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THE QUALITY OF THE SURFACE WATERS OF CALIFORNIA

BY

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CONTENTS.

ILLUSTRATION.

THE QUALITY OF THE SURFACE WATERS OF CALIFORNIA.

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INTRODUCTION.

OUTLINE OF INVESTIGATION.

On the 1st of July, 1905, the Director of the United States Geological Survey made a contract with the state engineer of California for the purpose of carrying on a study of the "natural waters of the State of California, their seasonal variation in composition and in physical characteristics, and the damage which they have sustained by reason of pollution." The agreement provided that the work should be carried on by a member of the United States Geological Survey, and Frederick M. Eaton, hydrographic aid, was detailed for this purpose. Through the courtesy of the University of California, laboratory space was procured in the basement of the chemical building, and all determinations were made there.

In December, 1905, sampling stations were established at the following points:

Feather River at Oroville; gaging station at bridge.
Yuba River near Smartsville; gaging station at Narrows.
Sacramento River above Sacramento; 3 miles above railroad bridge.
American River at Fairoaks bridge; gaging station at bridge.
Mokelumne River at Clements; gaging station near bridge.
Stanislaus River at Knights Ferry; above power company's dam.
Tuolumne River at Lagrange; gaging station near bridge.
Merced River at Merced Falls; gaging station above Merced Falls.
Kern River at Oil Center; gaging station known as "First point of measurement."
San Joaquin River near Lathrop; Southern Pacific drawbridge.
Alameda Creek near Niles; above stone dam.
San Lorenzo Creek at Big Trees; at bridge.
Arroyo Seco near Soledad; gaging station at Pettit's ranch.
San Benito River near Hollister; above dam.
Santa Maria River above Santa Maria; gaging station on Dutard ranch.
Santa Ynez River near Santa Barbara; gaging station at Gibraltar dam site.
Malibu Creek near Calabasas; gaging station on Chapman ranch.
Santa Ana River above Mentone; gaging station near power house.
San Luis Rey River near Pala; gaging station near mills.

At each of these nineteen places some person was engaged and instructed to take regular daily samples from the stream at the point selected and forward them to the laboratory at Berkeley. The work was begun on January 1, 1906, with the intention of continuing it, as far as possible, without interruption until December 31, 1906; but the earthquake of April not only interrupted the collection and transportation of some samples, but destroyed others already on hand in the laboratory, and therefore certain gaps appear in the records for the year. Most of the stations were inspected by Mr. Eaton on the first part of April and last part of October, and some of the more accessible stations were also visited from time to time during the investigation.

On July 1, 1907, a new agreement was entered into by the State Department of Engineering and the United States Geological Survey, under which the work done in 1905–6 could be continued and the scope of the investigation broadened. The essential details of the new agreement were identical with those of the contract for 1905, and the work was carried out along the same general lines. Walton Van Winkle, assistant analyst in the water-resources branch of the Survey, was detailed to carry on the laboratory and field work and to compile, in collaboration with Mr. Eaton, the present report.

Sampling stations were established on the following rivers:

- Russian River above Ukiah; 2 miles above town.
- Cache Creek at Yolo; gaging station at bridge.
- Sacramento River above Sacramento; 3 miles above railroad bridge.
- San Joaquin River near Lathrop; Southern Pacific drawbridge.
- Estrella River near San Miguel; one-half mile above ford.
- Salinas River at Paso Robles; at wagon bridge.
- San Antonio River above Bradley; at Branch's ranch house.
- Nacimiento River near San Miguel; one-eighth mile above Nacimiento ranch house.
- Santa Ynez River near Santa Barbara; gaging station at Gibraltar dam site.
- Ventura River above Ventura; at Ventura County Power Company's diversion dam.
- San Gabriel River above Azusa; gaging station near power house.
- San Gabriel River near Rivera; at upper end of old canal.
- Santa Ana River above Mentone; gaging station near power house.
- Santa Ana River near Corona; at Auburndale bridge.
- Santa Ysabel River near Escondido; gaging station near Pott's ranch.
- Cottonwood Creek near San Diego; gaging station at Barrett dam.
- Owens River near Tinemaha; gaging station at Charlies Butte.
- Owens River near Round Valley; gaging station.

Arrangements for sampling and forwarding were the same as those during 1905–6. The collection of samples was begun in December, 1907, and the work was continued without interruption until December 31, 1908. All accessible stations were inspected from time to time. In order to obtain some knowledge of the surface waters of those sections of the State which could not be exhaustively studied, single samples were collected by Mr. Van Winkle from the following streams:

Mad River at Blue Lake; at ford.
Eel River at Fortuna; at ferry.
Noyo River near Fort Bragg; below Alpine station.
Pescadero Creek near Hollister; at Grass Valley.
San Lorenzo Creek near Kings City; at proposed dam site.
Gaviota Creek near San Ardo; 2 miles above town.
Indian Valley Creek near San Miguel; at Douglas's ranch house.
San Juan Creek near Shandon; at ford.
Cholame Creek near Shandon; 150 feet above mouth.
Huer Huero Creek near Paso Robles; at ford on Cholame road.
Carmel River near Carmel by the Sea; 4 miles above mouth.
Rio Hondo near Rivera; at Rivera bridge.
Mohave River near Victorville; at "Narrows."
Salton Sea [a] near Mecca.

The analytical work connected with the investigation prior to March, 1906, was conducted by F. M. Eaton; for the remainder of that year the analyses were made by P. L. McCreary, field assistant. During 1908 the analyses were made by Walton Van Winkle, who was assisted during the greater part of the year by W. J. McGee, field assistant, and during the later part of the period by William Reinhart and W. C. Packard, field assistants.

A minute study of municipal water supplies was not attempted, the principal object of the work being to determine the value of the raw and undeveloped resources and the possible uses to which the water could best be put. For this purpose a broad field was covered and the results show the character of the principal drainage waters of the various areas.

In order that the report might contain statistical information regarding municipal water supply, inquiries were sent to the clerks and health officers of the 171 incorporated cities and towns of the State. Replies were received from 155, and the information is here given. The following table by George D. Leslie, statistician of the state board of health, is inserted to show the prevalence of water-borne diseases in a number of incorporated towns and cities:

Deaths from certain causes, with proportion per 1,000 total deaths, for California, 1906 and 1907.

Cause of death.	Deaths.		Proportion per 1,000 total deaths.	
	1906.	1907.	1906.	1907.
Typhoid fever	657	558	22.4	17.9
Malarial fever [b]	111	70	3.8	2.2
Diarrhea and enteritis, under 2 years	930	899	31.7	28.9
Diarrhea and enteritis, 2 years and over	338	288	14.4	9.3

[a] One sample submitted by G. K. Gilbert, United States Geological Survey; one analysis submitted by Doctor Bailey, University of Texas, Austin, Tex.

[b] Probably typhoid in part.

ACKNOWLEDGMENTS.

The University of California courteously placed laboratory space and facilities at the disposal of the Geological Survey for this work, and through its faculty aided the studies in many ways. The San Francisco office of the Forest Service, United States Department of Agriculture, furnished valuable information regarding the forests of the State. So much assistance was accorded the work by city authorities, water companies, engineers, and private individuals that it is impracticable to refer to all by name. Many of the daily samples were furnished free of charge by persons or companies interested in the work. The authors have drawn freely on the geologic reports of the University of California and of the United States Geological Survey for information relative to the geology of the State.

METHODS OF EXAMINATION.

The methods of examination employed were, with few exceptions, those outlined in Water-Supply Paper 236.[a] Departures from the procedures were made in the analyses of all rivers studied in 1906, in the determinations of suspended matter, dissolved matter, and magnesium; and in the analyses of those studied in 1908, in magnesium, alkalies, and chlorine.

In 1906 suspended matter was determined as follows: One hundred cubic centimeters of the well-shaken samples were evaporated to dryness on the water bath in a tared silver dish, dried at 100° C. for one hour, cooled, and weighed. The difference between this weight and the weight of dissolved matter, both in parts per million, represents suspended matter. Dissolved matter was determined as in the regular procedure,[b] except that the residue was dried at 100° C. for one hour. Magnesium was determined gravimetrically as the pyrophosphate, according to the method of Fresenius.[c] Potassium and sodium were determined by the indirect method from the weight of their combined chlorides and the amount of chlorine found by titrating the aqueous solution with silver nitrate.

In 1908 magnesium was determined gravimetrically as in 1906, suspended and dissolved matter being determined according to the procedure outlined in Water-Supply Paper 236.[d] Sodium and potassium were determined in a separate 250 cubic centimeter sample, as follows: The sample in a Jena beaker was made slightly acid with hydrochloric acid, evaporated to dryness on the water bath, and heated on the hot plate until no acid odor could be detected. The residue was then digested with 10 cubic centimeters of hot distilled

[a] Dole, R. B., The quality of surface waters in the United States, part 1: Water-Supply Paper U. S. Geol. Survey No. 236, 1909, pp. 9-26.

[b] Dole, R. B., op. cit., p. 13.

[c] Fresenius, C. R., Quantitative chemical analysis (transl. of 6th German ed.), vol. 1, 1906, p. 275.

[d] Dole, R. B., op. cit., pp. 12, 13.

water, barium hydrate was added in slight excess, and the solution was filtered, the precipitate being washed with hot distilled water. The filtrate from this operation was heated, and calcium and barium were removed by precipitation with ammonium carbonate and filtration. The resulting filtrate was evaporated to dryness in a porcelain dish, and heated to remove ammonium salts. The residue was then digested with 4 or 5 cubic centimeters of hot water, and treated again with ammonium carbonate to insure complete removal of calcium and barium. The solution was filtered into a small platinum dish, a small amount of hydrochloric acid added, the solution evaporated to dryness and cautiously heated nearly to fusion, cooled, and weighed. The residue in the dish was then treated with hot water, filtered through ashless filter paper, the paper being washed with hot water, ignited, and weighed in the dish. The difference between the weights was calculated to "sodium and potassium."[a]

Chlorine was ordinarily present in relatively large amounts, and the amount of this radicle was determined by direct titration of 50 cubic centimeters of water. When the amount of chlorine exceeded 40 parts per million, smaller quantities of water were used for titration, or chlorine was estimated by the gravimetric method.

EXPRESSION OF ANALYTICAL RESULTS.

The results of the analyses in this paper are stated in parts per million, the ionic form of statement being used.[b]

NATURAL FEATURES.

GEOGRAPHY.

The State of California extends from latitude 32° 40′ north to 42° north. Its average length is nearly 800 miles, its average width is about 200 miles, and its area is 155,980 square miles. The width gradually increases from a little more than 150 miles at the northern end to nearly 300 miles across the south-central part of the State, narrowing to about 150 miles at the southern end.

Two principal mountain ranges more than 100 miles apart run from northwest to southeast through the whole length of the State, a broad valley lying between. The western range, known as the Coast Range, is made up of numerous small ranges. Named in order from San Francisco Bay southward these are the Mount Diablo, Santa Cruz, Santa Lucia, San Rafael, and Santa Ynez. In southern California the Coast Range spreads out across the State in a confused mass, the Sierra Madre, San Bernardino, San Jacinto, and other chains, of which the Santa Ana and Ysidro Mountains are of the greatest importance, extending toward the south. North of San

[a] Dole, R. B., op. cit., p. 20. [b] Dole, R. B., op. cit., p. 39.

Francisco Bay the Coast Range is made up of the St. Helena, Trinity, and Siskiyou mountains, with smaller ranges between these and the coast. The great eastern range, the Sierra Nevada, forms the eastern boundary of the State for a great part of the distance. The Klamath Mountains of volcanic origin cross the north end of the State, forming a sort of barrier between California and Oregon; and the Tehachapi, lying between the Coast Range and the Sierra in the south-central part of the State, forms the line of division between northern and southern California.

The Great Valley, lying between the Coast Range and the Sierra Nevada, is about 400 miles long and from 40 to 50 miles wide. Other large valleys, some of which are fertile and others waterless and barren, lie between the smaller ranges of the coast. South of the Sierra Madre and between the coast and the San Jacinto Mountains lies the far-famed "orange belt" of California, while beyond these mountains are the Colorado Desert and the Salton Sea.

For the greater part of its length the Coast Range follows the shore line so closely that few large rivers flow directly into the ocean, and only one of these—Salinas River—is navigable. There are therefore very few natural inlets or harbors.

CLIMATE.

A great variety of climate, ranging from fairly humid in the northwestern redwood belt, through semiarid in the Great Valley, to desert in the eastern and southeastern parts of the State, renders it difficult to discuss this subject briefly. The mean annual rainfall varies from 1 inch to 75 inches in different localities, the extremes ranging from 0 to over 100 inches. Temperatures show equally wide variation. In the desert monthly mean temperatures not much below 100° are common, with an extreme of 130°. In the Sierras in the vicinity of Lake Tahoe a temperature of −30° has been recorded, and on other high peaks temperatures ranging from −17° to −30° are common. Snowfall is in general confined to the central and northern parts of the State and to the mountains of the south.

Prof. E. W. Hilgard, of the University of California, summarizes the climates of the various sections of the State as follows:

(1) Bay and coast region characteristics: Small range of temperature, the extremes being only 53° apart. Means of summer and winter are only 6° apart. There is no intense heat, and frosts are very rare. Fogs from the sea are quite common on summer afternoons. Rainfall averages 27.3 inches, about 25 inches of which falls between December and May.

(2) Great Valley characteristics: Average winter temperatures lower than those of the coast, though minimum is about the same. Frosts are rare. Summer heat is very intense, often above 100°. The nights are warm, but dry, and are therefore less oppressive. Extreme range of temperature 76°, mean range 23.6°. Rainfall averages about 21.5 inches, of which 19.8 inches fall between December and May.

(3) Sierra slope characteristics: Cool summers with frequent thunderstorms. The winters are often severe, with much rain and snow. Mean summer temperatures, 57.5°, with a mean range of 14° between that and the winter temperature of 43.5°. Rainfall averages 57.24 inches, fairly well distributed throughout the season.

Besides these general types there are many local varieties. The predominant features can be inferred from an examination of the accompanying table, which presents summarized data for the principal stations of the Weather Bureau.

Temperature and precipitation at principal stations of the Weather Bureau in the State of California.[a]

Location.	Temperature (degrees Fahrenheit).		Precipitation (inches).	
	Mean.	Extremes.	Mean.	Extremes.
Eureka	51.5	84–20	46.04	59.62–30.91
Red Bluff	62.4	114–18	25.40	49.01–12.91
Sacramento	60.0	110–19	19.41	34.92– 8.44
San Francisco	56.1	100–29	22.75	49.27– 7.40
San Jose	58.1	104–18	14.88	25.55– 5.51
Fresno	63.0	114–20	10.13	19.45– 4.94
Independence	58.7	105–11	2.78	4.22– 2.75
San Luis Obispo	58.9	106–24	17.32	26.39– 6.93
San Diego	61.4	101–32	9.52	27.59– 3.02

[a] U. S. Dept. Agr., Weather Bureau, Bulletin L.

HYDROGRAPHY.

DRAINAGE AREAS.

California may be divided into five great hydrographic provinces:

1. The north Pacific Ocean drainage, comprising that portion of the State lying between the Oregon line on the north and the Golden Gate on the south, the Pacific Ocean on the west and the Coast Range on the east. It is a heavily wooded, broken country, contains several large rivers, and occupies 13 per cent of the State.

2. San Francisco Bay drainage, consisting of that portion of the State bounded by the Sierra on the east, the Coast Ranges on the west, the Klamath Mountains on the north, and the Tehachapi on the south. This basin divides into two smaller areas, one drained by the Sacramento, whose valley, lying between the Coast Ranges and the Sierra on the east, slopes gradually southward from Klamath Mountains; the other, which contains the San Joaquin and Tulare valleys, comprising the area lying between the Coast and Mount Diablo ranges on the west and the Sierra on the east and sloping gradually northward from the Tehachapi. These two basins unite at Suisun Bay, where a break in the coastal mountains allows their confluent waters to flow through the Straits of Carquinez into San Francisco Bay.

3. The south Pacific Ocean drainage, extending from the Golden Gate on the north to the Mexican line on the south and bordered on the east by the Coast Ranges, San Bernardino Mountains, and San Jacinto Mountains. In this area are many fertile valleys, most important of which is the valley of southern California, the center of the citrus industry of the State.

4. The interior basin, including all the land east of the Sierra and comprising two lesser divisions, designated, respectively, the minor Great Basin and the Sierra subdrainage. The waters of the interior basin are entirely landlocked, either sinking into the sands of the deserts, as do the river waters of the Mohave Desert, or flowing into dead seas, as do Owens and Susan rivers.

5. Colorado River drainage, which includes a very small portion of the southeastern corner of the State in San Bernardino, Riverside, San Diego, and Imperial counties. In general this area drains into Colorado River, but a considerable part of it discharges its run-off into Salton Sea, which lies at the northern end of Imperial Valley in a depression 273½ feet below sea level.[a] This inland sea, or sink, receives whatever drainage there is from the Coachella Valley on the northwest and from the Imperial Valley on the southeast.

LAKES.

The total water surface of California, including San Francisco Bay, is 2,205 square miles,[b] in greater part large inland lakes. Chief among these lakes may be mentioned Lake Tahoe, at an elevation of 6,225 feet;[c] Honey Lake, 3,949 feet above sea level; Owens Lake, approximately 3,600 feet; Tulare Lake, averaging about 200 feet in elevation; and Salton Sea, whose surface on December 31, 1908, stood 206 feet below sea level and whose volume is slowly diminishing. Parts of Little Klamath and Goose lakes are in Oregon, and a part of Lake Tahoe is in Nevada. The parts of the surfaces of these lakes that are outside the borders of California have been omitted in calculating the total water surface.

Many of the lakes of the State, such as Tahoe, Goose, Little Klamath, and Eleanor, are fresh, draining regularly through some well-defined outlet. Others, as, for example, Tulare Lake, have an irregular drainage, discharging through a regular channel during periods of flood, but becoming at other times landlocked seas. Still others have no outlets whatever and retain their size only by means of the adjustment between the inflowing waters and percolation and sur-

[a] Clapp, W. B., The surface water supply of California, 1906: Water-Supply Paper U. S. Geol. Survey No. 213, 1907, p. 30.

[b] Gannett, Henry, The areas of the United States, the States, and the Territories: Bull. U. S. Geol. Survey No. 302, 1906, p. 5.

[c] Gannett, Henry, A dictionary of altitudes in the United States, 4th edition: Bull. U. S. Geol. Survey No. 274, 1906, p. 131.

face evaporation. In this class are Owens and Mono lakes and Salton Sea. The mineral content of the waters of these various lakes ranges from almost nothing in the snow-fed lakes of the Sierra to thousands of parts per million in some of the inland seas. No extended study of all these lakes has been made, but a few analyses are here recorded. Owens Lake, however, is treated in somewhat greater detail, for this body of water is one of the State's valuable economic assets. Less exhaustive studies are recorded of Salton Sea, which is at present attracting the attention of engineers and scientists because it affords possibilities for solving some of the important problems of evaporation and concentration.

FLOODS.

The two periods of high water in the streams of California are caused by the rainfall of the wet season and by the melting of snow. The early rains of the wet season soak into the ground and increase the stream flow to only a slight extent. Later winter rains, usually heavier and more prolonged, fall on saturated ground and produce floods. The soil covering of humus and organic detritus upon the drainage area is washed into the streams, especially where forests and vegetation are scant.

The later floods depend for their size and violence, first, on the amount of snow on the ground at the close of winter; second, on the age of this snow; and, third, on the rapidity of climatic change. That the amount of snow is an important factor is obvious; that its age also is important requires, perhaps, a word of explanation. Newly fallen snow, if moderately dry, settles upon the ground as a light, feathery covering. Resting there it slowly settles from its own weight, becoming continually denser and more compact. Each successive snowfall presses the already compacted mass still farther, and the process of settling continues until the mass attains a hard, icelike consistency similar to that of glacier ice. Snow so compacted melts more slowly than that recently fallen. The third factor—rapidity of climatic change—is important, because slow increase of temperature will cause slow melting, while a rapid increase, especially if accompanied by rain, will cause very rapid melting.

The snow-covered areas in California lie in regions of rough and broken topography and much of the underlying soil is frozen. The melting snow therefore yields a very high percentage of run-off and very little of the soil covering is carried into the streams, the small amount so carried being for the most part in a finely divided state. Hence, although many of the floods are of great magnitude they are unaccompanied by a large increase in turbidity.

Floods caused by the rainfall of the wet season occur in all parts of the State; those caused by the melting of the snow occur only on streams which drain the higher mountain regions.

The rivers of the southern coastal region are perhaps most subject to sudden floods. Most of these streams are short "arroyos," which are without flow during the dry season, but which become swollen to raging torrents during the heavier rains of the middle and late winter. It has been found by measurement that over one-half of the total annual discharge of some of these streams occurs during a period of two weeks or less.

The winter floods of the Sacramento and San Joaquin are due primarily to the very heavy rainfall in the mountain regions and to the steep slopes of the tributary streams. Many of these rains occur simultaneously on both sides of the valley and throughout its extent. The tributary streams, swollen to flood size, pour their waters into the main river valley, causing great loss of property and temporary blocking of transportation, both by land and water. These rivers are also subject to severe floods during the spring, when the snows that have accumulated on the Sierra slopes in the winter are melted. Flowing off from the already saturated ground, these snow waters form spring floods, some of which equal or surpass in magnitude those of the winter season.

Ordinarily floods on a watershed wash off the finely divided surface soil and humus and carry these rich materials downstream to be deposited in the lower valleys. Great alluvial fans and fertile valley lands have thus been formed. But the flood waters of the Sacramento Valley have washed also from the hillsides immense quantities of material left by the placer miner and deposited it along the lower reaches of the streams. In thirty years the bed of Yuba River alone has been raised at Marysville between 20 and 30 feet and at the mouth of the canyon more than 100 feet.[a] This mass of detritus is not rich alluvial matter that will benefit the country over which it is spread, but is composed of rock, gravel, and granitic sand which will not sustain vegetation. Rivers which were formerly clear and navigable are now shallow, turbid streams, with broad, shifting bottoms, and even constant dredging scarcely serves to keep them open to vessels.

INDUSTRIAL DEVELOPMENT.

Up to the time of the discovery of gold settlements in California were mostly clustered about places which had been chosen for the establishment of the missions. These places either afforded good harbors, as San Diego and San Francisco, or possessed good agricultural and grazing lands, as Santa Barbara, San Gabriel, Soledad, and

[a] Report of State Engineer of California for 1908, p. 160.

San Juan. Later those interested went farther into the interior to the fertile valleys of the Sacramento and San Joaquin, but never far from streams of good size. Thus at this period the settlements were confined almost wholly to the coast and to the navigable streams of the State. When gold was discovered a rush for the mountains immediately began, and numerous little mining communities sprang up along the smaller creeks in the hills. Gradually commercial centers formed on the coast and in the valleys—markets through which the agriculturists found an outlet for their products and from which the mining population could obtain its supplies. With the growth of the State other industries developed, such as lumbering and fishing. As the products of the country became more numerous and diversified, manufacturing of various kinds took its place with the other industries.

The mineral output of California includes gold, silver, copper, mercury, bituminous coal, granite, sandstone, cement, borax, petroleum, mineral waters, salt, and building stones.

Irrigation is carried on extensively in all parts of the State, both surface and underground waters being used. The largest irrigated districts at present are in the San Joaquin and Sacramento valleys, which derive the greater part of their waters from the Sierra streams. Smaller districts in the valleys are watered from underground supplies.

The most important field crops of the State are hay, wheat, barley, and potatoes. Sugar beets are cultivated extensively in the San Joaquin and Salinas valleys. Citrus fruits, peaches, plums, pears, and apples are the chief orchard products.

According to the census of 1900 there were over 12,000 manufacturing establishments in the State. These had a combined capital of $205,000,000 and had products valued at $303,000,000. The products include mining and agricultural machinery; lumber for building; tanning and dressing of leather; woolen goods; flouring mills; silk fiber and fabrics; wine and brandy; refined sugar, sirup, and candies; grain bags; dynamite; giant powder; and heavy chemicals for mining use.

The census of 1900 reported also 6,890 persons employed in the fisheries of California, $3,278,500 invested as capital, and product valued at $4,872,620. The products include oysters, herring, salmon, whale, and seals.

The principal trading centers of California are San Francisco and Los Angeles. Smaller trading centers located in the valleys, such as Sacramento, Stockton, Fresno, and Bakersfield, are points of shipment for the products of these regions. San Bernardino, Riverside, Redlands, and San Diego are the greatest centers for the shipment of citrus fruits; Sacramento and San Joaquin valleys for the shipment of grain and deciduous fruits and grapes; and the north Pacific coast, in the vicinity of Mendocino and Humboldt counties, for the shipment of redwood lumber.

NORTH PACIFIC OCEAN DRAINAGE.

DESCRIPTION.

The north Pacific Ocean drainage basin comprises a total area of 20,000 square miles and includes the counties of Del Norte, Humboldt, Trinity, and Mendocino, the greater part of Siskiyou, Modoc, and Sonoma counties, and a portion of Marin County.

The principal streams of this basin are the Klamath (whose chief tributary is Trinity River), Eel, and Russian rivers. The basin contains also many other smaller but important streams. The larger streams fluctuate in flow and their channels are as a rule normal to the mountain ranges until they reach their middle courses. Here, with one notable exception, they turn to the northwest, flowing through long, deep valleys to the coast. Immediately before entering the ocean they bend sharply to the west and join the sea at right angles to the coast line. The exception noted—Russian River—flows in a general southeasterly direction through its upper and middle course, then, turning sharply toward the sea, it enters it from the northwest. Most of the shallow coastal streams flow through short, steep valleys directly from the mountains to the ocean, cutting deep gorges in the soft sedimentary rocks of the coastal terraces.

As rainfall is generally abundant throughout this region, the stream flow is large, both in winter and in summer, and the rivers swell into torrents in the rainy season and on the melting of the snows.

Little has been written on the geology of the Coast Ranges; hence it is not possible even to summarize with accuracy or completeness the rock types there present. The few general statements made are based on the work of Professor Lawson,[a] or on personal observation. The oldest rocks of the area are probably granitic igneous rocks and pre-Cretaceous sediments. Overlying these are various later gravels, clays, sandstones, shales, and conglomerates, for the most part soft and easily weathered, and intruded here and there by basic eruptives. Many of these later sedimentaries have great thickness.

The soil is thin or lacking in the higher altitudes, but the middle and coastal sections of the area are characterized by a deep, rich soil which bears a heavy stand of redwood. The great fertility of this soil and the generally sufficient rainfall render agriculture very

[a] Lawson, A. C., Geomorphology of the coast of northern California: Bull. Geol. Dept. Univ. California, vol. 1, No. 8.

profitable, and where transportation facilities exist, as in the valley of Russian River, extensive farming industries are maintained.

The forests of the north Pacific coast area are among the most extensive in the State. According to figures of the United States Forest Service [a] there are within the Siskiyou, Klamath, and Trinity national forests, lying chiefly in this drainage basin, 560,670 acres, containing 5,211,360,000 feet b. m. of timber. The national lands of these forests comprise 3,820,195 acres, upon which is standing 31,505,337,000 feet b. m. of timber. According to an estimate made by Merrill and Hodge for the Forest Service, the coast redwood region, all of which is within this drainage area, contains 76,000,000,000 feet b. m. of redwood timber. There are also many square miles of privately owned timber land in Humboldt, Mendocino, Sonoma, and Marin counties, upon which a varied growth of evergreens is found. In Mendocino and Humboldt counties lumbering is a principal industry, and the coast cities of Eureka, Arcata, Fort Bragg, and Mendocino owe their existence chiefly to the lumber trade. The private lands are fast being deforested by large lumber camps, whose operations cause ever-increasing danger from forest fires, floods, and summer droughts.

The climate of the area is cool, the mean annual temperature being 51.2° at Eureka, 56.1° at Healdsburg, 57.6° at Ukiah, and 52.2° at Point Reyes. It is slightly cooler on the coast than in the interior. In summer the coastal region is visited by heavy fogs, which sometimes persist for weeks. During these months the rainfall is slight, but in the winter the precipitation ranges from about 30 inches in Russian River Valley to more than 120 inches in the northernmost section. The rainfall in the coastal region probably ranges from about 25 inches in the southern part to about 60 inches in the northern.

The population of the area, except along the coast and in the valley of Russian River, is small. Trinity County, in the mountainous inland district, has a population of less than 5,000; Del Norte County, an isolated, inaccessible region, has only half that number. Most of the inhabitants are concentrated in the coastal cities of Humboldt Bay and in the middle and lower valley of Russian River. The total population of the entire drainage area is about 95,000.[b]

The principal industries of the northern portion of the drainage basin are lumbering and dairying. Wherever the lumber has been cleared dairying is the chief occupation. The abundant rainfall, rich soil, rolling hills, and pure water well adapt this section to the dairy industry, and it yields some of the finest dairy products of the State.

[a] Data submitted by L. D. Woodbury, Forest Service, U. S. Dept. Agr., San Francisco, Cal.

[b] California Blue Book for 1908.

The southern portion of the drainage area, represented by the valley of Russian River, is given over chiefly to vineyard and hop industries.

WESTERN SUBDRAINAGE.

MAD RIVER.

DESCRIPTION.

Mad River rises near the Yallo Bally Mountains, in the Trinity Range, and flows in a general northwesterly direction to the Pacific Ocean. Its basin is separated by the South Fork Mountains from the valley of Trinity River on the northeast and by steep broken ridges from the basin of Eel River on the southwest. Its valley is long and narrow, and it receives no tributaries of importance. The broken hills are of sedimentary rocks—clays, sandstones, and conglomerates forming the greater part of the strata. Forestation is heavy, lumbering is the principal occupation near the coast, and the cleared lands are used for dairying.

The river has a steep grade and in times of flood it is very dangerous. Its violence at these times suggested its name. As the basin receives an abundant winter rainfall the run-off is large, but unfortunately it has not been measured.

At Blue Lake Mad River emerges from its narrow valley and flows for a short distance in a sinuous course over a sandy plain, finally entering another narrow valley farther down.

CHARACTER OF WATER.

A sample of water was taken from Mad River directly opposite the lumber town of Blue Lake on June 10, 1908. At this time the river was at medium low stage, the velocity was high, and the water was free from suspended matter. At the point where the sample was taken the river bottom was of gravel, with short reaches of coarse sand.

The following analyses show the character of this sample and of a sample taken from Mad River a few miles below Blue Lake later in the year, through the kindness of Mr. J. B. Lentell, of Eureka. As but little drainage water enters the river between the points of sampling, the analyses are fairly comparable. The later sample was taken in the dry season, as the analysis clearly shows.

Analyses of water from Mad River near Blue Lake, California.

[Analyst, Walton Van Winkle. Quantities in parts per million.]

	1.	2.		1.	2.
Silica (SiO_2)	9.2	8.0	Bicarbonate radicle (HCO_3)	77	127
Iron (Fe)	.03	.16	Sulphate radicle (SO_4)	13	21
Calcium (Ca)	21	34	Chlorine (Cl)	3.9	6.3
Magnesium (Mg)	4.3	5.7	Nitrate radicle (NO_3)	.28	.78
Sodium and potassium (Na+K)	6.3	10	Total solids	92	153
Carbonate radicle (CO_3)	0.0	0.0	Turbidity	Trace.	Trace.

1. Sample collected by Walton Van Winkle, June 10, 1908, at Blue Lake, California. Water at medium low stage.
2. Sample collected by J. B. Lentell, on or about October 1, 1908, near mouth of Bug Creek. Discharge estimated at 600-700 inches.

These analyses indicate that although the river, even at low stage, contains little dissolved mineral matter, yet the variation in mineral content between high and low stages is considerable. In June, 1908, at time of moderately low stage, the total dissolved solids were 92 parts per million. The flood waters of the winter undoubtedly contain much less dissolved matter than that shown by the analysis of sample 1, taken in June.

The chlorine content is low—about what might be expected in a coastal stream. Chlorine is an ever-present constituent of atmospheric water, the quantity being greatest near the sea and diminishing rapidly inland. This is strikingly shown by the "isochlors"—lines of equal normal chlorine—which have been platted for the unpolluted waters of various localities and which follow rather closely the contour of the coast line. The small chlorine content of the samples analyzed does not show the presence of the surface saline deposits found so abundantly in some parts of the State. Indeed, even had such deposits been present at some former time, the heavy rainfall of the region would long since have washed them out into the streams and thence to the ocean, as such saline beds can persist only in regions of generally deficient rainfall.

The principal basic material present is calcium; the chief acid constituents are carbonates and sulphates. The greater portion of the nitrates found is probably due to vegetal material from upstream lumbering and is not the result of animal decomposition.

Engineers familiar with this river state that the water has at times a decided reddish color, due to the dissolved organic matter from the cut lumber. At such times, it is said, the water has an unpleasant laxative effect and is not well adapted for drinking. Aside from this it would, if properly protected from bacterial pollution, make an acceptable town supply. The water is of first grade for steaming and would give little or no trouble in boilers.

Another evil resulting from the lumbering industry is the clogging of the streams by sawdust, which not only increases the organic material in the water, but drives away trout and other fish.

At present the principal timber cut along Mad River is the redwood. Eventually the fir and pine forests bordering the redwood belt will be attacked, and it is possible that paper mills will be introduced. The waters of Mad River are well adapted to paper-mill use, as the small amounts of objectionable matter present could be removed by slight treatment.

EEL RIVER.

DESCRIPTION.

Eel River rises on the eastern border of Mendocino County and flows in a northwesterly direction into Humboldt Bay. Its basin is separated from that of Mad River on the northeast by a broken range of mountains, and from the valleys of Bear Creek, Mattole River, and the ocean drainage by the rough summits of the Bear River, Rainbow, and Elk ridges. It receives numerous tributaries, of which the chief and only large one, aside from its three main forks, is Van Duzen Fork. This stream, flowing from the east, joins the main river above Alton. The total area of the basin is approximately 488 square miles.[a]

The valley of Eel River is long and narrow and is broken near the source into a fan-shaped series of smaller valleys. The surface of the basin is rough and irregular, deep canyons and valleys marking the courses of the streams and high plateaus forming the tops of the ridges. The valleys have the general southeast-northwest trend common to all the valleys of this portion of the State.

The soil is rich and deep near the coast and thins out toward the summits of the coast ranges. The geologic formations include clays, sandstones, schists, and shales, with intrusions of basic igneous rocks, of which the ferromagnesian silicates form a large portion. Forests are found in all parts of the valley, the lower course of the river lying across the great coastal redwood region. Rainfall is plentiful.

Along the upper reaches of the stream there are few habitations, but toward the mouth, from Pepperwood to Humboldt Bay, there is a constantly increasing population, chiefly in lumber camps and dairy farms.

The river bottom is rocky near its source, gradually becoming gravelly and finally, near the coast, sandy. Some distance above Fortuna the river leaves its narrow canyon and flows out through its broad, flat coastal plain.

CHARACTER OF THE WATER.

A sample of the water of Eel River was taken at the ferry at Fortuna on June 11, 1908, the river being at that time at moderately low stage. At this point the bed of the stream is sandy, the river flowing

[a] Hall, W. H., Physical data and statistics of California, p. 386.

in a winding course and with swift current. Results of the analysis of the sample are here presented:

Analysis of water from Eel River at Fortuna.

[Analyst, Walton Van Winkle. Quantities in parts per million.]

Silica (SiO_2)	9.4	Bicarbonate radicle (HCO_3)	96
Iron (Fe)	.18	Sulphate radicle (SO_4)	21
Calcium (Ca)	23	Chlorine (Cl)	4.9
Magnesium (Mg)	7.0	Nitrate radicle (NO_3)	.2
Sodium and potassium (Na+K)	8.5	Total solids	112
Carbonate radicle (CO_3)	2.4	Turbidity	Trace.

Collected June 11, 1908, by Walton Van Winkle.

This analysis indicates that the water resembles that of Mad River, except that it shows some normal carbonate alkalinity and also a higher magnesium content in proportion to its total dissolved minerals.

It is said that the water of this river also causes unpleasant diuretic effects, due to organic matter added to the stream by lumbering operations; but aside from this, if proper precautions were taken to remove bacteria, the river would be a suitable source of supply for town use. It is well adapted for use without treatment for dairying and similar industries. At high stages it would undoubtedly be low in dissolved minerals, and the small amount of suspended matter could readily be removed. The water may be used without treatment for steam making.

NOYO RIVER.

DESCRIPTION.

Noyo River is a small stream rising in the Coast Range near Sherwood, in the central part of Mendocino County, flowing generally eastward, and emptying into the Pacific Ocean near Fort Bragg. Its total length is approximately 25 miles. Throughout its whole course it descends with steep slope through a narrow valley among heavily wooded mountains. The rocks in this valley, like those of the region farther north, are sedimentary and contain basic igneous intrusions.

CHARACTER OF THE WATER.

A sample of the water of Noyo River was taken on June 15, 1908, at Alpine station, about 8 miles from Fort Bragg. At this point the bottom of the river is gravelly, the current is swift, and the banks are high and precipitous. The water of this river was assumed to be typical for this section of the State, and hence samples were not taken from other streams. An analysis of the water is presented in the following table:

Analysis of water from Noyo River, near Alpine station, Mendocino County.

[Analyst, Walton Van Winkle. Quantities in parts per million.]

Silica (SiO_2)	17	Bicarbonate radicle (HCO_3)	109
Iron (Fe)	.18	Sulphate radicle (SO_4)	18
Calcium (Ca)	20	Chlorine (Cl)	7.2
Magnesium (Mg)	7.2	Nitrate radicle (NO_3)	.64
Sodium and potassium (Na+K)	15	Total solids	132
Carbonate radicle (CO_3)	.0	Turbidity	Trace.

Collected June 15, 1908, by Walton Van Winkle.

The water is shown by the analysis to be moderately low in dissolved material. It is of the calcic carbonate type common to rivers in regions of abundant rainfall. The water is not so good for steaming as that of streams farther north, but its scale-forming materials could readily be removed. For manufacture of white paper the organic constituents would have to be removed, as they are present in sufficient quantity to cause annoyance.

SOUTHERN SUBDRAINAGE.

RUSSIAN RIVER.

DESCRIPTION.

Russian River rises in the north-central part of Mendocino County, near the town of Redwood, flows in a general southeasterly direction for about 60 miles, then turning to the southwest it empties into the Pacific Ocean. In its upper course it traverses a narrow valley surrounded by wooded hills. It receives no large tributaries, but numerous small creeks join it throughout its course.

The mountains in this area are somewhat lower and less broken than farther north on the coast, giving way to rolling hills toward the southern part of the basin, and the valley is broader and more mature. Basic magnesian rocks are also present in greater proportion than in areas farther north. The soil of the valley proper is an alluvial deposit of considerable richness.

Rainfall in this valley is plentiful. Precipitation from June to September is very light, but for the remaining months it is quite heavy, the region around Ukiah apparently receiving the smallest share. This abundant rainfall causes a very good flow in the streams, but measurements are lacking. As the foothills and mountains of the basin are in general covered with a good growth of timber, conditions are favorable for ground storage of rain water and distribution of stream flow, the summer flow being increased and the volume of the freshets diminished.

CHARACTER OF THE WATER.

A sampling station was established on Russian River about 2 miles above Ukiah late in 1907, and during 1908 samples of the water were collected daily by Miss Gertrude Howard. The valley of the river at this point is moderately wide and is bordered by foothills covered with a heavy growth of brush. The river winds through its valley in a bed of coarse sand and gravel and it receives near the town several small tributaries. The drainage area at this point is about 253 square miles.[a]

The results of the analyses are shown in the following table:

Mineral analyses of water from Russian River near Ukiah.

[Drainage area, 253 square miles. Quantities in parts per million unless otherwise stated.]

Date. From—	Date. To—	Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.
1907. Dec. 31	1908. Jan. 9	35	65	19	0.5	18	7.2	9.8	0.0	71	19	1.6	3.8	107
1908. Jan. 10	Jan. 19	15	24	18	.38	17	6.4	9.2	.0	83	18	1.8	4.1	116
Jan. 20	Jan. 29	60	39	17	.45	18	7.9	10	.0	71	13	1.4	4.0	101
Jan. 30	Feb. 8	50	53	19	.38	16	6.3	12	.0	67	15	.80	3.2	99
Feb. 9	Feb. 18	30	145	22	.32	14	8.2	15	.0	76	22	.77	3.0	107
Feb. 19	Feb. 28	5	......	20	.20	21	11	12	.0	102	17	2.1	4.3	126
Feb. 29	Mar. 9	20	34	19	.43	16	8.0	14	.0	82	24	2.1	5.7	112
Mar. 10	Mar. 19	5	......	19	.18	18	7.8	13	.0	107	17	1.1	5.1	131
Mar. 20	Mar. 29	Trace.	......	20	.07	19	9.3	10	.0	109	15	2.0	4.2	128
Mar. 30	Apr. 8	5	......	18	.08	20	11	9.6	.0	116	23	2.0	4.5	131
Apr. 9	Apr. 18	10	......	17	.07	21	12	12	.0	115	17	3.0	4.5	131
Apr. 19	Apr. 28	Trace.	......	16	.03	20	11	10	.0	118	14	1.1	4.5	127
Apr. 29	May 8	Trace.	......	16	.03	21	11	12	.0	122	16	1.9	5.4	132
May 9	May 18	Trace.	......	18	.06	21	12	12	.0	120	12	2.0	4.6	130
May 19	May 28	Trace.	......	19	.15	24	12	15	[b] 3.6	112	16	.86	5.2	141
May 29	June 7	Trace.	......	16	.15	22	12	14	.0	124	16	.96	4.6	131
June 8	June 17	Trace.	......	16	.08	22	12	11	.0	125	16	1.0	5.9	137
June 18	June 27	Trace.	......	15	.04	21	13	12	.0	128	12	2.0	5.5	131
June 28	July 7	5	......	19	.18	24	13	20	.0	138	17	.66	7.0	145
July 8	July 17	Trace.	......	24	.40	28	12	14	[b] 9.6	120	16	.92	6.0	155
July 18	July 27	Trace.	......	20	.05	28	14	15	.0	140	15	.92	7.0	149
July 28	Aug. 6	5	......	16	.04	23	15	14	.0	144	12	.70	7.4	148
Aug. 7	Aug. 16	Trace.	......	20	.37	25	15	16	.0	151	18	1.4	7.5	160
Aug. 17	Aug. 26	Trace.	......	27	.13	26	14	16	[b] 4.8	146	18	......	8.0	172
Aug. 27	Sept. 5	4	......	28	.43	26	15	15	.0	163	17	.56	8.0	173
Sept. 6	Sept. 15	5	......	30	.20	23	14	14	.0	150	17	.10	8.0	179
Sept. 16	Sept. 25	Trace.	......	21	.05	23	15	13	.0	149	17	.80	9.0	151
Sept. 26	Oct. 5	Trace.	......	17	.04	26	14	14	.0	158	15	.52	8.0	150
Oct. 6	Oct. 15	10	......	20	.04	30	17	23	.0	155	20	.40	11	192
Oct. 16	Oct. 25	Trace.	......	16	.02	29	15	23	.0	166	16	.18	14	189
Oct. 26	Nov. 4	Trace.	......	15	.04	29	16	26	.0	166	16	.28	18	187
Nov. 5	Nov. 14	Trace.	......	15	.10	31	16	28	.0	167	16	.66	20	192
Nov. 15	Nov. 24	5	......	17	.14	29	16	26	.0	169	19	.36	16	183
Nov. 25	Dec. 4	20	27	15	.28	25	14	31	.0	120	22	1.5	11	158
Dec. 5	Dec. 14	15	8.8	18	.38	26	13	15	.0	117	20	1.8	8.2	156
Dec. 15	Dec. 24	18	12	17	.40	24	13	15	.0	117	18	1.0	8.5	150
Dec. 25	Dec. 31	5	......	14	.30	23	11	27	.0	115	19	1.1	8.5	144
Mean		9	......	19	.19	23	12	16	0.0	125	17	1.2	7.4	145
Per cent of anhydrous residue		......	......	12	.1	14.6	7.6	10.1	39.4	......	10.8	0.8	4.6	.....

[a] Planimeter measurement on U. S. Land Office map.
[b] Abnormal. Computed as HCO_3 in the average.

The water is of the calcic carbonate class. Chlorine is higher than in waters previously considered, averaging 7.4 parts per million. Sodium and sulphates each form about 10 per cent of the total dissolved material. Normal carbonates are encountered at rare intervals. The amount of dissolved material and the slight amount of silt and other material carried in suspension vary little throughout the year. The heavy winter rains increase the suspended matter but slightly, the greatest turbidity recorded during 1908 being only 60 parts per million during the period from January 20 to 29. The greatest amount of suspended matter, by weight, in 1908 was only 145 parts per million, February 9 to 18, when the large run-off and high velocity of the river permitted it to carry in suspension coarse-grained sand.

This water is suitable for use in boilers. Containing chiefly hardness of a temporary nature, it may be effectively treated with very small amounts of reagents and by preheating before introduction into the boiler. It is also well adapted for use in laundries, because its soap-consuming power while noticeable is not excessive. For both municipal and irrigation use it is excellent, requiring only sand filtration to make it safe and palatable for drinking. Its use without treatment in wine making will not impair the quality of the wines. Paper making may some day occupy an important place among the industries of the Russian River valley, and for this purpose slight treatment should render the water perfectly satisfactory.

NOTES ON MUNICIPALITIES.

Reports were received from 16 settlements in the north Pacific Ocean drainage area. Of these three reported water supplies obtained from wells, the others all using surface waters, wholly or in part. Three cities use filtration in connection with their water supply, the rest taking no means to insure purity of supply.

The following table gives statistics of water supply of these incorporated settlements:

Statistics of municipal water supplies in north Pacific Ocean drainage basin.

Settlement.	Drainage basin.	Population.	Stream.	Source of supply.	Nature of system.	Ownership.	Method of purification.	Per capita daily consumption (gallons).	Nature of sewerage system.	Ultimate disposal of sewage.
Arcata	Humboldt Bay	952	Humboldt Bay	Stream	Gravity	Union Water Co.	None		Sanitary	Pacific Ocean.
Cloverdale	Russian River	a 1,200	Russian River	Russian River	Pumping	Municipal	Infiltration	100	do	Sewer farm.
Crescent City	Pacific Ocean	699	Pacific Ocean	Streams	do	Wm. L. Childers	None		Storm only	Pacific Ocean.
Etna	Klamath River	706	Etna Creek	Etna Creek	Gravity	Etna Development Co.	do		do	Creek, 2½ miles from town.
Eureka	Humboldt Bay	9,550	Humboldt Bay	Elk River	Pumping	Eureka Water Co.	Alum coagulation mechanical filters.	50	Combined	Humboldt Bay.
Ferndale	Pacific Ocean	921	Salt River	Streams	Gravity and pumping.	Francis Light and Water Co.	None		Sanitary	Tide-water stream 1 mile from town.
Fort Bragg	do	a 2,000	Noyo River	do	Gravity	Private company	do		do	Pacific Ocean.
Fort Jones	Klamath River	437	Scott River	Wells	Pumping	G. A. Reichman	do		None	
Fortuna	Eel River	a 1,200	Eel River	do	do	Fortuna Water Co.	do		do	
Healdsburg	Russian River	2,215	Russian River	do	do	Municipal	do		do	
Potter Valley	do	a 500	South Fork Russian River.	Stream and wells		Individual supplies			do	
Santa Rosa	do	7,980	Santa Rosa Creek.	do	Gravity	Municipal and Santa Rosa Water.	Sedimentation and filtration.	235	Sanitary (septic tank).	Sewer farm.
Ukiah	do	2,170	Russian River	do	Gravity and pumping.	Ukiah Water Improvement Co.	None	300	Combined	Do.
Willits	Eel River	791	Deep Creek	Streams	Gravity	Willits Water and Power Co.	do		None	
Yreka	Klamath River	1,384	Yreka Creek	Stream and wells	Gravity and pumping.	Municipal	do		Combined (septic tank).	Yreka Creek.

a Based on estimates of city or town clerks and health officers. All others estimated for 1909 from United States census, 1890 and 1900.

SAN FRANCISCO BAY DRAINAGE.

DESCRIPTION.

The San Francisco Bay drainage area comprises a large basin or valley extending lengthwise throughout the northern and middle portions of the State and rimmed in on all sides by mountains, the only outlet being the narrow break in the coastal hills at the Straits of Carquinez. The northern extremity of this area lies on the crests of the broken ranges which form the Klamath Mountains. The summits of the Sierra on the east, of the Tehachapi on the south, and of the Coast Ranges on the west complete the bordering rim. Inclosed within this oval of mountains are 64,000 square miles of land surface—about 40 per cent of the total area of the State. The northern portion of the basin makes the Sacramento Valley, the middle portion the San Joaquin Valley, and the southern portion, separated from the San Joaquin Valley by a low, alluvial divide, the Tulare Valley. These three valleys form a long, narrow plain, having an average width of 50 miles and a length of 400 miles, and include about 20,000 square miles of valley land.[a] On the west the Coast Ranges rise with great abruptness from the alluvial plain, while on the east the rise is gradual and in places almost imperceptible, forming a long, gentle slope to the summits of the Sierra, from 6,000 to 10,000 feet above the valley floor.

The area is drained by the two largest rivers in California, the Sacramento and the San Joaquin, which unite at Suisun Bay. A number of other streams, important merely as sources of water supply for the bay cities of San Francisco, Alameda, Oakland, and Berkeley, and the smaller towns, empty directly into San Francisco and San Pablo bays, the most important of these being Alameda Creek and Coyote River in the southern portion and Napa Creek on the northern shore.

The rock floor of the Sierra Nevada region consists of metamorphosed sediments and eruptives and later intrusive granitic or dioritic masses, except where scattered late effusives—rhyolites, andesites, and basalts—appear, or where weathering and stream action have caused local deposits, such as the auriferous gravels of the Tertiary period.

The soil of the San Francisco Bay drainage area can not be considered as a unit, owing to the extent of the area, the varying character of the bed rock, and the vast differences in climatic conditions and in alluviation. In the high regions of the Sierra there is little soil of any kind, but toward the valley the rich, iron-bearing, red soil

[a] Ransome, F. L., The Great Valley of California: Bull. Dept. Geology Univ. California, vol. 1, No. 14, p. 373.

of the slopes increases steadily in depth. Lower down in the foothills is a great depth of rich red soil, interspersed here and there with clay deposits and giving place locally to white ash or to black adobe soils. The valley floor is alluvium, portions of it semisubmerged, as tule swamps, and other portions choked with alkali. The soil of the Bay region is largely black adobe, merging into alluvium on the one hand and bed rock on the other.

The northern and eastern slopes of this drainage area are generally well forested, while, except in the northwestern portion, the western slopes are nearly bare. Much of the forest land is now held as national forests, but skirting these reserves are large areas of privately owned timber lands, extending from the Shasta National Forest on the north to the Stanislaus Forest on the south, and containing probably over a million acres.

In the reserved lands are 11,451,565 acres of woodland, comprising the Shasta, Lassen, Plumas, Tahoe,[a] Stanislaus, Sierra, and Sequoia national forests. It is estimated[b] that these national forests contain 53,961,213,000[c] feet b. m. green saw timber, as well as about 35,000,000 feet cordwood and over 375,250 feet dead saw timber. The private timber claims within the limits of the national forests mentioned contain about 28,542,350,000 feet b. m. merchantable timber. It is estimated that in the Yosemite, General Grant, and Sequoia national parks the total stand is 3,949,120,000 feet b. m. merchantable timber, and 6,380,896 cords of wood. Thus, with the private timber standing upon unreserved lands, the total amount of timber in the basin is very close to 90,000,000,000 feet b. m.—43 per cent of the total timber of the State. Almost all of this stands within the borders of the San Francisco Bay drainage area, small sections only over lapping into the north Pacific and Interior Basin drainage areas.

The principal industries of the Great Valley include mining, smelting, lumbering, dairying, grazing, orchard farming, graniculture, sugar manufacture, and fishing. The chief mine products are gold and copper, and there are also extensive quarries of granite, sandstone, and other rocks, and a number of mineral springs of economic importance. Dairying is growing rapidly in importance, as are also all agricultural industries except wheat production. Rice culture has recently been started in Glenn County.[d] In the alluvial plain and foothill regions agriculture, fruit growing, and dairying are the principal industries.

Fishing as an industry deserves more prominent mention than is usually given to it. Sacramento River alone yields annually nearly

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[a] Excluding 57,675 acres in the State of Nevada.

[b] Communicated by T. D. Woodbury, acting chief of silviculture, District 5, U. S. D. S., Forest Service, March 12, 1909.

[c] Including dead timber of the Stanislaus National Forest, for which estimate is lacking.

[d] Eighteenth Ann. Rept. California State Board of Trade, 1908, p. 23.

$1,250,000 worth of fish, representing about one-third of the total catch for the State. This whole industry is threatened with destruction if steps are not taken to prevent the pollution of the streams by mining and industrial wastes and municipal sewage. Directly above the city of Sacramento scores of fishermen's houseboats are anchored along the banks. The fish caught by these men are sold chiefly in such places as Sacramento and the bay cities. The river at Sacramento is a muddy, uninviting-looking stream, containing, besides all manner of débris, more or less pollution from all the settlements in the drainage area. The fish will eventually disappear from the river as the pollution becomes more pronounced. Acid and other industrial wastes, although at present not of great enough extent to be important, should nevertheless be prevented from contaminating the river and its tributaries, and sawdust from mills should not be allowed to fill the beds of the smaller streams to the destruction of the brook trout.

In some sections of this drainage area extensive irrigation projects are in construction or operation, while in other sections schemes for draining the fertile tule lands are being considered. According to the state engineer, the proper control of Sacramento River, together with necessary irrigation and the drainage of the tule swamps, would add to the permanently available area of the Sacramento Valley 1,000,000 acres.[a] The Reclamation Service is constructing a dam and an impounding reservoir on Stony Creek, in Glenn County, and on the completion of this project 14,000 acres will be placed under irrigation.

In the southern sections of the area, in the Tulare and San Joaquin valleys, the principal industries are grain and fruit raising, grazing, and mining. The Sierra slopes are used for grazing, for fruit growing, and for mining. In the western portion of the valley, near Coalinga and at Bakersfield, the pumping and refining of asphaltum and petroleum are the chief industries.

SACRAMENTO RIVER SYSTEM.

DESCRIPTION.

The Sacramento Valley, which lies between the Sierra Nevada on the east, the Klamath Mountains on the north, and the Coast Range on the west, is narrow and winding at its northern extremity, in places scarcely 10 miles wide, but near Red Bluff it widens out abruptly and becomes a broad, alluvial valley floor, sloping gently southward to its junction with the San Joaquin Valley. Sacramento River, the largest stream in California, rises in the Shasta Mountains and winds tortuously along the axis of the valley, skirting the steep bases of the Coast Ranges on one side and the long, gentle slopes of the

[a] Rept. State Engineer of California for 1908, p. 65.

Sierra Nevada on the other. The river flows in a general southerly course for about 200 miles; then turning to the west it meanders sluggishly through tule swamps into Suisun Bay. Thence its waters pass through the Straits of Carquinez into San Pablo Bay and reach the Pacific by way of San Francisco Bay and the Golden Gate.

The river drains all of the territory south of Mount Shasta between the Coast Range and the Sierra Nevada. The portion of the drainage basin above Red Bluff extends from the Trinity Mountains on the west to the Warner Mountains, near the California-Nevada line, on the east. The area on the west, bordered by the Trinity Mountains, is comparatively narrow—ranging in width from 10 to 35 miles—and furnishes a very small proportion of the discharge of the river, but that on the east includes Pit River, the most important tributary. The western portion of the basin is well timbered, as is also that portion of the drainage area in the Sierra Nevada lying between Mount Shasta and Lassen Peak. Farther east, however, there is little or no forest covering, and the country is used extensively for pasturage.

Below Red Bluff the Sacramento enters a long, broad, flat valley, through which it flows on a comparatively light grade until it reaches Suisun Bay. In its course through the valley it receives many tributaries, the largest from the eastern side.

Farming is the principal industry in this region. On the tributary streams mining and lumbering are followed extensively. Many large towns on the banks of the river owe their existence to the shipping which is carried on by boat and rail. The fishing trade is also very important along the Sacramento. In the central part of the valley considerable areas are given up to the cultivation of sugar beets.

TRIBUTARIES.

The Sacramento receives numerous important tributary streams from the Sierra and smaller ones from the Coast Ranges. At many places in its middle and lower course the river is bordered by tule swamps, in which the smaller western tributaries lose themselves, few of them reaching the Sacramento through well-defined channels. The larger and stronger tributaries from the east, however, have formed definite and regular channels that run directly to the main river. Most of these tributary streams from the Sierra flow southwestward, forming deep, narrow canyons, which give to the otherwise gently sloping land a very rugged appearance. The streams rising in the Coast Ranges, however, cut much smaller canyons, most of them trending distinctly west-east.

Pit River, the largest tributary of the Sacramento, drains an area extending about 120 miles eastward from the main stream and lying between Mount Shasta on the north and Lassen Peak on the south.

The greater part of this basin is composed of lava and shows other evidences of volcanic activity, such as volcanic cones and craters. Nearly all the tributaries of Pit River rise in large springs. The most important tributary of the Pit is the McCloud, which drains the southern slope of Mount Shasta and derives its waters principally from the melting snow from the high elevations of this mountain.

The principal tributaries below Red Bluff are Feather and American rivers, draining the western slopes of the Sierra, and Stony, Cache, and Putah creeks, draining the eastern slopes of the Coast Ranges.

The following table shows the names, relations, and geographic order from north to south of the more important tributaries of the Sacramento:

Principal tributaries of Sacramento River.

From the west.		From the east.	
Clear Creek.		Pit River	North Fork.
Cottonwood Creek	North Fork.		South Fork.
	Middle Fork.	Ash Creek.	
	South Fork.	Falls River.	
Red Bank Creek.		Hat Creek.	
Toms Creek.		Burney Creek.	
Stony Creek.		Squaw Creek.	
Willow Creek.		McCloud Creek.	
Cache Creek.		Cow Creek.	
Puta Creek.		Mills Creek.	
		Chico Creek.	
		Butte Creek.	
		Deep Creek.	
		Big Butte Creek.	
		Feather River	North Fork.
			Middle Fork.
			South Fork.
		Honcut Creek.	
		Yuba River	North Fork.
			Middle Fork.
			South Fork.
		Bear River.	
		American River	North Fork.
			Middle Fork.
			South Fork.
		Rubicon River.	

The streams here described are typical, and descriptions of the others are therefore not given in this report.

SACRAMENTO RIVER AT SACRAMENTO.

CHARACTER OF WATER.

Samples of water for this investigation were collected from the river at a point about 3 miles above the railroad bridge at Sacramento, where the stream is wide, shallow, and sluggish at low stages, but during flood periods is exceedingly swift and liable to overflow.[a]

[a] For data concerning gage heights and discharges of the river at the Red Bluff gaging station, see Water-Supply Papers U. S. Geol. Survey Nos. 81, 100, 134, 177, and 213.

The chemical analyses (see table following) show that the water of Sacramento River should be classed as carbonate—calcium, magnesium, and bicarbonates forming the greater part of the dissolved mineral matter. The total dissolved material is not high, and the water is fit for almost any industry that can use moderately hard water. It may readily be softened, however, by adding to it a small amount of soda ash, which will remove the excess of lime and magnesia.

Mineral analyses of water from Sacramento River above Sacramento.

[Parts per million unless otherwise stated.]

Date. From—	Date. To—	Turbidity.	Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.
1906.	1906.													
Jan. 1	Jan. 10	......	10	31	2.4	14	6.5	18	3.0	0.0	89	8.4	6.9	144
Jan. 11	Jan. 20	......	210	27	2.8	11	5.1	21	2.8	.0	121	18	13	118
Jan. 21	Jan. 30	......	174	20	.8	15	6.2	18	.8	.0	46	19	5.9	56
Feb. 4	Feb. 9	......	......	28	5.4	11	6.1	12	.9	.0	73	10	8.2	176
Feb. 10	Feb. 17	......	96	24	2.4	13	5.9	9.5	2.5	.0	73	10	7.6	106
Feb. 22	Mar. 1	......	122	16	4.2	11	6.0	8.5	1.1	.0	59	14	9.0	66
Mar. 2	Mar. 11	......	62	18	5.8	15	9.5	11	2.3	.0	58	25	7.4	130
Mar. 12	Mar. 21	......	22	16	6.0	12	4.8	7.1	4.2	.0	60	8.4	8.3	212
Apr. 1	Apr. 4	......	114	10	4.0	13	8.4	12	1.8	.0	49	14	5.1	104
Apr. 12	Apr. 20	......	54	16	6.8	14	6.2	11	2.3	.0	57	9.7	4.9	102
Apr. 21	Apr. 30	......	58	13	4.4	12	6.0	8.7	1.9	.0	58	8.2	4.9	112
May 1	May 9	......	56	9.2	4.8	13	6.1	6.3	1.3	.0	58	8.2	5.9	98
May 10	May 20	......	26	15	3.6	14	5.9	7.4	1.2	.0	53	8.7	6.4	80
May 21	May 30	......	42	10	2.8	11	5.5	6.0	0.9	.0	54	13	6.2	88
May 31	June 10	......	24	20	4.2	13	5.2	9.6	2.1	.0	50	16	6.2	100
June 11	June 20	......	22	15	4.0	12	10	10	1.7	.0	51	16	6.7	94
June 21	June 30	......	32	12	4.8	13	4.9	12	......	.0	53	7.1	6.8	80
					Fe.									
July 1	July 10	......	18	16	.20	14	6.8	16		.0	66	13	5.8	106
July 11	July 20	......	10	32	.50	16	5.9	10		.0	73	16	7.8	126
July 21	July 31	......	50	19	.10	16	5.9	15		.0	81	12	7.2	130
Aug. 1	Aug. 10	......	16	36	.08	21	9.3	21		.0	102	17	13	176
Aug. 11	Aug. 20	......	28	23	.15	17	9.0	19		.0	102	16	14	162
Aug. 21	Aug. 31	......	46	15	.13	17	8.1	18		.0	98	15	[illegible]	142
Sept. 1	Sept. 10	......	56	22	.25	15	8.1	19		.0	100	15	13	136
Sept. 11	Sept. 20	......	42	21	.30	19	9.5	16		[a] 2.0	96	14	13	148
Sept. 21	Sept. 30	......	42	24	.20	17	8.5	19		.0	97	16	12	154
Oct. 1	Oct. 10	......	38	18	.25	19	7.8	19		.0	90	12	12	138
Oct. 11	Oct. 20	......	18	26	.35	18	9.3	19		.0	104	14	9.1	150
Oct. 21	Oct. 31	......	24	25	.17	14	7.7	13		.0	98	8.2	8.1	134
Nov. 1	Nov. 10	100	60	17	.75	15	6.3	18		.0	88	13	8.1	120
Nov. 11	Nov. 20	20	46	21	.25	16	7.1	14		.0	102	13	8.6	146
Nov. 21	Nov. 30	20	......	18	.35	14	6.9	27		.0	90	16	8.6	156
Dec. 1	Dec. 10	15	54	22	.20	17	7.9	15		.0	93	8.7	8.1	118
Dec. 11	Dec. 20	100	140	18	.20	15	5.0	13		.0	55	16	7.7	118
Dec. 21	Dec. 31	100	152	6.0	.8	14	5.9	26		.0	55	14	9.2	100
Mean		......	60	19	[b] .29	15	7.0	15		.0	76	13	8.7	124
Per cent of anhydrous residue..		......	......	16.6	.2	13.0	6.1	13.0		32.2	......	11.3	7.6	......

[a] Abnormal. Computed as HCO_3 in the average.

[b] Mean of Fe values after July 1.

Mineral analyses of water from Sacramento River above Sacramento—Continued.

Date. From—	Date. To—	Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.
1907. Dec. 31	1908. Jan. 9	230	360	26	1.0	13	5.1	10	0.0	54	21	1.0	4.3	104
1908.														
Jan. 10	Jan. 19	115	102	24	.51	16	7.0	5.2	.0	56	25	1.4	4.9	114
Jan. 20	Jan. 29	85	106	24	.40	13	2.0	11	.0	49	16	1.1	4.1	104
Jan. 30	Feb. 8	75	117	27	.51	12	3.1	15	.0	50	24	.80	4.0	105
Feb. 9	Feb. 18	100	135	36	.80	11	5.9	11	.0	51	23	1.6	4.4	105
Feb. 19	Feb. 28	85	91	28	.30	13	6.4	10	.0	68	18	.37	6.0	107
Feb. 29	Mar. 9	50	91	27	.48	15	4.8	17	.0	71	25	.34	5.1	111
Mar. 10	Mar. 19	85	178	30	.75	13	6.1	13	.0	71	13	1.0	5.1	113
Mar. 20	Mar. 29	95	175	27	.50	13	4.0	9.5	.0	61	26	.48	3.6	107
Mar. 30	Apr. 8	20	148	27	.50	13	5.7	15	.0	63	21	Tr.	4.1	102
Apr. 9	Apr. 18	110	332	21	.85	10	5.2	10	.0	59	20	.70	4.0	85
Apr. 19	Apr. 28	135	100	26	.55	11	4.4	8.8	.0	55	16	1.0	3.4	94
Apr. 29	May 8	108	92	22	.28	9.7	4.4	8.8	.0	52	17	.68	4.0	88
May 9	May 18	40	48	19	.23	10	8.1	7.1	.0	56	13	.74	2.5	86
May 19	May 28	95	61	18	.30	9.7	3.8	5.8	.0	54	9.9	......	2.5	80
May 29	June 7	50	52	19	.38	12	4.7	8.5	.0	56	13	.48	3.4	81
June 8	June 17	50	43	22	.25	12	3.7	9.0	.0	59	11	1.0	4.2	89
June 18	June 27	45	46	26	.38	12	6.7	12	.0	71	18	.22	7.0	112
June 28	July 7	55	77	33	1.0	12	7.3	13	.0	73	13	.70	7.0	132
July 8	July 17	50	81	28	.38	15	9.4	11	.0	84	18	.92	6.5	124
July 18	July 27	60	78	24	.18	14	7.9	13	.0	87	12	1.2	6.0	118
July 28	Aug. 6	50	145	27	.31	16	10	14	.0	89	16	......	7.5	122
Aug. 7	Aug. 16	40	55	29	.25	16	8.7	16	[a] 1.2	99	16	.40	7.2	131
Aug. 17	Aug. 26	45	97	32	.20	15	9.3	17	.0	95	16	.56	8.0	131
Aug. 27	Sept. 5	30	58	29	.60	16	9.4	16	.0	95	16	.78	8.0	134
Sept. 6	Sept. 15	30	58	34	.38	17	7.9	15	.0	96	16	.10	7.2	132
Sept. 16	Sept. 25	25	43	24	.21	15	8.0	14	.0	92	16	.30	6.5	120
Sept. 26	Oct. 5	45	68	29	.04	14	8.9	11	.0	96	13	.54	5.5	120
Oct. 6	Oct. 15	50	80	33	.13	14	8.3	14	.0	93	21	.40	6.5	126
Oct. 16	Oct. 25	85	126	31	.55	13	7.8	15	.0	82	18	.50	6.6	123
Oct. 26	Nov. 4	65	116	31	.18	12	7.9	17	.0	85	13	.32	5.9	114
Nov. 11	Nov. 14	40	75	28	.18	12	7.1	19	.0	87	12	.20	4.0	117
Nov. 15	Nov. 24	45	76	34	.40	12	8.7	16	.0	85	14	.30	5.6	128
Nov. 25	Dec. 4	45	84	28	.40	15	7.9	15	.0	77	17	.44	6.0	114
Dec. 5	Dec. 14	50	90	43	.50	14	7.3	13	.0	81	15	.70	6.2	138
Dec. 15	Dec. 24	50	63	31	.45	14	7.2	19	.0	83	13	.48	6.2	128
Dec. 25	Dec. 31	30	38	40	.60	15	9.8	23	.0	87	16	.54	7.0	140
Mean		66	102	28	.43	13	6.7	13	.0	74	17	.64	5.4	113
Per cent of anhydrous residue		......	......	23.2	0.4	10.8	5.6	10.8	30.0	....	14.1	0.5	4.6	......

[a] Abnormal. Computed as HCO_3 in the average.

At high stages the water is exceedingly turbid and the suspended matter is fine and does not settle readily. At other seasons the water is not so turbid, but it is not very clear at any time.

The water of the river is used to some extent for irrigation and for the municipal supplies of several small towns along its course, and forms the main source of supply for the city of Sacramento. The water is pumped into the mains from the river without any treatment, the users depending solely upon faucet filters for its purification. Owing to the possibility of sewage contamination from the towns on its banks and from the boats that are constantly passing up and down the river, its water can not be recommended for domestic use unless it is thoroughly purified.

CACHE CREEK.

DESCRIPTION.

Cache Creek rises in Clear Lake, which lies in a narrow valley in the central part of Lake County directly west of the St. Helena Mountains. The lake is about 22 miles long and 7½ miles wide, extends generally northwest and southeast, and receives the drainage from approximately 500 square miles of land. Cache Creek, flowing toward the southeast, finally disappears in the swamp lands below Yolo, the total drainage area above Yolo being 1,230 square miles. Several tributaries join the creek in its short course, the largest of these being the North Fork, which rises to the northeast of Clear Lake and flows generally parallel to that body of water, joining Cache Creek at the point where that stream turns to the southeast. A short distance above Yolo Cache Creek emerges from the foothills and crosses a narrow alluvial plain extending from the foothills to Sacramento. Practically none of the water of the creek finds its way above ground to the Sacramento during the summer months, because of its extensive use for irrigation near Yolo.

CHARACTER OF WATER.

Waters of the region.—In the vicinity of Clear Lake are mercury deposits of considerable importance, and other evidences of intrusive disturbances appear in the numerous mineral springs of the vicinity. In a monograph relating to the mercury deposits of this section G. F. Becker[a] cites analyses of two of the sulphur springs, and these analyses are reproduced here to indicate the character of the soluble mineral matter of this region. An analysis of the water of Borax Lake, from the same source, is also given here.[b]

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[a] Becker, G. F., Mon. U. S. Geol. Survey, vol. 13, 1888, p. 259.

[b] Idem, p. 265.

Analyses of waters of Sulphur Springs, Borax Lake, and Clear Lake.

[Parts per million.]

	Sulphur Springs.		Borax Lake.[a]	Clear Lake.[b]
	Hermann shaft.	Parrott shaft.		
Silica (SiO_2)	37	42	11	7.9
Alumina (Al_2O_3)	....	....	2.9	.2
Ferric oxide (Fe_2O_3)	....	.68	3.8	....
Manganese (Mn)	....	....	.86	....
Calcium (Ca)	21	20	24	20
Magnesium (Mg)	5.5	1.6	273	13
Sodium (Na)	1,706	1,319	29 167	5.2
Potassium (K)	25	39	1.064	2.3
Ammonium (NH_4)	2.4	1.1	....	....
Borate radicle (B_4O_7)	1,451	1,857	3 866	....
Carbonate radicle (CO_3)	1,140	220	17,198	66
Sulphate radicle (SO_4)	17	466	98	4.1
Chlorine (Cl)	693	667	24.812	2.2
Bromine (Br)	....	....	30	....
Phosphate radicle (PO_4)	....	....	15	....
Organic matter	....	....	3 618	34
Hydrogen sulphide (H_2S)	4.6	.74	....	....
Carbon dioxide (CO_2)	262	1,751	684	....
Fixed organic matter	5.0	7.6	....	....
	5,370	6,393	80,868	155

[a] Analyst, Doctor Melville. [b] Analyst, Professor Price.

Borax Lake was, at the time of Becker's description, a small shallow pond. It was at one time a part of Clear Lake but was subsequently cut off from it and deprived of all outlet except, possibly, during rare periods of overflow. The analysis is cited here to show the unusual magnesium content of the lake waters as compared with the calcium content, and also to show the presence of large quantities of borax in the waters of both lake and springs. An analysis of the water of Clear Lake, made by Professor Price, in 1874, for the city of San Francisco, and cited by A. E. Chandler in his paper on the water-storage possibilities of Cache Creek [a] also given, shows the radically different character of this water and at the same time the high magnesium content peculiar to the waters of this region. Clear Lake contained at the time of the sampling considerably less dissolved mineral matter than was found at any time in the water near Yolo. However, except for large differences in percentage composition of alkalies, chlorides, and sulphates, the relations of the elements are similar. It is possible that the sample from Clear Lake was taken after a period of heavy rainfall, when the chlorine and alkali content would be low, and it is probable that the average content is greater than that recorded.

In Borax Lake, where the water exists in a closed basin, the magnesium-calcium ratio attains the surprising value of 11½ to 1, while in Clear Lake, immediately adjacent, the ratio is 1 to 1½.

Waters of Cache Creek at Yolo.—At the town of Yolo the course of the creek is practically straight for a quarter of a mile, and its

[a] Water-Supply Paper U. S. Geol. Survey No. 45, p. 33.

steep banks are crowned by protecting levees and by a growth of small trees. The river bottom is gravelly, with loamy stretches, and, except at low stage, the current is swift. As the bed is sandy and gravelly for a long distance upstream, the water shows high turbidity in flood season. During 1908 daily samples were collected by Mrs. Cornelia Bigelow at the United States Geological Survey's gaging station until August 7; for the remainder of the year the river was dry.

In the early part of the year the rainfall was heavy, and for the period between January 30 and February 8 the run-off reached an average of 4,711 acre-feet a day. This period was also the period of maximum suspended matter, but not of minimum dissolved matter, which occurred in the following ten days and resulted from a greatly decreased sodium and chlorine content. The flood waters receded after the middle of February, and there was a short period of lower discharge, followed by another flood period between February 29 and March 10. The turbidity at this time was much less—the soil had recently been washed clean of easily transported detritus and time for new accumulations was small—attaining an average of only 150 parts per million, as compared with 500 parts in the previous flood. The minimum value for dissolved matter was again found ten days later, this time not because of any change in the sodium chloride content, but because of decrease in amount of alkaline earths and carbonates. Sulphates and chlorides also show a slight diminution in the later analysis. From this time on the records show a steady decrease in stream flow and suspended matter and a fairly constant increase in dissolved mineral matter until the surface flow ceased entirely, when a maximum of nearly 300 parts per million was reached.

The results of the chemical analyses are presented in the accompanying table. The water is of the calcic and magnesic carbonate type. Normal carbonates were noted at various times, especially during the early part of July, when the tests showed about 12 parts per million. The water may be fitted for municipal use by sedimentary and bacterial purification. In its raw state it is not suited for use in laundries, as its high magnesium content and its relative hardness would cause fairly large consumption of soap. For economical steam production the addition of small amounts of softening reagents is desirable.

Mineral analyses of water from Cache Creek at Yolo.

[Drainage area, 1,230 square miles. Quantities in parts per million unless otherwise stated.]

Date.		Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.	Mean discharge.		Run-off per square mile (cubic feet per second).
From—	To—														Acre feet per day.	Cubic feet per second.	
1907. Dec. 31	1908. Jan. 9	145	162	19	0.19	35	23	44	2.4	173	35	1.5	47	290	1,448.0	730.2	0.5936
1908. Jan. 10	Jan. 19	85	64	26	.20	31	23	56	.0	198	34	1.08	47	298	1,102.8	556	.4520
Jan. 20	Jan. 29	155	239	22	.42	33	23	33	.0	170	29	1.6	32	241	2,155.2	1,086.8	.8826
Jan. 30	Feb. 8	500	560	20	.25	24	18	30	.0	151	24	.66	26	210	4,711.3	2,375.3	1.9311
Feb. 9	Feb. 16	230	366	16	.41	28	19	25	.0	160	25	.40	20	198	4,385.5	2,211	1.7975
Feb. 19	Feb. 28	20	33	15	.18	31	22	28	.0	185	30	.20	24	233	2,164.1	1,091.3	.8872
Feb. 29	Mar. 9	150	134	17	.31	29	21	25	.0	181	31	1.3	24	224	3,453.7	1,741.7	1.4161
Mar. 10	Mar. 19	18	....	14	.30	24	19	25	4.8	174	28	1.2	21	212	2,381.7	1,201	.9764
Mar. 20	Mar. 29	10	....	11	.05	26	22	27	7.2	172	23	.80	22	216	1,895.7	955.8	.7771
Mar. 30	Apr. 8	10	....	14	.15	28	23	25	.0	180	35	1.5	23	225	1,575.8	794.7	.6461
Apr. 9	Apr. 18	15	....	12	.28	28	21	30	.0	188	38	1.1	24	229	1,351.9	681.6	.5542
Apr. 19	Apr. 28	20	20	15	.13	28	20	27	.0	193	25	2.0	26	235	1,155.0	582.3	.4734
Apr. 29	May 8	Tr.	....	9.4	.11	28	22	29	.0	195	26	1.0	27	238	859.0	433.1	.3521
May 9	May 18	5	....	11	.05	30	25	29	2.2	191	20	1.6	29	242	628.7	317	.2577
May 20	May 28	10	....	16	.35	31	25	35	.0	200	31	2.0	29	261	499.2	251.7	.2046
May 29	June 7	10	....	17	.09	31	24	35	9.6	194	27	....	34	261	284.2	143.3	.1165
June 8	June 17	10	....	13	.19	33	26	37	.0	220	27	1.8	36	277	147.5	74.4	.0605
June 18	June 27	Tr.	....	12	.13	32	27	35	Trace.	224	22	1.5	35	272	69.6	35.1	.0285
June 28	July 7	10	....	15	.13	33	27	41	4.7	220	28	.65	37	283	19.0	9.6	.00780
July 8	July 17	Tr.	....	24	.18	35	27	36	12.	209	27	2.0	36	287	8.13	4.1	.00333
July 18	July 27	10	....	18	.08	30	26	41	3.6	229	26	2.0	37	291	5.36	2.7	.00219
July 28	Aug. 2[a]	5	....	18	.06	37	29	41	Trace.	243	28	1.8	37	282	1.98	1.0	.00081
Mean		64	....	16	.19	30	23	33	2.1	193	28	1.3	31	250	1,377	694	.57
Per cent of anhydrous residue		....	....	6.2	0.1	11.6	8.9	12.7	37.6	....	10.7	0.5	11.7	....	....	....	....

[a] Creek dry during the rest of the year.

FEATHER RIVER.

DESCRIPTION.

Feather River drains a portion of the western slope of the Sierra Nevada, extending eastward almost to the Nevada line, a distance of nearly 75 miles, and north and south a distance of 30 to 40 miles. The general course of the stream is west to southwest to the point at which it empties into Sacramento River near Verona.

The Feather receives numerous tributaries, the principal ones being the North, Middle, and South forks. The greater part of the basin is rough and mountainous. The bed rock in the southern and eastern parts of the basin is granite, on which rests the comparatively deep soil. Lava and other volcanic materials cover considerable areas in the middle and northern portions of the basin. The ground storage provided by the many meadows and valleys tends to maintain a steady stream flow during the summer months.

The entire basin, except the meadow lands, is well covered with a growth of brush and timber, much of which is large enough to make lumbering a profitable industry. The meadow lands are used for stock raising and grazing. Numerous large springs are found, especially in the lava districts, which supply a more or less constant flow throughout the year. Little artificial storage has been developed in the drainage area, and the water used for irrigation in the valleys is taken from the natural flow of the stream.

The principal industries of the region are mining, stock raising, lumbering, and power development in the upper basin, while in the lower valleys agriculture and placer mining or dredging compete for mastery of the ground.

CHARACTER OF WATER AT OROVILLE.

Samples for this investigation were collected by the gage reader at the gaging station near Oroville.[a] The river at this point flows in a rocky channel filled with coarse gravel. The current is sluggish at low stages and very swift at flood seasons.

During the winter and early spring the river is swollen from heavy rains and at this time carries a large quantity of suspended matter. Later in the season another period of high water is caused by the melting snow on the mountains, but at this time a much smaller proportion of suspended matter is carried and the water is of better quality.

Results of the analytical study are presented in the following table. Calcium, magnesium, and bicarbonates constitute the greater part of the dissolved mineral matter, and the water would therefore be classed as carbonate.

The water is well adapted for industrial and domestic use. It could be used in boilers with little danger of causing scale, and if properly filtered would form an admirable municipal supply. At present the water is used for irrigation, hydraulic mining, power development, and for a public supply for the town of Oroville.

[a] For data concerning gage heights and discharges see Water-Supply Papers U. S. Geol. Survey Nos. 81, 85, 100, 134, 177, and 213.

Mineral analyses of water from Feather River at Oroville.

[Parts per million unless otherwise stated.]

Date.		Turbidity.	Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle. (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total dissolved solids.	Mean discharge.	
From—	To—														Acre-feet per day.	Cubic feet per second.
1906.	1906.															
Jan. 1	Jan. 9	......	Trace.	.....	.....	17	7.0	......	......	0.0	87	12	5.9	138	2,560	1,291
Jan. 12	Jan. 20	......	260	16	2.6	7.4	4.1	14	2.1	.0	45	12	4.4	96	72,463	36,534
Jan. 22	Jan. 29	......	28	21	1.2	12	4.1	26	1.0	.0	63	13	5.9	104	17,645	8,896
Jan. 31	Feb. 9	......	4	27	1.4	8.6	......	......	0.9	.0	61	10	6.9	88	10,505	5,296
Feb. 10	Feb. 17	......	32	16	2.2	12	3.9	13	0.4	.0	56	8.1	8.8	100	17,383	8,764
Feb. 20	Mar. 1	......	Trace.	17	3.8	9.7	3.9	5.5	2.3	.0	48	5.9	5.7	92	34,534	17,411
Mar. 2	Mar. 11	......	24	18	1.8	9.7	5.1	4.1	1.8	.0	62	5.6	4.9	94	22,076	11,130
Mar. 13	Mar. 29	......	108	20	7.6	12	6.0	7.6	1.2	.0	51	15	6.9	92	51,315	25,871
Apr. 1	Apr. 10	......	74	15	4.2	13	7.2	11	2.8	.0	64	6.4	6.4	98	43,848	22,107
Apr. 11	Apr. 17	......	74	12	4.6	13	7.9	7.6	1.6	.0	68	8.6	5.9	84	45,399	17,847
Apr. 18	May 10	......	44	10	2.8	8.6	4.4	13	2.0	.0	48	6.9	7.8	78	37,430	18,871
May 11	May 20	......	42	10	5.0	9.7	4.9	6.0	1.8	.0	37	5.8	4.5	72	31,215	15,738
May 21	May 31	......	40	19	4.4	13	7.4	8.2	3.7	.0	42	17	4.9	84	32,502	16,386
June 1	June 10	......	20	12	3.6	11	5.4	5.8	0.7	.0	39	7.4	5.7	66	34,506	17,397
June 11	June 20	......	20	9.8	3.8	11	4.9	8.7	1.5	.0	41	7.4	4.9	70	29,050	14,646
June 21	June 30	......	28	10	4.0	14	3.8	16	1.9	.0	40	6.8	5.1	72	18,606	9,380
					Fe.											
July 1	July 10	......	12	13	.30	9.4	7.2	6.5		.0	48	14	5.6	90	13,432	6,772
July 11	July 20	......	60	14	.05	12	4.6	9.6		.0	59	7.1	4.8	84	10,680	5,384
July 21	July 25	......	42	16	.10	19	3.5	8.8		.0	69	4.8	4.8	84	8,037	4,556
Sept. 5	Sept. 10	......	34	34	.30	11	2.6	21		.0	84	22	6.1	108	3,923	1,978
Sept. 11	Sept. 20	......	20	23	.15	11	6.9	7.5		.0	76	6.3	6.9	116	3,919	1,976
Sept. 21	Sept. 29	......	2	16	.23	18	7.3	18		.0	81	10	5.1	122	3,816	1,924
Oct. 1	Oct. 10	......	20	15	.15	15	7.0	17		.0	86	7.1	5.1	132	3,808	1,920
Oct. 11	Oct. 20	......	20	20	.10	17	6.3	19		.0	105	12	5.0	138	3,808	1,920
Oct. 21	Oct. 31	......	32	15	.10	20	9.0	14		.0	96	16	6.6	120	3,808	1,920
Nov. 1	Nov. 10	......	70	19	.15	15	5.8	13		.0	78	16	5.6	112	6,224	3,138
Nov. 11	Nov. 20	20	4	12	.30	16	6.2	15		.0	86	23	7.0	116	4,086	2,060
Nov. 21	Nov. 29	10	20	17	.10	16	5.9	16		.0	84	15	6.1	108	4,078	2,056
Dec. 2	Dec. 10	30	56	22	.20	22	7.7	29		.0	81	....	6.1	122	5,963	3,006
Dec. 11	Dec. 20	10	34	19	.20	20	6.8	17		.0	67	8.3	5.1	94	10,482	5,284
Dec. 21	Dec. 31	20	42	8.0	.12	14	4.4	12		.0	48	8.3	5.6	96	24,726	12,466
Mean		......	41	16	[a].17	13	5.7	14		0.0	64	11	5.8	99	19,736	9,804
Per cent of anhydrous residue		......	......	16.4	0.2	13.3	5.8	14.3		32.8	....	11.3	5.9	.....	......	......

[a] Mean of Fe values after July 1.

YUBA RIVER.

DESCRIPTION.

Yuba River, fourth in size in the Sacramento Valley, unites with Feather River at Marysville, 30 miles above its mouth. It drains about 1,357 square miles of the western slope of the Sierra Nevada, comprising portions of Sierra, Nevada, Plumas, and Yuba counties. The extreme length of its basin is about 71 miles; the extreme width is 36 miles.

For the lower 10 miles of its course in the foothills the bed of the river is badly clogged with débris from hydraulic mining camps and is held between levees which have been raised from year to year to meet the overflow caused by the filling up of the area between them. The channel of the river in the lower foothills has been filled with cobbles and bowlders to a depth of more than 100 feet. From the foothills to the mouth of the river at Marysville the stream flows over a bed of gravel, sand, and clay recently built up from the mines above. The channels are irregular and change from winter to winter and sometimes during the summer.

The drainage basin may be subdivided into five small basins, namely: North Fork, 491.6 square miles in extent; Middle Fork, 218 square miles; South Fork, 360 square miles; Deer Creek, 89.6 square miles; and Dry Creek, 105.5 square miles. In addition to these an area of 92.5 square miles drains into the main stream just above the 100-foot contour. Dry Creek joins the river from the north just as it leaves the foothills; the other streams unite with it in the mountains.

In the western and lower portions of the drainage area are slates and kindred rocks, very much eroded, and merging into the gravel and alluvial deposits of the Great Valley of California. The rocks of the upper portions of the basin are principally lavas and granites, all deeply eroded. A stratum of serpentine traverses this basin in a direction generally parallel with the crest of the Sierra. It is intercepted by the North Fork at Goodyears Bar, by the Middle Fork at Moores Flat, and by the South Fork just east of Washington. This stratum is generally softer than adjoining strata, and through it the canyons of the various forks are upon lighter grades than immediately above and below and are generally much wider. It is of further interest because it forms the dividing line between the auriferous strata in the basin; west of it the mines are more extensive; east of it the gold-bearing rock occurs irregularly and is traced with difficulty.

The middle and upper portions of the basins of the three forks differ materially. The North Fork rises in a region of lavas which vary much in composition and hardness but which generally afford a deep soil for timber and shrub growth. The Middle Fork rises in similar lavas and in granite. The mean elevation of the crest of the Sierras at the heads of these forks is about 8,200 feet. The main and tributary streams fall rapidly and their canyons head well back into the mountains. The sides of these canyons are covered with timber and brush, which, with the deep soil, retain the moisture and feed numerous perennial springs. This condition is particularly noticeable on the North Fork. The mean annual precipitation upon the drainage areas of the North and Middle forks is about 54 inches. Warm rains and soft snow sometimes give a high flood run-off, but snow remains on the peaks until midsummer. The headwaters of the South Fork lie upon a broad granite surface into which the streams have not cut deeply until the main stream reaches a point 16 miles from the summit, where it drops rapidly into a deeply eroded canyon. This broad surface has been denuded by glacial action, and the harder nature of the granite has not permitted a deep soil to form. The area is, therefore, less heavily timbered than the drainage areas of the other two forks. This topography gives a broader and more gently sloping surface than characterizes the headwaters of other Sierra Nevada streams. Over the surface are scattered nearly 100 glacial lakelets and valleys, affording many excellent reservoir sites which have been or are to be utilized. This elevated area receives a mean annual precipitation of 60 inches, most of which is in the form of snow. The melting of this snow maintains the discharge of the tributaries until June or July, and with the natural and artificial reservoirs, makes the South Fork of the Yuba a highly valuable and reliable source of supply.

The basin of the Yuba is not thickly populated, most of the towns being mining communities of between 100 and 200 inhabitants. The principal industries in the upper reaches are mining, lumbering, and stock raising. Irrigation headworks of considerable size are located in the foothills, and these supply water for agricultural purposes in the lower valleys.

CHARACTER OF WATER NEAR SMARTSVILLE.

Samples of water for this investigation were collected at the gaging station near Smartsville [a] by J. R. McKeel, the gage reader. The stream at this point is swift at all stages. Both banks are steep and rocky and are not subject to overflow. The bed of the stream is composed of gravel and sand and is constantly shifting.

Calcium, magnesium, and bicarbonates constitute the greater part of the mineral matter in solution, and the water would therefore be classed as carbonate. Suspended matter is high during periods of extreme flood, but is at all times coarse and could be readily removed by sedimentation or filtration.

The water of the Yuba is used in no manufacturing industries at the present time, although, like that of other Sierra streams, it is fitted for almost any industrial use if properly clarified.

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[a] For data relative to gage heights and discharges for the years 1903 to 1906 see Water-Supply Papers U. S. Geol. Survey Nos. 100, 134, 177, and 213.

Mineral analyses of water from Yuba River at Smartsville.

[Parts per million unless otherwise stated.]

Date. From—	Date. To—	Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Mean discharge. Acre-feet per day.	Mean discharge. Cubic feet per second.
1906.	1906.														
Jan. 1	Jan. 10	124	18	2.4	11	4.6	26	3.2	0.0	63	18	6.4	110	1,111	560
Jan. 11	Jan. 20	.....	27	1.8	25	4.7	13	2.7	.0	69	23	8.6	106	35,958	18,129
Jan. 21	Jan. 30	248	17	.8	9.4	3.3	11	2.9	.0	46	20	3.9	62	8,946	4,510
Jan. 31	Feb. 9	172	18	3.0	14	4.8	6.6	.7	.0	44	23	4.9	106	4,471	2,254
Feb. 10	Feb. 19	298	13	2.6	10	3.4	5.2	1.9	.0	41	9.7	5.9	94	8,923	4,499
Feb. 20	Feb. 28	362	15	2.4	5.7	3.3	3.5	2.7	.0	36	7.1	6.3	56	16,287	8,211
Mar. 2	Mar. 11	326	13	3.0	8.3	4.4	5.2	1.0	.0	41	13	5.9	90	10,899	5,495
Mar. 12	Mar. 21	344	15	5.2	7.7	4.0	3.3	.4	.0	43	9.9	6.4	74	19,127	9,643
Apr. 1	Apr. 10	262	12	3.4	8.9	3.9	6.8	1.7	.0	33	8.7	3.9	64	20,559	10,365
Apr. 11	Apr. 20	234	7.2	4.0	7.7	4.5	8.7	2.2	.0	21	7.1	3.9	56	16,354	8,245
Apr. 21	Apr. 29	352	11	2.4	8.0	2.8	6.1	1.5	.0	33	7.9	4.9	70	15,273	7,700
May 3	May 10	290	15	3.0	8.9	3.4	6.6	1.3	.0	27	11	5.4	50	25,117	12,663
May 11	May 20	192	14	1.8	5.7	2.9	7.4	.7	.0	26	6.8	4.9	50	17,415	8,785
May 21	May 31	240	12	2.0	7.7	4.2	6.6	.6	.0	28	3.1	4.9	62	22,504	11,346
Jnne 1	June 9	346	12	3.6	7.7	4.7	7.4	....	.0	28	9.7	4.9	62	24,850	12.528
June 11	June 19	230	12	4.8	8.9	6.3	6.6	1.7	.0	23	7.1	5.1	54	22,494	11,341
June 20	June 30	142	11	4.6	10	5.7	11	.5	.0	31	12	5.8	68	12,556	6,330
				Fe.											
July 2	July 10	126	12	0.30	7.7	3.8	8.4		.0	35	11	4.9	74	10,605	5.397
July 11	July 20	162	16	.15	6.9	2.8	7.3		.0	36	8.4	4.9	70	6,413	3,233
July 21	July 31	264	14	.10	11	3.1	9.1		.0	45	8.6	5.4	80	3,221	1,624
Aug. 1	Aug. 10	96	13	.15	18	5.0	11		.0	59	12	4.9	88	1,730	872
Aug. 11	Aug. 20	74	20	.20	23	5.1	10		.0	72	12	4.9	114	3,161	1,594
Aug. 21	Aug. 30	84	15	.20	18	4.5	12		.0	60	13	4.4	88	1,283	647
Sept. 1	Sept. 10	50	13	.13	23	4.7	13		.0	63	10	4.4	98	1,099	554
Sept. 11	Sept. 20	36	14	.30	20	5.4	14		.0	64	13	5.1	104	1,016	512
Sept. 21	Sept. 30	30	11	.15	17	4.9	12		.0	62	17	4.6	100	979	494
Oct. 1	Oct. 10	34	10	.05	23	3.8	9.6		.0	80	12	6.1	94	813	410
Oct. 11	Oct. 20	28	8.4	.10	21	5.2	10		.0	76	15	5.6	100	801	404
Oct. 21	Oct. 31	18	9.6	.25	18	4.6	12		.0	73	13	5.0	118	785	396
Nov. 1	Nov. 10	240	13	.75	12	4.9	16		.0	58	19	6.6	110	2,284	1,152
Nov. 11	Nov. 20	18	14	.25	15	4.9	10		.0	63	23	7.1	106	1,103	556
Nov. 21	Nov. 30	2	13	.10	20	5.4	14		.0	67	22	7.1	112	1,099	554
Dec. 1	Dec. 10	136	12	.07	18	4.5	8.0		.0	59	15	6.1	100	1,756	885
Dec. 11	Dec. 20	386	10	.30	11	3.9	8.7		.0	46	19	6.1	84	8,966	4,520
Dec. 21	Dec. 31	536	11	.25	8.6	3.5	10		.0	33	10	6.1	70	13,542	6,827
Mean		191	14	*a* .21	13	4.3	10		.0	48	13	5.5	84	9,814	4,950
Per cent of anhydrous residue..		.....	16.7	0.2	15.5	5.1	11.9		28.6	......	15.5	6.5	......	....	....

a Mean of Fe values after July 1.

AMERICAN RIVER.

DESCRIPTION.

American River rises in the high Sierra at an elevation of about 9,000 feet above sea level and flows generally westward, emptying into Sacramento River just above the city of Sacramento. The river is 80 miles long and drains about 2,000 square miles of territory lying between the basins of Bear and Yuba rivers on the north and Cosumnes River on the south. The higher portions of the basin are composed of the characteristic granite of the Sierra, with fair soil covering and good timber growth. The river has three main tributaries—the North, Middle, and South forks—and many smaller ones.

The territory drained by the American is not thickly settled, few of the towns having a population greater than 1,000. The principal industries are mining in the upper reaches and on the smaller tributaries and agriculture in the lower valleys. In the past much hydraulic mining has been carried on, and at some places the stream bed has been filled with quantities of débris.

CHARACTER OF RIVER WATER AT FAIROAKS.

Samples of water for this investigation were collected by the gage reader at Fairoaks Bridge,[a] about 18 miles above the mouth of the river. The channel at this point is straight for 400 feet above and below the station. The bed of the stream is composed of gravel and is subject to slight changes at times of high water. At ordinary stages the river is about 210 feet wide and 4 feet deep.

During the winter months the flow of the stream is rather torrential, because of the large areas of barren and sparsely timbered country in the lower portions of the watershed, and the river carries a large quantity of suspended matter, much of which is deposited in a short time if the water is allowed to remain at rest. Later in the season another period of high water is caused by the melting snow from the mountains; at this time the water carries considerable suspended matter, generally finer than that of the winter season. This suspended material does not settle readily from the water, but remains to impart a decided turbidity for a long time.

As calcium, magnesium, and bicarbonates constitute by far the greater part of its dissolved material, the water from American River would be classed as carbonate. The total amount of dissolved mineral matter is not high, although it is somewhat greater than that in more southerly streams from the Sierra.

The water of this river is used for mining, power development, irrigation, and, in a small way, for the municipal supply of a few towns along its course, but it is not at present employed in manufactures, although it would be suitable for use in almost any industry if the suspended matter were removed by sedimentation or filtration.

[a] For gage heights and discharge data for this stream see Water-Supply Papers U. S. Geol. Survey Nos. 134, 177, and 213.

Mineral analyses of water from American River at Fairoaks.

[Parts per million unless otherwise stated.]

Date.		Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Mean discharge.	
From—	To—													Acre feet per day.	Cubic feet per second.
1906.	1905.														
Jan. 1	Jan. 10	98	25	1.4	17	6.3	17	1.0	0.0	86	9.4	11	102	714	360
Jan. 11	Jan. 20	610	29	.2	8.6	3.7	12	.0	.0	45	12	4.4	64	33,361	16,819
Jan. 21	Jan. 29	56	21	.4	9.7	6.0	11	2.8	.0	38	23	6.4	136	9,041	4,558
Jan. 31	Feb. 9	Trace.	20	1.2	8.3	2.5	8.2	.6	.0	40	12	8.8	108	4,539	2,288
Feb. 10	Feb. 19	......	17	2.6	8.0	3.3	4.2	.4	.0	35	6.8	6.9	....	10,102	5,093
Feb. 20	Mar. 1	240	17	2.4	6.3	3.2	8.5	1.8	.0	42	7.7	6.7	82	19,881	10,023
Mar. 2	Mar. 11	152	14	3.4	11	5.1	5.7	1.0	.0	64	14	8.6	86	15,547	7,838
Mar. 12	Mar. 21	278	17	3.8	8.6	3.4	5.5	....	.0	34	11	7.8	74	28,864	14,552
Mar. 22	Mar. 31	400	17	3.0	8.0	4.6	11	2.7	.0	33	6.8	7.8	92	39,467	19,898
Apr. 1	Apr. 10	234	16	4.0	8.3	4.2	8.8	1.8	.0	31	7.1	3.9	62	25,165	12,687
Apr. 16	Apr. 17	......	......	......	......	......	....	....	.0	29	......	4.4	....	24,000	12,100
May 1	May 10	286	11	3.0	6.9	4.0	9.3	1.2	.0	25	8.6	3.9	48	33,452	16,865
May 11	May 18	86	9.4	3.0	6.0	2.8	6.2	1.3	.0	20	8.4	3.9	56	27,161	13,694
May 21	May 28	212	19	3.6	5.9	6.1	8.5	1.4	.0	21	3.3	4.4	58	28,088	14,161
May 29	June 10	76	10	4.8	8.3	2.8	8.2	.6	.0	24	7.4	4.2	62	33,551	16,915
June 11	June 20	116	12	5.0	9.1	6.0	4.7	1.3	.0	25	7.3	4.9	66	34,886	17,588
June 21	June 30	142	14	4.0	6.9	2.1	11	....	.0	19	6.8	3.7	56	26,850	13,537
July 1	July 10	116	......	......	......	......	....	....	......	26	......	3.4	54	21,110	10,643
				Fe.											
July 23	July 30	68	15	.30	7.4	2.7	7.4		.0	30	9.2	5.6	72	5,558	2,802
Aug. 1	Aug. 9	46	21	.10	12	4.4	9.9		.0	40	13	4.8	74	3,165	1,596
Aug. 12	Aug. 20	46	19	.40	8.5	3.7	11		.0	37	11	4.8	74	1,823	919
Aug. 21	Aug. 30	32	14	.40	14	4.5	10		.0	43	15	4.9	80	1,285	648
Sept. 2	Sept. 10	48	13	.30	13	4.7	9.4		.0	44	13	5.8	80	998	503
Sept. 11	Sept. 20	70	15	.40	16	4.6	15		.0	53	12	7.1	104	864	436
Sept. 21	Sept. 30	58	14	.30	12	4.1	13		.0	48	12	7.1	92	702	354
Oct. 1	Oct. 10	72	14	.30	15	4.6	20		.0	61	13	8.1	96	686	346
Oct. 11	Oct. 20	122	17	.30	14	5.4	21		.0	59	13	7.6	98	627	316
Oct. 21	Oct. 31	92	18	.35	13	5.4	13		.0	58	13	7.1	114	696	351
Nov. 1	Nov. 10	164	19	.70	16	5.3	....		.0	50	14	9.1	96	1,515	764
Nov. 11	Nov. 20	76	24	.80	11	4.8	14		.0	48	22	8.1	100	966	487
Nov. 21	Nov. 30	108	16	.40	17	5.3	9.7		.0	55	24	7.1	98	892	450
Dec. 1	Dec. 10	264	18	.7	11	4.9	10		.0	47	13	6.6	100	1,202	606
Dec. 11	Dec. 20	158	11	.30	12	5.1	10		.0	46	22	10	98	8,569	4,320
Dec. 21	Dec. 31	140	15	.20	10	4.6	17		.0	37	12	5.6	80	12,921	6,514
Mean		146	17	a.39	11	4.4	11		0.0	41	12	6.3	83	13,478	6,795
Per cent of anhydrous residue		......	20.7	0.5	13.4	5.3	13.4		24.4	......	14.6	7.7	....	....	....

a Mean of Fe values after July 1.

SAN JOAQUIN VALLEY.

DESCRIPTION.

San Joaquin Valley proper and the Tulare Valley are so closely related and so merge into each other that they may be considered together. A low alluvial divide scarce serves to separate the two, so that, although at times of insufficient rainfall they form two distinct drainage areas, at other times the waters of Tulare Valley drain through Tulare Lake and Kings River into the San Joaquin.

The basin is in general a southern complement of the Sacramento, being bounded on the west by the Coast Range, on the east by the Sierra Nevada, and on the south by the Tehachapi Mountains. The total length of the valley is about 270 miles and its area is approximately 15,000 square miles. Owing to the great aridity of the eastern slopes of the Coast Range practically no streams flow into the valley from the west, but from the east several large rivers join the axial San Joaquin to form the second most important river system in the State. As a result of the great drainage from the east and the slight drainage from the west the San Joaquin has been gradually pushed westward by the deposition of detritus along the banks of the eastern tributaries which have built large, gently sloping fans across the valley.

SAN JOAQUIN RIVER.

DESCRIPTION.

San Joaquin River drains the western slope of the Sierra Nevada between Merced River on the north and Kings River on the south, the crest of its divide lying at an elevation of 13,000 to 14,000 feet above sea level in the vicinity of Mount Lyell and Mount Goddard. The river has numerous tributaries in this part of its drainage basin, many of which rise at high elevations.

The bed rock is granite, which in the upper reaches is bare and sharply marked by glacial action. The middle reaches are well timbered, the timber diminishing in the lower foothills as the stream approaches the valley, where the soil is well covered with brush and grass. The precipitation is largely in the form of snow on the higher elevations, which melts slowly and maintains a fairly constant stream flow throughout the season. Numerous small lakes also aid in equalizing the flow.

As the stream flows through the mountains its course is southwestward; as it reaches the valley it turns sharply to the northwest and flows along the axis of the valley. In this lower part of its course its fall is very slight, and the river is navigable for 100 miles or more from its mouth.

From its source in the high Sierra to the point where it joins the Sacramento at Suisun Bay the San Joaquin is about 200 miles long. It receives the discharges of all the Sierra streams south of the Mokelumne and from all the smaller creeks draining from the eastern slope of the Coast Range between San Francisco Bay and the Tehachapi. The rivers flowing from the Sierra to the San Joaquin run in a general southeasterly direction; the few creeks coming from the Coast Range flow northwestward. A list of the more important tributaries follows.

Principal tributaries of San Joaquin River.

From the west.	From the east.
Kings River: North Fork, Middle Fork, South Fork.	Mokelumne River.
Tule River.	Cosumnes Creek.
Kaweah River.	Calaveras River.
Kern River.	Stanislaus River: North Fork, Middle Fork, South Fork.
	Tuolumne River: North Fork, Middle Fork, South Fork.
	Eleanor Creek.
	Merced River.
	Yosemite River.
	Tanaya Creek.
	Chowchilla River.
	Fresno River.

Lumbering and mining are carried on in the upper part of the drainage basin. In the valley agriculture is the principal industry, and much fruit is produced in this section of the State. Grain is raised on the flat lands along the river bottoms. Water for irrigation is obtained from the Sierra streams.

CHARACTER OF WATER NEAR LATHROP.

Samples of water for this investigation were collected from the river at a point near the Southern Pacific Railroad drawbridge, between Lathrop and Tracy. The river at this point is sluggish at low-water stages, but during high water it overflows the levees that are built to confine it to its channel and floods the country for miles around. At the drawbridge the river is more or less influenced by the tides at periods of very low water. No gage records are available.

The chemical investigation shows the water to be of good quality, as regards dissolved mineral matter. It is, however, turbid at all seasons of the year, owing to the exceedingly fine silt which is brought down from the hills on the west side of the valley.

The presence near the river of so many large towns, sewage from which may contaminate the water, is sufficient to condemn the river as a source of public supply. There is no reason to believe, however, that the water could not be made pure and wholesome at slight expense by proper filtration and purification.

Mineral analyses of water from San Joaquin River at Lathrop.

[Parts per million unless otherwise stated.]

Date. From—	Date. To—	Turbidity.	Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.
1906.	1906.													
Jan. 1	Jan. 10	......	82	27	3.0	32	12	55	0.6	0.0	118	59	72	260
Jan. 11	Jan. 20	......	264	22	2.4	20	7.9	30	2.9	.0	76	46	39	186
Jan. 21	Jan. 30	......	160	21	1.2	10	5.0	22	4.2	.0	50	17	13	88
Jan. 31	Feb. 9	......	16	22	2.4	9.1	8.7	38	2.7	.0	85	36	20	204
Feb. 10	Feb. 19	......	84	17	1.6	15	5.9	17	1.3	.0	61	18	24	140
Feb. 20	Mar. 1	......	130	21	3.8	14	5.9	16	1.9	.0	57	15	12	122
Mar. 2	Mar. 11	......	128	20	6.0	13	6.4	11	1.3	.0	63	16	14	126
Mar. 12	Mar. 21	......	48	16	5.2	16	7.4	5.2	1.2	.0	64	22	15	138
Mar. 22	Mar. 31	......	78	22	4.0	15	6.5	8.7	2.0	.0	51	15	13	108
Apr. 1	Apr. 10	......	10	20	4.0	36	7.8	15	4.4	.0	71	15	15	186
Apr. 11	Apr. 20	......	76	16	2.0	11	5.2	13	2.0	.0	51	9.1	9.3	84
Apr. 21	Apr. 27	......	50	11	4.8	9.7	5.3	9.6	1.3	.0	38	11	6.9	84
May 3	May 10	......	58	10	2.4	8.6	2.9	8.7	2.1	.0	36	6.6	7.8	76
May 11	May 20	......	18	10	3.8	9.1	3.5	5.5	2.2	.0	26	9.1	7.9	60
May 21	May 30	......	32	10	2.0	8.9	3.6	6.9	3.7	.0	30	8.7	8.8	60
May 31	June 10	......	26	10	3.0	8.3	5.7	8.2	1.0	.0	38	9.7	9.6	68
June 11	June 20	......	8	8.0	3.2	8.8	4.6	10	.9	.0	29	12	7.8	72
June 21	June 30	......	6	14	4.8	11	6.4	6.2	.8	.0	30	14	7.8	70
					Fe.									
July 1	July 7	......	4	9.4	.20	8.0	6.7	9.5		.0	33	9.2	6.8	70
July 11	July 20	......	32	25	.20	8.6	2.9	6.4		.0	42	11	7.8	74
July 21	July 30	......	68	11	.10	8.0	3.2	12		.0	40	6.8	7.8	80
Aug. 1	Aug. 10	......	42	11	.15	16	4.6	15		.0	38	8.9	7.8	82
Aug. 11	Aug. 20	......	92	9.8	.27	11	3.9	12		.0	38	11	8.7	72
Aug. 21	Aug. 30	......	58	9.8	.30	11	4.5	15		.0	44	16	11	94
Aug. 31	Sept. 9	......	......	17	.25	19	6.8	20		.0	62	20	28	......
Sept. 10	Sept. 19	......	38	13	.20	25	8.5	27		.0	72	30	40	182
Sept. 21	Sept. 30	......	24	17	.20	29	12	37		.0	88	42	63	252
Oct. 1	Oct. 10	......	38	18	.15	36	13	64		.0	102	59	83	328
Oct. 11	Oct. 20	......	26	19	.10	41	16	68		.0	123	60	92	358
Oct. 21	Oct. 31	......	32	17	.10	33	16	56		.0	122	60	86	324
Nov. 1	Nov. 10	......	12	17	.7	32	14	52		.0	117	51	78	332
Nov. 11	Nov. 20	40	34	17	.30	28	12	52		.0	110	47	69	282
Nov. 21	Nov. 30	20	16	19	.20	30	14	48		.0	109	62	74	320
Dec. 1	Dec. 10	30	28	18	.25	31	13	68		.0	111	55	78	310
Dec. 11	Dec. 20	200	194	15	.40	22	8.8	25		.0	73	38	29	182
Dec. 21	Dec. 31	20	78	15	.15	21	6.4	26		.0	73	23	24	158
Mean.		......	60	16	*a*.23	18	8.0	27		.0	66	26	30	161
Per cent of anhydrous residue..		......	......	10.1	0.1	11.4	5.1	17.1		20.9	......	16.4	18.9	......

a Mean of Fe values after July 1.

Mineral analyses of water from San Joaquin River at Lathrop—Continued.

Date. From—	Date. To—	Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.
1907. Dec. 31	1908. Jan. 9	45	59	24	0.40	19	5.8	14	0.0	61	31	0.84	13	147
1908. Jan. 10	Jan. 19	60	37	20	.38	16	8.7	25	.0	57	36	2.4	22	155
Jan. 20	Jan. 29	80	84	22	.17	16	7.9	25	.0	59	29	1.4	22	146
Jan. 30	Feb. 8	50	91	23	.52	17	5.5	26	.0	59	29	1.2	22	149
Feb. 9	Feb. 18	70	193	21	.48	15	6.7	26	.0	61	27	.80	31	145
Feb. 19	Feb. 28	40	......	23	.15	16	8.8	33	.0	73	34	.88	31	172
Feb. 29	Mar. 9	65	57	21	.25	14	9.8	21	.0	66	28	.50	23	138
Mar. 10	Mar. 19	60	66	25	.39	14	6.3	24	.0	63	26	.34	17	124
Mar. 20	Mar. 29	40	61	23	.55	8.4	3.1	14	.0	42	17	1.4	9.0	94
Mar. 30	Apr. 8	50	56	20	.38	14	6.4	17	.0	37	27	1.1	19	112
Apr. 9	Apr. 18	30	78	13	.18	10	3.3	15	.0	37	25	1.2	13	84
Apr. 19	Apr. 28	65	80	14	.35	6.8	2.3	8.2	.0	29	16	1.2	6.0	62
Apr. 29	May 8	100	92	12	.45	6.6	3.1	6.1	.0	22	19	Tr.	4.0	52
May 9	May 18	35	40	14	.30	5.5	2.0	6.5	.0	26	14	1.7	5.0	58
May 19	May 28	40	51	17	.30	8.6	3.1	5.5	.0	32	14	.78	6.0	63
May 29	June 7	35	36	13	.25	6.0	2.4	8.0	.0	27	15	1.3	4.5	58
June 8	June 17	30	42	12	.32	6.8	2.8	6.2	.0	29	13	.92	6.1	56
June 18	June 27	25	52	11	.21	7.8	2.9	12	.0	32	15	.52	11	66
June 28	July 7	30	36	16	.20	20	7.2	17	.0	55	24	1.4	16	131
July 8	July 17	6	......	15	.20	17	4.4	21	.0	53	21	.35	28	125
July 18	July 27	30	29	23	.33	21	11	34	.0	76	30	.36	49	203
July 28	Aug. 6	15	18	15	.15	29	15	52	.0	98	51	2.0	77	286
Aug. 7	Aug. 16	7	......	16	.08	25	16	68	.0	107	58	......	103	357
Aug. 17	Aug 26	12	18	16	.28	33	18	70	.0	116	59	2.0	98	347
Aug. 27	Sept. 5	22	25	19	.20	39	20	72	.0	128	70	1.0	108	396
Sept. 6	Sept. 15	6	......	25	.20	40	21	77	.0	139	73	.64	116	416
Sept. 16	Sept. 25	30	37	20	.29	37	20	70	.0	126	72	.36	119	391
Sept. 26	Oct. 5	25	34	19	.10	34	18	58	.0	123	67	Tr.	87	364
Oct. 6	Oct. 15	10	......	24	.15	37	19	68	.0	124	67	.94	103	373
Oct. 16	Oct. 25	40	30	19	.12	25	14	43	.0	98	61	.86	73	297
Oct. 26	Nov. 4	35	26	18	.10	25	14	49	.0	95	52	.68	69	268
Nov. 5	Nov. 14	9	......	17	.18	29	15	56	.0	104	53	.70	80	302
Nov. 15	Nov. 24	Tr.	......	19	.75	31	18	73	.0	107	70	1.4	97	372
Nov. 25	Dec. 4	5	......	20	.28	28	15	60	.0	105	57	1.0	79	324
Dec. 5	Dec. 14	26	16	17	.38	25	15	49	.0	85	55	2.1	59	256
Dec. 15	Dec. 24	18	15	27	.50	21	13	46	.0	90	44	1.7	54	234
Dec. 25	Dec. 31	25	......	20	.50	23	14	49	.0	90	44	1.5	58	247
Mean..........		34	52	19	.30	20	10	36	.0	74	39	1.0	47	205
Percent of anhydrous residue..		......	......	9.1	0.1	9.6	4.8	17.3	17.3	......	18.7	0.5	22.6	......

MOKELUMNE RIVER.

DESCRIPTION.

Mokelumne River rises on the western slope of the Sierra Nevada in about the east central part of the State. It flows generally westward to southwestward and empties into the series of sloughs near the confluence of San Joaquin and Sacramento rivers. The drainage basin comprises about 657 square miles of territory, heading well back toward the crest of the Sierra at an elevation of 8,000 feet above sea level.

The bed rock is granite, with good soil covering and heavy timber growth in the middle and upper portions of the basin; in the lower portions the slopes are less rugged, the vegetation is brush and scattered oak timber, and there are large areas of cultivated land and pasture. Numerous small glacial lakes and moraines occur in the upper reaches of the basin. On the upper levels the precipitation is partly in the form of snow, which melts in the early spring, causing the greatest stream discharge to come during the months of April, May, and June. The river is diverted at several points for the purposes of mining and power development, but the diversions have no appreciable effect on the discharge.

CHARACTER OF RIVER WATER NEAR CLEMENTS.

Samples of water for this investigation were collected by the gage reader at the station near Clements.[a] The stream at this point is straight and the lower of its banks is liable to overflow at high stages. The bed is composed of gravel and is subject to slight change.

Except during periods of extremely high water the Mokelumne carries little suspended matter, and even this is such as can be removed easily by filtration.

The water may be classed as carbonate, for bicarbonates, calcium, and magnesium constitute the greater part of the dissolved mineral matter. Total solids are not high, showing that the water is fitted for almost any industrial use. It should give no trouble in boilers, even without preliminary treatment, and if filtered should furnish a satisfactory domestic supply.

[a] For data regarding gage heights and discharge see Water-Supply Papers U. S. Geol. Survey Nos. 134, 177, and 213.

Mineral analyses of water from Mokelumne River at Clements.

[Parts per million unless otherwise stated.]

Date. From—	Date. To—	Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Mean discharge. Acre-feet per day.	Mean discharge. Cubic feet per second.
1906.	1906.														
Jan. 1	Jan. 10	126	25	1.6	25	6.7	23	0.0	0.0	84	24	19	126	122	61.5
Jan 11	Jan. 20	504	22	5.0	23	3.4	16	2.3	.0	45	19	7.6	70	4,580	2,309
Jan. 21	Jan. 30	.....	19	2.6	12	3.1	......	2.3	.0	40	10	7.4	......	1,345	678
Jan. 31	Feb. 9	66	22	2.2	13	4.0	7.6	1.0	.0	40	17	8.8	86	742	374
Feb. 10	Feb. 19	46	17	2.0	10	3.0	13	2.0	.0	47	11	9.8	84	1,333	672
Feb. 20	Mar. 1	46	16	2.4	9.1	3.2	9.9	.9	.0	41	11	7.5	86	2,713	1,368
Mar. 2	Mar. 11	.....	16	2.2	9.1	2.7	5.2	2.4	.0	40	8.7	8.7	......	2,050	1,034
Mar. 12	Mar. 21	92	17	3.0	9.4	3.8	6.9	2.6	.0	43	14	8.8	86	4,562	2,300
Mar. 22	Mar. 31	126	11	6.0	11	3.8	7.9	2.5	.0	36	8.7	7.8	74	8,678	4,375
Apr. 1	Apr. 10	84	15	3.0	7.1	3.2	9.6	1.5	.0	35	6.4	4.9	70	5,725	2,886
Apr. 11	Apr. 20	60	7.6	3.8	7.7	4.4	5.7	1.7	.0	28	4.6	3.9	52	5,500	2,773
Apr. 21	Apr. 30	28	13	8.4	17	7.2	6.9	1.2	.0	24	11	5.9	46	6,276	3,164
May 1	May 10	60	11	2.6	6.6	1.8	6.0	1.7	.0	24	7.9	3.9	54	10,747	5,418
May 11	May 20	54	11	2.4	7.2	2.7	5.8	2.0	.0	24	5.3	5.9	42	9,320	4,699
May 21	May 30	40	7.2	2.0	6.0	2.7	5.5	.9	.0	22	8.4	5.1	46	8,192	4,130
May 31	June 10	28	8.8	2.6	7.4	4.0	6.8	1.3	.0	25	12	4.1	52	9,892	4,987
June 11	June 19	52	9.0	4.6	6.0	5.3	5.4	1.0	.0	17	8.1	4.4	46	14,457	7,288
June 21	June 30	66	11	4.0	6.3	1.8	9.0	......	.0	17	5.8	3.9	30	11,275	5,684
				Fe.											
July 2	July 10	56	17	.10	8.0	4.2	14		.0	22	4.9	4.8	56	12,081	6,091
July 11	July 20	74	20	.10	9.7	3.7	18		.0	39	8.6	6.7	56	6,835	3,446
July 21	July 30	86	8.4	.10	6.9	2.0	8.0		.0	25	4.8	5.8	44	2,923	1,474
Aug. 1	Aug. 10	42	11	.10	22	4.4	19		.0	43	14	5.8	78	1,111	562
Aug. 11	Aug. 20	60	13	.10	14	4.0	14		.0	40	12	5.8	78	653	329
Aug. 22	Aug. 30	58	12	.15	13	3.8	10		.0	44	14	7.7	76	392	198
Sept. 1	Sept. 10	42	9.4	.10	15	3.9	9.8		.0	47	13	6.3	74	378	191
Sept. 13	Sept. 20	52	19	.23	19	5.9	13		.0	62	18	12	118	394	199
Sept. 21	Sept. 30	50	11	.20	13	4.1	39		.0	46	13	8.1	90	384	194
Oct. 1	Oct. 8	68	12	.10	17	3.9	18		.0	63	10	9.1	97	351	177
Oct. 11	Oct. 20	68	9.2	.10	16	2.0	10		.0	49	11	7.6	70	382	193
Oct. 21	Oct. 31	90	9.6	.13	15	3.6	14		.0	49	16	6.6	78	384	194
Nov. 1	Nov. 10	88	13	.30	11	3.2	14		.0	65	12	6.6	84	603	304
Nov. 11	Nov. 20	64	16	1.00	14	5.2	13		.0	63	13	8.6	112	447	225
Nov. 21	Nov. 30	62	9.6	.07	17	4.9	14		.0	62	17	8.6	98	429	216
Dec. 1	Dec. 10	128	11.2	.20	21	4.1	13		.0	58	15	7.6	96	425	214
Dec. 11	Dec. 20	190	16	.15	15	4.5	14		.0	48	13	9.7	118	2,256	1,138
Dec. 21	Dec. 31	88	12	.05	11	4.0	15		.0	38	14	8.2	86	2,457	1,239
Mean		84	14	a.18	12	3.8	13		.0	42	12	7.3	75	3,900	1,883
Per cent of anhydrous residue		.....	16.8	0.2	14.4	4.6	15.6		25.2	......	14.4	8.8	......	......	....

a Mean of Fe values after July 1.

STANISLAUS RIVER.

DESCRIPTION.

Stanislaus River heads well back into the higher portion of the Sierra Nevada, at altitudes of 10,000 to 12,000 feet above sea level, and drains a portion of its western slope lying between the basins of Mokelumne River on the north and the Tuolumne on the south. Its course is in general southwestward, and it joins the San Joaquin in the vicinity of Vernalis, about halfway between Modesto and Stockton. In the upper parts of the basin the river has many tributaries which rise in small glacial lakes.

The topography of the drainage area is rough and broken, with high mountain peaks. The bed rock is granite, which is bare and destitute of timber growth above the elevation of 8,000 feet except about the lakes and on the moraines. In the middle parts of the basin the soil is deep and the growth of timber is good. Precipitation is largely in the form of snow, which remains on the higher elevations well into the summer months, and which produces on melting a fairly constant stream flow throughout the season.

The principal industries are mining in the higher areas and raising of grain and fruit in the lower valleys. Water for irrigation is taken from the river at points above Knights Ferry, to be used in the region between Knights Ferry and Stockton.

CHARACTER OF WATER.

Samples of water for this investigation were collected at the gaging station at Knights Ferry [a] by the gage reader during the first part of the year 1906. Results for that period showed such close resemblance between the waters of Tuolumne, Merced, and Stanislaus rivers that the sampling stations on the Merced and Stanislaus were discontinued and the results obtained with the Tuolumne were regarded as typical for the surface waters of this section of the State.

The stream at the sampling station flows between low banks of cemented gravel. The bed is composed of sand and gravel and is liable to slight change.

The results of the analytical study are presented in the accompanying analyses.

The chemical analyses show that the water would be well adapted to almost any industry if the suspended matter were removed, and proper clarification would fit it for use in boilers without further treatment. The large number of settlements in the basin make this water unsafe for domestic purposes without purification, and except in irrigation enterprises and power development, little use is made of it.

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[a] For data regarding gage heights and discharge see Water-Supply Papers U. S. Geol. Survey Nos. 81, 100, 134, 177, and 213.

Mineral analyses of water from Stanislaus River at Knights Ferry.

[Parts per million unless otherwise stated.]

Date.		Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Mean discharge, including canal.		Mean discharge without canal.	
From—	To—													Acre-feet per day.	Cubic feet per second.	Acre-feet per day.	Cubic feet per second.
1906.	1906.																
Jan. 1	Jan. 10	86	9.6	0.6	23	7.4	15	0.1	0.0	106	22	16	138	831	419	754	380
Jan. 11	Jan. 20	642	25	1.2	16	4.7	12	....	.0	63	14	5.4	116	10,872	5,481	10,774	5,432
Jan. 21	Jan. 30	118	20	1.4	14	4.7	37	2.7	.0	61	8.6	4.4	76	3,278	1,653	3,254	1,641
Jan. 31	Feb. 9	76	22	1.4	11	14	14	1.9	.0	61	15	5.9	126	2,294	1,157	2,169	1,094
Feb. 10	Feb. 19	190	18	2.2	17	5.7	6.8	.4	.0	61	14	6.2	118	3,526	1,778	3,383	1,706
Feb. 20	Mar. 1	118	19	1.8	16	5.8	4.3	1.3	....	....	8.4	....	98	6,409	3,231	6,328	3,190
Mar. 2	Mar. 11	124	16	3.6	....	5.7	6.5	1.3	.0	64	11	5.3	114	5,138	2,590	4,048	2,545
Mar. 12	Mar. 20	126	17	3.8	13	5.3	4.8	3.4	.0	60	11	9.8	114	9,387	4,733	10,317	5,201
Mar. 22	Mar. 31	574	20	3.4	12	5.5	9.0	1.4	.0	55	8.1	5.4	120	17,106	8,624	17,058	8,600
Apr. 1	Apr. 10	84	13	3.2	11	5.2	10	1.9	.0	55	6.4	3.9	76	9,814	4,948	9,755	4,918
Apr. 11	Apr. 20	94	10	2.4	8.6	5.0	3.6	1.1	.0	38	6.4	4.2	68	10,420	5,253	10,245	5,165
Apr. 21	Apr. 28	94	7.0	3.8	....	4.9	11	2.6	.0	34	6.4	3.7	54	12,164	6,133	11,949	6,024
May 2	May 10	80	11	3.2	7.1	3.1	5.8	1.0	.0	30	17	3.9	58	18,602	9,378	18,376	9,264
May 11	May 20	38	13	2.0	5.7	3.3	8.8	1.3	.0	30	23.4	4.5	58	16,884	8,512	16,649	8,394
May 21	May 30	58	11	2.4	6.0	3.6	8.8	1.2	.0	34	9.6	5.4	68	14,026	7,071	13,779	6,947
May 31	June 10	16	7.6	3.0	8.0	4.6	7.3	....	.0	28	8.2	4.4	66	15,178	7,652	14,909	7,516
June 11	June 20	86	8.8	2.8	7.1	3.5	7.4	0.8	.0	25	9.2	4.9	44	23,405	11,800	23,147	11,670
June 21	June 30	66	8.8	3.8	8.1	3.1	9.0	.6	.0	28	8.2	4.9	48	16,560	8,349	16,376	8,256
				Fe.													
July 1	July 10	78	7.0	.20	8.3	4.6	9.4		.0	26	9.4	3.9	46	15,989	8,061	15,716	7,923
July 11	July 20	48	11	.10	7.1	3.0	7.4		.0	33	6.8	4.1	68	9,506	4,793	9,304	4,691
July 21	July 31	138	13	.30	9.7	3.2	9.1		.0	38	6.8	4.9	74	5,955	3,002	5,721	2,884
Mean		140	14	a.20	11	5.0	11		.0	46	11	5.6	83	10,826	5,453	......	......
Per cent of anhydrous residue		...	17.3	0.3	13.6	6.2	13.6		28.5	....	13.6	6.9	...	......	......	......	......

a Mean of Fe values after July 1.

TUOLUMNE RIVER.

DESCRIPTION.

Tuolumne River rises on the western slope of the Sierra Nevada and drains the country between Stanislaus River on the north and Merced River on the south, flowing in a general west to southwesterly course, and emptying into the San Joaquin near Modesto. The country throughout the basin is rough and rugged, especially along the main river, which cuts through solid granite, with high precipitous cliffs on both sides. This stream drains the northern portion of the Yosemite National Park, within which lies the Grand Canyon of the Tuolumne and the Hetch Hetchy Valley.

The bed rock of the basin is granite, which on the higher elevations is bare and glaciated. Along the middle reaches of the river the soil covering is good, with a heavy growth of pine, fir, cedar, and kindred trees. On the lower reaches there is a good covering of brush, which diminishes in the foothills as the stream approaches the San Joaquin Valley. This part of the basin has a light soil covering, with growth of grass which is used for pasturage. In the upper portions of the basin are several glacial lakes, some of the larger offering exceptional advantages for the construction of storage reservoirs.

Several diversions are made from the river for purposes of irrigation. At Lagrange, where the stream leaves the foothills, are the head works of the Turlock and Modesto irrigation canals which supply water to the valley regions around Modesto. The main industries of this region are mining, stock raising, and agriculture. Water from the river is used for no other purpose until it reaches the valley, where some is used in the town of Modesto as a domestic supply.

CHARACTER OF WATER AT LAGRANGE.

Samples of water for this investigation were collected at the gaging station at Lagrange[a] by the gage reader. The river at this point is swift, shallow, and wide at high stages, and very sluggish during periods of low water. The bed of the stream is composed of coarse gravel and is fairly permanent.

The results of the investigation are shown by the accompanying analyses.

The water is well adapted to almost any industrial use without previous treatment. Owing to the comparatively large population in the lower drainage area the water would be unfit for domestic use unless diverted from the stream far above all points of possible contamination or unless proper means should be employed for its purification.

Mineral analyses of water from Tuolumne River at Lagrange.

[Parts per million unless otherwise stated.]

Date.		Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Mean discharge, including canals.		Mean discharge, without canals.	
From—	To—													Acre-feet per day.	Cubic feet per second.	Acre-feet per day.	Cubic feet per second.
1906.	1906.																
Jan. 1	Jan. 10	38	26	1.4	15	4.4	24	0.3	0.0	81	10	14	100	248	125	171	86.2
Jan. 11	Jan. 20	184	20	3.4	5.7	3.9	13	1.5	.0	41	14	5.9	...	13,456	6,784	13,135	6,622
Jan. 21	Jan. 30	72	18	2.2	11	4.4	19	2.2	.0	43	14	6.0	52	3,673	1,852	3,233	1,630
Jan. 31	Feb. 9	14	14	2.2	5.4	2.9	....	1.3	.0	38	19	5.4	72	2,298	1,159	1,180	595
Feb. 10	Feb. 19	40	15	1.8	9.1	4.7	8.4	1.2	.0	41	7.6	19	82	3,649	1,845	2,885	1,455
Feb. 20	Mar. 1	100	15	2.8	10	5.3	7.9	2.1	.0	51	9.8	6.1	100	6,875	3,466	6,292	3,172
Mar. 2	Mar. 11	64	15	2.6	9.4	5.1	8.0	1.5	.0	47	13	6.7	76	5,543	2,795	5,345	2,695
Mar. 12	Mar. 21	198	12	4.0	9.4	5.6	4.1	1.3	.0	46	9.2	5.9	70	15,547	7,838	15,257	7,692
Apr. 1	Apr. 10	82	16	4.8	11	5.1	14	3.8	.0	36	16	5.9	76	11,572	5,834	11,312	5,703
Apr. 11	Apr. 20	70	8.6	2.4	6.3	5.4	8.8	1.3	.0	26	4.8	3.9	48	12,522	6,313	11,608	5,852
Apr. 21	Apr. 30	84	7.2	3.0	7.7	4.6	5.8	1.2	.0	27	7.9	4.9	56	14,611	7,366	13,442	6,777
May 1	May 9	88	8.6	2.4	6.6	1.9	3.8	1.4	.0	25	4.8	4.5	58	19,776	9,970	18,054	9,102
May 11	May 20	68	10	2.8	5.1	1.7	6.9	1.9	.0	19	4.4	4.9	62	23,516	11,856	20,672	10,422
May 21	May 30	102	11	2.4	6.5	3.0	7.7	1.3	.0	20	9.2	4.1	42	22,215	11,200	20,896	10,535
May 31	June 10	24	7.6	4.0	9.7	3.9	6.6	2.6	.0	21	21	4.7	60	20,533	10,352	18,995	9,576
June 11	June 20	38	6.6	3.4	5.7	3.2	6.9	0.6	.0	16	6.9	3.9	42	33,525	16,902	31,618	15,941
June 21	June 30	20	6	3.0	3.7	2.0	8.5	0.8	.0	15	7.7	4.9	40	28,727	14,483	26,727	13,475

[a] For data concerning gage heights and discharges see Water-Supply Papers U. S. Geol. Survey Nos. 81, 85, 100, 134, 177, and 213.

Mineral analyses of water from Tuolumne River at Lagrange—Continued.

Date.		Suspended matter.	Silica (SiO_2).	Fe.	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Mean discharge, including canals.		Mean discharge, without canals.	
From—	To—												Acre-feet per day.	Cubic feet per second.	Acre-feet per day.	Cubic feet per second.
1906.	1906.															
July 1	July 10	28	5.4	.10	5.1	4.0	5.4	.0	13	6.3	3.9	42	31,893	16,079	29,8[illegible]	15,070
July 11	July 20	26	8.4	.05	5.1	1.9	7.9	.0	17	7.1	4.7	54	22,795	11,493	20,829	10,501
July 21	July 31	44	5.2	.10	4.9	1.4	9.0	.0	15	3.8	4.9	42	15,346	7,737	13,372	6,742
Aug. 1	Aug. 10	16	11	.07	7.9	2.1	11	.0	21	11	4.8	42	6,635	3,345	4,689	2,364
Aug. 11	Aug. 20	68	4.8	.18	7.4	3.0	8.0	4.0	14	5.8	5.8	46	4,300	2,168	3,040	1,533
Aug. 22	Aug. 29	88	6.6	.23	11	3.6	6.3	.0	30	7.9	4.9	46	2,560	1,291	1,418	715
Sept. 1	Sept. 9	74	6.6	.18	8.0	5.0	17	.0	52	8.1	10	74	132	66.4	48.4	24.4
Sept. 11	Sept. 20	18	9.8	.20	7.2	4.7	18	.0	52	9.1	8.1	82	86.7	43.7	0	0
Sept. 21	Sept. 30	20	16	.10	12	5.4	24	.0	59	15	8.1	112	629	317	0	0
Oct. 1	Oct. 10	46	8.8	.10	16	5.4	12	.0	73	13	6.1	92	550	277	69.4	35.0
Oct. 11	Oct. 20	50	11	.20	16	7.5	13	.0	65	18	7.6	104	457	230	181	91.5
Oct. 21	Oct. 31	50	11	.10	18	6.4	13	.0	72	17	7.1	134	289	146	289	146
Nov. 1	Nov. 9	96	14	.7	21	6.7	19	.0	77	15	8.1	116	536	270	536	270
Nov. 11	Nov. 20	12	8.8	.25	12	5.1	14	.0	53	28	7.6	100	577	291	577	291
Nov. 22	Nov. 30	32	9.8	.10	17	5.1	15	.0	64	10	7.1	88	321	162	321	162
Dec. 1	Dec. 10	72	16	.10	18	5.3	12	.0	65	15	7.1	122	457	230	457	230
Dec. 11	Dec. 20	284	8.4	.5	17	6.8	14	.0	72	21	7.1	94	3,456	1,743	3,456	1,743
Dec. 21	Dec. 31	64	7.4	.20	10	4.8	13	.0	39	13	5.6	74	4,647	2,343	4,647	2,343
Mean		68	11	[a] .19	10	4.3	12	.0	41	12	6.6	74	9,542	4,811	....	....
Per cent of anhydrous residue		...	14.4	0.2	13.1	5.6	15.8	26.3	....	15.8	8.8	...	....	....	....	....

[a] Mean of Fe values after July 1.

MERCED RIVER.

DESCRIPTION.

Merced River drains that portion of the western slope of the Sierra Nevada located between Tuolumne River on the north and the San Joaquin on the south, its drainage area being much smaller than that of the Tuolumne. It has numerous tributaries, many of which are of considerable size. The general course of the stream is from the mountains westward to southwestward, and it enters San Joaquin River near Newman.

The topography of this drainage area resembles that of Tuolumne River, being rough and broken in the upper reaches. This basin includes the Yosemite National Park and Yosemite Valley, with its precipitous walls and domes, and the great waterfalls, which plunge into the valley over cliffs that rise 2,000 to 3,000 feet above its floor.

On the upper reaches of the basin above Yosemite Valley the bed rock is granite, worn bare and smooth by glacial action. The middle reaches of the basin are well timbered. In the basin of the South Fork is the Mariposa grove of big trees. The timber growth extends well down into the lower elevations of the foothills, where the covering is brush and grass, which is used extensively for pasturage. Numerous lakes are scattered over the upper portion of the basin. The precipitation in the upper areas is largely in the form of snow, which melts in the spring except on some of the highest peaks, where it may remain during the entire year. Below Merced Falls canals divert water for the irrigation of lands along the river bottoms and in the San Joaquin Valley.

CHARACTER OF WATER AT MERCED FALLS.

Samples for this investiagtion were collected at the gaging station at Merced Falls[a] by the gage reader. The stream at this point runs in a rocky bed walled in on both sides by high, steep banks. The bed is of gravel and is subject to some change at high water. Owing to the similarity between the results obtained during the first six months on this stream and on the Stanislaus and Tuolumne, which drain practically the same watersheds, work was discontinued at the end of July on Merced and Stanislaus rivers and only the Tuolumne station was kept up. The results of the investigation are presented in the accompanying analyses.

The total mineral matter is low, as would be expected from a stream draining an area whose rocks are almost entirely granite. Except for the small amount of suspended matter, the water is fit for almost any industrial use, and, if filtered, it would constitute an excellent domestic supply. The water is now being used only for irrigation.

Mineral analyses of water from Merced River at Merced Falls.

[Parts per million unless otherwise stated.]

Date.		Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Mean discharge.	
From—	To—													Acre-feet per day.	Cubic feet per second.
1906.	1906.														
Jan. 1	Jan. 10	36	24	1.2	21	5.6	15	.03	0.0	77	19	9.4	116	206	104
Jan. 11	Jan. 20	260	27	1.4	8.3	4.0	11	2.9	.0	41	13	4.4	68	9,211	4,644
Jan. 21	Jan. 30	......	17	1.6	9.1	4.6	16	2.0	.0	40	42	4.9	.....	1,837	926
Jan. 31	Feb. 9	8	18	3.0	9.4	3.9	6.9	1.9	.0	43	15	5.9	68	928	468
Feb. 10	Feb. 19	18	20	1.2	7.4	3.1	7.2	1.3	.0	43	11	8.3	86	1,475	744
Feb. 20	Mar. 1	30	18	3.2	13	5.1	6.5	1.4	.0	51	7.9	6.9	86	3,897	1,965
Mar. 2	Mar. 11	6.0	13	1.2	15	5.3	5.5	.5	.0	49	11	8.0	88	3,290	1,659
Mar. 12	Mar. 21	86	15	4.6	7.7	4.8	8.0	1.3	.0	62	7.6	6.9	82	11,584	5,840
Apr. 1	Apr. 10	66	13	3.0	10	4.9	7.7	2.1	.0	47	10	5.5	74	6,794	3,425
Apr. 11	Apr. 20	66	12	2.6	9.7	5.0	6.6	2.5	.0	31	12	4.9	68	6,024	3,037
Apr. 21	Apr. 27	100	16	3.0	8.3	6.3	5.5	1.3	.0	28	5.4	3.9	42	8,136	4,102
May 2	May 10	40	9.4	2.8	10	2.4	4.9	1.7	.0	30	7.4	4.9	54	11,465	5,780
May 11	May 20	8.0	10	2.0	7.7	2.6	8.0	2.0	.0	20	4.3	4.9	68	13,350	6,731
May 21	May 30	......	6.8	2.6	5.7	3.1	4.7	1.3	.0	21	9.2	5.9	40	14,785	7,454
May 31	June 10	16	15	3.4	9.1	2.0	7.9	......	.0	25	8.6	4.9	62	11,858	5,978
June 11	June 20	32	6.4	3.6	4.8	3.9	6.8	.6	.0	16	8.6	3.4	54	20,262	10,215
June 21	June 30	68	6.4	4.6	6.9	1.7	8.2		.0	17	7.6	4.9	50	18,913	9,535
July 1	July 10	32	15	1.0	8.0	4.2	13		.0	17	7.3	3.9	40	18,718	9,437
				Fe.											
July 11	July 20	24	6.2	.10	4.0	1.5	6.5		.0	17	5.6	4.7	46	12,665	6,385
July 21	July 31	38	16	.10	6.9	1.3	6.3		.0	18	3.3	4.5	48	6,467	3,260
Mean............		52	14	[b].10	9.1	3.8	9.3		.0	35	11	5.6	65	9,093	4,584
Per cent of anhydrous residue..		......	20	0.2	13.0	5.4	13.3		24.3	.....	15.8	8.0	.....	......	......

[a] For data regarding gage heights and stream flow see Water-Supply Papers U. S. Geol. Survey Nos. 134, 177, and 213.

[b] Mean of Fe values after July 1.

KERN RIVER.

DESCRIPTION.

Kern River, rising in the highest elevations of the Sierra Nevada at the extreme southern limit of the range, and collecting its waters from the western and southern slopes of Mount Whitney and numerous other high peaks grouped around it which reach altitudes exceeding 14,000 feet above sea level, discharges into the San Joaquin just east of Bakersfield. For about 65 miles its course is in general southward; it then turns and flows southwestward into the valley. Its drainage basin, 2,345 square miles in extent, is larger than that of any other tributary of the San Joaquin. The Kern receives numerous tributaries, the principal ones draining the higher elevations of the main crest of the Sierra and entering from the east.

The topography of the basin is extremely rough and broken in the upper reaches, becoming less rugged in the middle areas in the vicinity of Kernville, where there is a large, cultivated valley. Below this valley the stream enters a rough canyon, from which it emerges into the flat country of the San Joaquin Valley. The entire flow of the stream, except during extreme flood stages, is diverted and used for irrigation at points where the river emerges from the foothills.

The bed rock of the Kern basin is largely granite. Above an altitude of 10,000 feet vegetation is practically absent, but between altitudes of 3,000 and 10,000 feet there is good depth of soil, with timber and brush covering. The lower reaches have a light covering of brush and grass.

A number of lakes and marshes are scattered throughout this basin, but they are less numerous than in the basins farther north. Several power plants are located on the Kern, none of which, however, receive water from storage reservoirs, the diversions being made from the natural flow of the stream and again returned to the river channel.

The precipitation is very light throughout the basin except on the higher elevations, where snow remains through the summer months. For this reason there are few floods during the winter and in the early spring, the periods of highest water occurring some time during the summer.

CHARACTER OF WATER NEAR BAKERSFIELD.

Samples of water for this investigation were collected at the gaging station of the Kern County Land Company about 5 miles above Bakersfield and at the mouth of the canyon.[a] The stream at this place is wide and shallow at ordinary stages, with sandy bottom. The channel has been improved as much as possible above and below

[a] For data concerning gage heights and discharge, see Water-Supply Papers U. S. Geol. Survey Nos. 85, 100, 134, 177, and 213.

the gaging station to facilitate measurement. The results of the investigation are presented in the accompanying analyses.

The dissolved solids are not high, and the water is well adapted for industrial use if clarified, for it contains little else except calcium, magnesium, and bicarbonates in solution.

During the greater part of the year it would probably be necessary to add small quantities of soda ash or some such scale preventive if the water were used in boilers, but the deposit formed would not be of objectionable character and could be readily removed. The amount of suspended matter carried by the river in times of flood is never very great, and owing to its coarse, sandy character it readily settles out on standing.

Mineral analyses of water from Kern River at Bakersfield.

[Parts per million unless otherwise stated.]

Date.		Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Mean discharge.	
From—	To—													Acre-feet per day.	Cubic feet per second.
1906.	1906.														
Jan. 1	Jan. 10	14	44	2.2	23	5.3	40	0.4	0.0	107	24	13	170	492	248
Jan. 11	Jan. 19	32	29	.8	23	5.4	25	2.1	.0	92	41	12	210	1,874	945
Jan. 21	Jan. 30	50	24	2.4	19	3.2	24	2.4	.0	89	25	13	158	1,467	740
Jan. 31	Feb. 9	1,836	22	.8	39	6.1	105	2.6	.0	110	71	14	270	1,083	546
Feb. 10	Feb. 19	Trace.	26	1.6	26	3.9	19	1.3	.0	96	37	15	200	1,220	615
Feb. 20	Mar. 1	1,168	22	1.8	22	3.3	59	2.2	.0	97	24	12	162	2,669	1,346
Mar. 2	Mar. 11	144	18	3.4	21	5.4	25	2.9	.0	90	33	14	134	1,597	805
Mar. 12	Mar. 21	196	25	5.4	19	3.8	14	3.8	.0	71	18	12	152	5,185	2,614
Mar. 23	Mar. 31	166	23	6.0	17	4.6	12	2.8	.0	74	16	17	142	5,963	3,006
Apr. 1	Apr. 9	88	23	5.2	16	4.0	16	3.1	.0	69	18	7.6	128	4,258	2,298
Apr. 11	Apr. 20	398	21	4.6	21	9.4	15	2.7	.0	90	22	9.8	190	5,405	2,725
Apr. 21	Apr. 30	102	11	......	19	8.9	13	1.8	.0	54	15	6.9	88	7,351	3,706
May 2	May 9	112	19	3.2	18	5.3	9.8	1.2	.0	53	11	6.9	112	8,263	4,166
May 11	May 20	170	18	3.2	9.4	3.2	11	.6	.0	46	6.8	6.4	84	12,429	6,266
May 21	May 31	146	12	4.2	13	4.3	10	1.3	.0	40	14	5.4	94	13,706	6,910
June 1	June 10	60	16	3.6	12	3.6	9.3	1.0	.0	43	16	6.9	82	11,602	5,849
June 12	June 20	130	11	4.6	8.3	3.5	10	.9	.0	33	9.1	4.5	70	17,742	8,945
June 21	June 30	128	12	5.0	10	2.6	12		.0	30	9.4	4.4	56	32,811	16,542
				Fe.											
July 1	July 10	116	12	.23	7.4	2.8	16		.0	36	12	4.6	68	15,623	7,876
July 11	July 20	126	7.4	.10	4.9	1.4	9.5		.0	32	10	5.3	60	28,779	14,509
July 21	July 31	90	9.4	.10	8.6	1.6	9		.0	30	5.8	5.8	56	10,189	5,137
Aug. 1	Aug. 10	30	12	.10	15	2.5	12		.0	38	13	5.8	78	5,991	3,020
Aug. 11	Aug. 19	30	12	.13	9.4	3.1	14		.0	44	10	5.3	80	4,616	2,327
Aug. 23	Aug. 30	22	20	.18	13	3.3	18		.0	57	14	6.4	118	3,011	1,518
Sept. 1	Sept. 10	28	11	.13	17	3.8	19		.0	60	18	6.8	102	2,471	1,246
Sept. 11	Sept. 20	18	23	.25	16	3.5	13		.0	63	17	7.6	114	1,803	909
Spet. 21	Sept. 30	30	15	.10	18	3.9	26		.0	72	16	8.1	118	1,517	765
Oct. 1	Oct. 10	30	14	.10	15	3.0	20		.0	80	18	7.1	114	1,319	665
Oct. 11	Oct. 20	Trace.	15	.10	25	5.5	23		.0	89	23	9.1	148	1,202	606
Oct. 21	Oct. 31	26	14	.10	22	3.5	22		.0	97	27	10	146	1,113	561
Nov. 1	Nov. 10	Trace.	14	.50	21	4.2	22		.0	95	26	10	146	1,091	550
Nov. 11	Nov. 17	18	20	.10	24	5.0	26		.0	100	30	11	148	1,004	506
Nov. 22	Nov. 30	14	17	.15	26	5.5	25		.0	105	27	10	150	930	469
Dec. 1	Dec. 10	22	16	.10	22	4.3	26		.0	89	26	14	162	1,101	555
Dec. 11	Dec. 12	......	.....	......	.....	.....	....		.0	107	......	10	.....	1,319	665
Mean		163	18	[a].15	18	4.2	22		.0	71	21	9.1	127	6,234	3,147
Per cent of anhydrous residue..		......	14.1	0.1	14.1	3.3	17.3		27.5	......	16.5	7.1	.....	......	......

[a] Mean of Fe values after July 1.

TULARE LAKE.

Tulare Lake is a shallow body of water lying in a large, elongated depression just south of Kings River. Its level fluctuates widely from year to year; at times it is of great extent; at other times its bed is practically dry. Its drainage area also is indefinite: Sometimes the waters of Kings River overflow into it; sometimes it discharges into Kings River; and sometimes there is no flow in either direction. In 1906 the bed was dry and large grainfields covered the lake floor; in 1909 the water area was many miles in extent.

The reason for these peculiar fluctuations in size and drainage is to be found in the climate and topography of the region. The alluvial divide between Tulare Lake and San Joaquin River is low; the bottom of Tulare Lake is at a level not differing greatly from that of the bottom of Kings River; hence the relative levels of the water in the two must determine the direction of flow. Floods in Kings River will send discharge waters into Tulare Lake, and low water in Kings River will cause flow in the opposite direction. The connection between the two, however, is not constant, and in times of low water it is absent altogether. At such times Tulare Lake gradually dries up and becomes a gently sloping valley.

In 1889 this process of evaporation had been in progress for several years and the waters of the lake were so concentrated as to be unfit for irrigation or other purposes. At this time an analysis of the water was made for Prof. E. W. Hilgard, of the University of California, and this analysis is here given to show the interesting results of concentration on the waters of the region.

Analysis of water of Tulare Lake, February, 1889.[a]

[Parts per million.]

Silica (SiO_2)	32	Carbonate radicle (CO_3)	958
Calcium (Ca)	13	Sulphate radicle (SO_4)	1,023
Magnesium (Mg)	11	Chlorine (Cl)	996
Sodium (Na)	1,763	Organic matter	227
Potassium (K)	121	Total solids	5,195

The analysis shows a strong alkaline sulphated water, with smaller amounts of the chlorides and carbonates.

ALAMEDA CREEK.

DESCRIPTION.

Alameda Creek drains that part of the Coast Range immediately east and south of San Francisco Bay. The creek rises in the Mount Diablo Range in the vicinity of Mount Hamilton, flows north and northwestward for about 30 miles, and empties into San Francisco Bay in the vicinity of Alvarado. The basin, steep and rough in its

[a] Hilgard, E. W., in appendix to Rept. Univ. California, Exper. Sta., 1890.

upper reaches, broadens out in the lower into pleasant valleys and sloping hillsides, which are extensively cultivated. Precipitation in this basin is almost wholly in the form of rain; any snow that may fall during the winter season soon melts and goes to swell the floods of early spring.

CHARACTER OF WATER AT NILES.

Samples of water for this investigation were collected at a point on the stream just above the stone dam above Niles by Fred Scott, the study of the creek waters having been included in this work at the request of Prof. Andrew C. Lawson, of the University of California. The bed of the creek at the sampling point is intercepted by rock strata, which serve to bring most of the underground flow to the surface. The results of the study are indicated in the accompanying analyses.

Mineral analyses of water from Alameda Creek at Niles.

[Parts per million unless otherwise stated.]

Date.		Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.
From—	To—												
1906.	1906.												
Jan. 1	Jan. 10	20	23	2.0	102	40	72	2.2	0.0	356	170	36	600
Jan. 11	Jan. 19	1,482	18	.6	35	12	10	2.3	.0	119	42	18	234
Jan. 21	Jan. 30	36	21	2.0	51	19	28	3.8	.0	188	56	26	332
Jan. 31	Feb. 9	Trace.	20	2.0	64	26	38	2.7	.0	243	86	38	400
Feb. 10	Feb. 19	90	21	1.8	71	25	44	2.8	.0	247	80	43	406
Feb. 20	Mar. 1	314	17	3.4	31	13	21	3.0	.0	142	30	27	228
Mar. 2	Mar. 11	110	14	3.2	37	16	22	1.3	.0	168	38	20	250
Mar. 12	Mar. 21	826	12	2.6	32	14	17	3.1	.0	139	32	24	216
Mar. 22	Mar. 31	1,112	15	2.4	39	14	22	4.8	.0	151	29	23	240
Apr. 1	Apr. 10	42	21	3.0	39	17	23	2.3	.0	182	36	22	322
Apr. 11	Apr. 20	76	18	4.4	77	25	36	4.6	.0	232	67	29	324
Apr. 21	Apr. 22	......	......	......	......	......	......	......	......	240	......	29	......
May 2	May 10	26	17	3.8	57	24	36	1.9	.0	255	58	33	374
May 11	May 20	26	18	3.0	62	24	41	1.6	3.3	256	60	35	362
May 21	May 30	26	17	3.8	57	25	32	3.4	3.8	251	63	39	382
May 31	June 10	......	20	4.2	56	25	37	2.5	10	242	62	39	404
June 11	June 20	......	17	4.8	58	27	50	2.7	.0	270	63	36	398
June 21	June 30	26	21	2.4	62	32	56	5.0	5.1	273	68	41	420
				Fe.									
July 1	July 10	46	19	.06	58	30	66		14	257	80	42	412
July 11	July 18	36	20	.05	57	29	48		10	268	68	40	428
July 21	July 31	160	20	.05	64	32	56		.0	296	100	37	466
Aug. 1	Aug. 10	Trace.	21	.05	96	30	55		8.0	264	82	36	422
Aug. 11	Aug. 20	12	25	.20	62	30	50		.0	287	113	33	410
Aug. 21	Aug. 30	14	20	.10	79	34	82		7.0	286	126	36	480
Sept. 1	Sept. 10	Trace.	20	.13	90	36	55		10	290	122	35	510
Sept. 11	Sept. 20	6	23	.10	70	34	73		12	249	124	38	502
Sept. 21	Sept. 30	Trace.	17	.05	87	34	61		10	327	123	41	504
Oct. 1	Oct. 10	8	16	.10	92	40	65		9.0	339	149	39	562
Oct. 11	Oct. 20	38	19	.15	90	40	50		10	329	152	40	584
Oct. 21	Oct. 30	......	17	.40	89	42	70		16	342	174	42	610
Nov. 8	Nov. 10	......	......	......	......	......	......		.0	358	......	35	......
Nov. 11	Nov. 20	10	19	.20	94	44	72		10	396	202	42	654
Nov. 21	Nov. 30	24	23	.15	98	42	71		4.0	420	160	37	606
Mean		163	19	a .13	66	28	49		4.4	262	91	34	421
Per cent of anhydrous residue		......	4.5	0.0	15.7	6.6	11.7		31.8	......	21.6	8.1	......

a Mean of Fe values after July 1.

At flood times the stream carries an excessive amount of suspended matter, both coarse sand picked up from the bed of the creek and finer material washed down from the adobe-like soil of the hillsides. As the waters subside they gradually become clearer, until at low stages they are quite clear. The mineral matter in solution is of considerable interest, containing as it does such a high proportion of magnesium. This is dissolved from the shales and magnesian limestones which are said to occur in considerable amounts in the vicinity of Livermore. This magnesium renders the water troublesome when used in boilers, and some form of softener or scale preventive is needed.

The waters of Alameda Creek are especially important because of the fact that a portion of the present water supply of San Francisco is drawn from wells sunk in the gravel beds of some of the tributary streams in the vicinity of Sunol. Furthermore, the waters of the creek, after leaving the hills near Niles, sink into deep gravel beds extending from the mouth of the canyon to the bay, and a number of driven wells in the lower end of these gravel beds furnish a part of the public supply for the city of Oakland. The reservoir furnishing the main supply for Oakland is located in the next drainage area north of Alameda Creek. The quality of these public supplies is well guarded. The first, that of San Francisco, is protected from contamination by patrolling the catchment basin; the second, the wells driven into the gravels, is probably free from pollution because of the efficient filtering action of the thick layers of gravel and sand; and the third, the impounded surface waters in the basin north of Alameda Creek, are protected by thorough inspection and are purified by filtration.

NOTES ON MUNICIPALITIES.

Reports were received from 79 settlements in the San Francisco Bay drainage area, including 24 cities and towns in the Sacramento Valley, 18 in the San Joaquin Valley, and 37 in the region bordering the bay.

In the Sacramento Valley 10 towns and cities report the use of surface water only, while one town reports a combination of stream and well water. The per capita consumption is generally high and includes large quantities of irrigation waters.

In the San Joaquin Valley 5 towns reported use of surface waters, one reported water obtained by railroad transportation, and the rest reported underground supplies. Data as to consumption were generally lacking.

Of the bay cities 15 places reported the use of surface water only, 9 reported using both surface and ground water, and 13 places used wells. The tabulated statistics follow.

Statistics of municipal water supplies in San Francisco Bay drainage basin.

SACRAMENTO RIVER.

Settlement.	Drainage basin.	Population.	Adjacent to—	Source of supply.	Nature of system.	Ownership.	Methods used for purification.	Daily consumption per capita (gallons).	Nature of sewerage system.	Ultimate disposal of sewage.
Alturas	Pit River	a 1,250	Pit River	Wells	Pumping	Individual	None		No system	
Auburn	American River	2,460	American River	South Yuba River	Gravity	South Yuba Water Co.	do		Sanitary—septic tank.	Auburn Ravine.
Biggs		a 875	Doe Creek	Wells	Pumping	Municipal	do		No system	
Chico	Sacramento River.	b 3,888	Sacramento River.	Shallow wells	do	Chico Water Supply Co.	do		Combined	Sewer farm.
Colusa	do	1,535	do	Stream and wells	do	Mrs. J. B. Cooke	do		No system	
Corning	do	a 1,200		Wells	do	A. Watkinson	do		do	
Dixon	do	783		do	do	Dixon Electric Power and Water Co.	do	60	None	
Grass Valley	Bear River	4,869	Bear River	South Yuba River	Gravity	South Yuba Water Co.	do	250 to 300	Sanitary	
Gridley	Feather River	a 1,700	Feather River	Wells	Pumping	Municipal	do		No system	
Lincoln	Sacramento River.	762	Auburn Ravine	Streams	Gravity	do	do		Sanitary	Do.
Marysville	Feather River	3,500	Feather River	Wells	Pumping	do	do	96	Combined	Deer Creek.
Nevada City	Yuba River	3,903	Yuba River	South Yuba River	Gravity	South Yuba Water Co.	do	300	No system	
Oroville	Feather River	3,500	Feather River	Feather River	do	Oroville Water, Light and Power Co.	do	c 6,000	Storm	Creek.
Placerville	American River	1,800	American River	Lakes and stream	do	Municipal	do	480	Separate systems	Sacramento River.
Red Bluff	Sacramento River.	2,878	Sacramento River.	Antelope Creek and Sacramento River.	Gravity and pumping.	Red Bluff Water Co.	do	240 to 400	Combined	Do.
Redding	do	3,500	do	Wells	do	Redding Water Co	do	150 to 260	No system	
Rocklin	do	1,050	Antelope Creek	Stream	Gravity	South Yuba Water Co.	do		Sanitary	Do.
Sacramento	do	31,892	Sacramento River.	Sacramento River	Pumping	Municipal	do	275	No system	
Sisson	do	a 700	do	Stream	Gravity	Sisson Development Co.	do		do	
Tehama		a 500		Sacramento River	Pumping	John Simpson	do		None	
Willows	Sacramento River.	893	Willow Creek	Wells	do	Northern California Power Co.	do		Storm only	Puta Creek.

Winters	do	a 1,100	Puta Creek	do	do	Municipal	do	200	Sanitary	Tule swamp.
Woodland	do	2,886	Sacramento River.	do	do	do	do			
Yuba City	do	a 1,200		do	do	do	do		Storm only	Slough.

a Estimates of local authorities; census figures lacking.
b Census of 1906. California Blue Book, 1907. All others estimated for 1909 from United States Census reports of 1890 and 1900.
c Including irrigation water.

SAN JOAQUIN RIVER.

Angels Camp	Stanislaus River.	a 3,000	Stanislaus River.	Stanislaus River	Gravity	Utica Mining Co	None		No system	
Bakersfield	Kern River	6,876	Kern River	Shallow wells	Pumping	Electric Water Co.	do	250 to 600	Separate system	Sewer farm.
Coalinga	San Joaquin River.	a 3,500	Arroyo Los Gatos.	Brought in by rail.		Pleasant Valley Water Co.	do		No system	
Fresno	do	13,955	San Joaquin River.	Deep wells	Pumping	Fresno City Water Co.	do		Sanitary—septic tank.	Do.
Jackson	Mokelumne River.	3,000	Jackson Creek	Stream	Gravity	Pacific Gas and Electric Co.	do		No system	
Kern City	Kern River	a 3,300	Kern River	Wells	Pumping	Kern Sewerage Co.	do	500	Combined	Open desert.
Lodi	Mokelumne River.	a 3,500	Mokelumne River.	do	do	Cary Bros	do		No system	
Los Banos	San Joaquin River.	1,000	Los Banos Creek.	Canal	do	Miller & Lux	do		do	
Madera	Fresno River		Fresno River	Wells	do	Municipal	do	60	Storm	
Merced	San Joaquin River.	2,000		Merced River	Gravity		do		Sanitary	Sewer farm.
Modesto	Tuolumne River.	a 4,000	Tuolumne River.	Wells	Pumping		do	250	do	
Oakdale	Stanislaus River.	1,203	Stanislaus River.	do	do	Municipal	do	75	No system	
Porterville	Tulare River	a 2,000	Tulare River	do	do	do	do		do	
Selma	Kings River	1,083	Kings River	do	do	San Joaquin Light and Power Co.	do		do	
Sonora	Stanislaus River.	2,354	Stanislaus River.	Streams	Gravity and pumping.	Gold Mountain Water Co.	do	60	Sanitary	Creek ¼ mile below town.
Stockton	San Joaquin River.	20,280	San Joaquin River.	Artesian wells	Pumping	Stockton Water Co	do	128	Combined	San Joaquin River.
Tulare	Kaweah River.	2,216	Tule River	Wells	do	Municipal	do		No system	
Visalia	do	3,265	Kaweah River.	do	do		do	100	Sanitary	Sewer farm.

a Based on estimates of town or city clerks and health officers. All others estimated for 1909 from United States Census reports of 1890 and 1900.

Statistics of municipal water supplies in San Francisco Bay drainage basin—Continued.

BAY REGION.

Settlement.	Drainage basin.	Population.	Adjacent to—	Source of supply.	Nature of system.	Ownership.	Methods used for purification.	Daily consumption per capita (gallons).	Nature of sewerage system.	Ultimate disposal of sewage.
Alameda	San Francisco Bay.		San Francisco Bay.	Wells	Pumping	Peoples Water Co.	None	50		
Alviso	do	a 200	Coyote River	do	do	W. A. Wood	do		No system	
Antioch	do	a 2,000	Suisun Bay	Stream	do	Municipal	do	100	Sanitary	San Francisco Bay.
Belvedere	do	a 650	San Francisco Bay.	Stream and wells	Gravity	Belvedere Land Co.	do		do	Do.
Benicia	do	3,102	Straits of Carquinez	Lake Herman	Gravity and pumping.	Benicia Water Co.	do	200	Combined	Carquinez Straits.
Berkeley	do	a26,283	San Francisco Bay.	Streams and wells.	do	Peoples Water Co.	Filtration of surface supply.	50	do	San Francisco Bay.
Black Diamond.	do		Suisun Bay	San Joaquin River.	Pumping	Black Diamond Water Co.	None	150	Sanitary	San Joaquin River.
Calistoga	do	a 1,000	Napa Creek	Streams	Gravity	Calistoga Water Co.	do		No system	
Emeryville	do	1,725	San Francisco Bay.	Streams and wells.	Gravity and pumping.	Peoples Water Co.	Filtration of surface supply.	95		
Fairfield	do	a 1,100	Suisun Bay	Wells	Pumping	Henry Goosen	None	250	Sanitary	Suisun Bay.
Hayward	do	2,456	San Lorenzo Creek.	Artesian wells	do	Municipal	do	100	do	San Francisco Bay.
Livermore	do	1,584	Mocho Creek	Mocho Creek and wells.	Gravity and pumping.	Livermore Water and Power Co.	do	150	No system	
Los Gatos	do	2,152	Los Gatos Creek	Stream	Gravity	San Jose Water Co.	do		Sanitary—septic tank.	Los Gatos Creek.
Martinez	do	a 1,500	Suisun Bay	Artesian wells	Pumping	Port Costa Water Co.	do	60		San Francisco Bay.
Mill Valley	do	a 3,500	Mill Creek	Streams	Gravity	North Coast Water Co.	do		Sanitary	Do.
Morgan Hill	do	a 600		do	do	Private companies	do		No system	
Mountain View.	do	a 1,500	Stevens Creek	Artesian wells	Pumping	Municipal	do	24	do	
Napa	do	4,036	Napa Creek	Stream and wells	do	Napa City Water Co.	Lime and iron coagulation.	120	Separate systems	

Oakland	do	238,010	San Francisco Bay.	Streams and wells.	Gravity and pumping.	Peoples Water Co.	Filtration of surface supply.	95	Combined	Do.
Palo Alto	do	3,500	San Francisquito Creek.	Wells	Pumping		None	100	Sanitary	Do.
Petaluma	do	4,035	Petaluma Creek	Streams	Gravity		do	125	do	Petaluma River.
Piedmont	do	a 1,900		Streams and tunnels.	Gravity and pumping.	Peoples Water Co.	Filtration of surface supply.	75	Combined	San Francisco Bay.
Pleasanton	do	a 1,800	Arroyo Valley	Wells	Pumping	Municipal	None	65	No system	
Redwood	do	1,725	Redwood Creek	Artesian wells	do	do	do	42	Sanitary	Redwood Creek.
Richmond	do	a 9,000	San Francisco Bay.	Wells	do	Peoples Water Co.	do	152	Separate systems	San Francisco Bay.
Rio Vista	do	713	Sacramento River.	Stream	do	Municipal	Filter tanks.	70	No system	
San Anselmo	do	a 1,800	Corte Madera Creek.	Lakes	Gravity and pumping.	Marin Water and Power Co.	None	350	Sanitary	Do.
San Francisco	do	450,000	San Francisco Bay.	Streams, artesian wells, and filter galleries.	do	Spring Valley Water Co.	Part of supply filtered.	85	Separate systems	Pacific Ocean.
San Jose	do	24,596	Coyote River	Stream and wells	do	San Jose Water Co.	None	175	Sanitary	San Francisco Bay.
San Leandro	do	a 2,500	San Leandro Creek.	Streams	Gravity	Peoples Water Co.	Filtration.	140	do	Do.
San Mateo	do	a 3,500	San Mateo Creek.	Wells	Pumping	San Mateo Water Co.	Filtered.	30 to 40	do	Do.
San Rafael	do	4,410	San Rafael Creek.	Streams	Gravity and pumping.	Marin County Water Co.	None	350	do	Salt water creek.
Santa Clara	do	4,423	San Tomas Aguinas Creek.	Artesian wells	Pumping	Municipal	do	102	do	Septic tank under construction.
Sausalito	do	1,893	San Francisco Bay.	Streams					Combined	San Francisco Bay.
Saint Helena	do	1,582	Napa Creek	York Creek	Gravity	Saint Helena Water Co.	None	150 to 200	Sanitary	Sewer farm.
Suisun	do	738	Suisun Creek	Streams	do	Municipal	do		do	Suisun Bay.
Vacaville	do	1,665	Alamo Creek	Wells	Pumping		do	100	Sanitary—septic tank.	

a Based on estimates of town or city clerks and health officers. All others estimated for 1909 from United States Census reports of 1890 and 1900.

SOUTH PACIFIC OCEAN DRAINAGE.

DESCRIPTION.

The south Pacific Ocean drainage area includes the narrow strip of land extending from San Francisco Bay to the Mexican boundary, a distance of about 350 miles, and bordered on the east by the Coast Ranges, the San Bernardino Mountains, and the San Jacinto Mountains. Its area of 23,000 square miles includes the fertile Salinas Valley, the great orange belt of southern California, and the San Diego lands. (See Pl. I, in pocket.)

Important among the river systems lying within this area are the Salinas, the Santa Maria, the Santa Ana, and the San Gabriel. The area includes also many smaller river systems, which, owing to the generally deficient rainfall of the region, are of great local importance. Much attention is being paid to the proper development of the water resources of this strip of coastal land, and for this reason special stress was laid upon investigations of the rivers utilized for irrigation. Systematic studies have been made of the waters of the Salinas system and the streams of the valley of southern California, as well as of the other more important rivers of the area. The principal streams in this drainage area are grouped in geographic order (north to south) in the table below:

Principal rivers of south Pacific Ocean drainage.

- Monterey Bay subdrainage.
  - San Lorenzo River.
  - Pajaro River.
    - San Benito River.
    - Pescadero Creek.
  - Salinas River.
    - Chalone Creek.
    - San Lorenzo Creek.
    - Gaviota Creek.
    - Indian Valley Creek.
    - Estrella River.
      - San Juan Creek.
      - Cholame Creek.
    - Nacimiento River.
    - San Antonio River.
    - Arroyo Seco.
- Carmel River.
- Big Sur River.
- Little Sur River.
- San Luis Obispo Creek.
- Santa Maria River.
  - Suey Creek.
- Santa Maria River—Continued.
  - Alamos Creek.
  - Sisquoc River.
- San Antonio Creek.
- Santa Ynez River.
- Ventura River.
- Santa Clara River.
- Malibu Creek.
- Valley of southern California.
  - Los Angeles River.
  - San Gabriel River.
  - Rio Hondo.
  - Santa Ana River.
- Southern subdrainage.
  - San Juan Creek.
  - Santa Margarita River.
  - San Luis Rey River.
  - San Dieguito River.
    - Santa Ysabel Creek.
  - Otay River.
  - Tia Juana.
    - Cottonwood Creek.

The summits of the coast ranges limit the south Pacific Ocean drainage area on the east. Southward from San Francisco Bay these mountains form a more or less broken and ill-defined chain, being divided into groups or series of parallel ridges following in general the direction of the shore line. The Mount Diablo Range, uniting with the Berkeley and Contra Costa hills on the north, forms with the Santa Cruz and Gabilan Mountains the northernmost group. The Tehachapi Mountains, crisscrossing the southern borders of these, form the connecting link between them and the Sierra Madre and San Bernardino Range of southern California. These in turn give place to the San Jacinto Mountains, which soon lose themselves in the broken and scarcely to be defined ranges of San Diego County.

The underlying formation of the coast ranges is mainly a thick bed composed largely of pre-Cretaceous sandstones and shales. In conjunction with this formation are light, coarse, easily weathered granites and other granitic rocks, which outcrop in various places all along the coastal region. The core of the San Francisco Peninsula and practically the whole of the Santa Lucia Range is granitic,[a] and granite also outcrops in the Mount Diablo Range. Granites are again found in the San Bernardino Mountains and in the Sierra Madre, and also in the highlands farther south. In these granitic mountain regions soil is almost entirely lacking and vegetation is restricted to a very scant growth of stunted shrubs. The sandstones of the area are usually massive and are made from disintegrated but only slightly decomposed granitic rocks.

Overlying the basement rocks are sedimentary sandstones, shales, and conglomerates, with scattered deposits of limestones. Asphaltum and bitumen are of common occurrence. Lying unconformably above these sediments are recent sandstones, poorly cemented and easily weathered, and in places rich in iron. Other rocks occasionally found are basaltic and diabasic intrusives, with here and there a small ore deposit. Several beds of coal are found in the Mount Diablo Range.

The soil cover varies both in quantity and character. In the mountain regions it is frequently almost lacking, and where found is rather in the nature of a talus than a true soil. Lower down in the valleys are deeper soils, as a rule sandy, and in certain localities are adobe lands.

Forests are in general of small extent, although in several places along the extreme coastal ridges and in the San Bernardino Mountains good stands of timber are found. Estimates of the Forest Service of the Department of Agriculture place the total standing live timber of merchantable size as approximately 1,512,000 feet b. m. for the whole drainage area, or less than 1 per cent of the total for the State. At present there is in some localities a decided tendency toward eucalyptus culture, which may eventually have a very salutary effect upon the run-off of this region.

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[a] A full description of this granite is given by A. C. Lawson in Bull. Dept. Geology Univ. California, vol. 1, No. 1, p. 9.

The population of the drainage area, based on figures of the California state board of health for 1907, is approximately 572,000. Of this population, about 40,000 are in San Diego County. San Benito County is the least populous in the region, the number of its inhabitants having been estimated at 6,788. In the valley of southern California the population is scattered over the whole region, centering in numerous small cities and towns and in the city of Los Angeles. In the remaining sections the coastal districts and river valleys only are well settled. The chief centers are San Diego, Oxnard, Ventura, Santa Barbara, San Luis Obispo, Paso Robles, Salinas, Monterey, Santa Cruz, Watsonville, Hollister, and Gilroy. Large areas of mountain and interior lands are practically without inhabitants.

Fruit growing is the chief business of the region, but cattle raising and dairying are important industries. The valley of southern California is concerned almost exclusively with citrus production; Nordhoff Valley, in Ventura County, is given over to orange groves; and the Pajaro and lower Santa Clara valleys and the coastal regions of Santa Cruz are devoted to the raising of apples. Walnuts and apples are grown extensively in the southern part of the region, and plums and prunes are of considerable importance in the northern part. Beet-sugar production is a large and profitable industry of the Salinas Valley.

Commerce is slight except by rail, as there are no really good harbors along this whole stretch of coast, although San Diego has a large and partially protected bay which, with proper sea wall and breakwater, would be a most valuable harbor.

MONTEREY BAY SUBDRAINAGE.

DESCRIPTION.

The first break in the coastal mountains south of San Francisco Bay occurs just south of the city of Santa Cruz, where an indentation in the coast line forms the dovetail-shaped Monterey Bay, into which drain several rivers of considerable importance. Through the gap in the mountains Pajaro River discharges the waters of San Benito River and of the several streams of the south Santa Clara Valley. North of this, at Santa Cruz, San Lorenzo River empties into Santa Cruz Harbor, and on the south Salinas River meanders through a fertile meadow land to the bay. Carmel River, although discharging its water into the smaller Carmelo Bay on the south instead of directly into Monterey Bay, is essentially a part of this drainage basin and will be considered with it.

SAN LORENZO RIVER.

DESCRIPTION.

San Lorenzo River rises on the upper slopes of the Santa Cruz Mountains, flows southward to southeastward for about 20 miles, and empties into the Pacific Ocean near the town of Santa Cruz.

In the upper part of its basin the bed rock is largely granite and is well covered with soil which supports a good growth of timber. In the lower reaches the stream crosses certain beds of shale and sandstone, from which it picks up a quantity of mineral matter. Numerous small tributaries drain into the San Lorenzo from the steep slopes at the sides of the basin, and almost all of these creeks carry water better than that of the main stream.

CHARACTER OF WATER.

Samples for this investigation were collected near the bridge at Big Trees, just below the town of Felton. No gagings are available. The results are shown in the accompanying analyses.

Mineral analyses of water from San Lorenzo River at Big Trees.

[Parts per million, unless otherwise stated.]

Date. From—	Date. To—	Turbidity.	Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.
1906.	1906.													
Jan. 6	Jan. 10	......	20	33	1.0	41	11.0	61	0.5	0.0	144	37	26	230
Jan. 11	Jan. 20	......	1,200	29	1.8	31	6.3	16	3.8	.0	79	30	17	198
Jan. 21	Jan. 30	......	72	28	.8	31	7.1	26	1.7	.0	100	41	18	152
Jan. 31	Feb. 9	......	28	24	.8	36	......	19	1.7	.0	118	34	22	238
Feb. 10	Feb. 19	......	68	21	1.4	27	8.0	13	0.3	.0	109	39	24	208
Feb. 20	Mar. 1	......	112	23	2.2	32	7.5	15	3.0	.0	99	39	17	170
Mar. 2	Mar. 11	......	116	23	3.6	33	8.4	18	5.4	.0	102	39	16	186
Mar. 12	Mar. 21	......	170	20	3.6	19	8.2	18	1.5	.0	87	39	30	216
Mar. 22	Mar. 31	......	176	20	5.8	26	6.9	13	1.8	.0	82	34	12	204
Apr. 1	Apr. 10	......	96	23	2.4	34	8.3	11	1.8	.0	99	36	14	202
Apr. 11	Apr. 20	......	62	21	4.4	41	10	19	3.6	.0	121	40	18	208
Apr. 21	Apr. 30	......	18	20	5.0	49	11	17	2.4	.0	156	48	22	276
May 1	May 10	......	30	25	3.2	54	12	22	3.6	.0	169	50	26	278
May 11	May 20	......	16	23	3.2	51	12	35	3.2	.0	170	47	29	288
May 21	May 31	......	114	26	3.8	42	12	21	2.2	.0	141	44	26	250
June 1	June 10	......	4	19	4.0	43	12	23	2.6	.0	142	45	25	254
June 11	June 20	......	16	22	4.4	47	12	28	1.9	.0	157	46	24	264
June 21	June 30	......	26	21	5.4	39	12	27	2.0	.0	162	47	32	260
					Fe.									
July 1	July 10	......	....	27	.10	48	11	16		.0	164	52	28	280
July 11	July 20	......	60	27	.10	56	14	27		[b] 5.5	162	58	31	280
July 21	July 31	......	48	25	.07	46	10	34		.0	167	53	34	286
Aug. 1	Aug. 10	......	Trace.	31	.05	54	11	27		[b] 7.0	154	43	35	296
Aug. 11	Aug. 19	......	....	28	.10	59	11	42		.0	176	43	35	310
Aug. 21	Aug. 31	......	18	21	.10	52	9.9	31		.0	166	40	36	274
Sept. 1	Sept. 10	......	Trace.	25	.15	47	11	38		.0	167	39	36	288
Sept. 11	Sept. 20	......	Trace.	26	.20	51	11	37		.0	164	38	38	284
Sept. 21	Sept. 30	......	2	24	.20	54	0.3	43		.0	163	37	40	288
Oct. 1	Oct. 10	......	38	21	.10	68	10	24		.0	189	39	41	260
Oct. 11	Oct. 20	......	Trace.	17	.05	48	9.5	44		.0	184	44	41	288
Oct. 21	Oct. 31	......	16	20	.10	44	9.7	32		.0	182	37	40	284
Nov. 1	Nov. 10	......	36	20	.30	46	9.8	37		.0	174	44	40	306
Nov. 11	Nov. 20	5	44	23	.70	56	11	41		.0	182	44	41	286
Nov. 21	Nov. 30	5	6	25	.50	51	12	43		.0	186	50	41	280
Dec. 1	Dec. 10	10	28	19	.07	48	11	46		.0	182	52	39	310
Dec. 11	Dec. 19	60	134	16	.10	40	8.9	32		.0	128	42	28	234
Dec. 21	Dec. 31	40	66	15	.20	37	9.8	32		.0	128	46	31	262
Mean		......	84	23	[a] .18	44	10	31		.0	147	43	29	255
Per cent of anhydrous residue		......	......	9.1	0.1	17.4	3.9	12.5		28.5	......	17	11.5	......

[a] Mean of Fe values after July 1.   [b] Abnormal. Computed as HCO_3 in the average.

The water from this river is not used in any manufacturing establishment, that from the smaller creeks being preferred. The city of Santa Cruz is furnished with water from these creeks. Two important industries are located in this basin, the California Powder Works and the plant of the Kron Tanning Company, both a short distance above Santa Cruz. No nitrating is done at the powder works, and there is therefore little or no acid waste to pollute the stream. The wastes from the tannery consist of spent liquors and washing from the hides, which are run into sedimentation basins alongside the river; from these the leachings eventually reach the stream. As both of these industries are located below the point at which the samples were taken, the effects of pollution, if any, do not appear in the tabulated analyses.

In the basin above the sampling station are several small towns, for the most part summer colonies. It is probable that considerable sewage and house drainage finds its way into the river at certain seasons of the year, rendering its water unfit for use. Otherwise the water is clear and free from objectionable mineral substances. In order to use the water successfully in boilers or for other industrial purposes for which a hard water is unsuited, it should be treated with soda ash or some similar softening compound to remove the excess of lime and magnesia. As these exist principally as the bicarbonates, the process of softening the water would be comparatively simple. Altogether this river is representative of the better class of coast streams, which for the most part drain areas in which shale and sandstone abound.

SALINAS RIVER SYSTEM.

DESCRIPTION.

The Salinas Valley extends from the Santa Lucia Mountains northwestward for about 150 miles to Monterey Bay. It is walled in on the northeast by the Mount Diablo and Gabilan ranges, which separate it from the San Joaquin and San Benito valleys, and on the southwest by the Santa Lucia Mountains and the Sierra del Salinas, which, respectively, shut it off from the Pacific Ocean and the Carmel Valley. Smaller valleys join it at intervals from both sides and combine to give its total drainage an area of 4,780 square miles.[a] The valley is narrow and winding in its upper stretches, but broadens out below the town of Bradley to an average width of 20 miles. Above Soledad it again narrows sharply, its average width at that point being about 5 miles. Nearing Monterey Bay it spreads out again into a broad, fertile coastal valley. Throughout its extent it is traversed by Salinas River.

[a] Hamlin, Homer, The water resources of Salinas Valley, California: Water-Supply Paper U. S. Geol. Survey No. 89, 1904, p. 10.

The valleys to the southwest of the main valley are fewer than those on the east, but they are in general well defined. In their bottoms are important creeks, and as assets they far outrank their northeastern complements. The latter are, with two exceptions, of little importance, containing only short mesa streams of torrential character. The difference between these two sets of tributary valleys is marked not only by the character and importance of their streams, but by the casual conditions of climate, rainfall, and forest covering. From north to south the tributary streams are as follows:

Principal tributaries of Salinas River.

Southwestern tributaries.	Northeastern tributaries.
Arroyo Seco.	Gabilan Creek.
San Antonio River.	Chalone Creek.
Nacimiento River.	San Lorenzo Creek.
San Marcos Creek.	Gaviota Creek.
	Bitterwater Creek.
	Indian Valley Creek.
	Estrella River:
	Cholame Creek.
	San Juan Creek.
	Huer Huero Creek.

The soil of the Salinas Valley is the disintegration product of the underlying rock and hence is principally sand. In places, owing to the slight decomposition of the original rock materials and to the semiaridity of the climate, the loose sandy soil is rich in feldspar and magnesium salts and is very fertile and rich. In other places, chiefly near the head of the valley proper, adobe soils occur. At present, as a result of injudicious methods of agriculture formerly used in this section, large tracts of land are unutilized and considerable reclamation work will be necessary in these regions to render farming productive. One important factor in deciding the crop-producing value of the lands, especially in the central and upper valley, is the wind. The loose, sharp sand of the river bottom is blown about by the strong northwest winds of summer and spreads over the surrounding country in rolling dunes, choking vegetation and giving to small areas the appearance of a desert.

Agriculture is the chief industry in the valley, but cattle raising holds an important position, the hills, useless for other purposes, being devoted to grazing. Oats and barley are the principal crops and alfalfa is extensively cultivated. In the lower central valley the raising of sugar beets holds an important position. The whole beet crop of the section is used by a large refinery at Spreckles, 4 miles up the valley from Salinas City. Nearer the mouth of the river dairying is an extensive industry, the products being marketed chiefly in San Francisco and the Bay cities.

At Stone Canyon, in the mountains above the town of Bradley, is a coal deposit of some local importance. The coal is said to be of good grade.

SALINAS RIVER.

DESCRIPTION.

Salinas River rises on the northeastern slopes of the Santa Lucia Range, in the region of the heaviest rains in these mountains, flows in a general northwesterly course and discharges its waters into Monterey Bay. The valley slopes of the upper reaches of the basin are well forested and the river has a large winter flow and moderate summer flow. It receives many small tributaries, the most important of which are listed on page 69.

CHARACTER OF WATER AT SPRECKLES.

Salinas River near Spreckles's sugar refinery above Salinas City is a broad, shallow stream meandering through a flat bottom land of loose, coarse sand interspersed with finer quicksands. The following table shows the estimated monthly discharge of the river for 1900 and part of 1901:[a]

Estimated monthly discharge of Salinas River 4 miles south of Salinas.

[Drainage area, 4,084 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1900.						
January 8-31	2,700	223	848	40,368	0.21	0.19
February	223	40	105	5,831	.03	.03
March	223	25	73	4,489	.02	.02
April	32	19	22	1,309	.01	.01
May	19	17	17	1,045	.00	.00
June	17	15	16	952	.00	.00
July	10	6	8	492	.00	.00
August	8	6	7	430	.00	.00
September	8	2	6	357	.00	.00
October	4	1	2	123	.00	.00
November	33,600	0	2,413	143,583	.59	.66
December	1,050	82	295	18,139	.07	.08
1901.						
January	35,162	380	4,921	302,580	1.21	1.39
February	20,927	540	4,131	231,701	1.02	1.06
March	1,772	430	1,063	65,361	.26	.30
April	405	160	270	16,066	.07	.07
May	2,012	160	533	32,773	.13	.15
June	160	30	56	3,332	.01	.01
July	30	25	27	1,660	.01	.01

[a] Hamlin, Homer, The water resources of Salinas Valley, California: Water-Supply Paper U. S. Geol. Survey No. 89, 1904, p. 48.

Samples of water collected at this point on April 6 and August 28, 1908, were analyzed, with the results shown in the accompanying table.

Analyses of waters of the Salinas River system.

[Collected and analyzed by Walton Van Winkle. Quantities in parts per million.]

	Salinas River at Spreckels's sugar refinery.		Gaviota Creek 1 mile above San Ardo.	San Lorenzo Creek at Matthews dam site.	
	Apr. 6, 1908.	Aug. 28, 1908.	Apr. 7, 1908.	Apr. 7, 1908.	Aug. 25, 1908.
Turbidity	20	10	Trace.	5	6
Silica (SiO_2)	28	25	102	23	24
Iron (Fe)	.15	.23	.38	.25	.15
Calcium (Ca)	66	72	286	167	159
Magnesium (Mg)	31	50	152	181	174
Sodium (Na)	51	70	402	617	725
Potassium (K)			17	39	46
Carbonate radicle (CO_3)	24	8.4	12	37	24
Bicarbonate radicle (HCO_3)	181	249	164	261	287
Sulphate radicle (SO_4)	150	253	1,848	1,793	1,728
Chlorine (Cl)	49	80	161	432	506
Nitrate radicle (NO_3)	1.3	1.0	1.0	39	.8
Total solids	501	781	3,231	3,689	3,653

	Indian Valley Creek at Douglas ranch.		Cholame Creek at Shandon.		San Juan Creek at Shandon.		Huer Huero Creek near Paso Robles.
	Apr. 8, 1908.	Aug. 25, 1908.	Apr. 9, 1908.	Aug. 24, 1908.	Apr. 9, 1908.	Aug. 24, 1908.	Apr. 9, 1908.
Turbidity	10	8	Trace.	5	10	9	Trace.
Silica (SiO_2)	28	43	14	27	31	41	35
Iron (Fe)	.18	.15	.18	.20	1.0	.15	.18
Calcium (Ca)	126	145	110	73	94	59	59
Magnesium (Mg)	81	86	100	101	35	24	21
Sodium (Na)	106	164	487	486	163	112	82
Potassium (K)	72		56	55	45	31	
Carbonate radicle (CO_3)	12	0.0	0.0	20	7.2	....	14
Bicarbonate radicle (HCO_3)	259	437	324	159	201	124	281
Sulphate radicle (SO_4)	644	611	836	891	403	272	55
Chlorine (Cl)	63	74	508	533	236	131	71
Nitrate radicle (NO_3)	....	2.0	.4	.7	.3	1.0	1.0
Total solids	1,316	1,352	2,354	2,332	1,031	746	451

The water is distinctively that of an arid region. The sulphate is the predominating acid radicle, carbonates ranking second. The chief basic constituent is calcium, the alkalis showing values almost as high. Magnesium is relatively high, the ratio of this element to calcium being, for the two analyses, 1 to $2\frac{1}{8}$ and 1 to $1\frac{4}{9}$. The normal carbonate radicle is present in large quantities, as is also the bicarbonate radicle. Chlorine is relatively low, averaging about 10 per cent, while the sulphate radicle forms about 30 per cent of the total dissolved matter.

The water is unfit for domestic or boiler use without treatment. Its high sulphate, carbonate, and sodium contents make it doubtful whether it could be safely used for irrigation. As all water taken from the river at this point would have to be pumped to the land on which it would be used, it is extremely improbable that it will be extensively applied in irrigation.

CHARACTER OF WATER AT PASO ROBLES.

Near Paso Robles the upper Salinas flows through a broad, rolling country with considerable covering of oak. The drainage area at this point is about 400 square miles.[a] The river here is practically perennial, but unfortunately there was no surface flow during the summer of 1908. No gage records were kept during the year, but the general conditions may be stated.

The greatest discharge occurred in January, February, and March; following this was a period of drought, during which the river gradually subsided, surface flow ceasing entirely on July 17, and from this time until October the river was dry. From October 1 until December the stream flow was slight and was produced almost entirely by rainfall in the Santa Lucia Mountains. During December rain occurred in the valley proper and the stream began to rise to winter conditions.

Samples of water were collected daily during the periods of flow, at first by C. B. Weiser, of the local water company, and later in the spring by J. M. Currell.

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[a] Planimeter measurement on United States Land Office map.

Mineral analyses of water from Salinas River at Paso Robles.

[Parts per million unless otherwise stated.]

Date. From—	Date. To—	Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.
1907. Dec. 31	1908. Jan. 9	Trace.	......	27	0.53	83	27	37	2.4	246	99	0.5	25	415
1908. Jan. 10	Jan. 19	Trace.	......	24	.02	65	27	33	1.2	249	103	1.8	25	423
Jan. 20	Jan. 29	175	249	25	.50	55	20	16	.0	183	80	1.2	17	307
Jan. 30	Feb. 8	50	62	34	.25	45	19	26	.0	168	72	.6	15	292
Feb. 9	Feb. 18	65	88	29	.35	44	21	30	2.4	173	74	1.3	14	296
Feb. 19	Feb. 28	50	32	28	.07	53	24	29	9.6	188	87	.81	18	334
Feb. 29	Mar. 9	60	92	26	.20	45	22	25	.0	185	83	.94	16	315
Mar. 10	Mar. 19	10	......	30	.30	55	25	28	7.2	215	96	.88	21	352
Mar. 20	Mar. 29	Trace.	......	26	.30	57	24	33	1.2	222	97	1.5	22	380
Mar. 30	Apr. 8	Trace.	......	27	.16	61	28	34	11	221	101	1.2	22	387
Apr. 9	Apr. 18	5	......	25	.08	60	26	33	.0	246	106	1.0	23	388
Apr. 19	Apr. 28	5	......	25	.18	61	27	32	12	229	98	.80	23	391
Apr. 29	May 8	Trace.	......	30	.05	60	28	32	12	229	99	1.0	24	391
May 9	May 18	Trace.	......	32	.03	61	33	35	17	222	98	.60	25	408
May 19	May 28	Trace.	......	30	.15	65	30	41	31	198	103	1.5	29	428
May 29	June 7	5	......	27	.05	64	28	51	9.1	255	100	.80	33	426
June 8	June 17	Trace.	......	24	.20	54	23	53	19	245	87	.62	37	427
June 18	June 27	Trace.	......	28	.05	63	30	66	2.6	305	97	1.2	51	466
June 28	July 7	Trace.	......	30	.19	61	29	83	4.3	312	95	.48	56	475
July 8	July 17	3	......	37	.10	65	30	79	1.2	339	116	.34	65	537
Oct. [a] 1	Oct. 5	Trace.	......	36	.02	57	31	88	2.4	326	103	.5	65	530
Oct. 6	Oct. 15	Trace.	......	42	.07	62	36	103	4.8	349	106	.4	63	544
Oct. 16	Oct. 25	Trace.	......	46	.04	60	32	99	6.0	344	99	.48	64	545
Oct. 26	Nov. 4	Trace.	......	35	.05	63	32	108	3.6	353	95	.30	63	540
Nov. 5	Nov. 14	5	......	35	.05	64	32	84	2.4	351	94	.24	62	544
Nov. 15	Nov. 24	6	......	33	.04	65	32	90	.0	354	98	.18	60	537
Nov. 25	Dec. 4	5	......	29	.08	64	34	93	.0	354	111	.18	60	555
Dec. 5	Dec. 14	Trace.	......	33	.12	66	32	89	4.8	332	106	.40	56	615
Dec. 15	Dec. 24	Trace.	......	35	.06	65	31	92	.0	354	104	.40	57	540
Dec. 24	Dec. 31	35	5.6	36	.08	63	36	126	.0	400	110	.18	64	648
Mean		16	......	31	.15	60	28	59	5.6	272	97	.74	39	448
Per cent of anhydrous residue		....	......	6.8	0.0	13.2	6.2	13.0	30.7	......	21.3	0.2	8.6	......

[a] River dry July 18 to October 1.

The most striking feature shown by the series of analyses is the remarkable increase in total dissolved material at the close of the year. From December, 1907, when the first samples were collected, until the river ceased flowing in the summer of 1908 the total dissolved material varied inversely with the stream flow, falling to 296 parts per million for the period from January 30 to February 8, inclusive, and slowly and gradually rising from that time on until the river ceased flowing, when the total dissolved matter was 537 parts per million. When the stream began flowing above ground in October this value remained practically constant until the first part of December. With the first rainfall of the year the dissolved material, instead of falling with the flood conditions, rose rapidly until the last sample taken showed a value of 648 parts per million. This rise, although at first appearance abnormal, is entirely in accordance with what might be expected in a stream in a semiarid region. During the drought of the summer the amount of soluble material in the soil due to weathering of the rocks and to other causes accumulates and lies ready to be washed into the rivers by the first rainfall. Thus with the first general rains of the winter, the dissolved material, instead of falling off, as during flood conditions in most seasons, rises constantly, and it falls again only when the surface of the drainage basin has been scoured by these early rains. Had the analyses been continued until the later floods of the winter of 1908–9, a constant decrease in the quantity of total dissolved material would have appeared, so that in January and February the figures for this would have been considerably less than 300 parts per million. As great floods occurred in the later winter of 1908–9, the decrease in dissolved material would probably have been very marked.

The water is calcic carbonate in type, but sulphates are important constituents. The alkalis, sodium and potassium, are relatively unimportant until after the drought of the summer, but following the first run-off of the next wet season they are greater than all other bases. This increase in sodium is accompanied by a corresponding though somewhat smaller increase in chlorine.

The water is not well suited for municipal use except at high stages of the river. Its use in the laundry will entail a large expense for soap. In boilers and in the engine its use will be accompanied by the formation of scale. Much of the hard scale can, however, be prevented by chemical treatment. Corrosion of boilers and of kitchen utensils may result from the excessive content of chlorides and nitrates in the water, but this can not be prevented by any chemical process. If the water should be used for municipal supply, therefore, proper storage facilities should be provided so that the flood discharge may be impounded and used throughout the year. No manufacturing plant which uses water as an essential element of its process can use the water of Salinas River with impunity, and the same may be said of all the waters in the Salinas drainage basin.

SAN LORENZO CREEK.

DESCRIPTION.

San Lorenzo Creek rises in the western slopes of the Mount Diablo Range. It is formed by the junction of two small streams, one flowing southeastward through a narrow valley for about 15 miles, the other, Lewis Creek, flowing northeastward from the head of Priest Valley in the Mount Diablo Range. The united waters flow southwestward to Salinas River, having received Peachtree Creek about 5 miles below their junction. The total drainage area of San Lorenzo Creek at the Matthews dam site, about 6 miles northeast of Kings City, is 235 square miles.[a] The stream is torrential, having a large winter flow and being almost dry in summer.

[a] Water-Supply Paper U. S. Geol. Survey No. 89, p. 69 et seq.

CHARACTER OF WATER.

Samples of water were collected from San Lorenzo Creek at Matthews dam site on April 7 and August 25, 1908. The analyses of these samples (see table on p. 71) show this stream to be heavily charged with dissolved mineral matter. Although one sample was taken shortly after the last of the winter rains and the other at the height of the dry season, the analyses show little difference in the quantity of matter in solution. The first sample yielded on evaporation 3,689 parts per million of dissolved matter, and the last 3,653 parts. The chief constituents of this dissolved matter are sodium and sulphates. The alkalies form over two-thirds of the total basic constituents, and on evaporation the water yields large quantities of sodium sulphate or white alkali. In the dry season this appears along the banks of the stream as a frothy effervescence on the rocks and soil. Qualitative analysis of a sample collected August 25, 1908, showed it to be almost pure sodium sulphate.

Normal carbonates are present in large amounts, and, however small their relative proportion, they can not be neglected. No permanently successful irrigation can be carried on with water of this character, and the ground over which it is poured will soon become fit for little else than salt grass, as the minerals dissolved in it are toxic to plant life.

The water is unfit for use in boilers because of its permanent hardness and its tendency to foam and to cause corrosion, and chemical treatment would not render it suitable. Its soap-consuming power is excessive, food cooked in it would lose in flavor and nutrient value, and persons drinking it would probably be unpleasantly affected.

GAVIOTA CREEK.

DESCRIPTION.

Gaviota or Poncha Rica Creek rises in the Mount Diablo Range, its headwaters being separated from those of Cholame Creek by a narrow divide. It flows through a deep canyon for about 10 miles in a northwesterly direction, and then, turning to the southwest, passes through the mesas to Salinas River near San Ardo. It is a torrential stream, with no summer flow in its lower reaches.

CHARACTER OF WATER.

A sample was taken from this creek about 1 mile above San Ardo on April 7, 1908, when the stream was at low stage. In August, 1908, when the creek was revisited, its bed was dry.

The analysis (see table on p. 71) shows that the water of this creek is of very different type from that of San Lorenzo Creek. Although the total dissolved matter is but slightly less, the percentage composition differs radically. The alkalies are present in amounts about equal to the alkaline earths, carbonates are present in small amounts only, and chlorine appears in about one-third the relative quantity found in San Lorenzo Creek. Silica is high, showing a value of more than 100 parts per million.

This water is unfit for irrigation, steaming, or domestic use. If used in irrigation it would saturate the soil with white alkali; in boilers it would cause corrosion, scale, and foaming, and treatment would not materially improve it. Its soap-consuming power is prohibitive. Taken internally its use would be attended with intestinal disorders.

INDIAN VALLEY CREEK.

DESCRIPTION.

Indian Valley Creek rises in the Mount Diablo Range in the vicinity of Stone Canyon and flows southwestward through a broad, deep valley to Salinas River, which it enters about 4 miles below San Miguel. In summer it is a mere trickling rivulet, but in winter it has the torrential character of all the streams of the region. The coal mine at Stone Canyon is the one feature that gives importance to the creek. No good reservoir sites are found on the middle or lower reaches of the creek.

CHARACTER OF WATER.

Samples of water were taken from Indian Valley Creek on April 8 and August 25, 1908.

The analyses (p.71) show the water to be much better than that of the other streams on the northeast side of the Salinas Valley. Total dissolved solids were, in one sample, 1,316 parts per million, and in the other 1,352 parts per million. The principal difference is in the amount of white alkali, as sodium and potassium together are present in about one-fourth the amount found in San Lorenzo Creek and about two-fifths that found in Gaviota Creek. The sulphate radicle predominates among the acids, carbonates being the acid element of second importance. Calcium is almost as high in value as the alkalies, the alkaline earths together being much greater in amount than the alkalies themselves.

Although the water is far superior to that of either San Lorenzo or Gaviota Creek, it is unfit for ordinary domestic or industrial use, and treatment would not materially improve it. In irrigation it might be used successfully if the greatest care and the most scientific methods were employed.

ESTRELLA RIVER.

DESCRIPTION.

Estrella River is formed by the union of San Juan and Cholame creeks. San Juan Creek rises near the head of Carrizo Plain, and, skirting its western edge, traverses a broad valley northward to Shandon, where it meets Cholame Creek, which rises in the Mount Diablo Range and flows southward through a narrow, barren valley. From Shandon the Estrella flows northwestward among rolling hills, uniting with Salinas River at San Miguel, at which place its drainage area comprises 924 square miles.[a] The country through which it passes is semiarid and the soil is sandy, being formed from the disintegration of sandstones and shales.

CHARACTER OF WATER.

Single samples were taken from San Juan and Cholame creeks at Shandon in April and August, 1908, and daily samples were taken from Estrella River near San Miguel throughout the year by J. A. Journey. As the greater part of the water of Estrella River is derived from the combined discharges of the creeks, the characteristics of the creek waters will be discussed first.

Mineral analyses of water from Estrella River near San Miguel.

[Drainage area, 924 square miles. Quantities in parts per million unless otherwise stated.]

Date. From—	Date. To—	Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.
1907. Dec. 31	1908. Jan. 9	30	40	35	0.08	86	49	221	4.8	278	336	0.4	185	1,094
1908. Jan. 10	Jan. 19	50	6	30	.30	80	47	202	4.8	273	345	.24	180	1,084
Jan. 20	Jan. 29	1,800	2,890	38	.30	94	47	155	0	232	299	2.0	145	926
Jan. 30	Feb. 8	950	1,631	28	.12	95	35	173	0	212	350	.26	146	955
Feb. 9	Feb. 18	1,200	1,889	24	.28	90	36	147	0	206	304	1.3	112	925
Feb. 19	Feb. 28	550	853	28	.08	90	48	189	0	240	394	1.0	160	1,039
Feb. 29	Mar. 9	750	910	26	.22	90	40	150	0	292	341	4.0	121	889
Mar. 10	Mar. 19	85	101	31	.32	86	47	195	5.0	266	391	.80	157	1,060
Mar. 20	Mar. 29	5	....	33	.05	86	49	208	14.0	264	403	.92	171	1,117
Mar. 30	Apr. 8	5	....	37	.15	86	54	212	19	257	408	.95	185	1,140
Apr. 9	Apr. 18	5	....	31	.05	80	55	216	17	254	408	.65	193	1,167
Apr. 19	Apr. 28	20	24	33	.33	80	55	219	17	261	408	.90	195	1,162
Apr. 29	May 8	Trace.	....	29	.08	79	56	223	17	261	393	.65	199	1,176
May 9	May 18	Trace.	....	36	.15	77	58	229	8.4	276	422	1.4	214	1,229
May 19	May 28	Trace.	....	40	.35	71	60	247	16	254	444	1.5	223	1,281
May 29	June 7	15	....	26	.08	83	62	259	0	408	383	.34	216	1,233
June 8	June 17	10	....	38	.29	98	75	276	0	394	480	1.6	252	1,433
June 18	June 27	Trace.	....	32	.14	68	54	230	18	230	387	.80	174	1,099
June 28	July 7	5	....	52	.18	69	56	243	19	229	406	.36	206	1,149
July 8	July 17	Trace.	....	42	.15	71	54	250	20	232	418	.34	217	1,182
July 18	July 27	5	....	37	.45	70	60	266	22	245	427	1.4	228	1,254
July 28	Aug. 6	Trace.	....	38	.08	74	59	254	19	259	404	.44	224	1,210
Aug. 7	Aug. 16	6	....	38	.35	64	60	298	19	243	425	1.6	252	1,345
Aug. 17	Aug. 26	5	....	34	.15	66	62	266	17	246	426	.50	234	1,243
Aug. 27	Sept. 5	15	27	38	.28	64	59	275	19	236	417	1.1	241	1,211
Sept. 6	Sept. 15	Trace.	....	36	.08	65	57	250	11	246	418	1.3	223	1,189
Sept. 16	Sept. 25	30	54	37	.15	73	55	235	0	289	455	.18	206	1,198
Sept. 26	Oct. 5	60	83	39	.08	80	55	235	8.4	304	397	.02	195	1,200
Oct. 6	Oct. 15	50	67	40	.18	76	57	218	9.6	310	371	.60	197	1,156
Oct. 16	Oct. 25	45	71	38	.11	80	54	244	7.2	327	381	.70	200	1,180
Oct. 26	Nov. 4	30	27	34	.45	79	56	239	11	315	359	.70	192	1,119
Nov. 5	Nov. 14	70	86	43	.12	81	53	223	9.6	310	356	.40	188	1,131
Nov. 15	Nov. 24	30	81	45	.08	75	51	218	11	292	334	.60	181	1,079
Nov. 25	Dec. 4	40	83	31	.14	69	52	210	2.4	298	348	.92	177	1,039
Dec. 5	Dec. 14	70	122	32	.36	78	46	211	4.8	283	336	.88	177	1,009
Dec. 15	Dec. 24	25	60	29	.13	77	44	195	0	293	324	.60	167	961
Dec. 25	Dec. 31	9	....	32	.10	80	52	216	4.8	276	334	.60	167	978
Mean		161	....	35	.19	79	53	224	9.6	273	385	.88	192	1,131
Per cent of anhydrous residue		....	....	3.1	0.0	7.1	4.8	20.1	12.9	......	34.6	0.1	17.3	......

[a] Hamlin, Homer, The water resources of Salinas Valley, California: Water-Supply Paper U. S. Geol. Survey No. 89, 1904, p. 49.

It is evident from the analyses (p. 71) that the two streams differ radically in the quantity and character of the dissolved mineral matter. The water of San Juan Creek, containing about one-half as much mineral matter in solution as Cholame Creek, is distinctively a sodic sulphated type, calcium being the second most prominent base and chlorine the second most important acid element. The water of Cholame Creek, on the other hand, is almost as highly impregnated with magnesium as with calcium, and one analysis shows magnesium greater. In San Juan Creek potassium is in excess of magnesium; in Cholame Creek the potassium content is only half as great as the magnesium. Carbonates are relatively unimportant in both streams, although the waters of both show at times some normal carbonates. Both are good types of arid region waters and their use is of necessity restricted to irrigation. Even for that use the waters might at times do as much harm as good, although that of the San Juan, if judiciously applied, can probably always be used to advantage.

The result of the blending of these two waters appears in Estrella River, the analyses showing strongly the sodium sulphated character of both. Chlorine is the second ranking acid element, and calcium is second among the bases. Magnesium, although its percentage is small, is present in large quantities, measured absolutely. Nitrates are usually small, but at times are quite high. Normal carbonates are present in considerable amount. Total solids are commonly high, showing a tendency to rise slightly throughout the dry season and to decrease correspondingly during the winter. The heavy floods of January, February, and March are marked by considerable variation in dissolved material and by extreme turbidity. The barren nature of the San Juan, Cholame, and Estrella valleys and the adobe-like character of the top soil combine to produce conditions of decided turbidity after rains. Thus in the flood discharge of January 20 to 30, 1908, the average turbidity for the ten days was 2,890 parts per million, or 784 pounds per acre-foot discharge.

The water of all three streams is unfit for steaming or municipal use. Cholame Creek is unfit for irrigation, but San Juan Creek may be used to advantage if the winter flow can be stored and used in the dry season or if suitable methods are employed.

Estrella River water is also unsuited for irrigation unless rigidly scientific methods are employed, for its use will be attended by the deposition of white alkali and, at times, of considerable black alkali.

HUER HUERO CREEK.

DESCRIPTION.

Huer Huero Creek is tributary to the Salinas south of San Miguel. Its drainage area, approximately 150 square miles [a] in extent, consists of rolling country, partly oak covered and partly under cultivation.

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[a] Planimeter measurement on United States Land Office map.

CHARACTER OF WATER.

A single sample of water was taken from Huer Huero Creek on April 9, 1908, at the ford on the Creston road. At this time there was a very good flow, but in August, when the locality was revisited, the bed was dry.

The water of this creek is shown by the analysis (p. 71) to be entirely different in character from that of the streams of the Estrella River valley. It contains only 451 parts per million of dissolved minerals, and chief among its constituents are, not sodium and sulphates, but sodium and bicarbonates. Normal carbonates are present, and the evaporation of the water would tend to produce black alkali, but the amount of white alkali is small.

The stream is unimportant, but it may find use locally for irrigation, for which its water is fairly well adapted.

ARROYO SECO.

DESCRIPTION.

Arroyo Seco, the most northerly of the tributaries of Salinas River, rises in the Santa Lucia Range, one of the smaller groups which go to make up the Coast Range, and flows in a general northeasterly direction to join the Salinas near Soledad. The upper valleys of this stream are far back in the range, surrounded by high mountains.

The drainage area of Arroyo Seco is made up almost entirely of steep ridges and canyons. The western part is well covered with brush and trees of moderate size, but this growth decreases toward the east until at the Salinas Valley the country is quite bare. The stream bed falls rapidly from an elevation of about 6,000 feet above sea level at its source to about 170 feet at its mouth. The stream is torrential in character, the flow being extremely high during winter and early spring and dwindling to almost nothing later in the season.

The basin is very sparsely settled, there being only a few towns of scarce a hundred population. The main industries are farming and stock raising.

CHARACTER OF WATER.

Samples of water for this investigation were collected by the gage reader at the gaging station near Pettitt's ranch, above Soledad.[a] The stream at this point flows between high rocky banks and its bed is composed of rock and gravel.

The floods of winter and early spring are accompanied by increases in the quantity of matter carried by the stream in suspension. Later

[a] For data concerning the gage heights and discharge of this stream see Water-Supply Papers U. S. Geol. Survey Nos. 81, 100, 134, 177, and 213.

in the season, as the flow diminishes, the water becomes almost limpid.

The water is essentially of the carbonate type, calcium and magnesium predominating in the basic matter. The total amount of mineral matter is fairly high, although not as compared with that of some of the other streams in the Salinas basin.

The water from Arroyo Seco is used for irrigation in the lower valley, canals and intakes being constructed to divert the water before it reaches the broad, level valley of the Salinas. Numerous reservoir sites have been surveyed on this watershed and on the tributaries with the object of storing the flood waters, but as yet the water has not been used except for irrigation.

Mineral analyses of water from Arroyo Seco at Soledad.

[Parts per million unless otherwise stated.]

Date.		Turbidity.	Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Mean discharge.	
From—	To—														Acre-feet per day.	Cubic feet per second.
1906.	1906.															
Jan. 1	Jan. 9	....	22	29	4.0	53	14	29	3.1	0.0	176	70	11	304	254	128
Jan. 11	Jan. 20	....	202	23	1.0	29	7.4	18	2.7	.0	95	40	8.8	140	2,367	1,194
Jan. 21	Jan. 30	....	38	26	1.6	32	7.6	29	3.6	.0	111	37	7.4	158	764	385
Jan. 31	Feb. 9	....	16	26	1.4	25	5.4	14	1.6	.0	134	21	14	226	281	142
Feb. 10	Feb. 18	....	44	21	1.6	35	8.5	7.1	1.7	.0	118	40	11	156	625	315
Feb. 25	Mar. 1	....	74	23	2.0	35	10	7.2	2.7	.0	114	37	9.5	132	807	407
Mar. 2	Mar. 10	....	30	26	2.8	33	9.1	12	1.7	.0	111	38	14	176	1,186	598
Mar. 12	Mar. 21	....	222	18	2.8	28	7.5	8.0	1.3	.0	93	32	15	178	3,764	1,898
Apr. 1	Apr. 10	....	16	19	4.2	35	8.4	16	3.1	.0	107	17	11	180	1,850	933
Apr. 11	Apr. 20	....	36	25	4.6	40	11	13	2.4	.0	126	43	7.8	200	823	415
Apr. 21	Apr. 27	....	....	30	2.0	42	11	15	1.7	.0	134	51	9.8	234	676	341
May 4	May 10	....	26	27	4.0	48	12	16	2.4	.0	154	62	12	238	419	211
May 11	May 20	....	12	28	2.0	51	13	21	2.2	.0	155	59	11	254	355	179
May 21	May 31	....	....	20	3.2	40	13	12	1.9	.0	131	52	12	230	1,024	516
June 1	June 10	....	Trace.	26	5.0	41	11	20	2.2	.0	137	46	9.0	246	510	257
June 11	June 20	....	....	32	3.6	53	14	18	1.8	.0	154	60	12	262	319	161
June 21	June 30	....	14	27	5.6	51	19	26	4.6	.0	161	65	14	264	230	116
					Fe.											
July 1	July 10	....	26	22	.7	45	16	25		.0	158	68	13	276	380	192
July 11	July 20	....	Trace.	25	.10	72	15	26		.0	184	75	13	320	910	459
July 21	July 31	....	22	24	.10	59	16	31		.0	193	87	16	320	649	327
Aug. 1	Aug. 10	....	12	34	.13	65	17	48		.0	207	102	14	270	48	24
Aug. 11	Aug. 20	....	18	33	.10	75	18	49		.0	214	104	15	384	32	16
Aug. 21	Aug. 31	....	8	29	.15	61	18	40		.0	211	105	11	370	24.6	12.3
Sept. 1	Sept. 10	....	20	29	.20	63	19	24		.0	217	110	17	402	2.58	1.3
Sept. 11	Sept. 20	....	16	29	.10	71	19	50		[a]5.0	210	114	19	414	8.93	4.5
Sept. 21	Sept. 30	....	20	28	.10	74	19	48		.0	255	120	11	408	40.7	20.5
Oct. 1	Oct. 10	....	6	30	.10	66	20	54		.0	244	127	19	440	21.2	10.7
Oct. 11	Oct. 20	....	24	27	.05	68	19	48		.0	258	117	20	424	24.8	12.5
Oct. 21	Oct. 31	0	4	23	.15	68	20	52		.0	258	119	18	420	36.7	18.5
Nov. 11	Nov. 20	2	8	28	.7	61	17	42		.0	238	107	16	386	47.6	24.0
Nov. 21	Nov. 30	2	18	26	.15	68	18	40		.0	238	107	18	362	63.5	32.0
Dec. 1	Dec. 10	2	Trace.	24	.10	66	18	43		.0	225	103	18	366	77.5	39.0
Dec. 11	Dec. 20	10	32	18	.30	40	9.1	32		.0	128	47	10	214	2,050	1,034
Dec. 21	Dec. 30	30	46	20	.07	32	9.4	22		.0	113	54	10	196	8,184	4,126
Mean..........		....	33	26	[b].20	51	14	29		.0	170	72	13	284	849	428
Per cent of anhydrous residue..		....	....	9.0	0.1	17.6	4.9	10.0		29.0	....	24.9	4.5	....	....	....

[a] Abnormal; computed as HCO_3 in the average.

[b] Mean of Fe values after July 1.

SAN ANTONIO RIVER.

DESCRIPTION.

San Antonio River rises in the Santa Lucia Mountains directly south of Santa Lucia Peak, which separates its drainage basin from that of Arroyo Seco. Flowing to the southwest in a rather narrow oak-studded valley, it leaves the mountains near the town of Jolon and enters there a series of broad valleys with sandy soil covering, through which it winds it way to the Salinas. Its total drainage area is estimated to be 340 square miles.[a] During the summer season this river has no surface flow in its lower course, although its subsurface flow is probably good.

CHARACTER OF WATER.

Samples of water for this investigation were collected daily during 1908 by Andrew Branch at Branch's ranch house, near the Pinkerton dam site, where the river flows through a narrow pass between sandstone hills. The bed of the stream at this point is sand to about 25 feet thick, and there is surface flow during the greater part of the year. In the dry season and even in the driest years water may always be found within a foot to 18 inches of the surface. During the last part of 1908 the river bed was dry and the samples for analysis were obtained by digging a hole in the sand bed until the underflow water was tapped. The drainage area of the river at the dam site is 322 square miles.[b]

Precise data regarding the flow of the river in 1908 are not available, but the general conditions may be summarized: Maximum-flow periods occurred in January and February, after which the discharge decreased and the bed of the stream at the ranch was quite dry until early in December. During December rainfall in the Santa Lucia Mountains brought a renewal of surface flow, and the river remained as a surface-flowing stream for the remainder of the year.

The results of the investigation are presented in the accompanying analyses:

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[a] Office records of U. S. Geol. Survey.

[b] Hamlin, Homer, The water resources of Salinas Valley, California: Water-Supply Paper U. S. Geol. Survey No. 89, 1904, p. 91.

Mineral analyses of water from San Antonio River near Bradley.

[Parts per million unless otherwise stated.]

Date.		Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.
From—	To—													
1907. Dec. 31	1908. Jan. 9	5	......	32	0.9	56	15	21	0.0	171	85	1.5	14	314
1908. Jan. 10	Jan. 19	5	......	32	.04	64	16	25	.0	181	81	1.4	15	316
Jan. 20	Jan. 29	122	76	31	.03	50	13	20	.0	149	52	1.2	11	260
Jan. 30	Feb. 8	50	68	32	.08	45	11	27	.0	146	60	.34	9.2	242
Feb. 9	Feb. 18	120	197	31	.25	46	13	25	.0	153	61	1.7	9.8	245
Feb. 19	Feb. 28	8	......	37	.14	52	17	24	6.0	157	70	.70	12	280
Feb. 29	Mar. 9	10	......	28	.05	42	12	19	6.0	154	62	.74	11	253
Mar. 10	Mar. 19	5	......	32	.18	47	15	25	.0	173	69	1.2	11	278
Mar. 20	Mar. 29	Trace.	......	34	.03	48	16	22	12.0	156	77	.78	11	291
Mar. 30	Apr. 8	5	......	30	.48	51	17	23	7.2	168	80	1.1	13	295
Apr. 9	Apr. 18	5	......	35	.06	54	16	26	.0	189	86	2.0	17	321
Apr. 19	Apr. 28	Trace.	......	53	.09	53	17	24	7.2	166	82	1.2	14	327
Apr. 29	May 8	Trace.	......	30	.19	53	20	23	8.4	162	82	1.9	14	310
May 9	May 18	5	......	34	.05	53	18	24	.0	185	85	2.0	15	318
May 19	May 28	Trace.	......	36	.12	57	18	24	3.6	184	88	1.7	17	336
May 29	June 7	Trace.	......	36	.18	67	21	21	2.4	214	108	.7	24	401
June 8	June 17	Trace.	......	41	.19	75	24	44	2.4	249	131	1.1	32	476
June 18	June 27	Trace.	......	41	.13	88	30	58	Tr.	298	161	.80	43	562
June 28	July 7	10	......	41	.15	120	39	87	.0	368	226	.68	63	746
July 8	July 17	Trace.	......	39	.21	108	35	78	17.	320	195	1.6	56	691
July 18	July 27	5	......	55	.03	103	36	70	1.2	356	180	1.0	54	683
July 28	Aug. 6	Trace.	......	47	.18	55	19	32	.0	246	58	1.2	19	352
Aug. 7	Aug. 16	Trace.	......	40	.18	55	18	38	.0	238	58	2.0	19	335
Aug. 17	Aug. 26	Trace.	......	43	.29	54	18	33	.0	242	60	1.4	19	334
Aug. 27	Sept. 5	Trace.	......	43	.15	54	17	33	3.6	232	59	1.0	29	336
Sept. 6	Sept. 15	9	......	43	.42	55	18	35	7.2	231	55	1.3	20	339
Sept. 16	Sept. 25	8	......	24	.05	53	17	37	.0	242	54	1.3	21	338
Sept. 26	Oct. 5	Trace.	......	36	.13	55	19	29	8.4	231	56	.1	20	344
Oct. 6	Oct. 15	5	......	37	.06	54	20	43	.0	257	52	1.3	21	333
Oct. 16	Oct. 25	Trace.	......	38	.18	53	19	41	.0	267	55	.62	21	349
Oct. 26	Nov. 4	Trace.	......	35	.03	81	32	76	.0	261	154	1.1	48	575
Nov. 5	Nov. 14	Trace.	......	35	.05	82	30	60	.0	311	142	.8	41	550
Nov. 15	Nov. 24	Trace.	......	35	.05	77	35	63	.0	297	137	0	37	502
Nov. 25	Dec. 4	Trace.	......	41	.08	74	28	52	.0	288	117	.24	31	477
Dec. 5	Dec. 14	Trace.	......	33	.06	66	23	43	.0	220	107	.50	26	394
Dec. 15	Dec. 24	Trace.	......	52	.08	62	22	42	.0	222	103	.34	25	392
Dec. 25	Dec. 31	Trace.	......	33	.28	66	20	43	.0	222	106	.30	27	406
Mean............		10	......	37	.16	63	21	38	2.5	224	94	1.0	24	387
Percent of anhydrous residue..		....	......	9.5	0.0	16.1	5.4	9.7	28.9	......	24.0	0.3	6.1	......

After the last heavy rains in February the amount of mineral matter in solution increased steadily until the end of May. Throughout the month of June this increase was greatly accelerated, the amount of dissolved matter rising from 336 parts to 746 parts per million within the month. After remaining at almost 700 parts per million for nearly a month there was a sudden drop, as the river became dry, to about 335 parts per million. This value was maintained with great constancy until the latter part of October, when there was another quick rise to 575 parts per million, followed by a steady falling off until the end of the year. Although all elements in solution increased during these two periods of great increase in dissolved materials, the largest increase was in the alkalies, sulphates, and chlorides. In each of these there was a percentage increase, while all other elements showed corresponding percentage decreases.

This curious phenomenon probably results from the evaporation of the water flowing just on or near the surface, which causes a much greater concentration of salts at the periods when surface flow is either just ceasing or just recommencing. Aiding the effect of renewed flow is the re-solution of leached salts as the subsurface stream rises in its bed and as the land is washed off later by the early rains. The extreme rise in total dissolved material shown during the first period is accounted for by the fact that the dry season was then well under way and the surface flow was very small—a mere ribbon of water flowing over the loose, sandy bed, from all parts of which evaporation was progressing. During the later period there was no surface flow to be evaporated and the water was rising in a dry sand bed into which it trickled slowly. Hence the absence of evaporation would be partly offset by the increased solution of salts remaining as leachings in the sand.

Suspended matter attained its maximum value during late January and early February, the largest average being 197 parts per million for February 9 to 18, inclusive. At no other time during the year was the water turbid. Corresponding to the period of turbidity is a period of low total dissolved solids, showing clearly the result of flood conditions.

The predominating basic element in this water is calcium, which averages nearly 16 per cent of the total dissolved matter. The variation of this element is entirely in accord with the variation in total mineral matter, the maximum quantity being 120 parts per million June 28 to July 7, and the minimum 42 parts per million February 29 to March 9. Sulphates are high, the analyses showing the marked tendency toward the predominance of the sulphate radicle in the water. In periods of drought the sulphate radicle replaces the bicarbonate radicle as the dominating acid of the water, one analysis showing a value of 226 parts per million.

This stream affords a striking example of the practically universal result of arid conditions. In regions of abundant rainfall vegetation is profuse and its decay produces considerable carbonic acid. The carbonic acid, combining with various elements to form soluble carbonates, is carried out in the soil waters as the carbonate radicle. Hence in the run-off from such regions the predominating acid will usually be carbonic acid. In arid countries, on the other hand, vegetation is deficient, carbonic acid is not produced in great abundance, and the predominating acid will be determined by the character of the mineral formations over which the water has flowed. In San Antonio River both of these processes operate, and in addition the effect of organic carbonic acid is to a certain extent masked by the presence of large amounts of mineral carbonates in the drainage area. In times of rainfall most of the water is derived from vegetated regions, in which the soil covering is sufficient to protect the underlying rock, and the water flowing off is impregnated with carbonic acid.

In the dry season this vegetation becomes dry and burnt. The soil is thus bared to the sun's action, and the water, flowing now from the greater depths only, loses its characteristic charge of carbonic acid and assumes a character depending upon the soluble minerals of the subsoil stratum—in this area largely sulphates and carbonates.

Chlorides are high—higher, possibly, than proximity to the coast alone would cause. The normal flood-discharge value of this radicle appears to be about 10 parts per million, but it reached as high as 63 parts per million during June, 1908, and its dry-weather value is unfailingly high.

The water of San Antonio River can be used at all times for irrigation—a use that would necessitate storage and thus reduce the content of dissolved minerals below the average shown. The water is hard, will form scale readily, will cause large consumption of soap, and in general is one which must be softened if used for industrial purposes. For drinking it should be boiled or filtered. The addition of a small amount of soda ash would tend to prevent the formation of scale on kitchen utensils.

The river is one of the most easily available and accessible sources of supply of water for irrigation in Salinas Valley. Crops would be exposed to little danger from black alkali in the river water. In flood seasons practically no normal carbonates are present, and when they are present the amount of water flowing is relatively small.

NACIMIENTO RIVER.

DESCRIPTION.

Nacimiento River rises in the Santa Lucia Mountains near the headwaters of San Antonio River, and flows parallel to the latter throughout its course. Its upper valley is narrow, with a decided slope, while the lower valley consists of broad, rolling mesa lands, through which the river winds in a wide, sandy bottom. Throughout most of the lower part of its course the river is dry in summer, flowing above ground only in short stretches. Practically the whole of the lower river is within the boundaries of the Nacimiento ranch, and its valley is devoted entirely to cattle grazing. The total drainage area of the river is about 380 square miles.[a]

The stream is torrential in character, the banks on either side being constantly worn away by the winter floods, and as a result the river bottom has in many places been widened to extend as much as 400 feet from bank to bank. There are practically no sites on this stream suitable for erecting dams for storage reservoirs, especially in the lower valley.

The discharge of the Nacimiento is of the same character as that of the San Antonio. Exact measurements for 1908 are lacking, but records for 1901[a] show that the flow is about the same in the two streams, Nacimiento River carrying slightly more water than the San Antonio.

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[a] Office records, U. S. Geol. Survey.

[b] Water-Supply Paper U. S. Geol. Survey No. 89, pp. 50–51; and No. 66, p. 154.

CHARACTER OF WATER.

Samples of the water were collected during 1908 by agents of A. F. Benton, of the Nacimiento ranch, at a point about 500 feet above the ranch house. The river here normally flows above ground all the year, but during the summer of 1908 it was dry for some months and a hole had to be dug in the sand bed to allow the cattle to water. Another smaller hole was used for a sampling station. The drainage area of the river at the sampling point is about 300 square miles.[a]

During 1908 there were two periods of turbid water. The first, in January and February, was due to the late seasonal rains of the winter; the second, in October, November, and December, resulted from the thunderstorms of the fall and the early rains of the new wet season. During the greater part of the summer the river was dry, and a decided increase was noted in the amount of dissolved mineral matter in the samples. The records show no fluctuation in the amount of dissolved material corresponding to the midseason drop in San Antonio River.

Calcium is the principal basic constituent of the water, sodium and potassium together rank second, and magnesium approaches very closely to and at times even exceeds the alkalies. The bicarbonate is the principal acid radicle, sulphates are second in importance, and chlorides are generally third, while the nitrates play a varying part, reaching a maximum of 40 parts per million in one set of samples.

The seasonal variation in dissolved matter is normal. The minimum quantity of dissolved material was found in January, when 178 parts per million were recorded. Maximum dissolved solids occurred August 17 to 26, inclusive, the analysis of the composite sample showing 403 parts per million. In general the dissolved salts appear to be less in the Nacimiento than in the San Antonio, except in the midsummer season, when the abnormal drop in the dissolved material in the San Antonio occurred.

The remarkable fluctuation in nitrates in the Nacimiento is easily accounted for by the fact that the whole middle valley is given over to cattle raising, the river being used as a watering place by between three thousand and four thousand head of cattle. The result is that in the dry season, when the stream flow is small and when the cattle frequent the river in greater numbers, large amounts of organic waste are deposited in the stream, charging the water very highly with chlorine and organic material. Decomposition of the latter gives rise to excessive nitrates and ammonia. Some of the samples collected in the dry season gave off a very strong animal odor and even showed at times a high color from the organic salts.

The water is excellent for irrigation, and if a storage reservoir could be located within reasonable distance of the Salinas Valley the water could be utilized to render large areas of the valley productive.

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[a] Planimeter measurement on United States Land Office map.

But there appear to be no good sites in the lower valley, none, at least, nearer than the Santa Lucia foothills. Neither in this river nor the San Antonio is serious danger to be apprehended from silting up of storage reservoirs or canals. So long as the mountain reaches are wooded and so long as the basin is not further bared of protective vegetation little suspended material will be brought down in floods.

If well filtered the water would make a good domestic supply provided the cattle were prevented from wading above the point of intake. Its hardness is largely permanent, and the addition of soda ash would be advisable to render it suitable for use in steam boilers. The high nitrates in the water at times might, however, cause corrosion. Both this river and the San Antonio vary so greatly in discharge that all general statements must be qualified by the assertion that the value of the water depends upon the amount of the stream flow at the time of use.

Mineral analyses of water from Nacimiento River near San Miguel.

[Parts per million unless otherwise stated.]

Date. From—	Date. To—	Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.
1908.	1908.													
Jan. 10	Jan. 19	5	....	25	0.10	38	19	16	0.0	157	55	0.56	10	238
Jan. 20	Jan. 29	45	58	22	.25	30	16	18	.0	131	49	.52	7.5	194
Jan. 30	Feb. 8	50	54	23	.18	30	13	12	.0	127	42	1.4	6.5	178
Feb. 9	Feb. 18	10	....	24	.18	36	17	16	.0	159	63	2.0	10	235
Feb. 19	Feb. 28	5	....	22	.15	35	18	16	.0	159	53	.44	8.5	220
Feb. 29	Mar. 9	4	....	27	.23	36	19	16	6.0	153	66	.56	9.1	249
Mar. 20	Mar. 29	Tr.	....	20	.14	45	21	23	.0	173	73	1.6	12	266
Mar. 30	Apr. 8	5	....	25	.18	39	19	20	.0	174	68	2.2	10	257
Apr. 10	Apr. 19	5	....	24	.35	42	22	26	2.4	173	75	2.2	11	278
Apr. 29	May 8	Tr.	....	19	.28	45	22	19	9.6	151	79	1.7	13	274
May 9	May 18	Tr.	....	14	.26	42	22	20	11	149	70	1.4	12	268
May 19	May 28	Tr.	....	17	.18	36	21	20	2.4	144	75	1.5	13	258
May 29	June 7	Tr.	....	20	.12	34	21	21	9.8	122	70	1.8	15	244
June 8	June 17	Tr.	....	26	.18	34	21	24	8.4	122	72	.20	14	251
June 18	June 27	Tr.	....	28	.21	40	21	22	3.6	148	73	2.0	15	278
June 28	July 7	5	....	30	.15	42	20	20	.0	168	74	2.0	16	300
July 8	July 17	[a] 50	42	29	.15	52	26	28	.0	222	66	4.0	19	340
July 18	July 27	Tr.	....	33	.11	45	24	33	.0	290	54	2.5	23	376
July 28	Aug. 6	[a] 325	734	34	.25	46	25	30	.0	244	69	2.0	20	380
Aug. 7	Aug. 16	[a] 450	1,000	35	.15	58	29	27	.0	218	95	40	18	383
Aug. 17	Aug. 26	....	....	43	.38	60	26	33	.0	199	102	8.0	17	403
Aug. 27	Sept. 5	Tr.	....	16	.39	53	25	29	.0	195	97	20	16	361
Sept. 6	Sept. 15	[a] 9	....	28	.21	44	22	23	.0	185	72	3.2	13	295
Sept. 16	Sept. 25	[a] 60	97	27	.02	42	20	21	.0	171	77	2.5	14	285
Sept. 26	Oct. 5	....	....	27	.09	42	23	21	.0	162	80	14	15	304
Oct. 6	Oct. 15	Tr.	....	20	.03	35	17	22	.0	159	64	7.7	10	227
Oct. 16	Oct. 25	20	19	25	.53	41	21	21	.0	156	81	6.5	14	301
Oct. 26	Nov. 4	8	....	25	.24	39	21	30	.0	154	73	2.1	15	278
Nov. 5	Nov. 14	25	57	30	.12	37	21	28	.0	156	68	1.2	15	265
Nov. 15	Nov. 24	55	72	26	.12	39	21	25	.0	151	72	3.6	13	274
Nov. 25	Dec. 4	8	....	27	.18	44	24	28	.0	176	81	4.0	18	313
Dec. 5	Dec. 14	12	39	24	.06	44	25	33	.0	193	79	4.0	18	314
Dec. 15	Dec. 24	Tr.	....	20	.16	46	26	32	.0	198	82	1.2	20	327
Dec. 25	Dec. 31	Tr.	....	21	.12	43	27	34	4.8	173	83	.32	22	310
Mean		36	....	25	.19	42	22	24	1.7	171	72	4.4	14	286
Per cent of anhydrous residue		......	....	8.6	0.1	14.5	7.6	8.3	29.8	......	24.8	1.5	4.8	......

[a] Turbidity due to cattle agitating pool from which samples were taken. High NO_3 due to cattle pollution.

SAN BENITO RIVER.

DESCRIPTION.

San Benito River drains that portion of the Coast Range lying south of Monterey Bay and east of the Salinas Valley—in all about 220 square miles. The river rises near San Benito and Lookout mountains, flows northwestward for about 60 miles, and joins Pajaro River in the vicinity of Sargents, whence it continues its course westward as the Pajaro and enters Monterey Bay a short distance south of Santa Cruz. The upper portion of the basin is rough and broken and the formation is of granite overlain with shales and sandstones. The bed of the valley is wide and flat and is composed of deep beds of sand into which the waters of the river disappear during the dry season.

The principal industry of this region is agriculture, although some stock raising is carried on in the hills. The waters of the San Benito are diverted into irrigation ditches a short distance above Hollister and used in the lower valley. Quantities of peaches, plums, and apricots are raised. Farther north, where the conformation of the bed rock again brings the ground waters nearer the surface and where Pajaro River cuts through the Coast Range, is the Pajaro Valley, the principal apple-raising district of the State.

The flow of the stream is torrential because precipitation on the watershed is altogether in the form of rain. Greatest discharge takes place during the late winter and early spring. No discharge measurements of the river are available.

CHARACTER OF WATER.

Samples of water for this investigation were collected at the headworks of the irrigation ditch a short distance above Hollister and forwarded to the laboratory through the courtesy of Mr. N. C. Briggs. The results of the study are shown in the accompanying analyses.

At times of flood discharge the river carries large quantities of suspended matter, mostly in the form of coarse sand. Later in the season the water becomes clear again, and still later the entire flow of the stream disappears in the deep beds of sand which fill its channel.

Owing to the amounts of magnesium contained in the rocks of this region the waters show on analysis quantities of magnesium proportionately much greater than in almost any other river in the State. As large amounts of sulphates are also present, it is evident that the water should not be used in steam boilers unless some adequate means of softening are adopted. It is, however, fit for irrigation, as experience in the valley has shown. For municipal supplies it can not be recommended. That the water in the smaller creeks at the higher levels is much superior is shown by the result of an analysis of the water of Pescadero Creek, the sample being collected at Grass Valley March 31, 1908, and an analysis of water from the San Benito at Hollister, the sample being taken on the same day. Pescadero Creek is the source from which the municipal supply of the city of Hollister is derived.

Mineral analyses of water from San Benito River at Hollister.

[Parts per million unless otherwise stated.]

Date.		Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.
From—	To—												
1906.	1906.												
Jan. 1	Jan. 10	176	25	1.4	65	92	234	2.0	27	356	383	184	1,136
Jan. 11	Jan. 20	4,448	26	1.4	58	35	80	4.7	0.0	229	140	68	516
Jan. 21	Jan. 30	1,224	25	3.2	92	......	126	5.4	0.0	375	246	118	856
Jan. 31	Feb. 9	94	15	3.4	62	59	165	5.4	6.5	384	270	147	950
Feb. 10	Feb. 19	934	16	1.6	52	60	119	2.4	16	363	208	99	728
Feb. 20	Mar. 1	2,376	27	3.0	38	36	44	3.0	0.0	....	109	......	502
Mar. 2	Mar. 11	3,650	25	3.4	54	40	58	2.4	0.0	273	144	60	522
Mar. 12	Mar. 21	5,808	24	4.0	35	27	36	......	4.9	191	80	32	356
Apr. 1	Apr. 9	1,518	26	2.0	49	39	42	5.4	0.0	271	88	40	508
Apr. 11	Apr. 17	132	23	3.8	47	53	67	3.3	5.0	322	130	59	576
May 13	May 20	100	26	4.0	64	58	110	5.3	2.7	331	197	96	718
May 21	May 30	2,530	28	3.0	57	62	105	3.8	8.8	318	217	98	776
May 31	June 10	92	24	3.8	53	70	91	1.8	11	362	187	76	740
June 11	June 20	34	26	5.8	53	67	90	3.6	0.0	359	235	106	824
June 21	June 30	172	24	6.6	62	72	123	5.1	3.0	362	272	130	936
				Fe.									
Dec. 1	Dec. 10	112	32	.10	68	80	180		8.0	456	310	141	1,000
Dec. 11	Dec. 20	1,104	21	.10	84	56	122		6.0	375	212	74	706
Dec. 21	Dec. 30	1,498	20	.07	57	66	144		12	372	254	93	836
Mean............		1,444	24	[a].09	58	57	110		6.2	335	204	95	732
Per cent of anhydrous residue..		....	3.3	0.0	8.1	8.0	15.3		23.8	....	28.3	13.2	....

[a] Mean of Fe values after December 1.

Analyses of water of Pescadero Creek at Grass Valley and San Benito River near Hollister.

[Analyst, Walton Van Winkle. Quantities in parts per million.]

	Pescadero Creek.	San Benito River.		Pescadero Creek.	San Benito River.
Silica (SiO_2)..................	28	17	Bicarbonate radicle (HCO_3)...	107	425
Iron (Fe)......................	.08	.17	Sulphate radicle (SO_4)........	13	214
Calcium (Ca)..................	30	50	Chlorine (Cl)..................	19	69
Magnesium (Mg).............	7.6	78	Total solids	166	756
Sodium and potassium (Na+K)....................	21	107	Turbidity......................	Trace.	50
Carbonate radicle (CO_3)......	0.0	7.2	Suspended matter............	....	78

CARMEL RIVER.

DESCRIPTION.

Carmel River rises on the coastal side of the Santa Lucia Range, flows in a generally northwest direction, and empties into Carmel Bay. Throughout its course it traverses a narrow, heavily timbered valley, which widens out near the coast into a broad, fertile plain edged by the Santa Lucia and Sierra de Salinas ranges. The total drainage area of the river is 275 square miles.[a] The formations exposed are chiefly granitic rocks with some sedimentary sandstones and shales.

CHARACTER OF WATER.

Two samples were taken from this river in 1908 about 2 miles above Carmel by the Sea, one on April 10 and one on August 29. The results of the analyses of these samples are shown in the following table:

Analyses of water of Carmel River, 2 miles above mouth.

[Collector and analyst, Walton Van Winkle. Quantities in parts per million.]

	April 10, 1908.	August 29, 1908.		April 10, 1908.	August 29, 1908.
Turbidity	5	Trace.	Carbonate radicle (CO_3)	0.0	7.2
Silica (SiO_2)	24	27	Bicarbonate radicle (HCO_3)	134	151
Iron (Fe)	.45	.14	Sulphate radicle (SO_4)	56	79
Calcium (Ca)	38	50	Chlorine (Cl)	25	47
Magnesium (Mg)	12	18	Nitrate (NO_3)	.36	.8
Sodium and potassium (Na+K)	33	43	Total solids	248	336

Being a typical coastal stream, Carmel River may be expected to carry large quantities of sodium and chlorine. The value for sodium is only slightly less than that obtained for calcium, while chlorine was present in the first sample analyzed to the amount of 25 parts per million, or 10 per cent, and in the second to the amount of 47 parts per million, or 14 per cent. The carbonates are low, in the second sample yielding place to the sulphates as the predominating constituent.

The water is suitable for irrigation and, if filtered, for domestic use, although it is hard. For use in boilers it should be treated with soda ash to remove permanent hardness and prevent the obnoxious sulphate scale. It can not be used without treatment for industrial purposes where water plays a chemical part. However, as a municipal supply it is fairly satisfactory, and the cities of Monterey and Pacific Grove so use it at present, the intake of the water supply being above the limit of habitations in the valley.

[a] Hamlin, Homer, the water resources of Salinas Valley, California: Water-Supply Paper U. S. Geol. Survey No. 89, 1904, p. 77.

SANTA MARIA RIVER.

DESCRIPTION.

Santa Maria River drains that portion of the Coast Range lying between the San Rafael Mountains and the southernmost end of the Diablo Range. It flows westward and discharges into the Pacific Ocean at Guadalupe, about 25 miles south of San Luis Obispo. It is torrential in character—subject to floods of short duration during the rainy season, but being practically dry during the summer months. It receives numerous tributaries, the most important of which is the Sisquoc, which joins it about 12 miles above Santa Maria.

The country throughout this basin consists of rolling foothills, except the higher elevations of the San Rafael Mountains, which reach altitudes of 6,000 to 8,000 feet above sea level. The river breaks from the foothills at the point where it is joined by the Sisquoc and flows through a flat for a distance of 25 miles until it reaches the ocean.

The bed rock is shale, sandstone, or conglomerate, with a good covering of clay soil. Considerable timber is found on the higher elevations, but over most of the region timber is scanty, large areas being covered with brush and grass. A large part of the basin, especially in the higher regions, is given up to pasturage. Lower in the valley agriculture is the principal industry. The water for the irrigation of these areas is derived chiefly from wells driven in the valley floor. No diversions are made from the river for this purpose. Precipitation in this basin is almost entirely in the form of rain, the small amount of snow that falls on the higher portions of the watershed being insufficient to maintain a constant flow in the stream during the dry season.

CHARACTER OF WATER.

Samples of water for this investigation were collected at the gaging station near the house on Dutard's ranch, about 25 miles above Santa Maria.[a] The stream at this point is swift at all stages; its bed is composed of sand and gravel, part of which is overgrown with brush, and its banks are high and rocky and not liable to overflow.

A large quantity of suspended matter is carried by the river during flood periods, when the water also carries its minimum quantity of dissolved mineral matter, and if the flood water could be stored it would form a fairly good supply for use in irrigation. During the dry season the flow is small and the mineral matter is high. Calcium, magnesium, and sodium are abundant, as well as sulphates, chlorides, carbonates, and bicarbonates.

[a] For data concerning gage heights and discharges, see Water-Supply Papers U. S. Geol. Survey Nos. 100, 134, and 177.

The water is unsuited for domestic or industrial use. The high content of magnesium and calcium, along with the sulphates, marks it as very bad for use in boilers. The tendency of the water to deposit black alkali at certain seasons shows it to be ill adapted for irrigation.

Mineral analyses of water from Santa Maria River at Santa Maria.

[Parts per million unless otherwise stated.]

Date.		Turbidity.	Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.
From—	To—													
1906.	1906.													
Jan. 2	Jan. 10	....	6.0	22	5.6	342	164	247	6.1	0.0	228	1,617	127	......
Jan. 11	Jan. 20	....	74	24	1.8	287	149	278	8.3	.0	200	1,492	127	2,776
Jan. 21	Jan. 30	....	1,030	68	5.0	314	164	......	......	.0	243	912	122	2,992
Jan. 31	Feb. 9	....	7,744	20	8.6	462	162	351	12	.0	429	1,684	137	3,252
Feb. 10	Feb. 19	....	1,998	18	6.6	406	152	170	6.7	.0	244	1,614	116	2,948
Feb. 20	Feb. 25	....	1,028	30	7.2	322	142	230	6.3	.0	248	1,458	115	2,540
Mar. 1	Mar. 8	....	190	20	2.8	346	162	181	7.2	.0	228	1,561	124	3,004
Mar. 18	Mar. 21	....	5,520	19	8.4	253	69	86	4.5	.0	190	768	54	1,516
Mar. 22	Mar. 31	....	2,002	18	4.6	190	60	78	4.5	[a] 9.8	224	556	48	1,200
Apr. 1	Apr. 10	....	456	20	3.2	206	82	83	3.5	.0	276	699	67	1,512
Apr. 11	Apr. 20	....	334	22	2.8	279	113	159	8.5	.0	269	977	87	1,926
Apr. 21	Apr. 28	....	Trace.	20	3.0	264	124	186	7.2	.0	264	1,122	103	2,274
May 4	May 9	....	70	17	5.0	258	123	197	11.0	.0	253	1,110	100	2,152
May 10	May 20	....	42	.....	5.6	273	134	181	5.6	.0	257	1,215	118	2,372
May 21	May 30	....	146	22	6.6	270	121	116	4.7	.0	254	1,080	87	2,126
June 1	June 10	....	46	26	7.0	272	131	163	5.4	.0	243	1,175	100	2,330
June 11	June 20	....	20	27	7.4	274	145	134	8.2	.0	232	1,325	110	2,508
June 21	June 30	....	Trace.	30	6.8	348	145	136	4.6	.0	222	1,287	110	2,480
					Fe.									
July 1	July 10	....	....	27	.10	233	125	226		[a] 4.0	212	1,123	94	2,218
July 11	July 19	....	38	20	.10	169	93	154		.0	301	734	84	1,564
July 20	July 31	....	8,430	24	.20	312	158	207		.0	291	1,557	127	2,910
Aug. 1	Aug. 10	....	414	30	.30	324	143	223		[a] 4.0	242	1,370	103	2,624
Aug. 11	Aug. 20	....	8	22	.10	321	146	192		.0	224	1,427	105	2,654
Aug. 21	Aug. 31	....	Trace.	20	.20	359	143	225		.0	227	1,357	101	2,526
Sept. 1	Sept. 10	....	50	17	.10	288	136	223		.0	219	1,261	00	2,386
Sept. 11	Sept. 20	....	8.0	19	.20	258	122	159		[a] 5.0	226	1,068	91	2,084
Sept. 21	Sept. 30	....	Trace.	20	.20	231	106	197		.0	290	957	81	1,878
Oct. 1	Oct. 10	....	Trace.	26	.05	203	93	191		.0	320	769	75	1,638
Oct. 11	Oct. 20	....	36	24	.10	274	122	244		.0	293	1,083	97	2,178
Oct. 21	Oct. 31	....	Trace.	22	.10	299	141	282		.0	264	1,381	121	2,592
Nov. 1	Nov. 10	5	Trace.	26	.30	334	158	102		[a] 7.0	224	1,503	127	2,824
Nov. 11	Nov. 20	5	24	35	.15	330	160	290		.0	247	1,569	130	2,832
Nov. 21	Nov. 30	400	274	26	.10	374	169	300		.0	282	1,700	140	3,014
Dec. 1	Dec. 10	400	224	20	.02	335	154	......	......	.0	243	1,461	130	2,974
Dec. 11	Dec. 20	4,000	5,600	18	.10	456	149	264		.0	278	1,648	131	2,946
Dec. 21	Dec. 31	>7,000	9,776	21	.02	406	128	229		.0	210	1,473	105	2,656
Mean...........		....	1,302	24	[b] .14	302	133	200		.0	254	1,253	105	2,412
Per cent of anhydrous residue..		....	....	1.1	0.0	14.1	6.2	9.4		5.8	.....	58.5	4.9	......

[a] Abnormal. Computed as HCO_3 in the average. [b] Mean of Fe values after July 1.

SANTA YNEZ RIVER.

DESCRIPTION.

Santa Ynez River rises in the mountains of Santa Barbara and Ventura counties and flows westward with a flat grade to the Pacific Ocean, a distance of about 75 miles. The basin is bounded on the north by the San Rafael Mountains and on the south by the Santa Ynez, altitudes ranging from 3,000 to 4,000 feet above sea level. The northern part of the basin is drained by streams running southward and uniting with the Santa Ynez proper, which hugs the base of the Santa Ynez Mountains. The principal tributary, Mono Creek, enters from the north.

The bed rock throughout this basin is shale and sandstone. The greater part of the area is covered with brush and small trees; only on the higher elevations is there any considerable amount of timber. As precipitation on this drainage area is almost entirely in the form of rain, the stream discharge is torrential, the greatest flow occurring during the late winter and early spring.

CHARACTER OF WATER.

Samples for this investigation were collected at the north portal of the tunnel known as the Gibraltar dam site by N. Clark. The stream at this point is swift, between banks which are low but not likely to overflow. The bed is composed of sand and gravel.[a]

At flood periods the river carries large amounts of suspended matter, but the water becomes clear again after a short time. The dissolved mineral matter is high, and is of such character that the water must be classed as sulphated. Trouble may therefore be expected in the use of this water for steaming. The adoption of a lime and soda process for softening the water would lead to great economy in any industry using this supply. The water may be unhesitatingly adopted for household purposes if the drainage area is kept in a sanitary condition.

The river water is not at present used industrially, but works under construction will conduct it under the Santa Ynez Mountains to supply Santa Barbara and neighboring coast towns.

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[a] For data concerning gage heights and discharge, see Water-Supply Papers U. S. Geol. Survey Nos. 81, 100, 177, and 213.

A more detailed account of the water supply of Santa Barbara is contained in Water-Supply Paper No. 116.

Mineral analyses of water from Santa Ynez River at Santa Barbara.

[Parts per million unless otherwise stated.]

Date. From—	Date. To—	Turbidity.	Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Mean discharge. Acre feet per day.	Mean discharge. Cubic feet per second.
1906.	1906.															
Jan. 1	Jan. 8	....	Trace.	27	1.0	80	39	45	2.6	0.0	309	224	26	686	7.58	3.8
Jan. 12	Jan. 20	....	446	23	2.0	90	40	21	3.2	.0	244	283	22	680	56.2	28.1
Jan. 21	Jan. 30	....	106	25	2.6	82	47	59	2.1	.0	289	334	27	806	30.8	15.4
Jan. 31	Feb. 9	....	42	29	2.6	87	48	63	2.3	.0	286	312	43	776	17.4	8.7
Feb. 10	Feb. 19	....	36	20	4.2	113	44	36	2.4	.0	255	317	33	758	111	56.1
Feb. 20	Feb. 28	....	36	21	3.6	116	49	37	3.9	.0	272	339	27	792	47.6	23.8
Mar. 2	Mar. 10	....	28	19	2.6	106	48	56	1.2	.0	233	309	26	754	69.2	35.1
Mar. 13	Mar. 20	....	692	18	3.6	104	40	32	3.1	.0	241	264	18	664	2,572	1,297
Mar. 31	Apr. 10	....	36	18	2.6	121	51	53	2.9	.0	270	326	18	800	597	301
Apr. 11	Apr. 20	....	18	24	3.2	111	53	36	2.2	.0	264	341	17	818	238	120
Apr. 21	Apr. 25	....	10	23	4.4	121	55	....	5.8	6.6	254	364	22	776	161	81.2
May 8	May 10	....	....	....	....	.....	....	....	....	.0	273	......	22	......	83	42
May 11	May 20	....	Trace.	27	5.0	122	55	69	3.5	.0	276	360	22	838	64.8	32.9
May 21	May 31	....	42	26	6.0	109	45	45	2.2	.0	251	302	19	736	234	118
June 1	June 10	....	36	24	....	111	51	73	....	.0	256	331	22	782	73.2	37.1
June 11	June 20	....	....	23	2.8	107	50	65	6.4	14	217	352	20	782	40	20.0
June 21	June 30	....	10	33	9.2	127	48	56	....	.0	217	330	24	730	28.8	14.5
					Fe.											
July 1	July 10	....	Trace.	22	.10	102	45	57		5.0	259	275	21	690	17.4	8.7
July 11	July 20	....	60	22	.05	95	44	59		12	235	275	28	690	10.2	5.8
July 21	July 30	....	12	30	.07	112	43	73		.0	264	263	21	654	6.40	3.2
Aug. 1	Aug. 10	....	12	29	.15	98	43	69		8.0	249	254	24	664	4.16	2.1
Aug. 11	Aug. 16	....	2	26	.20	103	43	70		8.5	232	258	24	696	2.78	1.4
Sept. 2	Sept. 10	....	2	28	.05	100	40	61		11	270	238	26	662	1.98	1
Sept. 11	Sept. 20	....	60	21	.05	88	44	72		5.5	273	254	24	646	1.98	1
Sept. 21	Sept. 30	....	24	23	.20	93	44	58		.0	290	251	27	670	1.98	1
Oct. 1	Oct. 10	5	48	29	.27	105	45	64		5.0	282	254	31	656	1.98	1
Oct. 11	Oct. 20	2	6	32	.10	86	51	67		.0	308	259	28	664	1.98	1
Oct. 21	Oct. 31	....	6	29	.10	92	41	74		5.5	304	290	28	664	1.98	1
Nov. 13	Nov. 20	2	6	25	.10	105	43	74		5.0	324	214	26	648	2.98	1.5
Nov. 21	Nov. 30	....	10	21	.07	74	43	51		.0	203	227	24	664	3.17	1.6
Dec. 3	Dec. 10	....	78	14	.15	61	40	51		.0	324	244	25	610	5.16	2.6
Dec. 11	Dec. 20	60	122	19	.02	114	42	62		.0	272	313	24	764	152	76.8
Dec. 21	Dec. 31	40	10	18	.05	105	35	58		.0	258	220	20	636	149	75.2
Mean............		....	64	24	a .11	101	45	58		2.6	265	287	25	714	145	73
Per cent of anhydrous residue..		....	....	3.6	0.0	15.0	6.7	8.6		19.9	......	42.6	3.6	......	....	....

Date. From—	Date. To—	Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.
1907. Dec. 31	1908. Jan. 9	5	......	20	0.10	138	51	60	4.8	253	421	0.12	17	864
1908.														
Jan. 10	Jan. 19	5	......	24	.08	64	57	132	4.8	268	419	.28	15	805
Jan. 20	Jan. 29	50	135	17	.15	136	45	49	4.8	244	336	Trace.	11	715
Jan. 30	Feb. 8	70	356	23	.18	99	47	54	0	264	357	1.1	15	794
Feb. 9	Feb. 18	60	64	29	.25	114	45	55	0	271	353	.33	12	769
Feb. 29	Mar. 9	Tr.	......	19	.12	103	53	47	0	250	350	.90	11	764
Mean............		32	......	22	.15	109	49	66	2.4	258	373	.46	14	785
Per cent of anhydrous residue..		......	......	2.9	0.0	14.3	6.4	8.6	16.9	......	49.0	0.1	1.8	......

a Mean of Fe values after July 1.

VENTURA RIVER.

DESCRIPTION.

The San Buena Ventura or, as it is commonly called, Ventura River, rises to the south of the Nordhoff Mountains and flows in a general southerly direction to the Pacific Ocean above Ventura. Its slope is steep and its valley is narrow in its lower course, while in its upper course it traverses Nordhoff Valley, a broad plateau devoted largely to the raising of oranges.

Just above the town of Ventura the Ventura County Power Company is building a dam to divert the waters of the river for municipal supply and for irrigation. The river at this point passes through a narrow canyon, the grade being high and the bed rocky. Bed rock is exposed on the northern side of the canyon and sinks away to the southward, but rises again nearly to the surface at the opposite bank. The bed of the canyon and its surface are covered with a good growth of brush and small trees.

CHARACTER OF WATER.

Samples of water were collected daily during 1908 at the dam site, through the kindness of Mr. J. E. Barker, and later of Mr. C. L. Frost, superintendent of the Ventura County Power Company. The company met all expenses for collection. No stream-flow records were kept during 1908 on this river. The results of the examination of the samples are shown in the accompanying analyses.

Mineral analyses of water from Ventura River near Ventura.

[Drainage area 210 square miles. Quantities in parts per million unless otherwise stated.]

Date. From—	Date. To—	Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.
1907. Dec. 31	1908. Jan. 9	5	......	23	0.09	132	29	49	2.4	222	268	0.56	22	620
1908. Jan. 10	Jan. 19	5	......	25	.10	118	32	43	1.2	226	252	.46	23	619
Jan. 20	Jan. 29	40	8	21	.16	101	27	48	.0	199	225	1.1	17	546
Jan. 30	Feb. 8	35	56	20	.10	101	26	52	3.6	194	225	.32	9.9	522
Feb. 9	Feb. 18	20	5	24	.08	107	27	38	4.8	195	249	1.2	12	557
Feb. 19	Feb. 28	7	......	24	.35	93	27	40	7.2	191	242	.50	13	563
Feb. 29	Mar. 9	Trace.	......	22	.03	95	28	42	6.0	187	249	.64	14	568
Mar. 10	Mar. 19	Trace.	......	21	.03	98	29	36	5.0	195	250	.84	16	563
Mar. 20	Mar. 29	Trace.	......	22	.08	98	29	38	9.6	198	250	6.0	16	574
Mar. 30	Apr. 8	Trace.	......	29	.04	100	30	40	12	193	252	1.8	16	596
Apr. 9	Apr. 18	Trace.	......	25	.07	99	28	46	.0	211	254	.90	17	582
Apr. 19	Apr. 28	Trace.	......	23	.05	101	28	43	9.6	198	259	.68	16	581
Apr. 29	May 8	Trace.	......	14	.05	100	29	40	3.6	212	251	.75	19	600
May 9	May 18	Trace.	......	18	.43	99	29	44	7.2	198	266	.46	18	600
May 19	May 28	Trace.	......	21	.15	101	29	45	4.8	212	253	.34	21	598
May 29	June 7	Trace.	......	23	.05	103	30	43	.0	223	252	.10	20	606
June 8	June 17	Trace.	......	27	.30	109	28	44	Tr.	239	261	.68	19	628
June 18	June 27	Trace.	......	11	.13	108	27	46	9.6	226	248	.70	20	595
June 28	July 7	Trace.	......	23	.12	103	32	43	16	200	250	1.2	21	513
July 8	July 17	Trace.	......	24	.08	101	30	42	4.8	221	252	.66	20	591
July 18	July 27	Trace.	......	26	.08	103	30	47	4.8	223	247	1.2	20	606
July 28	Aug. 6	Trace.	......	23	.18	106	31	44	7.2	230	251	.65	21	598
Aug. 7	Aug. 16	Trace.	......	24	.23	108	30	40	.0	246	262	.50	22	610
Aug. 17	Aug. 26	Trace.	......	28	.17	108	32	45	2.4	237	256	Tr.	22	632
Aug. 27	Sept. 5	Trace.	......	23	.17	104	29	48	7.2	220	251	.10	20	611
Sept. 6	Sept. 15	Trace.	......	24	.05	114	30	42	.0	255	255	.18	21	688
Sept. 16	Sept. 25	5	......	23	.15	107	28	41	6.0	244	252	.20	21	622
Sept. 26	Oct. 5	5	......	22	.12	107	30	45	.0	262	253	.50	22	639
Oct. 6	Oct. 15	5	......	23	.12	105	31	45	2.4	254	249	.76	22	623
Oct. 16	Oct. 25	Trace.	......	25	.04	105	30	65	.0	266	250	.24	23	637
Oct. 26	Nov. 4	Trace.	......	23	.07	109	31	58	.0	262	253	.26	23	655
Nov. 5	Nov. 14	Trace.	......	25	.15	108	31	61	.0	244	246	......	23	631
Nov. 15	Nov. 24	Trace.	......	28	.34	107	32	55	.0	249	252	.30	22	640
Nov. 25	Dec. 4	Trace.	......	23	.05	111	32	56	.0	259	249	.20	25	637
Dec. 5	Dec. 14	Trace.	......	24	.07	111	30	51	2.4	257	256	.64	24	635
Dec. 15	Dec. 24	Trace.	......	25	.28	111	31	56	.0	257	249	.40	27	651
Dec. 25	Dec. 31	Trace.	......	23	.35	112	35	74	4.8	259	263	.74	26	650
Mean		3	......	23	.14	106	30	47	3.9	226	251	.72	20	605
Per cent of anhydrous residue		......	......	3.9	0.0	17.9	5.1	7.9	19.4	......	42.4	0.0	3.4	......

The water of Ventura River, like that of other rivers of the coastal region of middle California, carries a large amount of dissolved solids. Prominent among the constituents appear calcium and sulphates, the latter averaging 42 per cent of the total dissolved material. Alkalies are high, as is also carbonic acid in the bicarbonate form. Chlorine is not exceptionally high nor is magnesium, the ratio of magnesium to calcium being 1 to $3\frac{1}{2}$.

The samples showed little variation in the mineral content of the water between flood season and time of drought. Minimum values occurred in 1908 in early February, 522 parts per million being recorded for the composite sample of January 30 to February 8, inclusive; while the maximum, 688 parts per million, occurred in the middle of September. Turbidity is invariably low, the soil covering of the area affording good protection from erosion and the rocky river bottom giving little chance for the gathering of silt from the bed of the stream.

The water is hard, is a poor supply for steaming, would need treatment to render it fit for use in boilers, and is to be classed among the less desirable supplies for municipal use. Although it is not bad for drinking, it is likely to produce unpleasant effects on persons not well accustomed to such highly charged waters. It should not be adopted for a municipal supply without purification.

MALIBU CREEK.

DESCRIPTION.

Malibu Creek, which enters the Pacific Ocean about 15 miles above the town of Santa Monica, is formed near the town of Calabasas by the union of Triunfo and Las Virgenes creeks. These creeks rise in the Santa Monica Mountains and flow southward to their confluence The drainage basin includes the northern part of the Santa Monica Range and the foothills immediately adjoining. The bed rock throughout the basin is of shale, sandstone, and conglomerate, with good soil covering. A sparse growth of timber is found on the higher elevations, but the greater part of the area is covered with brush and grass and is used for pasturage. Grain is raised on small areas. A reservoir has been constructed on the upper reaches of Triunfo Creek, and the water is used for irrigation during the dry months. The stream is very torrential in character, owing to the steep and barren nature of its drainage area and to the fact that the precipitation is wholly in the form of rain.

CHARACTER OF WATER.

Samples of water for this investigation were collected at the gaging station near Calabasas[a] by the gage reader. The stream at this point is swift and flows between high banks. The right bank is rocky. The bed of the river is composed of rock and gravel.

The creek carries large amounts of suspended matter during flood periods; at other times the water is fairly clear, but it then carries a high content of dissolved mineral matter. (See analyses.) Las Virgenes Creek, draining more of the sandstone area than Triunfo Creek, carries considerably more alkaline material. The discharge of Las Virgenes Creek is smaller than that of Triunfo Creek, and the water of Malibu Creek does not show the extreme alkalinity that might be expected.

[a] For data concerning gage heights and discharge, see Water-Supply Papers U. S. Geol. Survey Nos. 100, 134, 177, and 213.

The water would be classed as sulphate, because calcium and the sulphate radicle are both high. For this reason it is poorly adapted for industrial uses unless some means are taken to soften it. It is not unsuited for household use.

Mineral analyses of water from Malibu Creek near Calabasas.

[Parts per million unless otherwise stated.]

Date.		Turbidity.	Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Mean discharge.	
From—	To—														Acre-feet per day.	Cubic feet per second.
1906.	1906.															
Jan. 1	Jan. 10	....	32	33	3.0	160	78	104	4.1	0.0	344	566	66	1,266	1.59	0.8
Jan. 11	Jan. 20	....	50	42	2.0	143	70	98	......	.0	327	499	58	1,140	1.86	.94
Jan. 21	Jan. 30	....	Tr.	37	3.8	110	61	69	2.0	.0	304	367	53	930	4.64	2.34
Jan. 31	Feb. 9	....	24	31	1.6	126	56	79	2.8	.0	289	331	69	842	1.82	.92
Feb. 10	Feb. 18	....	112	31	2.0	66	31	34	1.7	8.1	218	138	33	448	5.10	2.57
Feb. 19	Mar. 1	....	20	35	4.0	102	50	50	3.1	.0	287	256	42	680	4.50	2.27
Mar. 2	Mar. 11	....	2	33	5.2	105	57	60	1.3	3.3	277	359	58	966	5.99	3.02
Mar. 22	Mar. 31	....	310	25	4.4	43	26	35	2.7	.0	199	90	27	400	11.17	5.63
Apr. 1	Apr. 10	....	14	34	3.8	64	38	38	1.6	.0	251	159	28	536	73.4	37.
Apr. 11	Apr. 20	....	.....	30	.....	79	46	55	3.6	.0	256	172	27	576	37.3	18.8
Apr. 21	Apr. 30	....	26	36	5.0	82	48	53	4.7	.0	312	204	31	636	12.75	6.43
May 1	May 10	....	38	34	4.2	78	45	54	2.8	.0	272	200	35	604	19.8	10.0
May 11	May 20	....	12	32	3.8	83	46	61	5.4	.0	287	236	36	670	15.8	7.96
May 21	May 31	....	50	31	5.4	94	46	58	4.4	2.9	267	212	36	624	18.6	9.36
June 1	June 9	....	34	39	4.4	91	43	58	2.1	7.0	258	198	31	570	14.1	7.1
June 10	June 19	....	34	35	5.2	85	40	44	2.0	6.0	253	186	29	582	14.1	7.1
June 24	June 30	....	.....	31	3.6	73	43	59	3.8	11	247	187	30	592	14.1	7.1
					Fe.											
July 1	July 10	....	48	44	.20	78	42	53		8.0	257	217	30	578	10.9	5.49
July 11	July 20	....	30	34	.10	72	40	44		.0	273	181	30	594	8.73	4.40
July 21	July 30	....	4	40	.08	198	100	195		.0	378	830	81	1,766	8.73	4.40
Aug. 1	Aug. 9	....	44	48	.07	95	42	65		.0	283	188	31	598	8.73	4.40
Aug. 11	Aug. 20	....	4	42	.20	86	41	48		5.0	275	191	32	584	8.73	4.40
Aug. 21	Aug. 31	....	.....	34	.10	85	32	....		.0	278	184	31	592	8.73	4.40
Sept. 1	Sept. 8	....	12	39	.20	89	42	34		9.0	261	186	30	596	8.73	4.40
Sept. 22	Sept. 30	....	26	41	.10	123	60	106		.0	324	399	50	976	5.02	2.53
Oct. 1	Oct. 10	....	4	39	.05	104	45	69		.0	322	238	41	708	8.73	4.40
Oct. 11	Oct. 20	....	30	37	.10	94	43	70		.0	319	198	36	614	8.73	4.40
Nov. 11	Nov. 20	5	60	43	.15	117	62	131		6.0	340	400	54	960	8.73	4.40
Nov. 21	Nov. 30	....	80	40	.15	138	70	111		.0	374	462	59	1,070	8.73	4.40
Dec. 1	Dec. 10	....	.....	30	.06	149	70	112		5.2	305	443	56	......	9.26	4.67
Dec. 11	Dec. 20	15	102	30	.05	124	62	94		.0	345	410	61	932	11.0	5.54
Dec. 21	Dec. 29	400	498	31	.01	104	42	76		.0	245	233	40	656	7.62	38.4
Mean		....	61	36	[a].11	101	50	73		2.2	288	285	42	751	47	24
Per cent of anhydrous residue		....	.....	4.9	0.0	13.8	6.8	10.0		19.7	.....	39.0	5.8	......	......	......

[a] Mean of Fe values after July 1.

VALLEY OF SOUTHERN CALIFORNIA.

DESCRIPTION.

The merging valleys of Los Angeles, San Gabriel, and Santa Ana rivers have been grouped together into what may be called the valley of southern California.[a] This valley lies south of the San Gabriel and San Bernardino mountains and west of the San Bernardino and San Jacinto mountains. On the south its limits are poorly defined,

[a] Mendenhall, W. C., Hydrology of San Bernardino Valley, California: Water-Supply Paper U. S. Geol. Survey No. 142, 1905, p. 9.

as it is there broken up into many smaller valleys by the irregular projecting ridges of the southern ranges. Much information has been gained concerning its waters by investigations made by the United States Geological Survey, and the literature on the subject is extensive.[a]

SAN GABRIEL RIVER.

DESCRIPTION.

San Gabriel River is formed on the southern slopes of the Sierra Madre by several small coequal streams, which unite just before the river enters its deep lower canyon, whence it emerges just above the town of Azusa into a broad alluvial valley, where it gradually sinks beneath the surface, its course being marked by a characteristic sand "wash."

At the lower end of the San Gabriel Valley, near Rivera, the seepage waters are brought to the surface again by an obstruction to the underflow and pass over the surface through a narrow gap in the surrounding hills in two distinct streams, one of which is called the San Gabriel and the other the Rio Hondo. Leaving the pass they again sink into the sandy soil of the valley below. The San Gabriel finally finds its way to San Pedro Bay, and the Rio Hondo joins Los Angeles River.

Above Azusa the San Gabriel Valley is rough and mountainous and the tributaries flow in deep, narrow canyons. The bed rock of these upper hills is granitic and the soil covering is fair. A heavy growth of timber is found in the foothills and a sparse growth above. Below Azusa the valley is broad and is covered with a deep soil of sand and alluvium. The bed of the river is gravelly and is interspersed with bowlders and sandy stretches.

The mountainous areas of the San Gabriel basin receive an annual rainfall of 20 to 40 inches. The greater part of this precipitation occurs during the winter, the months of June, July, and August being as a rule exceedingly dry. Ground storage facilities are, however, good, and there is continuous flow throughout the year.

Much of the water is diverted about 5 miles above Azusa for the power station of the Pacific Light and Power Company.

Samples of water were collected daily during 1908 near Azusa and at Rivera, and a single sample was taken from Rio Hondo near Rivera.

CHARACTER OF WATER NEAR AZUSA.

The samples of water for this investigation were taken from the diversion canal of the power company by J. P. Woodward, A. W. Peake, and J. W. Moon, of the company.

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[a] Water-Supply Papers U. S. Geol. Survey Nos. 81, 100, 134, 137, 138, 139, 142, 177, and 213.

According to measurements made at Azusa, 57 per cent of the total discharge of the stream during 1908 occurred between January 20 and April 18, the rise in gage height being very constant and the falling off rather gradual. Minimum summer flow was reached in the early part of September, the stream flowing from that time until the end of the year with slight fluctuation.

The analyses of the composite samples show no pronounced changes in the amount of total dissolved matter in the stream throughout the year. The period of maximum discharge was marked by a slight decrease in dissolved material, and the amount rose gradually from that time until the end of the year, but the total variation was only 56 parts per million.

Mineral analyses of water from San Gabriel River near Azusa.

[Drainage area, 222 square miles. Quantities in parts per million unless otherwise stated.]

Date.		Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.	Mean discharge.		Run-off per square mile (cubic feet per second).
From—	To—														Acre-feet per day.	Cubic feet per second.	
1907. Dec. 31	1908. Jan. 9	Trace.	......	24	0.20	60	12	19	2.4	190	40	0.40	3.7	240	103.5	52.2	0.2351
1908. Jan. 10	Jan. 19	Trace.	......	21	.10	57	12	21	.0	196	41	.76	5.2	238	117.6	59.3	.2671
Jan. 20	Jan. 29	10	......	21	.15	52	11	17	.0	161	33	1.2	5.1	204	493.3	248.7	1.1203
Jan. 30	Feb. 8	5	......	22	.05	40	8.7	21	.0	160	27	.28	4.4	190	686.6	346.2	1.5595
Feb. 9	Feb. 18	Trace.	......	25	.10	41	12	25	2.4	159	34	.48	3.5	196	487.9	246.0	1.1080
Feb. 19	Feb. 28	Trace.	......	22	.12	44	12	14	6.0	164	29	.85	4.0	198	379.8	191.5	.8626
Feb. 29	Mar. 9	Trace.	......	22	.08	44	11	16	.0	171	27	.38	4.0	195	377.6	190.4	.8552
Mar. 10	Mar. 19	5	......	20	.05	42	11	19	3.6	167	27	.34	4.0	193	393.5	198.4	.8937
Mar. 20	Mar. 29	Trace.	......	18	.03	41	11	11	2.4	161	29	.78	3.1	184	463.9	233.9	1.0536
Mar. 30	Apr. 8	Trace.	......	19	.29	43	11	13	7.2	159	32	2.0	3.1	195	378.2	190.7	.8590
Apr. 9	Apr. 18	Trace.	......	22	.04	44	10	13	.0	175	32	1.8	3.0	200	291.9	147.2	.6630
Apr. 19	Apr. 28	5	......	19	.20	43	11	11	4.8	161	29	.40	4.0	191	279.6	141.0	.6351
Apr. 29	May 8	Trace.	......	19	.05	42	12	9.9	13	143	29	1.0	2.6	187	314.7	158.7	.7149
May 9	May 18	Trace.	......	20	.21	44	13	16	7.2	160	38	1.2	3.0	198	249.3	125.7	.5662
May 19	May 28	Trace.	......	20	.08	46	12	12	7.2	163	36	1.0	2.5	192	182.9	92.2	.4153
May 29	June 7	Trace.	......	18	.17	41	11	17	4.8	167	28	.75	4.0	201	161.1	81.2	.3658
June 8	June 17	Trace.	......	18	.15	45	11	13	3.6	172	27	2.0	3.5	195	154.3	77.8	.3505
June 18	June 27	Trace.	......	18	.08	44	11	13	4.8	172	29	.15	3.5	196	133.1	67.1	.3022
June 28	July 7	5	......	21	.13	46	11	14	.0	171	42	1.1	3.7	211	92.2	46.5	.2095
July 8	July 17	5	......	21	.23	46	13	14	7.2	171	31	.30	14.0	206	81.5	41.1	.1851
July 18	July 27	Trace.	......	25	.15	43	13	18	1.2	178	29	1.3	6.0	212	73.4	37.0	.1666
July 28	Aug. 6	*a* 260	450	25	.50	44	14	15	1.2	179	32	.....	4.0	218	91.4	46.1	.2077
Aug. 7	Aug. 16	90	206	20	.32	43	11	25	3.6	171	32	.70	3.4	202	76.6	38.6	.1739
Aug. 17	Aug. 26	10	14	24	.35	47	14	15	7.2	166	39	.76	5.5	220	63.1	31.8	.1387
Aug. 27	Sept. 5	6	......	18	.38	45	12	24	4.8	171	33	1.0	4.8	204	56.3	28.4	.1279
Sept. 6	Sept. 15	300	452	27	.50	40	13	13	.0	163	35	17.0	3.3	222	55.1	27.8	.1252
Sept. 16	Sept. 25	90	45	21	.18	42	13	17	6.0	168	32	Tr.	4.2	204	65.8	33.2	.1495
Sept. 26	Oct. 5	40	91	18	.10	39	13	23	11	166	30	.....	3.7	208	67.6	34.1	.1536
Oct. 6	Oct. 15	10	......	21	.05	40	14	20	.0	196	35	Tr.	4.0	211	61.5	31.0	.1396
Oct. 16	Oct. 25	5	......	17	.04	48	12	18	2.4	200	30	Tr.	3.0	213	73.0	36.8	.1657
Oct. 26	Nov. 4	Trace.	......	19	.28	50	13	22	2.4	198	33	.28	5.0	228	63.7	32.1	.1446
Nov. 5	Nov. 14	Trace.	......	18	.05	50	16	15	4.8	196	22	.12	4.5	221	64.1	32.3	.1455
Nov. 15	Nov. 24	Trace.	......	19	.14	50	16	24	.0	201	24	.10	5.0	223	65.4	33.0	.1495
Nov. 25	Dec. 4	18	44	20	.08	47	14	27	.0	204	30	.20	3.7	223	92.4	46.6	.2099
Dec. 5	Dec. 14	4	......	18	.08	49	14	20	.0	195	37	.50	5.5	220	102.1	51.5	.2319
Dec. 15	Dec. 24	Trace.	......	21	.11	49	13	16	.0	205	34	.44	4.2	226	80.3	40.5	.1824
Dec. 25	Dec. 31	Trace.	......	20	.08	50	14	29	.0	209	29	.28	4.7	239	78.1	39.4	.1775
Mean............		23	......	21	.16	45	12	18	3.3	176	32	1.1	4.3	208	190.5	96	.43
Per cent of anhydrous residue..		......	......	9.4	0.1	20.1	5.4	8.0	40.3	....	14.3	0.5	1.9	....	......	......	......

a Cloudburst July 31. Turbidities as follows: July 31, 775; August 1, 725; August 2, 380; August 3, 400; August 4, 340; August 5, 335. "River rose 4 to 6 feet July 31, 1908" (J. W. Moon).

The water is distinctly of the calcic-carbonate type. The amount of normal carbonates in this water is decidedly high, as is apparent from the table of analyses. Owing to the small amount of total dissolved solids present, however, the water can not be considered dangerous for use in irrigation.

The water requires little treatment to make it well adapted for steaming. Small amounts of soda ash added to it will precipitate the greater part of the calcium and magnesium present, and thus prevent the formation of hard scale in boilers. With proper protection from bacterial pollution the water would make an excellent municipal supply, the high nitrates found in it appearing to be due not so much to animal as to vegetal organic material.

CHARACTER OF WATER AT RIVERA.

Although only a small quantity of water is added to the San Gabriel by rainfall between Azusa and Rivera, the seepage waters which are brought above ground at Rivera by an obstruction to the underflow contain, besides the original San Gabriel River water, such water as is brought from either side for irrigation at the edges of the valley and such as may be pumped from the underground waters of the valley for irrigation. The total influx of these foreign waters must, however, be small, and the effect of the seepage between the towns of Azusa and Rivera must be demonstrated by the analyses of the samples taken at the two places. The Rivera samples were collected daily during 1908 by Mrs. S. E. Palett.

The changes that occur in the water of San Gabriel River between Azusa and Rivera are noteworthy as illustrating those taking place in a water flowing underground for a short distance, and the following table brings together for comparison the average results of analyses of water taken above and below the place of subsurface flow.

Comparison of the quality of water of San Gabriel River at Azusa and near Rivera, 1908.

	Mineralization, in parts, per million.		Percentage composition of anhydrous residue.	
	Azusa.	Rivera.	Azusa.	Rivera.
Silica (SiO_2)	21	23	9.4	8.8
Iron (Fe)	.16	.11	.1	.1
Calcium (Ca)	45	55	20.1	21.0
Magnesium (Mg)	12	12	5.4	4.6
Sodium and potassium (Na+K)	18	22	8.0	8.4
Carbonate radicle (CO_3)	3.3	2.2	40.3	40.6
Bicarbonate radicle (HCO_3)	176	211	....	....
Sulphate radicle (SO_4)	32	33	14.3	12.6
Chlorine (Cl)	4.3	8.4	1.9	3.2
Nitrate radicle (NO_3)	1.1	1.9	.5	.7
Total solids	208	246	....	....

There are increases in calcium, alkalies, bicarbonates, and chlorine. The average increase in bicarbonates is 35 parts per million, corresponding to 11.5 parts per million of calcium if all is the result of solution of calcium carbonate. The average increase in chlorine is 4.1 parts per million, corresponding to 2.7 parts per million of sodium as sodium chloride. The increase in carbonic acid may be expected, inasmuch as one of the results of the decay of plant life is the formation of carbonic acid, which in solution readily attacks calcium carbonate rocks and dissolves them. As the water is used extensively for irrigation and passes in its course through sandy and gravelly soil covered by a good vegetation, all conditions are favorable for such action, and undoubtedly that is what actually occurs. The increase in the amounts of these two elements is typical of the effect of more intimate contact with the materials of the river bed. The attendant rise in the quantity of nitrates present probably occurs from vegetable decay. In fact, the manner in which the charring occurred upon heating the evaporated salts from the water of the San Gabriel at Rivera leads to the conclusion that the greater proportion of organic material present is vegetable matter.

The water of the San Gabriel at Rivera shows a magnesium to calcium ratio of 1 to 4.6, or considerably lower than that found at Azusa. In other words, there is no introduction of magnesium corresponding to the increase in calcium in this water. Silica, also, shows a scarcely appreciable change, while the change in the sulphate radicle is practically nothing. The total effect of the subsurface passage of the water is an increase in mineralization without much change in the relative proportions of the substances present.

The similarity of the waters of San Gabriel River at Azusa and Rivera is such that little can be said regarding the value of one which is not equally true of the other. Of course, as the river at the lower point has received, in addition to any pollution reaching it above Azusa, large amounts of sewage of the valley, its use for domestic purposes would be extremely unsafe unless measures were taken to insure the removal of pathogenic bacteria.

Mineral analyses of water from San Gabriel River near Rivera.

[Parts per million unless otherwise stated.]

Date. From—	Date. To—	Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.
1907. Dec. 31	1908. Jan. 9	8	......	25	0.15	68	11	17	0.0	218	40	15	6.9	262
1908. Jan. 10	Jan. 19	5	......	24	.01	76	9.8	19	.0	217	34	.16	7.0	266
Jan. 20	Jan. 29	100	151	22	.11	63	8.5	19	.0	185	37	1.4	7.9	231
Jan. 30	Feb. 8	20	31	20	.07	50	9.8	19	.0	185	31	1.2	7.2	223
Feb. 9	Feb. 18	5	......	22	.07	58	11	24	.0	200	38	1.1	5.0	236
Feb. 19	Feb. 28	5	......	22	.08	60	11	24	.0	214	34	1.9	9.0	244
Feb. 29	Mar. 9	Trace.	......	22	.05	58	13	21	2.4	207	33	1.8	7.4	241
Mar. 10	Mar. 19	5	......	25	.05	52	10	23	7.2	203	28	2.1	7.5	249
Mar. 20	Mar. 29	Trace.	......	30	.05	40	13	19	.0	213	26	3.0	7.9	237
Mar. 30	Apr. 8	5	......	24	.05	52	12	20	.0	211	36	4.0	8.5	248
Apr. 9	Apr. 18	5	......	25	.10	53	12	19	16	186	36	1.5	6.5	253
Apr. 19	Apr. 28	5	......	24	.18	52	9.8	22	.0	215	35	2.0	6.5	247
Apr. 29	May 8	Trace.	......	26	.03	54	13	18	.0	214	30	4.0	7.0	248
May 9	May 18	Trace.	......	26	.10	54	12	19	4.8	209	29	.84	6.5	251
May 19	May 28	Trace.	......	26	.18	57	12	22	.0	220	37	2.0	12	258
May 29	June 7	6	......	22	.04	55	11	23	6.0	203	33	1.8	7.7	244
June 8	June 17	Trace.	......	21	.08	54	12	18	.0	210	30	.56	8.9	238
June 18	June 27	Trace.	......	21	.15	54	11	18	.0	221	36	.82	15	251
June 28	July 7	Trace.	......	24	.08	53	11	18	9.6	193	29	1.6	8	240
July 8	July 17	Trace.	......	23	.00	55	10	20	7.2	200	28	.86	7.7	237
July 18	July 27	Trace.	......	19	.29	52	12	25	.0	212	30	1.2	7.5	243
July 28	Aug. 6	Trace.	......	23	.16	53	12	19	.0	212	30	......	8.5	240
Aug. 7	Aug. 16	3	......	20	.04	54	12	23	6.0	207	30	......	9.0	239
Aug. 17	Aug. 26	Trace.	......	22	.19	55	12	20	7.2	203	29	1.4	8.0	245
Aug. 27	Sept. 5	3	......	26	.12	62	13	26	9.6	201	32	1.6	17	268
Sept. 6	Sept. 15	Trace.	......	33	.22	55	11	20	Tr.	222	29	1.2	7.5	255
Sept. 16	Sept. 25	Trace.	......	20	.07	54	12	19	.0	224	29	1.3	8.5	246
Sept. 26	Oct. 5	Trace.	......	23	.08	52	12	18	2.4	217	30	......	7.5	230
Oct. 6	Oct. 15	5	......	26	.07	55	12	23	.0	237	34	1.8	8.3	258
Oct. 16	Oct. 25	Trace.	......	25	.13	53	11	38	.0	223	40	1.5	7.5	250
Oct. 26	Nov. 4	Trace.	......	21	.12	54	11	20	2.4	221	30	1.2	9.5	248
Nov. 5	Nov. 14	6	......	21	.08	52	11	20	.0	222	27	.98	8.0	246
Nov. 15	Nov. 24	Trace.	......	21	.08	52	12	32	.0	217	30	.96	7.5	250
Nov. 25	Dec. 4	Trace.	......	20	.15	50	13	24	.0	220	30	1.1	9.0	247
Dec. 5	Dec. 14	Trace.	......	22	.34	42	12	37	.0	212	46	1.0	9.0	246
Dec. 15	Dec. 24	6	......	25	.24	54	13	27	.0	220	38	.94	8.5	253
Dec. 25	Dec. 31	Trace.	......	23	.04	53	16	35	.0	222	38	1.6	8.5	249
Mean		5	......	23	.11	55	12	22	2.2	211	33	1.9	8.4	246
Percent of anhydrous residue		....	......	8.8	0.1	21.0	4.6	8.4	40.6	......	12.6	0.7	3.2	......

RIO HONDO.

DESCRIPTION.

Rio Hondo resembles the lower San Gabriel. Rising nearly at the same place in the narrows above Rivera, the rivers pass side by side through the gap in the hills but gradually draw farther apart, one merging with Los Angeles River and the other percolating underground to the Pacific Ocean.

CHARACTER OF WATER.

The following analysis of a sample of water collected from Rio Hondo near Rivera on March 16, 1906, shows the water to be essentially the same as that of the lower San Gabriel, and had daily samplings been made the average results would undoubtedly have been nearly identical.

Analysis of the water of Rio Hondo near Rivera, Cal., March 16, 1908.

[Sample collected and analyzed by Walton Van Winkle. Quantities in parts per million.]

Turbidity	Trace.	Carbonate radicle (CO_3)	2.4
Silica (SiO_2)	26	Bicarbonate radicle (HCO_3)	229
Iron (Fe)	.08	Sulphate radicle (SO_4)	21
Calcium (Ca)	50	Chlorine (Cl)	16
Magnesium (Mg)	13	Nitrate radicle (NO_3)	1.2
Sodium and potassium (Na+K)	26	Total solids	267

SANTA ANA RIVER.

DESCRIPTION.

Santa Ana River rises in the San Bernardino Mountains in the eastern part of the San Bernardino National Forest. Flowing westward in its upper course, the river emerges from the mountains through a deep precipitous gorge about 5 miles northeast of the town of Mentone, and traverses the broad San Bernardino Valley, sinking beneath its sandy bed and appearing on the surface only in flood seasons. Through this valley the river bottom is wide and shallow and the bed is composed of mixed sand and gravel. Near the city of San Bernardino the water rises to the surface and is here diverted for irrigation. Little of the river water appears again at the surface until it finally reaches the sea.

In its upper course the river passes through a rough, broken country, and receives many tributaries, chief among which is Bear Creek, the outlet of Bear Lake, on which a dam has been constructed to store the winter run-off for summer use. The bed rock of this part of the basin is granite and the soil covering is good.

The rich alluvial lands of the lower valley are devoted almost exclusively to the production of citrus fruits, the value of the river water for irrigation being great.

During 1908 samples of water were collected daily from the Santa Ana near Mentone and near Corona at the head of the canyon.

CHARACTER OF WATER NEAR MENTONE.

At Mentone the Pacific Light and Power Company has built a power station, to which much of the water of the river is diverted through a flume. The river bed at this point is composed of bowlders, with stretches of hard, firm sand; the current is swift, and the course of the stream is practically straight for a short distance. The samples were collected daily by Charles S. Putnam—from the flume during the period when all the water was diverted, but at other times from the river itself.[a]

The water of the upper Santa Ana is, like that of San Gabriel River, calcic carbonate in type. As stream flow is somewhat equalized by the effect of the storage of the headwaters, the mineral

[a] For data regarding gage heights and discharge of Santa Ana River, see Water-Snpply Papers U. S. Geol. Survey Nos. 81, 100, 134, 177, and 213.

content shows no marked variation, the changes that occur being due apparently to local conditions apart from season or stream flow. The bicarbonate radicle is the predominating constituent, calcium and silica sharing the second place. Sulphates average over 12.5 per cent of the total dissolved material, while chlorides are unimportant. Turbidity is seldom great. The value for suspended solids exceeded 50 parts per million only twice in 1908, both times as the result of severe storms which were reported as cloudbursts. The water is well adapted for all purposes. For use in boilers small amounts of soda ash may be added to it to remove hard incrustants, but the chemical treatment of the water for ordinary industrial use is unnecessary. The water should be filtered or otherwise purified before it is used for domestic purposes.

Mineral analyses of water from Santa Ana River above Mentone.

[Parts per million unless otherwise stated.]

Date.		Turbidity.	Suspended matter.	Silica (SiO_2).	$Fe_2O_3+Al_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Mean discharge including canal.		Mean discharge without canal.	
From—	To—														Acre-feet per day.	Cubic feet per second.	Acre-feet per day.	Cubic feet per second.
1906.	1906.																	
Jan. 1	Jan. 10	...	8	32	1.2	23	5.6	27	0.3	0.0	113	14	6.1	140	69.2	34.9	1.98	31.0
Jan. 11	Jan. 20	...	34	24	.8	31	4.4	16	2.4	.0	111	13	5.9	176	124	62.3	43.2	21.8
Jan. 21	Jan. 30	...	36	26	1.2	25	4.8	29	3.1	.0	119	16	6.9	132	88.3	44.5	11.5	5.8
Jan. 31	Feb. 9	...	42	26	1.8	37	10	14	1.8	.0	116	51	6 9	136	69.8	35.2	1.98	1.0
Feb. 11	Feb. 18	...	32	17	2.2	29	5.0	14	1.3	.0	112	9.9	11	156	113	57.0	1.98	1.0
Feb. 20	Feb. 28	...	8	21	2.8	25	4.8	18	1.2	.0	111	12	7.5	160	198	100	93.4	47.1
Mar. 2	Mar. 11	...	6	16	4.2	30	6.1	15	2.4	.0	117	15	8.8	156	124	62.4	25.8	13.0
Mar. 12	Mar. 19	...	808	13	2.4	19	4.1	9.1	1.5	.0	78	10	11	150	1,551	782	1,489	75.1
Mar. 23	Mar. 31	...	82	19	2.8	21	4.6	13	2.0	.0	82	7.4	6.9	160	1,926	971	1,846	93.1
Apr. 1	Apr. 10	...	4	18	4.0	33	7.2	16	3.8	.0	92	13	6.9	144	502	253	392	198
Apr. 11	Apr. 20	...	46	16	3.6	27	7.0	15	2.8	.0	96	15	5.9	124	384	194	246	124
Apr. 21	Apr. 30	...	16	14	4.4	24	6.8	13	2.4	.0	88	10	5.9	114	746	376	605	305
May 2	May 10	...	14	16	3.2	26	7.7	21	3.0	.0	94	10	6.2	138	530	267	388	196
May 11	May 20	...	24	16	1.8	20	5.2	12	1.1	.0	94	8.6	7.8	122	390	197	258	130
May 21	May 31	...	36	10	3.6	23	5.3	10	1.3	.0	90	11	5.9	128	544	274	423	213
June 1	June 10	...	32	16	3.4	23	5.7	12	2.0	.0	88	16	7.6	104	394	199	256	129
June 11	June 20	...	14	15	5.8	24	6.8	8.4	1.3	.0	89	12	5.9	142	329	166	190	95.8
June 21	June 30	...	....	....	....	....	....	....	....	....	....	....	....	....	297	150	159	80.2
					Fe.													
July 1	July 10	...	8	13	.10	21	6.7	14		.0	88	16	6.3	142	263	133	123	62.3
July 11	July 20	...	26	22	.05	19	4.7	15		[a]3.0	89	12	8.2	132	242	122	101	50.9
July 21	July 30	...	28	11	.08	28	5.0	14		.0	98	12	5.8	120	210	106	68.6	34.6
Aug. 5	Aug. 10	...	20	19	.07	32	5.8	22		.0	112	12	7.5	150	150	75.4	9.92	5.0
Aug. 12	Aug. 20	...	136	13	.17	33	5.3	18		.0	102	13	5.8	148	181	91.7	52.0	26.2
Aug. 21	Aug. 31	...	30	22	.40	23	5.8	18		.0	112	15	4.9	146	143	72.3	5.77	2.91
Sept 1	Sept. 10	...	Tr.	10	.20	18	4.5	22		.0	70	11	22	128	127	64.2	3.77	1.9
Sept. 11	Sept. 20	...	108	18	.30	29	6.3	12		.0	98	12	5.1	122	122	61.5	3.37	1.7
Sept. 21	Sept. 29	...	....	....	....	....	....	....		....	....	....	....	854	130	65.6	19.0	9.56
Oct. 1	Oct. 10	...	20	13	.10	25	4.6	22		.0	113	12	7.1	130	145	72.9	20.8	10.5
Oct. 11	Oct. 20	...	2	12	.10	26	6.4	20		.0	118	12	7.6	134	143	72.2	20.8	10.5
Oct. 21	Oct. 31	...	24	11	.10	25	5.6	18		.0	116	12	6.1	138	136	69.3	4.96	2.5
Nov. 1	Nov. 10	0	2	13	.5	26	5.1	18		.0	118	12	6.1	136	128	64.6	4.96	2.5
Nov. 11	Nov. 20	...	8	16	.15	26	5.9	17		.0	117	22	7.1	144	117	58.8	4.96	2.5
Nov. 22	Nov. 30	2	....	14	.10	25	4.8	19		.0	104	17	7.1	134	114	57.7	4.96	2.5
Dec. 1	Dec. 10	2	16	10	.10	28	6.2	18		.0	118	14	6.1	130	146	73.6	14.7	7.4
Dec. 11	Dec. 20	20	118	15	.05	28	5.0	16		.0	120	12	7.1	156	323	163	192	96.8
Dec. 21	Dec. 31	30	22	13	.05	....	4.6	15		.0	86	15	5.6	120	212	107	79.3	40.0
Mean		...	55	16	[b].15	26	5.7	18		.0	102	14	7.3	158	313	160	....	......
Per cent of anhydrous residue		...	....	11.7	0.1	19.0	4.2	13.1		36.4	....	10.2	5.3	....	....	.....	....	......

[a] Abnormal. Computed as HCO_3 in the average.   [b] Mean of Fe values after July 1.

Mineral analyses of water from Santa Ana River above Mentone—Continued.

Date.		Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).[a]	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.	Mean discharge.		Run-off per square mile (cubic feet per second).
From—	To—														Acre-feet per day.	Cubic feet per second.	
1907. Dec. 31	1908. Jan. 9	Tr.	....	27	0.02	33	4.9	13	2.4	110	28	......	3.6	150	106.9	53.9	2,960
1908. Jan. 10	Jan. 19	Tr.	....	22	.11	29	4.5	19	.0	111	19	1.2	3.7	148	115.8	58.4	3,208
Jan. 20	Jan. 29	25	45	25	.05	27	4.5	20	.0	99	21	.66	3.4	143	245.1	123.6	6,791
Jan. 30	Feb. 8	10	....	23	.13	29	6.0	18	.0	106	21	.44	3.9	141	252.8	127.5	7,005
Feb. 9	Feb. 18	5	....	20	.05	26	5.7	21	.0	109	20	.32	3.2	138	230.6	116.3	6,390
Feb. 19	Feb. 28	5	....	22	.18	29	6.4	15	Tr.	120	20	1.1	3.7	141	290.3	146.4	8,044
Feb. 29	Mar. 9	Tr.	....	20	.15	31	6.5	16	.0	118	16	.10	3.0	141	332.6	167.7	9,214
Mar. 10	Mar. 19	Tr.	....	24	.15	24	5.4	22	.0	118	20	.54	4.9	141	189.0	95.3	5,236
Mar. 20	Mar. 29	Tr.	....	26	.02	23	5.2	14	.0	117	18	.80	3.0	139	233.4	117.7	6,466
Mar. 30	Apr. 8	5	....	25	.11	26	5.5	15	.0	116	24	1.0	3.5	142	234.0	118.0	6,483
Apr. 9	Apr. 18	5	....	23	.05	25	5.3	14	.0	109	23	6.0	3.0	134	175.6	88.5	4,862
Apr. 19	Apr. 28	5	....	22	.08	25	3.9	14	.0	107	23	2.0	3.5	162	201.9	101.8	5,593
Apr. 29	May 8	Tr.	....	25	.08	24	6.7	15	.0	104	18	1.0	3.0	130	186.6	94.1	5,170
May 9	May 18	5	....	28	.10	24	7.1	15	.0	112	16	.80	3.5	142	150.3	75.8	4,109
May 19	May 28	5	....	29	.12	21	4.8	14	.0	100	20	1.3	3.5	137	129.7	65.4	3,593
May 29	June 7	Tr.	....	27	.18	25	5.3	16	.0	112	23	.70	2.6	149	129.7	65.4	3,593
June 8	June 17	Tr.	....	19	.18	31	7.4	14	.0	109	30	.20	4.0	128	121.8	61.4	3,373
June 18	June 27	Tr.	....	22	.08	24	5.5	16	.0	110	20	1.9	3.0	135	117.0	59.0	3,242
June 28	July 7	5	....	23	.20	25	4.6	18	.0	115	17	.34	4.0	136	121.4	61.2	3,362
July 8	July 17	Tr.	....	28	.25	25	7.8	13	.0	116	16	.38	4.0	140	132.3	66.7	3,664
July 18	July 27	Tr.	....	23	.23	24	7.4	17	.0	110	13	.90	4.0	138	125.1	63.1	3,466
July 28	Aug. 6	5	....	20	.14	25	9.1	15	.0	117	28	.35	4.5	139	129.7	65.4	3,593
Aug. 7	Aug. 16	130	128	23	.35	21	7.9	17	.0	120	15	......	2.8	146	130.9	66.0	3,626
Aug. 17	Aug. 26	Tr.	....	17	.37	23	8.1	15	.0	106	14	.70	3.5	122	125.0	63.0	3,461
Aug. 27	Sept. 5	5	....	23	.20	28	10	15	1.2	118	29	.70	3.5	178	122.8	61.9	3,401
Sept. 6	Sept. 15	8	....	17	.15	27	7.2	13	.0	121	14	.80	3.0	134	121.0	61.0	3,351
Sept. 16	Sept. 25	70	142	23	.33	24	7.1	14	.0	122	14	.20	3.5	142	122.0	61.5	3,379
Sept. 26	Oct. 5	Tr.	....	23	.20	21	6.6	11	.0	121	17	Tr.	3.1	145	106.7	53.8	2,956
Oct. 6	Oct. 15	Tr.	....	24	.44	23	7.6	14	.0	127	19	Tr.	3.2	146	117.2	59.1	3,247
Oct. 16	Oct. 25	Tr.	....	27	.10	24	6.2	17	.0	121	14	.34	3.0	146	109.5	55.2	3,033
Oct. 26	Nov. 4	Tr.	....	20	.15	24	1.8	17	.0	115	16	Tr.	4.0	137	109.1	55.0	3,022
Nov. 5	Nov. 14	4	....	78	.24	23	5.7	39	45	80	25	Tr.	6.0	256	82.1	41.4	2,274
Nov. 15	Nov. 24	15	16	36	.08	24	6.4	32	.0	121	22	Tr.	4.5	162	81.9	41.3	2,269
Nov. 25	Dec. 4	Tr.	....	29	.12	24	6.9	23	.0	115	22	1.8	4.1	144	88.9	44.8	2,461
Dec. 5	Dec. 14	Tr.	....	22	.18	25	6.7	31	.0	115	20	.70	7.0	142	89.3	45.0	2,472
Dec. 15	Dec. 24	Tr.	....	24	.08	25	6.1	17	.0	117	18	.36	4.9	141	81.7	41.2	2,263
Dec. 25	Dec. 31	4	....	21	.10	25	8.9	29	.0	120	22	.26	5.0	144	80 7	40.7	2,236
Mean		8	....	25	.16	25	6.3	18	.0	116	20	.75	3.8	145	149.2	75.22	4,131
Per cent of anhydrous residue		....	....	16.0	0.1	16.0	4.0	11.6	36.6	......	12.8	0.5	2.4	......	......	......	......

[a] The values given for CO_3 are abnormal and are computed as HCO_3 in the average.

CHARACTER OF WATER NEAR CORONA.

Samples of water were collected daily during 1908 by Mrs. W. C. Warner from the bridge near Auburndale, a small settlement on the banks of the Santa Ana, about 3 miles from Corona, from which it it may be reached by driving, and about 5 miles below the entrance to Santa Ana Canyon.

Near Riverside, at what is known as Riverside Narrows, the water of the Santa Ana is brought to the surface by bed-rock obstructions, and it gradually increases in volume until it reaches Santa Ana Canyon. At Auburndale the surface flow is continuous throughout the year, and the river contains not only the original waters of the Santa Ana, but added waters from artesian wells which are located above, especially near San Bernardino and Riverside. However, as all these waters have their origin in the San Bernardino Mountains, and as all flow through practically the same rock and soil formations, their mineral characteristics should be similar, and the waters of the Santa Ana near Corona should resemble in percentage composition the waters at Mentone; the difference is an increase in the mineralization of the waters near Corona, due to the effect of seepage, and measures that effect. The river bottom at Auburndale is wide and sandy, and the slopes are moderate.

The analyses (pp. 104–105) show that on reaching Corona, Santa Ana River has become charged with almost two and a half times as much mineral matter in solution as it held on leaving the mountains. Although all the constituents, even silica, share this increase, the percentage composition of the anhydrous residue shows that a decided change has taken place in the character of the water. Chlorine exhibits the greatest proportional increase, the total amount rising from 2.4 to 11.5 per cent. The alkalies exhibit the next largest rise, calcium and normal carbonates show smaller changes, and the remaining radicles show reductions, silica leading, with a decrease of 7.3 per cent, while the bicarbonates have fallen 3.6 per cent. It is thus evident that the changes that have occurred in the nature of the dissolved material are large and important.

Calcium has been added to a much greater extent than magnesium, the ratio of magnesium to calcium falling to 1 to 4.7—the smallest relative magnesium value noted so far in the samples. The increase in calcium is attended by an increase in bicarbonates almost exactly in ratio of composition as calcium bicarbonate, although it is probable that some, at least, of the magnesium increase found is the result of solution of magnesium carbonate. Sulphates show an increase of 22 parts per million, probably in great part due to solution of sulphates of the alkalies.

That the seasonal fluctuation is more marked in the water of the river at Corona is largely due to the fact that there is longer surface flow and relatively less seepage in winter than in summer, the result being that in the wet season less mineral matter is picked up in transit.

Turbidity also shows more marked variations in the lower than in the upper regions. Water returned to the river from irrigation ditches is turbid, while rain falling on the loose, sandy soil of the region sends to the streams water containing a large amount of suspended material. The high turbidity recorded in late September and early October in 1908 was due to severe storms throughout the drainage area.

The water is far inferior to that in the river above Mentone. Although it is still highly useful for irrigation, it has become hard, needing treatment to render it fit for use in boilers. Like all other waters high in carbonates and sulphates, it is poor for domestic use, for not only does it consume large quantities of soap, but foodstuffs cooked in it lose flavor and actual nutrient value. It would need sedimentation or coagulation and filtration to render it fit for a municipal supply.

Mineral analyses of water from Santa Ana River near Corona.

[Parts per million unless otherwise stated.]

Date. From—	Date. To—	Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.
1907. Dec. 31	1908. Jan. 9	15	32	30	0.08	79	12	39	0.0	244	51	2.0	41	362
1908.														
Jan. 10	Jan. 19	135	102	27	.12	75	12	52	.0	249	55	2.1	41	366
Jan. 20	Jan. 29	680	757	28	.21	60	12	46	.0	212	53	2.7	34	329
Jan. 30	Feb. 8	675	911	30	.38	66	12	45	.0	206	54	.9	30	317
Feb. 9	Feb. 18	450	489	27	.37	55	12	50	.0	201	52	1.6	29	313
Feb. 19	Feb. 28	50	96	25	.15	66	12	36	.0	210	49	2.9	25	292
Feb. 29	Mar. 9	55	128	23	.15	61	11	36	.0	205	45	2.1	24	285
Mar. 10	Mar. 19	20	49	28	.45	53	7.8	40	.0	227	46	3.5	28	312
Mar. 20	Mar. 29	10	......	39	.24	60	12	41	4.8	239	17	3.0	38	344
Mar. 30	Apr. 8	20	42	29	.17	61	13	49	1.2	232	48	Trace.	38	342
Apr. 9	Apr. 18	Trace.	......	31	.05	62	12	47	9.4	230	56	3.0	45	363
Apr. 19	Apr. 28	10	......	31	.05	63	12	51	.0	251	39	3.0	46	362
Apr. 29	May 8	Trace.	......	26	.20	62	18	47	.0	246	35	4.0	45	347
May 9	May 18	Trace.	......	28	.14	59	12	46	.0	240	40	2.0	41	342
May 19	May 28	4	......	32	.17	64	13	50	11	222	42	3.8	43	359
May 29	June 7	Trace.	......	29	.18	62	9.3	50	4.8	237	43	2.0	47	352
June 8	June 17	Trace.	......	35	.23	60	13	48	18	210	47	2.5	35	361
June 18	June 27	Trace.	......	29	.07	60	12	52	7.2	229	35	1.6	45	336
June 28	July 7	5	......	30	.18	59	13	44	9.6	218	36	1.6	43	336
July 8	July 17	Trace.	......	33	.70	59	13	49	9.6	218	41	1.6	43	356
July 18	July 27	6	......	32	.18	57	13	52	7.2	223	35	2.2	44	341
July 28	Aug. 6	5	......	38	.12	57	12	47	4.8	232	33	1.5	41	341
Aug. 7	Aug. 16	7	......	39	.08	58	12	59	.0	243	32	1.3	43	342
Aug. 17	Aug. 26	Trace.	......	41	.29	57	15	51	4.8	222	40	3.0	41	349
Aug. 27	Sept. 5	Trace.	......	34	.18	56	12	48	20	195	36	2.0	34	317
Sept. 6	Sept. 15	Trace.	......	38	.15	59	13	48	12	226	38	1.9	45	350
Sept. 16	Sept. 25	[a] 150	[a] 320	30	.15	60	14	47	1.2	245	43	2.0	49	364
Sept. 26	Oct. 5	60	57	33	.20	61	13	48	4.8	250	42	......	50	368
Oct. 6	Oct. 15	8	......	33	.11	61	14	49	2.4	246	38	2.2	44	344
Oct. 16	Oct. 25	10	......	35	.05	71	17	58	.0	256	55	1.9	47	418
Oct. 26	Nov. 4	Trace.	......	30	.22	60	11	48	.0	249	50	2.4	44	348
Nov. 5	Nov. 14	6	......	30	.08	61	13	49	.0	256	36	1.9	48	356
Nov. 15	Nov. 24	7	......	31	.08	61	14	52	.0	249	35	2.2	44	352
Nov. 25	Dec. 4	4	......	31	.25	62	14	55	2.4	248	38	2.5	49	370
Dec. 5	Dec. 14	12	14	29	.15	61	14	48	.0	254	44	3.6	49	362
Dec. 15	Dec. 24	4	......	32	.08	63	14	64	.0	259	37	3.8	47	361
Dec. 25	Dec. 31	Trace.	......	27	.04	63	15	66	2.4	246	50	4.0	48	366
Mean		65	......	31	.18	61	13	49	3.7	233	42	2.3	41	347
Per cent of anhydrous residue		....	......	8.7	0.0	17.1	3.6	13.8	33.0	......	11.7	0.6	11.5	.....

[a] September 25, turbidity 1,500, suspended matter, 3,200.

SAN LUIS REY RIVER.

DESCRIPTION.

San Luis Rey River rises on the western slope of the Coast Range in the northern part of San Diego County and, flowing westward, discharges its waters into the Pacific Ocean near the town of Oceanside. It has numerous small tributaries, none of which rise at elevations exceeding 5,000 feet above sea level. For a portion of its length the river flows through a deep, narrow canyon, but below the canyon the grade is light and the water soon disappears in a sandy gravelly bed, rising to the surface again near the town of Pala. From Pala to the ocean, a distance of about 25 miles, its grade continues light. The discharge of the river is irregular, most of the water flowing in the late winter and early spring. During the summer the flow is very slight.

Soil covering is good throughout the basin, and there is a considerable growth of brush and grass. On the upper reaches of the stream the country is rolling, and several small valleys are under cultivation for raising grain, olives, and lemons, or are used for the pasturage of stock.

CHARACTER OF WATER.

Samples for this investigation were collected daily by the gage reader at the gaging station near Pala Mills.[a] The stream at this point is narrow and swift, its bed is composed of coarse gravel and rocks, and the banks are low and subject to overflow at high stages.

At times of flood the river carries a great quantity of coarse material in suspension; during the summer months the water is fairly clear but it then carries considerable dissolved mineral matter, largely bicarbonates, calcium, and magnesium, which may, however, be removed by treatment. The total amount of dissolved material present is not large as compared with that in the coast streams farther north. (See analyses.)

The water is not at present used industrially except for irrigation, but it is admirably adapted for agricultural purposes as well as for those industries in which a moderately hard water is not objectionable. For use in boilers the water would require softening.

[a] For data concerning gage heights and discharge see Water-Supply Papers U. S. Geol. Survey Nos. 100, 134, 177, and 213.

Mineral analyses of water from San Luis Rey River at Pala.

[Parts per million unless otherwise stated.]

Date. From—	Date. To—	Turbidity.	Suspended matter.	Silica (SiO_2).	$Al_2O_3+Fe_2O_3$.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total solids.	Mean discharge. Acre-feet per day.	Mean discharge. Cubic feet per second.
1906.	1906.															
Jan. 1	Jan. 10	....	20	41	1.2	44	14	92	0.1	0.0	178	63	47	336	23.4	11.8
Jan. 11	Jan. 20	....	358	35	1.8	40	12	86	6.8	.0	56	54	7.7	346	69.8	35.2
Jan. 21	Jan. 30	....	80	35	0.8	41	14	48	4.5	.0	166	64	47	294	36.1	18.2
Jan. 31	Feb. 9	....	584	37	1.8	46	14	41	3.8	.0	176	69	48	354	21.8	11.0
Feb. 10	Feb. 19	....	380	33	3.4	37	13	30	4.5	.....	.....	11	.....	346	86.9	43.8
Feb. 20	Mar. 1	....	194	29	3.2	39	14	34	3.5	.0	168	63	46	320	57.5	29.0
Mar. 3	Mar. 10	....	266	37	2.2	41	14	37	3.1	.0	168	60	47	340	61.3	30.9
Mar. 22	Mar. 31	....	1,724	27	3.8	20	6.3	18	3.2	.0	89	20	17	224	5,284	2,664
Apr. 1	Apr. 9	....	240	28	8.4	28	12	20	1.6	.0	111	34	27	260	952	480
Apr. 11	Apr. 20	....	......	23	5.2	30	9.5	20	3.3	.0	127	36	26	....	538	271
Apr. 21	Apr. 30	....	76	29	2.4	35	9.8	33	3.8	.0	131	34	28	262	315	159
May 1	May 10	....	22	29	3.8	29	9.6	17	4.5	.0	132	35	29	252	317	160
May 11	May 20	....	32	29	3.4	31	11	25	3.7	.0	138	41	30	266	315	159
May 21	May 31	....	22	27	4.0	33	11	24	3.1	.0	136	37	30	276	309	156
June 1	June 10	....	20	29	3.4	44	13	34	4.1	.0	144	48	32	276	224	113
June 11	June 20	....	12	34	5.0	44	12	27	2.2	a13	132	47	35	312	104	52.7
June 21	June 30	....	20	40	4.4	44	12	42	3.3	.0	160	46	34	292	62.1	31.3
July 2	July 9	....	116	.....	.....	.....	....	....	.....	a 2.5	166	.....	41	242	37.7	19.0
					Fe.											
July 11	July 20	...	54	31	.06	39	12	42		.0	169	52	39	314	37.7	19.0
July 21	July 30	...	Tr.	27	.08	45	14	44		.0	175	54	39	342	37.7	19.0
Aug. 1	Aug. 10	....	Tr.	33	.10	58	14	50		.0	167	59	38	338	27.6	13.9
Aug. 11	Aug. 20	....	190	29	.05	43	13	45		.0	171	56	40	338	25.2	12.7
Aug. 21	Aug. 31	....	16	36	.13	48	14	51		.0	182	58	44	348	10.6	5.36
Sept. 1	Sept. 10	....	2	42	.20	46	14	26		.0	176	60	42	348	5.95	3.0
Sept. 11	Sept. 20	....	20	36	.10	46	14	50		.0	174	63	41	342	10.1	5.10
Sept. 21	Sept. 30	....	6	33	.20	48	13	60		.0	196	54	41	338	5.95	3.0
Oct. 1	Oct. 10	....	20	23	.20	56	18	58		.0	197	61	46	346	5.95	3.0
Oct. 11	Oct. 20	....	40	28	.15	48	14	36		.0	197	68	44	346	5.95	3.0
Oct. 21	Oct. 31	20	22	27	.25	48	14	50		.0	200	60	46	354	5.95	3.0
Nov. 1	Nov. 10	5	12	30	.15	46	15	49		.0	198	84	46	354	5.95	3.0
Nov. 11	Nov. 20	2	2	31	.05	48	14	62		.0	203	67	48	358	5.95	3.0
Nov. 21	Nov. 30	10	46	31	.10	50	16	53		.0	201	65	52	352	37.5	18.9
Dec. 1	Dec. 10	10	28	31	.04	46	24	50		.0	206	64	54	368	32.1	16.2
Dec. 11	Dec. 12	....	......	.....	.....	.....	...	....		a24	114	.....	50	....	556	280
Dec. 26	Dec. 31	60	56	22	.01	40	13	....		.0	170	.....	60	400	335	169
Mean.		....	142	31	b.12	42	13	44		.0	163	53	39	321	2[illegible]5	143
Per cent of anhydrous residue.		.. .	......	10.3	0.0	13.9	4.3	14.6		26.5	.....	17.5	12.9	....	....	....

a Abnormal. Computed as HCO_3 in the average. b Mean of Fe values after July 1.

SANTA YSABEL CREEK.

DESCRIPTION.

Santa Ysabel Creek rises on the western slopes of the Volcan Range, in the San Jacinto Mountains, and flows slightly to the southwest, emptying into the Pacific Ocean. In its upper course it is called Santa Ysabel Creek, lower down Bernardo River, and still nearer the ocean San Dieguito River. In this report the name Santa Ysabel is applied to the entire stream.

In its upper valley the creek traverses a rough, broken country, through which the streams have cut deep gullies. Leaving the mountains it sinks into the sands of the San Pasqual Valley, except during the rainy season, when there is surface flow. Like all the southern coastal streams, Santa Ysabel Creek is torrential in character, the maximum flow occurring in the early spring.

STREAM DISCHARGE.

In 1908 the maximum discharge of this stream occurred during January and February, the greatest average being for the ten-day period from February 9 to 18, inclusive, when it was 120.6 acre-feet a day. From January 20 to March 9, a period of seven weeks, 52.9 per cent of the total run-off for the year occurred, while in the twenty days from January 30 to February 18, 23.8 per cent of the total flow for the year was carried past the gage. The river was dry from July 10 until September 26, a period of seventy-eight days, or 21.4 per cent of the year. It is thus apparent that one-fourth of the total discharge occurred within three weeks, while during approximately one-fourth of the whole year there was no flow whatever. This condition is characteristic not only of Santa Ysabel Creek but of all the torrential streams of the San Diego mesas, and has a decided effect upon the appearance of the streams of the region as well as upon the agricultural development of the section. Most of the streams flow across the mesa lands in narrow canyons with abrupt, precipitous walls. They rush down these gorges with great violence in the rainy season, oftentimes overflowing their banks and spreading out over the mesas; but in the summer time no sign of flowing water is apparent, and the canyon floors become dry beds of sand and gravel. The waters of Santa Ysabel Creek are used for irrigation in San Pasqual Valley, but in years of abnormal flow, when the amount of water obtainable is insufficient, all the crops suffer. If agriculture were to become more extensive than at present it would be necessary to impound and store the flood waters of the streams of this region and hold them over until the irrigation season.

CHARACTER OF WATER.

Samples of water were taken daily during periods of surface flow in 1908 by F. S. Potts at the Potts ranch, about 13 miles east of the town of Escondido, where the creek leaves its canyon and enters San Pasqual Valley. The flow at this place is almost continuous, the stream becoming dry in summer only in exceptional years. The bed of the creek is of fine shifting sand, the slope is steep, and the current is consequently swift. The results of the analyses are shown in the accompanying table.

Mineral analyses of water from Santa Ysabel Creek at San Pasqual near Escondido, Cal.

[Drainage area, 128 square miles. Quantities in parts per million unless otherwise stated.]

Date. From—	Date. To—	Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.	Mean discharge. Acre-feet per day.	Mean discharge. Cubic feet per second.	Run-off per square mile (cubic feet per second).
1907. Dec. 31	1908. Jan. 9	5	......	40	0.11	37	16	43	0	158	33	2.0	40	277	21.8	11	0.0859
1908. Jan. 10	Jan. 19	5	......	37	.17	35	14	42	0	156	36	.76	39	270	21.6	10.9	.0851
Jan. 20	Jan. 29	90	274	39	.25	29	12	37	0	137	31	.48	33	236	99.0	49.9	.3898
Jan. 30	Feb. 8	30	38	40	.35	28	11	40	0	122	33	.16	29	232	117.4	59.2	.4624
Feb. 9	Feb. 18	40	151	38	.21	27	10	35	0	116	26	.48	28	209	120.6	60.8	.4750
Feb. 19	Feb. 28	8	......	44	.18	25	8.2	33	2.4	134	32	.68	31	237	81.3	41	.3203
Feb. 29	Mar. 9	19	......	41	.18	22	12	33	0	133	28	1.1	28	214	112.3	56.6	.4422
Mar. 10	Mar. 19	5	......	47	.08	26	11	32	0	138	32	4.0	32	243	67.2	33.9	.2648
Mar. 20	Mar. 29	15	......	47	.04	26	13	34	4.3	135	27	1.9	31	234	51.4	25.9	.2023
Mar. 30	Apr. 8	5	......	23	.49	26	12	32	0	144	31	1.9	31	241	46.8	23.6	.1843
Apr. 9	Apr. 18	10	......	32	.30	27	10	37	7.4	136	35	.40	33	261	30.3	15.3	.1117
Apr. 19	Apr. 28	10	......	38	.20	26	12	33	0	144	28	.50	31	244	51.2	25.8	.2015
Apr. 29	May 8	10	......	45	.13	26	12	35	0	148	24	2.1	32	241	35.1	17.7	.1383
May 9	May 18	Tr.	......	43	.18	27	9.6	33	7.2	132	25	1.2	32	238	32.5	16.4	.1281
May 19	May 28	Tr.	......	47	.09	26	12	35	4.8	138	27	.96	33	247	19.0	9.6	.0750
May 29	June 7	5	......	51	.21	27	12	36	0	154	26	1.2	34	250	15.0	7.54	.0589
June 8	June 17	Tr.	......	47	.06	28	13	37	0	159	24	Tr.	37	254	10.0	5.07	.0396
June 18	June 27	Tr.	......	50	.06	28	14	42	7.2	154	29	.48	40	273	7.54	3.8	.0297
June 28	July 7	Tr.	......	49	.13	32	13	48	0	179	25	.72	48	293	2.10	1.06	.0083
July 8	July 10	10	......														
Sept. 26	Oct. 5	60	25	54	.02	33	18	54	1.2	206	43	.02	58	349	.56	.28	.0018
Oct. 6	Oct. 15	Tr.	......	54	.24	33	18	46	0	206	31	.86	60	348	.46	.23	.0018
Oct. 16	Oct. 25	45	47	49	.05	30	16	54	0	185	30	.68	44	302	2.08	1.05	.0082
Oct. 26	Nov. 4	Tr.	......	49	.10	30	13	48	0	190	29	.08	45	317	1.69	.85	.0066
Nov. 5	Nov. 14	6	......	48	.28	30	15	61	2.4	181	32	Tr.	48	299	3.29	1.66	.0129
Nov. 15	Nov. 24	4	......	42	.16	32	17	55	0	181	30	Tr.	46	289	6.64	3.35	.0261
Nov. 25	Dec. 4	40	66	40	.18	30	14	52	0	167	33	.30	42	282	12.9	6.5	.0508
Dec. 5	Dec. 14	10	......	47	.05	30	15	52	0	176	29	.72	43	289	10.3	5.2	.0406
Dec. 15	Dec. 24	Tr.	......	49	.18	30	15	58	0	172	28	.44	43	286	9.60	4.84	.0378
Dec. 25	Dec. 31	6	......	47	.28	34	16	54	0	173	30	.24	44	292	10.7	5.4	.0422
Mean		14	......	44	.17	29	13	42	1.3	160	30	.84	38	260	34	17	.135
Per cent of anhydrous residue		......	......	16.0	0.1	10.5	4.7	15.3	28.4	.....	10.9	0.3	13.8	.....	.....	.....	......

Bicarbonates comprise a large part of the dissolved material in the water of this creek, while next in importance is silica, which attains a very high value, ranging from 38 parts per million with total solids at 209 to 54 parts per million with total solids at 349. The alkalies, which come next in order of quantity, show marked variations, and it is probable that a large part of the variation in total solids is due to the fluctuations of dissolved alkaline chlorides and silicates. Chlorides are extremely high, varying from 28 to 60 parts per million.

For irrigation the quality of the water is very good. A small amount of normal carbonates is occasionally present, and as a result black alkali might at times be deposited, but the quantity would be negligible, and evil results could be prevented by proper drainage of the lands.

The water of this creek is hard, but the hardness is largely of the temporary character which can be removed by preheating or chemical treatment. The addition of a little soda ash to the water will remove considerable of the lime salts and reduce the tendency to form scale. In boilers not frequently blown out this water might cause corrosion by reason of its high content of chlorides, and if the salts were allowed to concentrate greatly foaming might also occur. For drinking the water should cause no trouble if filtered or boiled before being used. The population of the district is not yet sufficiently dense to warrant the erection of filtration plants for any of the settlements.

COTTONWOOD CREEK.

DESCRIPTION.

Cottonwood Creek is a torrential stream rising on the western slopes of the San Jacinto Mountains and flowing southwestward to the Tia Juana, near the boundary between California and Mexico. The country through which it passes is very rough. The bed rock is a granite of loose texture and the soil covering is good. A growth of scrub trees, mainly oak, occurs throughout the basin.

CHARACTER OF WATER.

Samples of water were collected daily during 1908—except in July, August, September, and October, when the stream bed was dry—at Barrett dam, about 35 miles east of San Diego and about 8 miles north of the Mexican boundary, through the courtesy of William Clayton, manager for the Southern California Mountain Water Company, which is constructing the dam. The collector was M. M. O'Shaughnessy.

Fluctuations in the mineral content of this stream are irregular (see analyses, p. 113), as would be expected from the small size and semi-arid character of its drainage area. A change in dissolved material manifests itself after each rainfall, and the relation between discharge and quality for the winter months is therefore far less uniform than that for the summer or fall. In 1908 the least dissolved mineral matter was found for the period including late February and early March, the amount increasing steadily up to the time when surface flow ceased. It is probable that the subsurface flow during July, August, September, and October carried about 500 parts per million of dissolved mineral matter, approaching in character that recorded for the composite sample of June 28 to July 8.

The water is alkaline carbonate in type, calcium being second in importance to the alkali bases and chlorine being the second most prominent acid radicle. The increase in alkalies and chlorine is most conspicuous when an increase in total solids occurs, carbonates sharing the rise with chlorides. Normal carbonates appear in most of the analyses, and their presence, although in small quantities, is a danger sign for irrigation.

Considering the character of the region through which the stream flows, the water is fair for municipal use. It is hard, both temporary and permanent hardness being high. Soda ash or some similar softening compound should be added if the water is to be used for steaming, and much soft scale will then be formed, which must frequently be removed. The corrosion of boilers that is likely to result can not well be prevented by treating the water.

Mineral analyses of water from Cottonwood Creek at Barrett dam, San Diego County.

[Parts per million unless otherwise stated.]

Date.		Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.	Mean discharge.	
From—	To—														Acre-feet per day.	Cubic feet per second.
1907. Dec 31	1908. Jan. 9	5	.....	42	0.05	77	20	75	0.0	164	55	0.5	59	423	20.19	10.18
1908. Jan. 10	Jan. 19	15	.....	39	.18	56	20	66	2.4	261	62	1.0	61	431	25.98	13.10
Jan. 20	Jan. 29	105	88	38	.12	61	14	42	.0	237	57	.8	53	402	93.28	47.03
Jan. 30	Feb. 8	160	125	39	.28	47	18	59	.0	205	55	.26	48	361	127.73	64.4
Feb. 9	Feb. 18	45	67	40	.48	42	18	60	.0	199	55	1.2	42	341	140.18	70.7
Feb. 19	Feb. 28	30	14	43	.09	31	15	64	4.8	200	53	.69	49	356	78.94	39.8
Feb. 29	Mar. 9	50	40	39	.38	37	11	50	14	168	47	1.3	45	328	104.13	52.5
Mar. 10	Mar. 19	15	.....	43	.30	44	16	54	3.6	217	52	1.4	53	380	55.34	27.9
Mar. 20	Mar. 29	12	.....	43	.27	48	18	63	.0	242	53	2.0	54	384	49.12	24.77
Mar. 30	Apr. 8	10	.....	53	.05	45	17	61	9.6	220	38	2.1	54	341	35.20	17.75
Apr. 19	Apr. 28	15	.....	59	.04	47	19	62	.0	215	50	2.0	63	353	24.93	12.57
Apr. 29	May 8	Tr.	.....	42	.15	50	24	60	.0	253	55	.9	56	410	25.03	12.62
May 9	May 18	5	.....	42	.02	50	23	68	2.4	251	52	1.0	60	416	19.22	9.69
May 19	May 28	Tr.	.....	46	.35	52	21	68	8.4	245	55	1.5	64	431	14.53	7.33
May 29	June 7	Tr.	.....	43	.18	49	19	70	7.2	242	50	.56	66	417	12.81	6.46
June 8	June 17	Tr.	.....	48	.08	53	22	64	6.0	268	43	.82	66	423	7.44	3.75
June 18	June 27	Tr.	.....	49	.18	54	22	75	9.6	278	54	Tr.	70	455	3.93	1.98
June 28	July 7	5	.....	51	.13	56	24	82	.0	317	41	3.5	78	482	1.21	.61
July 8	July 9	Tr.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Nov. 6 [a]	Nov. 15	Tr.	.....	46	.12	55	23	91	4.8	298	39	Tr.	86	467	8.41	4.24
Nov. 16	Nov. 25	Tr.	.....	46	.16	54	23	85	2.4	286	43	Tr.	73	465	8.52	4.30
Nov. 26	Dec. 4	Tr.	.....	42	.14	54	26	84	2.4	273	61	1.3	73	455	10.95	5.52
Dec. 5	Dec. 14	Tr.	.....	44	.14	55	23	91	4.8	264	61	.80	74	454	10.33	5.21
Dec. 15	Dec. 24	10	15	51	.26	56	24	91	2.4	295	58	.74	73	479	13.47	6.79
Dec. 25	Dec. 31	Tr.	.....	42	.32	57	27	78	6.0	300	65	.32	73	474	13.15	6.63
Mean		19	.....	44	.18	51	20	69	3.7	246	52	1.0	62	413	37.66	19
Percent of anhydrous residue		.....	.....	10.4	0.0	12.0	4.7	16.3	29.5	.....	12.3	0.2	14.6	.....	.....	.....

[a] Creek dry during summer.

NOTES ON MUNICIPALITIES.

Reports were received from 58 settlements in the south Pacific Ocean drainage area. Sixteen of these towns and cities take their entire water supply from surface streams, 14 derive part of their supply from streams and a part from wells, 27 are supplied entirely by wells, and 1 uses a mineral spring. Only 6 places filter the surface supplies, the other 52 using no method of purification.

The statistical data regarding water supply are presented in detail in the following table:

Statistics of municipal water supplies in south Pacific Ocean drainage area.

Settlement	Drainage basin.	Population.	Adjacent to—	Source of supply.	Nature of system.	Ownership.	Methods used for purification.	Daily consumption per capita (gallons).	Nature of sewerage system.	Ultimate disposal of sewage.
Alhambra	San Gabriel River.	a 800		Wells and stream	Gravity and pumping.	San Gabriel Valley Water Co.	None	No data.	None	
Anaheim	Santa Ana River.	1,621	Santa Ana River.	Wells	Pumping	Municipal	do	200	do	
Azusa	San Gabriel River.	a 863	San Gabriel River.	Wells and stream	Gravity	do	do	175	Sanitary	Used for irrigation.
Boulder Creek	Monterey Bay	b 1,000	San Lorenzo River.	Stream	do	(?)	do	No data.		
Colton	Santa Ana River.	1,300	Santa Ana River.	Artesian wells	Gravity and pumping.	Municipal	do	do	None.	
Compton	Los Angeles River.	b 1,000	Compton Creek	Wells	Pumping.	Compton Water and Light Co.	do	87	do	
Corona	Santa Ana River.	a 1,434	Santa Ana River.	Wells and stream	Gravity and pumping.	Municipal	do		do	
Coronado	San Diego Bay.	a 935	San Diego Bay.	Streams	Gravity	Coronado Water Co.	do	200	Sanitary	San Diego Bay.
Covina	San Gabriel River.	b 1,600	San Antonio Creek.	do	do	Covina City Water Co.	do	30	None.	
Elsinore	Lake Elsinore	a 279	Lake Elsinore	Mineral spring	Pumping	Municipal	do	60		
Escondido	San Luis Rey River.	948	Escondido Creek.	San Luis Rey River.	Gravity	All real estate owners.	do		Sanitary	Valley about 1 mile below city.
Fullerton	San Gabriel River.	b 2,200	Coyote Creek	Wells	Pumping	A. L. Selig	do		None	
Gilroy	Monterey Bay	1,933	Uvas Creek	Uvas Creek and wells.	Gravity	Municipal	Sand box filtration.	No data.	Sanitary — septic tank and filter beds.	
Glendale	Los Angeles River.	b 2,500	Los Angeles River.	Wells and stream	do	Six different companies.	None	do	None	
Hermosa Beach	Santa Monica Bay.	b 800	Pacific Ocean	Wells	Pumping	Hermosa Beach Water Co.	do		Sanitary (ocean front only).	Sand hills.
Hollister	Monterey Bay	1,388	San Benito River.	Infiltration; Pescadero Creek.	Gravity	Hollister Water Co.	Infiltration galleries.	200	Combined system.	Sewer farm.
Hollywood	Santa Monica Bay.	a 300	Ballona Creek	Wells	Pumping	Union Hollywood Water Co.	None	No data.	None	
Huntington Park.	Los Angeles River.	b 1,800	Los Angeles River.	Artesian wells	do	South Los Angeles Water Co.	do	do	do	
Long Beach	do	12,591	Pacific Ocean	do	do	Long Beach Water Co.	do	300	Sanitary — septic tank.	Pacific Ocean.
Los Angeles	do	275,000	Los Angeles River.	Los Angeles River and wells.	do	Municipal	do	120	Separate systems	Do.

Monrovia	San Gabriel River.	1,470		Artesian wells and streams.	Gravity and pumping.	do	do	No data.	Flood	
Monterey	Monterey Bay	1,825	Monterey Bay	Carmel River	Gravity	Monterey County Water Works.	do	do	Sanitary	Monterey Bay.
National City	San Diego Bay	1,086	Sweetwater River.	Sweetwater River	do	Sweetwater Water Co.	do	do	None	
Newport Beach	Santa Ana River.	b 3,000	Pacific Ocean	Artesian wells	Pumping	Newport Beach Water Co.	do	240		
Ocean Park	Santa Monica Bay.	b 3,000	do	Wells	do	City Water Co.	do			
Oceanside	Pacific Ocean	b 800	do	do	Gravity and pumping.	Municipal	do	208	None	
Ontario	Santa Ana River.	757		San Antonio Creek and wells.	do	Municipal and two private companies.	do	20	Sanitary	Sewer farm.
Orange	do	1,531	Santa Ana River.	Wells	Pumping		do	300		
Oxnard	Santa Clara River.	b 2,500	Pacific Ocean	Artesian wells	do	Ventura County Power Co.	do	140		Pacific Ocean.
Pacific Grove	Monterey Bay	1,480	Monterey Bay	Carmel River	Gravity	Monterey County Water Works.	do	No data.	Sanitary	Monterey Bay.
Pasadena	Los Angeles River.	16,705	Arroyo Seco	Stream and wells	Pumping and gravity.	Several companies.	Infiltration galleries.	do	do	Sewer farm.
Paso Robles	Monterey Bay	1,581	Salinas River	Salinas River	Pumping	Paso Robles Light and Water Co.	Infiltration	100	do	Salinas River.
Pomona	Santa Ana River.	6,690	Chino Creek	Tunnel and wells	Gravity	Consolidated Water Co.	do	300	Combined system.	Sewer farm.
Redlands	do	7,360	Santa Ana River.	Streams	do				do	
Redondo Beach	Santa Monica Bay.	1,082	Pacific Ocean	Wells	Pumping	Redondo Water Co.	None			Do.
Riverside	Santa Ana River.	9,855	Santa Ana River.	Artesian wells	Gravity and pumping.	Riverside Water Co.	do	60	Combined system.	Alfalfa fields across river.
Salinas	Monterey Bay	4,177	Salinas River	Wells	Pumping	Monterey County Gas and Electric Co.	do	100	Sanitary	Sewer farm.
San Bernardino	Santa Ana River.	7,648	Santa Ana River.	Artesian wells	do				do	Do.
San Diego	San Diego Bay	19,860	San Diego Bay	Streams	Gravity	South California Mountain Water Co.	Mechanical filtration.	100	do	San Diego Bay.
San Jacinto	San Jacinto River.	b 1,000	San Jacinto River.	Artesian wells	Pumping	Municipal	None		None	
San Juan	Monterey Bay	b 500	San Benito River.	Streams	Gravity	do	do			
San Luis Obispo.	Pacific Ocean	3,044	South Los Angeles Creek.	Streams and wells.	Gravity and pumping.	do	do	150	Sanitary — septic tanks.	
San Pedro	Los Angeles River.	c 5,618	Pacific Ocean	Wells	Pumping	San Pedro Water Co.	do		Combined	San Pedro Harbor.

a United States census of 1900.

b Estimates by city or town clerk or by health officer; in some cases by Walton Van Winkle from the aforementioned.

c Census of 1906, Blue Book of California.

Statistics of municipal water supplies in south Pacific Ocean drainage area—Continued.

Settlement.	Drainage basin.	Population.	Adjacent to—	Source of supply.	Nature of system.	Ownership.	Methods used for purification.	Daily consumption per capita (gallons).	Nature of sewerage system.	Ultimate disposal of sewage.
Santa Ana	Santa Ana River.	6,107	Santa Ana River.	Wells	Pumping		None	175	Septic tank	Sewer farm.
Santa Barbara.	Pacific Ocean	7,415	Pacific Ocean	Mission Creek and wells.	Gravity and pumping.	Municipal and two private companies.	do	80	Combined	Pacific Ocean.
Santa Cruz	Monterey Bay	5,713	San Lorenzo River.	Laguna Creek	Gravity	Municipal	do		Separate systems and septic tanks.	Monterey Bay.
Santa Maria	Santa Maria River.	a 1,500	Santa Maria River.	Wells	Pumping		do	60	None	
Santa Monica	Santa Monica Bay.	b 7,223	Pacific Ocean	Stream and wells	Gravity and pumping.	Four companies	do	60	Sanitary — septic tank.	Pacific Ocean.
Santa Paula	Santa Clara River.	2,300	Santa Clara River.	Streams	Gravity	Santa Paula Water Co.	do		None	
Sawtelle	Santa Monica Bay.			Wells	Pumping	Two companies	do	25		
South Pasadena	Los Angeles River.	a 4,000		do	do	Three companies	do		None	
Upland	Santa Ana River.	a 2,500		Stream and wells	do	Two companies	do		do	
Ventura	Ventura River.	2,605	Ventura River.	Ventura River	Gravity and pumping.	Ventura County Power Co.	do	250		Do.
Vernon	Los Angeles River.		Los Angeles River.	Wells	Pumping	South Los Angeles Water Co.	do			
Watsonville	Monterey Bay	4,769	Pajaro River	Streams	Gravity	Watsonville Water and Light Co.	do	200	Sanitary	Tide water.
Watts	Los Angeles River.	a 3,000	Los Angeles River.	Wells	Pumping	Conservative Realty Co.	do		None	
Whittier	San Gabriel River.	2,495	Coyote Creek	do	do	Municipal	do	No data.	do	
Wilmington	Los Angeles River.	1,200	Pacific Ocean	do	do	San Pedro Water Co.	do		do	

a Estimates by city or town clerk or by health officer; in some cases by Walton Van Winkle from the aforementioned. All others estimated for 1909 from United States Census, 1890 and 1900.

b Census of 1905, Blue Book of California.

INTERIOR BASIN AND COLORADO RIVER DRAINAGE.

DESCRIPTION.

The interior basin of California comprises that portion of the State lying east of the Sierra. It extends the whole length of the State as a narrow strip running from the northeastern corner and widening out in the southern part to include the great Mohave Desert. Its extreme southeastern boundaries are the low-lying hills that separate it from the drainage basin of Colorado River, and its southern limits are the mountains that shut it off from the Imperial Valley and the Salton Sea drainage.

Included in this drainage area are two principal subdrainages, the Sierra and the minor Great Basin. The first includes the Honey Lake drainage, of which the chief river is the Susan; the Truckee River drainage in California; the Mono Lake drainage; and the Owens River system. In the second is the Mohave River system.

The predominating surface formation of the northern part of the interior basin drainage is made up of tuffs and lavas. The middle section takes its geologic character from the Sierra Nevada and its surface rocks are largely granites. The lower portion, comprising the Mohave Desert, is a wide plateau interspersed with bare, soilless buttes of granite. The desert floor is a coarse, undecomposed granite sand, and in places the surface is coated with alkali dust.

The soils of the upper and middle portions of the drainage area are rich and fertile, only the high Sierra being bare of covering. The soil of the lower portion, although intrinsically rich, has in most places suffered so greatly from the extreme aridity of the climate that large deposits of alkaline and saline material lie on the surface, rendering it unfit for use even should it be possible to bring water upon it. In restricted areas north of the San Bernardino Mountains, where it has been possible to obtain artesian water, the desert is being slowly converted into a more or less fertile plateau, but it will be impracticable to reclaim a very large amount of land as the available water supply is extremely small.

In the Honey Lake and Truckee districts forestation is good, most of the timber being on government reserve. The greater part of the drainage area, that lying to the south of Owens Lake, is bare of trees, only here and there a dwarfed and stunted growth being found.

Except in the Honey Lake district and in Owens Valley the population is very small, and much of the basin supports only straggling mining camps. The total number of inhabitants may be estimated roughly at 150,000.

Grazing and agriculture are the principal industries in the Honey Lake region and in Owens Valley, while other parts of the area are either without industries of any kind or are devoted chiefly to mining. The largest borax mines in the United States are in this region. Gold is mined at a number of places, and some sections of the desert yield materials suitable for the manufacture of cement.

The Colorado River drainage in California is small and unimportant and a general investigation of its waters was not attempted. Some analyses of the waters of Salton Sea are given on page 125.

SIERRA SUBDRAINAGE.

OWENS RIVER.

DESCRIPTION.

Owens River rises in the eastern slopes of the Sierra Nevada near San Joaquin Pass, at an elevation of over 10,000 feet above sea level, and about 90 miles from its source discharges into Owens Lake. Its course lies down the steep granite slopes of the Sierra, across the swampy meadow lands of Long Valley, and through a long canyon 800 feet deep, from which it finally emerges into Owens Valley proper. Passing eastward from the mouth of the canyon, it is deflected southward by the slopes of the White Mountains and flows slightly southeastward for the remainder of its course. Numerous tributary streams enter the valley, among which may be mentioned Rock, Pine, Bishops, Big Pine, Taboose, Oak, Independence, Shepherds, Georges, Long Pine, and Cottonwood creeks. All of these are relatively unimportant.

The drainage basin of Owens River is about 150 miles long and 20 to 25 miles wide.[a] It is bordered on the west by the Sierra Nevada, from which comes practically all the flow of its tributary streams, and on the east by the White Mountains, whose slopes, except in times of exceptional rainfall, are arid. The bed rock throughout all this basin is granite and the soil covering, except in the valley itself, is slight. Stock raising is the principal industry, but large areas are devoted to raising hay and grain.

The city of Los Angeles is building an aqueduct to take water from Owens River for its municipal supply, transporting it by siphon, flume, tunnel, and canal down Owens Valley, across the Mohave Desert, and through the San Fernando Mountains to the city.

Sampling stations were maintained on Owens River during 1908 at Round Valley and at Charlies Butte.

CHARACTER OF WATER AT ROUND VALLEY.

At Round Valley Owens River passes through a lava formation in a deep, rocky gorge. The bed of the stream is composed of rock and lava bowlders and the grade is sufficiently steep to cause a swift current.

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[a] Clapp, W. B., Surface water supply of California, 1906: Water-Supply Paper U. S. Geol. Survey No. 213, 1907, p. 34.

Samples of water were taken from the river at Round Valley daily from April 12, 1908, to the end of the year by L. Roberts.

Stream flow in upper Owens River reaches its maximum in summer, when the snows on the mountains are melting. During the winter the run-off is small.

The series of analyses of the water of Owens River at Round Valley is incomplete, and it is therefore impossible to form a conception of seasonal variations as exact as might be desired. The water is alkaline carbonated in type, being unusual among California surface waters in this respect. The analyses show that the amount of dissolved mineral matter varies greatly during the year, falling below 100 parts per million when the snows are melting and increasing to more than 275 parts per million during the dry period, the increase being chiefly in the alkalies and the acid radicles.

The water is good for municipal use, its hardness being largely temporary. The addition of small quantities of soda ash will prevent the formation of scale from calcic and magnesic salts. The water is also well adapted for irrigation.

Mineral analyses of water from Owens River near Round Valley.

[Parts per million unless otherwise stated.]

Date.		Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.	Mean discharge.	
From—	To—														Acre-feet per day.	Cubic feet per second.
1907. Dec. 31	1908. Jan. 9	15	1[illegible]	48	0.05	17	4.5	53	0.0	144	35	1.2	23	270	494.1	249.2
1908. Jan. 10	Jan. 19	10	...	50	.05	17	4.1	63	*a* 3.8	159	34	1.3	27	277	432.8	218.2
Jan. 20	Jan. 29	5	...	49	.05	23	5.7	58	.0	155	37	1.1	26	264	469.1	236.5
Jan. 30	Feb. 8	8	...	53	.55	18	4.5	68	.0	155	30	.66	28	26[illegible]	445.5	224.6
Feb. 9	Feb. 18	5	...	29	.07	11	2.6	21	.0	63	21	.43	4.4	10[illegible]	418.5	211
Apr. 9	Apr. 18	5	...	49	.15	16	5.2	56	.0	134	45	2.1	23	24[illegible]	459.0	231.4
Apr. 19	Apr. 28	10	...	55	.15	13	3.8	47	.0	131	41	1.8	21	24[illegible]	530.0	267.2
Apr. 29	May 4	4	...	53	.14	16	3.0	47	.0	124	30	1.9	22	21[illegible]	560.7	282.7
May 9	May 18	4	....	48	.36	17	2.1	44	.0	131	31	......	23	21[illegible]	516.7	260.5
May 19	May 28	4	....	44	.18	16	3.1	46	.0	126	38	2.3	20	22[illegible]	553.7	279.2
May 29	June 7	8	....	43	.15	14	4.0	41	.0	115	30	1.8	18	20[illegible]	581.9	293.4
June 18	June 27	30	41	33	.95	15	4.4	35	.0	94	29	2.0	14	17[illegible]	619.7	312.5
June 28	July 7	10	....	28	.30	14	7.3	20	.0	68	38	.34	8.5	13[illegible]	593.2	299.1
July 8	July 17	Tr.	....	30	.08	14	4.2	29	.0	85	19	2.8	15	15[illegible]	608.3	306.7
July 18	July 27	6	....	29	.19	15	4.5	24	.0	79	23	1.6	9.5	13[illegible]	526.6	265.5
July 28	Aug. 6	20	60	32	.32	16	3.1	31	.0	93	19	.4	12	15[illegible]	604.3	304.7
Aug. 7	Aug. 16	10	14	26	.28	13	3.1	15	.0	75	14	1.7	9.0	11[illegible]	554.7	279.7
Aug. 17	Aug. 26	Tr.	....	25	.13	11	1.7	12	.0	59	15	......	6.5	9[illegible]	469.1	236.5
Aug. 27	Sept. 5	8	....	36	.40	18	2.3	21	.0	84	26	.2	7.7	14[illegible]	458.2	231
Sept. 6	Sept. 15	10	....	32	.32	13	2.3	17	.0	78	18	......	6.8	12[illegible]	469.1	236.5
Sept. 26	Oct. 5	10	....	38	.16	12	4.0	31	.0	95	29	1.1	9.9	12[illegible]	393.9	198.6
Oct. 6	Oct. 15	Tr.	....	35	.04	12	3.3	38	.0	92	38	.96	16	15[illegible]	379.0	191.1
Oct. 27	Nov. 14	Tr.	....	23	.26	12	3.0	20	.0	62	23	.50	6.0	9[illegible]	373.5	188.3
Nov. 16	Nov. 24	Tr.	....	23	.14	8.8	5.1	19	.0	73	12	1.0	2.0	11[illegible]	362.8	182.9
Nov. 25	Dec. 4	Tr.	....	53	.08	15	5.7	64	.0	161	33	.88	29	27[illegible]	362.8	182.9
Dec. 5	Dec. 14	Tr.	....	53	.04	14	8.7	66	.0	154	41	.40	28	26[illegible]	368.2	185.7
Dec. 15	Dec. 24	Tr.	....	54	.06	15	10	54	.0	139	42	.42	22	23[illegible]	353.0	178.0
Dec. 25	Dec. 31	8	....	45	.04	18	5.9	77	.0	164	40	.48	29	27[illegible]	361.0	182.0
Mean		7	....	40	.20	15	4.3	40	.0	111	30	1.2	17	18[illegible]	476	240
Per cent of anhydrous residue		....	....	19.7	0.1	7.4	2.1	19.7	27.2	......	14.8	.6	8.4	......	......	......

a Abnormal. Computed as HCO_3 in the average.

CHARACTER OF WATER AT CHARLIES BUTTE.

The intake for the diversion canal of the Los Angeles aqueduct is located near Charlies Butte, a basaltic mass in Owens Valley about 7 miles south of Tinemaha.[a] Samples of water were collected daily during 1908 from Owens River at this point by Ray Bowers.

At Charlies Butte the maximum flow occurs in the winter, the lower valley receiving considerable runoff from the rains and melting snows of the rainy season. A second period of high flow, resulting from the melting snows on the Sierra Nevada, occurs in the summer. In 1908 the summer flood was considerably less in volume than that of the winter, but showed a very decided increase over the ordinary dry-season discharge.

Fluctuation in the mineral content of Owens River is less and the total content is persistently greater at Charlies Butte than at Round Valley. Minimum values occurred in 1908 in October, when 203 parts per million were recorded, and maximum values—432 parts per million—were reached in the early spring.

The water is alkaline carbonated in type, as at Round Valley, the percentage composition of the samples from the two places being similar in this respect. Silica is high in value, while calcium and magnesium are relatively low.

The water is well adapted for irrigation and is suitable for a municipal supply, the chief hardness being of the temporary type. Small amounts of soda ash should be added before using this water in steam boilers. It is not particularly well adapted for the greater number of manufacturing industries which use water in connection with chemical processes.

[a] See Water-Supply Paper U. S. Geol. Survey No. 177, p. 83; also No. 213 p. 37.

Mineral analyses of water from Owens River at Charlies Butte near Tinemaha.

[Parts per million unless otherwise stated.]

Date.		Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.	Mean discharge.	
From—	To—														Acre-feet per day.	Cubic feet per second.
1907. Dec. 31	1908. Jan. 9	10	....	44	0.15	28	7.4	66	0.0	171	46	1.0	27	290	1,017.5	513
1908																
Jan. 10	Jan. 19	20	....	44	.15	32	5.8	53	.0	167	49	1.4	29	288	1,035.5	522.1
Jan. 20	Jan. 29	20	36	45	.15	33	8.6	67	.0	199	63	1.7	36	362	1,127.2	568.3
Jan. 30	Feb. 8	30	79	43	.21	33	8.3	102	.0	233	73	1.4	49	407	1,288.4	649.6
Feb. 9	Feb. 18	20	38	42	.12	26	8.6	95	.0	212	65	1.5	43	366	1,106.2	557.7
Feb. 19	Feb. 28	30	57	42	.17	31	8.5	87	.0	216	63	5.7	41	374	1,095.8	552.5
Feb. 29	Mar. 9	18	....	43	.17	26	7.2	84	.0	211	50	2.5	39	344	989.2	498.7
Mar. 10	Mar. 19	25	87	47	.33	25	5.6	84	.0	205	51	3.2	39	353	1,108.9	559.1
Mar. 20	Mar. 29	35	79	43	.15	28	6.2	77	.0	218	45	3.0	34	338	878.3	442.8
Mar. 30	Apr. 8	10	....	48	.13	28	12	62	*a* 4.8	193	55	2.0	30	329	464.7	234.3
Apr. 19	Apr. 28	Tr.	....	45	.04	37	18	64	.0	272	63	.75	40	412	180.7	91.1
Apr. 29	May 8	5	....	42	1.0	41	22	79	.0	290	68	2.5	45	432	120.0	60.5
May 9	May 18	Tr.	....	43	.18	41	21	74	*a* 31	203	73	1.4	35	431	114.0	57.5
May 19	May 28	Tr.	....	41	.45	39	19	72	.0	266	67	2.1	40	396	115.0	58.0
May 29	June 7	Tr.	....	40	.15	38	19	70	.0	254	61	2.2	38	374	119.0	60.0
June 8	June 17	8	....	42	.13	39	20	72	.0	261	56	3.0	42	391	90.2	45.5
June 18	June 27	10	14	31	.18	37	14	68	.0	240	60	1.4	31	364	122.2	61.6
June 28	July 7	20	23	47	.33	32	20	79	*a* 2.4	249	53	.92	40	380	222.7	112.3
July 8	July 17	Tr.	....	41	.40	27	11	59	.0	188	41	.44	27	295	521.8	263.1
July 18	July 27	12	20	47	.13	32	16	55	*a* 6.0	212	45	1.1	30	331	323.8	163.3
July 28	Aug. 6	40	48	43	.08	26	11	51	.0	181	46	1.8	23	293	564.3	284.5
Aug. 7	Aug. 16	40	87	39	.30	28	8.5	49	.0	161	44	1.6	19	252	808.3	407.5
Aug. 17	Aug. 26	....	....	47	.55	32	11	51	*a* Tr.	195	43	1.0	14	302	320.5	161.6
Aug. 27	Sept. 5	8	....	39	.20	44	12	55	.0	210	48	2.0	27	317	213.2	107.5
Sept. 6	Sept. 15	50	30	40	.25	33	12	73	.0	222	49	1.8	37	351	272.3	137.3
Sept. 16	Sept. 25	20	28	41	.20	30	10	56	.0	196	45	......	29	379	398.4	209
Sept. 26	Oct. 5	10	....	30	.04	30	10	58	.0	202	43	.54	27	307	494.1	249.1
Oct. 6	Oct. 15	20	25	40	.05	27	7.7	62	.0	195	39	.78	25	284	507.0	255.6
Oct. 16	Oct. 25	25	40	49	.13	25	9.0	64	.0	188	52	.74	25	303	632.9	319.1
Oct. 26	Nov. 4	15	....	41	.26	26	7.9	57	.0	171	42	.70	24	273	768.6	387.5
Nov. 5	Nov. 14	20	35	43	.07	27	8.4	60	.0	173	41	.20	24	278	788.8	397.7
Nov. 15	Nov. 24	8	....	55	.34	28	8.8	70	.0	188	56	1.1	26	314	786.6	396.6
Nov. 25	Dec. 4	14	14	42	.08	29	9.1	76	.0	188	69	3.3	35	334	808.3	407.5
Dec. 5	Dec. 14	14	17	46	.36	30	11	81	.0	185	67	1.6	36	344	865.2	436.2
Dec. 15	Dec. 24	Tr.	....	45	.34	28	9.9	64	.0	189	48	3.8	30	310	748.7	377.5
Dec. 25	Dec. 31	10	...	46	.08	27	9.8	86	.0	190	79	.70	34	312	799.2	402.9
Mean		16	....	43	.22	31	12	69	.0	211	54	1.7	33	339	606	306
Per cent of anhydrous residue		....	....	12.4	0.1	8.9	3.4	19.8	29.9	......	15.5	0.5	9.5	......	......	......

a Abnormal. Computed as HCO_3 in the average.

OWENS LAKE.

DESCRIPTION.

Owens Lake, into which the waters of Owens River discharge, is a large, shallow body of water lying in the southern extremity of Owens Valley. The lake is without visible outlet, and its volume depends on the relation of inflow to evaporation. The general tendency of the lake toward gradual diminution in size has recently been checked by a succession of unusually wet seasons, which have sent abnormally large quantities of water to the lake. The summer droughts have failed to restore the water to its ordinary level, and, temporarily at least, the size of the lake is increasing. On May 1, 1909, the water level was higher than it had been for many years.

CHARACTER OF WATER.

The lake shows every evidence of having been at one time a body of pure, fresh water, but owing to its landlocked condition and to the resultant gradual concentration of the salts held in solution it is now one of the most strongly saline lakes in America. It has been of great interest to chemists and its waters have several times been analyzed. Oscar Loew estimated that in 1876 it contained 22,000,000 tons of sodium carbonate and 5,000,000 tons of potassium sulphate in solution.[a] At the time of his analysis it was not known that the water contained large amounts of borates, and only traces of these were recorded by him. Later, in 1886, T. M. Chatard made analyses of samples collected by I. C. Russell, of the United States Geological Survey, and his report[b] indicates a large amount of boric acid in solution. He, however, neglected to find any considerable amount of phosphoric acid, arsenic, or nitric acid, and his analyses can not therefore be considered complete. In 1906, at the request of Willis T. Lee, one of the geologists of the Survey, a complete analysis of the waters of the lake was made by C. H. Stone and F. M. Eaton. The results of the various analyses here referred to are presented in the following table:

Analyses of the water of Owens Lake.

[Parts per million.]

	1.	2.	3.
Silica (SiO_2)	164	207	297
Iron (Fe)		9.2	(as Al) 48
Aluminum (Al)	Trace.	12	
Calcium (Ca)	Trace.	13	34
Magnesium (Mg)	Trace.	4.7	15
Lithium (Li)	Trace.		57
Sodium (Na)	21,652	26,836	81,176
Potassium (K)	2,751	1,548	3,448
Carbonate radicle (CO_3)	13,146	18,265	52,326
Sulphate radicle (SO_4)	9,362	7,067	21,174
Chlorine (Cl)	13,444	18,214	52,898
Phosphate radicle (PO_4)	Trace.		238
Borate radicle (B_4O_7)	Trace.	346	296
Hydrogen (H)		59	130
Nitrate radicle (NO_3)	Trace.		948
Organic matter	Trace.		
Cæsium (Cs)			Trace.
Rubidium (Rb)			Trace.
Arsenic (As)			84
Total solids	60,430	72,471	213,661
Specific gravity	1.051	[a] 1.062	1.1954

[a] At 25° C.
1. Analysis by Doctor Loew, 1876.
2. Analysis by T. M. Chatard, 1886.
3. Analysis by C. H. Stone and F. M. Eaton, 1906.

The analyses show that the alkaline carbonates, chlorides, and sulphates form the greater part of the dissolved mineral matter, the sulphates being important because they are most troublesome in the manufacture of soda. Nitrates, phosphates, and arsenic, as reported

[a] Ann. Rept. U. S. Geog. Surveys W. 100th Mer., 1876, App. H3, p. 190.

[b] Chatard, T. M., Natural soda, its occurrence and utilization: Bull. U. S. Geol. Survey No. 60, 1886, p. 58.

in the analysis by Stone and Eaton, are present in greater quantities than have been elsewhere reported for surface waters.

The water is used commercially for the recovery of soda, and a large plant is situated on the shores of the lake at Kieler. This soda plant and the Death Valley borax plant form the two notable manufactories of eastern California, and the water of Owens Lake must therefore be ranked as one of the most important natural commercial assets of the region.

MONO LAKE.

Mono Lake lies in an elevated valley directly north of the headwaters of Owens River. It receives a scant drainage from the surrounding mountains, and, having no outlet, maintains its level by means of evaporation. An analysis of the water of this lake, made in 1882 by T. M. Chatard[a] is quoted here for comparison with the analyses of the water of Owens Lake.

Analysis of water of Mono Lake.[b]

[Analyst, T. M. Chatard.]

	Parts per million.		Parts per million.
Silica (SiO_2)	67	Carbonate radicle (CO_3)	13,101
Aluminum (Al), Iron (Fe)	1.5	Sulphate radicle (SO_4)	6,384
Calcium (Ca)	19	Borate radicle (B_4O_7)	153
Magnesium (Mg)	53	Chlorine (Cl)	11,581
Sodium (Na)	18,837	Hydrogen (H)	50
Potassium (K)	920	Total solids	51,170

The analysis shows that this water, like that of Owens Lake, contains chiefly alkaline carbonates, chlorides, and sulphates, but that it is less concentrated than the water of Owens Lake. Owing to its elevation and to the resulting brief duration of the warm season it is doubtful whether this lake can be developed commercially.

LAKE TAHOE.

Lake Tahoe is situated in the high Sierra region in the east-central part of California, and is the first of a series of lakes in California and Nevada connected by the Truckee and Carson rivers. It lies at a great elevation and derives its water chiefly from the melted snows of the Sierra Nevada. The following analysis, by F. W. Clarke,[c] shows the marked freedom of the water of this lake from mineral matter in solution.

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[a] Chatard, T. M., Natural soda, its occurrence and utilization: Bull. U. S. Geol. Survey No. 60, 1887, p. 53.

[b] Sample collected in 1882 by I. C. Russell on east side of lake at a depth of 1 foot.

[c] Clarke, F. W., The data of geochemistry: Bull. U. S. Geol. Survey No. 330, 1908, p. 122.

Analysis of water of Lake Tahoe.

[Analyst, F. W. Clarke.]

	Parts per million.		Parts per million.
Silica (SiO_2)	14	Carbonate radicle (CO_3)	28
Calcium (Ca)	9.4	Sulphate radicle (SO_4)	5.5
Magnesium (Mg)	3.0	Chlorine (Cl)	2.3
Sodium (Na)	7.4	Total solids	73
Potassium (K)	3.3		

From the above analysis it is apparent that the water is alkaline carbonate in type, similar to that of Owens River. It is of great mineral purity and could be used for any purpose without previous treatment, except that for domestic use its general bacterial purification is necessary.

MINOR GREAT BASIN SUBDRAINAGE.

MOHAVE RIVER.

DESCRIPTION.

Mohave River rises on the northern slopes of the San Bernardino Mountains, flows through high valleys in a general northerly direction to a point near Oro Grande, where it turns eastward and gradually loses itself in the sandy Mohave Desert. Few streams are tributary to this river and all of these join it in its mountain reaches. The bed rock at the headwaters is granitic, with a good soil covering, and this condition continues, except for occasional beds of limestone, throughout the entire course of the stream. The floor of Mohave Desert is composed of a disintegrated granite sand rich in feldspar, permitting the solution of large quantities of alkaline minerals.

The upper valley of the Mohave, between the San Bernardino Mountains and Victorville, receives no surface flow except in the winter months. At Victorville a granite ledge forms a barrier to the passage of the underflow, and the river rises to the surface through what is locally called the "Narrows." Northward from the "Narrows" the valley gradually broadens out and the river again sinks slowly into its sandy bed. The lower course of the stream in the desert is marked by a decided efflorescence of alkaline material, and it is probable that the waters here are very heavily impregnated.

CHARACTER OF WATER.

A single sample of water was taken from the Mohave at Victorville on March 17, 1908. At this place, at which it has been proposed to erect a dam to impound water for irrigation, the river bottom is rocky, with large stretches of shifting sand, and the current is swift. The results of the analysis are shown in the following table:

Analysis of water of Mohave River at Victorville, March 17, 1908.

[Analyst, Walton Van Winkle.]

	Parts per million.		Parts per million.
Turbidity	15	Carbonate radicle (CO_3)	.0
Silica (SiO_2)	25	Bicarbonate radicle (HCO_3)	83
Iron (Fe)	.20	Sulphate radicle (SO_4)	7.9
Calcium (Ca)	15	Chlorine (Cl)	6
Magnesium (Mg)	2.9	Nitrate radicle (NO_3)	.36
Sodium and potassium (Na+K)	15	Total solids	117

So far as may be judged from a single analysis, the water of Mohave River at the Narrows is of excellent quality. Total solids are low, hardness is small and chiefly temporary, and serious mineral contamination is not indicated. For use in boilers no treatment of the water is necessary. Soap consumption is small, and the water is admirably adapted for general purposes.

SALTON SEA.

As the Colorado River drainage in California is small and unimportant a general investigation of its waters was not attempted. For special purposes, however, analyses have been made of the waters of Salton Sea, the large, shallow body of water lying in a depression at the head of Imperial Valley in what was formerly called Salton Sink. Once an inland sea formed by the waters of the Colorado, it later lost its inlet through the silting up of the channel, and finally dried up into a saline bed or sink, and small streams flowing into it from the surrounding mountains lost themselves in its sandy wastes. In 1891 the high water in the Colorado overflowed into the sink, forming anew the Salton Sea. Flooding was renewed in 1905, increasing the size of the sea. Although the waters of Colorado River are now restrained from overflow into this valley, considerable seepage water and waste from the irrigating ditches still enters the sink, and as a result the evaporation of the sea will be a matter of many years.

In November, 1907, G. K. Gilbert obtained a sample of water from the sea, and in February, 1908, another sample was collected by J. A. Jeffrey. The first sample was analyzed in the laboratory at Berkeley; the later one was analyzed in the Survey laboratory, at Austin, Tex. The results of these analyses are presented in the following table:

Analyses of water of Salton Sea.

[Parts per million.]

	1.	2.		1.	2.
Turbidity	Trace.	....	Potassium (K)	150	155
Silica (SiO_2)	19	4	Carbonate radicle (CO_3)	12	11
Iron (Fe)	.08	.4	Bicarbonate radicle (HCO_3)	140	159
Aluminum (Al)	....	4.9	Sulphate radicle (SO_4)	559	562
Calcium (Ca)	107	142	Chlorine (Cl)	1,827	1,925
Magnesium (Mg)	68	77	Nitrate radicle (NO_3)	.35	....
Sodium (Na)	1,123	1,190	Total solids	3,912	4,087

1. Collected November 12, 1907, by Dr. G. K. Gilbert, and analyzed by Walton Van Winkle.
2. Collected February 28, 1908, by J. A. Jeffrey, Mecca, Cal., and analyzed by J. A. Bailey and A. M. McAfee.

The water is alkaline muriated, as might be expected in a sink of this nature. It is useless for practical purposes, and the analyses serve merely to indicate the commencement of the gradual increase in concentration of minerals which will occur until the lake finally disappears.

NOTES ON MUNICIPALITIES.

But three incorporated towns in these drainage areas reported water-supply conditions. The statistics appear in the following table:

Statistics of municipal water supplies in interior basin and Colorado River drainage basin.

Settlement.	Drainage basin.	Population.	River.	Source of supply.	Nature of system.
Bishop	Owens River	2,000	Owens	Stream	Gravity.
Imperial	Colorado River	2,000		Colorado River	Gravity and pumping.
Susanville	Honey Lake	1,000	Susan	Springs	Gravity.

Settlement.	Ownership.	Methods used for purification.	Per capita daily consumption (gallons).	Nature of sewerage system.	Ultimate disposal of sewage.
Bishop	Municipal	Sedimentation	No data.	Combined	Sewer farm.
Imperial	Imperial Land, Water and Power Co.	Sedimentation and filtration.	75	None	
Susanville	Lassen Land, Water and Power Co.	None	No data.	Sanitary — septic tank.	

FEATURES INFLUENCING THE QUALITY OF THE SURFACE WATERS.

The amount of mineral matter in natural surface waters depends principally on, first, the nature and the texture of the geologic formations with which the water comes into contact; second, climatic conditions; and, third, amount of vegetation. Other factors, among which may be mentioned distance from the ocean, affect the mineral content to a less degree.

INFLUENCE OF GEOLOGIC FORMATIONS.

It can be seen from study of the table on page 127 that the rivers of the eastern portion of the State receive but little mineral matter from the resistant granite formations of the Sierra, while the coastal rivers, draining areas composed in large part of loose sedimentary deposits, show much higher mineral content. The amount of magnesium does not vary appreciably with difference in climatic condition, hence the variation in percentage composition of the mineral residues from the waters, due to difference in geologic formations, is well illustrated by this constituent. All rivers studied whose content of magnesium was above 6.5 per cent of the total anhydrous residue flow over the sedimentary deposits and ferromagnesian eruptive rocks of the coast region.

The four rivers whose magnesium is below 4 per cent flow from granite formations, two from the southern portion of the Sierra, one from the San Bernardino Mountains, and one from the Santa Cruz Mountains. The lowest magnesium was found in the two streams from the Sierra—Kern and Owens rivers, Owens River averaging slightly less than Kern River. The low magnesium content in Santa Ana River at Corona is attributed to the effect of using the water to irrigate soil poorer in magnesium than the formations nearer the headwaters. The percentage of magnesium in solution at Mentone before the water is drawn out for irrigation is slightly greater. San Lorenzo River is the fourth river of low magnesium content, and like Kern and Owens rivers owes its small percentage to the granite formations over which it flows in its upper course.

Owing to other and greater variations in mineral content in the waters of California it is not proper to compare percentage compositions in studying silica values. A comparison of absolute quantities of silica present, however, indicates a relation between geologic structure and the amount of silica in the river waters. The following table shows the average values, in parts per million, of silica for the rivers studied. The rivers are arranged in order of geographic position, from north to south.

Silica (SiO_2) in California rivers.

[Parts per million.]

COASTAL RIVERS.		SIERRA RIVERS.	
Russian	19	Feather	16
Cache Creek	16	Yuba	14
Alameda Creek	19	American	17
San Lorenzo	23	Sacramento (1906)	19
San Benito	24	Sacramento (1908)	27
Arroyo Seco	26	Mokelumne	14
San Antonio	37	San Joaquin (1906)	16
Nacimiento	25	San Joaquin (1908)	19
Estrella	35	Stanislaus	14
Salinas	31	Tuolumne	11
Santa Maria	24	Merced	14
Santa Ynez (1906)	24	Kern	18
Santa Ynez (1908)	22	Owens, Round Valley	40
Ventura	23	Owens, Charlies Butte	43
Malibu Creek	36		
San Gabriel, Azusa	21		
San Gabriel, Rivera	23		
Santa Ana, Corona	31		
Santa Ana, Mentone (1906)	16		
Santa Ana, Mentone (1908)	25		
San Luis Rey	31		
Santa Ysabel	44		
Cottonwood Creek	44		

The silica content in the coastal rivers increases with considerable regularity from north to south, slight irregularities being occasioned by some high values in the Salinas River system and in Malibu Creek. This tendency to a regular increase is not noticeable in the Sierra rivers, in which the amount of silica varies but slightly, except in Owens River, on the southeast side of the Sierra, which has, however, a silica content about three times as great as that of the streams on the western slope. Near the coast and in the central arid regions the influence of vegetation is overshadowed by the greater effect of geologic conditions, but on the western slope of the Sierra the effects of vegetation mask those of rock composition. The rock formations in California are, broadly speaking, basic in the northern portions, increasing in acidity toward the south. North of San Francisco Bay the basic character is pronounced, in the sedimentary rocks of the Gabilan Range a more acidic nature is manifest, and in the mountains of the southwest corner of the State the formations are markedly acidic. A slightly more basic character is noticeable in the formations of the valley of southern California and of its mountain girdle and in those of the Santa Ynez Range. The table of silica values shows a change in amount of silica dissolved in the river waters for each corresponding change in basicity of the rock formations and the analyses of the "spot" samples scattered through the report give further evidence of this close relation.

INFLUENCE OF CLIMATIC CONDITIONS.

Climatic conditions, through their influence on the quantity of vegetation, have important effect on the quality of water. There is no distinct division between regions of abundant and those of deficient rainfall in California, and for purposes of comparison an arbitrary line of division must be selected. In the present work a lower limit of 15 inches of rainfall annually has been chosen for humid regions, and all areas showing in general a less amount have been classed as semiarid, because it appears from study of the rainfall map of California,[a] that those regions of California commonly called semiarid receive average annual rainfalls of less than 15 inches, and that the maximum for such areas seldom exceeds that figure. The average precipitation for each catchment area was then roughly determined from the rainfall map, particular emphasis being placed on the rainfall of the headwater regions, as this furnishes the greater portion of the run-off of the California streams. The rivers were thus classified under the two heads, humid and semiarid.

Although the classification so obtained is crude, it serves to indicate several points of importance regarding rivers in California. First, the average mineral content of waters in semiarid regions is, roughly, four

[a] McAdie, A. G., Climatology of California, U. S. Weather Bureau Bull. L, 1903, Chart VIII.

times that of waters in humid regions. Second, differences in percentage composition of the anhydrous residues show that the waters in semiarid regions contain about two-thirds the proportionate amount of silica, less calcium, four-fifths as much carbonates, and twice as much sulphates, as the waters of the humid regions. Other constituents are similar in amount. In regions of abundant rainfall disintegration of rock material can not keep pace with solution, erosion, and chemical decomposition. The more soluble constituents of the rocks are rapidly removed as they become exposed to the action of water, and their total amount in a given quantity of the solvent water is seldom great. In arid or semiarid regions, however, chemical action is frequently less marked than physical disintegration. The soluble materials of the disintegrated rock masses accumulate through periods of drought, allowing the water from subsequent rainfalls to take into solution a greater relative amount than is found in waters from the more humid regions.

In the waters studied the average amount of mineral in streams from the semiarid regions was 627 parts per million; in rivers of the humid regions it was 165 parts per million. The greatest average mineral content, 2,412 parts per million, occurred in Santa Maria River, which flows through a sandstone country receiving barely 10 inches of rain a year. The smallest amount of mineral matter was found in Merced River, 65 parts per million, or about one-fortieth of the amount for Santa Maria River. Merced River drains a granite country receiving in its upper portions over 45 inches of rain annually. The greatest individual determination of total solids was in water of San Lorenzo Creek, in the semiarid Salinas Valley, 3,689 parts per million on April 7, 1908. The smallest, 30 parts per million, was in Mokelumne River, June 21 to 30, 1906, when that river was receiving a large amount of water from the melting snows on the Sierra slopes, as well as from the spring rains.

As the silica content is apparently unaffected by the amount of the other dissolved constituents, it may be expected that the percentage of silica in rivers of high dissolved solids will be correspondingly low. This is true in California waters, the average silica for the humid-region rivers being 13.4 per cent and for the semiarid-region waters 8.0 per cent of the total mineral matter in solution. The principal effect, then, of climatic condition on silica content is a negative one and it is apparently due merely to change in total mineral content.

By the decay of the abundant organic material in humid regions carbonic acid is set free, being dissolved in the surface waters or entering the air as carbon dioxide. This carbonic acid, uniting with the carbonic acid of the alkaline-earth carbonates, produces the bicarbonates which are readily dissolved, so that surface waters in regions of abundant rainfall, carry large amounts of the bicarbonate radicle and of the alkaline earths. In regions of deficient rainfall, on the other hand, carbonate rocks are attacked to less extent and the gypsum and alkaline sulphates that are present are brought more largely into solution.

In considering the foregoing comments on the mineral constituents of the waters, it must be borne in mind that simple conditions do not occur in any of the regions, but that the effect of a stated geologic or climatic condition may be completely masked by that of another, or may be increased beyond the normal by that of still another. The effect on one constituent may thus be so clouded by changes in others as to be indeterminate. Geologic conditions vary throughout the State, and are not in general similar for the arid and the humid regions. Gypsum, for example, is more abundant in the formations of the southern part of the State than in the northern portions or in the Sierra. Some rivers also show certain irregularities not due to natural causes, as, for example, Alameda Creek, the water of which is high in its mineral content because it receives an abnormal proportion of ground water on account of an obstruction to subsurface flow above the point of sampling. Such influences must be considered before any general conclusions are made.

INFLUENCE OF DISTANCE FROM THE OCEAN.

Distance from the sea affects the chlorine content of river waters by reason of the chlorine in finely divided salt spray that is carried inland with dust particles by the wind and precipitated with the rain. Therefore, within the limits of wind-carried salt the nearer a stream is to the sea the greater its chlorine content will be. In the northeastern United States determinations of this normal chlorine content have been made,[a] and such estimates have been valuable in sanitary studies of water supplies. In California, however, in most of the drainage basins studied, the chlorine derived from the atmosphere is completely masked by the much greater amount derived from saline deposits and from other chloride-bearing rocks. Therefore it is impracticable to locate lines of equal normal chlorine (isochlors) from present information regarding the quality of the waters.

SUMMARY.

The average mineral content of the 37 rivers studied in detail is 368 parts per million, the average in the humid regions being 165 parts and in the semiarid regions 628 parts. The bicarbonate radicle is predominant in most of the waters. Its place is taken by the sulphate radicle in the water from the regions of least rainfall. The

[a] Jackson, D. D., The normal distribution of chlorine in the natural waters of New York and New England: Water-Supply Paper U. S. Geol. Survey No. 144, 1905.

average amount of the bicarbonate radicle, computed as normal carbonate, is 27.3 per cent of the anhydrous residue, and the amount of this constituent is never abnormally high as compared with that found in surface waters of other sections of the United States; but in the waters of the more arid regions its relative amount sinks into insignificance, averaging only 5.8 per cent in Santa Maria River. The sulphate radicle fluctuates in inverse ratio to the bicarbonate radicle. It forms 58.5 per cent of the residue of the water from Santa Maria River, and in the humid regions it is as low as 10.2 per cent in the average of Santa Ana River at Mentone in 1906. In examination of the "spot" samples, the lowest carbonate and the highest sulphate percentages were found in the same stream, Gaviota Creek, where carbonates were only 3.1 per cent and sulphates were 60.3 per cent of the total anhydrous residue.

ECONOMIC VALUE OF THE WATERS.

The following table shows the average values of the waters examined with reference to their steaming qualities. The results obtained also serve to indicate the qualities of the waters for many other purposes, and may be assumed to indicate the economic value of the waters. The properties considered are the tendency to foam, to prime, and to cause corrosion, the amount of scale deposited by the water, and the nature of the scale. The method of study was that outlined by Stabler,[a] the suspended matter not being considered, it being assumed that this would be settled or filtered out if the water were to be put to industrial use. The values are averages for the period of examination, and figures are not given.

Under foaming the following classification was employed: Nonfoaming indicates that the water could be used for one week or more in a locomotive boiler without foaming; semifoaming, that it could be used for two days to one week under the same conditions without foaming; and foaming, that it would cause foaming in less than two days. Similarly, classification of the corrosive tendency is made as noncorrosive when there was no chemical evidence that corrosion of metals might occur; semicorrosive when certain conditions of its use might cause corrosion; and corrosive if a positive tendency to produce corrosion existed. Under scale, if not over 1 pound of scale would be deposited for each 1,000 gallons used, the water is classed as giving very little scale; if between 1 and 2 pounds of scale would be deposited per 1,000 gallons, the water is classed as producing little scale; if between 2 and 4 pounds of scale would result from its use, the water is classed as giving much scale; and if over 4 pounds of scale would

[a] Stabler, Herman, The mineral analysis of water for industrial purposes and its interpretation by the engineer: Eng. News, vol. 60, 1908, p. 356.

deposit on the use of 1,000 gallons of the water it is classed as depositing very much scale. The nature of the scale is described as soft, medium, or hard, according to the ratio of the hard scale to total scale formed, soft scale containing not over one-quarter of the total as hard scale, medium scale, not over one-half or under one-quarter, and hard scale not under one-half of the total scale as hard scale.

The industrial values of California surface waters.

Stream.	Priming	Corrosion.	Scale.	Nature of scale.	Nature of drainage basin.
Alameda Creek	Semifoaming	Semicorrosive	Much	Medium.	Humid.
American River	Nonfoaming	do	Very little	do	Do.
Arroyo Seco	Semifoaming	Noncorrosive	Little	do	Semiarid.
Cache Creek	do	do	Very little	Hard	Humid.
Cottonwood Creek	do	do	Much	Medium.	Semiarid.
Estrella River	Foaming	Semicorrosive	do	Hard	Do.
Feather River	Nonfoaming	do	Very little	Medium.	Humid.
Kern River	do	do	do	do	Do.
Malibu Creek	Semifoaming	do	Much	Hard	Semiarid.
Merced River	Nonfoaming	do	Very little	Medium.	Humid.
Mokelumne River	do	do	do	do	Do.
Nacimiento River	Semifoaming	do	Little	Hard	Semiarid.
Owens River, Charlies Butte	do	Noncorrosive	do	Medium.	Do.
Owens River, Round Valley	do	do	Much	Hard	Do.
Russian River	Nonfoaming	Semicorrosive	Very little	Medium.	Humid.
Sacramento River, 1906	do	do	do	do	Do.
Sacramento River, 1908	do	do	do	do	Do.
Salinas River	Semifoaming	do	Much	Hard	Semiarid.
San Antonio River	do	do	Little	Medium.	Do.
San Benito River	Foaming	do	Much	do	Do.
San Gabriel River, Azusa	Nonfoaming	Noncorrosive	Little	Soft	Humid.
San Gabriel River, Rivera	do	do	do	do	Do.
San Joaquin River, 1906	Semifoaming	Semicorrosive	Very little	Hard	Do.
San Joaquin River, 1908	do	do	do	do	Do.
San Lorenzo River	do	do	Little	Medium.	Do.
San Luis Rey River	do	do	do	do	Semiarid.
Santa Ana River, Corona	do	Noncorrosive	Much	Soft	Humid.
Santa Ana River, Mentone, 1906	Nonfoaming	Semicorrosive	Very little	do	Do.
Santa Ana River, Mentone, 1908	do	Noncorrosive	do	Medium.	Do.
Santa Maria River	Foaming	Corrosive	Very much	Hard	Semiarid.
Santa Ynez River, 1906	Semifoaming	Semicorrosive	Much	do	Do.
Santa Ynez River, 1908	do	do	do	do	Do.
Santa Ysabel Creek	do	do	Little	Medium.	Do.
Stanislaus River	Nonfoaming	do	Very little	do	Humid.
Tuolumne River	do	do	do	do	Do.
Ventura River	Semifoaming	do	Much	Hard	Semiarid.
Yuba River	Nonfoaming	do	Very little	Medium.	Humid.

It is apparent from this classification that the surface waters of California are in general hard; that none of the semiarid region waters are of excellent quality for industrial purposes; that the Sierra rivers have a tendency to produce a small amount of hard scale in boilers; that the number of nonfoaming waters is small, but that the number of waters bad in this respect is less in the humid than in the semiarid region; and that the softest and best waters for steaming purposes are those in the orange belt of southern California.

The waters from the Gabilan and Diablo ranges and from Santa Maria River are classed as foaming. The Santa Maria furnishes the sole example of a corrosive water, though others, notably Estrella River, show strong tendency to cause corrosion under certain circumstances.

Owens River between Round Valley and Charlies Butte shows a change from a poor water depositing much hard scale in boilers to a far better water producing but little medium scale. This is the result of inflow of softer, less strongly mineralized water between the points of collection.

The marked differences in the quantity of mineral matter in the waters, from analysis to analysis, and in the averages for each of the two years, where work was done in both 1906 and 1908, show how important it is for the engineer or chemist to have data covering a long period of time before he can correctly determine the most suitable means of treating these waters for industrial use. Analyses made from single samples of any of the rivers studied would have given decidedly erroneous ideas of the quality of the water and the limits of mineral content which it might be expected to reach.

SUMMARIES.

In conclusion are presented three tables giving in summary form the results of the analyses recorded in this report.

Summary of results of mineral analyses of surface waters of California.

Source of sample.	Average mineral content (parts per million).													Chemical composition of mineral matter (per cent of anhydrous residue).								
	Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).
Alameda Creek, Niles	....	163	19	0.13	66	28	49	4.4	262	91	....	34	421	4.5	0.0	15.7	6.6	11.7	31.8	21.6	....	8.1
American, Fairoaks	....	146	17	.39	11	4.4	11	.0	41	12	....	6.3	83	20.7	.5	13.4	5.3	13.4	24.4	14.6	....	7.7
Arroyo Seco, Soledad	....	33	26	.20	51	14	29	.0	170	72	....	13	284	9.0	.1	17.6	4.9	10.0	29.0	24.9	....	4.5
Cache Creek, Yolo	64	....	16	.19	30	23	33	2.1	193	28	1.3	31	250	6.2	.1	11.6	8.9	12.7	37.6	10.7	0.5	11.7
Cottonwood Creek, Barrett dam	19	....	44	.18	51	20	69	3.7	246	52	1.0	62	413	10.4	.0	12.0	4.7	16.3	29.5	12.3	.2	14.6
Estrella, San Miguel	161	....	35	.19	79	53	224	9.6	273	385	.88	192	1,131	3.1	.0	7.1	4.8	20.1	12.9	34.6	.1	17.3
Feather, Oroville	....	41	16	.17	13	5.7	14	.0	64	11	....	5.8	99	16.4	.2	13.3	5.8	14.3	32.8	11.3	....	5.9
Kern, Bakersfield	....	163	18	.15	18	4.2	22	.0	71	21	....	9.1	127	14.1	.1	14.1	3.3	17.3	27.5	16.5	....	7.1
Malibu Creek, Calabasas	....	61	36	.11	101	50	73	2.2	288	285	....	42	751	4.9	.0	13.8	6.8	10.0	19.7	39.0	....	5.8
Merced, Merced Falls	....	52	14	.10	9.1	3.8	9.3	.0	35	11	....	5.6	65	20.0	.2	13.0	5.4	13.3	24.3	15.8	....	8.0
Mokelumne, Clements	....	84	14	.18	12	3.8	13	.0	42	12	....	7.3	75	16.8	.2	14.4	4.6	15.6	25.2	14.4	....	8.8
Nacimiento, San Miguel	36	....	25	.19	42	22	24	1.7	171	72	4.4	14	286	8.6	.1	14.5	7.6	8.3	29.8	24.8	1.5	4.8
Owens:																						
Charlies Butte	16	....	43	.22	31	12	69	.0	211	54	1.7	33	339	12.4	.1	8.9	3.4	19.8	29.9	15.5	.5	9.5
Round Valley	7	....	40	.20	15	4.3	40	.0	111	30	1.2	17	189	19.7	.1	7.4	2.1	19.7	27.2	14.8	.6	8.4
Russian, Ukiah	9	....	19	.19	23	12	16	.0	125	17	1.2	7.4	145	12.0	.1	14.6	7.6	10.1	39.4	10.8	.8	4.6
Sacramento, above Sacramento (1906)	....	60	19	.29	15	7.0	15	.0	76	13	....	8.7	124	16.6	.2	13.0	6.1	13.0	32.2	11.3	....	7.6
Sacramento, above Sacramento (1908)	66	102	28	.43	13	6.7	13	.0	74	17	.64	5.4	113	23.2	.4	10.8	5.6	10.8	30.0	14.1	.5	4.6
Salinas, Paso Robles	16	....	31	.15	60	28	59	5.6	272	97	.74	39	448	6.8	.0	13.2	6.2	13.0	30.7	21.3	.2	8.6
San Antonio, Bradley	10	....	37	.16	63	21	38	2.5	224	94	1.0	24	387	9.5	.0	16.1	5.4	9.7	28.9	24.0	.3	6.1
San Benito, Hollister	....	1,444	24	.09	58	57	110	6.2	335	204	....	95	732	3.3	.0	8.1	8.0	15.3	23.8	28.3	....	13.2
San Gabriel:																						
Azusa	23	....	21	.16	45	12	18	3.3	176	32	1.1	4.3	208	9.4	.1	20.1	5.4	8.0	40.3	14.3	.5	1.9
Rivera	5	....	23	.11	55	12	22	2.2	211	33	1.9	8.4	246	8.8	.1	21.0	4.6	8.4	40.6	12.6	.7	3.2
San Joaquin:																						
Lathrop (1906)	....	60	16	.23	18	8.0	27	.0	66	26	....	30	161	10.1	.1	11.4	5.1	17.1	20.9	16.4	....	18.9
Lathrop (1908)	34	52	19	.30	20	10	36	.0	74	39	1.0	47	205	9.1	.1	9.6	4.8	17.3	17.3	18.7	.5	22.6
San Lorenzo, Big Trees	....	84	23	.18	44	10	31	.0	147	43	....	29	255	9.1	.1	17.4	3.9	12.5	28.5	17.0	....	11.5
San Luis Rey, Pala	....	142	31	.12	42	13	44	.0	163	53	....	39	321	10.3	.0	13.9	4.3	14.6	26.5	17.5	....	12.9
Santa Ana:																						
Corona	65	....	31	.18	61	13	49	3.7	233	42	2.3	41	347	8.7	.0	17.1	3.6	13.8	33.0	11.7	.6	11.5
Mentone (1906)	....	55	16	.15	26	5.7	18	.0	102	14	....	7.3	158	11.7	.1	19.0	4.2	13.1	36.4	10.2	....	5.3
Mentone (1908)	8	....	25	.16	25	6.3	18	.0	116	20	.75	3.8	145	16.0	.1	16.0	4.0	11.6	36.6	12.8	.5	2.4
Santa Maria, Santa Maria	....	1,302	24	.14	302	133	200	.0	254	1,253	....	105	2,412	1.1	.0	14.1	6.2	9.4	5.8	58.5	....	4.9

Santa Ynez:																						
Santa Barbara (1906)	....	64	24	.11	101	45	58	2.6	265	287	....	25	714	3.6	.0	15.0	6.7	8.6	19.9	42.6	....	3.6
Santa Barbara (1908) *a*	32	....	22	.15	109	49	66	2.4	258	373	.46	14	785	2.9	.0	14.3	6.4	8.6	16.9	49.0	.1	1.8
Santa Ysabel, San Pasqual	14	....	44	.17	29	13	42	1.3	160	30	.84	38	260	16.0	.1	10.5	4.7	15.3	28.4	10.9	.3	13.8
Stanislaus, Knights Ferry	....	140	14	.20	11	5.0	11	.0	46	11	....	5.6	83	17.3	.3	13.6	6.2	13.6	28.5	13.6	....	6.9
Tuolumne, La Grange	....	68	11	.19	10	4.3	12	.0	41	12	....	6.6	74	14.4	.2	13.1	5.6	15.8	26.3	15.8	....	8.8
Ventura, Ventura	3	....	23	.14	106	30	47	3.9	226	251	.72	20	605	3.9	.0	17.9	5.1	7.9	19.4	42.4	.0	3.4
Yuba, Smartsville	191	....	14	.21	13	4.3	10	.0	48	13	....	5.5	84	16.7	.2	15.5	5.1	11.9	28.6	15.5	....	6.5

a Part of year only.

Summary of results of analyses of surface waters of California from drainage areas receiving 15 inches or more annual rainfall.

Source of sample.	Average mineral content (parts per million).													Chemical composition of mineral matter (per cent of anhydrous residue).								
	Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).
Alameda Creek, Niles	....	163	19	0.13	66	28	49	4.4	262	91	.....	34	421	4.5	0.0	15.7	6.6	11.7	31.8	21.6	....	8.1
American, Fairoaks	....	146	17	.39	11	4.4	11	.0	41	12	.....	6.3	83	20.7	.5	13.4	5.3	13.4	24.4	14.6	....	7.7
Cache Creek, Yolo	64	....	16	.19	30	23	33	2.1	193	28	1.3	31	250	6.2	.1	11.6	8.9	12.7	37.6	10.7	0.5	11.7
Feather, Oroville	....	41	16	.17	13	5.7	14	.0	64	11	.....	5.8	99	16.4	.2	13.3	5.8	14.3	32.8	11.3	....	5.9
Kern, Bakersfield	....	163	18	.15	18	4.2	22	.0	71	21	.....	9.1	127	14.1	.1	14.1	3.3	17.3	27.5	16.5	....	7.1
Merced, Merced Falls	....	52	14	.10	9.1	3.8	9.3	.0	35	11	.....	5.6	65	20.0	.2	13.0	5.4	13.3	24.3	15.8	....	8.0
Mokelumne, Clements	....	84	14	.18	12	3.8	13	.0	42	12	.....	7.3	75	16.8	.2	14.4	4.6	15.6	25.2	14.4	....	8.8
Russian, Ukiah	9	....	19	.19	23	12	16	.0	125	17	1.2	7.4	145	12.0	.1	14.6	7.6	10.1	39.4	10.8	.8	4.6
Sacramento, above Sacramento (1906)	....	60	19	.29	15	7.0	15	.0	76	13	.....	8.7	124	16.6	.2	13.0	6.1	13.0	32.2	11.3	....	7.6
Sacramento, above Sacramento (1908)	66	102	28	.43	13	6.7	13	.0	74	17	.64	5.4	113	23.2	.4	10.8	5.6	10.8	30.0	14.1	.5	4.6
San Joaquin:																						
Lathrop (1906)	....	60	16	.23	18	8.0	27	.0	66	26	.....	30	161	10.1	.1	11.4	5.1	17.1	20.9	16.4	....	18.9
Lathrop (1908)	34	52	19	.30	20	10	36	.0	74	39	1.0	47	205	9.1	.1	9.6	4.8	17.3	17.3	18.7	.5	22.6
San Gabriel:																						
Azusa	23	....	21	.16	45	12	18	3.3	176	32	1.1	4.3	208	9.4	.1	20.1	5.4	8.0	40.3	14.3	.5	1.9
Rivera	5	....	23	.11	55	12	22	2.2	211	33	1.9	8.4	246	8.8	.1	21.0	4.6	8.4	40.6	12.6	.7	3.2
San Lorenzo, Big Trees	....	84	23	.18	44	10	31	.0	147	43	.....	29	255	9.1	.1	17.4	3.9	12.5	28.5	17.0	....	11.5
Santa Ana:																						
Corona	65	....	31	.18	61	13	49	3.7	233	42	2.3	41	347	8.7	.0	17.1	3.6	13.8	33.0	11.7	.6	11.5
Mentone (1906)	....	55	16	.15	26	5.7	18	.0	102	14	.....	7.3	158	11.7	.1	19.0	4.2	13.1	36.4	10.2	....	5.3
Mentone (1908)	8	....	25	.16	25	6.3	18	.0	116	20	.75	3.8	145	16.0	.1	16.0	4.0	11.6	36.6	12.8	.5	2.4
Stanislaus, Knights Ferry	....	140	14	.20	11	5.0	11	.0	46	11	.....	5.6	83	17.3	.3	13.6	6.2	13.6	28.5	13.6	....	6.9
Tuolumne, La Grange	....	68	11	.19	10	4.3	12	.0	41	12	.....	6.6	74	14.4	.2	13.1	5.6	15.8	26.3	15.8	....	8.8
Yuba, Smartsville	191	....	14	.21	13	4.3	10	.0	48	13	.....	5.5	84	16.7	.2	15.5	5.1	11.9	28.6	15.5	....	6.5
Mean	....	....	19	.20	26	9.0	21	.75	105	25	.....	15	165	13.4	.2	14.7	5.3	13.1	30.7	14.3	....	8.3

Summary of results of analyses of surface waters of California from drainage areas receiving less than 15 inches annual rainfall.

Source of sample.	Average mineral content (parts per million).												Chemical composition of mineral matter (per cent of anhydrous residue).								
	Turbidity.	Suspended matter.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radical (NO_3).	Chlorine (Cl).	Total solids.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).
Arroyo Seco, Soledad	....	33	26	0.20	51	14	29	0.0	170	72	....	13	284	9.0	0.1	17.6	4.9	10.0	29.0	24.9	....	4.5
Cottonwood Creek, Barrett dam	19	......	44	.18	51	20	69	3.7	246	52	1.0	62	413	10.4	.0	12.0	4.7	16.3	29.5	12.3	.2	14.6
Estrella, San Miguel	161	......	35	.19	79	53	224	9.6	273	385	.88	192	1,131	3.1	.0	7.1	4.8	20.1	12.9	34.6	.1	17.3
Malibu Creek, Calabasas	....	61	36	.11	101	50	73	2.2	288	285	....	42	751	4.9	.0	13.8	6.8	10.0	19.7	39.0	....	5.8
Nacimiento, San Miguel	36	......	25	.19	42	22	24	1.7	171	72	4.4	14	286	8.6	.1	14.5	7.6	8.3	29.8	24.8	1.5	4.8
Owens:																						
Charlies Butte	16	......	43	.22	31	12	69	.0	211	54	1.7	33	339	12.4	.1	8.9	3.4	19.8	29.9	15.5	.5	9.5
Round Valley	7	......	40	.20	15	4.3	40	.0	111	30	1.2	17	189	19.7	.1	7.4	2.1	19.7	27.2	14.8	.6	8.4
Salinas, Paso Robles	16	......	31	.15	60	28	59	5.6	272	97	.74	39	448	6.8	.0	13.2	6.2	13.0	30.7	21.3	.2	8.6
San Antonio, Bradley	10	......	37	.16	63	21	38	2.5	224	94	1.0	24	387	9.5	.0	16.1	5.4	9.7	28.9	24.0	.3	6.1
San Benito, Hollister	....	1,444	24	.09	58	57	110	6.2	335	204	....	95	732	3.3	.0	8.1	8.0	15.3	23.8	28.3	....	13.2
San Luis Rey, Pala	....	142	31	.12	42	13	44	.0	163	53	....	39	321	10.3	.0	13.9	4.3	14.6	26.5	17.5	....	12.9
Santa Maria, Santa Maria	....	1,302	24	.14	302	133	200	.0	254	1,253	....	105	2,412	1.1	.0	14.1	6.2	9.4	5.8	58.5	....	4.9
Santa Ynez:																						
Santa Barbara (1906)	....	64	24	.11	101	45	58	2.6	265	287	....	25	714	3.6	.0	15.0	6.7	8.6	19.9	42.6	....	3.6
Santa Barbara (1908)	32	......	22	.15	109	49	66	2.4	258	373	.46	14	785	2.9	.0	14.3	6.4	8.6	16.9	49.0	.1	1.8
Santa Ysabel, San Pasqual	14	......	44	.17	29	13	42	1.3	160	30	.84	38	260	16.0	.1	10.5	4.7	15.3	28.4	10.9	.3	13.8
Ventura, Ventura	3	......	23	.14	106	30	47	3.9	226	251	.72	20	605	3.9	.0	17.9	5.1	7.9	19.4	42.4	.0	3.4
Mean	....	......	32	.15	78	35	75	3.1	227	225	....	48	627	7.0	.1	12.8	5.5	12.9	23.7	28.8	....	8.3

INDEX.

Page.

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