REPORT

ON THE

HYDROLOGY

OF THE

WARNER WATERSHED

ON THE

VOLCAN LAND & WATER COMPANY

SAN LUIS REY RIVER

SAN DIEGO COUNTY
CALIFORNIA

MADE FOR

MR. WM. G. HENSHAW

BY

WALTER HY. BROWN
MEMBER AM. SOC. C.E.

SAN FRANCISCO
DECEMBER, 1915

Reports No 106

WALTER HY. BROWN
M. Am. Soc. C. E.
CONSTRUCTION AND HYDRAULIC ENGINEER

R E P O R T

ON THE

H Y D R O L O G Y

OF THE

W A R N E R

W A T E R S H E D

OF THE

V O L C A N   L A N D & W A T E R   C O M P A N Y

SAN DIEGO COUNTY, CALIFORNIA.

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701 Post Street,
San Francisco,
December 1,1915.

Mr.Wm.G.Henshaw,
Mills Building,
San Francisco.

Dear Sir:-

Herewith is appended a report upon the hydrology of Warner watershed,San Diego county, California,as controlled by the Volcan Land & Water Company.

The dependable annual yield,with storage, is found to be as follows:

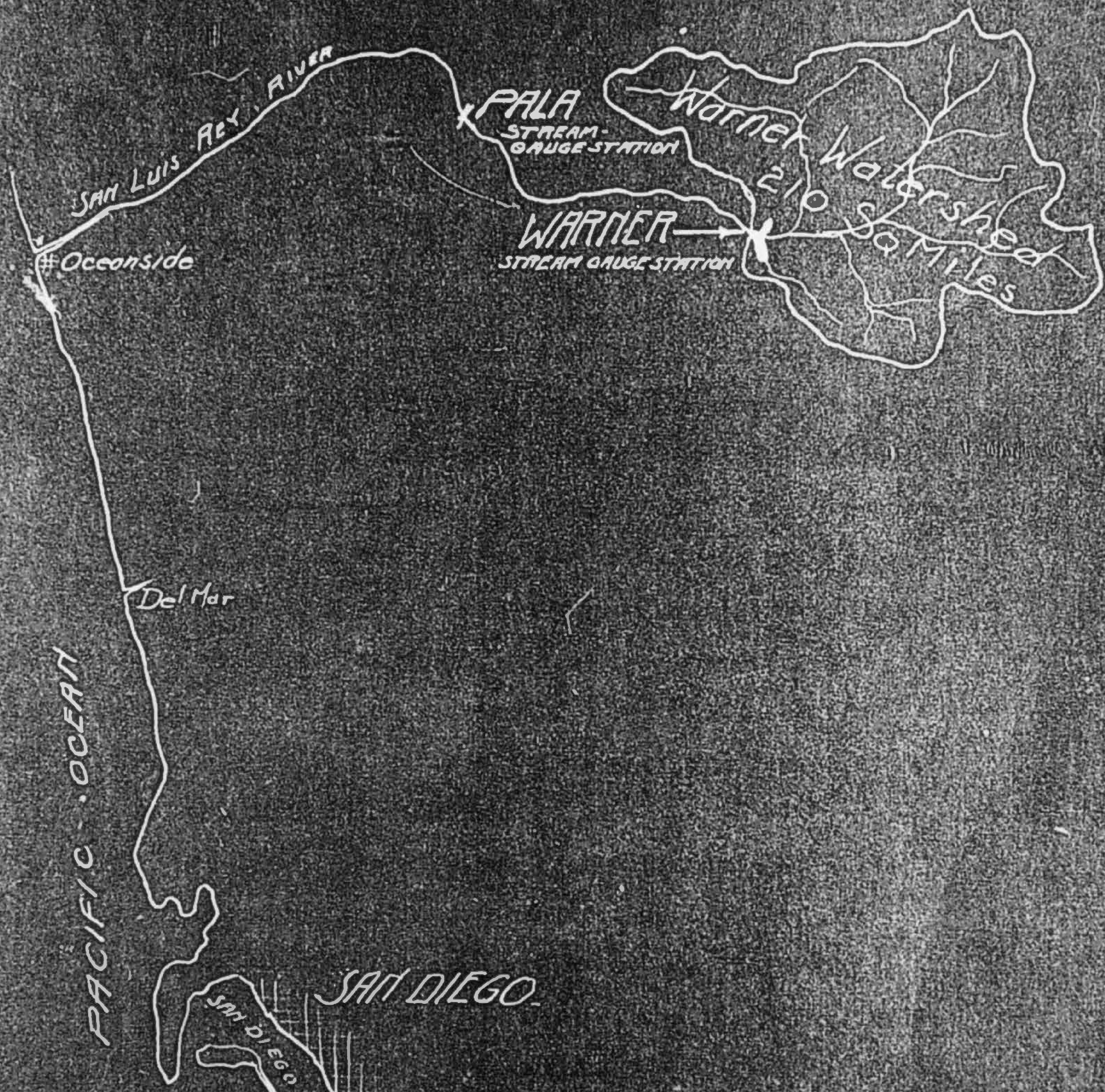
RESERVOIR STORAGE REQUIRED. ACRE FEET.	DEPENDABLE YIELD PER ANNUM IN ACRE FEET.	DEPENDABLE YIELD IN MILLIONS OF GALLONS DAILY.
117,000	21,759	19.4

With an allowance for diversion by the system of the Escondido Mutual Water Company of a mean of 762 acre-feet,(see page 26),the dependable net yield of Warner watershed would be 20,997 acre-feet annually, or 18.74 million gallons daily.

Attention is drawn to the general method employed in arriving at determinations which has the effect of disposing of any question as to just what the seasonal rainfall on Warner watershed may have been during early years when precipitation records were not actually made on the watershed named. The nine years of records which have contributed to definite information as to actual rainfall conditions on Warner watershed bear a discernible relation,year by year,to the seasonal mean of Julian, Cuyamaca,Valley Center and Escondido as representative of conditions on and surrounding the watershed under investigation. Certain precipitation records on or close to the Warner watershed,(see pages 20,21,22,),have been eliminated from computations in this report which,if used,would have shown a greater rate of seasonal precipitation on Warner watershed than has been accepted in this report. Were a higher,or a lower,seasonal precipitation assumed to have occurred there would result,because of the method of analysis followed,no material change in the ultimate findings of the dependable yield of the watershed. Further attention is directed to Table XI,page 37,concerning the dependability of the Warner Run-off Curve relied upon in the report. Text upon this subject will be found on pages 6,7 and 8.

Endeavor has been made to include in the report full detail data relating to precipitation and stream flow for the purpose of facilitating re-investigation or checking.

Respectfully submitted,


San Luis Rey River
PALA
STREAM-GAUGE STATION
Warner Watershed
210 Sq Miles
WARNER
STREAM GAUGE STATION
Oceanside
Del Mar
PACIFIC OCEAN
SAN DIEGO
SAN DIEGO BAY

WALTER HY. BROWN
M. AM. SOC. C. E.
CONSTRUCTION AND HYDRAULIC ENGINEER

HYDROLOGY OF THE MOUNTAIN REGIONS OF THE SAN LUIS REY RIVER AND THE UTILIZATION OF WARNER RESERVOIR.

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The sources of the San Luis Rey river are on the western slope of the Coast Range mountains in the north-easterly portion of San Diego county,California, at an altitude varying from 2600 to 6250 feet above sea. Flowing in a westerly direction the stream discharges into the Pacific Ocean at Oceanside,about thirty-five miles north of San Diego. A sketch-map showing the general location of the San Luis Rey and the Warner Watershed,as located from the city of San Diego,is shown on the preceding page.

On the upper region of the San Luis Rey lies a great natural basin,or reservoir site,on property known as the Warner Ranch while back of and draining towards this basin are two hundred and ten square miles of territory,all lying within the Cleveland National Forest Reserve. Of the total area approximately eighty square miles are in broad valley in which there are many acres of swamp lands,continuously wet,and which, with the presence of two natural lakes,will have a bearing,later on in this report,on the evaporation losses to be expected from the surface of the proposed Warner Reservoir. The chain of mountains which surround this basin,or valley,have both gentle and rugged slopes covered with dense brush and with oak and pine timber in the higher altitudes towards the crests. Snow,in the higher regions,is usual during the winter seasons.

It is proposed to impound the water flowing from this two hundred and ten square miles of territory in the Warner Reservoir which may be created by the construction of a dam of moderate height and on a favorable site. By this method of conservation there can be secured a supply of water,in storage,which may be drawn upon,for diversion to the arid valley regions, throughout periods of freshet and drought. The characteristic of all streams in Southern California is to greatly diminish-and in many instances even cease-in flow during the summer months. The winters,or wet seasons,witness the rising of streams,when,with the approach of June, rains become less and less frequent and,from the latter month until October or November,little rain-fall may be expected. This "dry" period is accompanied by a rapid falling off in the quantity of water flowing in natural channels and, in many streams of importance, frequently ceases to flow for a period. This characteristic is true of the San Luis Rey river in its lower regions, at Oceanside, on the Coast, and at Bonsal, some fourteen miles inland from Oceanside, but on the upper regions of the river, on the Warner watershed, the stream does not "go dry" during the period of the non-rainy season. At Pala, some thirty miles inland from the Pacific and twenty miles below the proposed Warner reservoir, the records of the United States Geological Survey, kept for the past twelve years, (since 1903), show the San Luis Rey to be a live stream at all times. At Warner dam site, as at Pala, there is always flowing water and, at times, more at Warner than at the latter point. The locations of the points mentioned are shown on the sketch-map preceding page 1.

Referring to this map it will be seen that stream gaugings, simultaneously conducted at both Warner and Pala, should assume a general relation, one to the other. Warner and Pala are approximately twenty miles apart, by the river channel, and at these two points stream-flow measurements have been conducted by the United States Geological Survey and by the Volcan Land & Water Company, in co-operation, so that an excellent series of observations is available. At Pala measurements have been made since the latter part of the year 1903 while at Warner dam site records of stream-flow were secured during 1905-1906. Following this period there is a break in the records at Warner dam site until the year 1911 when stream measurements were undertaken by the Volcan Land & Water Company and have since that time been systematically conducted without interruption.

During the interval when gagings were not made at Warner the records secured at Pala, by the U.S. Geological Survey, afford opportunity for interpolating the volume of stream-flow at Warner through the medium of the ratio of stream-flow at the two points. There are records covering four consecutive years during which time simultaneous measurements were made at Pala and at Warner and a portion of two additional years making, in all, six years of simultaneous measurements available for practical comparison in determining upon the relation, or the ratio, of stream discharge at the two points. This factor has been determined, as set forth in detail in Table 1, as 0.629; that is, the mean annual discharge of the San Luis Rey river at Warner is 62.9 % of the discharge at Pala and in constructing the hydrograph of the river at Warner, back over years unmeasured at that point, this ratio has been used.

To accept the total or the mean annual of the findings reached in this way as the probable capacity of the stream over long and continuous periods of time would be to either under- or over-estimate the true probability and it becomes necessary to view precipitation and stream flow conditions over a cycle longer than the period of actual stream-gauging affords;for "wet" and "dry" cycles occur in this section of the West in periods of seven to ten years duration and the characteristics of previous years,grouped into cycles,must be inquired into and developed to view as a means of gauging the relative value,wet or dry,of the cycle during which the base measurements,(at Pala),were made.

The point may be illustrated by stating that during the eleven year period,or cycle,of simultaneous or co-ordinate measurements here used,the mean seasonal discharge at Warner was,in round numbers,32,000 acre-feet while the mean for a forty-three year period,back to 1872-1873, was 29,700 acre-feet;showing that the actual measurements were made during a fairly high cycle and if followed,uncorrected,would produce figures of run-off which would be unsafe to rely upon over a period of many cycles,for,with the occurrence of the inevitable "dry" cycle,a shortage of water,with the figures otherwise accepted,would occur. In order to extend the view into the time before actual stream-gauging was conducted in this region recourse is had to the precipitation records available at Escondido and at Valley Center in the lower region and to the west of the Warner water-shed and also at Julian and Cuyamaca,in the mountains,south-easterly from Warner water-shed. These precipitation data,given in TABLE II, extend back to the seasonal year 1872-73. The mean of Escondido and Valley Center, shown in Column I, indicates rain conditions on the lower altitudes while the mean of Julian and Cuyamaca, Col.2, gives an index as to occurrences in the high mountains. The mean of all, Col.3, indicates what did occur over a large territorial area and by taking each years mean and determining its relation to and over the entire forty-three year period there is shown how each year, in the past, has varied in general precipitation.

With this data in hand for reference another step is taken by plotting the seasonal run-off, (as set forth in Table I), on logarithmic scale, (Diagram A), the annual precipitation, in inches in depth, as ordinates, and the annual discharge, in acre-feet, as abscissa.

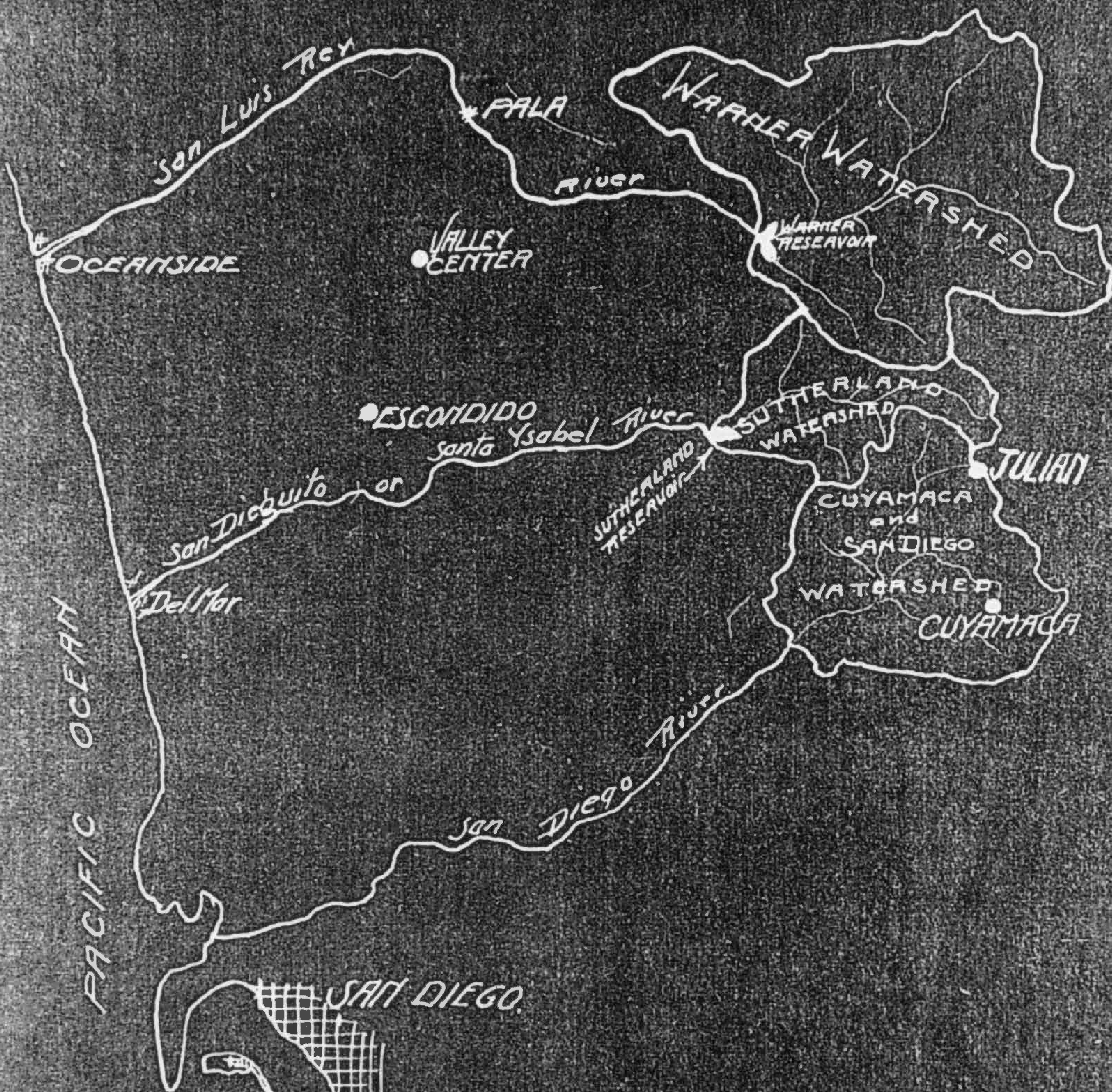
The years covered by actual stream-gaugings include seasons of wide divergence, being from sixty-two per-cent to one hundred and thirty-eight per-cent of normal for that, (11-year), period and affording opportunity to see, on the diagram, what may be expected in the volume of stream-flow in either a very wet or a very dry year of given rainfall. It is not to be presumed that the method employed will give accurate results for each and every individual year, for the quantity of run-off varies, not only with the total amount of rainfall, but also with the manner of its distribution throughout the season; whether it be concentrated in a few heavy downpours in short interval or spread in many light rains throughout the season. The manner of arriving at conclusions is,however,one which balances any deviations and,with the data in Table III,points are obtainable from which to determine the curve on Diagram A . That the readings taken from this Log.Curve are free from material error is shown over the twelve-year period as set forth in Table XVI,page 49. The total run-off,taken from this Log. curve for the last twelve years,is 706 acre-feet short of the total measured run-off for the same period as based upon Pala and Warner measurements. This error of the Log. curve readings,on the safe side however, of $\frac{19}{100}$ of one per cent,is negligable.

For four consecutive years of actual gaugings at Warner,(the last four years to date),the total discharge was 100,495 acre-feet and the Log.curve,though showing off for individual years,designates a total discharge of 100,400 acre-feet which is 95 acre-feet less,in four years,than the measured quantity. The use of the curve,in this instance, underestimated the stream flow by $\frac{9}{100}$ of one per cent. Table XVI shows the method of arriving at these determinations.

These checks on the accuracy of the Log.curve on Diagram A are mentioned to show that with years varying in the rate of precipitation from 55 % of normal to 153 % of normal for a 43-year period and 52 % to 144 % of normal for a 12-year period,the curve readings total,practically,the measured amounts and justification is thus given for the use of the curve in projecting back into unmeasured periods.

Referring to Table III it is found that the date was 92.8 % of the mean of Escondido-Valley Center-Julian-Cuyamaca precipitation over a period of nine comparative and consecutive years. Assuming nine years to be a lone enough period to justify its use in establishing ratio,the precipitation on the Warner watershed has been projected back by taking 92.8 % of the mean of Escondido-Valley Center-Julian-Cuyamaca and applying the individual amounts for each year as the rainfall upon Warner watershed for corresponding years. From these data the annual run-off from Warner watershed has been read from the Log.curve on Diagram A and reservoir requirements and safe annual yields computed on the draft sheet,Table VIIIand as shown on the mass curve,Diagram C.

On the following page is a sketch-map similar to the map preceding page 1 though with additional locations showing Escondido,Valley Center,Julian and Cuyamaca. Aside from records at the city of San Diego they offer the only long-period records of that section of the State and it is felt that the use of the records at the points named gives a proper index of the precipitation which has occured on the territory in between the points named. The mean of Escondido and Valley Center indicates what has taken place in the regions below Warner watershed while the mean of Julian and Cuyamaca indicates precipitation conditions back of Warner watershed,in the high mountains. The mean of all will show the general effect of storms which sweep the entire locality.Local showers,in their effect,are practicaly eliminated.


San Luis Rey
PALA
River
WARNER WATERSHED
WARNER RESERVOIR
OCEANSIDE
VALLEY CENTER
ESCONDIDO
Santa Ysabel River
San Dieguito or
SUTHERLAND WATERSHED
SUTHERLAND RESERVOIR
JULIAN
CUYAMACA and SAN DIEGO WATERSHED
CUYAMACA
Del Mar
PACIFIC OCEAN
San Diego River
SAN DIEGO.

As a check on this method other forms of analysis have been employed and a tabulated summary of the various forms is appended. The ground has been covered as follows:

(1) The Warner drainage areas are sandwiched in between the Hemet watershed on the north and the Cuyamaca and San Diego(at Diversion) watersheds on the south. The seasonal discharges from these surrounding areas has been combined and the seasonal discharge reduced to the run-off, in acre feet,from a unit of a single square mile. These figures have,in turn,been multiplied by the area of the Warner watershed (210 square miles) and the product taken as the seasonal run-off from the latter watershed,for given years. This finding is 22,000 acre-feet,gross.

(2) Using Escondido-Valley Center variations of their mean seasonal precipitation. This method shows practically the same as the principal method used.It fails,however,to account for a few general storms which are known to have prevailed in the mountains and not present in the region about Escondido. Determinations for Warner, by this method,show 21,750 acre-feet,gross.

(3) Using Cuyamaca-San Diego(at Diversion) run-off averaged with the run-off of the Arrowhead watershed,in the San Bernardino mountains and in close proximity to the watershed of the San Gabriel river.

The Arrowhead watershed is approximately eighty miles north of the Warner areas and its use as a balancing factor(in conjunction with the Cuyamaca and San Diego)in establishing the yield of Warner watershed results in determinations showing a greater run-off for the Warner watershed than any of the other methods of analysis employed.The use of the San Gabriel run-off,in combined percentage with the Cuyamaca-San Diego, shows a run-off for Warner of 20,000 acre-feet, while by the same method,only substituting Arrowhead for San Gabriel,shows that the run-off of Warner watershed would have been 22,280 acre-feet.

Computations along this method,of using the percentage run-off as it occurred in the San Bernardino mountains,as a balancing medium for Warner watershed determinations,were not carried out to evaporations conditions and storage requirements because of the evidently mistaken premises upon which the theory rests. The watershed conditions, the regimen of the streams on the areas north of the Santa Ana valley in the vacinity of Ontario and San Bernardino differ from those of the Warner areas.

This is shown by the reversal of conditions which have occurred on the areas under discussion, as shown below. A 21-year mean is used.

Seasonal Year.	Combined Cuyamaca and San Diego. Percentage of Mean.	San Gabriel Watershed. Percentage of Mean.	Arrowhead Watershed. Percentage of Mean.
1894-95	274	171	202
1900-01	54	79	180
1905-06	287	194	148
1910-11	78	224	139
1911-12	107	58	152

Reading straight across the table for any given year should show a comparatively even variation from the mean, - if the regimen of the streams were similar. It will be noted that in the year 1905-06 the Cuyamaca-San Diego percentage was high,-compared with the other two watersheds, while in the year 1910-11 its condition fell well below its normal while the other streams were flowing above their normal. The year 1911-12 reverses this latter.

Diagram D has been prepared showing the values in percentage of the mean for each individual watershed for Cuyamaca-San Diego, the San Gabriel and the Arrowhead watersheds. The one hundred percent line, representing the mean of 21-years, is drawn prominently and the deviations from this line, or line of normal run-off, are shown.

The San Gabriel Gaugings are from the U.S. Geological Survey Reports and the Arrowhead gaugings are from records filed with the City of San Diego and with the California State Railroad Commission.

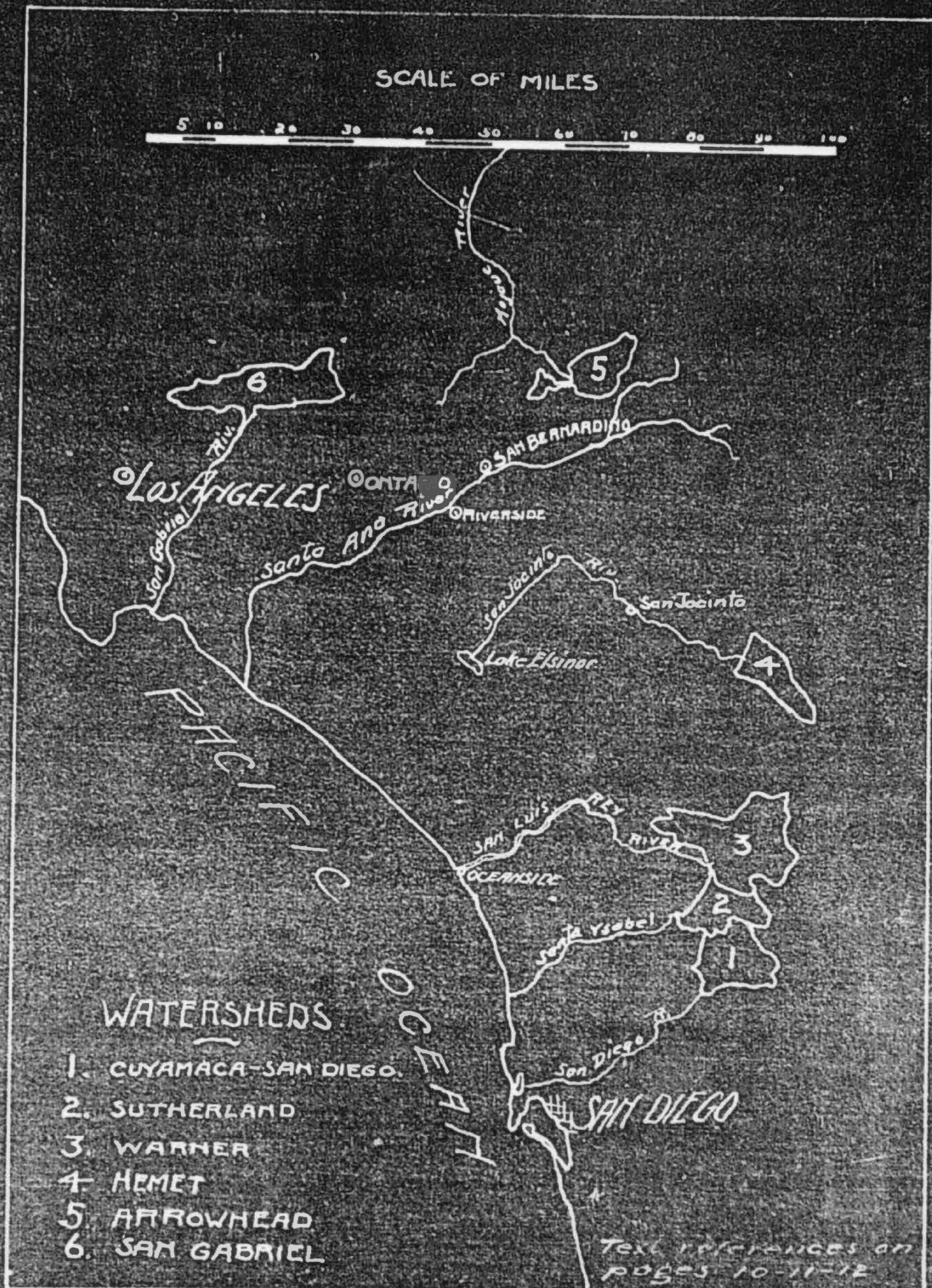
A summary of the foregoing forms of analysis follows.

Computing the run-off of Warner watershed by combining the seasonal percentages of the Cuyamaca - San Diego (at Diversion) run-off with the streams as designated in column headings the mean seasonal run-off at Warner would have been as follows, for the 21-year period.

Cuyamaca-San Diego Watersheds used in conjunction with:-	Approximate distance from center of Warner Watershed in miles.	Estimated mean seasonal run-off from Warner Watershed, in Acre-feet.
San Gabriel - - - -	110 miles northerly. - -	20,000
Hemet, - - - - - - - -	30 " " - - -	21,324
Arrowhead, - - - - -	80 " " - - -	22,280

A survey of all of the original records available, both for streamflow and precipitation, makes it seem advisable to use only data of local origin having seasonal characteristics which have been impressed upon and experienced by the water bearing areas involved.

A sketch map showing the relative locations of the watersheds under discussion is shown on the following page.


SCALE OF MILES
5 10 20 30 40 50 60 70 80 90 100
Mojave River
6
5
San Gabriel Riv.
LOS ANGELES
SAN BERNARDINO
RIVERSIDE
Santa Ana River
San Jacinto Riv.
San Jacinto
Lake Elsinor
4
PACIFIC OCEAN
San Luis Rey River
3
OCEANSIDE
2
Santa Ysabel
1
San Diego R.
SAN DIEGO
WATERSHEDS
1. CUYAMACA-SAN DIEGO.
2. SUTHERLAND
3. WARNER
4. HEMET
5. ARROWHEAD
6. SAN GABRIEL
Text references on pages 10-11-12

RESERVOIR STORAGE
AND
RESERVOIR EVAPORATION.

Reference has been previously made to the swamp lands and natural lakes within the Warner reservoir site which will be submerged upon the partial filling of the reservoir. From experiments made during the course of the Los Angeles Aqueduct investigations it was determined that retarded soil-water will evaporate,during the summer months,to a depth of six feet and from determinations as to soil porosity the conclusion is reached that this evaporation in soil to a depth of six feet is the equivalent of nineteen inches(in depth)of water,per annum,over the swamp areas. In other words;it would require nineteen inches (in depth) of water to saturate the soil to a depth of six feet,and this amount of water is evaporated from the soil annually;if the ground continues wet,throughout the year,it goes to show that the amount evaporated is being constantly replaced by an inflow of water.

To determine the quantity of water which would be conserved,seasonally,because of these swamp lands Diagram B has been prepared showing the annual conservation,in acre-feet,as it would occur with varying areas of swamp lands due to differing stages of water level in the reservoir.

Under operating conditions of the reservoir the gains from swamp land conservation amounts to a minimum of six hundred acre-feet and a maximum of 2760 acre-feet per year.

EVAPORATION FROM RESERVOIR SURFACE.

The annual evaporation from the exposed surface of the reservoir is taken as thirty-six inches in depth for the following reasons.

The Volcan Land & Water Company has conducted evaporation observations in the Warner reservoir site with Standard (United States Geological Survey) three foot square floating evaporation pans designated on the Company records as Pan No.4 and Pan No.5. The latter is floating in water at Warner dam site, the former on Big Lake, a natural pond covering about fifty acres. Evaporation from these pans has been as follows:

Year.	Depth of Evaporation in Inches.	
	Pan No.4.	Pan No.5.
1913	47.16	58.08
1914	54.11	61.94
Mean of Two years	50.63	60.01

$$\text{Combined mean} = \frac{50.63 + 60.01}{2} = 55.32$$

A mistake is sometimes made in determining the evaporation from reservoirs by applying,without correction,results of pan tests as the actual evaporation from a large and free water surface upon which the test pans are floated. There are reasons why this should not be done.

Standard evaporation pans are made of galvanized sheet iron,they are three feet square and ten inches deep and,encircled by a protecting boom to prevent wave and spray action,are floated on the water surface under investigation. Water is placed in the pan to within about two inches of the rim. As the contained water evaporates the interior depth is maintained by replenishment and record of such made,due allowance is made for any rainfall occurring as may be noted by the rain gauge located on or near the float. Excessive rates of evaporation,over natural conditions,are set up as follows:

(1) By reason of the capilary creeping,up the sides of the interior of the pan,thus increasing the exposed surface. This capilary film becomes heated from the exposed metallic sides of the pan which project above the water surface of the reservoir and evaporation is accelerated.

(2) There is lost the effect of the thermal circulation constantly taking place in water and the results from the influence and the intimate mixing of the cooler

water from the depths with the warmed surface water which is being constantly reduced by this natural circulation. Thermal circulation occurs,of course,in a pan but because of the limited depth its temperature is kept down only to the extent of the warmer surface strata in the reservoir as it comes in contact with the outer surface of the pan. In the open reservoir the circulation is taking place from top to bottom and with the intimate mixing,or co-mingling,of the warm and cold currents the temperature of the water will be kept lower than that within the confines of the evaporating pan.

The question as to what ratio to accept as between pan observations and actual open water conditions has received the attention of many concerned in the matter but it has been only within the past few months that collective data have been made available,and this through the efforts of Messers Duryea and Haehl,Members of the American Society of Civil Engineers,who,with elaborate attention [redacted] to detail,have made available not only the results of their own observations at Lake Conchos,Northern Mexico,but have collected from wider fields the work of other investigators. The contribution referred to is now,(Nov.1915),being presented in the Proceedings of the American Society of Civil Engineers and,summarized,is as follows:

EVAPORATION FROM LARGE RESERVOIRS.

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Authority.	Location.	Evaporation depth as a proportion of that of a 3-ft. floating pan
F.H.Bigelow,U.S.Weather Bureau,	Salton Sea,	61.4 percent
" " "	" "	60.5 "
F.T.Robson,Mem.Am.Soc.C.E.,	" "	58.8 "
C.E.Grunsky, " " "	" "	64.6 " (a)
Duryea and Haehl " "	Lake Conchos,	64.7 " (b)
Mean, - - - - - - - - - - - - - -		62.4 "

(a) Computed from a broken term and employed as a suggested value.

(b) The conclusions of Messers Duryea and Haehl are: "Evaporation from large reservoirs is certainly less "than 67.5 % (and in all probability as little as "62 %) of that from three-foot square pans floating "thereon". In the above tabulation the mean of 62 % and 67.5 % has been taken,i.e. 62.4 %. In this connection Messers Duryea and Haehl have to say cn page 1752 of Proceedings,Sept.1915,

" * * * * Therefore,the yearly evaporation depth from the surface of Lake Conchos was adopted as sixty-two percent of the evaporation depth from a three-foot square pan floating thereon or from a six-foot square land pan near-by."

In the computations of evaporation from Warner reservoir 65% of floating pan evaporation is used.

As justification for using this value of 65 % of the floating pan evaporation as representing the true evaporation from Warner reservoir extensions of the foregoing tabulation are here given:

Mean ofthe five values previously given,	62.4 %
Mean of Bigelow's two values, - - - - - - -	60.95 %
" " Robson and Grunsky, - - - - - - - -	61.70 %
" " Duryea & Haehl and Bigelow, - - -	62.87 %
" " " " Robson, - - -	61.75 %
" " " " Grunsky, - - -	64.65 %
" " Robson and Bigelow, - - - - - - - -	64.87 %
" " the last six values, -- - - - - - -	62.79 %
Value accepted by Duryea and Hahel, - - -	62.00 %

CREDIT DUE TO RAINFALL ON SURFACE OF RESERVOIR.

It is considered that 10% of the rainfall is accounted for in the stream gaugings and that 90% of the rainfall(which is precipitated directly on the water-surface of the reservoir)should be credited to reservoir accumulations.Had it fallen on brush,timber or grass areas much of the total would have been lost by direct evaporation,absorption by plant life,etc., but falling on a water surface it immediately becomes a part of the storage,and is so considered in this report. To arrive at the value of this gain Table V has been compiled from precipitation records at four stations on the reservoir site,four years of records being available.

The mean of these, year by year, has been compared with precipitation at Warner Springs, adjacent to the reservoir site, where records are available for the past nine years. This relation being established, for determining the rainfall on the reservoir site by the use of Warner Springs records for a nine-year period, the figures have, in turn, been compared with the conditions as shown by the mean of Escondido, Valley Center, Julian and Cuyamaca, otherwise termed the mean of Mountain and Plain, for the same period of time, year by year. The general relation to the latter being thus established the precipitation records have been projected back to 1872-1873. That is, as the mean precipitation varied, from year to year, the amount of rainfall on the reservoir site varied likewise, each varying in the same proportion from its own mean.

Ninety per cent of the measured and the estimated rainfall on the Warner reservoir site is shown in Table VI, Col. (3) and the amount of gain + or loss - to or from the storage due to rainfall gains or evaporation losses will be found in Column (5), as depth in feet. These quantities, + or - , are further used in the storage and draft calculations in Table VIII.

RAINFALL AND RUN-OFF
ON
WARNER WATERSHED.

Table VII is presented as showing the method used in estimating the rainfall on the entire Warner watershed and from which data the Warner run-off curve, Diagram A,was constructed.

In the table referred to are shown the records of precipitation at fifteen stations scattered over the Warner watershed,covering a period of four consecutive years. Comparing these four years records with records for the identical period at Warner Springs,which is practically in the center of the entire watershed, it is found that the general precipitation,over the entire watershed,is 134% of that occurring at Warner Springs, (rain-gauge station No.21), Records at the latter station extend back nine years and by the use of the factor 1.34 the record has been projected back over the period during which measurements were made at Warner Springs.

It is further found,by referring to Table III, Column (2),that the relation of depth of precipitation on the Warner watershed to that of the mean of Escondido, Valley Center,Julian and Cuyamaca,for the same period,is 0.928 or 92.8 %,and in estimating the early unmeasured rainfall on the Warner watershed there has been taken 92.8% of the mean of the four stations named. The calculations are made, year by year, back to 1872-1873.

It will be observed that there have been eliminated from all computations the records at rain-gauge stations #3, Monkey Hill; #16, Nellie; #14, Davis' Mesa Grande and #15, Angel's Mesa Grande. Had these stations been included in the computations the estimated precipitation over the entire watershed would have been appreciably greater and, during "dry" times, would have added sufficiently to the run-off, as accepted, to show a very material increase in the capacity of the watershed as estimated upon in this report. These stations are either uponor very close to the Warner watershed, their locations being shown on the general map. The reason for excluding the records of these stations from this report are:

Station No.3, Monkey Hill. Located in Warner reservoir site. The rain gauge is located on a pinnacle where upward sweeps of wind, coming from the broad valley floor, carry the rain in upward swirls, or eddies, permitting unfair registry at the gauge.

Station No.16, Nellie. Located on the summit of the westerly edge of Warner watershed. This region is prolific in rainfall and unquestionably Warner watershed secures some of the unusually heave precipitation occuring there. The zone affected, however, would be of limited area as compared with the total area dealt with and to average this station in with all others would be adding undue weight to larger areas with less precipitation.

Comparison with Station No.17, Mendenhall Valley, indicates that a greater portion of the precipitation at No.16, Nellie, falls on the westerly slope of the mountain range; some of it undoubtedly blows over the ridge and onto the Warner watershed and while its exclusion militates against a larger water yield of the Warner areas it is felt that the reasons for excluding its records outweigh those that might be presented for its use. In an isohyetal study of the Warner watershed the station records should be used in common will others similarly located but not in the form of analysis adopted in this report.

Station No.14, Davis Mesa Grande. Located south-westerly from the edge of the Warner watershed, distant about 1-1/2 miles from the Warner shed. Excluded from computations for the same reasons as given for Station No.16, Nellie.

Station No.15, Angel's Mesa Grande. Located about 1-1/2 miles south-westerly from the edge of Warner watershed and about three miles north of No.14. Excluded from computations for the same reasons as given for No.14 and No.16.

The records of these stations are not elsewhere given hence are stated below. In reading over these stations it should be carried in mind that the measured mean of the precipitation on Warner watershed is 24.66 inches and with this figure in mind it will be noted that the yield at the excluded stations is, each, greater than the accepted mean for the watershed. To have used them would have beento increase the estimate of the capacity of the watershed.

SEASONAL PRECIPITATION

on or near

WARNER WATERSHED

(July to June)

Year.	Station #3	Station #14	Station #15	Station. #16
L()L#)				
1901-02	----	----	-----	(43.21)
1903-04	----	----	-----	(24.86)
1904-05	----	----	-----	54.71
1905-06	----	47.03	-----	77.44
1906-07	----	33.66	-----	-- --
1907-08	----	27.67	-----	-- --
1908-09	----	36.67	-----	(52.31)
1909-10	----	29.55	----	44.21
1910-11	----	27.75	-----	44.96
1911-12	11.68	27.60	29.28-	39.08
1912-13	9.63	25.65	31.15-	38.59
1913-14	16.45	31.77	36.89	-- --
1914-15	22.34	44.46	33.12°	67.19
MEAN	15.02	30.03	36.77	45.73

° Year 1914-15 for Station 15, four months are missing The entry 33.12 is the actual and reported rainfall and by interpolation with the adjacent station (14) it is determined that the probable year's precipitation at Station 15 was 49.79 inches giving a mean obvr the 4-year period of 36.77 inches as stated in the tabulation.

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Table Vllli is a Draft Sheet showing method of determining the varying areas of Warner reservoir surface during periods of replenishment and draft for the purpose of arriving at evaporation losses during operating conditions. Column headings designate the purpose of the computations as they occur.

This Draft Sheet is computed as a trial for determining,principally,the seasonal evaporation losses, the seasonal gains due to the submerged swamp lands and the gains to be realized from rain falling directly upon the surface of the flooded area.

The method is open to objection in that it considers the inflow,or replenishment,as occurring practically at one time,-at one brief interval of the year. The seasonal run-off,as the figures in Col.(2) are shown,is apparently dumped into the reservoir as though in a single torrent and is all subject,thereafter, to evaporation losses. As a matter of fact the inflow is not spontaneous;periods of freshet occur but instead of drying up abruptly the diminishing streams follow a more even curve and do not cease at any time of the year. "New" water,from which deductions for evaporation should not be made,(and which is a portion of the seasonal run-off), is constantly inflowing and in order to account for this condition and round out the abrupt changes arising from the construction of the draft sheet a mass curve has been prepared,Diagram C,which compensates for the severe assumptions necessarially used in the draft sheet during the course of finding the unknown quantity, x = evaporation area in acres.

The safe yield of the Warner watershed,as shown by the Mass Curve,(Diagram C,is 21,759 acre-feet yearly, covering a cycle of twelve years duration and being the cycle of lowest run-off since the begining of precipitation records at San Diego in the year 1850. It may be said, in passing, that of all the Engineering Reports submitted at various times, by Mr. Hawgood, Mr. Lippincott, Mr. O'Shaughnessy, Mr. Harroun and Mr. Post, all Members of the American Society of Civil Engineers, none has disagreed on the finding that the cycle referred to is the lowest and the most trying on the capacity of the Warner watershed since the begining of the 1850 records, and in this conclusion the writer agrees.

In the Warner reservoir and watershed studies this report goes back to the seasonal year 1872-1873; the begining of the compiled data of precipitation at Escondido, Valley Center, Julian and Cuyamaca, and, assuming an empty reservoir at the start, calculations are then carried forward in order to determine the volume in storage at the begining of the twelve-year dry cycle referred to.

REQUIREMENTS OF THE ESCONDIDO MUTUAL WATER COMPANY.

There are deductions to be made from the gross available run-off of the Warner watershed to satisfy rights recognized as due the Escondido Mutual Water Company, diverting water from the San Luis Rey river below the proposed Warner reservoir. The Volcan Land & Water Company has agreed to protect the Escondido diversion, in the event of the construction of Warner dam, and the consequent stoppage of the stream at that point, by releasing, under certain conditions, certain amounts of water from Warner reservoir for the Escondido Mutual Water Company,-provided the the seasonal run-off conditions would naturally supply these needs with Warner reservoir not in existance. There have been many years when the natural run-off from the watershed lying below Warner reservoir and above the head gate of the Escondido ditch were sufficient, and more, to supply the rights of this latter conduit, while again there have been years when this intermediate watershed has not supplied sufficient water and if, at such times, the natural flow of the branch upon which Warner is located would supply the deficiency (assuming there had been no impounding at Warner) then, with the unrestricted flow warranting it, Warner reservoir would be required to release the deficiency.

While the amounts to be released, if any, depend entirely upon seasonal conditions of run-off the mean annual amounts required for release have been computed as follows:

Harroun, - - - - - - - -	742	acre-feet per annum.
Lippincott & O'Shaughnessy, - -	744	" "
Post, - - - - - - - - -	802	" "
Mean - - - - - - - - -	762	" "

Negotiations are now pending between the Escondido Mutual Water Company and the Volcan Land & Water Company by which it is possible that the Escondido conduit may be reconstructed, increasing its carrying capacity so as to alter, materially, any calculations, made under present conditions.

With an increase in the carrying capacity of the Escondido ditch conditions would be so changed at the Escondido reservoir, as a result of increased amounts diverted from the watershed intermediate to the Escondido diversion point and Warner, that any possible subsequent requirements for release from Warner would be less than under the present conditions of restricted capacity of the Escondido conduit.

Pending such new form of arrangement as may be reached between the two Companies no attempt has been seriously made to determine the amounts that might be required for release.

TABLE I.

ESTABLISHING THE RATIO OF DISCHARGE AT WARNER RESERVOIR SITE WITH STREAM DISCHARGE AT PALA

SAN LUIS REY RIVER.

Seasonal Year. (July-June)	Discharge at Pala.	Escondido Diversion	Escondido plus Pala = total	Discharge at Warner.
1904-05	41,868	2,937	44,805	28,182°
05-06	106,302	1,742	108,000	67,682 M (1)
06-07	84,571	3,319	87,890	55,282°
07-08	24,850	2,705	27,555	17,311°
08-09	48,120	3,488	51,608	32,461°
09-10	47,086	2,686	49,772	31,306°
10-11	32,257	3,212	35,469	22,310°
11-12	16,860	2,562	19,422	12,036 M
12-13-	6,278	4,256	10,534	5,944 M
13-14	29,942	5,783	35,725	22,859 M
14-15	87,306	6,326	93,632	59,856 M

° Calculated from the measured discharge at Pala, being 62.9% of the latter.

M = Measured discharge.

The sum of the "M" discharges at Warner is 62.9% of the sum of the measured discharges at Pala for corresponding years.

(1) The actual measured discharge at Warner in 1905-06 was 66,957 acre-feet. To this amount has been added 725 acre-feet which was the unmeasured sub-flow at that point at that time as was developed by the construction of the out-off wall at Warner dam site.

TABLE II.

MEAN PRECIPITATION OVER MOUNTAIN AND PLAIN.

$$\frac{\left(\frac{\text{Escondido+Valley Center}}{2}\right) + \left(\frac{\text{Julian + Cuyamaca}}{2}\right)}{2} = \text{Mean.}$$

Year	(1) Combined Mean of Escondido and Valley Ctr.	(2) Combined Mean of Julian & Cuyamaca	(3) Mean of Columns (1) & (2)	(4) Items in Col. (3) are % of mean of 26.47"
1872-73	10.02	19.00 x	14.51	54.8
73-74	32.20	61.00 x	46.60	176.0
74-75	11.35	21.35 x	16.35	61.8

	Valley Ctr.		Cuyamaca			26.47"
1872-73	10.02		19.00	x	14.51	54.8
73-74	32.20		61.00	x	46.60	176.0
74-75	11.35		21.35	x	16.35	61.8
75-76	20.10		38.00	x	29.05	110.0
76-78	8.58		16.20	x	12.39	47.0
77-78	26.65		50.50	x	38.52	146.0
78-79	8.58		16.00	x	17.39	65.8
79-80	22.19		42.00	x	32.09	121.0
80-81	13.35		25.20	x	19.27	73.0
81-82	13.46		25.50	x	19.48	73.8
82-83	9.82		18.70	x	14.26	54.0
83-84	41.28		78.00	x	59.64	226.0
84-85	11.38		21.45	x	16.41	62.0
85-86	25.71		48.50	x	37.10	140.0
86-87	12.11		22.75	x	17.43	66.0
87-88	19.82	a	19.82	b	19.82	75.0
88-89	22.48	a	47.00	b	34.74	131.0
89-90	25.68	a	64.80	b	45.24	171.0
90-91	20.75	a	54.09	b	37.42	142.0
91-92	14.83	a	40.93	b	27.88	105.0
92-93	19.48	a	34.55	b	27.01	102.0
93-94	7.90	a	31.93	b	19.91	75.0
94-95	21.63	a	43.29	b	32.46	123.0
95-96	9.93	a	16.70	b	13.31	50.5
96-97	19.75	a	31.04	b	25.39	96.0
97-98	9.80	a	19.50	b	14.60	55.0
98-99	11.45	a	17.05	b	14.25	53.8
99-00	16.74	a	24.52	b	20.63	78.0
1900-01	17.40	a	33.78	b	25.59	98.0
01-02	14.03	a	30.21	b	22.12	84.0
02-03	21.40	a	33.67	b	27.53	104.0
03-04	9.85	a	19.39	b	14.62	55.2
04-05	28.34	a	49.24	b	38.79	147.0
05-06	30.74	a	50.80	b	40.77	154.0
06-07	21.62	a	38.70	b	30.16	114.0
07-08	16.16	a	37.42	b	26.79	101.2
08-09	21.96	a	36.72	b	29.34	110.5
09-10	22.76	a	28.64	b	25.70	97.5
10-11	18.62	a	30.25	b	24.43	92.2
11-12	17.72	a	29.29	b	23.50	89.0
12-13	10.14	a	25.92	b	18.03	68.0
13-14	19.96	a	34.93	b	27.44	104.0
14-15	26.62	a	54.28	b	40.45	153.0

Mean of 43 years - - - - - - - - 26.47

The sum of "b" items is 189% of the sum of the items designated with "a" and the unmeasured period, x, at Julian and Cuyamaca is taken as 189% of the mean, for the given years, at Escondido and Valley Center.

TABLE III.

RAINFALL AND RUN-OFF

WARNER WATERSHED.

Showing method of computing same as basis for Log.run-off curve on Diagram A.

Year. --- July and June.	Mean of Mountain and Plain (Rain, in inches)	Rainfall on Warner Watershed (inches)	Rainfall at Warner Springs (Inches)	Run-off at Warner. Estimated and Measured. (Acre Feet)
	(1)	(2)	(3)	(4)
1872-73	14.51	13.46		3900
73-74	46.60	43.24		103000
74-75	16.35	15.17		5200
75-76	29.05	26.95		27000
76-77	12.39	11.50		2400
77-78	38.52	35.74		59200
78-79	17.39	16.14		6300
79-80	32.09	29.78		35500
80-81	19.27	17.88		8400
81-82	19.48	18.08		8600
82-83	14.26	13.33		3700
83-84	59.64	55.34		200000
84-85	16.41	15.22		5400
85-86	37.10	34.42		53100
86-87	17.43	16.17		6350
87-88	19.82	18.59		9250
88-89	34.74	32.24		44400
89-90	45.24	41.98		93000
()-(L	37.42	34.72		54500
91-92	27.88	25.87		23900
92-93	27.01	25.06		21900
93-94	19.91	18.47		9200
94-95	32.46	30.12		36800
95-96	13.31	12.35		2900
96-97	25.39	23.56		18500
97-98	14.60	13.55		3820
98-99	14.25	13.22		3600
99-00	20.63	19.14		10100
1900-01	25.59	23.74		19000
01-02	22.12	20.52		15000
02-03	27.53	25.54		23100
03-04	14.62	13.56		3825
04-05	38.79	35.89		26182 (I)
05-06	40.77	37.83		67682 (M)
06-07	30.16	31.12	23.23 M	55282 (I)
07-08	26.79	21.31	15.91 M	17311 (I)
08-09	29.34	23.69	17.68 M	32461 (I)
09-10	25.70	30.08	22.45 M	31306 (I)
10-11	24.43	23.43	17.49 M	22310 (I)
11-12	23.50	20.45 M	14.06 M	12036 (M)
12-13	18.03	17.28 M	18.81 M	5944 (M)
13-14	27.44	25.87 M	18.55 16 M M	29659 39856 (M) 22659 39856
~~14-15~~	~~40.45~~	~~35.06 M~~	~~27.16~~	

From o5-06, 92.8% of amounts in Column (1) are taken.

TABLE V.

RAINFALL ON WARNER RESERVOIR.

****

PRECIPITATION IN INCHES.

Station.	1911-12	1912-13	1913-14	1914-15
1 - - - -	26.31 - - -	19.58	31.77	43.70
2 - - - -	26.15	23.46	34.97	46.39
4 - - - -	15.26	11.93	19.31	27.76
5 - - - -	14.20	11.53	19.52	28.06
Mean - -	20.48	16.62	26.39	36.47

Seasonal Year.	Mean for Warner Res'voir	Mean for Mountain & Plain	Warner % of Mt.& Pl.	Warner Springs Sta.#21	Warner Res, = % of Warner Sp'gs.
1911-12	20.48	23.50	87.1	14.06	145.6
1912-13	16.62	18.03	92.1	13.81	120.3
1913-14	26.39	27.44	96.1	18.55	142.2
1914-15	36.47	40.45	90.1	27.16	134.2
Mean - - -	24.99	27.35	91.1	18.39	135.8

The precipitation on Warner reservoir site being thus established at 135.8 % of the precipitation at Warner Springs, we have:-

Seasonal Year.	Rain at Warner Sp'gs Measured.		Rain on Warner Reser'vr	Mean of Rain on Mt.& Plain.	Rain on Warner Res. is % of Mt.& Plain.
1906-07	23.23	x 135.8% =	31.54	30.16	
1907-08	15.91	" =	21.60	26.79	
1908-09	17.68	" =	23.00	29.34	
1909-10	22.45	" =	30.48	25.70	
1910-11	17.49	" =	23.65	24.43	
1911-12	14.06)	4-year	(20.48	23.50	
1912-13	13.81)	mean, meas-	(16.62	18.03	
1913-14	18.55)	ured,=	(26.39	27.44	
1914-15	27.16)	135.8 %	(36.47	40.45	
(9-Yr. Mean,			25.58	27.31	(93.66 %

TABLE VI.

RAINFALL ON WARNER RESERVOIR.

	(1)	(2)	(3)	(4)	(5)
Year. July-June.	Mean of Mount'n and Plain. (Precipi-tation)	Rainfall on Warner Reservoir (Inches)	90 % of rain on Resvoir (Inches)	Evaporat-ion of 36" minus- Col. (3) (Inches)	LOss Or Gain due to rain or evaporation. (Feet)
1872-73	14.51		12.18	- 23.82	- 1.98
1873-74	46.60		39.14	± 3.14	+ .26
1874-75	16.35		13.73	- 12.27	- 1.02
75-76	29.05		24.40	- 11.60	- .96
76-77	12.39		10.40	- 25.60	- 2.13
77-78	38.52		32.35	- 3.65	- .30
78-79	17.39		14.60	- 21.40	- 1.78
79-80	32.09		26.95	- 9.05	- .75
80-81	19.27		16.18	- 19.82	- 1.65
81-82	19.48		16.36	- 19.64	- 1.63
82-83	14.26		11.97	- 24.03	- 2.00
83-84	59.64		50.09	+ 14.09	+ 1.77
84-85	16.41		13.77	- 22.23	- 1.85
[illegible]	37.10		31.16	- 4.84	- .40
86-87	17.43		14.64	- 21.36	- 1.77
87-88	19.82		16.65	+ 19.35	- 1.61
88-89	34.74		29.18	- 6.82	- .57
89-90	45.24		37.99	+ 1.99	+ .16
90-91	37.42		31.43	- 4.57	- .38
91-92	27.88		23.41	- 12.59	- 1.05
92-93	27.01		22.68	- 13.32	- 1.11
93-94	19.91		16.72	- 19.28	- 1.60
94-95	32.46		27.26	- 8.74	- .72
95-96	13.31		11.17	- 24.83	- 2.07
96-97	25.39		21.34	-14.66	-1.22
97-98	14.60		12.26	- 23.74	- 1.98
98-99	14.25		11.97	- 24.03	- 2.00
99-00	20.63		17.32	- 18.68	- 1.55
1900-01	25.59		21.49	- 14.51	- 1.21
01-02	22.12		18.58	-17.42	- 1.45
02-03	27.53		23.12	- 12.88	- 1.07
03-04	14.62		12.28	- 23.72	- 1.98
04-05	38.79		32.58	- 3.42	- .28
05-06	40.77		34.26	- 1.74	- .14
06-07	30.16	31.54 c	28.38	- 7.62	- .63
07-08	26.79	21.60 c	22.44	- 13.56	- 1.10
08-09	29.34	23.00 c	20.70	- 15.30	- 1.27
09-10	25.70	30.48 c	27.43	- 8.57	- .71
10-11	24.43	23.65 c	21.28	- 14.72	- 1.22
11-12	23.50	20.48 M	18.43	- 17.57	- 1.46
12-13	18.03	16.62 M	14.96	- 21.04	- 1.75
13-14	27.44	26.39 M	23.75	- 12.25	- 1.02
14-15	40.45	36.47 M	33.82	* 2.18	- .18

c = Computed from precipitation at Warner Springs.
M = Measured.

TABLE VII.

RAIN ON WARNER WATERSHED.

(Inches in Depth)

Station.	1911-12	1912-13	1913-14	1914-15
1	26.31	19.58	31.77	43.70
2	20.15	23.46	34.97	46.39
4	15.26	11.93	19.31	27.76
5	14.20	11.53	19.52	28.06
6	18.06	12.19	23.81	32.45
17	30.38	24.05	37.40	42.00
19	16.09	13.53	26.02	34.34°
20	10.88	11.32	17.17	22.66°
21	14.06	13.81	18.55	27.16
23	21.28	15.56	26.42	32.21
24	19.25	16.93	24.74	35.13
25	32.93	32.83	32.77	46.90
32	17.58°	14.39	18.80	20.18
58	26.63°	20.53	29.73	44.32
59	23.79°	17.70	27.20	42.71
Mean	20.45	17.28	25.87	35.06

SEASONAL RAINFALL.

1911-12 ---- 20.45
1912-13 ---- 17.28
1913-14 ---- 25.87
1914-15 ---- 35.06

4-Year mean, 24.66

° Interpolated.

Year (July-June)	(1) Acre Ft. in Res. at begining of Year.	(2) Seasonal Run-off Estimated Acre Feet	(3) Draft in Wet Season Acre Feet	(4) Acre Ft. Stored or Withdrawn	(5) In Res. End Wet Season (1)+or-(4)	(6) Draft During Dry Se
1872-73	0	3900°	0	+ 3900	0	
73-74	3342	103000°	7000	+ 96000	99342	1400
74-75	85304	5200°	7000	- 1800	83504	1400
75-76	66409	27000°	7000	+ 20000	86409	1400
76-77	71403	2400°	7000	- 4600	66803	1400
77-78	49510	59200°	7000	+ 52200	101714	1400
78-79	87444	6300°	7000	- 700	86744	1400
79-80	69749	35500°	7000	+ 28500	98249	1400
80-81	83454	8400°	7000	+ 1400	84854	1400
81-82	68311	8600°	7000	+ 1600	69911	1400
82-83	53721	3700°	7000	- 3300	50421	1400
83-84	34006	200000°	7000	+ 82994	117000	1400
84-85	105904	5400°	7000	- 1600	104304	1400
85-86	86519	53100°	7000	+ 30481	117000	1400
86-87	103552	6350°	7000	- 650	102902	1400
87-88	85412	9250°	7000	+ 2250	87662	1400
88-89	71181	44400°	7000	+ 37400	108581	1400
89-90	94277	93000°	7000	+ 22723	117000	1400
90-91	105962	54500°	7000	+ 11038	117000	1400
91-92	104331	23900°	7000	+ 12669	117000	1400
92-93	101768	21900°	7000	+ 14900	116668	1400
93-94	101173	9200°	7000	+ 2200	103373	1400
94-95	86475	36800°	7000	+ 29800	116275	1400
95-96	101776	2900°	7000	- 4100	97616	1400
96-97	79363	18500°	7000	+ 11750	91193	1400
97-98	75540	3820°	7000	- 3180	72360	1400
98-99	55340	3600°	7000	- 4400	50940	1400
99-00	34545	10100°	7000	+ 3100	37645	1400
1900-01	22393	19000°	7000	+ 12000	34393	1400
01-02	19626	15000°	7000	+ 8000	27626	1400
02903	12682	23100°	7000	+ 16100	28682	1400
03-04	14056	3825°	5810Δ	- 1985	12071	1161
04-05	94	28182° I	7000	+ 21182	21276	1400
05-06	7311	67682 M	7000	+ 60682	67993	1400
06-07	53722	55282 I	7000	+ 48282	102004	1400
07-08	86900	17311 I	7000	+ 10311	97211	1400
08-09	81868	32461 I	7000	+ 25461	107329	1400
09-10	90906	31306 I	7000	+ 24306	115212	1400
1910-11	99904	22310 I	7000	+ 15310	115214	1400
11-12	98244	12036 M	7000	+ 5036	103280	1400
12-13	86786	5944 M	7000	- 1056	85730	1400
13-14	68921	22659 M	7000	+ 15659	84580	1400
14-15	69593	60435 ~~59856~~ M	7000	+ 47407	117000	1400
15-16	103576	1,276,453				

I=Interpolated/Pala. ° Estimated. M=Measured.

TABLE VIII.

DRAFT SHEET FOR WARNER RESERVOIR.

STORAGE CAPACITY - 117,000 ACRE FEET.

= (5) n Res. En[d] et Seaso[n] 1)+or-(4	(6) Draft During Dry Season	(7) Amt. in Res. End of Dry Season. (5)-(6)	(8) Mean Area due to (10 & (5) for Rain Gains	(10) 90% Of Rain on Res. in feet.	(11) Gain by Rainfall (8)x(10)	(12) Mean Area due to (5)&(7) for Evaporath Loss	(Sw La Ga du ar
0	0	3900	280	1.01	282	280	
99342	14000	85342	2200	3.26	7172	3130	2
83504	14000	69504	3040	1.14	3465	2320	1
86409	14000	72409	2820	2.03	5724	2890	1
66803	14000	52803	2630	.86	2261	2400	1
101714	14000	87714	2800	2.70	7560	3360	2
86744	14000	72744	3120	1.21	3775	2910	1
98249	14000	84249	3020	2.24	6765	3240	2
84854	14000	70854	3020	1.35	4077	2840	1
69911	14000	55911	2625	1.36	3570	2480	1
50421	14000	36421	3215	1.00	2215	2010	1
117000	14000	103000	2790	4.17	11634	3830	2
104304	14000	90304	3600	1.14	4195	3420	2
117000	14000	103000	3570	2.60	9282	3830	2
102902	14000	88902	3620	1.22	4416	3390	2
87662	14000	73662	3100	1.39	4309	2920	1
108581	14000	94581	3200	2.43	7976	3560	2
117000	14000	103000	3700	3.16	11692	3830	2
117000	14000	103000	3840	2.62	10061	3830	
117000	14000	103000	3845	1.95	7498	3830	
116668	14000	102668	3820	1.87	7220	3825	
103373	14000	89373	3580	1.40	5012	3395	
116275	14000	102275	3560	2.27	8081	3800	
97616	14000	83616	3545	.93	3297	3230	
91193	14000	77113	3060	1.78	5447	3020	
72360	14000	58360	2750	1.02	2805	2520	
50940	14000	36940	2240	1.00	2240	2020	
37645	14000	23645	1840	1.45	2668	1710	
34393	14000	20393	1650	1.79	2953	1620	
27626	14000	13626	1530	1.55	2371	1445	
28682	14000	14682	1445	1.92	2774	1475	
12071	11620Δ	451	1180	1.02	1203	720	
21276	14000	77276	1050	2.71	2845	1230	
67993	14000	53993	1880	2.85	5358	2435	
102004	14000	88004	2850	2.36	6726	3360	
97211	14000	83211	3290	1.87	6152	3210	
107329	14000	93329	3250	1.72	5762	3520	
115212	14000	101212	3615	2.28	8242	3770	
115214	14000	101214	3760	1.75	6580	3770	
103280	14000	89280	3540	1.53	5416	3390	
85730	14000	71730	3085	1.25	3856	2875	
84580	14000	70580	2825	1.98	5593	2835	
117000	14000	103000	3300	2.82	9306	3830	

Δ = 83% Of usual draft.

(12) Mean Area due to (5)&(7) for Evap'n Loss	(13) Swamp Land Gains due to area(12)	(14) Total Gains (11)+(13) Rain & Swamps	(15) Evap'n Loss (12)x3 ft.	(16) Algebraic sum(14)&(15)	(17) Amt. in Res End of Year (7)-(16)	(18) Overflow from Res.	Year. (July-June.)
280	0	282	840	- 558	3342	------	1872-73
3130	2180	9352	9390	- 38	85304	------	1873-74
2320	1900	5365	8460	- 3095	66409	------	1874-75
2890	1940	7664	8670	- 1006	71403	------	1875-76
2400	1650	3911	7200	- 3289	49514	------	1876-77
3360	2250	9810	10080	- 270	87444	------	1877-78
2910	1960	5735	8730	- 2995	69749	------	1878-79
3240	2160	8925	9720	- 795	83454	------	1879-80
2840	1900	5977	8520	- 2543	68311	------	1880-81
2480	1680	5250	7440	- 2190	53721	------	1881-82
2010	1400	3615	6030	- 2415	34006	------	1882-83
3830	2760	14394	11490	+ 2904	105904	110006	1883-84
3420	2280	6475	10260	- 3785	86519	------	1884-85
3830	2760	12042	11490	+ 552	103552	15619	1885-86
3390	2260	6676	10170	- 3490	85412	------	1886-87
2920	1970	6279	8760	- 2481	71181	------	1887-88
3560	2400	10376	10680	- 304	94277	------	1888-89
3830	2760	14452	11490	+ 2962	105962	63277	1889-90
3830	2760	12821	11490	+ 1331	104331	36462	1890-91
3830	2760	10258	11490	- 1232	101768	4231	1891-92
3825	2760	9980	11475	- 1495	101173	------	1892-93
3395	2275	7287	10185	- 2898	86475	------	1893-94
3800	2760	10841	11400	- 559	101716	------	1894-95
3230	2140	5437	9690	- 4253	79363	------	1895-96
3020	2040	7487	9060	- 1573	75540	------	1896-97
2520	1735	4540	7560	- 3020	55340	------	1897-98
2020	1425	3665	6060	- 2395	34545	------	1898-99
1710	1210	3878	5130	- 1252	22393	------	1899-00
1620	1140	4093	4860	- 767	19626	------	1900-01
1445	1020	3391	4335	- 944	12682	------	1901-02
1475	1025	3799	4425	- 626	14056	------	1902-03
720	600	1803	2160	- 357	94	* *	1903-04
1230	880	3725	3690	+ 35	7311	------	1904-05
2435	1675	7033	7305	- 272	53722	------	1905-06
3360	2250	8976	10080	- 1704	86900	------	1906-07
3210	2135	8287	9630	- 1343	81868	------	1907-08
3520	2375	8137	10560	- 2423	90906	------	1908-09
3770	2760	11002	11310	- 1308	99904	------	1909-10
3770	2760	9340	11310	- 1970	98244	------	1910-11
3390	2260	7676	10170	- 2494	86786	------	1911-12
2875	1960	5816	8625	- 2809	68921	------	1912-13
2835	1925	7518	8505	- 987	69593	------	1913-14
3830	2760	12066	11490	+ 576	103576	5449	1914-15

* * Deficiency of 3496 Ac.Ft.

TABLE IX

MASS CURVE COMPUTATIONS- WARNER RESERVOIR.

Seasonal Year.	(1) Natural Stream Flow. Acre Ft.	(2) Gain from 90% of rain on Res'voir Acre Feet.	(3) Gain from Swamp Land Conservatn Acre Feet.	(4) Gross Amt. Securable- all sources (1)+(2)+(3)	(5) Evaporat Losses f Reservoi Acre F
1872-73	3900	282	0	4182	840
73-74	103000	7172	2180	112352	9390
74-75	5200	3465	1900	10565	[illegible]460
75-76	27000	5724	1940	34664	9870
76-77	2400	2261	1650	6311	7200
77-78	59200	7560	2250	69010	10080
78-79	6300	3775	1960	12035	8750
79-80	35500	6765	2160	44425	9780
80-81	8400	4077	1900	14377	[illegible]520
81-82	8600	3570	1680	13850	[illegible]440
82-83	3700	2215	1400	7315	[illegible]030
83-84	200000	11634	2760	214394	11490
84-85	5400	4195	2280	11875	10260
85-86	53100	9282	2760	65142	11490
86-87	6350	4416	2260	13026	10170
87-88	9250	4309	1970	15529	8760
88-89	44400	7976	2400	54776	10680
89-90	93000	11692	2760	107452	11490
90-91	54500	10061	2760	67321	11490
91-92	23900	7498	2760	34158	11490
92-93	21900	7220	2760	31880	11475
93-94	9200	5012	2275	16487	10185
94-95	36800	8081	2760	47641	11400
95996	2900	3297	2140	8337	[illegible]890
96-97	18500	5447	2040	25987	9060
97-98	3820	2805	2735	8360	7560
98-99	3600	2240	1425	7265	8060
99-00	10100	2668	1210	13978	8130
1900-01	19000	2953	1140	23093	[illegible]860
01-02	15000	2371	1020	18391	[illegible]335
02-03	23100	2774	1025	26899	[illegible]425
03-04	3825	1203	600	5628	[illegible]160
04-05	28182	2845	880	31907	[illegible]690
05-06	67682	5358	1675	74715	[illegible]505
06-07	55282	6726	2250	64258	10080
07-08	17311	6152	2135	25598	9630
08-09	32461	5762	2375	40598	10560
09-10	31306	8242	2760	42308	11310
10-11	22310	6580	2760	31650	11310
11-12	12036	5416	2260	19712	10170
12-13	5944	3856	1960	11760	8625
13-14	22659	5593	1925	30177	8505
14-15	59856	9306	2760	71922	11490
TOTAL	1275874	229836	85600	1591310	371415

SERVOIR.

	(5)	(6)	(7)	
. - es 3)	Evaporation Losses from Reservoir. Acre Ft.	Net Amount available, Col (4)-(5) for Diversion.	Mass Accumulations from Col.(6) for plotting Mass Curve.	Seasonal Year. July to June. Inc.
	840	3342	3342	1872-73
2	9390	102962	106304	73-74
	8460	2105	108409	74-75
	8670	25994	134403	75-76
	7200	- 889	133514	76-77
	10080	+ 58930	192444	77-78
	8750	3305	195749	78-79
	9780	34705	230454	79-80
	8520	5857	236311	80-81
	9440	6410	242721	81-82
	9030	1285	244006	82-83
	11490	202904	446910	83-84
	10260	1615	448525	84-85
	11490	53652	502177	85-86
	10170	2856	505033	86987
	9760	6769	511802	87-88
	10680	44096	555898	88-89
	11490	95962	651860	89-90
	11490	55831	707691	90-91
	11490	22668	730359	91-92
	11475	20405	750764	92-93
	10185	6302	757066	93-94
	[illegible]	36241	793307	94-95
	[illegible]	- 1353	791954	95-96
	[illegible]	+ 16927	808881	96-97
	[illegible]	800	809681	97-98
	9060	1205	810886	98-99
	9130	8848	819734	99-00
	[illegible]	18233	837967	1900-01
	[illegible]	14056	852023	01-02
	4425	22474	874497	02-03
	2160	3468	877965	03-04
	[illegible]	28217	906182	04-05
	7805	67410	973592	05-06
	10080	54178	1027770	06-07
	9930	15968	1043738	07-08
	10560	30038	1073776	08-09
	11310	30998	1104774	09-10
	11310	20340	1125114	10-11
	10170	9542	1134656	11-12
	8625	3135	1137791	12-13
	6505	21672	1159463	13-14
	11490	60432	1219895	14-15
	371610	1219895	1219895	TOTAL.

TABLE X.

In laying down the Mass Curve, Diagram C, allowance has been made for the depletion of Warner reservoir in the extremely dry year of 1903-04 as indicated on the Draft Sheet, Table VIII, page 34, and for the purpose of determining the capacity of the watershed with this allowance, for depletion, the Mass Accumulations in Table IX, page 35, have been constructed as given below.

WARNER ACCUMULATIONS.
From 1903-04 with allowance for reservoir depletion, in 1903-04, of 3,496 acre-feet. Capacity of reservoir= 117,000 A.F.

Year.	Mass Accumulations.
1903-04	874469
1904-05	902686
1905-06	970096
1906-07	1024274
1907-08	1040242
1908-09	1070280
1909-10	1101278
1910-11	1121618
1911-12	1131160
1912-13	1134295
1913-14	1155967
1914-15	1216399

For use in construction of Diagram C, page 40.

All figures are in Acre-feet.

TABLE XI.

CHECKING THE DEPENDABILITY OF THE RUN-OFF CURVE SHOWN ON DIAGRAM A.

Seasonal Year.	(1) Total Run-off at Pala.	(2) Total Run-off at Warner. Estimated° and Measured, M.	(3) Total Run-off at Warner as read by the Log.Curve.
1903-04	7396	4652°	3875
04-05	44805	28182°	59600
05-06	108044	67682 M	69000
06-07	87890	55282°	40000
07-08	27555	17311°	13500
08-09	51608	32461°	18500
09-10	49772	31306°	36100
10-11	35469	22310°	18000
11-12	19422	12036 M	12500
12-13	10534	5944 M	7800
13-14	35725	22659 M	24000
14-15	93632	59856 M	56100
Total,	571852	359681	358975
Mean,	47654	29973	29914

° Estimated by comparison with discharge at Pala.(Measured)
All figures are in Acre Feet.

Mean of 12-year period, from measurements, - - - 29973 Ac.Ft.
" " " " " Log.Curve, - - - - 29914 "
Difference, - 59 "

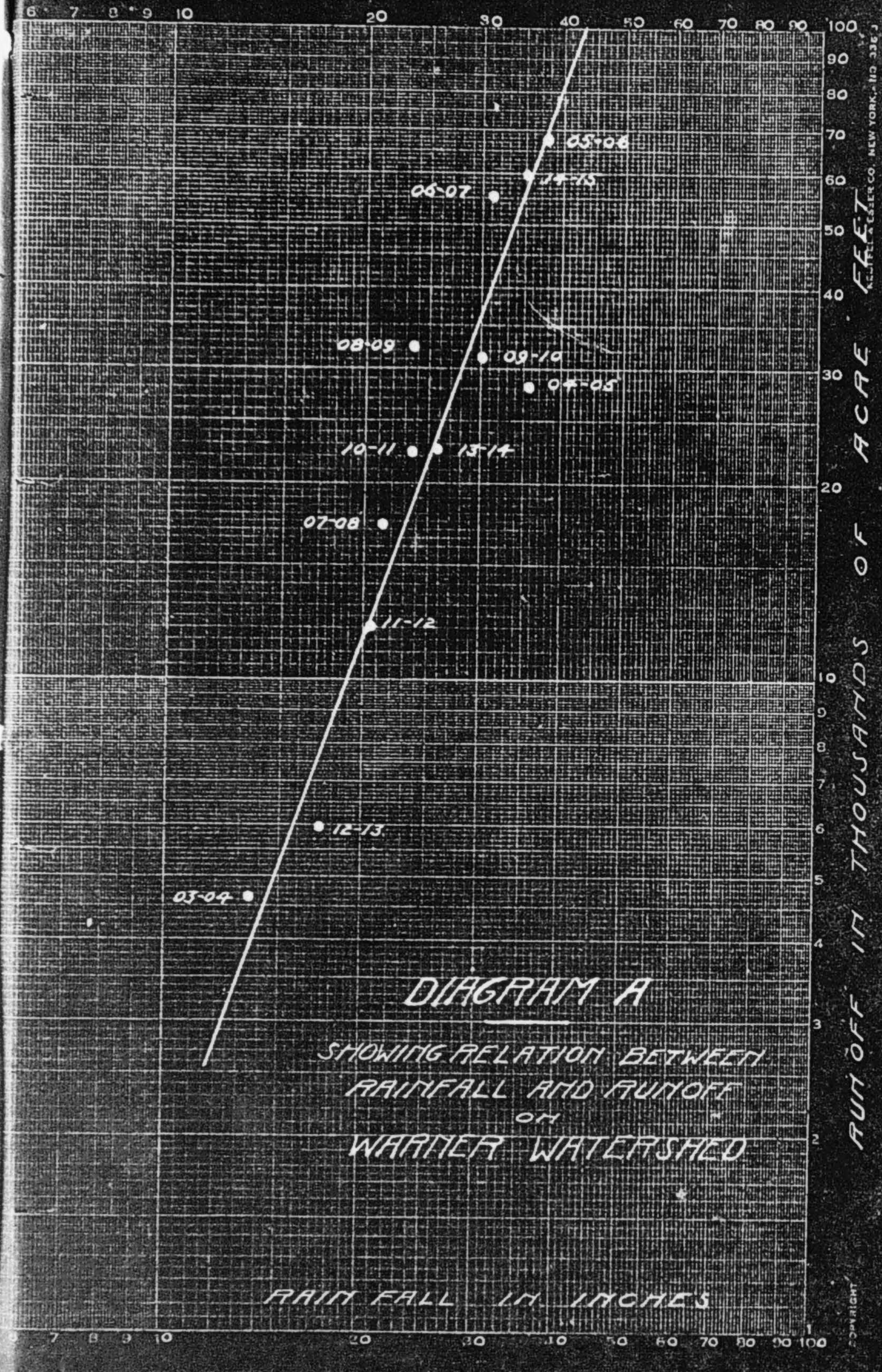
59 ÷ 29973 = 0.0019 = 0.0019 % underestimated by the use of the Log.Curve readings over a period of twelve years.

FOUR YEAR PERIOD.

Seasonal Year.	Warner Run-off by measurement.	Warner Run-off by Log.Curve.
1911-12	12,036	12,500
1912-13	5,944	7,800
1913-14	22,659	24,000
1914-15	59,856	56,100
Total,	100,495	100,400
Mean, - - - - -	25,124 - - - - - - -	25,100

Difference between means = 24 and this divided by 25,124 = 0.0009 or 0.0009 % underestimated by the Log.curve readings

For text relating to this table refer to page 7.



Text references on pages

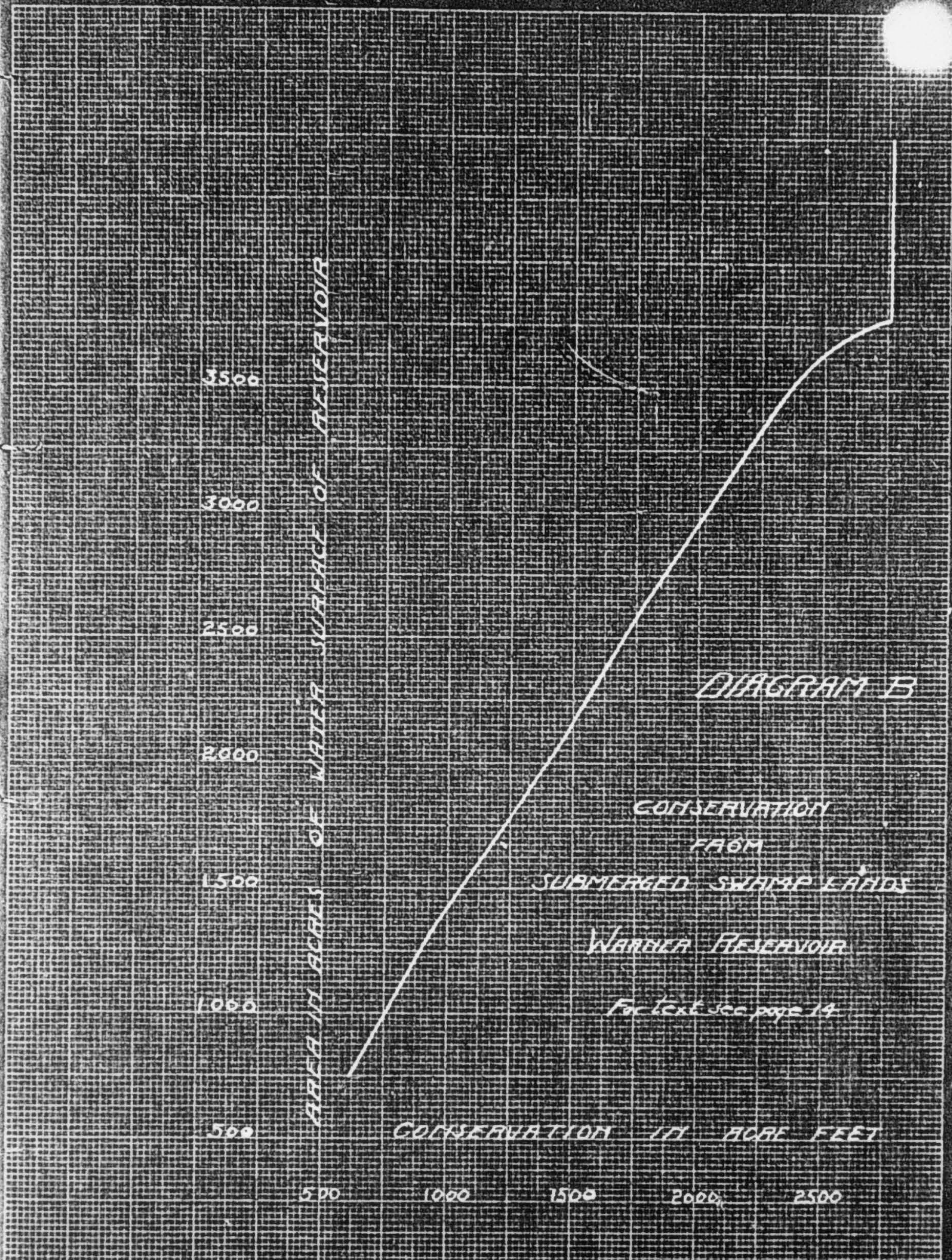


DIAGRAM B
CONSERVATION
FROM
SUBMERGED SWAMP LANDS
WARNER RESERVOIR
For text see page 14
AREA IN ACRES OF WATER SURFACE OF RESERVOIR
3500
3000
2500
2000
1500
1000
500
CONSERVATION IN ACRE FEET
500
1000
1500
2000
2500

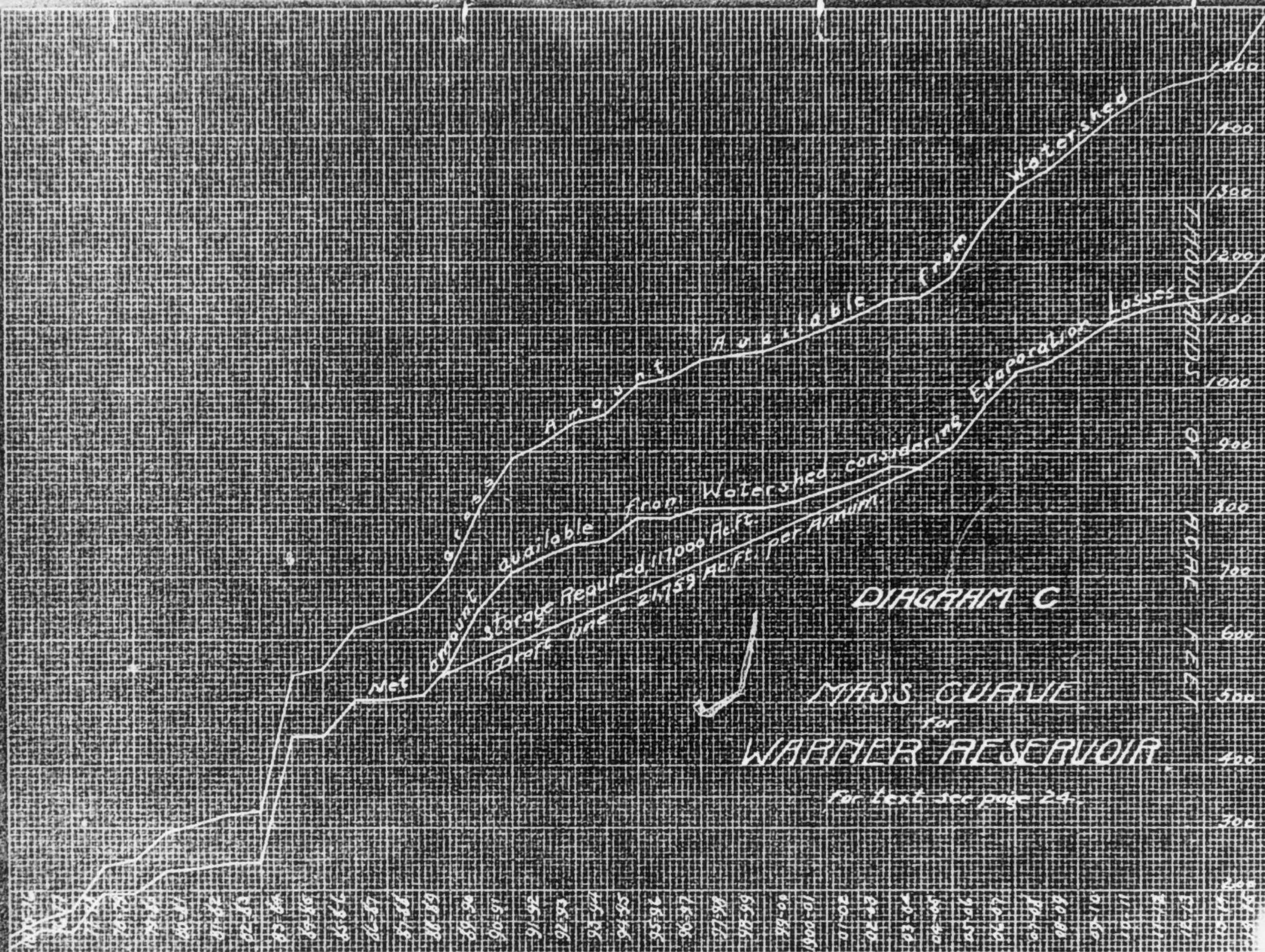


DIAGRAM C
MASS CURVE
for
WARNER RESERVOIR
For text see page 24.
THOUSANDS OF ACRE FEET
Gross Amount Available from Watershed
Net amount available from Watershed considering Evaporation Losses
Storage Required 117000 Ac.Ft.
Draft line - 24759 Ac.Ft. per Annum
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200

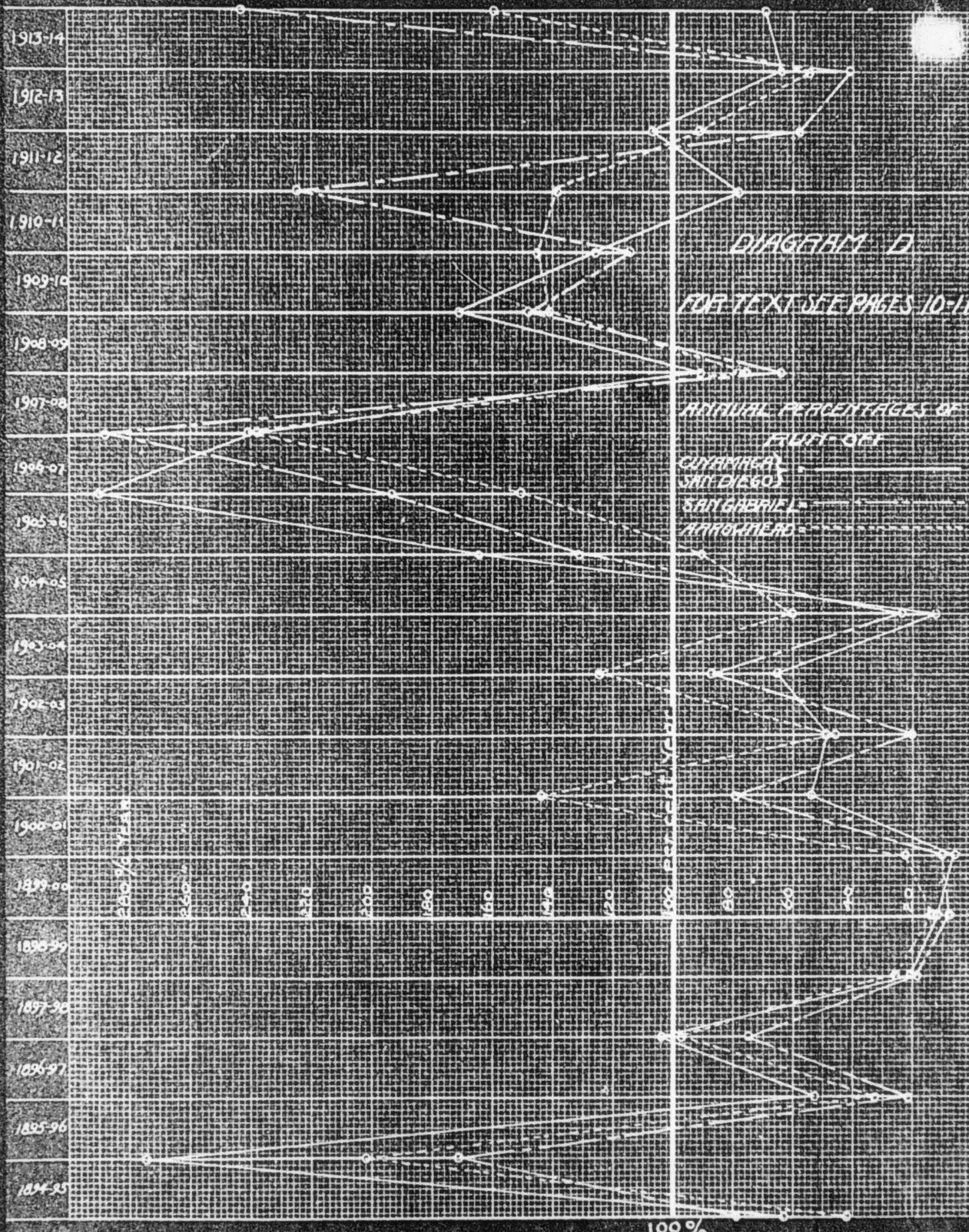


DIAGRAM D
FOR TEXT SEE PAGES 10-11
ANNUAL PERCENTAGES OF RUN-OFF
CUYAMACA
SAN DIEGO
SAN GABRIEL
ARROWHEAD
1913-14
1912-13
1911-12
1910-11
1909-10
1908-09
1907-08
1906-07
1905-06
1904-05
1903-04
1902-03
1901-02
1900-01
1899-00
1898-99
1897-98
1896-97
1895-96
1894-95
260
240
220
200
180
160
140
120
80
60
40
20
100%