1442 Issued May 23, 1912.

U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 236 (Revised).

A. C. TRUE, Director.

THE USE OF UNDERGROUND WATER FOR IRRIGATION AT POMONA, CAL.

BY

C. E. TAIT,

Irrigation Engineer in Charge of Work in Southern California.

UNDER THE DIRECTION OF

SAMUEL FORTIER,

Chief of Irrigation Investigations.

[Based on work done in cooperation between the Office of Experiment Stations and the State of California.]

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OFFICE OF EXPERIMENT STATIONS.

A. C. TRUE, *Director*.
E. W. ALLEN, *Assistant Director*.

IRRIGATION INVESTIGATIONS.

SAMUEL FORTIER, Chief.
R. P. TEELE, Assistant Chief.[1]

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JOHN H. GORDON, R. G. HEMPHILL, W. H. LAUCK, R. E. MAHONEY, and JOHN KRALL, Jr.

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[1] On furlough, in charge of irrigation census of Bureau of Census.

LETTER OF TRANSMITTAL.

United States Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., March 1, 1912.

Sir: I have the honor to transmit herewith a revision of a report on the use of underground waters for irrigation at Pomona, Cal., prepared by C. E. Tait, under the direction of Samuel Fortier, chief of irrigation investigations of this Office. The work upon which this report is based was done in cooperation between this Office and the State of California, each paying half the expense.

The Pomona Valley is typical of localities in the citrus belt of southern California, where water has a high agricultural value, but can be secured only at high cost. Much of the water is pumped, and there is no other section where water is used more economically or where greater effort is made to improve methods of development, distribution, and application. This report describes the problems confronting the irrigators, the methods employed, and the progress made in the economical use of the water resources. It is believed that it will be of value both as suggesting further possible progress in southern California and in leading to the use of more economical methods in other regions where the supply of water is limited or difficult to obtain.

In view of important recent changes in the methods of developing and applying the water and in the value of the lands and crops it has been deemed advisable to revise the report, which is recommended for publication as Bulletin 236 (revised) of this Office.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

[Bull. 236.]

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THE USE OF UNDERGROUND WATER FOR IRRIGATION AT POMONA, CAL.

INTRODUCTION.

Much of the water used for irrigation in southern California is pumped from wells, and there are no sections where water is used more economically. This fact has been brought about by a strong combination of influences. One of these is the characteristics of the settlers themselves, who are mostly people of means and education, having come from Eastern States to enjoy the climate and other attractions for which the section is noted. Professional men, business men, and farmers alike have come to lead a retired life and to engage in fruit growing, which appealed to them as a method by which they can augment their means and at the same time live a more independent and outdoor life devoid of the hard labor of their former occupations.

The kind of communities that have been built up is another important factor. These represent one of the highest types of agricultural settlements and the rural homes found in them are unsurpassed in this country. The land holdings are small, the predominating sizes being 10-acre orchards and 40 to 80 acre alfalfa farms, and are bunched together into settlements. This leads to a lively exchange of ideas and to a strong rivalry between localities. The corporate limits of the towns are so extensive that often they include most of the orchards around the business centers, from which avenues lead out into the country for miles. There is in a single county 25 incorporated cities, and $3,500,000 is being spent on highway improvements outside of the limits of the cities. The fruit growers have been ready to band together in movements for whatever might be beneficial to them. The organization for marketing fruit is the most proficient of its kind in existence, and has placed the citrus industry on a sound commercial basis. Active farmers' clubs have been effective in leading to progress in all industrial methods.

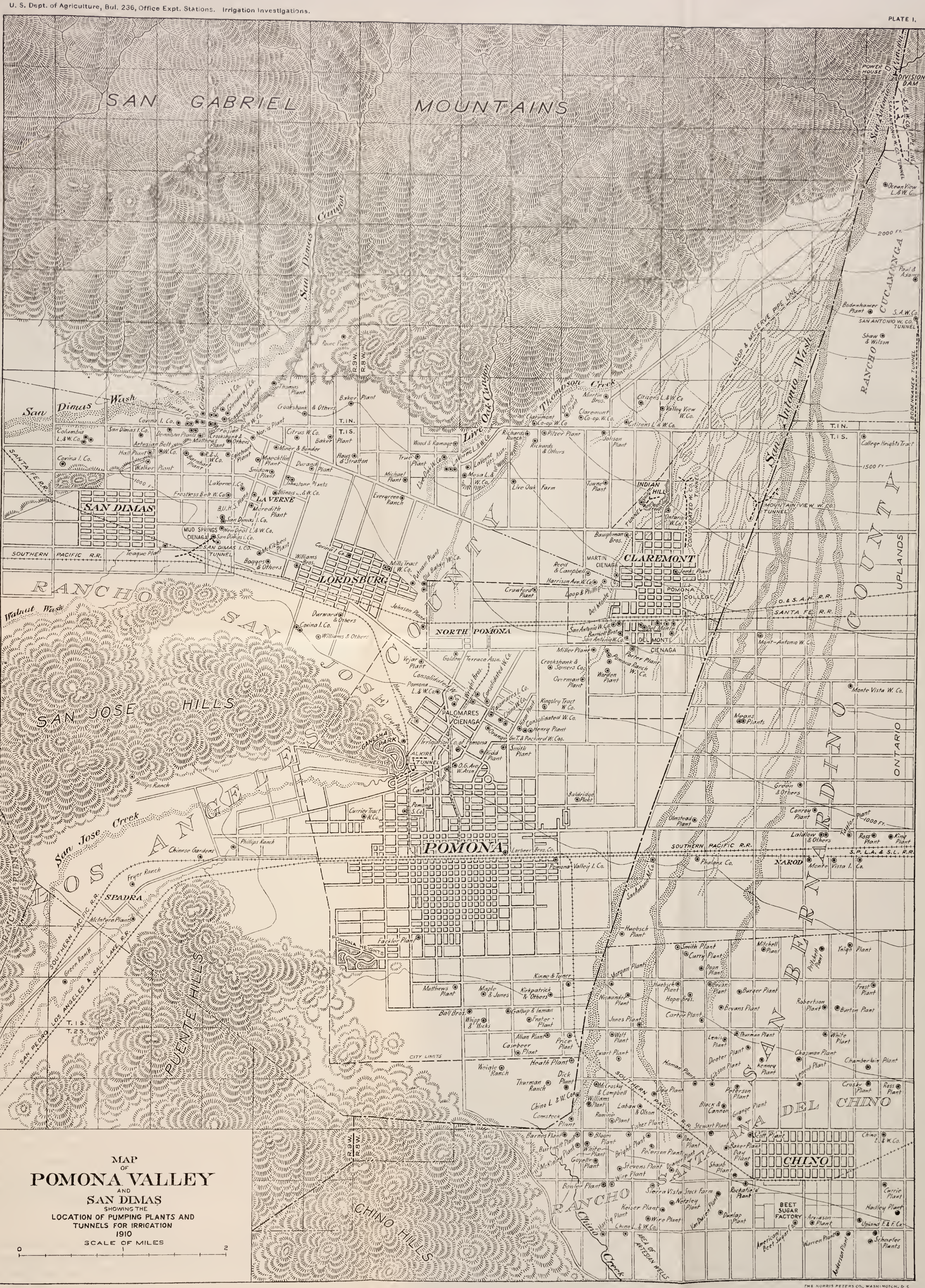
But the most potent factor has been the fact that the water supply was limited and expensive, while there were exceptional possibilities of achievement, both agriculturally and in the creation of high property values and beautiful estates. Few agricultural pursuits yield as large profits as the growing of citrus fruits and the other products which have been the source of much of the wealth of southern California. The localities where soil and climate permit these industries are rare, and the temptation to extend them to the utmost possible limit is great. It is only natural that measures should be taken for protection of rights, conservation of resources, and economy in use of that which is both expensive and the base not only of the prosperity, but of the very existence of the communities. It is natural, with a strong incentive for economy, a high average intelligence, fairly adequate finances, and unusual possibilities, that there should be a strong tendency to study the problems of irrigation and that it should be easy to subscribe capital for improvements intended to bring about greater economy.

Pomona is a type of the localities of the citrus belt and of sections where water is secured at a cost above the average. It is a locality that has rested on agricultural and horticultural advantages, and although it has not drawn so many people of wealth as have some communities more widely known as tourist points, yet its wealth per capita is high. It is probable, also, that organization at Pomona is not so complete as that in some of the older localities, but this is accounted for largely by the fact that there is no single source of water, and consequently a large mutually owned irrigation system is not possible. Growth here has been more natural than in many places where lands under canal systems have been colonized by special efforts of promoters. Nearly all the water used about Pomona is pumped from wells, and within a radius of 6 miles from the center of the city there are 260 pumping plants and some artesian wells, representing an investment of approximately $1,000,000, together with fully $500,000 additional for distributing pipe and small reservoirs.

A study of the situation that has confronted the irrigators and the progress they have made in the economical use of the water resources may suggest even further advance, and it should have value in leading to the use of better and more economical methods in other localities where natural forces prompting improvement are less strong. The extent of agriculture in the West will be limited by the water available instead of the land irrigable, and the time is approaching when further extension will depend entirely upon the saving of water, and it is therefore impossible to predict what methods the future will bring forth in any locality.

GENERAL DESCRIPTION OF POMONA VALLEY.

The settlements or communities of southern California are often referred to as districts, but as the use of this term might lead to confusing the region under consideration with the systems under the State irrigation district law, in this report it has been called, for want of a better term, Pomona Valley. It does not include all of



MAP OF POMONA VALLEY AND SAN DIMAS SHOWING THE LOCATION OF PUMPING PLANTS AND TUNNELS FOR IRRIGATION 1910

SCALE OF MILES 0 1 2

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

the valley of San Antonio Creek, a large part of which is overlapped by the Ontario settlement. Pomona Valley, as shown on Plate I, lies between the San Gabriel Mountains on the north and the Puente and Chino Hills on the south. The San Jose Hills project into the valley from the west, and are not connected either with the mountains on the north or the hills on the south, a long, narrow valley opening out toward the west being left on either side of them. The open country of the San Bernardino Basin stretches eastward unobstructed until it reaches the San Bernardino Range, 35 miles distant.

The greater part of the region is situated in the eastern part of Los Angeles County. A portion is in San Bernardino County, the county line almost coinciding with the main channel of San Antonio Wash.

The city of Pomona is located at the eastern end of the San Jose Hills in the center of the valley, and has an area of 12 square miles and a population of 10,207. It is difficult to draw a distinct line between the city and the surrounding country, although its commercial business is confined to a comparatively small area. The two merge and the whole is a rural community with good homes, well-improved avenues, electric street railways, excellent schools and libraries, and high moral influences. Claremont, the home of Pomona College, joins Pomona on the northeast. Lordsburg, which was colonized by a religious sect, joins Pomona on the northwest. San Dimas, at the extreme northwest of the region, is an important point for packing and shipping fruit. Chino, to the southeast of Pomona, in San Bernardino County, has a beet-sugar factory. North Pomona, a station on the Santa Fe Railroad, is a part of Pomona. The village of Spadra is located in the dale of San Jose Creek west of Pomona, and La Verne is an old settlement on the mesa northwest of Lordsburg.

The valley is traversed from east to west by three trunk railways. The Southern Pacific crosses through the center and leads to Los Angeles by way of San Jose Creek. A branch leaves the main line at Ontario, detours southward through Chino, and after returning to and crossing the main line at Pomona runs north of the San Jose Hills, finally returning to the main line before reaching Los Angeles. The Santa Fe crosses the northern part of the valley and passes through Claremont, Lordsburg, and San Dimas. The San Pedro, Los Angeles & Salt Lake parallels the main line of the Southern Pacific through the valley. An electric railway from Los Angeles to Pomona is nearly completed.

SOIL.

The soil of the valley in general ranges from a gravelly loam near the foothills on the north to a sandy loam at the hills on the south. Here and there are found stretches of clay or adobe, principally where the slope of the valley meets the San Jose, Puente, and Chino Hills. This latter class of soils is very tight and difficult to irrigate properly. The various grades of sandy loam which predominate through the central portion of the valley lend themselves best to irrigation. The gravelly soil near the mountains takes water very readily. The slope is from north to south at a rapidly decreasing rate of fall, the land near Claremont having a fall of about 100 feet to the mile, while in the southern part of the valley the fall is only one-half as great. The soil is very fertile.

CLIMATE.

It is difficult to classify southern California, exclusive of the inland deserts, in regard to its aridity. Its rainfall is that of a semiarid region, but its semitropical climate and comparatively dry atmosphere make it in some respects strictly arid, according to the generally accepted meaning of these terms. The days of the summer and early fall are hot and dry except for an occasional fog, but there is a great daily range of temperature and the nights usually are cool. The winters are very mild, the late winter and early spring being the rainy season. Few of the fruit-growing sections are entirely free from frost, but the frosts seldom are heavy enough to do any damage. They are too heavy, however, in the lower portions of most of the valleys for citrus fruits, the culture of which is limited to the better protected and more nearly frostless areas near the hills or mountains. The following table, compiled from the annual summaries of the United States Weather Bureau, shows the monthly maximum and minimum temperatures at Claremont from 1899 to 1909:

Maximum and minimum temperature at the United States Weather Bureau Station, Claremont, Cal., 1899–1909.

Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
MAXIMUM TEMPERATURE.												
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
1899	78	81	83	91	84	......	97	96	99	94	80	79
1900	75	79	86	77	89	95	......	105	92	92	89	76
1901	72	83	81	80	80	102	95	103	87	93	80	83
1902	83	82	78	83	81	102	106	100	95	89	86	......
1903	83	76	83	85	86	103	107	106	101	101	90	78
1904	85	81	89	96	93	100	100	101	107	96	94	87
1905	81	74	84	87	94	90	103	108	104	101	84	79
1906	80	80	83	90	80	105	102	105	107	107	96	85
1907	75	86	85	91	92	104	110	99	100	94	88	85
1908	84	86	85	90	88	98	108	104	106	97	88	78
1909	80	76	78	89	104	105	98	112	104	101	96	72
MINIMUM TEMPERATURE.												
1899	30	20	31	33	34	......	46	36	46	36	35	30
1900	34	32	35	31	37	43	48	38	41	37	37	23
1901	22	28	31	30	40	45	48	47	41	40	38	24
1902	25	30	29	34	37	39	45	41	44	41	31	28
1903	30	26	28	31	37	40	42	50	46	42	38	34
1904	30	33	34	35	40	42	46	54	45	44	41	32
1905	37	30	36	39	41	46	49	49	45	42	34	27
1906	29	31	33	33	43	45	57	48	49	40	30	32
1907	26	34	33	40	40	45	48	50	44	47	37	35
1908	36	30	33	37	35	41	51	49	45	40	33	28
1909	33	34	33	40	42	45	50	49	44	41	35	28

The prevailing winds are slightly south of west and are mild sea breezes which have traveled 35 miles from the coast. They enter the valley by way of San Jose Creek and San Dimas Pass, where, being confined to a narrow space, they are intensified and temper the summer heat. As they pass eastward they gradually lose their force. The winds usually rise in the forenoon and increase in velocity until near nightfall, when they cease. Their drying effect is neutralized in a measure by fogs, many of which come as far inland as Pomona. The fogs occur more frequently during the rainy season, but occasionally in other seasons, and they usually come in the night and often last until noon the following day. Investigations by this Office show the evaporation near Pomona to be 65 inches per annum.[a] The valley is practically free from the strong cold and dusty winds known as "northers," which come down over the Sierra Madre Range and sweep across the greater part of the San Bernardino Basin in the winter season. Their full force has been felt only a few times, and although the edge of a "norther" sometimes reaches Pomona, the most noticeable effect is the floating down of the dust.

The rainfall is watched with great interest, not only on account of its effect in replenishing the subterranean water, but also for its direct benefit to crops. The amount of rainfall is such that if it were properly distributed, only little supplemental irrigation would be necessary, but unfortunately the distribution is very unequal. The rainfall has been measured at Pomona for the last twenty-six years by the Pomona Land and Water Company, and the average annual precipitation for that period is 19.79 inches. While some water is used through the winter, the irrigation season proper is from May to October, inclusive, during which period the mean rainfall is 1.94 inches as against 17.85 inches for the other six months. The following table shows the mean monthly precipitation from 1883–84 to 1908–9:

Mean monthly precipitation at Pomona, Cal., 1883–84 to 1908–9, inclusive.

Season of regular irrigation.		Season of irregular irrigation.	
Months.	Rainfall.	Months.	Rainfall.
	Inches.		*Inches.*
May	0.73	November	1.58
June	.10	December	2.90
July	.00	January	4.15
August	.03	February	3.78
September	.19	March	4.28
October	.89	April	1.16
Total	1.94	Total	17.85

[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 177.

The mean for March, 4.28 inches, is the highest, while more than one-half the total annual precipitation occurs in January, February, and March. It has rained only three times in July in twenty-six years. The unequal distribution of the rainfall and the need of supplying water by irrigation during the summer months are clearly shown by figure 1.

The rainfall varies greatly for different seasons. The meteorological year in southern California for convenience begins with the month of July, although it is not as applicable as the calendar year for measuring the amount received by crops.

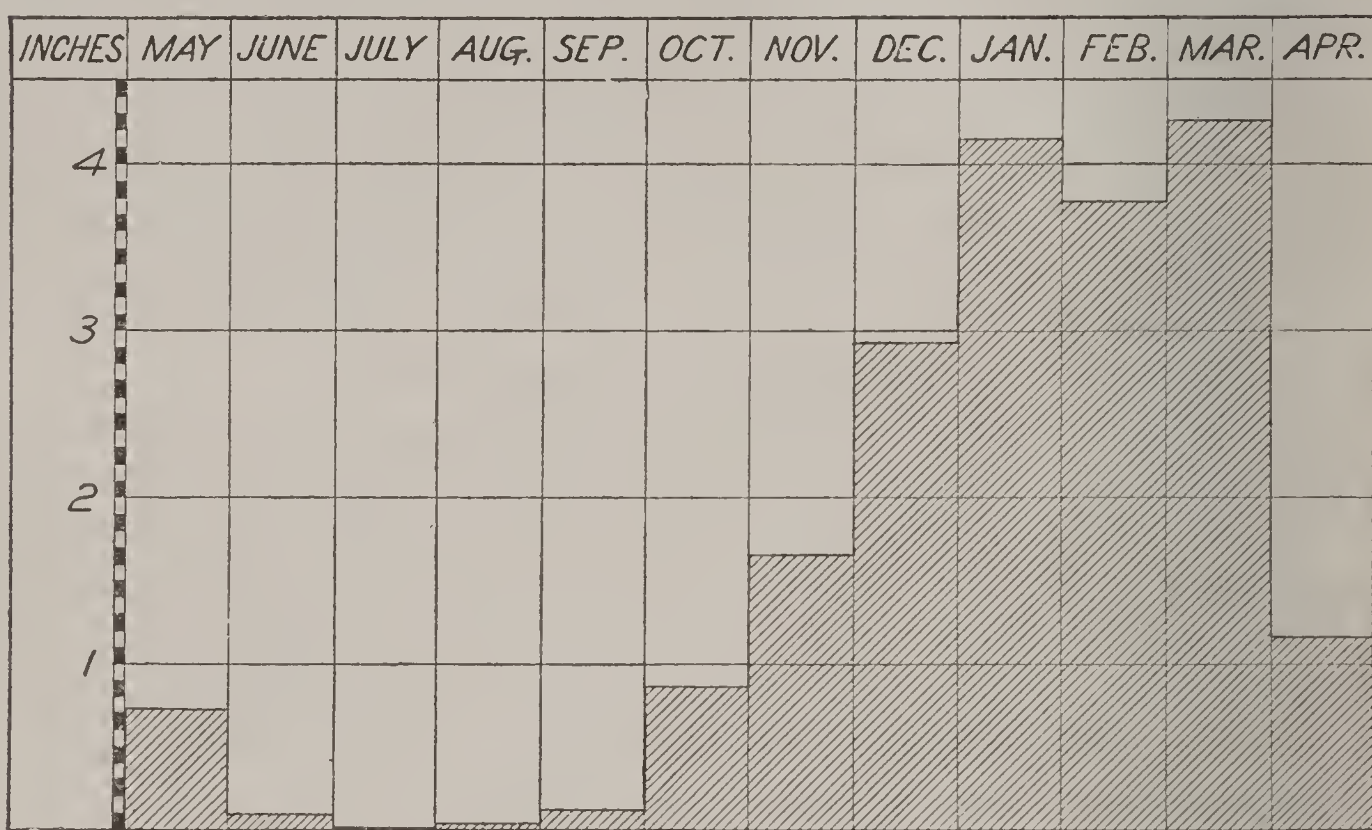


FIG. 1.—Mean monthly rainfall at Pomona, 1883–84 to 1908–9, inclusive.

The following table, compiled from the records of the Pomona Land and Water Company, shows the total annual rainfall at Pomona from 1883–84 to 1908–9, inclusive:

Rainfall at Pomona, Cal., 1883–84 to 1908–9.

Season.	Rainfall.	Season.	Rainfall.
	Inches.		*Inches.*
1883–84	39.77	1897–98	11.18
1884–85	10.57	1898–99	7.77
1885–86	23.49	1899–1900	11.76
1886–87	13.33	1900–1901	21.91
1887–88	21.84	1901–2	13.44
1888–89	23.35	1902–3	19.92
1889–90	28.75	1903–4	10.31
1890–91	21.86	1904–5	26.45
1891–92	14.66	1905–6	23.33
1892–93	29.08	1906–7	28.96
1893–94	12.70	1907–8	16.53
1894–95	26.68	1908–9	24.00
1895–96	10.15		
1896–97	22.97	Average	19.76

It will be noticed from the foregoing table that a series of wet years was followed by a series of dry years, each period being something less than a decade. A striking contrast is shown by the eight seasons from 1887–88 to 1894–95 and the nine seasons following. The average for the eight seasons is 22.36 inches, while that for the nine seasons is only 14.39 inches. The average for the seasons since is 23.85 inches.

There is a theory that there are cycles of variation from maximum to minimum and back again about every fifteen or twenty years, but records have not been kept long enough to formulate an exact

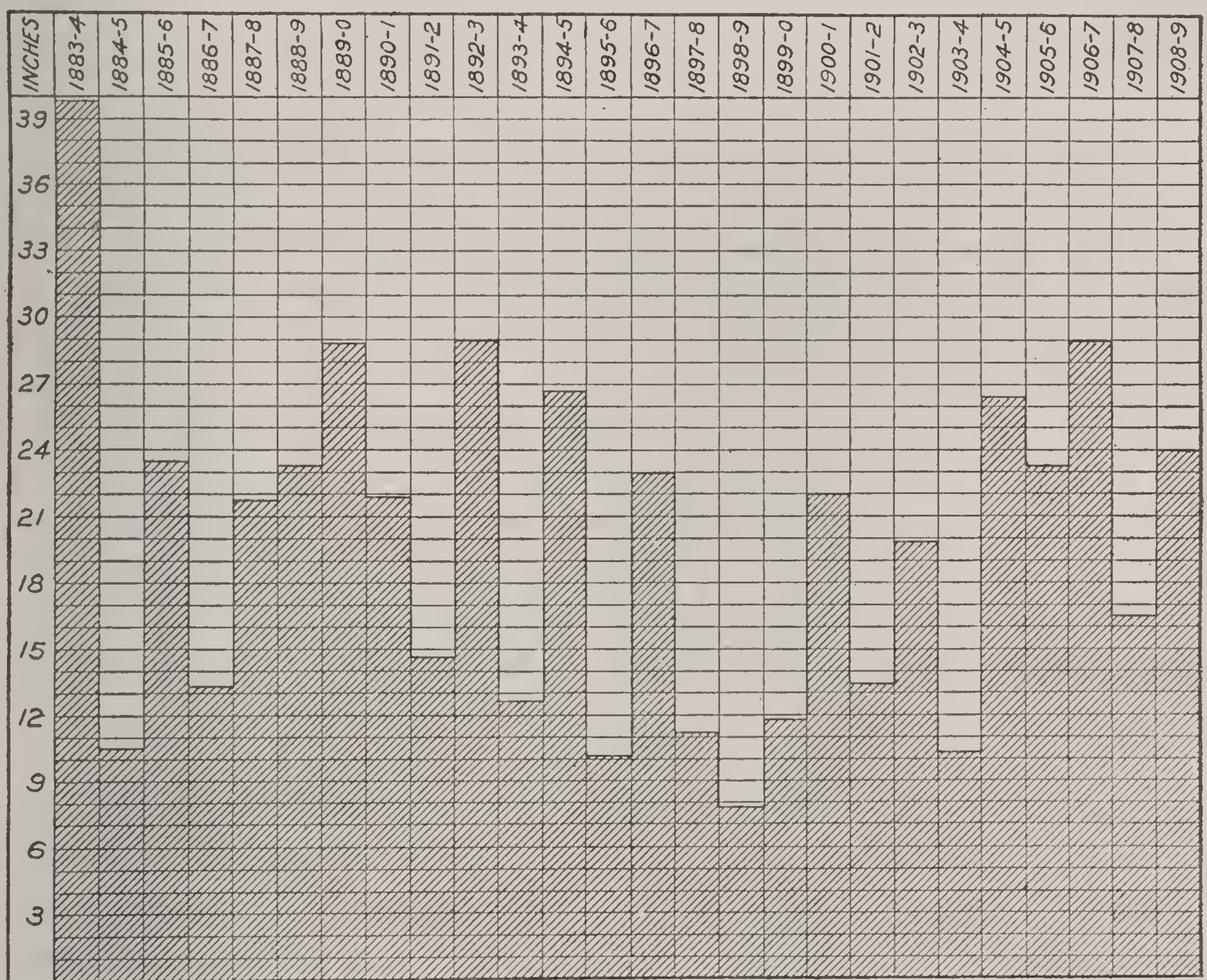


FIG. 2.—Rainfall at Pomona for seasons 1883–84 to 1908–9, inclusive.

law for such variations. They serve to call attention to the great importance of keeping in mind the probable recurrence of dry years.

Figure 2 shows not only the periodical change in the amount of rainfall, but also the alternation of comparatively high and low precipitation from season to season. The rainfall records of southern California show that as the mountains are approached the precipitation increases. There seems to be an exception to this general rule, however, in Pomona Valley. The measurements at Claremont show an average of 17.13 inches for the past eighteen years, the average at Pomona for the same period being 18.44 inches. The two stations are only 3 miles apart. The following table shows the precipitation at Claremont:

Rainfall at Claremont, Cal., 1891–92 to 1908–9.

Season.	Rainfall.	Season.	Rainfall.
	Inches.		*Inches.*
1891–92	12.54	1901–2	12.45
1892–93	26.03	1902–3	18.81
1893–94	11.37	1903–4	10.89
1894–95	24.40	1904–5	22.75
1895–96	9.58	1905–6	21.65
1896–97	23.14	1906–7	26.29
1897–98	11.05	1907–8	15.64
1898–99	7.85	1908–9	22.28
1899–1900	10.65		
1900–1901	21.02	Average	17.13

The precipitation in the Pomona section, fortunately, is one of the greatest among the fruit districts of southern California. Its rainfall exceeds that of Los Angeles on the west, Santa Ana and San Diego on the south, Riverside, Redlands, and San Bernardino on the east, but it is exceeded by that of Pasadena. Why it should be greater than the fall at San Bernardino and Redlands, both situated nearer the mountains, is not clearly apparent; possibly the San Jose Hills and other local conditions cause an increased precipitation of the moisture of the clouds, which invariably come inland from the ocean. The precipitation on the mountains north of the valley is known to be much greater than that in the valley. The higher peaks are covered with snow during a part of each winter and spring.

CROPS.

Pomona was once called the most representative fruit-growing section in the entire State of California on account of the great diversity of fruits. There is now perhaps less diversity of commercially grown fruits, but in addition to the fruit there is a large acreage of alfalfa.

Nearly all of the region lies within the confines of two old Spanish grants, and most of the reclaimed area has been in private ownership from the first. The only public land was along the base of the foothills. The territory about the present municipalities of Pomona, Claremont, Lordsburg, and San Dimas was a part of Rancho San Jose, while a large part of the region south of the railroads and east of San Antonio Wash was in Rancho Santa Ana del Chino. The country, before the railroad was built, was little more than a stock range. Pomona was settled in 1875, but very little improvement by cultivation was made until the field was entered by the Pomona Land and Water Company, organized in 1882, which acquired 12,000 acres of Rancho San Jose. Claims to canyon water were purchased and artesian wells were bored. The success of orange culture had already been demonstrated at Riverside, and by 1884, 1,345 acres of orchard and 828 acres of vineyard had been planted at Pomona. The early attempts at irrigation at San Dimas were begun by the San Dimas Land and Water Company and the San Jose Ranch Company about 1885 and 1887.

By a coincidence the Southern Pacific and Salt Lake railroads practically divide the region into two main parts, the northern being almost entirely in citrus orchards, with a few grapes, while the southern one is in alfalfa, deciduous orchards, and diversified crops. Over 80 per cent of the oranges and lemons are marketed through the San Antonio Fruit Exchange, which is a local branch of the California Fruit Growers' Exchange, a cooperative organization of growers. The San Antonio exchange is the selling agent for nine minor organizations, which pack the fruit.

The last of these organizations, the El Camino Citrus Association, was not organized until 1911. The acreages in the eight organizations existing in 1910, as represented by the shipments in that year, were as follows:

	Acres.
San Antonio Fruit Exchange:	
Pomona Fruit Growers' Exchange	2,300
Claremont Citrus Association	1,003
College Heights Orange Association	580
Indian Hill Citrus Association	1,050
La Verne Orange Growers' Association	550
San Dimas Orange Growers' Association	1,071
San Dimas Lemon Association	750
Walnut Fruit Growers' Association	175
Independent shippers	1,300
Total	8,779

Of the above, 365 acres of the San Dimas Lemon Association, at Covina and Azusa, and all of the lands in the Walnut Fruit Growers' Association are outside of the territory covered by this report.

Of the 2,300 acres under the Pomona Fruit Growers' Exchange, 200 are in lemons, so that in the whole territory there are 7,654 acres of oranges and 585 acres of lemons. In addition to the producing orchards there are about 2,500 acres of young trees, making a total of 10,739 acres in citrus orchards in the territory covered by this report.

There are two leading varieties of oranges, Washington Navels and Late Valencias, but the former greatly predominate. Valencias are of better quality and can be held on the trees until fall with less difficulty in the cool summers near the coast than in interior sections. Pomona being about midway between the coast and the interior should be representative. Lemons are a little slower in maturing near the coast than in the interior, consequently there is more summer crop with its accompaniment of better prices on the coast. Excellent lemons are produced as far inland as Highlands, where there is less trouble with scale pests than along the coast where fogs are more frequent. Three hundred and eighty-five acres of fine lemons are grown at San Dimas in this section. Lemons are grown also along San Jose Creek and near the foothills north of Claremont. Grape fruit and the pomelo are grown in small quantities, but the lime is too sensitive to stand the light frosts that occur.

There are at present about 500 acres in vineyards, the acreage not being so large as formerly when there was better profit. Most of the grapes are within the city limits of Pomona. Wine grapes are raised principally, and there are several local wineries.

Much of the land south of the railroads and west of San Antonio Wash in Pomona city limits in the early days was set to deciduous orchards, but in later years they have not given a good revenue with regularity and many of them have given place to alfalfa. The ownership of Chino rancho changed in 1881 and development was begun. The ranch was divided into 10-acre tracts and offered for sale to settlers, and in 1900 the owner organized the Chino Land and Water Company and the property was transferred to the corporation which continues to promote settlement. A sugar factory was built in Chino in 1891 and 6,500 acres on the ranch were planted to beets. The soil is well adapted to beet culture, except that without drainage it remains damp so late in the spring that there has been difficulty in getting the beets planted early enough. There were 2,500 acres of beets in 1908, the greater part of which was grown by the sugar company. About 14,000 acres of the valley lands of Chino rancho have been sold and are being occupied by settlers. Alfalfa is the principal crop grown on these lands, but there are some deciduous orchards, walnuts, and a great diversity of crops along the northern border. There are about 9,000 acres of alfalfa in the lower part of the valley, of which 7,200 acres are on Chino rancho, the remainder, except a few acres near Spadra, being in southern Pomona.

The removal of so many of the deciduous orchards in southern Pomona has been offset by the increase on Chino rancho, and the total acreage remains at about 1,000. The orchards on the ranch, however, are often only an adjunct to alfalfa growing, and no particular part is devoted entirely to them as was the case formerly. Deciduous fruit growing as an industry has declined, although increased planting of trees is expected with the settlement of the rancho lands.

Peaches and apricots are grown principally, but the prune and pear have been grown at times with good profit. There are some apple orchards near Chino and some fig trees in the valley, but no orchards. English walnuts thrive and in recent years have yielded as large profits as oranges and lemons. The walnut orchards are confined principally to the heavy soil, much of which was unproductive until it became apparent that it was adapted to walnut growing and that the industry was a profitable one. The best walnuts are grown in the cool climate near the coast. About 700 acres are devoted to walnuts, the greater part of which is on Chino rancho. Almond trees are found, but there are no orchards, as they stand but little frost. The olive is grown to some extent in this region and is found to be profitable when improved methods of marketing the fruit and oil are used. Olive and walnut trees have been much used to make borders or street rows for orange orchards in place of ornamental trees. The growing of eucalyptus trees in groves for profit is becoming a feature. Truck gardening and berry growing are followed principally to supply the local demand.

The total number of acres irrigated in this region is in excess of 20,000. In addition to the irrigated crops there are several thousand acres of grain on Chino rancho and on the lesser slopes of Chino, Puente, and San Jose Hills, grown with fair success, except in the very dry seasons, without irrigation.

WATER SUPPLY.

San Antonio Creek, which rises in the San Gabriel Mountains, a part of the Sierra Madra Range, is the only important stream in the region. After leaving its canyon it traverses the valley in a direction west of south, but during the greater part of each year its channel is a mere wash, all the water either having been taken out for irrigation or having disappeared in the gravel beds near the canyon. When the channel approaches the base of the Chino Hills water appears on the surface again. The continuation of the same stream beyond this point is known as Chino Creek, which follows close to the base of Chino Hills in a southeasterly course to its junction with the Santa Ana, a river flowing into the Pacific Ocean.

San Dimas Creek is a small stream having its source in San Gabriel Mountains. After reaching the valley the course of its wash turns westward, crossing the open country north of the San Jose Hills until it reaches San Gabriel River. While San Dimas Creek is a part of the San Gabriel drainage, which is entirely distinct from the Santa Ana drainage, of which San Antonio Creek is a part, the country in the vicinity of San Dimas is largely tributary to Pomona and, aside from water supply, may be considered a part of the community under consideration.

San Jose Creek, or Wash, is another small stream beginning at the eastern end of San Jose Hills and draining to the west through the little valley south of the San Jose Hills.

SAN ANTONIO CREEK.

The mountain watershed of San Antonio Creek is 27½ square miles, and ranges in elevation from 2,250 feet above sea level at the mouth of the canyon to 10,080 feet at the summit of Mount San Antonio. The floor of the canyon is divided by projecting hills and rock into basins several hundred feet wide and approximately a mile long, filled to an unknown depth with detritus. These basins act as reservoirs for large volumes of water and regulate the stream to such a degree that the summer and fall run-off is much larger than would be expected, considering the light rainfall of these seasons. The fall of the stream in the 7 miles of main canyon from the junction with Icehouse Canyon, at an elevation of 5,000 feet, to the mouth varies in the several sections from 50 to 500 feet per mile, the most abrupt drop being at Hogback, a hill which narrows the canyon to a gorge. Timber and undergrowth are found in the canyons. The mountain slopes are not heavily timbered, but are covered with a dense growth of scrub oak and other brush up to an elevation of 6,000 feet. There is very little vegetation on the peaks to shield the winter snows from the direct rays of the sun, and snows do not remain long, except on San Antonio, Ontario, and Cucamonga Peaks.

Just after heavy rains San Antonio Creek is torrential, but its floods soon pass, and throughout the greater part of the year it is only a small mountain stream. Its channel above all diversions is never dry. The discharge from year to year is as variable as is the rainfall on which it depends. The minimum occurs in the fall and sometimes is only 200 miner's inches. The maximum has never been measured, but is perhaps 100,000 miner's inches, or 2,000 cubic feet per second some years. The average discharge for the summer months for twenty-two years, as shown by measurements made for the water companies by their engineers, is as follows: July, 820 miner's inches; August, 736 miner's inches; and September, 557 miner's inches. The average for the season of regular irrigation, May to October, is probably 800 miner's inches.

After leaving the canyon the creek passes down the more gentle slope of the alluvial deposit, but except in times of high floods it does not flow very far as surface water. This sloping alluvial plain constitutes the valley lands and is the vast accumulation of material formed by the disintegration of the soft granite of the mountains. This is one of the many débris fans stretching southward from the Sierra Madra Range. The numerous channels leading off from the main channel below the mouth of the canyon (see Pl. I) indicate how the stream has turned from one side to the other in its effort to seek a lower course and to get away from the elevations of its own building.

The main channel is the one along which the county line runs. Just to the east there is a secondary channel, which follows the same general course down to Chino Valley. Farther east there is a third channel, which is finally lost in the artesian area west of Chino. These are the only channels from the canyon. On the west side there are three well-defined channels branching off from the main channel below the canyon. The one in which the Del Monte Cienaga is located passes just east of Claremont; that in which the Martin Cienaga is located passes east of Indian Hill and west of Claremont; and the third bears well toward the west and ends in Palomares Cienaga. Thompson Creek, which is not a channel of San Antonio Wash but rises in the slopes southwest of the canyon, after skirting the base of the hills toward Lordsburg may be traced to Palomares Cienaga.

From a point on the Chino Hills high enough to afford a view unobstructed by the pepper and eucalyptus trees, which line the avenues of the valley, the channels of the washes are seen diverging from the canyon 15 miles distant, the gray of the gravel and cobble contrasting with the dark-green masses of the orange groves and desert growth, and looking directly up the main wash the eye follows through the canyon to Mount St. Antonio, which rises 9,200 feet above Pomona. The view also shows the similarity of the deposit to a cone when the topography is considered. The roads, running east and west across the valley at almost right angles to the wash, appear arched, and the channel is shown to be situated a little to the west of the top of the ridge. Apparently it is a great cone with its apex at the mouth of the canyon and a segment of its surface standing out in relief. The map (Pl. I) shows each 100-foot contour line, as taken from the topographic sheets of the United States Geological Survey. These lines resemble segments of circles circumscribed by radii from the mouth of the canyon. The view also shows very clearly the difference in the rate of fall along the main wash or along any of the other radial lines of the cone.

The slope becomes much steeper as the canyon is approached. From the canyon to San Bernardino base line, a distance of 2½ miles, the fall in the wash averages 240 feet per mile; from the base line to the Santa Fe crossing, 2 miles, 175 feet per mile; from the latter point to the Southern Pacific and Salt Lake Railroad crossing, 2½ miles, 107 feet per mile; and from that point to the Chino Hills, a distance of 3¼ miles, only 57 feet per mile. The creek drops from an elevation of 2,150 feet at the mouth of the canyon to 750 feet at the base of Chino Hills.

There is not only a diminishing rate of fall from the canyon outward, but there is a gradation also in the composition of the alluvium, varying from the coarsest at the canyon to the finest at the base of the hills on the south, for the deposit spreads entirely across the basin. The heavy bowlders have been left banked up against the mountains, while the finer material has been carried a greater distance from the canyon. The coarser material extends far down the slope in the washes, and the borings made in the valley show alternate strata of different classes of material at nearly all points. There is a gradual change from an abundance of bowlders near the canyon down through gravel, sand, and sandy loam to clay at the intervening hills, the latter having been formed by the finest silt-like material. Plate II, figure 1, shows the mouth of the canyon and the character of the gravels below.

Before it was taken out for irrigation or power the normal flow of San Antonio Creek was absorbed by the coarse material near the canyon. The surface flow during the freshets often reaches as far down as the Southern Pacific and Salt Lake crossings before being absorbed completely, but it is only in the highest floods that water continues on the surface all the way to Chino Creek. The water which enters the coarse gravel at the canyon percolates downward and outward rapidly at first, but the rate of percolation must diminish gradually as finer materials are reached. Its downward course must cease altogether when the impervious bottom of the basin is reached, or in places it may be confined by strata of clay and compelled to pass laterally through the more porous material between. Wherever any impervious barrier to this lateral movement is reached there is an accumulation of water behind it, and the water rises until it passes over and around the barrier. The San Jose, Puente, and Chino Hills constitute such barriers. Their impervious rocks intercept the water that percolates down, causing the ground water to rise until it either appears on the surface or passes westward toward the San Gabriel or southeastward toward the Santa Ana. There are evidences also of other barriers which are now wholly buried, but which at one time possibly were rock masses projecting above the surface or irregular deposits of clay through which percolation must be very slow. Such masses need not be entirely impervious to cause the water to rise behind them, for the same result will be produced if the material be dense enough to reduce the rate of percolation.

UNDERGROUND WATER.

CIENAGAS.

The forcing of the ground water up to or near the surface gives rise to the well-known cienagas, and these have been the most favorable places to secure water by tunneling and the boring of wells. The ground surface in the cienagas is nearly level, particularly in those

FIG. 1.—GRAVELS AT MOUTH OF SAN ANTONIO CANYON.

FIG. 2.—ELECTRICAL PUMPING PLANT.

lying near the low hills. The lands originally were known as moist or damp lands, and some of the basin-like places were bogs in which water stood on the surface at times. The soil is clay or adobe, composed of the finest materials, and is not entirely impervious. The fertility of the soil and moisture produced plant life, the decay of which has blackened the adobe. Farther up the slopes the clay is lighter in color.

The San Jose Hills have played an important part in the formation of cienagas. The Mud Spring Cienaga lies just southeast of San Dimas, where water from Live Oak and San Dimas Canyons is intercepted by spurs of the hills, giving rise to Walnut Wash. The Palomares Cienaga lies within Pomona just northeast of the visible end of San Jose Hills. Water which undoubtedly comes from San Antonio Canyon and Thompson Creek is intercepted here by the now buried portion of these hills, there being every evidence that the range extends farther to the east and northeast beneath the surface. The Alkire Tunnel passes entirely through this rock. The Martin Cienaga west and the Del Monte Cienaga south of Claremont belong to the class where there is an invisible barrier. It is probable that these also owe their existence to the San Jose Hills, the ridge of which is believed to extend in a northeasterly direction from Pomona, and it is possible that the water in each of these cienagas is forced up to its level by spurs on the north side of the ridge. Borings, as well as the difference in the water level, show that there is a distinct division between them, although they lie very close together. Wells bored here have yielded water on being pumped, but they have never flowed, while in the cienagas on either side wells have flowed through periods of wet years. There are still other localities less marked in that section of the country from Pomona to Claremont and beyond where the underground water apparently is forced up to a certain level before it can pass on. As the San Jose Hills are approached there is a series of water tables, each successive one lower than the preceding one. Each is a reservoir whose water level is determined by the height to which it must rise to overflow to the next below. This level is governed in a measure by the amount of water entering the gravel beds and the amount drawn out for irrigation.

A very complete study of these underground water sources was made by Willis S. Jones, of Pomona, in 1907. Systematic measurements of the wells in this section enabled him to locate definitely the several reservoirs. He and F. H. Olmstead were appointed consulting engineers by the city council of Pomona to report on the value of the plant of the Consolidated Water Company, the purchase of which the city had under consideration. The results of their investigation, which are of value to the entire community, are set forth in their joint report made in 1907. In discussing the section referred to they say:

Geologically this region is separated from the rest of the cone of débris from San Antonio Canyon by a more or less impervious dike or dikes, which hold the water in underground reservoirs. While the water is comparatively level in each reservoir, they are separated from each other by wide differences of elevation. The steps down can be tabulated as follows:

Hanson's well.—Commencing with the well on the Hanson place, less than a quarter of a mile north of the Consolidated Water Company's tunnel, the water stands at an elevation of 1,375 feet above sea level.

Consolidated Water Company's tunnel.—The tunnel and Ontario wells at Indian Hill have an elevation of 1,275 feet, an abrupt drop of 100 feet in less than a quarter of a mile.

Del Monte wells.—The Del Monte wells east of College avenue, Claremont, have an elevation of 1,100 feet, a drop of 175 feet. This elevation holds approximately as far north as Eighth street in Claremont to George Jencks's well. Coming west to Santa Fe Station east of Alexander avenue, the elevation in the two new Del Monte wells is 970 feet, another drop of 130 feet.

Pomona Reservoir.—Thence southwest nearly 3 miles to Ganesha Park, this basin has a very gentle slope, the entire drop being only 50 feet. Of this, 30 feet occurs in the first one-fourth mile. When the Irrigation Company of Pomona pumps its 16 wells it draws on this entire reservoir, lowering it to such an extent that a rest of thirty-six hours causes their wells to rise 6 feet. This rise extends to the northeast in a diminishing ratio to the wells along Mountain and Alexander avenues, where the rise is about 9 inches.

The existence of these reservoirs is a demonstrated fact, as can be easily shown from our personal investigation, and on their existence depends to a large extent the value of the various pumping plants and tunnels in this region.

In the foregoing, the five localities mentioned are in a line running northeast toward San Antonio Canyon from Ganesha Park, which is at the end of San Jose Hills. The Del Monte wells east of College avenue, Claremont, are in the Del Monte Cienaga, and the Pomona Reservoir referred to is at the Palomares Cienaga. The Martin Cienaga is not included, as it lies a little to the northwest of the general line running through the others. It is possible that additional light may be thrown on the conditions influencing the movements of the underground waters by a more systematic study of the strata as shown by the records of the many borings for wells. To the southeast of the barrier, supposed to be the extension of San Jose Hills, there is a great drop in water level. A glance at the map (Pl. I) shows the large number of wells and pumping plants, principally in the cienagas northwest of this buried ridge, while to the southeast there is a large section of country crossed by San Antonio Wash in which the small number of pumping plants gives a correct idea of its comparative value for producing water. In several places where two wells are located only a few hundred feet apart but on opposite sides of the supposed division line, the one on the northwest is an excellent well while the one to the southeast is practically a failure.

The moist lands along the base of Chino Hills, although they have no special names, are cienaga lands, entirely separated from those at Pomona and Claremont. The water which passes the end of the range of hills at Pomona percolates to the southeast to Chino Creek and westward along San Jose Creek. The water which follows the general direction of San Antonio Wash without being diverted westward from the canyon reappears when it reaches Chino Hills, and these sources give rise to Chino Creek. Data are not available to show the location of all the water levels in this lower section, but it should not be considered as one vast cienaga, as there are three distinct groups of artesian wells and as many or more water levels. One is west and slightly south of Chino at the old steam pumping plant of the Chino Land and Water Company and the other two are located southeast of this group. The lower one is the best group of flowing wells in this region.

The country about San Dimas Canyon, including San Dimas, La Verne, and the heights at the mouth of Live Oak Canyon north of Lordsburg, is of different origin and character from the valley below San Antonio Canyon. Doctor Hilgard, in a bulletin of this Office,[a] points out that the occasional red mesas which contrast with the gray of the valleys are evidences of an older alluvium than that of the valley land along the southern slope of the Sierra Madras. Traces of this older deposit are found here and there at the foothills all the way from Redlands to Pasadena. Red Hill, northeast of Uplands, and Indian Hill, north of Claremont, are remnants of this class found in this particular region. W. C. Mendenhall, of the United States Geological Survey, calls attention to the existence of much of this older topography between the San Jose Hills and the mountains, and that San Dimas Wash is a canyon cut in the old alluvium and partially refilled with the modern stream débris.[b] The reddish character of the lands from the bluffs at San Dimas Wash to those at Thompson Creek, as well as their elevation, distinguish them from other parts of the valley and identify them as a part of the older deposit.

It is probable that the ground water in San Dimas Wash moves westward with the general course of the stream and that most of the water in the mesa lands comes from Live Oak Canyon. This section has not been investigated as thoroughly as has that along San Antonio Wash.

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[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 119.

[b] U. S. Geol. Survey, Water-Supply and Irrig. Paper 219.

ARTESIAN WELLS AND TUNNELS.

Pomona Valley was a vast Mexican sheep range prior to 1875. None of the towns existed except the village of Spadra, which was a Spanish settlement and station on the old San Bernardino and Los Angeles trail. Chino rancho had passed into the hands of an American owner and was operated as a large stock ranch. Settlement began with the starting of Pomona in 1875, just after the building of the Southern Pacific Railroad, and the census of 1880 shows that the town had then a population of 417. Real development did not commence until 1882, when the Pomona Land and Water Company was organized. This company acquired 12,000 acres of the San Jose rancho and undertook systematic promotion by offering for sale lands with water rights. Pomona in 1890 had a population of 3,634, and in 1900, 5,526. Claremont, Lordsburg, and San Dimas sprang up after the building of the Santa Fe Railroad in 1887; the Salt Lake Railroad was not built through until 1904. Chino had its origin in 1887, and the beet-sugar industry was instituted in 1892.

The first iron-cased well was drilled near the present plant of the Pomona Land and Water Company in the Palomares Cienaga in 1877. Previous to this time there were a few shallow wooden-stave wells. The promoting company began sinking wells in the Palomares Cienaga in 1883. A few wells were put down in the Del Monte Cienaga in 1882 and 1883, but no more were drilled until 1887. The development of the Martin Cienaga was begun in 1884. In 1885 there were 33 artesian wells in the three cienagas from which the company was able to furnish nearly 400 miner's inches of water. An additional amount was available also from San Antonio Canyon through a pipe line that had been laid. There are now 17 wells in the Martin, 12 or more in the Del Monte, and 40 or 50 in the Palomares Cienaga. The Alkire Tunnel was constructed at the head of San Jose Creek, and drew water from the Palomares Cienaga. The Indian Hill Tunnel penetrated the side of the hill which is a mesa north of Claremont. The Fleming Tunnel, now the property of the Consolidated Water Company, was located near an old channel of San Antonio Wash east of Indian Hill. Several tunnels were made to draw water from the gravels fed by San Antonio Creek for use in the Ontario district. The Mountain View Water Company's tunnel, 1¼ miles long, is in San Antonio Wash east of the Consolidated Tunnel. The Bodenhamer Tunnel, 1 mile long, was made several miles farther to the northeast. The San Antonio Water Company has a 3,000-foot tunnel in the mouth of the canyon, also a tunnel completed in 1909 just above the Bodenhamer Tunnel.

Wells drilled in Mud Springs Cienaga at San Dimas about 1887 flowed at the surface, but they were intersected 30 feet below by a tunnel, thereby increasing their discharge. The combined flow of the wells and tunnel was about 55 miner's inches, throughout the irrigating season.

The early development on Chino rancho was near Chino Creek, where the first wells were drilled about 1886. These were excellent flowing wells.

NECESSITY FOR PUMPING.

Water was cheap and used very freely as long as it flowed from the ground, little thought being given to the sources from which it came and the need for its conservation. There was a good market for all fruits also when the fruit-producing area was small. These things led to a very rapid development, and the fast increasing acreage made a heavy demand on the water supply. There also had been a heavy rainfall for the twelve years for which measurements had then been made, and it seemed that this period was long enough to clearly establish the average rainfall for the locality, but a period began in 1895 for which the average was much lower. It was realized that as the flow of the wells and tunnels diminished a more economical method would have to be practiced, but this could not check the lowering of the water and pumping was inevitable.

The first pumping was in 1895 at the Martin Cienaga, where the flow of the wells had become very weak. It was necessary in 1898 to pump the wells in the Palomares Cienaga, and the flow of Mud Springs Tunnel and wells at San Dimas became so weak that it was necessary to begin pumping there also. The Consolidated and Alkire tunnels never ceased to flow entirely, but during the dry years the discharge of the latter was reduced to 25 miner's inches, and the flow of the former fell below 60 miner's inches. The Indian Hill Tunnel, as might be expected, knowing the origin of the hill, yielded but little water. Of those supplying Ontario, the San Antonio Canyon Tunnel has always delivered some water, but the Mountain View Tunnel ceased to flow and the Bodenhamer had not reached water-bearing gravels. By 1905 water was being lifted 90 feet in Del Monte and Martin Cienagas, 45 feet in the Palomares Cienaga, and 95 feet in the Mud Springs Cienaga. The 7-inch well at the pumping plant of the Kingsley tract flowed until 1898, and it is said to have delivered 40 miner's inches at one time. The water from it was lifted 95 feet in 1905. The discharge of the Mud Springs Tunnel and wells at San Dimas became so weak that a pumping plant was installed in 1898. Wells drilled in San Dimas Wash, the gravels of which have been a very fruitful source of water, never flowed. The first well was drilled by the Artesian Belt Water Company in 1895. A pumping plant was installed the next year, the lift being 44 feet, but the lift had increased to 100 feet in 1905. The success of the first well led to the installation of numerous other pumping plants in the wash. Water was lifted over 200 feet at some of these wells in 1905. Wells at La Verne and on the mesa north of Lordsburg were never artesian, the underground water coming probably from Live Oak Canyon. There has been a gradual reduction in the water level of this section, and as yet the only response to the increased rainfall is a decrease in the rate of fall.

There were springs on the Phillips ranch near Spadra until about 1900. Pumping from a well followed their failure, the water being lifted 67 feet when the tests were made in 1905. There has been a reduction of about 50 feet in the water level in the southern part of Pomona. Water stood 6 feet below the surface on the Thurman ranch in the nineties, and in 1896 it rose to the surface in places. The land was so wet as late as 1900 that it was used only for pasture, and a well bored that year discharged a good stream. After two seasons it ceased to flow, and in 1905 the water was lifted 55 feet. Many other wells were put down in this locality, nearly all of which yielded good streams of water when pumped.

There has been less fluctuation on Chino rancho, where the greater distance from the source and the finer material through which the water must percolate cause a better regulation. The entire Chino region appears to be a vast reservoir, subject to slight annual variations only.

Good artesian wells are confined to a strip of country along Chino Creek between Chino and the hills and extend southwest from San Antonio Wash for several miles. On October 9, 1905, the combined discharge of the better wells near the old steam pumping plant in this area was 19 miner's inches. Now 17 wells in the same locality are discharging over 125 miner's inches. Located in a less extensive strip, stretching from Chino toward the southeast, are wells which flow lightly. Most of these cease flowing in the pumping season. There are fully 100 artesian wells on Chino rancho. The flow of many of these has diminished in recent years, and some wells that formerly flowed no longer discharge water at any season. Many of the wells on Chino rancho farther east and north, as well as in the two artesian areas, when pumped deliver large quantities of water. The lift at many of these pumping plants has increased slightly in the last five years. In general, the water in other parts of the valley has been lowered as much in the wells that never flowed as in those that have, the reduction being 50 to 100 feet, the lowest level having been reached in 1906.

EFFECT OF RAINFALL ON THE UNDERGROUND WATER.

It is interesting to note the effect rainfall has had upon the underground waters. There was a time when some of the water users believed that the source of underground waters was other than rainfall in the watershed of San Antonio Creek, but it is not probable than anyone would now advance that theory. The rainfall from 1895–96 to 1903–4, inclusive, was 35 per cent less than for the preceding 12 years. Three dry years came in succession from 1897 to 1900, the total for the season 1898–99 being less than 8 inches. Following this, many pumping plants were installed in the years 1899, 1900, and 1901.

The decline of the water level ending in 1906 occasioned some uneasiness and it was feared that too heavy a drain was being made upon the supply. It was reasoned correctly that the dry years would be followed by a series in which the rainfall would be as great as it was in the first period of settlement, but it was not known definitely whether such increased rainfall would overcome the opposite effect of increased acreage, until the water actually began to rise in the wells. For the last four seasons the rain has been slightly greater than during the first period, and when many of the wells began to flow again there was a general feeling of relief, for it is now known that so long as the acreage is not materially increased the community can pass through other dry periods. Nature has been aided in leading the waters of San Antonio Creek down into the subterranean reservoirs by some very effectual work in diverting the flood water from the channel below the canyon and spreading it over the porous gravels. This work has been done chiefly by the Consolidated Water Company for 10 or more years, and the method will be described more fully in another place.

During the season of 1905–6 there were 26.45 inches of rain, which amount has been exceeded only four times since 1883. The following season there were 23.33 inches. The first rise in the wells in the Del Monte and Martin Cienagas was noticed in August, 1906. During the previous winter the water had been spread from the creek as far south as Indian Hill. The water rose 10 feet in thirty days, although the wells were being pumped, and began to flow again in the spring months of 1907. That season there was 28.96 inches of rain and the flow increased. The wells in the Palomares Cienaga commenced to flow in the winter of 1907 and the spring of 1908. The flow at present is diminishing in the two upper cienagas and increasing in the lower one. There has been no rise as yet in the southern part of Pomona, and the water was drawn down slightly lower than before in 1908. The rise naturally will advance much more slowly as the water approaches the lower levels of the valley where the soil is more compact, but it is believed that this section will be benefited eventually. The water has risen at the Philips pumping plant until it stands 25 feet higher than in 1905. There has been little change on Chino rancho. The water plane in 1909 was slightly higher than in 1906, but it is doubtful if this level is being maintained. The development has extended eastward and many new pumping plants have been installed during the last three years. The flow of Chino Creek has increased, but this is due mainly to return seepage waters from irrigated lands. No general rise has taken place at Lordsburg and La Verne. The amount of water that can be pumped in the Mud Springs Cienaga has diminished until it is of little value, but it is believed that this is due to the supply being cut off by pumping plants outside the cienaga. The water has risen 40 feet at some of the pumping plants at San Dimas Wash. Sufficient data have been given to show what the action of the water has been in the many wells.

RIGHTS TO THE USE OF WATER SUPPLIES.

"CANYON WATER."

It would not have been necessary to pump such a great quantity of water from wells if Pomona were entitled to use the entire discharge of San Antonio Creek. When the Pomona Land and Water Company was organized, in 1882, an agreement was reached with the individuals who later transferred their interests to the San Antonio Water Company, by which, after 20 miner's inches had been taken out to satisfy the prior claim of the Gird ranch, located in the canyon, the creek was to be divided equally between Pomona and Ontario at a point in the canyon near its mouth. It was necessary to pipe the water through the coarse gravel in order to bring the water down to the orchards, none of which, in the Pomona district, were nearer the canyon than 5 miles. Both Ontario and Pomona laid pipe lines from the division point, the Pomona line being completed in 1885. The San Antonio Water Company in 1896 purchased the Gird right, and transferred both the points of diversion and use of this 20 miner's inches. The Pomona Land and Water Company in 1897 sold the San Antonio Water Company all their interest in the waters of the creek after they had received 312 miner's inches, which amount they were under obligation to furnish to certain tracts of land at Pomona as long as the quantity in the creek was sufficient under the existing agreement with Ontario.

The San Antonio Water Company in 1902, through a subsidiary organization known as the Ontario Power Company, built a power plant in the canyon, and water was diverted from the creek, 2½ miles above, and carried by pipe through the power house, and finally returned to the creek just above the division point. The water company, after conducting a series of measurements, found that 19 per cent of the flow of the creek was lost by seepage in July, August, September, and October, 1902, between the points of diversion for power and the point of return to the channel, and that this would be saved by conveying the water through the pipe line; and they claimed the right, therefore, to use all this 19 per cent. The Pomona companies then brought suit, which resulted in a decision by the lower court to the effect that Ontario was entitled to use the 20 miner's inches secured by the purchase of the riparian right, but not the 19 per cent saved. This decision has been reversed in part by the supreme court of the State, which held that the purchase of the riparian right did not entitle the San Antonio Water Company to the use of the 20 miner's inches, but that they were entitled to 18 miner's inches, because they had diverted the water for five years without protest.[a] They were also given the water saved by the pipe line, but the case was returned to the lower court for a more exact determination of the salvage in miner's inches. The lower court decided, in January, 1910, that the salvage was 17 per cent. Provided there is no further appeal, the creek will now be divided as follows: After giving Ontario the salvage and 18 miner's inches, the remainder will be divided equally between Pomona and Ontario until Pomona has received a total of 312 miner's inches, all the surplus going to Ontario. The San Antonio Water Company conveys a certain amount of water to a point near Red Hill through the winter, when it is not needed for direct irrigation. The discharge of the creek during floods is often many thousand miner's inches, and when there is more than the San Antonio Water Company can use, Pomona also diverts water for spreading over the gravel beds on the west side of the wash. Pomona is not entitled to use more than 312 miner's inches through the irrigating season, and the greater part of the time the discharge of the creek is so small that its share is much less. The right to use parts of Pomona's share is held by the Canyon Water Company, Loop and Messerve tract owners, the North Palomares tract, and Kingsley Tract Water Company.

The creek supplies two other power houses besides the Ontario Power Company. The plant of the Pacific Light and Power Company returns water to the intake of the Ontario plant. Below the division point and before it is used on orchards Ontario's share passes through the power plant of the Ontario and San Antonio Heights Railway Company, situated below the canyon. Thus the use of water for power does not prevent its use for irrigation

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[a] Pomona Land and Water Co. *v.* San Antonio Water Co., 93 Pac., 881.

or domestic purposes and all the normal flow is used twice and a part of it three times for power, the heads being 620, 700, and 90 feet, before being used for irrigation.

UNDERGROUND WATER.

While there has been some litigation over rights to use subterranean water, this section has had less than some others in the same region. It has been difficult enough to decide justly questions of right to the use of surface waters in California, where the few laws in existence confront the courts with two such antagonistic doctrines as priority of appropriation and riparian rights. The usual complications with ground water are further aggravated by the inability to ascertain beyond doubt what takes place under ground. There are always many theories and honest differences of opinion regarding such matters, each with expert testimony in proof of its correctness.

It is only natural that there should be disagreements as to rights under such conditions as existed in Pomona Valley, where there are several hundred wells, owned by nearly as many companies and individuals, taking water from several basins connected in such a way that the usefulness of some depends upon the status of others, and all drawing from the same original source—the creek and its watershed. The matter is further complicated by the fact that the water is used in several independent districts with diverse interests.

It is only in recent years that it has been necessary to consider separately the rights to the use of subterranean water. Although there have been conflicting decisions, there are evidences that a few fundamentals have been accepted. A distinction is made between percolating water, or that which seeps slowly through the ground without having a well-defined channel and direction of movement, and subterraneam streams, and the underflow of streams in the sands of their channels which has a movement with the surface stream. The difference is clear enough in theory, but often vague in practice. Much of the trouble has centered about operations in the washes near mountain canyons, where the difficulties first resolve themselves into the question of the class to which the underground waters belong. The rules and regulations for surface streams apply to subterranean streams, but there is practically no law for guidance in settling questions of right to the use of percolating waters and the principles governing their use are not well defined.

At first the common law was followed and it was held that percolating water belonged to the land in which it was present, and as such could be brought to the surface and used or disposed of at will by the owner of the land regardless of damage to other landowners in the same basin. Percolating water consequently was not subject to appropriation as was water in a public stream. In more recent decisions the courts have attempted to maintain proper relation between community interests and those of the individual by restricting each landowner to a reasonable use of the percolating water in a subterranean basin where he is the owner of land in common with others. The landowner is allowed to take from his land what water he can use on the land or in proportion to his holding, with due regard to his neighbors in the same basin, but water can not be sold or carried outside the basin to the detriment of other landowners with corelative rights.[a] At the same time an attempt is made to consider priority and to protect vested rights.[b] Where water has been diverted from a basin and beneficial use made of it on distant lands for five years without objection being raised, it has been held that rights to use have been acquired.[c]

In the absence of statutes the courts appear to have given the chief consideration to the needs of the claimants rather than technicalities. In one case complaints against an intruder, withheld until after money had been invested and the works completed, failed of recognition because the right to proceed was not disputed within reasonable time after the work was instituted.[c] Weight has been given the use to be made of the water in question. Between a municipality needing water for domestic use and ranchers claiming it for irrigation, the former was held to have the better right.[d] Where both claims were for agricultural purposes in different localities, such a pure economical factor as the relative values produced by the water in the two places has had influence,[e] the prior appropriator being allowed damages, however, for the loss of his right. A recent decision allows parties who had drawn water from a basin without interference for a number of years by means of a tunnel to sink wells in the same locality and pump during a period of drought, provided no more water was carried away than before, and permits a change in the point of diversion in taking water from a saturated basin not in the channel of any stream so long as the amount taken out is not increased.[f]

The development in Pomona Valley has been uniform, and for this reason the difficulties over underground water probably have been few, as compared with some other sections situated similarly. Few,

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[a] Katz *v.* Walkinshaw, 70 Pac., 663.

[b] Burr *v.* Maclay Rancho Water Co., 98 Pac., 260; Barton *v.* Riverside Water Co., 101 Pac., 790.

[c] Hudson *v.* Dailey, 105 Pac., 748.

[d] Los Angeles *v.* Baldwin, 53 Cal., 469; City of Los Angeles *v.* Hunter, 105 Pac., 755.

[e] Newport *v.* Temescal Water Co., 87 Pac., 372.

[f] Barton *v.* Riverside Water Co., 101 Pac., 790.

if any, contentions have been carried into the courts as among the many individuals owning pumping plants. All water used near Pomona, Claremont, Lordsburg, and San Dimas is diverted comparatively near its point of use. Some water used on the northern part of Chino rancho is diverted at Pomona. Water pumped at the head of San Dimas Wash and at Lordsburg is carried to Covina, Glendora, and Azusa for use. Water is taken by tunnel from the gravels below San Antonio Canyon and by both tunnel and wells from the ground near Claremont for use on lands at Ontario. Litigation is now in course that should establish the respective rights of the Mountain View Water Company, of Ontario, and the Consolidated Water Company, of Pomona, to operate their tunnels east of Indian Hill.

ORGANIZATIONS FOR PUMPING AND DELIVERING WATER.

Had San Antonio Creek been large enough to furnish all the water necessary for the irrigation of the Pomona section there would probably have been to-day a single mutual company delivering water to all the lands, but the failure of this, or any other single source, to furnish an adequate amount has prevented unity of organization. Aside from the Canyon Water Company, all of the mutual irrigation companies were formed for securing and distributing water from wells and tunnels, and most of them expected to pump much of the water delivered.

A mutual company organized for the distribution of pumped water is not of necessity different in type from one organized for the distribution of water diverted from streams, yet there are some features in the methods which seem to be the outgrowth of the conditions under which the water is secured. As a consequence of the diversity of water sources the irrigation companies are small. Small streams are dealt with, measurements are precise, and charges are figured with exactness.

Some expressions used in southern California which often seem to be merely local parlance have some real significance. The term "water company" is more common than the term "irrigation company." The companies supply the water, but the irrigation is done by their individual members. Many of the small water companies in rural communities supply water for domestic use as well as for irrigation. The great value of the water on which agricultural districts, cities, and towns all depend for their existence, and the many sales or rentals of water, together with the transfers of the points of use of this so made commodity, have the effect of emphasizing the term. When water is obtained from wells or tunnels it is said to be "developed," and numerous legal contracts pertain to the right "to develop" water on certain lands. "Canyon water" is a localism used in referring to water from the mountain canyons and to the surface flow of streams to distinguish it from underground water designated after being recovered as well water or tunnel water. Percolating water is a legal distinction.

The mutual companies have different methods of providing the funds to meet their expenses. The capital stock representing the original investment in property often includes the purchase of land as a site for wells or the right to secure water on the land and the cost of distributing pipe and rights of way, as well as the cost of the pumping plants and the wells themselves. Some of the cienaga lands are valued very highly. The Del Monte Irrigation Company paid $25,000 for the right to develop water on 68 acres, embracing most of the Martin Cienaga. This did not give them title to the land itself. Companies have purchased favorably located land for which they have no immediate need to retain it for possible future use, if not for the sole purpose of keeping others from sinking wells where they would interfere with the service of their own wells. There is often much speculation in sinking wells, although much more is known now than formerly about locations where good wells may be secured. There are about 30 abandoned pumping plants and probably 75 wells which have never flowed and which do not yield sufficient water to warrant pumping, the cost of which is estimated at $150,000. Some companies have sunk a large number of wells before securing even a small stream of water. The Chino Water Company has twenty-one wells in the northern part of Pomona, of which only two have been pumped.

Most of the pumping plants of the larger companies are run only about six months in a year; those of smaller companies and of individuals less. The life of pumping machinery is short, and depreciation, with interest, taxes, and insurance, must be figured at from 15 to 20 per cent, being less for electrical than for engine-driven plants. In some of the companies the cost of operation is provided for by a charge for the water delivered, and the stock is assessed to cover the cost of maintenance, permanent improvements, and payment of bonded indebtedness and interest. This method apportions the cost among the stockholders correctly, since betterments to property benefits each stockholder in proportion to the stock he owns, while the operation benefits him in proportion to the time water is furnished to his land. Some companies, on the other hand, meet all expenses by assessments alone, and in others the water rental is high enough to cover all ordinary repairs, and an occasional assessment is made when an unusually large expense is incurred, such as the purchase of new machinery. In case expenses are less than estimated and the charge for water is fixed high enough to bring money into the treasury that is left unused, it is generally held over for future use. Dividends are rare and are not advisable, as they would offer an inducement to own shares of stock not needed for the land, and such speculation is not consistent with the purposes of the companies.

Most of the larger mutual companies deliver water only to stockholders, but some of the smaller ones, whose pumping plants need not be operated continuously through the irrigating season to supply the stockholders, make a profit by renting or selling water to others. This is always prohibited, however, if any of the stockholders need the water, and the charge is usually higher than that made to members of the company. The La Verne Land and Water Company charges stockholders 1½ cents per miner's inch per hour for the water delivered, and others 3 cents per miner's inch per hour. Stockholders in the Orange Grove Tract Water Company pay 30 cents per hour for the head of water delivered, from 40 to 50 miner's inches, while others must pay 50 cents per hour. The operating expense of companies consists chiefly of salaries of secretary, superintendent, zanjeros, engineers of pumping plants, and fuel or electrical power.

The law of California makes it the duty of boards of supervisors of counties or the trustees of cities, when petitioned by a certain number of taxpaying inhabitants, to fix water rates chargeable by corporations or individuals conducting a business of a public utility nature. The law specifies that the rate shall be fixed to give a profit of not less than 6 or over 18 per cent on the value of the plant. Were a sufficient number of people in some of the southern counties interested enough to petition such action, it is presumed that the rates charged nonmembers of the water companies could be established according to law, but the law was intended to apply to larger companies organized for no other purpose than the profit in the sale of water. The customers of a small company are fewer than the number of petitioners required, and, further, the rates charged are well within the limitations of profit, or at least well below the maximum allowable. The purchasers of water usually consider it a favor to have their land served, and do not complain of the charges; so, regardless of what legal interpretation might be placed upon the law, in practice it does not concern the little water companies.

Of the mutual companies in this section serving orchards there are only four that supply water to 1,000 or more acres. Three of these, the Irrigation Company, of Pomona, the Del Monte Irrigation Company, and the San Dimas Irrigation Company are distributers of pumped water, while one, the Canyon Water Company, is, as its name implies, a distributer of "canyon water."

The Pomona Land and Water Company, the pioneer private corporation, after sinking artesian wells, caused the organization of three mutual companies, the Irrigation Company of Pomona in 1886, the Del Monte Irrigation Company, and the Palomares

Irrigation Company in 1887. The wells, together with the right to use the water they produced and the right "to develop" more water, were transferred to these mutual companies in exchange for the stock of the mutual companies. This stock, a share of which was equivalent to a water right, was then sold with the land to settlers by the Land and Water Company. There is a State law which permits a corporation to incorporate in its by-laws a requirement that stock representing a water right be appurtenant to the land with which it is sold, and this provision was taken advantage of. The Land and Water Company forbids the purchasers separating the stock from the land unless the stock be first returned to the company, or, in other words, unless the transaction be made through the medium of the company. The purchasers were also not allowed to sink wells and develop water on their own land, the intention being to prevent them selling water. The company, however, has always granted purchasers permission to develop water for their own use when it was desired, and no occasion has arisen to test the legality of the restriction. The right to lay pipe lines through the lands sold was reserved by the company. In 1885, before the organization of the mutual companies, unimproved orange land with water sold for from $75 to $150 per acre.

IRRIGATION COMPANY OF POMONA.

The Irrigation Company of Pomona was originally organized to serve 2,450 acres of land lying between Pomona proper and San Antonio Wash on both sides of the Southern Pacific and Salt Lake Railroad tracks. North of the tracks there are citrus orchards principally, while south of the tracks the farming is diversified and includes a large area of alfalfa, some deciduous orchards, small fruits, and truck gardens. The company has twenty wells in the Palomares Cienaga, which have flowed some years. When the artesian flow becomes light or ceases altogether, they pump from sixteen of these wells with one air compressor.

The company is capitalized at $245,000, making the par value of the shares, of which there was intended to be 10 for each acre, $10 each. Each 10 shares entitles the holder to the equivalent of a continuous flow of 1 miner's inch of water. The number of shares actually used per acre varies from 5 to 20, the average being near 13. On this basis the owner is entitled to 1.3 miner's inches for each 10-acre unit, or 1 miner's inch for about 8 acres, and the par value of a water right for an acre is $130 instead of $100. The market value of a share at present is only about $2, being equivalent to a value of $20 for a water right for an acre with the use of 1 inch for 10 acres or $26 for a right for an acre with the use of 1 inch for 8 acres. Some unusual conditions have brought about this great depreciation.

For a time after the company was organized there was a large area of deciduous fruit to be served in the southern part of Pomona, but these orchards gradually grew less profitable and many of them have been replaced by alfalfa. Some of this land was subdivided into lots and sold as the city grew. Some gardening and growing of small fruits is carried on, for which water for irrigating is secured through the city's domestic service. A few of the remaining orchards are not irrigated at all and private pumping plants have been substituted to a large extent where alfalfa is being irrigated. Consequently, there are many water rights for sale, and since the wells of the company are so low that only a limited portion of the citrus district can be supplied from them, the demand for the rights is small.

The installation of the machinery at the pumping plant cost $14,729, and the total cost of the plant, including the air pipe, was $22,506.10. This brought the indebtedness of the company up to $33,000, but the debt has now all been paid. The company distributes water through mains of 8, 10, and 12-inch vitrified clay and cement pipe, the cost of the system being estimated at $50,000. A cement concrete reservoir 9 feet deep, 190 feet in diameter, and having a capacity of nearly 2,000,000 gallons, was constructed recently as a part of the distributing system.

Annual assessments of 10 to 50 cents per share have been levied, but with the indebtedness cleared they should be less in the future. A charge of 50 cents per hour is made to the stockholders for each head of water delivered, the heads varying from 40 to 60 miner's inches. The total received from water rentals in 1908 was $5,144.20. This exceeded all running expenses by about $1,200. The expenses for the year were as follows: Salaries of secretary, superintendent, zanjero, and directors, $1,330; pumping, including salary of engineer and assistant, cost of fuel, lubricants, electricity, etc., $2,342.69; maintenance and repairs, principally for pipe lines, $766.11; insurance and taxes, $105.47; office expenses, telephone service, printing, etc., $272. The cost of pumping and of maintenance and repairs for the previous four years is as follows:

Cost of pumping, maintenance, and repairs of the Irrigation Company of Pomona.

Year.	Cost of pumping.	Cost of maintenance and repairs.	Year.	Cost of pumping.	Cost of maintenance and repairs.
1904	$4,486.97	$595.06	1906	$2,820.20	$236.85
1905	3,013.75	293.57	1907	3,127.01	587.85

The cost of pumping varies considerably because there is much less pumping done when the wells flow.

DEL MONTE IRRIGATION COMPANY.

The Del Monte Irrigation Company supplies water for 2,000 acres lying southeast of Claremont, all in citrus orchards. The water is derived from a large number of wells in the Del Monte and Martin cienagas. These flowed enough when first made and again in recent years to supply all the water needed, but for a number of years it was necessary to pump. Formerly seven of the wells were pumped by an air plant, while one other was fitted with a deep-well pump, driven by an electric motor. The air plant has now been abandoned and five other plants of the type just described, drawing water from the best wells, have taken its place. The basis of the water right is the same as in the Irrigation Company of Pomona, and the average number of shares used per acre is the same. The number used by different individuals varies greatly, some renting enough shares to give them 20 shares per acre. The present value of a share is $13, making a water right for an acre worth about $170. Two assessments, one for 50 cents per share and the other 25 cents per share, have been made annually, the receipts from which have been sufficient to pay all running expenses of the company and $5,000 of the indebtedness as well. These two assessment brought $15,750 in 1908. The debt has now been cleared and the assessments may be reduced. No charge is made to stockholders for the water delivered through the irrigating season, but sometimes special runs are made and 40 cents per hour charged for the head delivered. The revenue from this source in 1908 was $539.32.

The following is a copy of the company's financial statement for 1908, which shows in full the receipts and expenditures for the year, together with the value of its property:

Financial statement of the Del Monte Irrigation Company for 1908.

RECEIPTS.	
Balance from last year	$1,349.11
Sale of old pipe (pipe lines)	82.00
Sale of injector and old brick (air plant)	28.45
Assessment No. 27 (50 cents per share)	10,500.00
Assessment No. 28 (25 cents per share)	5,250.00
Received from water runs	539.32
Certificate transfer fees	10.75
Total	17,759.63
DISBURSEMENTS.	
Ten bonds	5,000.00
Bills payable	6,000.00
Taxes and insurance	370.81
Interest	848.48

Salaries:		
Secretary	$300.00	
Zanjero	600.00	
Superintendent	180.00	
Directors	102.50	
		$1,182.50
Office expenses:		
Auditing books	10.00	
Telephone	18.50	
Postage and supplies	47.10	
		75.60
Printing and advertising		52.24
Operating expense		3.85
Electric power		1,493.65
Water from Consolidated Water Company		513.94
Pipe-line repairs		56.00
Pump repairs		60.20
Maintenance and repairs		1,060.23
Cash on hand		1,042.13
Total		17,759.63

ASSETS.

Water-development rights	210,000.00
Real estate	1,750.00
Buildings	2,700.00
Pipe lines	18,079.29
Air plant	850.43
Deep-well pumps and motors	14,000.00
Office supplies (estimated on hand)	10.00
Operating supplies (estimated on hand)	50.00
Fuel (estimated on hand)	300.00
Tools (estimated on hand)	100.00
Cash in bank	1,042.13
Total	248,881.85

LIABILITIES.

Capital stock	210,000.00
Bonded indebtedness	10,000.00
Bills payable	3,000.00
Surplus or estimated excess value of plant over liabilities	25,881.85
Total	248,881.85

The foregoing shows the operating expense, together with the cost of electrical power, to be $1,497.50. This varies from year to year, according to the flow of the wells. In 1908 the aggregate flow diminished from 180 miner's inches in April to 50 miner's inches in November. As an attempt is made to maintain four heads of 50 miner's inches each throughout the season, it was necessary to start one pump in May, a second in July, and two more in August, and in the latter part of the season a stream of 20 miner's inches was rented from the Consolidated Water Company at a cost of 30 cents per hour. The total cost for this last item was $513.94, but it was considered cheaper than starting another pump. The previous year it was not necessary to pump at all. In 1905, when the air plant and one electrical plant were operated, and when all the water was lifted about 90 feet from the wells, the cost was as follows: Operating expense, engineers' salaries, lubricating oils, etc., $2,176.16; fuel, $2,923.40; and electric power, $1,132.60; making a total of $6,232.16.

In 1906 about $18,000 was spent for new wells, pumps, electric motors, pipe lines, buildings, and real estate, bringing the total disbursements up to $34,000, and two assessments of 50 cents each were required.

SAN DIMAS IRRIGATION COMPANY.

The San Dimas Irrigation Company is a mutual company, organized in 1894, which serves 1,025 acres of oranges and lemons at San Dimas. It succeeded to the property and rights of the San Jose Ranch Company, a corporation which had absorbed the San Dimas Land and Water Company in 1887. The company owns and operates four pumping plants, one being in Mud Springs Cienaga, where several wells were pumped with compressed air. There was formerly a steam engine and centrifugal pump unit also, but this has been replaced by electrical power. The amount of water produced by the cienaga has been diminished to such an extent by the heavy draft made upon it, not only by these wells, but by others outside the cienaga, which apparently intercept the flow toward it, that it is now of much less service than formerly. At its Bonita plant, just above the cienaga, the company operates two deep-well pumps with gasoline engines. At another plant in San Dimas Wash, known as the Wash plant, a centrifugal pump and electric motor are used. At the newly acquired Walnut Avenue plant, also located in the wash, there is a gasoline engine and centrifugal pump. By a compromise made in 1905 ending the litigation over the rights in this stream, and by recent purchase of rights of other claimants, the company is entitled to one-fifth of the discharge of San Dimas Canyon until the total flow exceeds 37½ miner's inches and all of the excess. The amounts produced in the season of 1908 were as follows: Cienaga plant, 50 miner's inches; Bonita plant, 65 miner's inches; Wash plant, 125 to 80 miner's inches; and from the canyon a small and variable amount, depending upon the rainfall. Since the addition of the Walnut Avenue plant to the system an average of about 255 miner's inches is distributed through the irrigation season.

The company was formed to irrigate 1,600 acres and is capitalized at $160,000, with the par value of shares at $100, there being one share for each acre.

One miner's inch was intended to serve 10 acres, but the entire tract is not irrigated, and since the number of full-grown trees has increased, each 10 acres is allotted a continuous flow of 1½ miner's inches, making 1 inch serve 6⅔ acres. The company has an indebtedness of $28,000 and 1,025 shares have been issued. The value of a share or right for 1 acre is conservatively estimated by Mr. Bowring, the company's manager, at about $100. The expenses are provided for by a charge of 2 cents per miner's inch per hour to stockholders and 2½ cents per miner's inch per hour to others, who can be furnished water only when there is more than the stockholders need. The canyon water is sold before the regular irrigation season at prices regulated by supply and demand, but the charge usually is less than in the pumping season. The company also is a carrier and distributor of water pumped by others, for which service a charge of one-fourth cent per miner's inch per hour is made. A small revenue also is received from domestic water furnished the town of San Dimas. No assessments have been necessary in recent years. The total receipts in 1908 were $19,206.88, and the total disbursements $18,863.52. The cost of pumping and repairs for 1908 is summarized for each plant as follows:

Cost of pumping and repairs, San Dimas Irrigation Company, 1908.

Cienaga plant:	
Pumping	$2, 218. 05
Repairs	101. 77
Repairs to shaft and pipe line	273. 78
Wash plant:	
Pumping	2, 554. 24
Repairs	218. 54
Bonita plant:	
Pumping	1, 740. 34
Repairs	526. 58

The cost of water per miner's inch per hour was:

Cienaga plant	$0. 0133
Wash plant	. 0092
Bonita plant	. 0116

CANYON WATER COMPANY.

The Canyon Water Company, although not a distributor of pumped water, is a mutual company furnishing water to about 1,500 acres in the northern portion of Pomona. As the water supplied by the canyon falls low during the latter part of the irrigating season much of this land then receives a supplemental supply from pumping plants, and those owning stock in the company are usually owners of shares of stock in other companies having pumping plants or wells. The company controls 66 per cent of Pomona's share of the water from San Antonio Canyon, and as the latter has fallen as low as 100 miner's inches and is limited to a maximum of 312 miner's inches, the quantity distributed by the company varies from 66 to 206 miner's inches. The stockholders in the company include a greater portion of the landowners of the Loop and Meserve tract and all of those on the subdivision known as the Kingsley tract. The remainder of the canyon water is used by the other landowners on the Loop and Meserve tract and those on the North Palomares tract. The company is capitalized at $312,000, the par value of a share being $10. Thus there are 100 shares for each miner's inch of water received by all of the Pomona interests, and it was the original intention that all landowners owning rights to canyon water should become members of the company. In practice one miner's inch serves about 8 acres and the water is valued at $1,500 per miner's inch, making an acre water right worth $187.50. Landowners on the Kingsley tract have organized the Kingsley Tract Water Company, whose pumps supply additional water when the creek is low. The creek water is brought from the canyon through the Loop and Meserve cement pipe line, which is maintained jointly by the company and the other users of the canyon water. The maintenance and operation cost about $3 per miner's inch annually, or about 37½ cents per acre.

OTHER IRRIGATION COMPANIES.

The following small incorporated mutual companies also supply pumped water to citrus orchards:

Serving lands near Pomona: Palomares Irrigation Company, Kingsley Tract Water Company, Currier Tract Water Company, Orange Grove Tract Water Company, Packard Water Company, and Monte Vista Irrigation Company.

Serving lands near Claremont: Claremont Cooperative Water Company, Pomona Ranch Water Company, Monte Vista Water Company, Valley View Water Company, Mont Antonio Water Company, Harrison Avenue Water Company, and Indian Hill Water Company.

Serving lands near Lordsburg: La Verne Land and Water Company, Mesa Land and Water Company, Live Oak Water Company, Citrus Water Company, Old Baldy Water Company, Illinois Land and Water Company, Mills Tract Water Company, and Richards Irrigation Company.

Serving lands near San Dimas: Artesian Belt Water Company, Frostless Belt Water Company, La Verne Irrigating Company, and New Deal Land and Water Company.

In the foregoing the largest area served by one company, the Palomares Irrigation Company, is 600 acres. The principal difference in the manner of conducting the business of the smaller and the larger companies is one of magnitude and not of method. The smaller ones have one or sometimes two pumping plants, and distribute only one head of water, which, where the plant capacity is small, is often of a small size. The expenses of such companies vary from $3 to $10 per acre per annum. In the Palomares Company an annual assessment of 30 cents per share has been sufficient for several years, since the indebtedness has been cleared. This amounts to $3.90 per acre on the basis of the average use of 13 shares per acre, or about 1 miner's inch to 8 acres.

The Chino Water Company is the only mutual company in the district serving land entirely in the alfalfa and diversified-crop region. It was organized as subsidiary to the Chino Land and Water Company, a close corporation, which has been selling the subdivided land of Chino rancho. It was organized for about 1,000 acres along the north border of the ranch, and a share of stock represents one-tenth miner's inch. More than half the tract has been sold to settlers at present, and consequently they control the company. The water rights may be considered to have a present market value of about $75 per acre, although they are not sold separately from the land. A head of 50 to 60 miner's inches is delivered and a charge of 2 cents per miner's inch per hour is made except to the holders of certain old rights, who pay only 1½ cents per hour. This rental was sufficient to pay all expenses of the company last year, but it is expected that assessments will have to be made when any unusual expenditures are incurred. The company owns two pumping plants and seventeen wells in the Palomares Cienaga in Pomona. A 16-inch cement pipe line carries the water from these pumping plants to the land irrigated. The distributing system includes two concrete reservoirs.

Several other corporations organized for profit pump water principally for use on their own lands. The Pomona Land and Water Company operates one pumping plant. The Chino Land and Water Company has two pumping plants and a number of flowing wells. The latter company leases water to some of the landowners on Chino rancho. For a number of years prior to 1905 Chino rancho was mortgaged and, as this prevented the sale of the land, development was slow. The ownership of the stock of the company changed in that year, and the indebtedness was cleared. Settlement has been rapid since and has extended eastward until about three-fourths of the valley lands of the rancho are now owned by settlers. Alfalfa land has been sold at $125 and $150 per acre without water, the purchaser being at liberty to develop water on his own land but not allowed to sell it to others.

The American Beet Sugar Company pumps water for use in their factory at Chino from a number of wells by compressed air, and the waste from the factory is used in irrigating their best lands.

There are about twenty partnership pumping plants in the valley, and numerous others under individual ownership. These are found in all parts of the district and seem to be preferred by the alfalfa ranchers. It gives them greater independence in regard to the time for irrigating, which is more necessary with alfalfa than with orchards. One partnership plant in the alfalfa region is located with the well and pump on one ranch and the engine on the other. Each of the owners pays the other 50 cents per hour when he runs the plant, which delivers about 24 miner's inches, and each is limited by agreement to the irrigation of 42½ acres.

COMPANIES FURNISHING WATER FOR DOMESTIC USES.

The character of the towns of southern California is such that it is difficult to distinguish between the domestic and agricultural uses of water. The towns are spread over large areas and the possibilities of growing many varieties of fruits, flowers, and ornamental trees and of gardening throughout almost the entire year cause much of the water nominally supplied for domestic purposes to be really used for irrigation. The city of Pomona is supplied with domestic water by the Consolidated Water Company, a private corporation. The company owns one tunnel and several pumping plants, a large distributory system of cement and iron pipe, and a concrete reservoir holding 1,000,000 gallons. Its property was valued at $362,000 in 1907 by engineers appointed by the city of Pomona. Chino is supplied with domestic water by the Chino Domestic Water Company, the stock of which is owned entirely by the Chino Land and Water Company. Claremont is supplied by the Citizens' Light and Water Company, which operates two pumping plants. San Dimas depends on the San Dimas Irrigation Company for domestic water, and Lordsburg is supplied by a municipal system with two pumping plants. There are no other municipally owned domestic water plants.

PUMPING INSTALLATIONS.

The map (Pl. I) shows the location of 260 pumping plants, and about 30 additional plants recently constructed are located on Chino rancho, east of these limits. The map does not show the location of wells not pumped. It is estimated that $1,000,000 has been invested in pumping plants and wells in this territory.

WELLS.

The part of a pumping plant that is most difficult to obtain is the well, and not the machinery. The first wells were of 7-inch casing. Later 10 and 12 inches were the common sizes, while now 14 to 26 inch wells are driven. The larger sizes are more suitable for the use of both deep-well and centrifugal pumps, and give a larger area for water to enter the wells from the gravel strata. Wells are bored much deeper than formerly, for with a changing ground water level it has been found desirable to penetrate several good water-bearing strata. The rapid and cheap hydraulic, or rotary, process of sinking wells so much used in the southern rice belt can not be employed on account of the many bowlders encountered, the standard water rig with drill and sand bucket being required. With such a rig the casing is forced down to follow the excavation by hydraulic pressure, often reaching 100 tons. The wells are cased with a double thickness of riveted steel, 12 and 14 gauge, in lengths of 2 feet, placed with broken joints. This is known as stovepipe casing, and, as it has no couplings like screwed casing, it is smooth on the outside and more easily forced down.

At the bottom of each well is the starter, a riveted sheet-steel tube of treble thickness, 20 feet long, carrying a steel shoe at the lower end. Strainers are unnecessary, as there is no quicksand or very fine sand unmixed with gravel, but the casing is slashed where it is in contact with water-bearing strata. This is done after the casing has been sunk by a special implement lowered into the well. The cutter of the tool is forced through the sheet-metal casing from the inside, and leaves a slot with edges bent outward, with the narrowest part of the opening at the outside, so that anything that enters the outside will be drawn through by the pump, thus preventing any tendency to clog. It is advantageous to make as many openings through which the water can enter as possible, without weakening the casing. Four cuts are made in the circumference of 10 and 12 inch casing, and more for the larger sizes. The cuts are vertical, and must be less than 2 feet long, since that length might sever an entire joint. Perforated starters like those sometimes used for wells near the coast have not been used in this locality. A cut or perforated section of casing should be rather below than above the water-bearing stratum from which it is to draw, since, when pumping, the surface of the ground water falls rapidly as the water is drawn toward the well and the head forces water into the casing. Many new wells on first being pumped deliver much sand. This is an indication that the well will be a good producer of water after the fine sand has been removed from the material immediately around the casing, thereby providing a more free passage for the water through this contracted portion.

The price of drilling wells is much greater where there are bowlders than in fine material. Among bowlders a large well is also cheaper in proportion to its size than a small one, because the bowlders can be removed more readily through a large casing, while in drilling a small well they must be pushed aside or cut through. In fine material 7 to 14 inch wells, not over 350 feet deep, are drilled for $1.50 per foot. Near the foothills, where there are many large bowlders, 12-inch wells cost $2 per foot, and 50 cents is added for each additional 2 inches in diameter, making a 24-inch well cost $5 per foot. These prices do not include the cost of steel casing, which is as follows:

Cost per foot of steel well casing.

Diameter.	16-gauge.	14-gauge.	12-gauge.	10-gauge.
Inches.				
7	$0.59	$0.68	....	....
10	.83	.99	$1.20	....
12	.90	1.06	1.37	$1.78
14	1.08	1.20	1.62	1.97
16	1.21	1.33	1.94	2.17
20	....	1.57	2.23	2.64
24	....	....	2.69	3.20

In fine material 2-ply starters are used, but among bowlders 3-ply should be used for the lower 15 feet and 2-ply for the remaining 5 feet. A 12-inch 2-ply starter of 24-gauge iron costs $48 and a 24-inch 3-ply starter of the same gauge $127.

TYPES OF PUMPING MACHINERY.

After passing through several stages in the use of pumping machinery, in which nearly all kinds of installations have been tried, the practice has narrowed down to the use of a few kinds which have proven to be best adapted to the conditions. The number of plants now operated, representing the several common types of installation, are about as follows: Gasoline engines and centrifugal pumps, 100; gasoline engines and deep-well pumps, 50; electric motors and centrifugal pumps, 30; electric motors and deep-well pumps, 40; steam engines and centrifugal pumps, 6; steam engines and air lifts, 6.

The manufacture of pumps and irrigation supplies is an important industry at Pomona, and is the outgrowth of the need of machinery adapted to the high lifts of the locality and appliances better adapted to control the water than those that can be secured in the general market. There is a new centrifugal pump manufactured in addition to the several deep-well pumps that have originated there.

CENTRIFUGAL PUMPS.

The centrifugal pumps used are of the vertical kind and have closed runners balanced by a distribution of the head over unequal areas on top and bottom of the runner that will overcome the weight of the runner and the shafting above. The balance in some of the pumps is accomplished by a top suction and the local pump has a bottom suction, thereby dispensing with some pipe and two elbows in the suction. The common sizes are 4-inch and 5-inch pumps, and these are fitted with 10-inch discharge pipes and with as large suction pipes as will enter the well casing, thereby reducing the friction to be overcome in pumping. Pumps are provided with a water seal at the stuffing box to prevent air leaks. When the ground water is receding pumps are rarely found submerged, and many of them on poor wells work with suction lifts almost to the limit. While it should make no difference theoretically how the lift is distributed between suction and discharge so long as the suction limit is not exceeded, in actual practice on account of air bubbles entering the wells the shorter the suction lift the better. The pumps are placed at the bottom of open shafts excavated as deep as the ground water will permit. These shafts, or pits, usually are 6 by 6 or 5 by 7 feet when curbed with 2-inch redwood boards, or circular when curbed with concrete. The cost of the excavation varies with the depth. When the ground water recedes the pumps must often be lowered to keep them within suction reach of the water. This necessitates deepening the shafts and removing additional joints of the well casing. During the dry years many of the pumps were lowered 20 feet every two years. One shaft in the San Dimas Wash, already a little over 200 feet in depth, was lowered 20 feet and curbed at a cost of $400. At a plant near Chino the shaft and pump were lowered from a depth of 40 feet to one of 60 feet at a cost of $218.

Curbing sinks unless it is suspended from the top. This is commonly prevented by fastening it to two timbers laid across the open shaft on the surface. The life of a wooden curbing is short and many pump shafts made ten or more years ago have caved as a result of the decay of the curbing. Concrete curbing, although more expensive to put in, is the most economical in the end, and many shafts are now curbed with this material.

The Consolidated Water Company has a 60-foot circular shaft, with inside diameter of 6 feet curbed with a 6-inch wall of reenforced concrete. The reenforcement consists of $\frac{5}{16}$-inch twisted steel rods laid both vertically and horizontally, with a spacing of 18 inches. The curbing was constructed on top of a steel shoe and lowered with the excavation. The weight of the curbing is supported by four $\frac{5}{8}$-inch steel cables fastened to the shoe at the bottom and passing through the concrete walls to the timber at the top.

Centrifugal pumps are placed at the bottom of a wooden frame, which also supports the shafting with its bearings and the suction and discharge pipes, the whole being suspended in the shaft from the timbers across the top. The pump and frame are then independent of the well curbing, and the settling of the latter does not disturb the alignment of the shafting. The pump also may be very conveniently raised for repairs or lowered to follow a receding water level. The frames are built of 2 by 12 inch timber, the sides being of double thickness. These are bolted together in sections, and in raising the pumps the sections may be taken off separately. It is only necessary when the pumps must be lowered to lengthen the frame and shafting at the top and add more shaft bearings. Steel pump frames, although heavy and costly, are coming to be more generally used on account of their strength and durability. One of these, 98 feet in length, is built of 12-inch channel iron, with diagonal bracing, the cross beams and the shaft bearings being spaced 6½ feet apart. The cost was $2.50 per linear foot.

The seasonal and periodical changes in the ground-water level are so great that it is not practical to connect a centrifugal pump with two or more wells by suction pipes passing through tunnels from the shaft. For the same reason it is not practical to use either a horizontal centrifugal pump, directly connected to an electric motor at the bottom of the shaft, or a vertical pump and vertical motor directly connected. With the direct-connected vertical installation the only objection would be the difficulty of changing the pump speed for changes in lift. With belted machinery a set of pulleys enables the changes to be made in the pump speed that are required for good efficiency.

A type of vertical pump much used in the Louisiana and Texas rice fields has been installed on a few wells near Chino. This pump is placed in a steel-cased shaft or pit less than 30 inches in diameter. The casing, or shell, carries an auger at the bottom and is bored into the ground by a rotary well rig. These pumps and pit casings are primarily for use where it is desired that a pump run submerged or where quicksand makes it difficult to lower a pit in saturated ground in the ordinary way.

Turbine pumps are used on a few wells in the northern part of the valley. This pump is a modification of the centrifugal pump, made to avoid the necessity of a pit where the lift is from great depths. It consists of several small runners on a vertical shaft, each within its own shell, the entire series being placed under water inside the casing of a bored well. The runners are given a high speed. The efficiency is not high, and the 5-inch pump is not recommended for lifts over 225 feet.

DEEP-WELL PUMPS.

The deep-well pumps used raise water by means of plungers working in a cylinder attached to the bottom of a discharge or column pipe, the whole of which has been lowered into the well until the cylinder remains under water while pumping. The cylinder is of brass and is about 2 inches less in diameter than the well casing, while the column pipe is only 1 inch less.

The pumps are double-acting, and two plungers, in which valves are combined, are worked in one cylinder by rods connecting with a power head at the top of the well. A solid rod connecting with the lower plunger passes inside a hollow rod connecting with the upper plunger and both rods pass through a stuffing box at the surface. The pumps are provided with a check valve and air chamber. The customary sizes are from 7-inch cylinder and 24-inch stroke to 16-inch cylinder and 36-inch stroke. Speeds of from 18 to 30 strokes per minute are used, and one plunger makes its upward while the other makes its downward stroke, so that there is a constant discharge. Power heads are a combination of gears and levers by which the circular motion of the belt wheel is transformed into the reciprocating motion of the rods and plungers. The heads are ingeniously arranged to cause one plunger to begin its upward stroke by means of a quick return before the other has quite completed its upward stroke, and thus in a measure avoids pulsation in the discharge. Without the lap the long water column would have to be started in its upward movement twice in each revolution of the crank arm as the latter passed the dead centers, and this would require more power as well as cause more wear on the machinery.

The usefulness of deep-well pumps depends much on the condition of the leathers on the plungers. These wear rapidly, and must be replaced every two years on pumps that are used much, and if sand is pumped they wear out in much less time. The cost of leathers themselves is small, but the pulling of the rods and plungers necessary to replace them is expensive. As the column pipe is larger than the cylinder, the plungers may be removed through the column pipe. Power heads are placed on concrete floors on the surface or in concrete-lined pits 6 feet deep.

COMPRESSED-AIR PUMPS.

Compressed air has been used principally in pumping a large number of wells, usually from 6 to 20, from one central plant. The mechanical efficiency of the air lift is low, due in part to the useless work represented by the heat that accompanies compression. The first cost of the air lift is high for pumping single wells. Water can, however, be pumped very cheaply when the air can be piped to 10 or more wells, but when it is carried more than one-half mile from the compressor the loss of pressure by friction in 6 to 2 inch air pipe is high, and long lines of larger pipe would be expensive.

Air is supplied to wells at pressures from 50 to 100 pounds per square inch, and it is carried down into the well and released under water by different arrangements. A discharge pipe is placed inside the well casing, and in most lifts the air pipe is inside the discharge pipe. A new lift, for which certain improvements are claimed, has given satisfaction when pumping only one or two wells from one compressor. In this lift the air pipe passes down into the well outside of the discharge pipe, and the air is released into a slightly enlarged section of the discharge pipe containing a specially designed foot piece.

The lifting power of air is due to its expansion and displacement. In pumping against any head there is a certain ratio between the volume of air and the volume of water in the mixture that rises from the well that gives the highest efficiency. More air must be supplied to pump the same quantity of water if the head increases, and this requires greater pressure. The aim is to keep the velocity low and maintain a pressure just sufficient for the water to be raised with the air bubbles. The air should be mixed thoroughly with the water.

For the best results air must be released at a depth in the water equal to about twice the lift. This limitation has made it necessary for some of the air plants to be abandoned when the water level receded, because the wells were too shallow to allow the proper submergence of the air pipe. The largest pumping plants in the locality have been air lifts of 100 to 200 horsepower, the compressors being in tandem with Corliss compound steam engines. Air lifts are best adapted for pumping several small wells reasonably close together and with certain limitations of lift.

ADAPTABILITY OF THE SEVERAL TYPES OF PUMPS.

Centrifugal pumps are best adapted for lifts not over 100 or 150 feet, but may be used up to 200 feet if the well is very productive. The size of the well does not limit the size of a centrifugal pump that can be used as it does that of a deep-well pump of the plunger type. The makers of centrifugal pumps furnish tables showing the proper speed at which the pump should be run for the highest efficiency for certain lifts and streams of water raised. An increase in either the lift or rate at which the water is pumped requires a corresponding increase in speed. From 900 to 1,100 revolutions per minute is the maximum speed at which most 4 and 5-inch pumps can be run without undue wear, belt slippage, and loss in efficiency. If a higher speed is required it is better to use a compound centrifugal pump which will do the work at less speed. It is practical to use the single pump for heads up to 100 feet, but above 75 feet compound pumps are better.

Deep-well pumps are best adapted for lifts over 100 or 150 feet, provided the well casing will admit a cylinder large enough to enable the well to be pumped to its full capacity. Some 26-inch wells are being drilled, but the largest cylinders on the market are only 18-inch. Such a cylinder with a 36-inch double stroke has a maximum capacity of about 100 miner's inches. Deep-well pumps are more efficient than centrifugal pumps and cheaper to operate, but as a rule they are much more expensive to keep in repair. The plunger rods of deep-well pumps often break, and in a few extreme cases almost an entire summer has been spent in making repairs of this nature. Too high speed is often the cause of such breaks, and it is better to use a large cylinder and long stroke with a slow speed. Centrifugal pumps often run through several seasons with scarcely any repair, and they are not damaged as much by sand in the water as are the deep-well pumps. Deep-well pumps have taken the place of centrifugal pumps at many of the pumping plants in the northern part of the district, where the water level has lowered to depths of 150 to 200 feet. The cost of deepening shafts after these depths have been reached is so great that it must be considered. Sometimes, however, it is not possible to change to a deep-well pump, because the well casing is so crooked that it does not permit the use of the plunger rods, and some wells have been abandoned for this reason. No deep-well pumps have been used to raise water for alfalfa. The highest lift for which they are used is about 400 feet, at the Mont Antonio pumping plant near Claremont.

The triplex pump, although one of the most efficient types for forcing clean water to considerable heights above the ground, is not suited for pumping from deep wells.

POWER USED FOR PUMPING.

Steam was the first power used for pumping, both for the large air lifts and for driving the centrifugal pumps then used altogether at the small plants. The drift has been gradually away from steam power for the small plants, and the engines have been replaced by gasoline engines or electric motors, which have proven to be better adapted to smaller plants. Only five or six steam engines are now operated in addition to those at air plants, and those in use are at plants of large capacity. The steam engines used at air plants are combined with the compressor as one piece of machinery. The air lifts of several companies have recently been replaced with single pumps and electric or gasoline power. The fuel used for steam power is crude oil, costing about $1\frac{3}{4}$ cents per gallon. Steam power, if used at all in the future, probably will be used only for plants of 100 horsepower or more, running continuously for long periods. Steam engines require constant attendance, which is one of the principal objections to their use. Plants of the type referred to are used principally by large companies and are installed by competent engineers.

In the design or arrangement of plants of less than 50 horsepower, engineering advice is rarely sought. Pumps are installed by their makers, gasoline engines by their selling agents, and electric motors by the companies supplying power. The question of the best kind of power to use in the small plant is one that depends on several things, and each special case must be considered by itself. At the usual prices of gasoline and electric power, the gasoline engine is the cheaper power, providing there is no cost for attendance, but if it is necessary to employ an attendant at the usual wage of 25 cents per hour, electric power is the cheaper. Gasoline engines very often can be made to run with but very little attendance, and where they are owned by individual orchardists or ranchers it is not usual to employ an engineer, as the owner or irrigator finds time to visit the engine occasionally while irrigating the orchard or alfalfa. The engines must be oiled at least every six hours, and, as a rule, engines which receive as little care as this need expensive repairs or soon wear out. It is difficult to estimate the cost of attendance in such cases. It is better for the engines run without constant attention to be slightly underloaded, so that they will miss an explosion occasionally. The underloading, however, is more often carried to such an extreme that a marked loss in efficiency is the result. Although it is unwise to run gasoline engines at too high a speed, a common practice, which lowers their efficiency, is to run them as much as 10 to 20 revolutions per minute under the normal or best speed. At the plants of the small water companies, where attendants are employed, the engines are of the higher speed type. They are more often fully loaded, but even with underloading they are governed by regulating the quantity of fuel in each charge instead of by cutting out explosions. This gives them a more uniform speed. When the mechanical tests were made in 1905, No. 1 engine distillate cost $6\frac{3}{4}$ cents, and No. 2 distillate $5\frac{1}{2}$ cents, per gallon. The prices have now advanced to 9 and 8 cents per gallon, respectively.

Several gasoline engines with generators are operating on the intermediate grades of fuel oils known as stove distillates. The generators utilize the heat of the engine exhaust in volatilizing the oil admitted to the engine. The temperature maintained in the generator depends upon the kind of oil used. At the plant of the

Artesian Belt Water Company the fuel is oil, about 32 Baumé, costing 4½ cents per gallon, delivered at the plant. Five gallons of stove distillate is equivalent to about 4 gallons of engine distillate. With the plant in operation five or six months each year, the residue left in the engine makes it necessary to replace the cylinder rings each year and to rebore the cylinder or get a new one every two years. Even allowing for these expenses, there is a saving over the cost of operation on engine distillate.

Oil engines designed to use the lower grades of crude oil directly, by vaporizing the fuel at its entrance to the cylinder by the engine's own heat, are on the market. These have been used successfully for some time with eastern paraffine base oils, but until quite recently no engines of this type were used in southern California. They had been greatly improved, however, in the last few years and are now being installed in southern California and operated, using asphaltum base oils. The first of these engines to be installed was one of 180 horsepower at the Orange Cove Tract plant in San Fernando Valley.

It uses 19 gravity oil which costs 2¾ cents per gallon. This engine gave satisfaction during its trial and was accepted after being run only a part of one season. The real test of such an engine, however, should be its condition after two years' service. The first cost of engines of this type is high, being about $100 per horsepower, but if they prove a success they will be a cheap form of power. A 250-horsepower engine of this type is being installed at Corona.

It is probable that producer gas from crude oil will be used for power to some extent in the future at pumping plants of large capacity, but it is doubtful if its use will become very general in this section, where most of the pumping plants are small, as the first cost of gas producers is high for small plants, and few producers are made in sizes of less than 150 horsepower. Gas produced from crude oil for use in the gas engine is a very cheap power, although the producers for oil are not so surely past the experimental stage in their development as are those for coal and other fuels. The chief trouble has been to wash or scrub the gas of coal tar, asphaltum, and other impurities, which must not be carried into the cylinder of an engine. It is now claimed for the improved producers that when operated properly the gas is practically free from coal tar and asphaltum, leaving only lampblack to be removed by washing. Tests show that the producers have an efficiency of about 75 per cent and that the systems furnish 6 to 7 brake horsepower per hour per gallon of crude oil. The gas produced is fixed. Its heating value varies from 150 to 200 British thermal units per cubic foot for the grades of oil ordinarily used.

The Glendora Mutual Water Company has installed a gas-producer plant in San Dimas Wash. It consists of a 150-horsepower producer and a 114-horsepower, vertical, 3-cylinder, 4-cycle engine with a speed of 250 revolutions per minute. Crude oil, 12 to 20 Baumé scale, is used for fuel and costs 2 cents per gallon. The producer is equipped with a centrifugal washer for the purpose of cleansing the gas of impurities. There is also a small gas holder for regulating the supply to the engine and for use while the producer is being burnt out. The auxiliaries of the plant consist of a small geared pump for pumping the fuel oil; a small air blower worked up to a pressure of 1 pound per square inch for the purpose of aiding combustion; two small centrifugal pumps, one for circulating the water in the centrifugal washer and the other to pump the water used to cool the engine; an air compressor, together with storage tanks for use in starting the large engine; and a 6-horsepower gasoline engine for operating the auxiliaries when the plant is being started. The engine is belted to a turbine pump which delivers 70 miner's inches, the head under which it is operated being 212 feet. It is intended that the producer shall also supply another engine.

The cost of the producer engine and auxiliaries was $10,000, and the total cost of the plant, including the well, pump, and the building, was $21,600. Three men are required to operate the plant.

This plant has been in use only a few months, but it has worked well and the indications are that it will work successfully and that there will not be the numerous delays which made the operation of some of the first plants of this type so costly.

The cost of power with such a plant, including attendance and all fixed charges, is about 1 cent per horsepower hour and is little less than the price of electric power, including attendance and fixed charges, paid by some of the water companies of southern California which operate ten or a dozen pumping plants. Twelve per cent should cover the depreciation for such a plant. The producers need to be rebricked every few years where they are used continuously during the irrigation season. There being little probability that the price of oil will be reduced in the near future, and as the cost of electric power is expected to become lower with increased competition, water companies have not been in haste to replace present installations with new systems until the latter are shown by thorough test to be perfect.

While electric power for pumping is more expensive than gasoline, induction motors have the advantage of requiring less attention than any other kind of power machinery, and of running with less repair and with a little higher efficiency. They show also less loss in efficiency when underloaded and are devoid of adjustments, as in the gasoline engine, which must be properly made to obtain the best results. These features, together with the ease with which they are started, make them the most convenient kind of power. Some of the water companies pump very cheaply with electric power by running several pumps, thus enabling them to get a low rate and to have all the plants under the care of one attendant. An arrangement has been made through the medium of a power company by which one man cares for several small plants under different ownership at a cost of about $10 per month for each. The attention given motors by individual farmers is so little as hardly to be considered.

The alternating current and motors wound for 60 cycles (7,200 alternations per minute) are used. The current furnished by power companies is generated by water power in mountain canyons from whence it is transmitted long distances. The circuit is three-phase and the voltage is reduced at each plant to 440 or 550 volts. The rates charged vary with the quantity used, but the average is about 2 cents per kilowatt hour, or 1½ cents per horsepower hour. One of the companies running several pumps gets a rate of 1¾ cents per kilowatt hour. At one plant, which supplies water to a few acres of oranges only, a rate of 3 cents per kilowatt hour is paid for nine months, with a minimum charge of $15 for the other three months. This plant uses power at the rate of about 10 kilowatts per hour. A rate of 1 cent per horsepower hour, or 1⅓ cents per kilowatt hour, has been offered, provided a certain number of customers will use the power only during the night, at which time there is a surplus. In order to accept the offer, the users either would need small reservoirs in which to store the water pumped or would be compelled to irrigate altogether at night. In 1905 a proposal was considered by the Pomona and Claremont farmers' clubs to construct a cooperative central power plant from which electric power was to be distributed over the entire district for pumping. A joint committee was appointed to investigate and report on the possibilities, but it was difficult to bring the diversified interests into unison and nothing further was accomplished. One of the difficulties would be to dispose of the engines now used without loss to their owners.

Contrary to general belief, the cost of fuel is not the greatest expense of pumping. The fuel cost usually is no more than one-fourth of the total, including interest, taxes, depreciation, repairs, and attendance. This will be discussed more fully under cost of irrigation. The tests made in 1905 show that for plants of 10 to 100 horsepower the cost of gasoline and electric power for pumping water per foot acre-foot (an acre-foot raised 1 foot) is as follows:

Gasoline—centrifugal plants	$0.016 to $0.074
Gasoline—deep-well plants	.015 to .059
Electric—centrifugal plants	.047 to .110
Electric—deep-well plants	.033 to .070

The wide variation in these figures indicates the great difference in the service of pumping plants.

In orchard sections, where cobbles and bowlders are available, pumping plant buildings that do not detract from the surrounding landscape have been constructed of them. Galvanized corrugated iron serves as a durable material for coverings in places more remote from residential locations. Permanent derricks are built over the wells, so that pumps, frames, piping, cylinders, or rods can be raised or lowered conveniently. Belt centers usually are 25 feet apart, and the belt pulleys are large so that the weight of the belt is sufficient to prevent excessive slipping and at the same time the pull on the bearings is not so great as with a short, tightly stretched belt. Centrifugal pumps that need priming are provided at the top of the shaft with a small hand pump connected with the large pump casing by a small pipe. With such an arrangement a vacuum can be produced in the centrifugal pump casing. A check valve is placed in the discharge pipe above the pump and a foot valve is unnecessary. At some of the electric plants which are not watched constantly, automatic switch pullers are used which shut off the electric current if by accident the pump ceases to raise the water. At some of the gasoline plants a float in the weir box is connected by a wire to the electric igniter of the engine, so that the latter fails to work if the water falls, thus preventing the racing of an unloaded engine. Another safety arrangement is a bell alarm, which warns the irrigator of any accident that may stop the discharge of the pump. Large gasoline engines are equipped with an appliance for starting by compressed air. Gasoline tanks are buried outside the buildings. A typical pumping plant is shown in Plate II, figure 2.

METHODS OF DISTRIBUTING WATER.

The distribution of water has reached high efficiency, and in the prevention of losses from seepage and evaporation in the conveyance of water from its source to its point of use the system is unsurpassed. Ordinary ditches were first used, but much of the water was lost in the porous, gravelly soils. The loss by evaporation, although small in comparison to seepage, was material in such a warm and dry climate. In many cases the greater part of the water failed to go where it was intended to go. With the small supply of water available, and its great value, measures were taken very soon to make the channels water-tight, and now practically all the water used at Pomona is piped underground and is not seen from its source to the head of the furrow in the orchard or to the exact point of application in an alfalfa field. In some of the fruit districts, where more gravity water is used, the larger streams are carried in open cement-lined ditches, but at Pomona the main channels as well as the smaller lateral lines are closed, so that both seepage and evaporation are reduced to a minimum.

CONCRETE PIPE.

Iron pipe is used for carrying water in some places, but as a rule this is where it is under pressure of a head of over 10 or 12 feet. For lines under less pressure, or no pressure at all, as many of them are, concrete pipe is used principally, its cheapness and durability when properly made making it a most desirable conduit. The first concrete pipe laid at Pomona, although not the first in southern California, was the Loop and Meserve line, which was completed in 1885 from the division point at the mouth of San Antonio Canyon to Claremont in order to bring canyon water down to the orchard district. Every drop of water would have been lost had an attempt been made to carry it in an open, unlined ditch. It is still the largest pipe line in the district, being 16 inches in diameter from the canyon to the San Bernardino base line, a distance of 4 miles, and 14 inches in diameter for the remainder of the distance. It is in fine condition and has gained in thickness in places by a lime deposit. It was intended to be constructed of a mixture of 1 part cement to 4 parts sand and gravel, which is the mixture used in this section unless another is specially ordered.

Considerable pipe in southern California has been found deficient, but in almost every case the trouble can be traced to improper making. Unclean sand and not impure cement is known to be the more common cause of defective pipe. Foreign, eastern, and California cements are all used in the construction of pipe, and recently there has been but little complaint of any of these. The sand and gravel used by the pipe makers is procured from the washes, that at Pomona being principally from San Antonio Wash, only 2 miles distant. Pipe makers are often careless in the selection of sand, especially when using fine grades, in which it is more difficult to detect the impurities. The dirt and impurities in the concrete apparently disintegrate and are washed out, and the weakened pipe can not withstand the force of the roots of trees growing along the lines.

Tree roots, however, can not penetrate pipe that is properly made and laid.

The Irrigation Company of Pomona and the Del Monte Irrigation Company are using vitrified pipe for their mains in preference to cement pipe, regardless of the higher cost, because much of the latter has been unsatisfactory. H. J. Nichols, manager of the companies stated, however, that if he could be assured that proper materials were used in the construction of concrete pipe he would have no hesitation in using it. The Irrigation Company of Pomona relaid 600 feet of 8-inch concrete pipe with vitrified pipe in 1907. The concrete pipe was 1 to 4 mixture, and was laid in 1888. About 7 per cent of the joints were perfectly sound, the rest having disintegrated, although they were all made at the same time. The Del Monte Irrigation Company replaced a half mile of 8-inch concrete pipe, which had been damaged by tree roots, with vitrified pipe in 1908. A drain of 8-inch concrete pipe at the end of San Jose Hills, which had been rejected for irrigation purposes, was used for eighteen years before it became useless. It was replaced with vitrified pipe in 1908. On the Chino rancho, where some of the low-lying damp land has been drained, vitrified pipe has been used, as it was feared that the alkali would destroy concrete pipe. Although much trouble has been experienced, due, it is believed, to the careless selection of material, probably the greater part of the concrete pipe in use is in excellent condition. Pipe that has been used for a long time often is found upon inspection to be harder than when laid. An 8-inch line laid in black adobe soil in 1900 was broken in 1908 by being run over with a heavily loaded wagon, and was found to be in perfect condition. There is nothing in either pure cement or pure sand to decay, and in time it hardens like rock, the pores fill with silt, after which it holds water better than when new. A mixture of 1 to 4 is sufficient, but occasionally pipe is ordered of 1 to 3 mixture to insure greater strength. Concrete pipe of the same thickness as vitrified pipe, but having the same amount of cement per linear foot as the thicker pipe, has been made at Los Angeles, Anaheim, and other points, and gives a much stronger mixture. The pipe has been used with much success, and will no doubt be more generally used. The city of Riverside is using concrete pipe in preference to the vitrified for sewage purposes. Care is taken to select and test the material used in the construction of the pipe, which is of 1 to 4 mixture. Much trouble has been experienced there in getting good vitrified pipe, much of which, while apparently perfect in glaze and burning, has been found defective. It "quarter checks," or cracks longitudinally on the outer face, and some of it softens with age, so that holes for connections can be made with single blows of a sledge. The cost of cement pipe of 1 to 4 mixture at Pomona is as follows:

Cost of cement pipe at Pomona, Cal.

Size.	Cost per foot.	Cost per foot laid.
Inches.	*Cents.*	*Cents.*
8	12½	17
10	16	22
12	22	32
16	35	50

The 1 to 4 mixture used is 19 per cent water and is called a dry mixture, as the forms can be removed immediately after molding. The

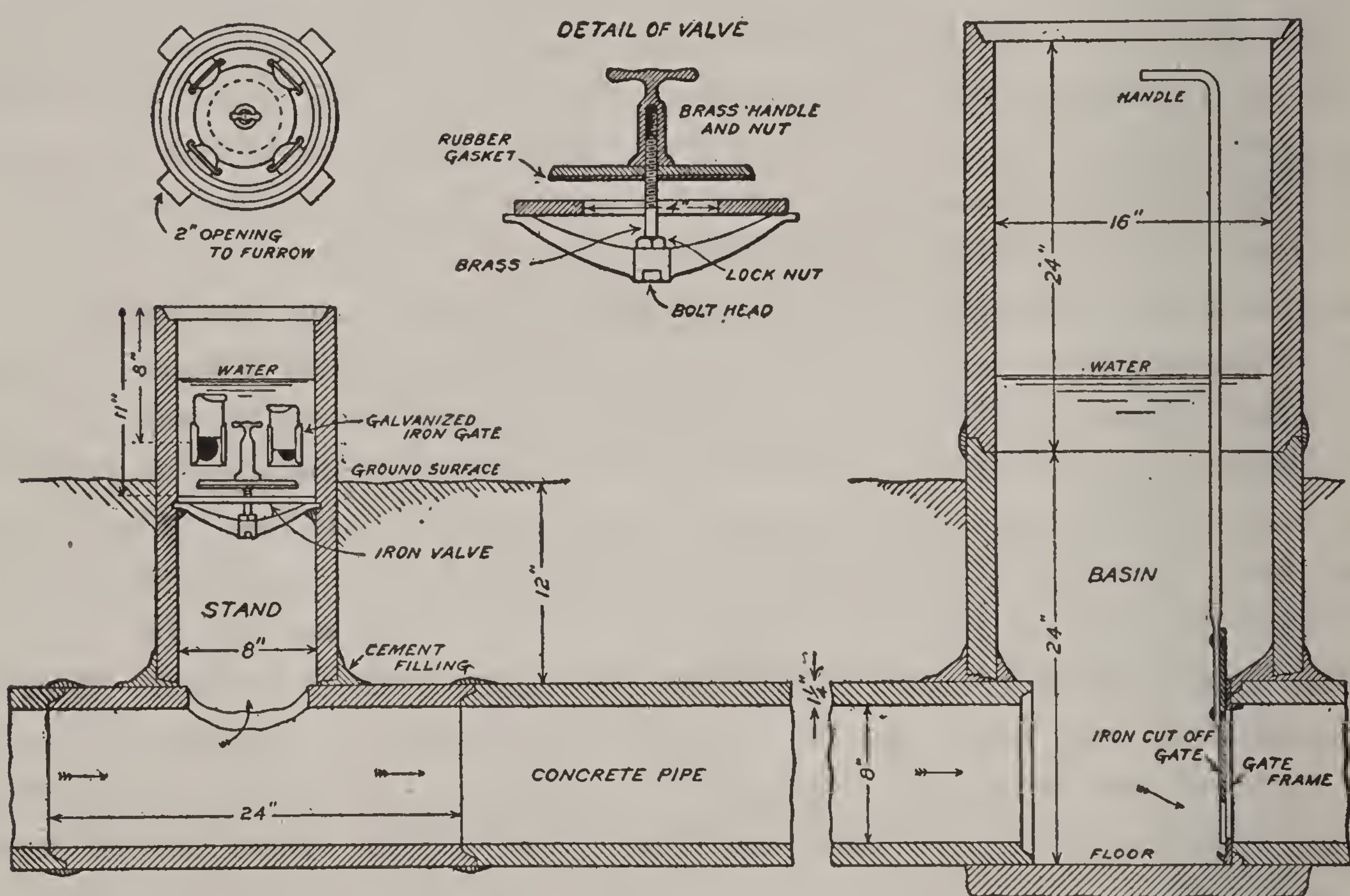

FIG. 3.—Design of concrete pipe and stand system for orchard irrigation.

pipe is more porous than wet mixture pipe, but this is overcome to some extent by a cement wash applied to the inside during the curing.

Eight and 10-inch pipe of 1 to 3 mixture costs about 3 cents per foot more than the same sizes made of 1 to 4 mixture. Cement costs $2.50 per barrel.

Vitrified clay pipe in the 8, 10, and 12 inch sizes costs 16, 24, and 30 cents per foot, respectively, in the same locality.

Eight-inch cement pipe is made 1¼ inches thick and the 10-inch size 1½ inches thick. In the orchard sections 10-inch pipe is used for the main distributing lines of companies and 8-inch pipe for the private lines and head lines. Ten or 12-inch pipe lines are laid from private pumping plants for irrigating alfalfa, the size depending on the stream pumped and the fall.

FIG. 1.—LAYING CONCRETE PIPE.

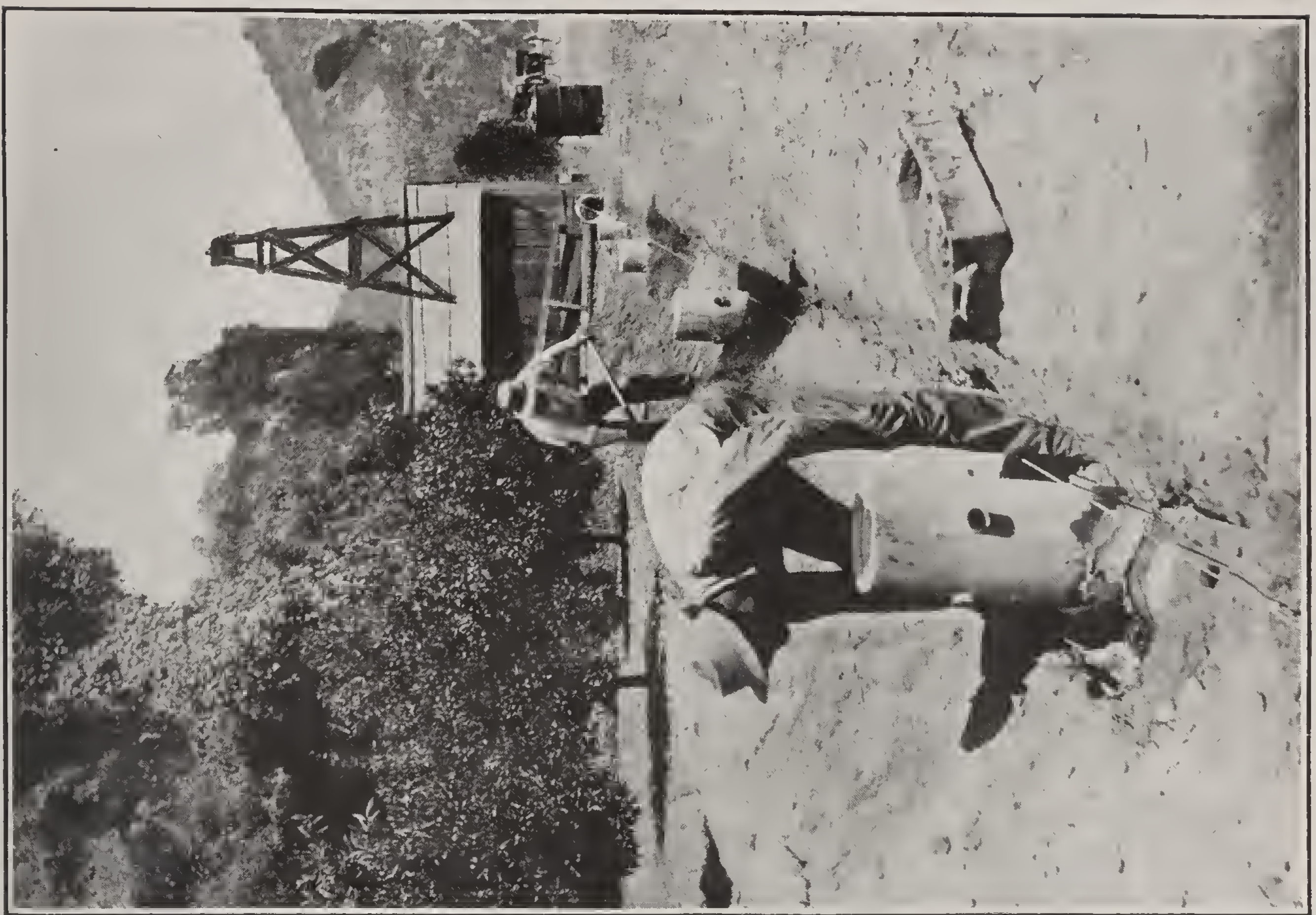

FIG. 2.—JOINING STANDS TO PIPE.

Pipe is laid with the top 1 foot or more beneath the surface. The joints are cemented together with a trowel, a short piece of galvanized-iron pipe being placed on the inside as a mold during the process. Plate III, figures 1 and 2, illustrates the manner of laying the pipe and connecting stands. The weakest point in the ordinary pipe line is at the joints, and if the pipe is disturbed after being laid leaks occur sometimes at these points. A machine for molding and laying continuous cement pipe has been used at Riverside, but its use is not general.

All pipe-line structures, such as division or measuring boxes, are of either concrete or cobble walls plastered with cement. A division

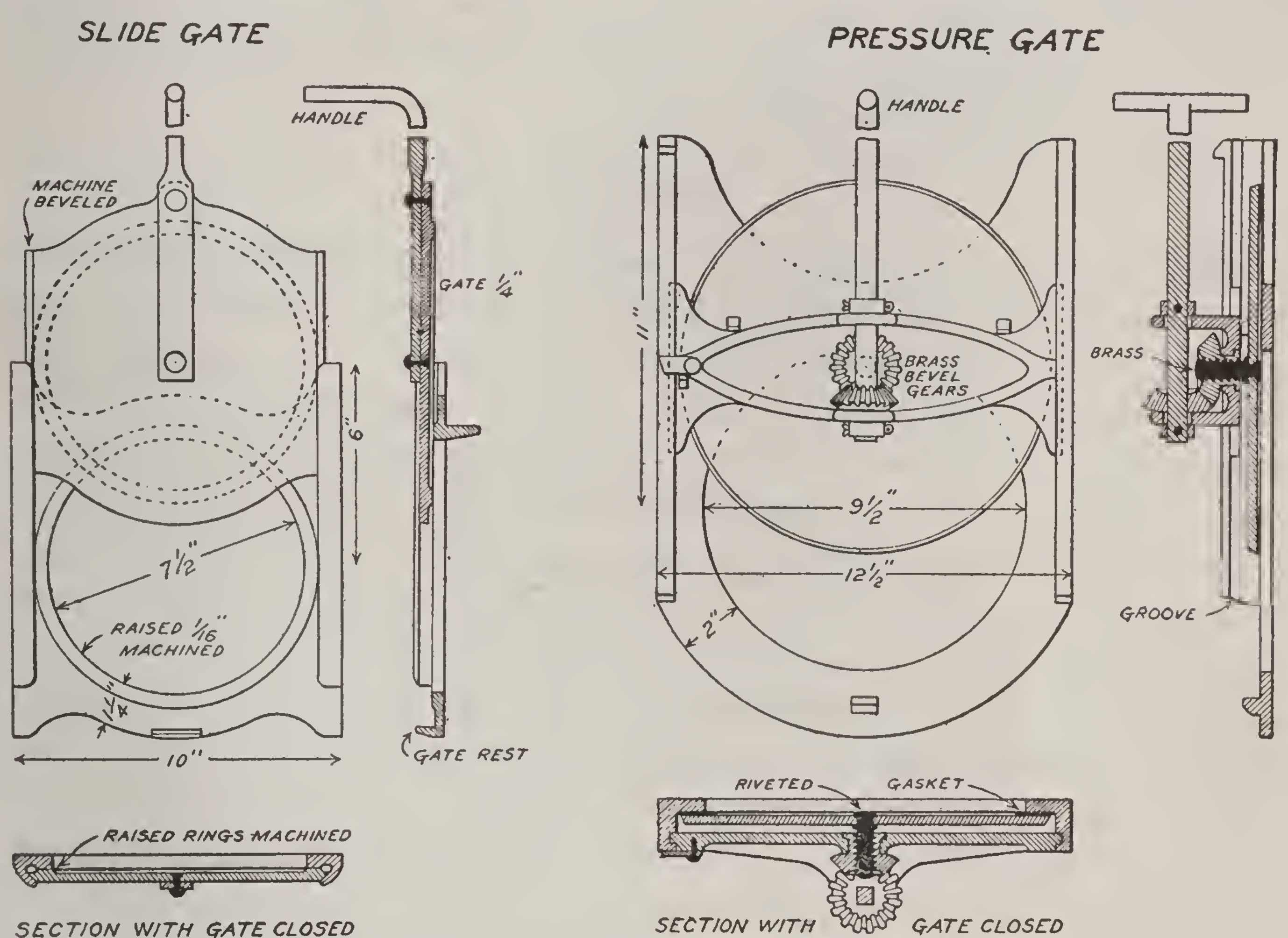

FIG. 4.—Cast-iron gates for concrete pipe lines and reservoirs.

is often made by the lines branching off from a standpipe called a "turnout" and formed by one or more sections of concrete pipe resting on a concrete floor. A similar standpipe containing a gate is placed in an orchard or field head line to form a check. These are called "basins." Sixteen-inch basins are used on 8 and 10 inch lines. Figure 3 shows one of these in a pipe line.

The controlling gates used in all pipe-line structures, including turn-outs and basins, are of cast iron. The most common type and the simplest and cheapest of such gates is shown in figure 4. The 8-inch size costs $1.05 and the 10-inch size $1.60 at the foundry, and the handle from 25 to 75 cents additional, depending on its length. The average cost of turn-outs or basins, including one of these iron gates, is from $4.50 to $5. These gates are nearly water tight, as the parts of the gate and gate frame which come into contact are milled so that they fit very close together. The gate must slide loosely in the grooves of the frame, but by being placed on the upstream side of an opening the pressure of the water holds the gate against the frame when closed. Figure 4 also shows another form of gate which is more expensive and is used only when it is desired to prevent all leakage. It is constructed so that after the gate has been lowered into position a twisting of the handle brings pressure on the back of the gate, which, being provided with a rubber gasket, can be made perfectly water tight. This gate costs $3.25 for the 8-inch size, $4 for the 10-inch, $5.30 for the 12-inch, and $9.50 for the 16-inch. There are several kinds of water-tight or pressure gates, but they differ only in their details. All devices for the control of water are manufactured locally.

ROTATION.

The frequency of irrigation of orchards through the foothill belt is so uniform and so complete are the distributing lines of pipe and appliances for the perfect control of the water that companies serving orchards alone deliver water to their stockholders by rotation, according to schedules which are often prepared in advance for an entire season of six or seven months. If a stockholder's land is entitled to the equivalent of a continuous flow of a certain number of miner's inches the flow for each month is cumulated into a water run. The number of monthly runs depends on the length of the dry season. The water is delivered in heads of from 25 to 60 miner's inches, the size being governed to some extent by the supply and the size of the holdings irrigated. Usually the entire head is used by each stockholder for a period of time proportional to the amount of stock he owns. The schedule of rotation is either prepared by the board of directors, the superintendent, or the zanjero. There is usually a complete rotation about every thirty days, so that each orchard receives water at thirty-day intervals. It is customary to skip the 31st day of a month in the regular schedule and to reserve these for emergencies. In case of short delays, due to breaks in pumping machinery or pipe lines, this gives opportunity to catch up with the schedule. It also simplifies the schedule itself, so that each stockholder receives the water during the same hours of the same day every month of the season. For example, 4½ acres of oranges was irrigated with 42½ shares in the Orange Grove Tract Water Company, and the owner was entitled to use the water from 4 p. m. on the 15th to 7 a. m. on the 16th of each month during a season. If an orchardist is not ready for the water when his time comes, after due notice has been given him, he is skipped and the water he might have had can not be added to his quota in a future month. More adequate storage facilities would be required to hold much water in reserve. Written notice is given the user at the beginning of the season of the time he is to use the water each month or it is given him a few days in advance of each irrigation, so that he may have time to furrow his orchard and be ready for the water.

The Del Monte Irrigation Company serves four heads, which were originally intended to be 52½ miner's inches each, but at times they have been allowed to fall as low as 40 miner's inches. The water is measured over a weir at the head of each lateral, and, as only one head is run in a lateral, it is unnecessary to measure the water at each point of delivery. The rotation usually begins at the upper end of the line and proceeds in succession to the lower end. Each run is 0.12 hour per share, so that 10 acres receive the water for 12 hours, provided the original 10 shares per acre are used. The schedule month is 26½ days in this company.

The Palomares Irrigation Company delivers one head of 60 miner's inches in accordance with a rotation schedule prepared in advance for the season.

The San Dimas Irrigation Company makes a schedule at the beginning of the season, and there is a complete rotation in thirty days. Each user determines the head to be delivered to him, but it must be such as will give him his proper allotment with a run of either twelve or twenty-four hours. The water is measured over a weir at each delivery. This company makes no attempt to serve lands along a pipe line in regular succession as regards location.

The La Verne Land and Water Company delivers one head of 50 miner's inches, and each orchard receives water about once every five weeks. The head is run 2½ hours per share, and most of the members use one share per acre. Some purchased extra shares when the company was first organized but later found they did not need them. The company sells no water to nonmembers, but any of the stockholders who are entitled to use more than they desire pool the surplus water and place it in the hands of the zanjero for sale and delivery. This may be sold either to members or nonmembers, the charge being 3 cents per miner's inch per hour, while the regular charge which the company makes to its stockholders is only 1½ cents per miner's inch per hour.

The Irrigation Company of Pomona has been unable to deliver water by rotation because of the great diversity of crops irrigated, which include alfalfa, deciduous and small fruits, as well as citrus fruits. The irrigation of all these, except the citrus fruits, is very irregular. Stockholders may leave orders with the secretary not earlier than the twentieth day of the month for water to be used for the next calendar month, and preference of date for irrigation is in the order that these are made. Each user may have one-half the water to which his stock entitles him in the daytime. If he has a day run one month, he must take a night run the next when using his full quota, but as many do not use all the water to which their stock entitles them, they are able to do all their irrigating in the daytime. The head is fixed and the hours are in proportion to the stock owned. Orders are taken in triplicate by the secretary—one for himself, one for the zanjeros, and one for the user. The secretary has a large sheet on which are ruled spaces, representing time units or hours for the month. The spaces are marked off as the orders are received, and the names of those making the order written in so it shows at a glance what dates are open.

The distribution and delivery of water is cheap. Zanjeros use automobiles, motorcycles, or bicycles, which are, as a rule, furnished by themselves. Companies serving over 3,000 acres employ two zanjeros, while those serving less require only one. While the acreage served by one man is small, he must make a great many deliveries on account of the small holdings, but the completeness of the distributing systems and the speedy method of conveyance make this easy. Delivery boxes or turn-outs are provided with covers and may be locked. Some small companies dispense with the services of a zanjero altogether, and in that case each member is informed as to what the schedule is and the head of water is sent down the main pipe line by the engineer at the pumping plant and passed from one to another. The Irrigation Company of Pomona pays its zanjero $65 a month for seven months and $30 for the remaining five months. He uses an automobile and only a part of his time is required. The Del Monte Irrigation Company pays its zanjero $50 per month for the entire year. Smaller companies pay at the same rate, but employ zanjeros only through the irrigation season, leaving the zanjeros much time for other duties while employed. The zanjero is the highest-salaried man, as a rule, and, although not an executive officer, is often depended upon to take entire charge of the water delivery. The larger companies have a manager or superintendent, but, like the secretary, he devotes only a portion of his time to company business, and his compensation is small.

RESERVOIRS.

Some companies, notably the Irrigation Company of Pomona, the Kingsley Tract Water Company, and the Chino Water Company, have concrete reservoirs as a part of their distributing systems. These add much to their efficiency, as water may be stored when not needed and drawn out later to aid in keeping a constant head. The reservoir of the Irrigation Company of Pomona has a capacity of

2,000,000 gallons and is a little above the middle of the system. This is a good situation for a reservoir of this kind, especially for a company that does not deliver by rotation, as it permits the constant running of the pumping plant both day and night, and the utilization of all the artesian water when the wells are flowing. Water unused through the night is stored in the reservoir and run out the following day to supply the customers below the reservoir, while those above use the water that comes directly from the wells. There are over 50 reservoirs in this section which are used with private pumping plants.

It is necessary in many of the orchards in this locality to remove large quantities of cobbles for the planting of the trees, and where they are near at hand the walls of reservoirs are constructed cheaply by being built up with cobbles laid in cement mortar or lime mortar. The floors are of concrete, and both floors and walls are lined with a

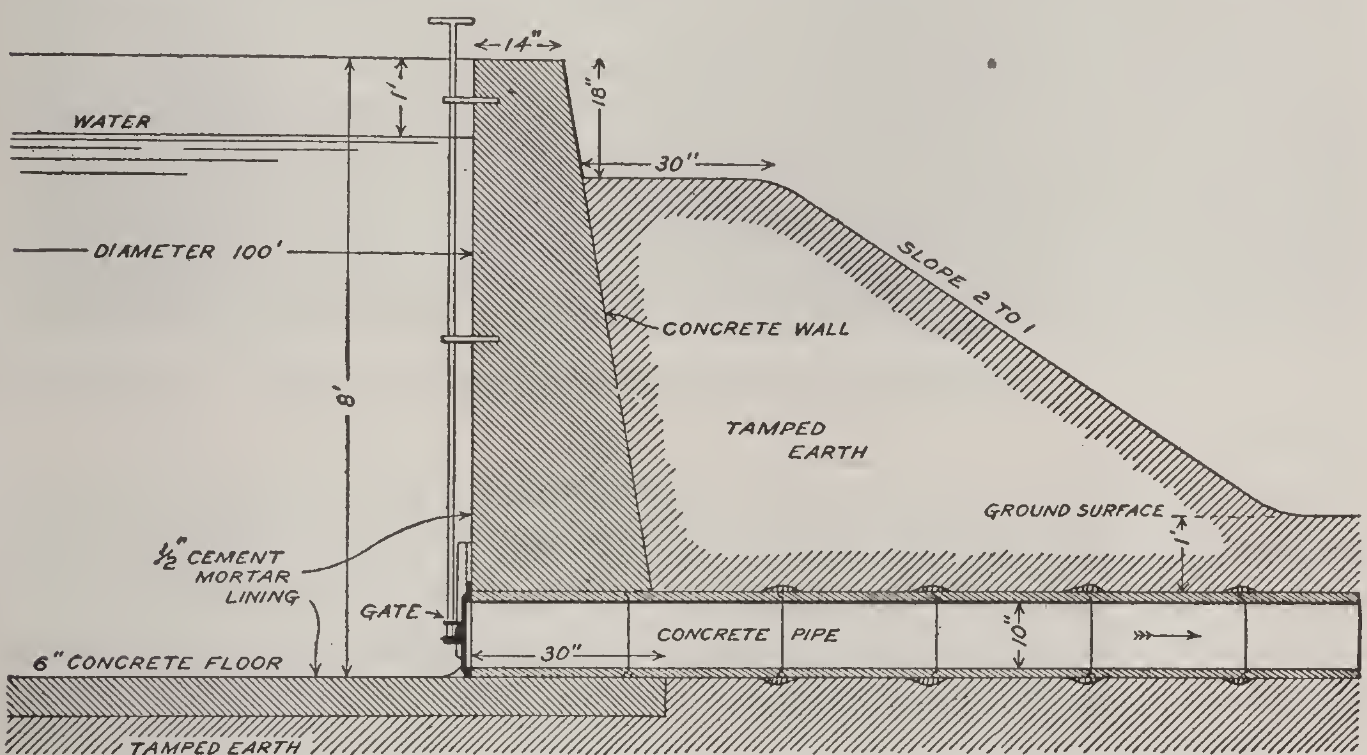

FIG. 5.—Design of concrete reservoir.

thin sheet of cement mortar. If rock must be hauled some distance, and if gravel is near by, the walls are constructed as cheaply of concrete. For the larger reservoirs concrete walls are reinforced, heavily at the bottom and gradually lighter above, but for sizes not over 100 feet in diameter and 8 feet deep reinforcing is not common. The inner face of a wall is made vertical, while the outside face is given a batter. The floor need not be placed below the natural surface of the ground, but much strength is added if this is done. Earth is banked up against the outer face of the wall and tamped or puddled to give it stability, and the earth on which the floor is to rest is tamped. The diameters of reservoirs range from 50 to 200 feet and the depths from 6 to 12 feet.

The plan for a good reservoir for use with a 10-acre orchard is illustrated in figure 5. It is 100 feet in diameter, 8 feet deep, and holds approximately 450,000 gallons, or 1.38 acre-feet. This is sufficient to cover a 10-acre orchard to a depth of 1.7 inches. The wall is of concrete and tapers from a thickness of 30 inches at the bottom to 14 inches at the top. The floor is 6 inches thick and the entire basin is lined with cement plaster. The cost of such a reservoir is about $1,500 including the iron gate. If the wall was built of cobbles it would be given a width of 36 to 48 inches at the base and 20 inches at the top. If the outlet pipe is to be under a head of over 12 feet it should be of iron.

Small reservoirs are very useful in connection with private pumping plants for orchard irrigation, especially where the stream produced is too small for an economical irrigating head. The pump may be run night and day, while the orchard is irrigated only through the day. The water pumped at night is stored in the reservoir and drawn out the following day to double the head. The reservoir may be filled in advance and drawn on to supplement the discharge of the pump for a short irrigation. Many of the pumping plants near the foothills deliver 15 to 30 miner's inches only. Larger heads may be used to better advantage, especially in the porous soils of these localities. A pumping plant discharging 25 miner's inches would fill the reservoir described above in thirty-three hours. Plate IV, figure 1, shows another reservoir with pumping plant for orchard irrigation.

Reservoir gates are the pressure iron gates manufactured for pipeline structures and may be locked water-tight. There is an automatic gate in the outlet of the reservoir of the Irrigation Company of Pomona which delivers a constant stream under a changing head. It may be set to discharge a stream of any size.

MEASUREMENT OF WATER.

The miner's inch as defined by statute in California is one-fortieth of a cubic foot per second, or the equivalent of 11.23 gallons per minute, is not used in southern California except in legal matters. The old miner's inch of southern California, the value of which is one-fiftieth of a cubic foot per second, or 9 gallons per minute, is still retained as the unit of measurement. The cubic foot per second is almost unknown in the pumping districts. The miner's inch has the disadvantage of not having a standard value, but its size is convenient for such small streams as are measured where water is pumped. It is measured more often, however, over a weir than under pressure.

At Pomona and San Dimas water is measured over weirs altogether. They are found at most of the private pumping plants pumping for orchards as well as for company plants, but are seldom

FIG. 1.—PUMPING PLANT AND RESERVOIR.

FIG. 2.—ORCHARD IRRIGATION WITH CONCRETE STANDS.

seen at the private plants pumping for alfalfa. Here larger streams are pumped and water costs less. Water sold for orchards is charged for by the miner's inch per hour and must be measured, but for alfalfa the charge is for the stream, the size being estimated.

Weir boxes are of concrete or of brick covered with cement and are permanent. Galvanized iron is used for the weir plates. Through ignorance of hydraulic principles the details of construction are often not in keeping with the excellent materials used. The most common defect is that the weir plate is set in the middle of a 4 or 6 inch cross wall, the notch in the wall being but a little longer and deeper than the notch in the iron plate, so that the plate projects only 1 or 2 inches, and the result is that the end and bottom contractions are insufficient. A better construction would be to fasten the weir plate against the upper face of the cross wall. The rectangular weir is nearly always used. They are usually too long rather than too short for the amount of water to be measured. It is common to find 24-inch weirs for measuring streams of 20 miner's inches, while lengths of 12 or 18 inches would enable the head to be read with more accuracy. A rectangular weir without end contractions is also used. It consists of a crest reaching entirely across the box, there being no end plates. An objection to this form of weir is that if the box be wide the weir is too long for the stream of water to be measured, while if the weir be short the narrow box increases in velocity of approach. The short weir boxes used require the insertion of screens to retard the velocity of the water as it is discharged from the pumps and to quiet the surface for a correct reading of the head, but this is too often overlooked.

The Cippoletti weir, or one in which the sides have a slope of 1 horizontal to 4 vertical, is not well known in this section. Farmers usually compute the discharge according to weir tables prepared by the local pump manufacturers. These tables give numbers which are used as multiples to determine the discharge in miner's inches, with the length of the weir and the head as known quantities. They, however, are computed for the Cippoletti weirs, and are only approximately correct for rectangular weirs.

METHODS OF APPLYING WATER.

IRRIGATION OF ORCHARDS.

PREPARATION OF LAND.

There is a great difference in the cost of clearing and grading orchard land for irrigation. The gravelly soils lying close to the foothills are desirable for citrus orchards, because the region is nearly frostless and produces a fine quality of oranges, but they are the most costly to prepare for the setting out of the trees. The native brush is removed by hand, and many loads of bowlders and cobbles are often hauled from a 10-acre tract. After both brush and stone have been removed, there is often considerable grading to be done to fill swales and give the orchard an even slope. An expense of $100 per acre for the preparation of an irrigated orchard is not uncommon, and it cost $250 per acre for one orchard above Claremont. Lower down on the slopes the preparation consists principally of the removal of the scant growth of brush and some plowing and grading. Most of the orchard land has been cleared and leveled for from $10 to $50 per acre. After removing any stone or brush the land is plowed during the winter to turn under weeds or stubble in order that they may act as a fertilizer. It is disked or harrowed to pulverize it, after which it may be surveyed and graded. Citrus trees are least disturbed if transplanted when they are dormant. The time usually selected is after the winter rainy season, when the tree is yet in the dormant stage and the soil is moist and warm. The last irrigation in the nursery may be shortly before the trees are removed. When balled stock is used, the earth around the roots of the young trees protects them from drying out when being changed from the nursery to the orchard. A stream of water is run along the row when planting to moisten the soil and settle it around the roots. Orange trees are spaced 20 to 24 feet apart, lemon trees about 24 feet, deciduous trees 24 to 30 feet, and English walnut trees 40 feet.

Orange land without water costs $100 to $400 per acre, and the water rights from $100 to $600. It requires an additional outlay much greater than the cost of the land itself to bring an orchard into full bearing. The trees may begin to bear in the third year, and the fruit produced the fourth year may pay expenses, but there is rarely a profit until the crop of the fifth year, so that in addition to the initial cost the expenses for the first five years must be included. The cost for a 10-acre orchard, exclusive of interest, is represented by the following:

Cost of bringing a 10-acre orchard to bearing age.

10 acres of orange land	$2,500
Water right	1,300
Preparing and grading land	300
1,000 trees, at $1 each	1,000
Planting trees, at 7½ cents each	75
Irrigating system	175
Irrigation and cultivation, 5 years	1,500
Taxes and incidentals, 5 years	250
Fertilizer, 3 years	250
Total	7,350

To irrigate an orchard there should be an even division of the water between units of space, and the water should be applied so that it reaches the proper place in the soil to be retained until taken up by the roots of the trees. There have been many theories as to how these ends are best accomplished. Subirrigation would seem to have merits, but the difficulty has been to get a system of underground pipes with enough openings and of a size to admit a sufficient quantity of water to the soil without the openings being eventually filled up by the extension of tree roots in their natural growth toward the moisture in the undrained pipes. A few systems have been devised, one of which was put in operation near Claremont, by which the openings in the underground pipes could be controlled from the surface and need be open only while water was being supplied to the orchard. These openings were of necessity small, to keep the earth from falling into the pipes through them, and they did not allow enough water to enter the soil. To increase the number of small openings so as to reach all parts of the soil would require more than one pipe to the tree row. This would be too expensive, and the many valve stems for closing the openings would interfere with operations on the surface. As no system has yet been found practical, the methods of applying water have been on the surface. The ideas of orchardists on the best methods of irrigation have changed greatly since the beginning of the citrus industry. The subject is one that has been given much thought by scientists and practical orchardists, and there never has been a unity of opinion, but it comes nearer being reached at present than at any time in the past. The successful growing of citrus fruit depends very largely upon proper irrigation, together with cultivation and other associated processes.

THE BASIN, OR CHECK, METHOD.

Fifteen years ago most of the orchards were irrigated by running water into basins formed around the trees by throwing up ridges with a ridger. What was known as single checking consisted in making ridges in both directions between the rows of trees, thus forming basins in the middle of each of which was a tree. This method was used in citrus orchards mostly, each basin being about 20 feet square. The head line usually was an open, unlined ditch along the high side of the orchard. Each basin had to border on a lateral ditch leading from the head ditch in order that all could be furnished with water, and it was necessary only to make one lateral to each two tiers of basins. These laterals were formed by making a double instead of a single ridge between the basins, and the water was turned into the basins on either side. The ridges when new were about 1 foot above the original surface of the ground. The borrowing of the earth to make the ridges also left a ditch on each side. In traversing one set of ridges with another at right angles the first set was broken down at the crossings. The fills to close these breaks and complete the scheme were made with a jump scraper and finished with hand implements. The ridges parallel with the head ditch were made first, so that the double ridge forming the supply ditch made in the other direction did not have to be crossed, and the work that had to be done with the jump scraper was lessened.

When a head of water is being used for filling the basins it requires constant attention. The irrigator cuts the ditch bank with his shovel at the upper corner of each basin and leaves it open until sufficient water has entered. A metal tappoon is used to dam the head ditch and force the water into the lateral ditch, and another is placed in the lateral ditch just below the one or more openings cut into the basins. In irrigating the orchard the water is diverted from the head ditch into the first lateral and the basins on either side are filled in succession, beginning at the upper end, or the irrigator may work down one side and up the other. The water is then changed to the second lateral, and so on until the orchard is finished.

Often, if walnut orchards were irrigated with single checking, the basins, on account of the wider spacing of the trees, would be too large for the slope unless the orchard were nearly level. In such a case double checking is used. In this system four basins occupy the same space as one in single checking, only one of the four inclosing a tree. The check systems and the implements for laying them out are more fully described in bulletins of this Department.[a]

Basin irrigation is in reality a modified form of flooding, the purpose of the basins being to give an approach to an even depth over the entire orchard. Enough water is run into the basins to give an average depth of several inches, it being much deeper in the depressions along the ridges than in the central portion beneath the limbs of the trees. This unevenness is, however, not an objection. In gravelly soils the water disappears in a few hours, but in adobe it is visible for a day or two. The disappearance of the water depends also on the rate of evaporation, for a large part is lost in this way.

No fault can be found with the basin system as a means of dividing water between units of the surface, as it allows better control of the distribution than any other system. The work preparatory to receiving the water and that done in destroying the ridges after the run is completed is of minor consideration in the irrigation of 10-acre orchards producing high values. The chief objection is that so little of the water reaches the proper place in the soil to be taken

[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 108; Farmers' Buls. 116, 373, and 404.

up by the roots of the trees. Also, as the water disappears from the basins the surface is dried and baked by the hot sun before teams can be driven over it for its cultivation, and cracks open up and allow much of the moisture previously absorbed to be evaporated. The loss from the water surface in the basin and from the baking soil is great. With the surface flooded the air in the soil can not well give place to the water, and there is poor soil aeration. The system has practically been abandoned in citrus orchards in favor of furrow irrigation, although it is still used sometimes on very tough adobe, where it is claimed it is the only way to get sufficient moisture into the soil. In such places the waste is very great and large quantities of water are allowed to run into the basins. It is also used to some extent on deciduous and walnut orchards in heavy soils, but in the walnut orchards near the coast it is found to be less harmful to sandy than to clayey soils.

FURROW METHOD.

Furrow irrigation is now used almost exclusively in irrigating fruit trees. Furrows have long been used, but in recent years there has been a great change in this method of irrigation. The furrows are now made much deeper than formerly and farther apart, a less number being used to the tree row. One requisite for the success of furrow irrigation is the proper division of the water between furrows, and the most improved appliances for controlling the water are now used.

APPLIANCES FOR CONTROLLING WATER.

The first substitutes for the head ditches were board flumes. These were constructed of 1 by 12 inch boards, thus giving a flume with a cross section of a little less than 1 square foot. The flumes were raised slightly above the surface and auger holes bored in one side to allow the water to flow into the furrows, the flow being controlled by means of little gates of wood or galvanized iron. The alternate wetting and drying out of wooden flumes warped the boards and caused leaks, and at best their life was short.

More permanent structures soon were sought, and concrete head flumes, or, better still, irrigating systems of concrete pipe, were installed in all new works and replaced the wooden flumes as they wore out. Cement flumes sometimes have been damaged by the earth being washed from the lower side. They are used chiefly where water is obtained from large canals, while pipe systems are more common where most of the water is pumped. Small openings about 2 inches in diameter, controlled by galvanized-iron gates, supply the furrows.

Provision sometimes is made for the insertion of iron slides at places along the flume to check the water, while in other cases the same result is accomplished by merely placing a large bowlder or cobble in the flume. If the fall be unusually high, the flume is constructed with abrupt drops in its grade wherever necessary, each section of flume being kept nearly level. A good cement flume, with its fittings complete, costs 23 to 25 cents per linear foot.

The superiority of pipes and stands over cement flumes was soon demonstrated and at present practically nothing but stands are being installed. Many flumes, however, will be in use for years to come. Stands furnish the least possible obstruction on the surface. The head line for an orchard is of 8 and sometimes of 10 inch concrete pipe laid with its top not less than a foot below the surface. The only visible parts are the stands which protrude above the surface at the end of each tree row, where they do not interfere with the free cultivation between the rows and along the upper side of the orchard. With a flume it requires hand labor to keep down the weeds along its its course. Figure 3, page 58, shows the details of the pipe system most commonly used. This system is also illustrated by Plate IV, figure 2. The stand consists of one length of 8-inch concrete pipe cemented in place on the pipe line. Water from the pipe line rises in the stand through the iron valve, and the latter may be set to maintain a slight head over the six openings above, through which the water flows into the furrows leading away from the stand. The openings are 2 inches in diameter, and each is controlled by a small galvanized-iron gate, which, together with the valve below, allows perfect control over the water entering each furrow. The valve has a rubber gasket and is closed when not in use. Threaded parts are of brass and do not rust. In a variation of this system, used less now than formerly, the tops of the stands are permanently sealed with cement caps, the iron valve is dispensed with, and the little gates at the openings are on the outside instead of the inside, as in the open-top stand. The water then rises to the top of the stand and is confined under slight pressure except as it is allowed to flow from the openings. With such an arrangement it is more difficult to make an equal division of the irrigating head, for, if the pipe line is on a grade, the water is under a greater pressure at the lower than at the upper end, and it is unsatisfactory unless the pipe line is nearly level. In the open-top stand with a valve an equal head may be maintained over the openings of all the stands, and it is recommended, regardless of its higher cost, due principally to the valve. Close-top stands, complete, cost $1 each and open-top stands $1.75 each. If there is much fall, the pipe line is divided into several sections by an iron gate placed in a large stand called a basin. It is then possible to shut off one or more series of stands at the lower end of the pipe line while the upper ones are being used, and prevent undue pressure on the lower parts of the line.

Various other devices for the division of water between furrows have been tried. Some are efficient but too expensive, and others have objectionable features that prevented them coming into general use. The cement stand system is about as simple in construction and as cheap as it can be made to be convenient and give perfect control of the water, and the latter have been the chief considerations of the orchardists in making their selection. The cost of a system for a 10-acre orchard includes 650 feet of 8-inch pipe laid for 17 cents per foot, 32 open-top stands 20 feet apart at $1.75 each, and the cost of one turn out complete at $5, making a total of $171.50.

ARRANGEMENT OF FURROWS.

The old way of irrigating was to make from 6 to 12 furrows about 3 inches deep to each tree row. Now furrows are made about 8 inches deep, and the number and distance apart depends upon the soil, more being used in clayey than in sandy soils, unless the sandy soil is thin and underlaid with gravel. In some localities where they have red loams the present practice is to use four or six furrows to the tree row, but in this locality and others of the foothill belt where sandy and gravelly soils predominate two or four furrows are used to the row. Plate IV, figure 2, shows typical furrow irrigation for orchards at Pomona. Orchards are furrowed with plows attached to the frames of wheeled cultivators in place of the cultivator teeth. Several sizes of plows are used. Some of these have a spread of 10 inches at the bottom, 15 inches at the top, and a height of 9 inches.

Experiments conducted by this Office on the Arlington Heights groves at Riverside have thrown much light on the action of water in the soil in orchard irrigation.[a] In applying the results of these experiments it must be kept in mind that much of the soil at Pomona is looser in character than the soil where the experiments were made. It was found that the area wetted from a furrow decreased with the depth, so that contrary to the belief of many the greatest width of moist soil is at a level with the bottom of the furrow and not several feet below the furrow. If there is hardpan or other impervious stratum at a shallow depth the downward movement of the water is arrested and lateral percolation is more rapid and extensive. In one case where there was plow sole at a depth of 5 inches the moisture reached an average depth of only 12 inches in four days. Such a condition often causes a large area of the surface to show moisture

[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 203.

when the moisture has scarcely reached the depth of the tree roots and is misleading. If the soil is uniform to a good depth the downward movement of the water being aided by gravity is more rapid than the lateral movement, but while the moisture may meet between furrows at their level there may yet be dry spaces between the moist areas directly underneath the furrows.

It was found that with four straight furrows, spaced about 4 feet apart to a tree row, the moisture met between furrows in 12 hours in some cases and in 24 hours in others. It is quite evident that if it requires four furrows to moisten the space between tree rows under such circumstances that there are wide spaces between the trees in each tree row that do not receive moisture especially at the depth of the tree roots. With trees planted 22 feet apart this dry space may be 6 feet wide. Nothing is to be gained by supplying moisture to the soil directly around the base of the tree, but the lateral roots should branch out on all four sides of the tree alike, and those that lie between trees in a row should receive moisture as well as those that lie between the tree rows. On the more porous soils at Pomona two furrows to the tree row are sufficient, one on either side as close to the tree limbs as they can be made. The space between the rows of trees with such an arrangement is but little greater than the distance between the two furrows on either side of each row. Where percolation is slow, four furrows to the row are used. It is rare that provision is made for irrigating an orchard alternately in two directions, as this not only requires a greater outlay for the irrigating system but many orchards are not situated so that it is possible. A number of kinds of zigzag or cross furrows have been much used to give a more equal distribution of the water over the surface and to better reach the spaces on all sides of the trees than is possible with straight furrows. Another purpose of such furrows is to overcome the effect of high slopes, as some orchards have a fall of 150 feet per mile. The increased length of the furrows reduces the fall which, together with the changing direction, retards the velocity of the water.

A means used to give the lower part of the orchard as much water as the upper part without wasting water at the same time from the lower ends of the furrows is to cross furrow the lower half, third, or fourth. The water then takes an indirect course in the lower part and the reduction in the size of the stream is counteracted by the greater absorption, due to the slower velocity and the increased wetted area of furrow. A common way of cross furrowing is illustrated by figure 6. The furrows parallel to the head line, indicated by the dotted line, are made first and then crossed at right angles by the furrows running down the greatest slope. The scheme is finished by making the necessary cuts and fills by hand or with an implement similar to the jump scraper. This leaves two straight furrows in the center which necessarily must have less water turned into them than is turned into the others. Each furrow must be independent of the others or the water will collect in certain ones.

Limited hillside areas are terraced for orange orchards. Each terrace has one row of trees, and they are irrigated with furrows on the contour with the terraces.

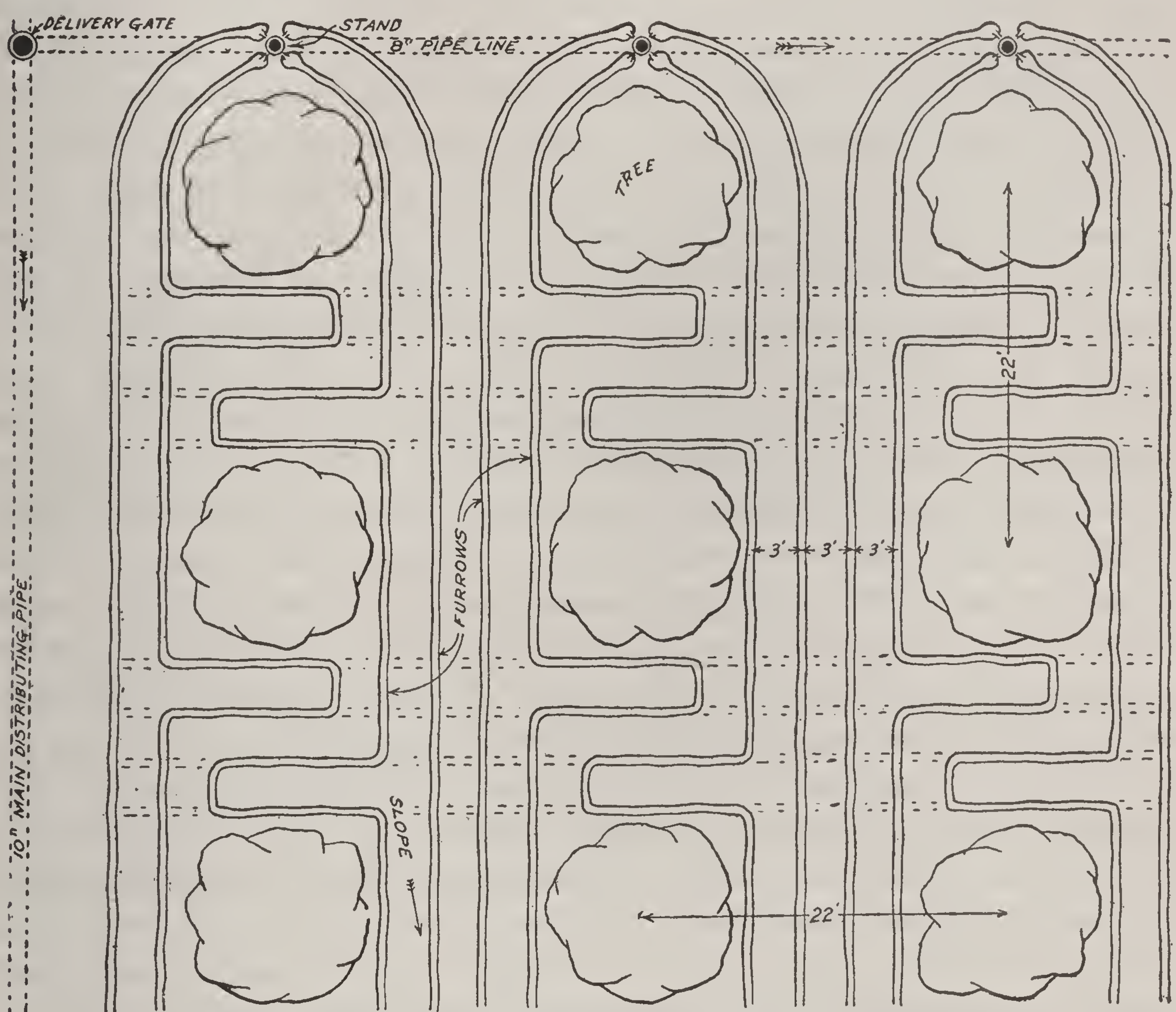

Fig. 6.—Plan for laying out zigzag furrows.

PREVENTION OF LOSSES OF WATER APPLIED.

The streams of water or heads used in irrigating are from 25 to 60 miner's inches in size. One-half miner's inch may be run into a single furrow, but the amount depends on the soil. A large stream, sometimes 4 miner's inches, must be used in sandy soil to prevent its all being absorbed at the upper end, while on tight soil a small stream must be used to prevent its running through too quickly and wasting away at the lower end, or if precautions are taken to prevent waste to keep the lower part of the orchard from receiving too much water. In beginning an irrigation a large stream is first turned into a furrow and rushed to the lower end, after which, the furrow being wetted, the stream is reduced to such a size as will give an even distribution without waste.

To irrigate an orchard the things to be considered include its size, the slope and character of the soil, the size of the head, and the duration of the run. The number and kind of furrows to be used and the division of water between them must be arranged in proper relation for each case. Nature has helped by providing steep slopes in the loose soils near the mountains and flat slopes on the tight soil farther away. Orchards, as a rule, receive only a shallow depth of water at one irrigation, for where a head of 40 miner's inches is used for 24 hours on 10 acres the depth applied is a little less than 2 inches.

Location and depth of furrow.—The greatest problem in orchard irrigation is to apply the water uniformly with the least loss. The evaporation of the water in the furrow is small, but a greater source of loss is the evaporation from the wet surface or furrow and soil after the water has been turned off and before the ground is dry enough for cultivation. Moisture will rise to the surface from depths of 2 or 3 feet by capillary attraction and evaporate into the atmosphere. The best way to overcome this loss is to apply the water well below the surface by the use of deep furrows and follow with deep and thorough cultivation as soon as the ground is dry enough to be worked. Irrigation with deep furrows puts the water where it is least exposed to the rays of the sun and where a greater portion may be utilized by the trees. If the irrigation is shallow, the moisture is so near the surface that a large portion of it may be lost before the ground can be cultivated. Shallow irrigation also trains the roots of the trees upward and they are soon reached by the drying out of the soil. Deep irrigation, on the other hand, trains the roots downward and they are better protected from drought and are not interfered with by deep cultivation. Observations have been made in one orchard near Claremont where two furrows about 8 inches deep were used to the row. The soil was porous and the lateral percolation was so rapid that practically the entire subsoil was moistened in nine hours, while a large portion of the surface was still dry, it having been in a fine granular condition when the irrigation was begun. There is less wetted area exposed to evaporation if the moisture can be put below the surface layer in this way.

It was thought at one time that it was necessary to apply the water close to the base of the tree, and low limbs touching the ground were not encouraged. The lateral roots of citrus trees, however, are much longer than the limbs, often reaching lengths of 15 or 20 feet, and consequently most of the many tiny roots which feed the trees with moisture are reached better by applying the water beyond the branches. The application of the water well away from the base of the tree also develops the roots in that direction and produces a more extensive root system.

It is possible for water to pass below all tree roots and be lost, especially in sandy and gravelly soils. The tap roots of orange trees are 4 to 10 feet in length and the most of the lateral roots are in the second or third foot of soil. The only way to be certain about what is actually taking place is to make an excavation or boring and determine by inspection or by tests the moisture contained in different places.

Cultivation of the orchard.—The retention of the moisture is as important as the manner of application. The earlier the cultivation the less the danger of loss of moisture from a baking surface. Sandy soils may be cultivated much sooner than adobe soils, and there is a wider limitation of time for the good working of sandy soils. Heavy soil must be worked at just the right time, and at best is much more difficult to pulverize, for if too wet it is sticky and if too dry it breaks up in clods. Sandy soils may be cultivated sometimes the day following the irrigation, while on heavier soils a delay of two days longer may be necessary. Deep cultivation is recommended along with the application of water in deep furrows, except for shallow sandy soils underlaid with gravel. A granular mulch, 8 inches thick, is much more effective in holding down the moisture than one only 3 or 4 inches thick. An early theory was that deep cultivation interfered with the roots of the trees, but cultivation to depths of 8 or 9 inches has not been found detrimental in deep soils, and if the cultivation is accompanied by deep irrigation the tree can not suffer from this cause. The depth at which the lateral roots of orange trees are found varies, as some stocks are deeper rooted than others, but few are above a depth of 10 inches unless the irrigations have been shallow.

Some orchards have plow sole, a layer of soil hard and impervious to water just below the surface layer. This is not a natural condition, and as a rule it occurs where the irrigation and cultivation have been continuously shallow, and is more pronounced in the dry season. The hard layer is near enough to the surface to be baked by alternate wetting and drying, yet it is not broken up by the cultivation. It has been destroyed in some orchards by the use of a subsoiler reaching a depth of 20 inches, but in such a process there is danger of severing the main tree roots, and it is better to use the preventive—deep furrows and deep cultivation.

The benefits of applying the water well below the surface and of cultivating to a good depth have been proved in the results achieved in many orchards. One young orchard of 80 acres, near Azusa, was kept in a thrifty condition for four years without irrigation by keeping the surface soil in good condition by intensive cultivation. With an annual rainfall of 15 or 18 inches, most of which came in the spring, it was necessary only to hold the moisture long enough to carry the trees through the summer.

The results of experiments by this Office at Arlington Heights, Riverside, and at the old experiment station farm near Pomona have been very conclusive.[a] These tests were made by sinking large tanks containing representative soils in the ground. The tanks were arranged so that they could be raised and weighed at intervals, thus enabling the actual loss of moisture from the soils by evaporation to be determined accurately. One series of tests showed a great saving in deep furrows over shallow ones. Another series compared cultivated and uncultivated soils, with a result very much in favor of cultivation. A similar comparison between mulches of different depths showed that the deeper the mulch the more effective it is. The downward movement of the water is no greater from deep than from shallow furrows, but the water from the former enters the soil at a lower plane and must be raised a greater distance by capillarity before evaporation can take place, and consequently the loss by evaporation is lessened. Deep furrows and good mulches reduce to the minimum the amount of moisture that rises to the surface.

The practice in cultivating orchards varies somewhat. Sometimes the first cultivation after an irrigation is made with a spring-tooth harrow before the soil has dried out to a sufficient depth to permit a deep cultivation with a stiff-tooth cultivator. This is a good implement for shallow cultivation and clearing out weeds, and may be used for loosening the ground for a distance of 2 or 3 feet under the tree branches, a thing that can not well be done with the wheeled or riding cultivator, and it does not entirely destroy the furrow. Later a more thorough cultivation is given with the wheeled cultivator having stiff teeth 1 to 2 inches wide. These teeth are run to depths of 7 or 8 inches and loosen up the soil without turning it over or exposing more moisture. This implement is furnished usually with about 9 teeth, but more or less may be arranged in almost any position, thus making the implement a very useful one for several purposes. Sometimes small plows are fastened to the cultivator frame in place of one or two of the teeth in such a position as to close in the furrows by throwing the earth back into them. Furrows should be broken up as soon as possible after the irrigation, as they are inclined to bake. The cultivation may be repeated one or more times, and in some cases the teeth are set still deeper for the later cultivations, and 4 horses used. The process of destroying furrows by cultivation is illustrated by Plate V, figure 1.

[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 177.

FIG. 1.—DESTROYING FURROWS BY CULTIVATION.

FIG. 2.—IRRIGATING ALFALFA WITH SURFACE PIPE.

Orchards often are plowed to good depths in the winter and spring in order to loosen the soil and make it capable of absorbing as much of the rainfall as possible. The plowing usually is done transverse to the slope, so that the furrows will catch and hold the water. Some orchardists do not believe in plowing, but rely instead on the cultivator alone, and there are some well-cultivated orchards showing good results that have not been plowed for many years.

Costly measures have been resorted to for improving the condition of the soil of several orchards planted in tight adobe soil near San Dimas. The application of lime and gypsum is recommended sometimes, but in this case many wagonloads of sand were hauled from the wash, spread over the surface, and plowed in. On one orchard 4 to 6 cubic yards of sand was added for each tree, at a cost of 25 cents per cubic yard, which is equivalent to an expense of $135 per acre. The effect has been to increase materially the moisture absorbing and retaining qualities of a soil on which the use of stable manure and the growing of cover crops alone had but little effect.

Cover crops.—Cover crops are grown in many orchards and in addition to the well-known properties of furnished plant food in the form of nitrates through the medium of soil bacteria, have much value in improving the capacity of most soils to take and hold water. These crops are the legumes and include vetches, peas, lupines, fenugreek, burr clover, etc. Vetches, however, are the most popular, because the crop is sure and gives a fair tonnage. They are also deep rooted and do not require a great quantity of water. The cowpea has been much grown in some localities. Cover crops are seeded early in September so that they will make a growth before cold weather begins. The orchards are irrigated before planting and often shallow furrows are made in the moist soil for future irrigations before the seed is sown. The crop is then irrigated as required until it rains or a full growth is made. The crop is plowed under, usually in February, so that it may be decayed by the spring rains. It is important that the crop be turned under when it is yet succulent, for if the plants are allowed to become fibrous they are a source of trouble by being dragged behind the cultivator teeth through the summer. Some growers first use the disk harrow to cut up the plants, after which they are plowed under. Others use the disk plow, disking in different directions at short intervals.

Cover crops if grown for several seasons are beneficial to both sandy and clayey soils. The humus resulting from their decay makes sandy soils more retentive of the moisture supplied by irrigation without impairing good drainage. Clayey soils are made more porous and granular so that they are more easily worked and have less tendency to bake, their capacity to take and hold water is increased, and they are given aeration by the better ventilated condition and more free movement of air and water. This is especially important, as fruit trees require a drained soil and will not thrive in a water-logged area. The growing of cover crops may be advantageous also where there has been trouble with hardpan or plowsole, provided the roots can penetrate the hard layer. It has been found in some places that they prevent washing by winter rains in orchards on steep slopes.

IRRIGATION OF DIFFERENT KINDS OF TREES.

CITRUS FRUITS.

It is the general practice to irrigate citrus orchards about every thirty days, although at Riverside some orchards are irrigated every forty-five days with a correspondingly greater quantity of water at each irrigation. Some orchards under the Del Monte system, instead of being irrigated once a month in each space between tree rows, are irrigated in each alternate space at one time and in the other spaces two weeks later, one-half the water to which they are entitled for the month being used for each irrigation. With thirty-day intervals there are five or six complete irrigations, depending on the dryness of the irrigation season, which extends from April or May to October, inclusive. Canyon water is used to some extent through the winter, although with much less regularity than in the summer. The reason for such use is the cheapness of the water rather than the fact that the land needs the water. Canyon water is used sometimes to prevent the damaging effect of frost to citrus fruits, and when it is very urgent pumps are started for the same purpose. The heat given up by artesian or pumped water may prevent freezing, or the moisture resulting from the wetting of the soil may retard the thawing of the fruit. Young trees require much less water than full-grown trees. They are irrigated when first planted and should receive water at fifteen-day intervals during the first summer. Some growers apply the water to young trees along the row only, but it is better to moisten the whole space, as the roots then develop more rapidly.

Orange trees have three new growths of foliage, with a check in the sap between them, one in the spring, one in the summer, and the third in the fall. The trees are dormant through the winter and bloom in March or April at the time of heavy rainfall. The Washington Navels, which constitute the bulk of the orange crop, begin to ripen in December and the picking and shipping continue until June. Seedlings and miscellaneous varieties do not begin to ripen quite so early, and the Late Valencias do not become sweet until summer and often many are not picked until the following October. It requires a full year to produce a crop of Navels, and a longer time for Valencias, so that with the latter there are two crops, one green and the other ripe, on the tree in the summer when the trees must receive moisture from irrigation. For this reason the Valencia trees require slightly more water than the Navels, and the preservation of the ripe fruit, as well as the production of the new crop, depends on their care. Either too much or too little water may be detrimental by causing the fruit to drop or by impairing its quality. Growers claim that critical periods with citrus trees are when there is a change from the cool, wet days to the warm days in the spring, when cold weather begins in the fall, and when changes in the flow of the sap occur. The trees should be in good condition to pass through these periods, and this is best done by keeping the moisture even. Citrus trees respond very readily to proper irrigation and the liberal use of fertilizer, and both are necessary for success. The grower must be willing to make a large outlay and practically force the trees to produce. Commercial fertilizer and barnyard manure both are necessary to supply all the elements of plant food, and the amount spent on these is $40 to $80 per acre per year. If the fertilizer is not applied in the rainy season it is disked and washed into the subsoil by an irrigation. Sometimes when reviving a neglected and run-down orchard $100 per acre is spent in a single year for fertilizer. Trees must be fumigated also to kill scale and the pruning must be systematic, but no orchard operation is more important than the irrigation, together with cultivation and fertilization, which are so closely related to it. The change brought about in the condition of the trees by proper treatment for a few seasons is sometimes marvelous.

Lemons require more water and more attention than oranges. They are not always given more water, particularly if the orchard is under an irrigation system used principally for oranges. Lemon trees are bearing constantly. They bloom in all seasons, have fruit in all stages of growth at the same time, and are picked at intervals of several weeks the year round, according to size instead of color, the green lemons being cured afterwards. The largest number of blossoms, however, come in the spring when the orange trees bloom, and consequently the most fruit is picked in winter, as it requires nearly a year for the fruit to mature. With such continuous bearing the treatment of the tree can not be neglected at any time, for if there is not sufficient moisture the fruit is lacking in acidity. Growers believe that the shape and smoothness of the fruit may be influenced also by the manner of using water and fertilizer. A lemon orchard should be irrigated just after the picking.

DECIDUOUS FRUITS.

The irrigation of deciduous fruits is much more irregular than that of citrus fruits, and there are several theories regarding the best practice. Most peach orchards are irrigated from one to three times during the growing season, many growers claiming that one irrigation, about March, is sufficient in any of the soils in Pomona or on Chino rancho. Some are irrigated a little in the winter and others not at all. One 75-acre orchard east of Chino is plowed once in January and again in March or April, after which it is thoroughly harrowed. It is then well cultivated from time to time to hold the moisture supplied by the spring rains, which alone are depended upon to produce the crop. Moisture from the rains has been found to penetrate the soil 8 or 10 feet. Peaches grown by these methods are small and are all used by local canneries. One orchardist growing peaches for shipment has his trees irrigated five times during the growing season, but no cover crop or fertilizer of any kind is used. The fruit is large and of excellent quality, but it is not certain that the results are due altogether to the quantity of water used, as much care was used in selecting a variety adapted to the soil, and the pruning of the trees is done carefully.

Apricots should not be irrigated near the time of ripening if the fruit is to be shipped. Some growers believe that the trees should have water early in the growing season; others that little or no irrigation during the growing season is best. The latter irrigate the orchards well through the winter, plow and cultivate thoroughly during the growing season, and give one irrigation in the late summer after picking. The trees should first be pruned, after which the application of the water starts the buds for the next crop.

ENGLISH WALNUTS.

There are many views among walnut growers as to the manner, time, and frequency of applying water, and the amount that the trees should receive. Basin irrigation in the past was preferred for walnuts, it being held that when the soil was well worked up it allowed a better soaking than furrow irrigation, and the aim was to give orchards as much water as possible with a small number of irrigations. Many growers are practicing furrow irrigation at present. Some do not irrigate at all if the moisture from the winter rains penetrates the soil to a depth of 7 feet or more, believing that the trees are deeper rooted if not irrigated, and that if the roots are trained toward the surface by the use of water they are cut by the cultivator and the plow to the detriment of the tree. Such persons prefer to use no water and to cultivate continuously through the dry season. If the water is applied in deep furrows instead of in basins, it is probable that their objections to irrigating would be overcome. Others give a single irrigation in July, or some time after the rains cease, and try to put a large quantity of water into the soil. An attempt is made to retard the new crop by giving the trees no water in the spring and keeping the soil cool with a cover crop, in the belief that there is less liability to blight if the blossom can be held back until after the damp season. Still others irrigate at an earlier date, with a second irrigation in the summer, and perhaps a third if the season is very dry. The trees are not irrigated near the time of harvesting the nuts, which is in September and October. Walnut orchards are cultivated thoroughly and are plowed once in the winter. As there are not a great many in this locality, they are not irrigated as systematically as at Whittier and in Orange County, where large areas are devoted to the industry. The acreage, however, is increasing and there should be better practice in the future.

IRRIGATION OF ALFALFA.

There is no romance in the way alfalfa is irrigated near Pomona and Chino. The rancher from many sections of the West, who is accustomed to turning large heads of water onto broad fields, little caring if there is waste, thinks the spreading of water over 20, 40, and 80 acre alfalfa farms by hand-laid surface pipe is ridiculously painstaking. However, when it is considered from the economical viewpoint this method is greatly in advance of others. All the alfalfa is irrigated from wells. A few of these have a light artesian flow, but in most the water must be pumped from depths of 30 to 100 feet. Two or three crops in a season would not warrant such expense, but with six or seven crops there is an inducement for extreme measures in securing and taking care of the water.

The system of irrigating alfalfa is to systematically carry the head of water to first one point and then another in the field by detachable iron pipe laid on the surface. It allows excellent control of the water and makes it possible to apply it at any point for as long a time as is desired. It also dispenses with ditches and borders in the field, so that the entire area is utilized for the crop. Plate V, figure 1, shows the irrigation of alfalfa with detachable surface pipe. The pipe can be laid to force the water onto slightly elevated portions of the field, but the land is, in fact, graded as carefully as for flooding with other methods. If the field were left uneven it would cause scalding of the crop and hardening of the soil in the low places. After plowing and grading, the field is irrigated to settle the soil to a permanent position, and then any unevenness can be smoothed before seeding. Seeding in the spring is preferred and the soil is first irrigated, unless already wet from rains. The soil is inoculated and nurse crops are not used. Thin spots in the stand are disked and reseeded.

USE OF CONCRETE PIPE AND STANDS FOR CONVEYING WATER.

Concrete pipe lines are laid for conveying the water from the pumping plant to the fields. They are 10-inch lines, unless the well is more productive of water than the average, in which case 12-inch pipe is required. The head line is provided with stands about 100 feet apart. They differ from the stands for an orchard by having only a single opening and that large enough to discharge the entire stream. A 12-inch stand is used on a 10-inch pipe line. There are two kinds of stands, the most satisfactory of which is illustrated in figure 7 and also in Plate V, figure 2. In this a 10-inch elbow of galvanized iron is firmly cemented in the top of the stand. When

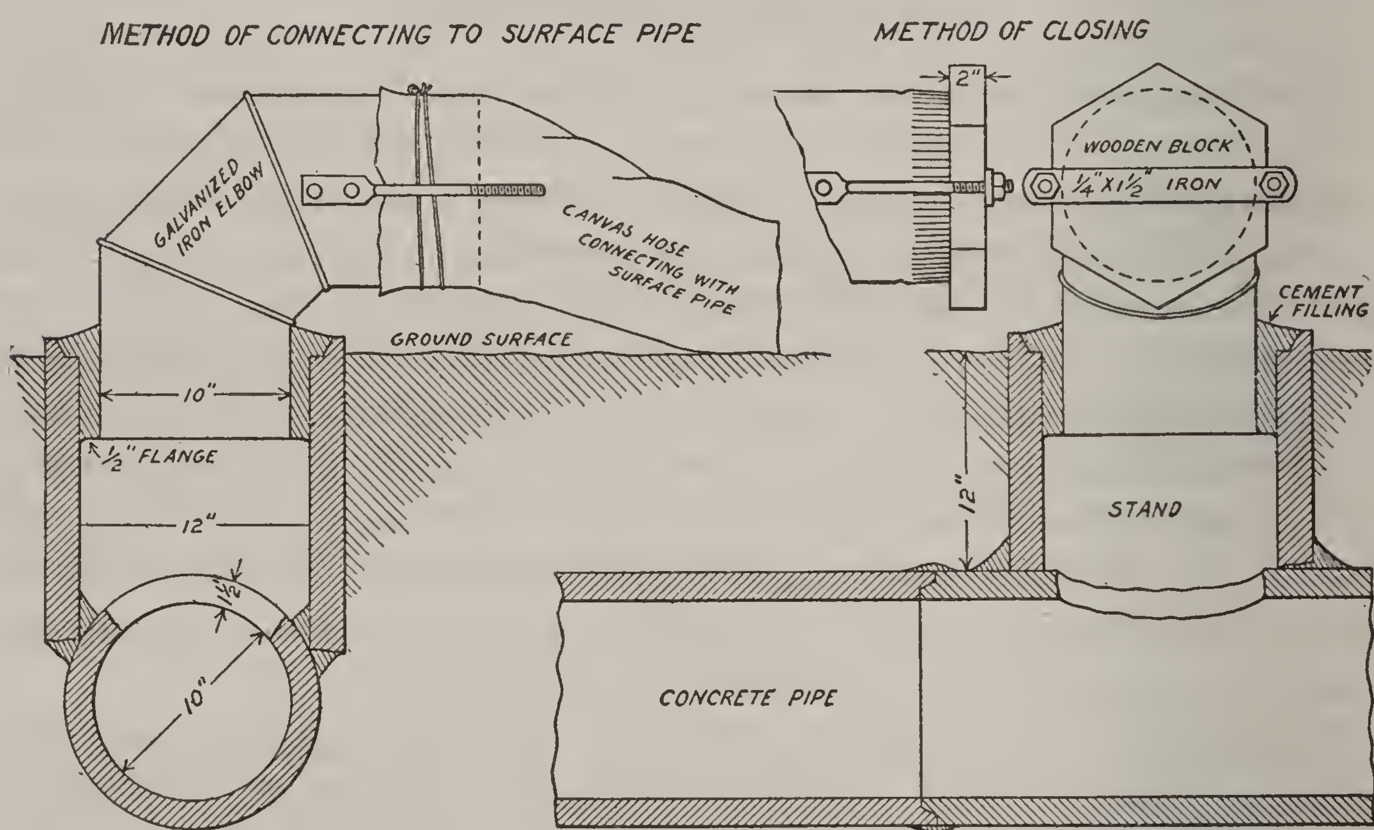

FIG. 7.—Design of concrete stand for alfalfa irrigation.

not in use the opening is closed by a wooden block held tightly against the end of the elbow by two nuts. In the other kind of stand the opening is made by inserting a short piece of pipe in one side of the stand, the top of which is capped with concrete. When it is necessary to have a large stand in the pipe line for a basin or turnout, it may be equipped so that it will serve as an ordinary stand also. Stands should be marked by posts so they can be avoided when mowing. The cost of a head line for 40 acres, with 1,300 feet of 10-inch pipe laid at 22 cents per foot, 12 stands at $1.75 each, and one basin at $5, is $312. Iron stands, which are more convenient to open and close, are made, but they are not yet in general use on account of their greater cost.

Both iron pipe and canvas hose have been used for distributing the water over the fields from the stands. The hose is cheaper, and at one time was used as much as the pipe, but with the best of care it rarely lasts more than two years, hence iron pipe is best. Saturated hose is heavy and disagreeable to handle. Hose is made of about 12-ounce canvas and is often treated with a preparation which makes it nearly water-tight and more durable. Ordinary hose, if left wet on the ground, has its usefulness destroyed in a few days. Plain 9-inch hose costs about 8 cents per foot, and the prepared hose about 10 cents per foot. The flexibility of the hose adapts it for making bends. The general practice now is to use pipe altogether, except one piece of hose a few feet in length for making connection with the stand. It is slipped over the opening in the stand and tied or wired in place and the other end is merely placed inside the pipe. The hose is 1 inch larger in diameter than the pipe. It can not be used under a high pressure. The water is often forced through the pipe line by the pump, and there is generally a standpipe near the

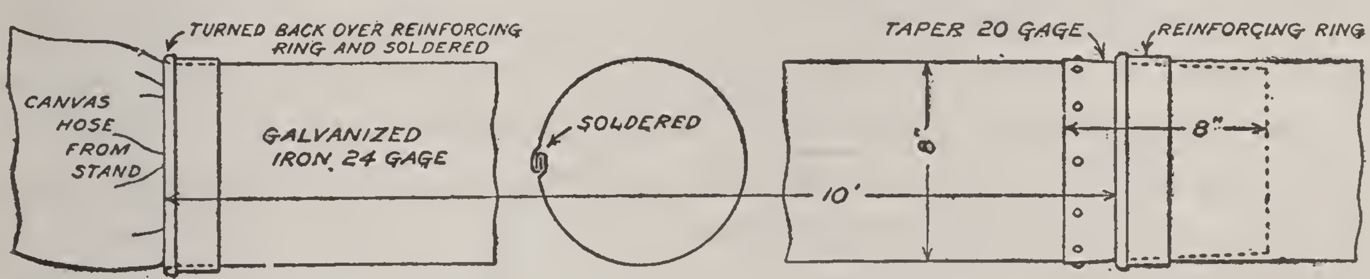

FIG. 8.—Surface pipe for irrigating alfalfa.

pumping plant in which the water is free to rise. This acts as a regulator and prevents sudden strain on the pump and pipe line. The head in the standpipe seldom exceeds 3 or 4 feet, provided the water is not forced up a grade.

Detachable surface pipe is made of galvanized iron usually 24 gauge. It is 8 inches in diameter and is made up in sections of several lengths, but the shorter lengths of 10 feet are the most durable, and are now preferred. The pipe is now made by special machinery in 10-foot sections, each from a single sheet of metal, as shown in figure 8. Aside from the circumferential seam at one end where the taper begins this section has only a longitudinal seam, which is soldered but not riveted. The taper is 8 inches long and is of heavier iron (about 22 gauge) for inserting in the end of another section. The pipe costs 22 cents per linear foot and 1,300 feet, which is sufficient to irrigate a square 40-acre tract from one head line, cost $286. The expense is warranted by the productiveness of the land and the permanency of the crops. Some pipe is not furnished with the reenforcing ring and the taper is formed by merely crimping the end, but this is a less durable kind. The cost is double the cost of hose, but it lasts for ten or fifteen years or even longer with proper handling. The principal source of damage is in the loading and unloading of the sections when hauling to or from the field.

With a head of 60 miner's inches one man can irrigate $2\frac{1}{2}$ acres per day of ten hours. To irrigate a field the water is used from one stand for a strip equal in width to the distance between stands and with length from the head to the foot of the field. Since without reservoirs there must be an outlet for the water whenever the pump is in operation, it is best to have one stand temporarily open when the surface pipe is being connected to another. The best way to irrigate with surface pipe is to begin applying water at the upper end of the strip, and proceed toward the lower end by gradually adding sections of pipe. If the strip is narrow a single stringing of the pipe through the center is sufficient to wet the full width, but if the strip is wide more than one location of the line must be made. This is done by swinging the short piece of canvas hose at the stand to one side or the other in order that the pipe may be strung on either side of the center line.

When care is used there need be no waste and no draining of surplus water to prevent scalding. If too much water is being applied, it will flow toward the lower side of the field and as the work approaches the foot it is easy for the irrigator to make proper allowance for the surplus. When one side of the strip has been completed, the hose connection at the stand is swung to the other side of the strip for a new location of the surface pipe. The irrigator then begins at the upper end by carrying the pipe across to the new location section by section. After the entire strip has been irrigated by either one, two, or three locations of the surface pipe the connection is changed to the next stand for the irrigation of a new strip. The second stand is opened and the new connection made before the first stand is closed. The leakage at the joints of pipes is slight and the loss is not of consequence since it occurs on the land being watered.

There are some moist lands on which alfalfa is grown with little or no irrigation, but the crops are light and the dry lands which comprise the greater part of the region must be well irrigated. The water is applied as soon after each cutting, except the last, as the hay can be disposed of, and a second irrigation before the next crop is cut is not common. In wet years the first one or two crops are raised without irrigation. There are from five to seven cuttings of irrigated alfalfa, the practice being to cut when the basal shoots start, regardless of the bloom. The first cutting comes in April or May, and the seventh is often made as late as November. It grows more slowly in the late fall, when the nights become cool, and the last crop is light. The average yield is from 1 to 1½ tons per acre for each crop. Nearly all of the alfalfa is disposed of on the ranches to fruit growers, who haul it away. A little is baled and shipped to Los Angeles. The price is influenced somewhat by the size of the barley crop. For several years it has been from $7 to $10 per ton, and it has been at the latter figure for the last three years. An improved ranch with pumping plant is valued at $300 to $600 per acre. The ranches contain from 10 to 80 acres.

IRRIGATION OF OTHER CROPS.

The winter and spring rains are ample usually for the growing of sugar beets, except in very dry seasons, when they are given a single irrigation. The factory at Chino receives 80,000 tons of beets per year, but most of these are from Santa Ana and other localities. The yield is given as 12 tons per acre. The price is in proportion to the percentage of sugar contained, being $5 per ton for beets containing 15 per cent of sugar. Nearly all of the 3,000 acres of beets on Chino rancho are grown by the sugar company. The beet lands are low-lying moist lands south of Chino, with too much alkali for alfalfa. The company's lands have been tiled to allow early planting. This also removes some of the salt from the soil. Drainage of these lower lands was not made necessary by the irrigation of higher lands, as they were moist before irrigation was begun. The method employed is to flood the fields by the use of a detachable surface pipe.

Grapes require very little water, and the mistake of irrigating them too much is common. Vineyards in this locality are given one to three irrigations, depending upon the soil and the season. The grapes have not stood shipment to the eastern market well, and are used in making wine. Many thousands of acres of grapes are grown without irrigation at Cucamonga, 10 or 15 miles to the east. The soil is very sandy and retains the moisture supplied by the rainfall.

The irrigation of berries, melons, vegetables, and miscellaneous fruits is very irregular. As gardening is begun in winter, the rains supply much of the moisture needed, and there often is little irrigation. Strawberries ripen from April to November, inclusive, and are irrigated quite frequently through the dry season. Water is applied in very deep furrows or ditches, so that it will reach the plant roots without wetting the tops of the ridges, which would cause the berries to decay. The olive requires very little moisture, and the trees will live without irrigation, although they require water to produce well. The splitting of figs is believed to be caused by late watering. Eucalyptus trees require irrigation only when young.

DUTY OF WATER IN POMONA VALLEY.

Although there is yet room in many cases for water to be used more economically, the duty is very high, even considering that the rainfall is greater than in most western localities. The principal reasons for the sparing use of water are its high cost, together with the dependence of the cost on the amount used and the independence of the irrigators. Pumping-plant owners can use water at their own pleasure, and where mutual water companies meet operative expenses by a water charge, members have an opportunity to save by being skipped in the rotation schedule. Data are available to show the duty for fruits from 1905 to 1909, inclusive, and for alfalfa for 1905 and 1908. The depth of rainfall is much greater than the depth of irrigation, but the value of the rainfall in supplying moisture is not in proportion to the quantity, on account of its poor distribution. It has another value, however, in replenishing the gravel beds for pumping. Irrigation supplies the moisture in the summer when it is most needed. The rainfall for the calendar year represents the amount of moisture supplied naturally through a growing season more nearly than that for a meteorological year except in the case of deciduous fruits. The rainfall by months for the period 1905 to 1908, inclusive, as shown by the records of the Pomona Land and Water Company, are as follows:

Rainfall at Pomona, Cal., 1905–1909, inclusive.

Month.	1905.	1906.	1907.	1908.	1909.	Month.	1905.	1906.	1907.	1908.	1909.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*		*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches*
January	3.36	4.81	8.66	6.84	9.94	August	.00	.00	.00	.03	.16
February	8.05	2.50	3.53	3.89	5.65	September	.02	.07	.00	1.88	.04
March	8.50	9.61	5.74	.83	3.44	October	.12	.00	2.63	.88	.43
April	1.35	1.58	.52	.91	.07	November	2.71	1.62	.02	.27	2.01
May	2.34	1.31	.05	.34	.03	December	.64	8.33	1.07	1.64	9.63
June	.00	.03	.41	.00	.17						
July	.00	.03	.00	.00	.36	Total	27.09	29.89	22.63	17.51	31.93

The above totals reduced to feet are 2.26 for 1905, 2.49 for 1906, 1.89 for 1907, 1.46 for 1908, and 2.66 for 1909.

DUTY FOR CITRUS FRUITS.

For 1905 certain tracts representing all the different kinds of soils have been selected where the total number of hours that water was applied during the season was known and where careful measurements had been made of the water used. No tracts were selected where canyon water was used, because the variation in the amount of canyon water would make results uncertain.

Duty of water for citrus fruits at Pomona, Cal., 1905.

Number of tract.	Crop.	Acres.	Irrigations.	Hours pumped.	Rate of pumping.	Depth applied by pumping.	Total, including rainfall.
					Miner's inches.	*Feet.*	*Feet.*
1	Young oranges	70.00	4	440	16	0.2	2.5
2	do	10.00	7	1,560	2	.6	2.9
3	Oranges	30.00	5	550	23	.7	3.0
4	do	36.50	5	507	16	.4	2.7
5	do	60.00	5	1,100	28	.9	3.2
6	do	20.00	5	500	24	1.0	3.3
7	do	24.75	2	180	15	.2	2.5
8	do	8.00	6	365	7	.5	2.8
9	do	5.66	5	300	16	1.5	3.8
10	do	4.25	5	75	43	1.3	3.6
11	Oranges and lemons	35.00	5	593	29	.8	3.1
12	Lemons	15.00	6	720	12	1.0	3.3
Average						.8	3.1

Tracts 1 and 2, being in young trees, did not require as much water as full-grown trees. Nos. 1, 2, 3, and 12 are in loose, gravelly loam near the foothills, and No. 11 is in similar soil in San Dimas Wash. Tract No. 10 is in tight soil near Spadra and the others are in the medium sandy loams near Pomona and Lordsburg. It does not appear that the unequal amounts of water applied to these tracts has been due to the different requirements of soils, but rather to the amount of water available.

For the seasons 1906, 1907, 1908, and 1909 the general duty for citrus fruit is represented by the amounts used under the systems of the Del Monte Irrigation Company and the Palomares Irrigation Company. All of the land under the Del Monte system and three-fourths of the land under the Palomares system is in citrus fruit. The results are based on the total number of hours that one or more heads of water are delivered. The average aggregate heads, in miner's inches, delivered by the Del Monte Irrigation Company were increased during 1907 by a good supply of flowing water. An attempt is made to maintain constant heads, but they are usually slightly less than they are intended to be. This in a measure counteracts the error that would occur from making no deduction in the total acreage served by the companies for buildings and roads.

Duty of water, Del Monte Irrigation Company system, Pomona, Cal., 1906–1909.

Year.	Acres.	Number of rotations.	Hours in schedule.	Size of stream.	Depth applied.	Total, including rainfall.
				Miner's inches.	*Feet.*	*Feet.*
1906	2,000	7	636	200	0.73	3.22
1907	2,000	7	636	300	1.10	2.98
1908	2,000	7	636	200	.73	2.19
1909	2,000	7	636	200	.73	3.39
Average					.82	2.94

Duty of water, Palomares Irrigation Company system, Pomona Cal., 1906–1909.

Year.	Acres.	Number of rotations.	Hours in schedule.	Size of stream.	Depth applied.	Total, including rainfall.
				Miner's inches.	*Foot.*	*Feet.*
1906	600	6	720	60	0.71	3.20
1907	600	7	720	60	.83	2.71
1908	600	7	720	60	.83	2.29
1909	600	7	720	60	.83	3.49
Average					.80	2.92

The use of 1 miner's inch on 8 acres would give the land a depth of three-twentieths of a foot per month or about 1 foot for the irrigating season, but the foregoing tables show that only about four-fifths of a foot of water is applied annually by irrigation to citrus orchards. It will be noted that the average duty for the four years under the two systems is nearly the same as the average for the twelve tracts for 1905. If the irrigation by canyon water were included, the general duty would be slightly raised by the greater use of water through the winter. The total depth applied, including the rainfall, is 2.93 feet, but allowance should be made for the high rainfall of this period. The average of the five years for which the duty is given is 50 per cent greater than the average for twenty-five years and is double the rainfall of some former dry years. In dry seasons more water is pumped, but not enough more to bring the total quantity applied to the land up to that shown. The quantity of well water used does not increase in a period of dry years as much as would be expected, for artesian wells cease to flow and good heads of pumped water are harder to get. The distribution of the rainfall is much the same for wet and dry years. With the average rainfall of about 1½ feet the total depth applied would probably be less than 2½ feet. Comparison of the duty with that of the interior districts shows it to be higher. At Riverside the depth of irrigation is from 2 to 2¼ feet, and the average rainfall brings the total up to about 3¼ feet. There are several reasons for this difference: Riverside has canal water, consequently there is much more winter irrigation; there are fewer young trees there; the soils there are heavier; and loss by evaporation is probably greater. On the other hand, there is probably a greater loss at Pomona by moisture going below the roots of the trees.

DUTY FOR DECIDUOUS FRUIT AND DIVERSIFIED CROPS.

The water used under the Irrigation Company of Pomona gives some idea of the duty on deciduous orchards and diversified crops which occupy about one-half of the acreage, the other half being in citrus fruit. The company does not deliver by rotation. The quantity of water used in 1906 and 1907 is found from the total number of hours and the average size of stream pumped. In 1908 and 1909 the company had some flowing water in addition to that pumped, so that results can not be based on the number of hours pumped, but the total quantity used is shown by the receipts from the charges for water at 50 cents per hour for 60 miner's inches through the irrigating season and a small amount of winter water at one-half charge, making the average for the twelve months about 40 cents.

Duty of water, Irrigation Company of Pomona system, Pomona, Cal., 1906–1909.

Year.	Acres.	Hours pumped.	Rate of pumping.	Receipts from water runs at 40 cents per 60 hour-inches.	Hour-inches.[a]	Depth applied.	Total, including rainfall.
			Miner's inches.			*Foot.*	*Feet.*
1906	2,500	2,489	234			0.39	2.88
1907	2,500	2,589	256			.44	2.32
1908	2,500			$5,144.20	771,630	.51	1.97
1909	2,500			4,850.00	727,500	.48	3.14
Average						.45	2.58

[a] 1 miner's inch per hour.

The average duty for the four years is only 0.45 foot, showing by comparison with the duty for citrus fruits that much less water is used.

DUTY FOR ALFALFA.

The duty for alfalfa is shown by the depth of water used on seven tracts in 1905 and on six tracts in 1908 in various locations in southern Pomona and on Chino rancho. In all of these cases the total number of hours pumped were ascertained and measurements were made of the water.

Duty of water for alfalfa at Pomona and Chino, Cal., 1905.

No. of tract.	Acres.	Irrigations.	Hours pumped.	Rate of pumping.	Depth applied by pumping.	Total, including rainfall.
				Miner's inches.	*Feet.*	*Feet.*
1	22.5	4	1,080	44	3.6	5.9
2	58.5	4	1,694	71	3.4	5.7
3	100.0	3	1,440	52	1.3	3.6
4	20.0	3	500	49	2.1	4.4
5	10.0	3	300	49	2.5	4.8
6	28.0	3	470	68	1.9	4.1
7	48.0	3	847	49	1.4	3.7
Average					2.3	4.6

Duty of water for alfalfa at Pomona and Chino, Cal., 1908.

No. of tract.	Acres.	Irrigations.	Hours pumped.	Rate of pumping.	Depth applied by pumping.	Total, including rainfall.
				Miner's inches.	*Feet.*	*Feet.*
1	70	4	1,204	62	1.8	3.3
2	40	5	800	68	2.2	3.7
3	10	4	480	49	3.6	5.1
4	15	4	640	49	3.2	4.7
5	40	5	800	68	2.2	3.7
6	43	3	600	55	1.3	2.8
Average					2.4	3.9

The tables show that 2.3 feet was applied in 1905 and 2.4 feet in 1908. The quantity pumped in 1905 is just equal the rainfall for the entire calendar year. In 1908 there was less rain and the quantity of water pumped was about double the rainfall. The extent of pumping for alfalfa is affected more by the rainfall than it is for fruits. With a rainfall of only 1 foot there would be much more pumping, and the total depth of water received by the land in 12 months would not fall below 4 feet. All the tracts selected, with one exception, were irrigated from pumping plants of their owners. Where the water is purchased there are, as a rule, fewer irrigations, but the production on the land is less.

COST OF IRRIGATING AND RAISING DIFFERENT CROPS.

CITRUS FRUITS.

The cost of irrigating citrus fruits includes the cost of the water and of its application to the orchard. The cost of the water is represented by the cost of pumping, where pumping is necessary, or the interest on the amount invested in water rights where canyon water is used, in addition to the cost of delivery.

The value of a miner's inch of canyon water varies from $1,500 to as high as $2,500 in some localities. The value of pumped water is not less than $1,000 per miner's inch. A continuous flow of 1 miner's inch is used to irrigate on an average about 8 acres, thus making the minimum investment per acre $125, and the interest at 6 per cent thereon $7.50 per year.

The cost of pumping, as ascertained from the water charges and assessments of the several companies in this section, averages about 2½ cents per miner's inch per hour, or $15 per acre-foot. The cost of pumping for citrus fruits may be said to average $12 per acre, allowing a duty of eight-tenths of an acre-foot per acre.

The methods used by the various companies for securing funds for operation vary somewhat. The Del Monte Irrigation Company is representative of those which secure all funds by assessments on the stock. The assessments in the company aggregate 75 cents per share or $9.75 per acre, there being 13 shares held per acre. This, together with the interest on the investment in water rights, makes the total cost of water at the point of delivery $17.25 per acre per annum. The company, however, has been paying $5,000 of indebtedness annually. This indebtedness has now been cleared and the assessments may be reduced a fourth or a third.

Water is very cheap in the Palomares Irrigation Company. This company is now out of debt, and it has been fortunate in not having to bore more wells or spend much money on new installation.

The Irrigation Company of Pomona is not representative. Conditions previously referred to have depreciated the value of its water rights and the pumping with a low lift of a large number of wells in one cienaga makes the cost unusually low. The interest on an acre water right valued at $26 is only $1.56, the charge for water made by the company is five-sixths of a cent per miner's inch per hour, and the annual assessments average $4 per acre.

The San Dimas Irrigation Company charges 2 cents per miner's inch per hour to members and 3 cents to nonmembers. Its water rights are valued at $100 per acre. The charges for water will meet all ordinary expenses.

Out of fourteen small companies for which the charges were learned, eight charge 2 cents per miner's inch per hour, three charge 1½ cents, and the others three-fourths of a cent, 1¼, 3½, and 5 cents, respectively. Some of these companies also deliver to nonmembers at rates 25 to 50 per cent higher than the charge to members, while others do not deliver to nonmembers at all. In the small companies, as in the case of the San Dimas Irrigation Company, the charges for water meet all expenses, except when there is some unusually large expense, such as the installation of new machinery, for which purpose the stock is assessed, and most of the companies get along without assessments for five or six years. The charge made to members represents more nearly the ordinary running expenses, for it is intended that there be a profit in the sale of water to nonmembers. In the Citrus Water Company the charge produced a surplus, and a dividend was declared. A fair average for the annual cost of delivering to irrigators from the pumping plant is $18 per acre, and when a cover crop is irrigated in the winter this may be raised to $22.

Water pumped at private plants often is sold, and the charges vary from 2½ to 5 cents per miner's inch per hour. Such plants are constructed primarily for the use of their owners, who are often not desirous of selling water. If they do sell, there must be a profit to them to aid in replacing the plant when the machinery is worn out. The depreciation, together with taxes and interest, for pumping plants is about 20 per cent per year, or $600 on an investment of $3,000. The cost of pumping at private plants varies more than at company plants, because often there is no charge for attendance. The cost of attendance at small plants is about $3 per day of twelve hours and $3.50 per day of twenty-four hours. The tests of 1905 show that the cost of pumping for fruit at private plants of 10 to 100 horsepower, with lifts of 100 to 300 feet, varied from $10 to $90 per acre-foot.

The application of water to orchards requires, as stated before, an expenditure of $193 for a head line for a 10-acre orchard, and the interest on this, which, at 6 per cent, amounts to $1.16 per acre per annum. An irrigator is paid about 25 cents per hour when hired, and his services for seven irrigations of twelve hours each for 10 acres costs $2.10 per acre. Where a cover crop is grown there are not less than nine irrigations and the cost is $2.70 per acre. This makes the total cost of obtaining and applying the water about $24 per acre, or as much as the cost of a water right in some sections of the West.

These figures, however, have little meaning unless considered in relation to the total cost of production of citrus fruits and the net return to the grower. The number of boxes of fruit produced per acre varies through a wide range and depends, among other things, on the location, the age of the trees, the care of the orchard, the variety of the fruit, and the season. Occasionally a crop of 500 boxes of oranges per acre is obtained by heavy fertilization, but even on well-managed groves 300 boxes per acre is an exceptional average for several years. It is only in late years that orchardists have learned how to grow larger and better crops of lemons. In general, trees bear more heavily near the coast than in the interior, but are more troubled with scale and must be fumigated more frequently.

The following table gives the quantity of fruit shipped and the returns to the growers for the total bearing acreage in oranges under the Pomona Fruit Growers' Exchange, Claremont Citrus Association, College Heights Orange Association, Indian Hill Citrus Association, La Verne Orange Growers' Association, and San Dimas Orange Growers' Association for the past five seasons. The general manager of the California Fruit Growers' Exchange has stated that the territory represented by these associations is the heaviest producing of all the larger fruit districts of the State.

Number of boxes of oranges produced per acre, price per box, and gross return to growers, 1906–7 to 1910–11, inclusive.

Season.	Acreage in associations.	Total shipments.	Total amount paid growers in cash and picking.	Average yield per acre.	Average price per box.	Average gross return per acre.
	Acres.	*Boxes.*		*Boxes.*		
1906–7	5,037	625,183	$835,913.06	124	$1.34	$165.95
1907–8	5,322	648,830	849,556.76	122	1.31	159.63
1908–9	5,413	1,037,082	1,070,590.80	192	1.03	196.78
1909–10	5,837	990,364	1,204,449.88	170	1.22	206.35
1910–11	6,336	1,483,664	1,984,289.62	234	1.34	313.18
	27,945	4,785,123	5,944,800.12	171	1.24	212.73

The selling price of citrus fruits varies greatly. The cost of marketing is deducted from the gross receipts before the grower is paid for his fruit, as is also the cost of picking, where the fruit is picked by the association. The cost of marketing includes packing at 39 cents per box for oranges and 65 cents per box for lemons, freight at about 83 cents per box for oranges and about 97 cents per box for lemons, and a refrigeration charge of 15 to 25 cents per box for about one-half the oranges and a small per cent of the lemons. The prices for single shipments of oranges vary more than those given in the table above. The variation in the price of lemons is as great as that for oranges.

The average crops include some neglected orchards and some that are not in full bearing, and although helpful in showing the status of the industry, they do not show what can be done with an orchard with skillful handling or perhaps even with fair treatment. For the purpose of illustration the production will be taken as 250 boxes per acre, which, at an average price of $1.25 per box, gives $312.50 per acre as the grower's gross receipts. The cost of irrigation, exclusive of interest on the investment in water right or pumping plant, is about $15 per acre. Orchards are now fertilized more than ever before, and the cost of fertilization often reaches $100 per acre. Some orchardists use little fertilizer, but as a rule their profits are small. On the other hand, the useful age of the orange tree has not been determined and experience may teach that the forcing of the trees to great extreme is unwise. The practice on some orchards is to use 10 tons of stable manure per acre and 10 pounds of commercial fertilizer per tree. In most localities trees must be fumigated at intervals of two or three years at a cost of $15 to $30 per acre for oranges, depending on the size and condition of the trees, and more for lemons. Pruning costs $4 to $10 per acre for oranges and twice as much for lemons. Picking and hauling cost 10 cents per box for oranges and 30 cents for lemons. The following table represents the cost of raising, picking, and hauling a crop of oranges:

Cost of raising, picking, and hauling an orange crop of 250 boxes per acre.

Irrigation	$15
Cultivation	20
Fertilizer	60
Pruning	8
Fumigation	10
Taxes	10
Picking and hauling	25
Total	148

This leaves $164.50 to cover depreciation and the grower's profit and interest on the investment in land, water right, packing-house stock, etc. This is 11 per cent on a valuation of $1,500 per acre, or 8 per cent on a valuation of $2,000 per acre. Some orange groves have sold for $4,000 per acre, and lemon groves are to be found in the most favored localities valued at a higher figure.

Stories are current of fabulous profits from orange growing. A grove does occasionally return a large sum for a single year, but these are exceptions, and the publicity given such has left a wrong impression with many unfamiliar with the industry. The general condition of the districts as regards homes and mode of living is not always a true index to the profits of the grooves, for much wealth has been brought from other sections by attractions of the country other than the profits in fruit growing, but there is a fair profit even on the large investment, and the high cost of irrigation is fully warranted.

ALFALFA.

The cost of irrigation is a much larger part of the total cost of production for alfalfa than for fruit. Water seldom is measured carefully when sold for alfalfa, and the customary charge for heads of approximately 60 miner's inches from private plants is 85 cents per hour, or about 1⅓ cents per miner's inch per hour. At this rate an acre-foot costs $8, and with a duty of 2.4 acre-feet per acre the cost of water delivered is $19.20 per acre.

The tests made in 1905 show the cost of pumping for alfalfa to vary from $5 to $25 per acre-foot for plants of 10 to 30 horsepower, and with lifts of 0 to 100 feet, the majority being 30 to 60 feet. A representative plant has a 12-inch well 400 feet deep, a 25-horsepower gasoline engine, and a No. 5 centrifugal pump, and cost $3,000. The total lift is 50 feet, of which 10 feet is suction, and 60 miner's inches, or 540 gallons, per minute are pumped. It is necessary to run the plant 640 hours to irrigate 40 acres four times. The cost of operation may be summarized as follows:

Fuel, 3 gallons No. 2 grade engine distillate per hour, at 8 cents per gallon	$153.60
Attendance, part of the time of one man, 5 cents per hour	32.00
Repairs (estimated)	30.00
Interest, 6 per cent first cost	180.00
Taxes, 1 per cent first cost	30.00
Depreciation, 13 per cent first cost	390.00
Total	815.60

The total cost is thus $1.27 per hour—a little over 2 cents per hour for each miner's inch of water pumped, or $12.85 per acre-foot.

By this it would appear that money is lost in selling a head of 60 miner's inches for 85 cents per hour, but it must be remembered that the interest and taxes are the same whether the plant is run or not and these have been figured as $210. A little less than half of the depreciation and the repairs also should be charged for a plant run equally as much for selling water as for irrigating the owner's land. The depreciation of the building, moreover, is not confined to the time of running. The profit, however, is small at such a rate.

For a 40-acre tract the investment in a cement head line 1,300 feet long is $312 and the same length of detachable surface pipe $286. At 6 per cent the interest is 90 cents per acre. A man's time for irrigating is worth 25 cents per hour, and it requires 16 days of 10 hours each to irrigate the tract once. At an average of four irrigations his wages would amount to $4 per acre for the season. This, with water delivered at a cost of $12.85 per acre-foot and the use of 2⅓ acre-feet per acre, brings the total cost of irrigation up to $35.

The only other item of any consequence, aside from interest and taxes, on the land entering into the cost of production of alfalfa is the cutting and raking of the hay, and this costs about $1 per acre for each crop. Alfalfa is better if reseeded occasionally, but if well cared for this is not required for several years. There is no expense for marketing much of the hay, as the fruit growers pay $9 a ton for it in the field and haul it away. Some is baled, at a cost of $2 per ton, and shipped to Los Angeles. There is a gross return of $54 to $108 per acre, about one-half of which is profit, with a production of 6 to 9 tons per acre. The percentage of profit on the investment is as high as that for orange land.

FUTURE USE OF WATER.

NECESSITY FOR ECONOMY IN ITS USE.

The high cost of water for fruit and alfalfa and the close approach of the quantity used to the limit of the supply make it desirable that all means be used to make what there is go as far as possible.

Probably there are certain locations in this district where further development would not be to the detriment of the present acreage, but in general any material increase in the acreage requiring the boring of new wells must be done at the expense of existing wells and tunnels. There has been a partial recovery from the depleted basins of the dry period of several years ago, but a study of the complete record of the rainfall and of the history of development can lead only to the belief that this conforms to the change from a dry to a wet period and that the limit will be reached soon. It still remains to be seen whether the wells will flow as strongly as they once did and whether the present rise in the water will extend to all parts of the district before another period of drought. It must be kept in mind constantly that the minimum rather than the average amount governs the possibilities for irrigating. There is reason to believe, however, that with judicious use of water dry periods can be passed through with no greater pumping lifts than those of the past. It can not be said just what the maximum depth is from which it would pay to lift water. Years ago the highest lifts of the present time. 400 feet for fruit and 100 feet for alfalfa, were unthought of.

It is impossible to make a very helpful comparison between the influx and the output of the subterranean reservoirs when neither can be ascertained accurately. Messrs. Jones and Olmstead, in their report to the city of Pomona, had to consider only the region from Pomona to San Antonio Canyon, and while diversions are made in this locality for Ontario and Chino, water pumped near Chino was not taken into account. They show that in the region investigated by them a steady draft of 1,600 miner's inches is being made on the watershed of San Antonio Creek and, further, that 40 per cent of the average precipitation of 27 inches over the watershed must be taken up by the gravels for 1,600 miner's inches to be stored naturally. Their conclusions are given in the following words:

> We believe that the existing relation of supply and delivery can be maintained if no further extensive extraction of water from the gravels is made, and that in even ordinary dry years this yield can be made permanent.

It is more difficult to consider properly all of the region in which a draft is made on waters having their source in the San Antonio watershed. Provided 1,600 miner's inches is taken up by the gravels, the supply from the mountains, including the average surface discharge of 740 miner's inches, is only 2,340 miner's inches. The total irrigated area about Pomona, Claremont, Uplands, Ontario, and Chino is approximately 20,000 acres. If water were used on this area at the rate of 1 miner's inch for each 8 acres, the basis of the average water right, 2,500 miner's inches would be required, or if the average depth of 1½ feet, which has been ascertained as the amount actually applied to fruit and alfalfa, 2,100 miner's inches would be required. A small part of the water used on the 6,000 acres at Ontario and Uplands must come from the Cucamonga watershed, and it is also probable that some of the water pumped at Chino originates in other than the San Antonio watershed, and, although doubtful, still another part may be seepage from higher irrigated lands. It is reasonable, however, that 1,800 or 2,000 miner's inches is drawn from San Antonio watershed, and it is not probable that water is being used in excess of the rate at which it is furnished by the creek.

STORAGE AND PREVENTION OF LOSS.

There is no opportunity to impound the winter floods in San Antonio Canyon in the ordinary way. It appears to the casual observer that a dam can be thrown across the canyon for a storage reservoir, but there are no suitable sites, and if there were it is a question whether or not the great mass of débris, largely bowlders, brought down by the floods could be handled. The fall in the creek above supposed dam sites is deceiving and is so great that no basin of sufficient capacity could be made at reasonable expense. The site known as Browns Flat is situated in the mountains west of the canyon. In order to utilize this site the water would have to be piped both in and out, and it has not been found promising enough to survey. The even slopes of the valley below the canyon are devoid of basins or depressions that might lend themselves to improvement for storage purposes such as it has been the fortune of Colorado and other States to have. Such natural features, if they had existed, would have been utilized long ago. It has been necessary to resort to other means for holding the flood waters in reserve.

The only practical kind of storage for San Antonio Creek, and a very efficient one, is the storage of the floods in the gravels below the canyon (Pl. II, fig. 1), to be drawn out several months later by the wells and tunnels farther down. Very effective work of this nature has been done for twelve winters by the Consolidated Water Company and the Mountain View Water Company, with some assistance on occasions from the Del Monte Irrigation Company. The method has been to divert the flood waters, which otherwise would run so far down the wash that they would be of no benefit to the wells in the orchard region, or which possibly would continue down the wash all the way to the sea and be of no service either to the orchard or alfalfa regions. It is a question if serviceable permanent diversion works that would keep the water under control can be made, for they would be in danger of destruction by the floods and the shifting channels in the gravels, and care must be used to avoid permanently changing the course of the water to channels where damage would be done to the settlements below. Temporary diversions into ditches leading away from the wash have been made by the use of sandbags and other material, and in the more recent work large quantities of blasting powder were used to tear up the channel. The water thus diverted is carried to the south and west and spread over the gravels, where it will be caught by the buried dike, which is believed to carry the water southwestward to San Jose Hills through a belt in which the tunnel and wells of the Consolidated Water Company, as well as other tunnels and many other wells, are located. The cost of this work has been the pay of two men employed.

Diversions made in March have the effect of increasing the flow of the Consolidated Tunnel the following August, and of the wells in Martin Cienaga in September. Only a small part of the water in the highest floods has been saved by this means. When the creek is low Ontario gets most of the water, and the San Antonio Water Company carries some flood water eastward through a pipe line to the west channel of Cucamonga Wash. Litigation is pending between the Consolidated Water Company and the Mountain View Water Company of Ontario over the right to spread the flood waters northeast of Indian Hill, where the tunnels of these companies are located, and the court has issued a temporary order for the joint spreading of the water by the two parties concerned, and work was done in conformity with such orders during the last two seasons.

Similar methods of storage have been practiced at the mouth of the canyon of Santa Ana River by the water companies of Riverside, San Bernardino, and Orange Counties, and at their request the Government has withdrawn from entry some of the wash lands, in order that their operations may not be interfered with by encroaching homesteaders, the position being taken that the benefits from the use of the gravels for storage to the large area of already highly developed land outweighs the opportunity for settlement of a small area of rough wash land.

There is need of more concerted action at Pomona in the storage of the flood waters and for all other measures for the benefit of the valley as a whole. Water absorbed by the gravels is for the benefit of most of the wells in the community, and if the expense was shared by all much more extensive work in this direction could be undertaken. The diversified interests at Pomona are more closely brought together for the welfare of the valley by the recent organization of an association the membership of which is on the basis of the quantity of water claimed or used. A total of about 1,800 miner's inches is represented. One purpose of the association is to bring about community storage of the flood waters, and, in 1909 and 1910, when the discharge of the creek was more than was diverted by Ontario and by the Consolidated and Mountain View water companies in their joint work, the association diverted and spread water near the mouth of the canyon. The association also purchased some of the wash land, on which water may be spread in the future. There are other ways in which such an organization can promote the welfare of the community, as by encouraging a better use of water and discouraging any unwarranted increase in the acreage, as there are many orchards in this section under five years of age which will require more water when they are older. The rise in the wells in the past four or five years should not lead to overconfidence.

Water flowing unused from an artesian well is such obvious waste that there has been full recognition of the importance of preventive measures by the passage of a State law requiring the capping of artesian wells when the water is not needed. This law should be obeyed in spirit, even if it is not always possible to obey it to the letter. It is difficult to close some wells, for if the top is sealed the water finds its way to the surface along the outside of the casing, and if allowed to continue damages the well. Scientific work has demonstrated that there are few, if any, wells that can not be closed at reasonable expense by using cement under pressure around the casing. Fifteen wells near Chino are being closed, at a cost of $100 each, and contractors agree to close any well for $200. Most wells, however, can be closed with little trouble. The exigencies of this case of waste are met at once by legislative act, but of vastly greater importance than the closing of the wells is the proper use of water, to be brought about only by an educational campaign of long duration.

FUTURE POSSIBILITIES.

After all measures for conservation have been taken, further extensions in the area irrigated in the coast region of southern California by water secured south of the Sierra Madre divide must be limited to a comparatively small percentage of the present area. The city of Los Angeles, realizing the need of more water in order that its rapid growth might continue unhampered, is spending $23,000,000 to bring water a distance of 240 miles from Owens River. It involved the buying out of certain interests that already had made use of some of this water, so that it might be brought where it would be given a higher value. In this case a great city is spurred by municipal pride, if not by actual necessity, to make the enormous outlay. Another great undertaking of much significance where the cost is to be repaid only by the commercial value of the water for irrigation and power, is the construction of the Arrowhead Reservoir in San Bernardino Mountains at a cost of millions of dollars. One of the largest dams ever constructed is being built across the channel of a stream which flows naturally to Mohave Desert, where a part of the water has been lost in the sands.

But there must be an end to such works, and the extreme measures taken emphasize the fact of the scarcity of water to be had in large quantities. About 250,000 acres are now irrigated in the coast region of southern California. Work now progressing and other possible developments may add another 150,000, but finally the only possible further increase must come from a more economical use of the water available. Little improvement can be made over the best systems now in use in the transmission of the water from its source to its point of use. The greatest opportunity for saving is in a more economical application of the water to the land and, moreover, whatever may be saved is as useful in the development of additional territory as the same amount of water from new sources, and it may be cheaper.

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