles. It has a bottom width of about 16 feet and carries water about 2 feet deep. Water is taken from Carother Slough so long as the slough has a sufficient flow; thereafter a little work is done at the head of Wrights Cut to turn more water from the river into the canal.

The canal is reported to have been in use since 1868. It replaced a small ditch, about 5 feet wide, which had been in use some years before. The canal belongs to a number of farmers, who by mutual agreement apportion its water and expense of maintenance among themselves. There is no regulator at the head of the canal. Water is taken by each irrigator as he may require it. No water is sold, and all contributions toward expenses of maintenance are voluntary, as there are no means of enforcing their payment.

There are times when much more water flows in Wrights Cut than can be carried by the lower sections of the canal. The surplus reaches Green Slough through Carother Slough, thence Esrey Slough and other natural channels, and is finally reclaimed for the irrigation of lands about 4 miles southwest of Lemoore.

Jacobs Canal.—This is a private high-water canal, constructed about ten years ago for the benefit of lands along the northern margin of Tulare Lake, below the lake's high-water line. Its head is about 6 miles southwest of Lemoore.

SUNSET IRRIGATION DISTRICT.

As the construction of the works for this district has not commenced, a brief reference to the district and its proposed source of supply will suffice. The district covers the lowest portion of the west side plain of San Joaquin Valley, extending northward from the southern limit

of Tulare Lake about 70 miles, to within 3 miles of Las Juntas, the point where Fresno Slough unites with San Joaquin River. Its width ranges from 1 to 12 miles and its area is about 363,500 acres. The district organization was completed in March, 1891. After estimates of the cost of works necessary for its irrigation were made, a bond issue of $2,000,000 was voted. Of this bond issue $250,000 were paid for water rights, reservoir site, and rights of way.

The plan of irrigation involves the construction of a large reservoir in the vicinity of Summit Lake, which is to be formed by the construction of two embankments of earth, each crossing the valley trough from east to west. Water is to be supplied to this reservoir from Kings River by way of Cole Slough, the enlarged Grant Canal (which is to be used in common with the owners of the Grant), and a canal extension to be carried from near the lower end of the Grant Canal in a direction a little south of west across the North Fork of Kings River to the reservoir site. From the reservoir there is to be a canal northward and a second one southward, both supplied with water by gravity flow from the reservoir. In addition to these two low-level canals there are to be eight other canals, four northward and four southward, each 11 feet higher than the one next below, and each to be supplied with water by means of centrifugal pumps arranged in four pumping stations.

The specifications drawn for this work do not indicate how the seventeen pumps that are prescribed are to be apportioned to the several pumping stations. The pumps are each to have a capacity of 100 second-feet raised 11 feet. The district canals are to be of sufficient size and length to carry water to all parts of the district. The requirements concerning canal dimensions are not made specific; they are to be suitable to the service required, which, it appears, remains to be determined as work progresses. The aggregate length of the proposed district canals is estimated at 500 miles. The contract for the construction of the canal system complete, including the necessary pumps, engines, and boilers, has been let for $1,500,000, and the same person who has taken this contract is also the purchaser of the bonds of the district. It is distinctly expressed in the contract that in case the bonds are not taken the contract may, at the option of the district directors, be set aside. The contract was made several years ago, and was conditioned upon a decision by the Supreme Court of the United States sustaining the irrigation-district law. This having been rendered, it is understood that the contractor has now declared his readiness to proceed with actual construction work.

THE FRESNO PLAINS.

DESCRIPTION.

The main canals which divert water from the north side of Kings River at or near the upper end of Centerville Bottoms and command that portion of the San Joaquin Valley plain in the vicinity of Fresno, Selma, and Kingsburg may be designated the Fresno group of canals. These canals are the Kings River & Fresno Canal, the Fresno Canal, the Fowler Switch Canal, and the Centerville & Kingsburg Canal, all of which have already been described. Their branches extend throughout an area of nearly 400 square miles, which before canal construction was a treeless, sandy plain. It was almost devoid of natural water courses. The few creeks whose periodical flow reached the eastern border of the plain to the north of Kings River were soon lost, and there was no sign of a channel beyond their "sinks." The natural water courses in the eastern portion of the district under consideration, in their order northward from Kings River, were Burns Slough, Kip (Lone Tree) Slough, Mud Slough, Mud Creek, Fancher (Fanshaw) Creek, Red Bank Creek, Frolic Creek, and Big Creek. Of these, the first three lie to the south of the point of the mountain which with gentle slope extends westward on the north side of Kings River to a point 2 miles north of Centerville. Burns Slough is a tributary of Kip Slough. The sink of Fancher Creek, now a fine vineyard, is about 4 miles east of Fresno. The waters of Red Bank and Frolic creeks, after uniting in one channel, spread and disappear 6 miles east of Fresno, near where Temperance Colony has been established. The sink of Big Creek is several miles to the northwest of Fresno.

Some of the channels of these creeks have been made part of the canal system. Portions of Burns Slough and Big Creek are utilized for water of the Kings River & Fresno Canal. Other portions of Burns Slough, Kip Slough, Mud Slough, Mud Creek, and Fancher Creek are now the main channel of the Fresno Canal. Lone Tree Creek is an important distributary of the water of the Fresno Canal. By the utilization of these natural water courses the canals are made the recipients of the drainage water from the foothills, and are, at time of considerable rainfall, taxed beyond their capacity, and have repeatedly in the last few years inundated parts of Fresno and vicinity. A proper drainage system in this locality is now recognized as a necessity, and no doubt will be planned and executed in the near future. The general slope of the Fresno irrigated region is from northeast to southwest, at the rate of 5 to about 7 feet to the mile. The surface of the country for the most part is very smooth, though broad belts of hog-wallow or knolly ground are occasionally found. The knolls of these hog-wallow belts are generally 1 to 2 feet in height, rarely as high as 3 or 4 feet. The knolls are close together, and diameters at the

base of from 20 to 40 feet are most common. Where they occur the expense of preparing land for irrigation is increased. Except where unusually high they do not interfere seriously with ordinary farming operations when land is not irrigated. They often indicate land of inferior quality, hardpan being frequently found beneath a shallow layer of surface soil.

Near Centerville the soil of the upland is a red sandy loam, resting on a yellow clay hardpan, which is usually at 4 to 6 feet below the surface. Hardpan is not continuous; it disappears frequently at about one-half mile from the margin of the upland, where the surface soil becomes lighter and more sandy. At depths of 10 feet or more beds of cobble and gravel are found, which in proximity to the low river bottoms afford thorough underdrainage to these lands. The soil is very productive. Ground water is at 12 to 15 feet below the surface.

Westward from Centerville toward Fresno the soil of the plains is a loamy sand. This generally rests on a firm clay hardpan, which is sometimes impregnated with sand. Soil is from 1 to 3 feet deep. At the sinks of the several creeks near Fresno the soil is a deep, heavy, red loam, baking on the surface after being wet. Where a hardpan substratum is encountered at all it is at 10 to 30 feet below the surface. Westward from the immediate vicinity of the sinks of the creeks the soil is a loamy sand, several feet deep, resting on a firm clay hardpan. The soil far toward the southwest merges into the sandy soils of the alkali belt which skirts the edge of Fresno Swamp, and these in turn are succeeded by the rich peaty alluvium of the swamp lands. To the south of Fresno the sandy soil of Fresno and Central California colonies changes to the light so-called ash of Washington Colony. The hardpan dips farther below the surface toward the south, and there are points in the latter colony where it has disappeared altogether. In the southern and southeastern portion of the region commanded by this canal system sand predominates. The surface of the country is comparatively smooth, though occasionally crossed by low sand ridges. Firm hardpan, partaking of the nature of cemented sand, immediately below the surface soil is rarely found. It occurs most frequently where the surface presents the peculiar hog-wallow appearance.

The rainfall in the region commanded by the Fresno Canal system is greatest near the base of the foothills. It decreases from there toward the west. At Centerville the average fall of rain is about 16 inches, while at Fresno and Kingsburg it is 9 inches. The average fall at Firebaugh, 30 miles to the west, in the trough of the valley, is about two-thirds of that at Fresno. For the irrigated region near Fresno the mean annual fall of rain may be noted at about 9 to 10 inches. When this amount of rain falls at the proper time it is sufficient to insure fair crops of grain. Throughout a large part of the region rainfall is relied upon to produce a crop, and irrigation of grain is resorted to only when an unusually dry spring threatens the destruction of a growing crop. The products which can not be raised without irrigation are alfalfa,

grapes, fruits of all kinds, including citrus fruits, corn, melons, etc. Two of the canals irrigating lands near Fresno have a perennial flow; the others divert water only during medium and high stages of the river, generally from January to August, inclusive. The aggregate capacity of the four canals already enumerated is about 1,550 second-feet. None of them, however, flow for long periods at their maximum capacity. The demand for water is, fortunately, greatest at the time when the flow of the river is greatest, during spring and the early part of summer.

THE CANAL SYSTEM.

All of the canals of the Fresno system take water from Kings River above Centerville. Each of them is out upon the upland before passing that village. Such duplication of canal work seems unnecessary.

Each of these canals was constructed for the purpose of supplying water to some particular point or place of use; thus, the Fresno Canal to irrigate lands in the immediate vicinity of Fresno, the Kings River & Fresno Canal to irrigate a strip of land just north of the Fresno Canal, the Centerville & Kingsburg Canal to irrigate lands near Selma, and the Fowler Switch Canal to supply water to the vicinity of Fowler and lands westward from that point. By reason of such special requirement in each case, each canal received an alignment as direct as possible from the proposed source of water to the point of delivery. The main canals were therefore constructed without attempt to hold them to any uniform grade. They have alignments in the direction of the greatest fall of the country, and generally, when their grade is excessive, check weirs are used to prevent erosion. The flow of water in the Kings River & Fresno Canal and in the Centerville & Kingsburg Canal is thus regulated. The regulation in the case of the Fresno and the Fowler Switch canals is only partial. The water of the former of these canals in Fancher Creek is generally 8 to 15 feet below the surface of the ground, its elevation being uncontrolled by structures.

The Fowler Switch Canal was constructed on a very irregular grade line. Its grade, when possible, was placed at 1.92 feet to the mile, which was established as the minimum gradient. At some points, however, the grade was no less than 12 feet to the mile for short distances. The dimensions of the canal were calculated on a basis of a fall of 1.92 feet to the mile, and were not modified for heavier grades. Consequently, canal dimensions where this grade was exceeded are excessive. The canal was originally constructed without structures, either for the regulation of its flow or to facilitate diversion. Rapid erosion at once commenced where the canal bed was not in very firm material, and after a short experience a limited number of check weirs were put into it at the points where most required. The structures in this and in the other canals of the district are very light timber affairs, but generally well adapted for the purpose which they are to serve.

In view of the fact that the irrigation of this region has in the past

caused a rise of the ground-water plane, and that it will continue to influence its elevation, the question whether water has been or is being lost by the apparent duplication of canals remains an open one. Certain it is that were all water drawn from the river in one main canal it would still be necessary for branch canals to extend to every portion of the irrigated region. The ground water would be expected to rise equally as rapidly as at present, and the only marked saving of water would result from the exposure of a decreased surface area of flowing water to evaporation, and, in this special case, from a possible reduction of the flow of water from the main canal through subsoils back into Centerville Bottoms.

LOSS OF WATER BY EVAPORATION AND SEEPAGE.

The loss by evaporation, when expressed in second-feet, is small for any of the canals of the Fresno system when compared with their capacity or with the total loss by infiltration into subsoils. The State engineering department made experiments to determine the rate of evaporation in this vicinity. The observations were extended through a four-year period at Kingsburg.[1] The greatest total monthly evaporation during the four years 1881 to 1885 occurred in August, 1883. The amount of water evaporated in that month from an open sheet of water was equivalent to a depth of 0.945 foot. At this extreme rate per month the loss by evaporation from the surface of the Fresno Canal throughout the 24.5 miles of its length, if the canal be considered 60 feet in average width (which allows ample margin for wet banks), would have been equivalent to a continuous flow of 2.8 second-feet.

To determine the amount of water which sinks into the subsoils from the canals of this region, measurements of their flow were made in the summer of 1882 by the writer, then assistant State engineer. The results will be found on pages 76 and 77, in tabular form. For the better understanding of the results presented in the tables it is necessary to refer briefly to the character of the several canals and ditches whose flow was at that time measured.

The Kings River & Fresno Canal at its head cuts at once into the upland to the north of Centerville Bottoms. For a long distance it is nearly parallel and sometimes very close to the Fresno Canal, with a water surface at a higher elevation than that of the latter. At many points the canal carries its water above the surface of the adjacent plain. Ponds and swamps were kept full of water which the canal lost by percolation. The canal, throughout the last few miles of its first 12, lies in a good channel with hardpan bed. The loss of water in the upper 12 miles was at the rate of 3.77 second-feet per mile. In 1882 the section of the canal below Red Bank Creek was poorly maintained. Water was allowed to spread out in ponds, and a former channel lying parallel to the present canal, and generally very close to it, frequently carried part of the canal waters. No lands on this section of the canal were

[1] See Physical Data and Statistics, Wm. Ham. Hall, State Engineer of California, p. 379.

irrigated close by the main canal. Ground water was at 20 feet or more. An indurated clay hardpan lies below the surface soil along this portion of the canal. Here, throughout 4.76 miles in length of the canal, the average loss by percolation was 3.45 second-feet per mile, a trifle less than in the 12 miles above. In the next section of the canal copious irrigation of lands close by the canal, particularly on its south side, had been practiced for several years preceding the experiments. The soil is a light sandy loam, with ground water at 7 to 14 feet below the surface. The water surface of the canal was carried at about the elevation of the ground. The land is very smooth; no high levees are necessary to hold water in its channel. The canal is of uniform dimensions and character, and is better maintained than at points above. These circumstances all combined to reduce the loss by percolation, which, for 3.55 miles, was found to be 1.25 second-feet per mile. Evaporation at the maximum rate above noted would have caused a total loss from the 20 miles of the main Kings River & Fresno Canal under consideration of a little more than 1 second-foot, equivalent to a loss of 0.04 second-foot per mile in length of the canal.

The water of the Fresno Canal flows in natural channels throughout nearly all of the first 19 miles of its course. It lies in Centerville Bottoms for a mile, then, after passing through Long Cut, is carried along sloughs and depressions, frequently with a levee only on one bank. Willows, reeds, and grasses grow in the water and on the banks of the canal in that locality. In Mud Creek and Fancher Creek the canal water flows in the bottom of a narrow, deep channel. At the time of making the experiments, in June, 1882, there were 95.51 second-feet lost from the canal in the first $11\frac{1}{4}$ miles of its course below the point where it leaves the river bottoms. The loss of water was at the rate of 8.49 second-feet per mile.

The ground-water plane was quite close to the surface of the ground near the Fresno Canal in its next section, from the Limbaugh dam (the head of the Fresno Mill Ditch) to the head of the Washington Colony branch, a distance of 7 miles, throughout which the total loss by percolation was only 5.20 second-feet, or 0.74 second-foot per mile. Here the depth to ground water ranged only from 4 to 10 feet, and the surface soil and the subsoils were kept saturated by water diverted for irrigation. The canal lies in a natural channel. Its water surface is generally 2 to 4 feet below the surface of the ground. From the head of the Washington Colony branch the main canal flows for 4 miles in an artificial channel of uniform dimensions. Water is carried at about the elevation of the surface of the ground. The lands adjacent to this part of the Fresno Canal were practically unirrigated in 1882. Ground water was not so near the surface as in the preceding canal section. The total loss in this section of the main canal was found to be 3.81 second-feet, or 0.95 second foot per mile.

The Centerville & Kingsburg Canal, for about 8 miles after it is out upon the surface of the upland, has a course nearly parallel to the

edge of the bluff from upland to the river bottoms, and less than half a mile distant from it. For several miles the canal is within several hundred yards of the edge of the descent to the bottoms, which lie 20 to 30 feet below the surface of the upland. This location in porous soils and subsoils causes great loss of water by percolation. Nearly 86 second-feet were lost by the canal in less than 6 miles, and in its seventh mile the canal lost 52 second-feet. This last result is based on measurements of the flow of water over two weirs 1 mile apart, apparently in good condition. The average loss per mile from the canal in the 5½ miles of the upper section examined was 15.63 second-feet.

Loss of water from the Kings River & Fresno Canal.

Name of canal or ditch, and locality.	Distance below head of canal, in miles.	Discharge, in second-feet.		Loss between stations, in second-feet.	
		Main canal.	Diverted.	Total.	Per mile.
K. R. & F. C., one-half mile below head	0.50	133.83	.....		
Burns Ditch	1.00	.....	0.25		
Hansen Ditch	4.00	.....	3.23		
Fancher Creek (wastage)	8.00	.....	.30		
Ditch on south side	8.00	.....	4.05	43.36	3.77
Do	9.00	.....	.05		
K. R. & F. C. at Hawkins Weir	9.00	[1]78.18	.....		
Wastage	.....	.....	.15		
Ditch on south side	11.50	.....	2.04		
K. R. & F. C. in Red Bank Creek Flume	12.00	80.40	.....		
Dog Creek (wastage)	13.25	.....	.15		
Ditch on north side	16.00	.....	3.36	16.50	3.48
Eggers Ditch	16.75	.....	4.67		
K. R. & F. C. at Eggers Weir	16.75	55.72	.....		
K. R. & F. C., west line of section 17	17.75	[1]49.56	.....		
Ditch on south side	17.80	.....	3.08		
Scandinavian Colony Ditch	18.25	.....	3.86		
K. R. & F. C. at upper Scand. Col. Weir	18.25	[1]36.74	.....		
Scandinavian Colony Ditch	18.35	.....	1.46		
Do	18.50	.....	2.42		
Do	18.60	.....	1.00	4.44	1.25
Do	18.70	.....	2.39		
Do	18.80	.....	14.50		
K. R. & F. C., lower Scand. Col. Weir	19.00	[1]25.51	.....		
Big Creek (wastage)	19.25	.....	1.50		
Wastage	.....	.....	.20		
Ditch on north side	19.75	.....	.43		
Cooper & Helm Ditch	20.25	.....	8.71		
K. R. & F. C. at Cooper Weir	20.30	11.73	.....		

[1] Approximate.

Loss of water from the Fresno Canal.

Name of canal or ditch, and locality.	Distance below head of canal, in miles.	Discharge, in second-feet.		Loss between stations, in second-feet.	
		Main canal.	Diverted.	Total.	Per mile.
Fresno Canal at Road Bridge	1.25	381.00	.....		
Centerville Branch	1.75	.....	17.80		
Lone Tree Branch	3.25	.....	69.39	95.51	8.49
Ditch on south side	5.00	.....	.50		
Limbaugh Dam Ditch	12.50	.....	58.72		
Fresno Canal at Limbaugh Dam	12.50	139.08	.....		
Briggs Canal	14.00	.....	.30		
Eisen Canal	14.00	.....	14.09		
Fresno Canal at Hobler Dam	14.00	107.88	.....		
Easterby Ditch	17.25	.....	5.60	5.20	.74
Malters Ditch (north)	19.00	.....	6.30		
Malters Ditch (central)	19.00	.....	1.69		
Washington Colony Branch	19.50	.....	45.50		
Fresno Canal at head of Wash. Col. Branch	19.50	60.40	.....		
Fresno Colony Canal	23.50	.....	14.15		
North Central Colony Canal	23.50	.....	13.88	3.81	.95
Main Central Colony Canal	23.50	28.16	.....		

Loss of water from the Centerville & Kingsburg Canal.

C. & K. Canal, one-half mile below head	0.50	346.00	.....		
Ditch on west side	5.50	.....	5.06	85.94	15.63
Do	5.75	.....	4.00		
C. & K. Canal at weir, in sec. 23	6.00	251.00	.....		
Garfield Canal	7.00	.....	26.65	52.35	52.35
C. & K. Canal at weir, in sec. 26	7.00	172.00	.....		

Other examples of the loss of water from smaller ditches by percolation into the subsoil are the following:

On June 21, 1882, water was being used for the irrigation of a vineyard in Scandinavian Colony. The water was diverted from the main supply canal into a small ditch about 2 feet wide. It was conducted past alfalfa fields and vineyard lands a distance of one-half mile to the point where it was being used for irrigation. The soil crossed by the ditch is a sandy loam, with ground water at 8 feet below the surface. Water was measured at the point of diversion and at the point of delivery in exactly the same way, over small overfall weirs. The amount diverted was 1.70 second-feet, and the loss in transit 0.79 second-foot.

On June 14, 1882, the orchard of the Gould Ranch north of Fresno was being irrigated. The water used for this purpose was flowing in a ditch having an average width of 3 feet. One mile above the point where the water was being used the discharge of the ditch was 2.41 second-feet. The loss by percolation before reaching the point of delivery was 1.42 second-feet. Shade trees were growing along portions of the ditch, and its banks were overgrown with grass. The ditch had been in use several years. The soil through which it flows is a sandy loam 5 to 8 feet deep.

On June 26, 1882, a ditch which leaves the Fresno Canal at a point about 4 miles east of Fresno was carrying 5.60 second-feet near its head. One mile below it was receiving 0.03 second-foot, and at other points 0.64 second-foot; its flow 4 miles below its head was only 1.89 second-feet; it had lost 4.38 second-feet. This ditch has an average width of about 8 feet. It carried its water at or a trifle above the level of the ground's surface.

EFFECT OF IRRIGATION ON THE WATER TABLE.

In no other irrigated region in California is the effect of irrigation on the elevation of the water table so plainly apparent as in the vicinity of Fresno. Here, notwithstanding the 6 feet per mile slope of the surface of the country, the subsoils have been and are being gradually saturated with water. When irrigation commenced the loss of water from canals in transit to lands to be irrigated was very great, and after reaching its destination it was found that frequently enough water was put upon the surface of individual small tracts of land to have covered them to an average depth of 15 to 20 feet in a season. Most of this water found its way into subsoils, together with the direct loss of water from the canals. When the first wells were dug at Centerville water was found at about 20 feet. It is now at 10 to 15 feet below the surface, and will probably not rise much higher on account of ample drainage of subsoils and a comparatively free subsurface flow toward the low river bottoms.

Along Fancher Creek, where the creek is used as a canal, ground water was formerly at 50 to 75 feet below the surface; it is now at 12 to 20 feet along the upper portion of the creek, and still nearer the surface near the former sink of the creek, about 4 miles east of Fresno. In the Eisen vineyard, 5 miles east of Fresno, ground water is at 4 to 6 feet below the surface, and drain ditches have been constructed to prevent a further rise. Ground water is found at 4 feet below the surface in many parts of Temperance Colony, Nevada Colony, and Fresno and Central colonies. Throughout a considerable area near Fresno its surface is nowhere more than 16 feet below ground, though before irrigation commenced depth to water was 60 feet. Cellars which were in use until 1884 in Fresno have been condemned because ground water made its appearance in them. Near Selma and Kingsburg

ground water was formerly found at about 30 feet. It is now at about 15 feet. The so-called "Sand Hollow," which is a depression 100 yards to one-fourth of a mile wide, 12 miles long, and about 16 feet deep, having a southerly course and passing about midway between Selma and Kingsburg, was formerly as dry as the surrounding plain. About 1880 the soil in its bed was found to require less moisture to produce crops than the adjacent plain; in 1885 water appeared at the lowest points of the bed, and in June of that year it had risen to the heads of ripening grain. Spots of black alkali now mar its bed and sides, which before were a light sand, apparently free from any excess of alkaline salts.

Near Sanders and at points eastward from there toward Kings River ground water was at 50 to 60 feet before irrigation commenced; it is now at 20 to 30 feet. Here, as in the case of Centerville, proximity to the river, which lies 60 feet below the surface of the plain, may interfere with a much greater rise of the ground-water plane.

In connection with this change in the elevation of the ground-water plane, it must be remembered that the effect of irrigation extends far beyond the points now under ditch. Owing to the slope of its surface and consequent hydrostatic pressure, ground water has a slow but certain motion westward through pervious subsoils of the Fresno region, and may therefore ultimately contribute more or less toward the flow of Fresno Slough and San Joaquin River.

METHODS OF IRRIGATING AND DUTY OF WATER.

At the time irrigation commenced near Fresno the soils and subsoils were dry; depth to ground water was 30 to 60 feet. The ground was porous, generally sandy, sometimes very hard on the surface. When wet it was converted into a bog. Water passed through it readily into the lower strata. Thorough wetting compacted the soil, and it was less liable to conversion into slush after the first and second wettings than before. It settled, as a result of the first wetting, about 8 inches to 1 foot, on an average. Sometimes the full supply of a ditch would flow for hours into a hole formed by the breaking in of the surface. Cavities 20 feet in diameter and 6 to 10 feet deep were occasionally formed in this way, and had to be refilled after the first wetting. The stability of buildings was in danger when water was first brought near them. It is not surprising, under these circumstances, that when irrigation commenced in this region sometimes enough water was run on small areas at one irrigation to have covered them 5 feet in depth, and that enough water was delivered to some of the 20-acre colony lots south of Fresno to have covered them to an average depth of 20 feet. After irrigation was practiced for a time the soils became more compact, absorbed water less rapidly, and a smaller amount of water passed into subsoils. At present the ground water near Fresno is so near the surface that the roots of alfalfa, vines, and trees readily penetrate to

it and soils are kept moist by the water rising from below. Surface wetting has become unnecessary in many sections.

Where land is held in tracts of 20 to 40 acres, as in the colonies near Fresno, the subdivisions of alfalfa, vineyard, orchard, etc., are small. The individual irrigator has but a small area of soil to moisten and, because many irrigators in his neighborhood necessarily require water at the same time, he can probably command but a small flow with which to accomplish his irrigation; consequently he devotes more than ordinary care to the preparation of his land, and if the duty of water is not so high on his lands as it ought to be the good will of the irrigator is not at fault.

The subdivision of land holdings into small tracts and the greedy absorption of water at the outset by the dry soil of the Fresno plains were the prime factors which have controlled methods of irrigation. That which most frequently found favor was flooding in small checks whose surface had been made perfectly level, it being extremely desirable to quickly cover the whole surface to be wet with a thin sheet of water. Drainage appeared unnecessary, as all surplus water delivered into a check rapidly sank into the ground.

The area of these level checks generally ranges from one-quarter of an acre to 2 acres. They are nearly always made rectangular. In alfalfa fields the levees inclosing them are often made so flat and low that farming implements can pass over them. Their position is adapted to the configuration of the country, in order to make the work of leveling as small as possible. Irrigation ditches are so arranged that there is an inlet from a ditch into each check. No drains are provided. All surplus water entering a check is allowed to sink into the soil. The cost of preparing land in this way has been variously stated by the irrigators at from $15 to $50 per acre.

Water is admitted into the several checks through small gates, or occasionally through small sluice boxes, generally constructed of 1-inch redwood. Water in the irrigating ditches is controlled by means of small gates closed by loose boards moving easily in vertical grooves. Sometimes a notched board is set across the ditch, so arranged that the notch can be closed by means of a board upon either side of the notch.

The system of flooding in checks formed by contour levees, which has found much favor with Kern River irrigators, is in use only for the irrigation of large tracts of alfalfa, but where used in the vicinity of Fresno the area of the checks is kept small, rarely exceeding in any case 3 or 4 acres, whereas in the Kern River country the area of a single check frequently exceeds 10 acres. Contour levees are lower for checks of smaller area. The expense of ground preparation is greater, but irrigation is more economical, as with small checks much time and water are saved. The contour levees usually follow closely 4-to-6-inch contour lines. Soils are so porous that irrigation in each check is complete when water has been made to cover its whole area,

otherwise there is no deviation from the ordinary practice of irrigation in contour checks.

A third system of flooding is sometimes practiced, though it has not found general favor. It is that of flooding the surface with water from small ditches which are carried along the tops of ridges, or very nearly on contour lines. The water of these is made to overflow one or both banks, and as the thin sheet of water flows over the surface it is guided and to some extent controlled by attendants. Unless the ground is very knolly this system requires but little preparation, except the construction of the irrigating ditches, but the application of water is attended with much greater expense than under the preceding systems. It has been in use for trees and vines as well as for alfalfa.

The furrow method of irrigation is growing in favor. It is practiced in many ways, according to conditions of surface slope and crops to be irrigated. When water is to be supplied to the surface of grain land in large areas it is generally done by the furrow method. Distributing ditches supply water to plow furrows or to small temporary ditches which are placed so close together that water can readily permeate the surface soil, particularly that portion of it which has been loosened by the plow. The furrows may be run on or near contour lines; they may be run in the direction of the greatest slope of the ground's surface, or they may be run in parallel lines between the rows of trees, vines, corn, vegetables, etc. Sometimes this system of irrigation is practiced in level checks for trees and vines in preference to the plan of flooding the whole surface.

When grain land is to be irrigated by the furrow method the furrows are drawn 8 to 12 feet apart in the direction of the greatest slope of the ground, unless this be so great that water flowing in the furrows would cause erosion. Should this be the case they are drawn obliquely to the greatest slope. The irrigating ditches are located on the ridges, if there be any, or on grade at intervals of one-half to one-quarter mile from near the upper edge of the tract to be irrigated, and about parallel with it, to near the lower edge of the tract. The irrigation commences at the highest point of the field from the upper ditch. Water is admitted into a number of furrows, in which it flows until moisture reaches the next ditch; it is then turned into other furrows, until all the furrows between the first and second ditches have been wet. Hereupon the water is turned into the second ditch, another set of furrows is wet, and so on until irrigation is complete.

This system of wetting from furrows is practiced for grain land as well before seeding as when a growing crop is to be irrigated. In the latter case the refilling of small ditches and furrows that would otherwise interfere with harvesting operations adds somewhat to the expense of irrigating.

Under the furrow system of irrigating each attendant ordinarily controls about 1½ to 2 second-feet, and water is generally turned off at

night, owing to the difficulty of controlling it in the dark. On the sandy soil of the region covered by the Centerville & Kingsburg Canal, where this methed of applying water has found more favor than elsewhere, irrigation progresses at the rate of about 2 acres per day for each second-foot of water. Each irrigation is there equivalent to an average depth of one-half foot of water over all the land irrigated. It should be stated, however, that very little wheat land is regularly irrigated on the Fresno plains at points where water must be applied to the surface soil. Irrigation is rather a last resort to save a growing crop which the farmer hoped would mature without irrigation. For the regular irrigation of grain land it is customary to rely upon one irrigation in the fall of the year before plowing. The moisture then absorbed is sufficient to supplement the scant rainfall and make a good harvest reasonably certain.

The lack of natural deep-cut drainage lines through the lands of the Fresno district has already been alluded to. Their absence has made possible the remarkable filling of the subsoils with water and the rising of the ground water to within a few feet of the surface. Whenever ground water is brought so near the surface that capillary attraction and the hygroscopic properties of soil cause water to rise sufficiently high to moisten the surface layers of soil, other methods of supplying moisture become unnecessary. Crops are irrigated if ground water is permanently held at this height, or if it is so frequently raised to this height that the soils under cultivation receive all the moisture required from below. Where water is thus brought within reach of plant roots the system of irrigation is locally often referred to as "irrigation by percolation." It becomes a system when, as in the Mussel Slough country south of Kings River, the canals at the proper season supply the requisite amount of moisture to the cultivated tracts without burdening them with an injurious surplus during the rest of the year.

By the rising of the ground-water plane near Fresno large tracts of land have been permanently moistened. Some are very thoroughly subirrigated, and in many instances injuriously so. Relief must be sought in some localities either by drainage or by proper regulation of the supply of water to the district, whereby the elevation of the water table may be controlled.

Near the Fresno Canal, about 7 miles northeast of Fresno, lands were already too moist in 1882 to permit farming operations. Drain ditches 4 feet deep were then in use in Temperance Colony to drain the surface soil. In 1885 drain ditches 4 to 6 feet deep were in use in the Eisen vineyard, 5 miles east of Fresno, to keep ground water at least 4 feet below the surface of the ground. Parts of the town of Fresno, parts of Fresno and Central colonies, and lands to the north and west of Fresno may be cited as other instances of the too close proximity of ground water to the surface.

Some reference has already been made to the time of irrigating cer-

tain kinds of crops and the amount of irrigation accomplished by a stated amount of water. Some further illustration of the time when water is required for different products, and of the quantity absorbed by soils under the various conditions of irrigation in this vicinity, may not be out of place here.

Alfalfa, except when the water table is so near the surface that soil is kept moist from below during the entire growing season of this plant, is almost invariably irrigated once for each crop of hay cut. The first irrigation is early in spring and the first hay is cut in May; the succeeding ones at intervals of about five or six weeks. The number of crops cut is generally four; the average yield per acre is 1 to 1½ tons per cutting. Irrigations subsequent to the first of the season are given either before or just after the cutting of each crop. It is said in favor of irrigation before cutting (about one week or ten days) that then the ground's surface is shaded, it does not bake so hard in drying, and the new growth of alfalfa is better able to withstand the heat of the sun than if subjected to an irrigation after the hay is cured. But, whenever alfalfa is irrigated before cutting, in checks not perfectly level, water in some parts of these stands too long about the plant, too much of the plant is submerged, and the quality of the hay is impaired.

Where the ground water is so close to the surface that it supplies sufficient moisture to alfalfa land, occasional floodings are necessary to drown gophers.

Trees and vines were, until the last few years, very copiously and very frequently irrigated in this region. Trees were generally watered three or four times during the spring and summer; vines sometimes every two to three weeks. The water during the first years of irrigation near Fresno was, almost without exception, applied to the surface, and the result was that the roots of trees and vines frequently failed to penetrate into the subsoils, entailing evils which could not easily be corrected and which were particularly apparent in the quality of the product. The lesson was not quickly learned, but there has been decided improvement. Less moisture is supplied to the surface soils and greater care is taken to keep the surface well cultivated. Capillary attraction is thus interrupted at the depth to which the plow has penetrated, less moisture is brought into direct contact with the air, evaporation is consequently reduced, and plants are enabled to get the greatest possible benefit from the moisture already in the soil. Some examples from actual experience may illustrate how water is here used.

On June 16 to 17, 1882, 5 acres of alfalfa in small checks thoroughly leveled were irrigated in eight hours, from 6 p. m. to 2 a. m., in Central California Colony. The head of water used was 0.84 second-foot. The amount of water absorbed by the soil was equivalent to a depth of 0.11 foot over the entire 5 acres.

On the 17th of June, 1882, in Central California Colony, a supply of 2.26 second-feet was divided into four parts and each admitted into an

alfalfa check having an area of 1¼ acres. The irrigation of the alfalfa commenced at 6 a. m., and at 4 p. m. the water had been made to cover the entire area of each check. Alfalfa was being irrigated before cutting. The checks were level and no water was drawn off. The total amount supplied was equivalent to a depth over all of 0.37 foot. The soil was sandy loam; hardpan was 6 feet below the surface; ground water at about 12 feet. Less water would have been required if the whole stream had been admitted in turn to each check.

On June 12, 1882, in Central California Colony, two checks of alfalfa, 290 by 130 and 290 by 200 feet, respectively, were irrigated at the same time with 1.2 second-feet. Water was applied from 9 a. m. to 8 p. m. The total amount supplied was equivalent to a depth of 0.49 foot over the whole area of the alfalfa. The soil was a sandy loam, with hardpan at 1 to 2 feet. This alfalfa was to receive five such irrigations during the season.

On the Gould Ranch, north of Fresno, one attendant in 1882 handled about 1 second-foot of water. With this amount of water orchard lands were irrigated at the rate of about 4 to 5 acres per day of twenty-four hours. The average depth of the water applied over the whole surface of the orchard was 0.40 to 0.50 foot. The orchard received two to three irrigations per season. The trees of the orchard are set about 16 feet apart in rows 24 feet apart. Water was run in small ditches along each row, and was made to stand around the body of each tree while irrigation was in progress. The surface of the ground was not leveled when the orchard was set out. The soil is a heavy, dark loam, with hardpan at an average depth of 5 to 7 feet.

About 4 miles northeast of Selma 2 to 3 acres of vines or trees could be irrigated in 1882 in one day of twelve hours with 1 second-foot of water. The soil is a sandy loam, with no hardpan under it. It bakes on the surface in drying. Ground water was then some 40 feet below the surface. The method of irrigation is that of running water in furrows between rows. Several such irrigations per season are given to trees and vines.

In the same vicinity in 1882, irrigation of grain with 2 to 3 second-feet was progressing at the rate of 3 to 4 acres per day of twenty-four hours. The method of irrigation was the furrow method. Furrows were 10 to 12 feet apart. The soil was thoroughly saturated by percolation. The amount of water absorbed was sufficient to have covered the entire surface to a depth of 1.42 feet. One irrigation at any time after harvest is sufficient to mature the grain crop of the next season. The soil is a sandy loam, which bakes after wetting, unless cultivated before drying. Hardpan is not continuous; where it does occur it is generally at 8 feet below the surface. Ground water is at 35 to 40 feet.

On June 12, 1882, in Central California Colony a small check of grape-vines, one-fourth acre, was irrigated in fifty-five minutes. The check was level and all water standing in it at the end of the fifty-five minutes

was allowed to soak into the ground. The soil was still somewhat moist at the time this irrigation commenced. The soil is a sandy loam 1 foot deep, resting on a firm hardpan, through which holes were cut when the vines were set out. The amount of water supplied was 0.8 second-foot, and the total amount was sufficient to cover the ground 0.25 foot deep. The vines appeared thrifty and in splendid bearing. Such irrigation was repeated about every three weeks until the grapes had matured.

About a mile east of Selma, where the soil is a sandy loam 10 to 25 feet deep, with ground water at 24 feet, it was said in 1882 that 2 acres of wheat land could be irrigated in one day of twenty-four hours by one attendant with 1½ to 2 second-feet of water, equivalent to a depth of water over all of about 1.74 feet.

The foregoing statements must not be accepted as an indication of the ultimate duty of water on the Fresno plains. The area irrigated per unit of water will continue to increase, at least until irrigation produces no further permanent changes in the elevation of the ground-water plane.

Without attempting to express in detail the acreage irrigated per cubic foot per second of canal capacity or actual flow of water, it may be noted that the total volume of water brought to the vicinity of Fresno during the seventeen years 1879 to 1896 would at a very low estimate have covered to an average depth of about 0.8 foot per annum the entire 260,000 acres of the region through which the canals send their branches. It would have covered the 50,000 acres to whose surface water is actually applied to an average depth of 4½ feet per annum, or to a total depth of 75 feet. Some of this water has of course been consumed in sustaining plant life, more has been evaporated, but the most of it still permeates the subsoils of the irrigated region and of the lands to the west.

WILDFLOWER.

The Wildflower country is a small portion of the east-side plain of San Joaquin Valley just south of the Kings River delta lands. Its limits may be considered coextensive with the area covered by the Emigrant Canal and its branches. Sandy soils predominate, the heaviest being near Cole Slough in the southeastern portion of this region, and the lightest along its northwestern border. The usual strip of bad lands, strongly alkaline, is found at the south, near the overflow limit from Kings River. Hardpan does not appear in a continuous layer under the soil; it is found in spots or belts of small extent, generally 4 to 8 feet below the surface, and usually but a few inches thick.

For a number of years all the water used for irrigation near Wildflower was supplied by the Emigrant Canal. As this canal became unreliable as a source of supply (due mainly to litigation concerning

ownership of its head works), water from other canals, the Fowler Switch and the Centerville & Kingsburg, was brought into the same district.

The irrigating period while the Emigrant Canal was in full service continued from March to the end of August. All the water of the canal during that period was apportioned to the distributing and irrigating ditches, and was allowed to sink from these into the subsoils. The method of irrigation was essentially that of subsurface saturation, which will be fully described in the notes on the Mussel Slough country. Alfalfa fields are sometimes subdivided into small rectangular checks of one-half acre to 2 acres each, and receive an occasional flooding. The surface of the country is very smooth, and no leveling or smoothing of the surface was necessary, as at Fresno. All water delivered into a check is allowed to sink into the soil, which readily takes it. Orchards and vineyards are irrigated, while water is available, by conducting it between the rows of trees and vines in small ditches. Summer crops are irrigated by the furrow method. Before lands were irrigated ground water was here at 10 to 16 feet below the surface; it has risen, as the result of irrigation, about 6 feet.

LIBERTY AND MILLRACE SETTLEMENTS.

The region watered by the Liberty and Millrace canals is a continuation of the Wildflower country westward, and the same notes with reference to soils apply. Water supply has usually been restricted to a few months each year, and the process of subsoil saturation has been rather slow. Irrigation is accomplished by flooding in small contour checks or by filling small ditches or furrows between rows of trees, vines, corn, or vegetables. Water is so freely absorbed by soils that no drainage is necessary.

LAGUNA DE TACHE RANCHO.

This grant, which extends southwesterly along the north side of the main channel of Kings River a distance in a direct line of about 25 miles, from near Kingsburg to Summit Lake, embraces the major portion of the north-side delta lands. Its hydrographic features have already been dwelt upon, and but little more is to be said concerning the use of water upon it for irrigation. The surface of the ground is smooth; there are no irregularities except such as have been produced by Kings River waters. Predominating soils are deep, sandy loams. Some of the depressions near present water courses, particularly in the northwestern and northern portions of the rancho, have sedimentary soil. The upper portion of the rancho, along Cole Slough, is in the alkaline belt. The surface slope from east to west is about 4 feet to the mile. Near Kings River is a fine growth of oaks. Willow thickets abound near the river in the southern portion of the rancho.

The many delta streams have always furnished an abundance of water to subsurface strata, so that depth to ground water has never been very great—4 to 16 feet, varying somewhat according to locality, and no doubt also somewhat with the seasons. The local control of fluctuations in the elevation of the water table is one of the features of the method of irrigation. The canal supply is ample from February to August. Little or no water is put upon the surface of the ground. Tracts to be irrigated have ditches generally located on the slight ridges built up by former water courses, from which water sinks into subsoils. Surplus waters are drained from the flat depressions between these ridges by a simple system of drain ditches. Crops irrigated are principally natural grasses and cereals.

MUSSEL SLOUGH COUNTRY.

Description.—All of the Kings River delta south of the main channel of the river and west of Cross Creek is commonly known as the Mussel Slough country. Many water courses, locally called sloughs, former channels of Kings River, course through this region from north to south. The heads of most of these have long been filled with deposits from the river. Others have more recently been artificially closed. A great many have been made parts of the distributing system of the irrigation works of this region.

The surface of the Mussel Slough country slopes from northeast to southwest at the average rate of about 4 feet to the mile, which is only about one-half the fall of the ground's surface in the vicinity of Fresno.

The soil of this region is all sedimentary. Most of it is sandy loam, varying somewhat in texture and color in different localities. It is sandiest toward the east and northeast; heaviest toward the west and south, where it merges into the peaty clays of the swamp-land belt. From northeast to southwest, at Grangeville, a strip of land several miles wide extends through this region, whose soil is a dark, rich loam, generally considered of the best in the delta. All soils are deep, resting upon subsurface strata of sands and soft, sandy clays.

Before the construction of the irrigation canals in the Mussel Slough country, depth to ground water was 10 to 18 feet. It was found at greatest depth in the eastern and southern portions of the delta. Irrigation very soon brought the water table close to the surface of the ground, and throughout the irrigated portion of the south-side delta it does not now sink to over 8 feet below the surface. It has an annual fluctuation, rising during the spring months when canals are full of water, and falling again in the fall of the year. In some localities this rise is so pronounced that standing water appears in the depressions, forming ponds which do not entirely disappear until the close of the irrigating season.

Canal system.—The Mussel Slough country is supplied with water

for irrigation from Kings and Kaweah rivers. The former sends water through the Peoples, Last Chance, Lower Kings River, and Rhoads canals to the northern, central, and western portions of the south-side delta, while Kaweah River supplies water to its eastern portions through the Settlers and Lakeside canals. For about six months each year, commencing with February, Kings River furnishes an abundance of water for the canals leading from it. The canals from Kaweah River are not so copiously supplied with water, because that river is subject to greater irregularities of flow than Kings River. Their period of flow is not so long as that of Kings River canals, and is largely dependent on the conditions of the diversion of water at the head of St. Johns River, where conflicting interests of different irrigated regions have given rise to repeated modifications of natural channels. Ordinarily the flow of Settlers and Lakeside canals commences in January and continues to the end of June.

The total amount of water supplied to the Mussel Slough country by the canals above enumerated is sufficient to cover the entire area under these canals and their branches to an average of several feet per annum. It was sufficient in 1885 to cover the land which was then in actual cultivation in this part of the Kings River delta to a depth of about 4 feet.

Irrigation on a noteworthy scale commenced in 1870 in the Mussel Slough country when the Lower Kings River Canal was constructed. The construction and extension of the several other canals quickly followed. There has been but little extension of the canal system since 1880.

Each canal project (with the possible exception of the Mussel Slough Canal) had its origin with the settlers who needed water. The sole consideration in each case seems to have been the securing of a fairly reliable water supply at reasonable cost for use upon the lands of the projectors of each enterprise. This circumstance will account for the apparent duplication of canals; for, as the irrigated area was extended and additional lands were settled, it was but natural for the landowners of the new settlements to construct new canals and to control independent canal works. The seven canals that are or have been in use in the Mussel Slough country could well be replaced either by one main canal from Kings River or, perhaps better, by one such canal and one smaller one from Kaweah River.

The canals distribute water throughout the delta in a network of branches and natural channels, often so intertwined that large areas are benefited by the water of several canals at the same time. It happens, too, that lands whose owners have no claim upon water in any canal are here and there so favorably located that they are irrigated without cost to owners by the canals and ditches of their neighbors.

Method of irrigation.—The rainfall in the Kings River delta is only 9 inches per annum. Irrigation is necessary for the successful cultiva-

tion of all soil products. Cereals and alfalfa were practically the only cultures from 1870 until 1884. More attention is now given to fruit raising, to the cultivation of the grape, and to diversified farming.

To prevent wholesale inundation of south-side delta lands a levee is maintained along the south bank of the main channel of Kings River.

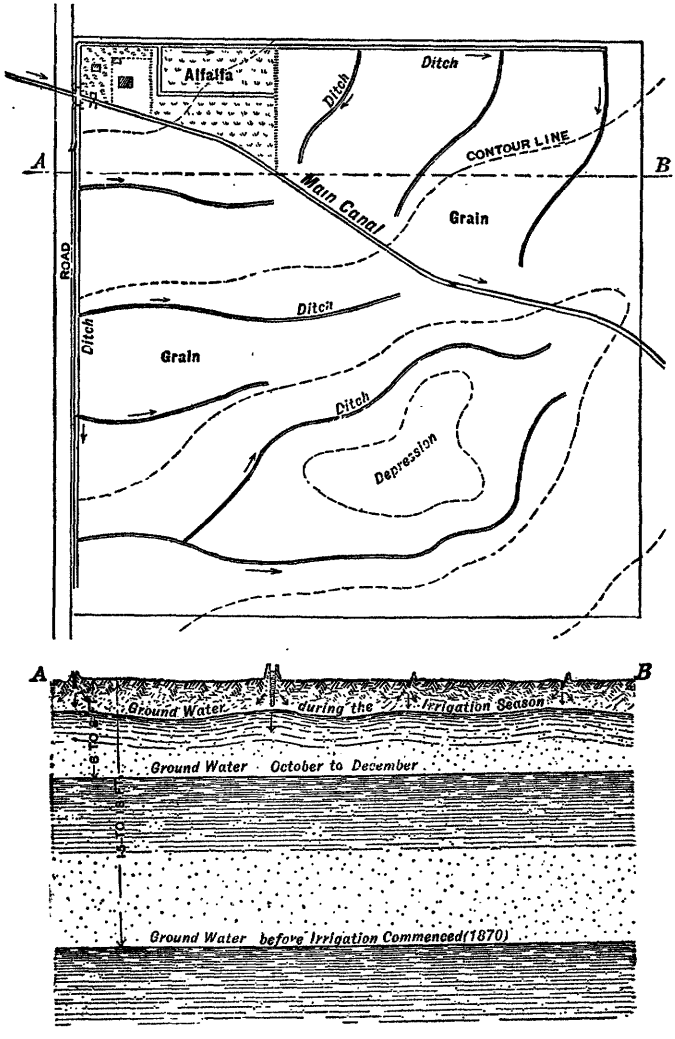


FIG. 21.—Irrigation by filling subsoils with water, Mussel Slough country.

The inflow of irrigation water into the district is controlled by means of regulators in the heads of the principal canals. The flow of water in some of the main canals and in most canal branches is sluggish, water being generally held at a very light grade, often by use of check weirs.

Water is rarely spread over the surface of the ground. This is done only in seasons when the supply to the canals comes late, or when gophers become too numerous in the alfalfa fields. The ordinary method of irrigation may be described as a periodical saturation of subsoils. From the time that water becomes available in the spring the canals and their branches, as well as small irrigating ditches, are kept as full of water as the available supply will permit. The water which sinks into the porous soils gradually saturates subsurface strata, bringing ground water within reach of plant life and sometimes even out upon the surface. Irrigation is considered complete when the water table has risen to within 3 to 4 feet of the ground's surface, as this will insure a thorough moistening of surface soils by capillary attraction.

Throughout the Mussel Slough country the range of water-table elevation is clearly defined. It drops from its general position at the height of the irrigating season, about 4 feet below ground, to a greatest depth of 7 to 10 feet during the fall and winter months. This fluctuation is the direct result of irrigation, and it is more or less rapid in the different portions of the district according to the character of the soil, the distance between irrigating ditches, and other local conditions.

Locally this method of irrigation is rarely understood. It is referred to as irrigation by percolation, and according to the ordinary conception of the method there should be a direct lateral horizontal percolation of water through surface soils.

For the irrigation of grain or alfalfa it is customary, if the land be at all uneven on the surface, to carry distributing ditches along the highest points of the ground. From these the water is drawn into irrigating ditches 3 to 6 feet wide and 1 to 2 feet deep, which are cut with a slight fall out upon each side from the distributing ditches, and are from 300 to 600 feet apart. These irrigating ditches are either temporary or permanent. If temporary, they are usually plowed in after each irrigation and reopened for the next one. When orchards and vineyards are to be irrigated the ditches are constructed in straight lines between the rows of trees or vines, whenever such arrangement is possible.

Simple as this method of irrigation may appear, it has its disadvantages, not the least being directly due to the preponderance of the upward movement of the moisture in the surface soils. The water, before moving upward, often passes for long distances through permeable subsoils. Where ground is wet by irrigation 150 feet from the nearest ditch, the water reaching it must have passed at least 150 feet through porous strata, besides the distance it may have had to sink originally and the height it again rose to reach the surface soil. Water thus permeating, at times saturating, soils which are rich in salts ordinarily classed as alkaline, is sure to dissolve more or less of these mineral substances, and it will retain some of them in solution until sooner or later it arrives at the surface and there evaporates. Though the

quantity of these salts in solution may be very small, they will, if present at all, ultimately become apparent at the surface, because the moisture there evaporating is periodically replaced from below, not from above. Careful inquiry establishes the fact that some injury has already resulted from this cause; that many fields whose soil a few years ago was of excellent quality now have soil too strongly alkaline to produce good grain crops, and that even alfalfa fields have been injured. There seems to be no limit to the extent of damage which may result from this cause unless the method of irrigation be properly modified.

The simplest remedy for this evil, suggested by its cause, is to secure a preponderance of downward motion of moisture. If this can be done, more of the salts leached out of the soils by water will move downward away from the surface than upward toward it. The quantity of alkali at the surface, where it is most injurious, will necessarily be decreased. The remedy will be made still more effective if subdrainage be resorted to—if the water descending to the subsoils through the surface soil be in large part carried off in deep drainage channels.

It is not without interest in this connection to note the effect of rain on those spots of the plains where alkali is seen on the surface as an efflorescence or has formed a crust. A gentle rain, with no run-off from the surface, wetting the ground to the depth of a foot or two, may dissolve the efflorescence and all alkaline crusts, carrying the salts downward into the soil. But they return to the surface with the returning moisture, all of which is ultimately evaporated. A long-continued rain may send water vertically downward to ground water. It may thus cause a permanent reduction of alkaline salts at the surface. Sudden heavy rainfall, dissolving the salts on the surface, may carry them into natural drainage channels and permanently remove them from the soil.

It remains to be said that the accumulation of alkali at the surface is retarded by thorough tillage and occasional deep plowing. By tillage the capillary upward movement of moisture is checked; there is less evaporation from the surface layer of soil; consequently, the amount of alkali accumulating at the surface is minimized. Deep tillage buries the surface salts, removing them for a time at least from that layer of the soil where they are most injurious.

The cost of preparing land for irrigation in the Mussel Slough country has been relatively small because the surface required no shaping and only limited areas have been arranged for flooding in checks. The cost of constructing the small irrigating ditches has been variously estimated at from $2 to $4 per acre, and the annual expense of irrigating at from 25 cents to $1 per acre.

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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 waters 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 calendar 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.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton, and "A 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 W. F. 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.
18. Irrigation near Fresno, California, by C. E. Grunsky, 1898.

In press:

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.]

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