REPORT OF J. B. LIPPINCOTT

TO THE

CHAMBER OF COMMERCE

AUGUST 21, 1913

August 21st, 1913.

San Diego Chamber of Commerce,

San Diego, California.

Gentlemen:

I have been requested by your special Water Committee to review the items provided for in the proposed bond issue, to be submitted to the City of San Diego, to provide additional funds for extensions and betterments for your municipal water system.

I have endeavored to view this situation in as broad a light as was possible with the limited funds that were available. I have visited all the points involved in the bond issue, have been over practically the entire drainage basin of Cottonwood Creek, and have spent several days along the course of the San Diego River, from the diversion point of the San Diego Flume to the sea. Mr. H. A. Whitney, Assistant Superintendent and Hydraulic Engineer for your Water Department, has given me a great deal of his personal time and attention, has placed the files of his office at my disposal, accompanied me to all points of interest with the automobiles of the Water Department and has in every way assisted me in inspecting the works and checking up his estimates. I wish to take this occasion to state my appreciation of his courtesies and of the grasp that he has obtained of your local water works problems in the short time that he has been with your department.

In making this report to a body of conservative men, I am assuming that you desire me to present the cold facts, without exaggeration and without concealing unpleasant features, in order that you may intelligently and wisely judge and arrange for the future. The following report is made in compliance with your instructions;

THE GROWTH OF THE CITY OF SAN DIEGO.

The growth of the City of San Diego, particularly during the past two years, has been one of the marvels of the Southwest. Starting with a village of 2,300 people in the year 1870, it passed through the following decade with slight development, the census of 1880 showing a population of 2,637. The advent of the Santa Fe Railroad made itself felt during the subsequent census period, for in 1890 we find 16,159 people and 17,700 in the year 1900. By 1910 the steady growth of the city had set in and the federal census of that year credited your city with 39,578 souls. On August 1, 1913, your city Directory estimated the population at 84,533. This may be somewhat excessive.

In 1910, when the census was taken, making certain minor adjustments due to the months involved, there were 8,164 connections with the pipes of your Water Department, or at the rate of 4,85 persons per tap. It is customary among water works engineers to estimate population from the number of taps or connections and the figure frequently used is 5 persons to the connection. On July 31, 1913, your Water Department had 13,770 taps in your city, which, under the ratio of 5 to 1, would indicate 68,850 persons, but it is argued that there is an unusually large number of persons in San Diego living in hotels and apartment houses and that this ratio should be higher. In my judgment it is not apt to exceed 5.5 persons to the tap, which would indicate a population at present of 75,735 souls.

It is difficult to make forecasts that are sufficiently high for cities of the Southweste In the past 20 years I have found that estimates that I have made, as a rule have been too low, but putting in a diagram the past growth of your city, it would appear that you should have 105,000 by the year 1915, 150,000 by the year 1920, and 200,000 by the year 1925. These estimates I realize are materially lower than those made by your own statistician, who estimates the population by 1925 as 590,000.

This forecast of the population of your city is important in determining what the prospective quantities of water will be in the near future. Manifestly it is essential that a rapidly growing metropolis should have a water supply that is secure and ample. While it is not wise to overestimate prospective population, it is not safe on the other hand to underestimate it in providing for your future necessities in the way of water. You have every reason to look into the future with reassurance. The building of the new transcontinental railroad, the opening of the canal, the improvement of the harbor and the great trend of population towards California that is not setting in throughout the entire United States, all justify encouragement over future development.

WATER CONSUMPTION.

The following statistics shows the growth in water consumption in your city during the past few years, and a forecast into the future:

1907		3,300,000	gals.	per	day
1908		3,800,000	"	"	"
1909		3,900,000	"	"	"
1910		4,500,000	"	"	"
1911		5,000,000	"	"	"
1912		5,700,000	"	"	"
1913		7,000,000	"	"	"
1915	(estimated)	10,500,000	"	"	"
1920	"	15,000,000	"	"	"
1925	"	20,000,000	"	"	"

To these figures should be added the water served from your mains for Coronado and Encanto, which in 1912, was 1,100,000 gallons per day.

In 1904, when I made a report to a special committee of San Diego Improvement clubs, there was approximately two million gallons daily being extracted from the Mission Valley on the lower San Diego River, and some additional water was being purchased from the San Diego Flume.

Your City is now fully metered and waste of water has thus been stopped. Your present daily consumption per capita is approximately 93 gallons, which indicates as careful a use as any city in the state with which I am familiar. You cannot expect any further substantial reduction in this per capita consumption, which will be consistent with the beautification and healthfulness of your city.

It would, therefore, appear that within the next 12 years you will have to look forward to a consumption three times as great as that at present, if you are to have a population of 200,000 and certainly it is none too soon to begin looking this squarely in the face.

PRESENT WATER SYSTEM.

After the discontinuance of the pumping of water from wells in the mission valley, in May 1905, you at first purchased water from the

Southern California Mountain Water Company on a ten year contract, at the rate of 4 cents per thousand gallons, with a guaranteed supply of 7,760,000 gallons per day. A year ago the city purchased the plant of this corporation for $4,000,000.00.

The principal source of water from this new system is from Cottonwood Creek. The elevation of this basin above the Delzura Aqueduct ranges from 1,500 to 5,000 feet of mountainous and brush coveree country, with frequent valleys and broad canyons. There are 276 square miles of drainage above this point of diversion, 135 square miles of which is controlled by the Morena Dam and 141 square miles of which is at present unregulated, but which is subject to diversion by the Delzura Aqueduct, up to a flow of 39 million gallons per day.

The Morena Dam is the principal structure in the Mountain Water System. It is built high enough to impound water to a depth of 150 feet. The capacity of the reservoir is very large and equals 15,226,975,000 gallons, or 46,608 acre-feet. It storage capacity is in excess of any flood discharge that probably was available at that point during the last 20 years. It is of the rock-fill type. There is a leak through it which amounts to about 30,000 gallons per day, when the reservoir is filled to 85 feet on the gage.

At a lower point on this stream and commanding 141 square miles of mountain drainage area not subject to regulation at the Morena Dam, is the Barrett dam site. The Dam at this point has not been built, but a structure 175 feet high would have a capacity of impounding 15,630,000,000 gallons, or 47,843 acre feet, or practically the same as the Morena Dam. This dam site is situated about a mile down stream from the diversion point of the Dulzura Aqueduct and at an elevation of approximately 80 feet lower than the grade of this aqueduct, so that it would be necessary to impound a depth of 80 feet before diversions could occur thereby to your city. The city owns the land that would be flooded by this reservoir.

The Dulzura Aqueduct has an elevation at its intake of 1,506 feet above the sea and the elevation at its outlet is 1,436 feet. This aqueduct is 13.38 miles in length and is composed of lined canal, flumes and tunnels. It discharges into Dulzura Creek, which flows in a northwesterly direction and enters the Lower Otay Reservoir.

The Lower Otay Reservoir has a drainage area, exclusive of the Upper Otay Reservoir, of 80 square miles, ranging in elevation from 400 to 3,000 feet above the sea. The height of the dam is 130 feet and the storage capacity is 35,793 acre feet, or 11,679,413,652 gallons. This capacity is in excess of the annual run-off of the local drainage basin, Mr. Whitney estimated the available supply from this basin for a term of good years as one million gallons per day, net. In dry years there is no run-off whatever, according to Mr. James D. Schuyler. In the four years prior to September, 1899, not over 5,000 acre feet in the aggregate was discharged into this reservoir, or 1.1 million gallons per day, without deduction for evaporation losses. The greatest flow according to this authority, was in the season 1906-7, when the reservoir was two thirds full. The outlet is 48 feet above the base of the dam, which has a capacity of 1,988 acre feet, or 650 million gallons, at that level.

The elevation of the Chollas Reservoir is 432 feet at the flow line and 390 feet at the outlet. Its capacity is 90 million gallons. It is a portion of the domestic distributing system, in that it may maintain a few days' supply near your city limits. Its elevation is unfortunately high.

The upper Otay Dam has a height of 77.2 feet, a capacity of 1,091,000,000 gallons, or 3,147 acre feet, and a drainage area of 20 square miles. The elevation of the outlet of the reservoir is 521 feet It is difficult to understand why the Upper Otay Reservoir was built. It regulates the run-off of a small area that otherwise would be tributary to the Lower Otay Reservoir.

From this Lower Otay Reservoir the water is conducted through a wooden stave pipe main, which ranges in size from 40 inches to 24 inches, in internal diameter, and which has a length of 19.6 miles. The carrying capacity of this pipe line diminished as it approaches the city, apparently the idea having been to distribute this water en-route. It should be remembered that this system was not primarily built as a portion of the domestic water works of the City of San Diego. The condition of this main is said to be fair. The steel bands are rusting and may not have an additional length of life of over 10 or 15 years. The wooden staves, of which the pipe is built, however, have the appearance of being sound. The water for Coronado is taken out of this main at the end of the 40 inch pipe.

The Peublo of San Diego originally owned all of the lands in the Mission Valley, south of the city limits, and I am informed by representatives of some of the abstract companies that the city has reserved the right to pump water from this portion of the Mission Valley. In addition, the city owns some 100 acres of water bearing land below the mouth of Murphy Canyon in the Mission Valley. The Total area of these Mission Valley lands, below the box canyon, and the 100 foot contour, and as far west as the County Road, is 5.1 square miles. Formerly the city pumped approximately 2 million gallons daily from over 100 shallow wells in these sands.

This, in brief, is a short synopsis of the sources from which the city has obtained its water supply.

AVAILABLE SUPPLY.

A study is made below of the probable amount of water that will be available to your city from the plant purchased from the Southern California Mountain Water Company.

As the hydrographic records of the available supply from this region have been kept by the Geological Survey for but 7 years, it is necessary to make an estimate by comparison with other neighboring basins where longer records exist. Fortunately there is a very good opportunity to do this with accuracy. The Cuyamaca Reservoir is situated hear the head waters of the San Diego River, adjacent to the headwaters of Cottonwood Creek. This reservoir is at an elevation of 4,600 feet and the drainage basin culminates in the Cuyamaca Peak, whose elevation is 6,515 feet. The basin contains but 12 square miles. The record of catchment into this reservoir begins in 1893 and extends to date. It is conspicuous for the high rates of run-off, or flood discharge per square mile. The character of the storms that have fed this reservoir resemble those that have contributed to the headwaters of Cottonwood Creek.

The drainage basin of the Sweetwater Reservoir borders that of Cottonwood Creek on the north. This basin contains 186 square miles and ranges in elevation from 125 feet to 6,515 feet. The record of catchment into this reservoir extends back to the year 1887 and is continuous to date.

While the Cuyamaca Reservoir is situated opposite the headwaters of Cottonwood Creek, the Sweetwater Reservoir may be broadly stated to be opposite the lower portions of Cottonwood Creek and by averaging their annual percentages of run off each year with the mean for their entire period of observation, gives a very fair indication of the fluctuation of the flow during this long period in the basin of Cottonwood Creek. By studying these two older records it is impressive to note that particularly in the years of low rainfall the high elevation reservoir at Cuyamaca makes a very much better showing than that at Sweetwater in the lower elevation. The reason is plain.

In years of light rainfall, the long stretches of broad sandy river valleys, over which the Sweetwater must flow before reaching the reservoir, absorb the small quantities of water but on years of heavy rainfall, when the whole country is well saturated, the discharge into the Sweetwater is relatively much greater. A diagram is attached to this report which clearly indicates this fact that which shows not only the wide range in the fluctuations of these streams, but also the peculiar grouping of wet and dry years that has occurred.

Table No. 1 shows the discharge in percentages for each seasonal year, at both the Cuyamaca and the Sweetwater Reservoirs. These percentages are determined by comparing the year in question with the average run-off for the period of observation at each point. Beginning with the year 1903-4 these percentages at the Cuyamaca and the Sweetwater are averaged to determine the mean for the two and this mean is used as an index to find what the probable percentage would have been for each one of these seasons for the Cottonwood Creek above the Barrett dam site. Beginning with the season of 1905-6, the U. S. Geological Survey started measuring the flow of Cottonwood Creek at the Barrett dam site and this record has been maintained to date, the records for the season 1911-12 being the last ones available. There are, therefore, records of both the Cuyamaca and the Sweetwater extending back over a period of 20 years and a record of the Cottonwood Creek, extending back over the past seven years. By means of the percentages above referred to, in Table 1, it is found that the seven years of record at the Barrett dam site has been above the average in stream flow, or 155½ per cent of the mean.

Table No. 1 - Discharge in per cent per seasonal year.

Season	Cuyamaca 12 sq. mi.	Sweetwater 186 sq. mi.	Mean
1887-8		59	
8-9		212	
9-90			
90-1		180	
1-2		82	
2-3		136	
3-4	60	11	35
4-5	266	615	440
5-6	51	11	31
6-7	99	58	78
7-8	20	0	10
8-9	11	2	7
9-1900	6	0	3
1900-1	72	7	39
1-2	55	0	28
2-3	59	0	29
3-4	12	0	6
4-5	160	12	86
5-6	301	293	297
6-7	218	252	235
7-8	75	44	60
8-9	169	141	155
9-10	121	73	97
10-11	65	28	46
11-12	83	38	60
12-13	100	9	55
Mean	4,250 acre ft. 1,385 m.g.	11,927 acre ft. 3,893 m.g.	

The diagram of stream flow at the Sweetwater, Cuyamaca and Barrett dam sites graphically illustrates the fact that the seven years of observation at Barrett Dam are above normal and that there is not only the possibility, but strong probability of much dryer cycles of years occurring than those for which we have a record on Cottonwood Creek.

A rainfall diagram is also attached to this report showing the fluctuation in rainfall in San Diego County for the last 63 years. This illustrates the same characteristics.

Table No. 2 shows the measured run-off at the Barrett dam site, as gaged for the last 7 years by the U. S. Geological Survey. It indicates that the discharge for the past 7 years has averaged 23,873 acre feet, or 7,773 million gallons yearly. This period being 135.5 per cent of a mean year the deduction is made that during a 100 per cent. year the discharge would have been 17,618 acre feet, or 5,738 million gallons. This table shows all the water passing the Barrett dam site, including the Morena water and that diverted through the Dulzura Aqueduct.

Table No. 2-Total discharge of Cottonwood Creek past the Barrett Dam Site:

Year	Actual Measurements. Million Gals.	Actual Measurements. Acre-feet.	Computed Quantities Acre Feet.	Per Cent. Year
1905-6 a	18,100	55,700	52,300	297
1906-7	13,600	41,700	41,400	235
1907-8	3,350	10,300	10,600	60
1908-9	10,020	30,800	27,350	155
1909-10	4,720	14,500	17,100	97
1910-11	1,670	5,110	8,110	46
1911-12	2,930	9,000	10,600	60
Average	7,770	23,873	23,923	135.5

a - Year 1905-6 from Jan.1, 1906 to Sept. 30, 1906. All other years from Oct. 1 to Sept. 30th.

Computed quantities ARE based on percentages shown in Table #1 and show close relation to quantities actually measured at Barrett as given in column 3 of Table No. 2. Average or 100 per cent. year is computed as 17,618 acre feet, or 5,738,000,000 gals. for total flow at Barrett.

From table No. 1 it is shown that for the three minimum years, 1897-8 to 1899-1900 inclusive, the entire basin above the Barrett dam site yielded an average of but one million gallons per day, or about one-eighth of the present consumption of your city. The case, however, is not so extreme as this would indicate, because there would have been certain holdover water. No allowance, however, has been made for evaporation losses or seepage in this statement. The 3 years from 1901-2 to 1903-4 inclusive would have yielded a total or gross amount of 3.3 million gallons per day, or about 40 per cent. of your present consumption, no allowance being made for holdover water or for evaporation losses.

Mr. H. A. Whitney, the engineer of your water department, has made a study in detail of the available water supply, based on these gagings during this 7 year period from 1906 to 1912 inclusive, allowance for evaporation and seepage losses and based on the system as it exists today, taking the Morena Dam as filled and the Dulzura Conduit delivering flood waters up to its capacity of 60 second feet, or 39 million gallons daily. He concludes that there is available the following amounts.

Net amount from Morena	1,659,685,000 gals
Diversions through Dulzura conduit .	1,500,000,000 "
Net available from the Otay	377,534,000 "
TOTAL	3,537,219,000 "

This is equivalent to a continuous supply of 9.7 million gallons per day. The demands on this system in 1913 are estimated by Mr. Whitney to be as follows:

City of San Diego	7,000,000 gals per day
Coronado and Encanto	1,100,000 " " "
Total	8,100,000 " " "

Surplus above present demands - 1,600,000 gals per day.

It would be impossible to prevent the very large evaporation losses that occur from the Morena and Lower Otay Reservoirs, but it would be possible to make a substantial saving in the seepage losses which occur mostly in transmission from the Morena Reservoir to the Dulzura Aqueduct, which amounted to 1.4 million gallons per day in 1913 and to also pump back the leakage from the Lower Otay dam, which amount to .3 of a million gallons per day. These two economies, if added to the above mentioned surplus, would give a surplus above the present requirements of your city of 3.3 million gallons per day. I have reviewed these computations of Mr. Whitney's and have checked them. It must, however, always be remembered that this period on which these computations are based, covers a group of years that represent 135.5 per cent. of the mean flow and that they do not cover groups of dry years.

There are so many complications that enter into a study of what the available water supply would have been for a term of 20 years, under conditions as they exist, that it is unsatisfactory. If, however, it is assumed that the Barrett Dam is built to a height of 175 feet, as has been proposed, then all of the water that has been discharged through the entire period of 20 years from the 276 square miles of Cottonwood Creek, and which was available for diversion to your city through the Dulzura Aqueduct, could have been regulated and there would have been no wastage by overflow.

What is known as a Mass Curve has been prepared and is shown in the diagram attached to this report. In this 50 per cent. of the flow of Cottonwood Creek is assumed to have been caught by the Morena Dam and 50 per cent. by the Barrett Dam. The height of water in each reservoir each year is computed and the evaporation losses have been estimated from the areas of the exposed surfaces. The evaporation loss is taken as 56 inches in depth each year, as determined by observation at numerous points in San Diego County. The amount of water available in each reservoir at the end of each season is then known. It is assumed that the diversion that is made for use by your city is the present requirement of 8 million gallons per day; it is assumed that at the beginning of this 20-year period 10,000 acre feet of water was in storage at the Morena Reservoir and 15,000 acre feet in the Barrett Reservoir. The conclusion of this study is that there would have been but 62,000 gallons per day available from March to October, 1904, which is but one per cent. of your requirements with both dams built. To repeat, it is assumed that all of the water flowing down Cottonwood Creek has been conserved; that there have been no losses in transmission to the city seepage and that your consumption is the present requirements on your water system, yet that the supply would have failed.

From these figures it is manifest that with the Morena Reservoir alone, and with present seepage losses, the situation would have been much more serious and I feel justified in stating that with your present system, there is not only the possibility, but the probability of a radical shortage in your water supply sometime within the next 5 or 10 years.

It is, therefore, most important that your city stop unnecessary losses and undertake at once to meet this situation by drawing on some new source of supply, and particularly sources of such character as will be available during groups of dry years. It is difficult to comprehend the serious losses due to evaporation from reservoirs in which water is impounded for terms of years. On the other hand, underground water supplies are not subject to such serious evaporation losses. When a water level stands 8 feet or more beneath the surface, evaporation through the surface soils ceases, except that which is transpired through the leaves of trees and deep rooted plants. Consequently gravel beds that have been charged through years of floods hold over indefinitely, unless they are drawn upon artifically. If such underground reservoirs could be held in reserve to carry by groups of two or three dry years, they would supplement surface storage reservoirs in a desirable way. While the condition is unsafe with the present water consumption, it will be aggravated with the increased growth of your city.

The conclusion to be drawn from the above study is that it is most important for you to conserve every particle of water possible that you have from your present system and that you should extend your supply to new sources.

MORENA CONDUIT

The water from the Morena Reservoir is discharged in a narrow and precipitous mountain gorge, which apparently has bed rock near the surface and in which the water flows for a distance of about one and one half miles. It then emerges into a broader canyon, which increases in width as it proceeds toward the Barrett dam site. This canyon is filled with sand and gravel and a dense growth of cottonwoods and willows. At the lower end of the valley there are swamps and moist lands with tules. In the first mile and a half of the gorge the seepage losses should be light and the construction expenses of a conduit, because of its precipitous and rocky nature, would be very high and it is not advisable that any construction should be done therein, for the present. In the lower six and a half miles, between the mouth of this gorge and the intake of the Dulzura Aqueduct, the seepage losses undoubtedly are heavy and from a field inspection I have no hesitancy in accepting the accuracy of the measurements that have been present by your water department indicating them. The Morena Reservoir waters were run through this gorge and canyon in as large a body as the Dulzura Aqueduct could carry to the Lower Otay Reservoir, between March 27th and May 6, 1913, for a period of 39 days. A time was selected when humid conditions existed in the atmosphere and when the bed of the canyon was moist with rain. Precipitation occured at Barrett on April 2d and 3d, amounting to one-tenth of an inch; on April 14th and 15th, amounting to .14 of an inch and on April 18th and 19th .11 of an inch. In other words, the engineers selected a time when these seepage losses would be as near the minimum as possible for the passing of this water through the canyon. There is an accurate weir at the outlet of the Morena Dam, on which measurements of the volumes of discharge were kept. A weir, known as No. 1, at the lower end of the Dulzura Aqueduct, was also observed upon, and a further record kept at the point where the water entered the

Lower Otay Reservoir, at what is known as Weir No. 3. A total volume of 1,183,359,427 gallons were liberated from the Morena Reservoir and of this amount 658,192,527 gallons reached the lower end of the aqueduct, indicating a loss of 44.4 per cent. in transit. The loss in the aqueduct proper is not known, but probably varied from 5 to 10 per cent., so that it might be stated that 40 per cent. of the Morena Water was lost in passing through the canyon of Cottonwood Creek, before it reached the aqueduct. An additional loss of 4.4 per cent. occurred between the end of the aqueduct and the Otay Reservoir, showing a total loss in transit of 48.8 per cent. of practically half of the stored water. While you were able to stand this water loss during the past season, it has seriously depleted your reserve supply and in years of lower rainfall, the situation would have been worse. At the prices which this water is sold in your city, this loss would represent $57,778.00 and at the price which this water cost your Water Department, it would have been $133,000.00 for this one season, almost as much as the estimated cost of a conduit to obviate it.

In order to prevent these seepage losses in the canyon of Cottonwood Creek, it is proposed to construct a concrete conduit, connecting the mouth of the gorge with the head of the Dulzura Aqueduct. This conduit should have a concrete cover to prevent the washing of soil and debris from the side-hills into it. It should be given a capacity of 60 second feet, or as great as that of the Dulzura Aqueduct. With the heavy grade in the canyon, this would call for a ditch that would be only three feet wide and three feet deep in the clear. In the estimate which I have prepared, I have considered the sides and bottom of the ditch to be at least 6 inches thick and with a cover 4 inches thick. No surveys have been made of this line and therefore the estimate is crude. The distances and grades were taken from the U. S. Geological Survey topographic sheets. The cost of this work, as estimated by Mr. Whitney, is $180,000.00, and a small diversion dam $5,000.00, and it is believed that this estimate is adequate.

DULZURA AQUEDUCT

The Dulzura Aqueduct consists of 56,957 feet of lined canal, 4,490 feet of flume, and 9,220 feet of unlined tunnel, or a total of 70,667 feet, or 13.38 miles. The flume is of wood and therefore is perishable. The policy should be adopted of gradually eliminating this wooden flume from the aqueduct. The tunnels that were inspected were unlined and sound but some of them have caved in in places and require concrete lining. Portions of the lined canal do not have substantial sides and in one case observed it has no bottom where built in the valley soil. The conduit at its upper end is partially filled with sand from the creek. More sand boxes are necessary to keep this from obstructing its carrying capacity. The ditch is not covered and in many places along the mountain side the winter storms wash surface soils into it. The aqueduct should be gradually improved, the sides being strengthened where necessary and concrete cover placed where the washings enter the ditch and a concrete bottom put in where the seepage losses are apt to occur. $30,000.00 should be provided in this bond issue for immediate work on this aqueduct.

Water is being sold to your consumers at less than half its actual cost to your city. A statement has been prepared by your Water Department for the State Railroad Commission showing Revenues and Disbursements for the period February to May, 1913, inclusive, which shows an actual cost of 23 cents per thousand gallons.

Under the figures of cost are included interest on bonds and other debts and an amount for the redemption of bonds of $37,941.00, which represents 4.9 cents per thousand gallons, and which possibly should not be included in this estimate of cost, unless considered as covering depreciation. At any rate, it is apparent that the water is costing the city double the price at which it is sold. The loss is made up from the general tax levy on your city, which properly imposes a portion of the burden of maintaining this system on vacant lots. Nevertheless, it is perfectly evident that the rates should be increased sufficiently to give an adequate fund for ordinary betterments and improvements, such as the gradual repair of the Dulzura Aqueduct or the enlargement of mains in your city. When you have to pump water from Mission Valley, this will add to your cost of water and this extra expense should be taken care of. Under your present rates it will be necessary to be doing work of this kind by continuous bond issues, which, if carried on indefinitely, will lead to financial trouble.

In the Fourth Annual Report of your Water Department the rates are given of 19 California Cities and there are but two other places in the state where water is sold at as low a figure as in San Diego, and no place where it is so difficult to obtain. San Francisco charges 30 cents, Berkeley 35 cents and Santa Barbara 20 cents. It is fair to require vacant property which you stand ready to serve on demand at any time, to contribute towards the support and maintenance of the system, but your rate should be increased so that you can take care of the ordinary current repairs to your plant from your water revenue fund. An increase in the rate of 5 cents per thousand gallons would yield an increased revenue of $127,000.00 per year, which should be used for this purpose. At present your water works engineer does not have any funds that would permit him to make ordinary surveys or hydragraphic investigations, which are most essential, to say nothing about reasonable demands for necessary improvements.

DULZURA CREEK

The water from the Dulzura Aqueduct is discharged into Dulzura Creek and it runs in this natural channel for a distance of about 15 miles to the Lower Otay Reservoir. This stream meanders through open pastures barnyards and along country roads. The situation is unsanitary and wasteful of water.

During the test run described above there was some natural winter water in this creek, so that the losses were not serious at that time, but it is practically prohibitive for you to run small quantities of water through your aqueduct and this creek during summer months. If this conduit were in good shape it would be possible to pump water from the sand and gravel beds in the Cottonwood Wash. In the near future you should build a closed concrete conduit down Dulzura Creek.

The obtaining of a water supply in these semi-arid regions is a serious matter and the City of Los Angeles has expended over 25 millions of dollars in bringing the waters of Owens River through steel and concrete channels a distance of 250 miles to their city. San Diego will have to face a problem that is proportionately as large before they adequately solve their water problems.

LOWER OTAY DAM

The Lower Otay Reservoir has been described above. It is the head of the pipe main that enters your city. It is a rock-filled dam and there is a leak either through the dam or through the abutments of 300,000 galmns per day. At the cost value of your water this would represent a loss of $69.00 per day, besides the wasting of a valuable commodity. This water should be saved by being pumped back into your reservoir. The cost would be small and probably could be provided for in some manner from current funds.

MAIN PIPE LINE

The main pipe line to the City of San Diego originates at the Lower Otay Reservoir and terminates at the University Heights Reservoir. It consists of the following sizes:

13,698	feet	of	40	inch
29,483	"	"	36	"
2,843	"	"	34	"
3,593	"	"	32	"
30,905	"	"	30	"
23,000	"	"	24	"

Total, 103,522 feet, or 19.6 miles.

The elevation of the outlet of the Otay Reservoir is 400 feet and of the water surface at the University Heights Reservoir 396 feet. This results in a very flat gradient. This University Reservoir was not built originally as a portion of the Mountain Water System. The pipe line also discharges into the Chollas Reservoir, the bottom elevation of which is said to be 390 feet and the maximum water surface of which is 432 feet. The elevation of the water surface in the Otay Reservoir is normally above its outlet and this additional elevation of the water in the reservoir improves the hydraulic gradient through the pipe line, as the level in the reservoir falls, however, this gradient becomes flat and the carrying capacity of the pipe is reduced. This is quite an unsatisfactory condition and is one of the principal reasons why the new pipe line is proposed from the end of the section of the 36 inch wooden stave pipe.

In order to help out the carrying capacity of this pipe, what is known as a booster pump of the centrifugal type has been installed near the Chollas Reservoir site at the upper end of the 24 inch section. This pump forces an additional head on the 24 inch pipe of 89.5 feet and by this method succeeds in deliverying through it 10 million gallons per day, to meet the present demands of your city. The maximum daily consumption in July, 1913, was 10½ million gallons.

Assuming that the water level in the Otay Reservoir has been reduced to the outlet, the pipe line will deliver, at the end of the 36 inch section, 8.2 million gallons per day, but with the grade on which the pipe is built of .0003, the 30 inch section will only carry 5.18 million gallons a day.

It is proposed to lay an additional pipe from the end of the 36 inch section, at a point near what is called Bonita Station, towards the city, for a length of 35,500 feet. This pipe was originally estimated by Mr. Whitney to be 28 inches in diameter, but after reviewing the figures with him, it was decided to reduce it to a 24 inch diameter, This line will have a fall of approximately 147 feet and a carrying capacity of 9 million gallons per day. It will be under pressure heads up to 450 feet. Heavy steel plates have been estimated upon, to give a long length of life to the pipe and to provide for its deterioration. If this line is built, it will save a large amount of work that is being done by the booster pump at Chollas and will increase the capacity of the main lines from Otay to the City, which are not restricted and are only adequate because of the pumping. No surveys have been made of this line, as Mr. Whitney informs me that funds were not available for this purpose. The line should not cost over $165,000. It is necessary and should be built.

DOMESTIC RESERVOIR

It is proposed to construct a domestic reservoir at the end of this pipe line, about a mile east of the present city limits, with a capacity of 15 million gallons per day. It is desirable to have a safe supply of water in the immediate vicinity of the city, so as to prevent a shortage of water, due to any temporary breakes in the long pipe line and to provide further for any unusual drafts due to fires and particularly for the maximum drafts that occur during certain hours of the day in the hot days of summer.

No surveys have been made in detail of this reservoir site and detailed cost estimates are impossible. From previous experience in building a number of these lines and covered domestic reservoirs, it is found that they may be constructed for about $5,000 per million gallons, or $75,000 for a 15 million gallon reservoir. This is Mr. Whitney's estimate and I believe it to be reasonable. I think this reservoir is necessary and that it should be built.

FILTER PLANT

It has been proposed to install an additional system of filters and to pay for the same under the proposed bond issue. The filters proposed are of the Jewell pressure type. This is as good a filter of this character as can be obtained on the market. The estimated cost is $60,000 for the additional filters.

There is already in existence, as a portion of your water works, a filtering plant of this type. It has not been in use for over 7 months because the quantity of the water coming into the city was in excess of the capacity of the filter.

I have made numerous inquiries among the people of San Diego concerning the water, including prominent hotel men and they inform me that there is no complaint as to its quality. The filtering of this mountain water is largely sentimental. There are so many other essential things to do in connection with your water works system that I think this question of the filtoring of the water should be postponed until some later date, when it can be more easily accomplished.

ADDITIONAL PIPE LINE

It is necessary to connect the new 15 million gallon domestic distributing reservoir with the present city distributing system. This will call for a length of 11,100 feet of 28 inch pipe, to provide for heads up to 225 feet. No. 8 gauge steel plates, approximately 3/16 of an inch in thickness are recommended, in order to obtain a long life for this pipe line. The large size of pipe is desirable to take care of the maximum drafts which may occur on hot days or during fires. I have estimated the cost of this line to be $55,000. This thickness of plate is not required for this pipe with the heads that it has to carry when new, but by using heavy plate, it will greatly lengthen its life.

This pipe line is necessary and should be built.

RIGHTS OF WAY

The estimate carries an item of $15,000 for rights of way for pipe lines and reservoirs. I have no personal knowledge of the value of these rights of way and you are doubtless in a better position to judge of them than I am. It would require considerable investigation on my part to determine these costs, especially in view of the fact that the lines have not been located. The estimate impresses me as being too low and I have increased it to $25,000 in the final summary.

AUXILIARY SYSTEM FROM SAN DIEGO RIVER

I am instructed by your Committee to investigate the possibilities of getting an auxiliary supply of water immediately from wells located along the San Diego River. I am instructed that legal complications possibly may follow any extensive pumping diversions from the Cajon Valley, or from the upper portion of the river bed, but that the city has reserved the right to extract water from the old Pueblo lands in the Mission Valley; consequently in order to provide immediately for an auxiliary supply, it must come from these Mission Valley lands. I am, however, familiar with the other portions of the San Diego River, and have again gone over this ground in order to refresh my recollections of the situation.

The drainage of the San Diego River may be classified as follows: Above the Cuyamaca Reservoir 12 square miles; above the San Diego Flume diversion 104 square miles; above the government gauging station at Lakeside 208 square miles; above the Murray Canyon 431 square miles. Of this entire area 12 square miles at Cuyamaca are subject to flood regulations by storage. The balance of the water passes down over the sands and gravels on its way to the sea. From 1906 to 1912 inclusive, the San Diego River at the government gauging station at Lakeside discharged, exclusive of San Vicente Creek and the San Diego Flume, an average of 27,780 acre feet, or 9,040,000,000 gallons per year. This is equivalent to 24.8 gallons per day for the entire period. Those years, however, were above the normal supply.

Mr. Charles H. Lee, in a report recently submitted to the State Railway Commission, estimates that during a period of twenty years the following average annual quantities of water were discharged from the drainage basin of the San Diego River; Above the Cuyamaca Dam, 4,250 acre feet; above the diverting dam, exclusive of the Cuyamaca, 12,630 acre feet; between the diverting dam and the government gauging station at Lakeside 8,270 acre feet; between the gauging station and the Old Mission dam 6,320 acre feet; between the Old Mission dam and Murray Canyon 879 acre feet. The grand total for the basin is 32,349 acre feet.

It will be noted that the amount of water estimated as entering below the Old Mission dam is equivalent to a continuous flow of 800,000 gallons per day, but it must be remembered that a good deal of the flood waters from the upper part of the basin also passes over these absorbent sands. Of these 32,349 acre feet of estimated runoff there probably is not over one half beneficially used. The waste is lost either in flood discharges, or by evaporation along the moist lands of the river bottom, and by transpiration through the leaves of growing plants.

This general statement is not made as absolute, but rather as an expression of judgment based on previous observations on this river channel. In the year 1911-12 it has been estimated that 15,000 acre feet of water passed to the sea, equivalent to 13.6 million gallons a day. This was a year above normal rainfall in San Diego, but not above normal rainfall in the mountains. These figures are given, not as expressing an amount of water available for pumping at the San Diego narrows, but rather as indicating that there are very considerable bodies of water presenting themselves for absorption by these sands and gravels in the Mission Valley. With water as valuable as it is in your vicinity, these flood discharges should be conserved as much as possible, as is being done in many localities in Southern California at present by spreading them over these sandy washes in order to facilitate the absorption in the winter time.

It should be constantly remembered that your city would not expect to draw on this source of supply except in an emergency, when other sources showed serious indication of failure. This source should be considered as a reserve supply. The large amount of water being extracted from this entire area for irrigation is a serious factor in the situation. In 1912, above the Mission Dam, 1,345 acres were being irrigated, much of it in a wasteful manner, and the area subject to irrigation above the Mission Dam is estimated as 3,460 acres.

As you proceed along the river up from Mission Dam, the sands and gravels of the river bed become coarser, and therefore will absorb flood waters more readily, as well as give them up more freely for pumping and the water becomes purer in quality, as may be seen from the table of Analysis below. Mission Valley, below the Box Canyon, is 5.1 square miles, or 3,264 acres. The depth to bed rock in this area is not clearly known, most of the wells being shallow. Two deep wells have been put down, however, that would indicate a cover of about 100 feet of porous material. If we should estimate that the water could be extracted to a depth of fifty feet, the storage capacity for this basin would be 41,000 feet. If but one half of this amount could be actually drained from the sands by the lowering of the water plane, the yield might be 18.3 million gallons for one year. This is an extreme quantity, which in practice would not be accomplished, and which would be seriously modified by the irrigation pumping now being practiced in this region. Time and funds were not available for a determination of the irrigated areas in the Mission Valley or the amount of pumping that is practiced. This investigation should be made and the city should endeavor to protect its rights to this water, whatever they may be. I con- this storage basin near your city as of great value to you. It should be held in reserve as previously stated for years of drouth and necessity. The use of the Mission Valley sands for emergency purposes does not at all solve your water problem for the future. If your city continues to grow at the amazing rate that is indicated now, your water supply must be trebled over the present amount used and active steps must be taken to meet this situation.

QUALITY OF MISSION VALLEY WATER

All natural stream waters or underground waters absorb some mineral matter. There is no such thing as a chemically pure natural water. Upon evaporation there is left a residium, which is called salts in solution, or total solids in solution. These mineral salts cannot be extracted by filtration. The hard crystaline rocks and metamorphosed rocks such as granites and basalts, do not readily yield their salts for solution, and, therefore, mountain water is usually relatively pure. However, the sedimentary rocks which are usually laid down along the sea shore are softer, and contain more mineral salt, and waters flowing through such drainage basins, or percolating through such soil, usually contain a higher percentage of these mineral salts. Table No. 3, given below justifies these conclusions. It will be noted that the mountain waters, whether from reservoirs or wells, are purer than waters nearer the sea. Sixteen samples of water were taken in the field, and the total salts in solution were determined by Smith, Emery and Co., a firm of reputable chemists in Los Angeles, for the purpose of this report. The well waters of the Monte Ranch, and as far down as Santee are good waters, but the waters of the Mission Valley are not so good. The average analyses of the waters sampled in the Mission Valley show 61.8 grains per gallon.

In extensively extracting water from these gravels some such blend would be obtained. These waters would be mingled with the waters, probably, from the mountain reservoirs on dry years, and the resulting water would be better than the water from the Mission Valley alone. At the end of Table No. 3 is given an analysis of other coastal waters in California for the purposes of comparison.

The standard most generally accepted in the eastern portion of the United States and Europe allows 29 grains per gallon as a reaonable limit of impurity, or for calssifying it only as fair. Prof. Hilgard of the University of California, has placed the limit for domestic use at 40 grains per gallon. J. K. Haywood, Chief of the Water Laboratory of the Bureau of Chemistry of the U. S. Department of Agriculture, states:

> "Some water analysers would cast aside all doubt by declaring that waters containing above 40 grains per gallon are to be condemned, but such is not the case, as there are many instances, especially in the west, of there being 70 grains per gallon, and their being used without apparent evil results."

There are a number of western cities using water high in mineral salts. The water used at Phoenix carries 70 grains per gallon. The City of San Diego itself has used these Mission Valley waters without bad effect. I am not arguing in favor of sustaining this city with a water high in mineral contents, but I do believe that this water is suitable to carry you through an emergency, and that it will not be injurious to health. It none the less is desirable, when additional supplies are obtained, to get them of better quality.

Two pumping plants are estimated upon. One near the original pumping plant of the city, and the other higher up in the Valley; one to connect with the Old Town Reservoir, and the other with the University Heights Reservoir. It is exceedingly difficult to estimate on the cost of these pumping plants until the amount of water that is available for pumping is determined by tests. They probably should be installed in duplicate, starting with units capable of producing one-half the estimated supply. If four or five million gallons daily can be extracted from the wells of this valley, the plant will be quite successful. The sands, unfortunately, are fine and will not yield water freely. In former years the wells used were shallow. It is now proposed to put down about 24 cased wells to depths of about 100 feet. It is interesting to note that two deep wells that have been put down in Mission Valley have found water bearing strata about 200 feet in thickness below the 700 foot level. Their yielding capacity is not known, and the quality of this deep water is not quite so good. The total cost of the two pumping plants, with connecting mains, is $165,000.00.

DISTRIBUTING SYSTEM

In the list of items for the bond issue which I have, is included one for $125,000.00 for the improvement of the distribution system. It would be entirely impossible for me to study the complete distribution system of the city of San Diego for this present report. It would take weeks of time, and I am not in a position to pass upon the necessity of these proposed improvements. The feeling I have in the matter is decidedly that the water rates should be so increased that this maintenance expense and minor betterments should be paid from the water revenue funds, and not by the process of bonding. If you continue the bonding policy to cover maintenance expenses, a debt will be rolled up against your city that will be destructive in the end, and consequently for the reasons given above I do not feel inclined to approve such an expenditure with my present information.

ENGINEERING STUDIES

In the past there has been lack of scientific knowledge in in the design of the water system that is serving your town. This is particularly due to the fact that information concerning run-off, evaporation and the like was not available to as great an extent as it is now. Fof instance, the study of the mass curve for the Morena Reservoir, for a period of 20 years, indicates that 37 per cent. of the entire water crop at that point would have been lost by evaporation. It also was not appreciated that groups of dry years would yield so small a run-off or water crop. Practically all the dams in this locality are constructed for capacities far in excess of the necessity. We have, for instance, the building of the Upper Otay Reservoir, which to me at present seems to have been unnecessary. Instances could be referred to quite indefinitely of this character. For some strange reason people seem to prefer taking risks in the expenditure of money on construction, while they hestate to expend small funds on scientific investigators. Records of stream flow, evaporation and the like cannot be immediately obtained, simply by putting up money; it takes a period of time, usually extending over several years, to get any record of value. For this reason particularly hydrographic studies should be started well in advance of construction, and I cannot too strongly urge upon you the necessity of this important matter.

I have stated in numerous places in this report that I consider your water situation grave, and that you should promptly begin getting ready for it, particularly in view of the fact that you will probably require a safe supply for three times what you are using at present inside of twelve years. I think you should start an engineering investigation of all the available water supply practically in your County, and that these investigations should also extend somewhat across the line into Mexico.

The amount of money that is proposed for engineering in the bond issue($20,000), I consider wholly inadequate, if all applied for this hydrographic work. The estimates for pipe lines, reservoirs, and pumping plants are high enough to provide for the engineering for this construction. Surveys should be made, streams should be gauged, bed rock explorations of dam sites, and many other necessary studies made. I think $50,000 would be an amount that would be very modest as compared to your undertaking, if all expended on new studies. It is far less than is usually expended by cities and corporations in making such investigations. You have corporations in your own county that are spending from $1500 to $2000 per month in studying water problems.

In addition to the amount suggested for water investigations, I submit for your consideration the advisability of having an additional fund for options on water bearing lands and water rights. These, if obtained, could be subsequently submitted to your electors for approval.

According to the bond statement issued August 1st, 1913, by your Assessor, the present available bonding power of the city is $1,039,423.00 on the present basis of assessed valuation. He states that it is proposed to increase the valuation of property during the coming year, and estimates that the amount available for future bond issues, after the present fiscal year, will be $14,428,662.00. You, therefore, will be in a financial position to take up a substantial extension of your water system after this year.

Table No. 3. - Analysis of Water.

Sample No.	Date	Location	Authority	Grains per gal.
	Fall,1912	City pipes (mountain water)	Whitney	19.0
---	Aug 1913	Upper San Diego River above flume in pool	Smith-Emery	17.7
5	Aug 1913	San Diego flume at Monte	"	10.1
4	"	Well at Monte Ranch	"	24.5
6	"	Well from Lower Monte Valley	"	28.0
7	"	Well 1/2 mile North of Santee	"	27.8
8	"	Scripps House Water, said to come from well on North side of bottom in Cajon Valley	"	45.4
---	"	From Lagoon on Scripps Ranch	"	90.0
17	"	Well Mission Valley, near Gravilla, Mission Valley	"	85.4
15	"	Well at mouth of Murphy Canyon Mission Valley	"	70.0
16	"	Well below mouth of Murphy Canyon Mission Valley	"	51.5
14	"	Hoff Well near City boundary	"	28.0
13	"	Johnson well, 1/2 mile above Murray Canyon, Mission Valley	"	48.0
12	"	Glenn well at mouth of Murry Canyon Mission Valley	"	116.5
3	"	Bates well 1/2 mile east of Harrington's store, from 720 ft level, well 900 ft. deep	"	76.5
---	July 1913	Same well	Univ of Cal	77.0
9	Aug 1913	Balboa Oil well, 2410 ft deep 1 m. above city pumping plant from 700 ft level	Smith-Emery	69.0
10	"	Stebbin well (shallow) near Balboa well, 3/4 m above old city pumping plant	"	141.5
1	"	City well at pumping station near center of Valley	"	19.4
2	"	Wind mill well opposite old city pumping station	"	58.6
		Average of wells in Mission Valley		61.8
		Santa Ynez river, source for Santa Barbara	U.S.G.S.	42.0
		Ventura River, source for Ventura	"	39.0
		San Gabriel River, source for Azusa	"	12.0
		Santa Ana River, source for Redlands,	"	9.0
		Santa Ana River, source for Santa Ana	"	20.0
		San Luis Rey at Pala	"	18.0
		Santa Ysabel at Pamo	"	16.0
		Cottonwood Creek at Barrett	"	24.0
		Alameda Creek at Niles (San Francisco)	"	25.0
		Kern River at Bakersfield	"	7.0
		Los Angeles River at L.A.	"	28.0
		Owens River at Aqueduct intake	"	20.0

Table No. 4.
Assessed Valuation of the City of San Diego.

YEAR	TAX RATE	VALUATION
1895	1.1[illegible]	$ 12,984,081.00
1900	1.10	12,651,714.00
1901	1.10	12,447,523.00
1902	1.45	12,154,919.00
1903	1.40	12,516,383.00
1904	1.48	14,387,105.00
1905	1.45	17,636,988.00
1906	1.28	20,020,011.00
1907	1.35	23,749,670.00
1908	1.48	26,619,596.00
1909	1.48	33,814,991.00
1910	1.30	41,949,727.00
1911	1.45	45,888,340.00
1912	1.58	51,520,718.00 (1)
1913	1.90	60,738,409.00 (1)

(1) - Exclusive of corporation tax $3,424,000. Basis of present assessment is assumed to be 50 per cent. of value, but it is not as high. It probably is on a 40 per cent. basis. The present real value is about $160,336,965, as considered by the Assessor.

ESTIMATE OF J. B. LIPPINCOTT

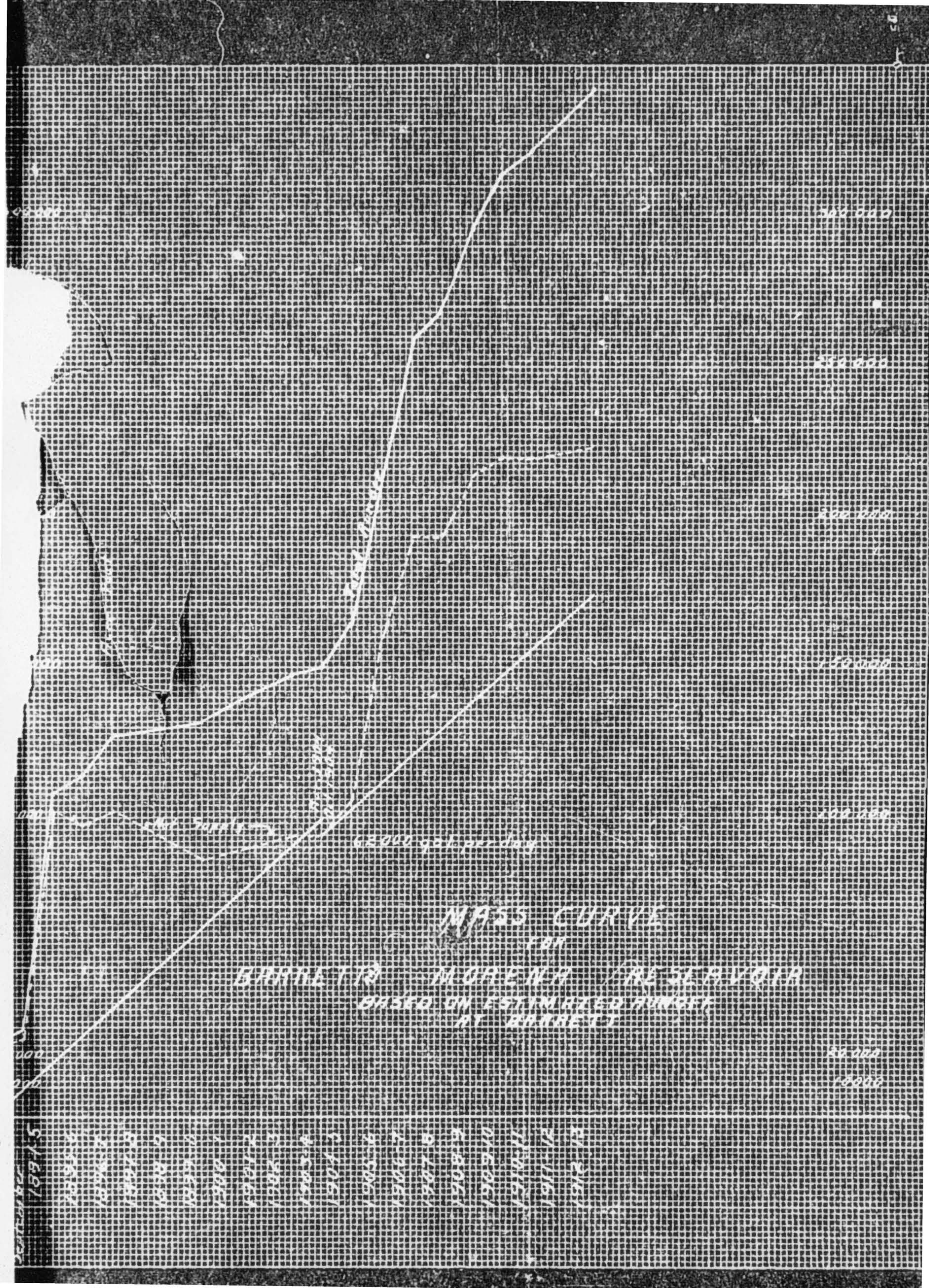
for proposed bond issue

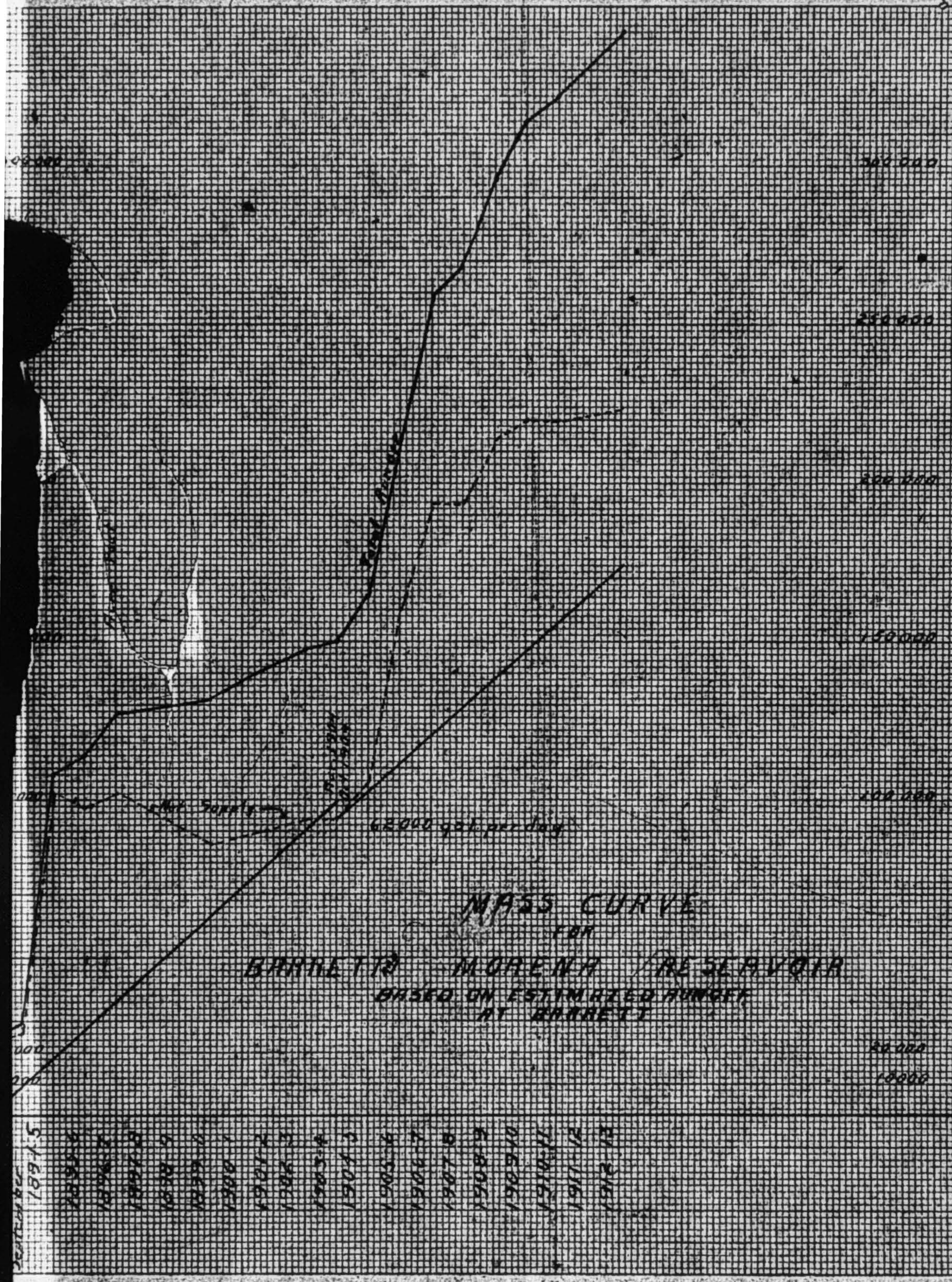
Item	Class of work	Cost.
1	Diverting dam and conduit in Cottonwood Creek to prevent seepage losses	$ 185,000
2	Repairs to Dulzura Aqueduct, important for its proper use /	30,000
3	Pipe Line from Bonita to proposed 15 million gallons reservoir to increase the capacity of the mains to the city and to eliminate a large portion of the present pumping	165,000
4	15 million gallon reservoir at the of new main to secure a supply near city in case of temporary breakdowns and for substantial fire protection	75,000
5	Filter plant, to be temporarily postponed, in order to secure a more essential addition to the present inadequate supply on probably dry years and because it is not essential	
6	Engineering for the investigation of additional water supplies, including stream measurements, exploration of dam sites and surveys.	50,000
7	Pipe line from proposed 15 million gallon reservoir to present city distributing system	55,000
8	Rights of way	25,000
9	Pumping plants in the Valley of San Diego River, for additional water supply for emergency in dry years	185,000
10	Improvement of present distribution system, to be paid for from the water revenues fund by an increase in rates	0
	TOTAL	$ 770,000

Very truly yours,

(SIGNED) J. B. LIPPINCOTT

Consulting Engineer.


62000 gal per day
300 000
250 000
200 000
150 000
100 000
20 000
10000
MASS CURVE
FOR
BARRETT & MORENA RESERVOIR
BASED ON ESTIMATED RUNOFF
AT BARRETT



MASS CURVE
FOR
BARRETT MORENA RESERVOIR
BASED ON ESTIMATED RUNOFF
AT BARRETT
Total Runoff
Net Supply
62000 gal per day
300,000
250,000
200,000
150,000
100,000
20,000
10,000
1894-5
1895-6
1896-7
1897-8
1898-9
1899-0
1900-1
1901-2
1902-3
1903-4
1904-5
1905-6
1906-7
1907-8
1908-9
1909-10
1910-11
1911-12
1912-13

VARIATION IN SEASONAL PRECIPITATION

EXPRESSED AS PERCENTAGE OF THE MEAN

SAN DIEGO COUNTY

from U.S. Weather Bureau and V.L.&W.Co. Records

The Diagram is the average of a number of Stations thru the County

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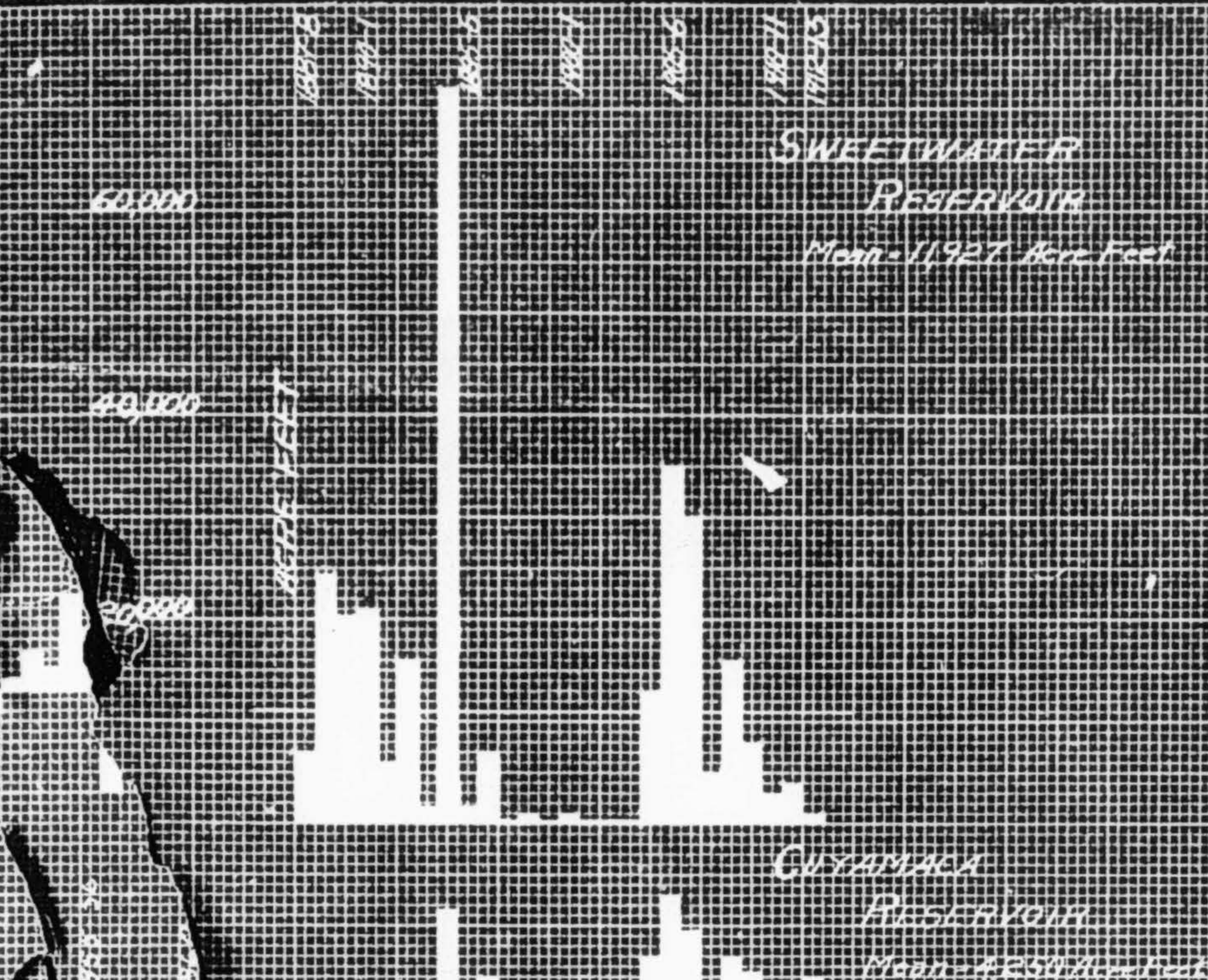
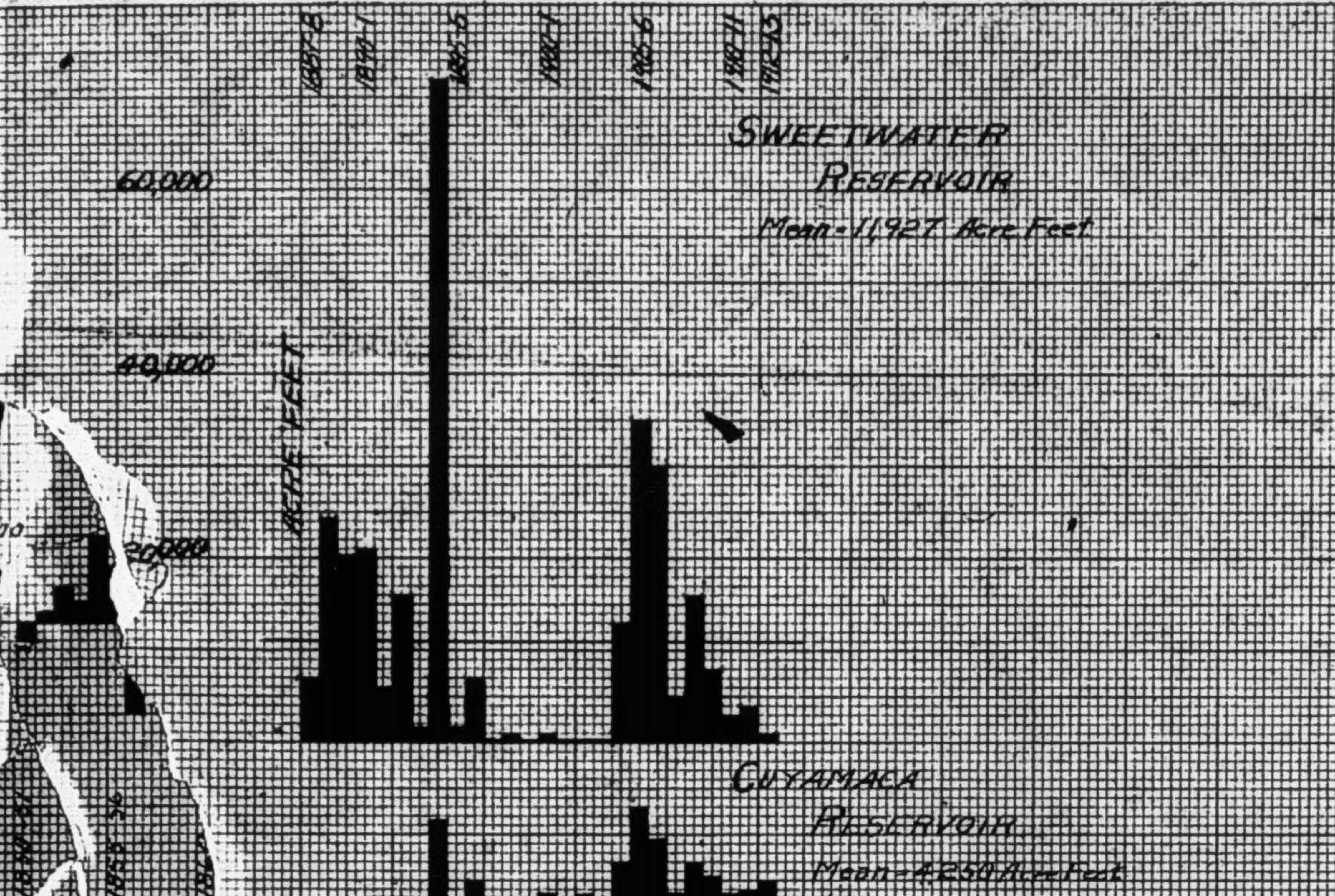


RUNOFF IN ACRE FEET AT
SWEETWATER & CUYAMACA
RESERVOIRS & OF COTTONWOOD CREEK
AT BARRETT DAMSITE



RUNOFF IN ACRE FEET AT
SWEETWATER & CUYAMACA
RESERVOIRS & OF COTTONWOOD CREEK
AT BARRETT DAMSITE.

RUN-OFF OF SANTA YSABEL RIVER

AT BERNARDO AND CARROLL

Year	(2) Run-off of Santa Ysabel at Pamo Acre-feet	(3) Per Cent Mean	(4) Per Cent Bernardo of Pamo	(5) Run-off at Bernardo	(6) Run-off at Carroll 100% of Bernardo Acre-feet	(7) Per Cent Mean	(8) Future Use in S.P. Valley	(9) Released for Priorities Below Carroll	(10) Net Run-off into Carroll Reservoir
1893-94	12770	71	115	14680	16150	65	1800	1000	13350
94-95	40520	224	129	52300	57700	231	1800	1000	54900
95-96	6740	38	50	3370	3710	15	1800	1000	910
96-97	16230	90	118	19150	21100	84	1800	1000	18300
97-98	3650	20	7	260	280	1	282	0	0
98-99	1640	9	0	0	0	0	0	0	0
99-00	1460	8	0	0	0	0	0	0	0
1900-01	12220	68	113	13810	15210	61	1800	1000	12410
01-02	6200	34	38	2360	2600	11	1800	800	0
02-03	13860	77	117	16220	17870	71	1800	1000	15070
03-04	3280	18	5	160	176	1	176	0	0
04-05	25090	138	118	29600	32600	131	1800	1000	29800
05-06	57450	317	196	112500	124000	495	1800	1000	121200
06-07	33970	187	119	40450	44500	179	1800	1000	41700
07-08	11870	65	111	13170	14500	58	1800	1000	11700
08-09	43480	240	138	60000	66000	264	1800	1000	63200
09-10	33430	184	118	39450	43400	174	1800	1000	40600
10-11	19700	109	118	23250	25600	102	1800	1000	22800
11-12	10170	56	98	9970	10950	44	1800	1000	8150
12-13	6071	33	35	2218	2440		1800	640	0
13-14	20679	114	118	24430	26950	108	1800	1000	24150
Mean	18118			22726	25034				22772

RUN-OFF AT CARROLL WITH SUTHERLAND RESERVOIR BUILT TO CAPACITY

OF 18.400 a.f.

Year	Total Run-off at Carroll	Total Run-off at Pamo	Run-off at Sutherland	Run-off Between Pamo and Sutherland	Run-off Between Carroll & Pamo	Run-off Between Carroll & Sutherland	Wasted from Sutherland	Total Run-off at Carroll
1893-94	16150	12770	7280	5490	3380	8870		8870
94-95	57700	40520	23100	17420	17180	34600	16180	50780
95-96	3710	6740	3840	2900	42	42		42
96-97	21100	16230	9310	6920	4870	11790	2180	15970
97-98	282	3650	2080	1570	0	0		0
98-99	0	1640	940	700	0	0		0
99-00	0	1460	830	630	0	0		0
1900-01	15210	12220	6970	5250	2990	8240		8240
01-02	2600	6200	3540	2660	0	0		0
02-03	17870	13860	7900	5960	4010	9970		9970
03-04	176	3280	1870	1410	0	0		0
04-05	32600	25090	14300	10790	7510	18300		18300
05-06	124000	57450	32750	24700	66550	91250	24350	115600
06-07	44500	33970	19370	14600	10530	25130	14970	40100
07-08	14500	11870	6760	5110	2630	7740	2140	9680
08-09	66000	43480	24790	18690	22520	41210	20050	61260
09-10	43400	33430	19060	14370	9970	24340	14440	38780
10-11	25600	19700	11230	8470	5900	14370	6520	20890
11-12	10950	10170	5800	4370	780	5150	1090	6240
12-13	2341	6071	4084	1987	0	0		0
13-14	26950	20679	10542	10137	6271	16408	2313	18721
Total	525639	380480	216346	164134	165133	317410	104233	421643
Mean	25034	18118	10302	7816	7860	15100	4960	20060

Reservoir	Depth	Capacity	Gross Evaporation	Safe Yield	
Warners		120000	55"	12000	
Warners		130000	55"	12800	
Sutherland		18400	55	3600	
Pamo		47500	55	7000	
Carroll		23000	62"	1500	with Pamo built
Carroll		34800	62"	6000	none other built
Carroll		66000	62"	8000	none other built
Carroll		34800	62"	3500	Sutherland built

Lippincott Results
April 15th 1915
see change May 1-1915

superseded -

Reservoir	Capacity	Safe Yield acre ft.	M.G.D.	Assumptions
Warners	120000	13500	12.0	90000 ac. ft. to slant wells
Warners	117000	13000	11.6	80000 " " "
Sutherland	18400	5000	4.45	Pamo built.
Pamo	47500 + 8570 sediments	7800	6.95	Sutherland not built
Pamo	47500 + 8570 "	4000	3.6	Sutherland built
Carrol	23000	1500	1.35	Pamo and Sutherland built
Carroll	34800	6400	5.70	No other dams built on stream
Warners / Pamo	117000 / 47500 + 8570	17500	15.65	Sutherland built. Water passed from Warners to Pamo storage but mean yield of Pamo more than 2000 ac. ft. [illegible] of stream

Probably Carroll Canyon Dam

Warners and Pamo	15.65
Sutherland	4.45
Carroll	1.35
	21.45

May 1st 1915

Warner's Reservoir Mass Curve Computations — as computed by C.E.H. under direction & method of J. B. Lippincott.

Copy of

Year	Vol. in Reservoir at end of Season	Runoff per Lippincott	Accumulated Runoff	Released for Escondido	Consumed Evaporation from Submerged Moist Lands	Net Runoff into Reservoir	Vol. in Res. at begining of Draft Season	Mean Area Flooded acres	Net Evap. inches	Net Evap. ft.	Evap. acre ft.	Draft	Remarks
1893-94	90000	14000		960	2200	15240	105240	3350		3.6	12080	12800	
94-95	80360	44400		0	2750	47150	127510	3960		2.5	9900	12800	
95-96	104810	7400		1897	2400	7903	112713	3550		3.7	13100	12800	
96-97	86810	17800		460	2250	19590	106403	3400		2.8	9520	"	
97-98	84080	4000		2451	1920	3469	87552	2920		3.7	10800	"	
98-99	67952	1800		1350	1600	2050	66002	2350		3.75	8820	"	
99-1900	44382	1600		723	1330	2207	46589	1850		3.4	6300	"	
1900-01	27489	13400		1048	1240	13592	41081	1700		3.1	5275	"	
01-02	23006	6800		1497	1040	6343	29349	1400		3.4	4750	"	
02-03	11799	15200		404	1020	15816	27615	1370		2.8	3840	"	
03-04	10975	3600		1505	640	2735	13710	820		3.7	3030	"	deficiency 2120 ac. ft.
04-05	0	27500		0	1040	28540	28540	1400		2.2	3080	"	
05-06	12660	66957		0	1850	68807	81467	2800		2.2	6160	"	
06-07	62507	54000		0	2720	56720	119227	3720		2.75	10200	"	
07-08	96227	16900		0	2560	19460	115687	3650		3.2	11700	"	
08-09	91187	31700		0	2750	34450	125637	3900		2.75	10710	"	
09-10	102127	30560		0	2750	33310	130000	4000		3.1	12400	"	waste 5437 ac. ft.
1910-11	104800	21600		0	2750	24350	129150	3960		3.0	11660	"	
11-12	104670	12030		833	2560	13757	118227	3650		3.2	11650	"	
12-13	93777	6042		2028	2220	6234	100011	3360		3.4	11420	"	
13-14	75791, 78225	22521		457	2140	24204	99995	3260		2.75	8970	"	
		419810.		15613.	41730	445927					185585		

743

mean

Reservoir Capacity of 130 000 ac. ft.

Curve Showing
Evaporation from Submerged Moist Lands
in
Warner Reservoir
which would be conserved.