5/8/15

Report on

THE VOLCAN LAND AND WATER COMPANY

to the

CITY OF SAN DIEGO, CALIFORNIA

by

M. M. O'SHAUGHNESSY, Mem. Am. Soc. C. E.

and

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I N D E X

TABLES

LIST OF DRAWINGS

San Francisco, California,
May 8th, 1915.

To the Honorable City Council,

City of San Diego, California.

Gentlemen:

In accordance with authority granted under your Ordinance No. 5985, your engineers have made a study of the undeveloped water system owned by the Volcan Land and Water Company, which study is herewith appended.

We have been asked to report upon:-

First: "The reasonable value of said system in its present condition."

We find this value to be $2,880,625. land and water rights.

ESTIMATE OF VALUE OF RESERVOIRS, RIGHTS OF WAY AND WATER RIGHTS.

For an undeveloped system this subject presents a very complex problem. Great enterprise has been exercised in procuring practically the entire available riparian rights to the San Luis Rey River and at a very heavy outlay. Considerable rights have also been acquired on the Santa Ysabel River below the diversion points and in the hydrographic studies due allowance has been made for released water to compensate fully all legitimate demands by adjacent users. On the most conservative basis, the following elements of value may be applied to the different units of this system:-

RESERVOIR LANDS TO BE CONVEYED:

Warner's	2960	acres	@ $100.	per	acre,	$296,000
Pamo	654	"	" 150.	"	"	98,100
San Clemente	166	"	" 200.	"	"	33,200
Carroll	829	"	" 75.	"	"	62,175
Sutherland	127	"	" 100.	"	"	12,700
Santa Maria	80	"	" 100.	"	"	8,000
Total	4817					$510,175

Your engineers are not assuming to pass on the title of the riparian rights or other realty holdings of the Volcan Land & Water Company. A certain schedule of these properties has been submitted to the City of San Diego and referred to us by the Volcan Land & Water Company, which shows the character and extent of these rights, which we are assuming in this report to be correct. It will be necessary before any purchases are made by the city for your City Attorney to review these titles as well as contracts with certain claimants to water, such as the Escondido Irrigation District, Indian rights, and small canals along the Santa Ysabel River.

RIGHTS OF WAY:

Surveys, rights of way, test borings, hydrographic data, etc., actual outlay	$240,000.

WATER RIGHTS:

While the most careful computations conclusively prove a productiveness of 1647 miner's inches of water from this system, your engineers believe that economic development would warrant us in estimating for purpose of purchase 1467 inches at $1000. per miner's inch,	1,467,000.

This allowance of $1000. per miner's inch is for a continuous net flow of one miner's inch of water for a twelve months year, and is in distinct contrast with the irrigation inch which provides ordinarily for an eight months delivery of water. A miner's inch which is developed and in a going system delivering water for domestic uses under such conditions as are here considered would probably have a greater value, but allowance is here made for the fact that the system is at present undeveloped. Riparian rights according to the schedule submitted for 55,583 + acres are to be conveyed under the option.

This price per miner's inch is assumed to cover all the outlay that is necessary for the compensation for the riparian rights and riparian lands purchased by the Volcan Land & Water Company, and which riparian rights it is assumed will be transferred to the city together with such other rights as have been outlined in the schedules and options that have been presented to the city by this company. In determining the number of miner's inches of water available, allowances have been made for contracts between the Volcan Land & Water Company and the Escondido Irrigation District, certain Indian rights and canal rights on the Santa Ysabel River. These agreements should be reviewed by the City Attorney before any purchases are consummated.

POWER:

The drop from the end of Warner's aqueduct into the Pamo shed will yield continuous hydro electric power which should give a net annual revenue of $30,000., which would be the equivalent of 5% on	$600,000.
TOTAL	$2,817,175.

The amount of power that can be developed from the regulated waters of Warner Lake in passing to the Pamo Reservoir will be approximately 1500 kilowatt continuous output on the switchboard. The conduit from the Warner Reservoir has been designed so that this water may be delivered to the power plant to meet peak load conditions. The situation is unusually favorable for the development of power in this manner because there will be a reservoir both at the upper end and lower end of the power drop which will permit of this regulation without the loss of water, and the conduits have been designed of sufficient capacity to permit of these fluctuating flows. With this plant constructed in this locality it is believed that this power would be worth one cent per kilowatt hour wholesale at the switchboard. At this rate it would earn $131,000. per annum. The power companies at Los Angeles have offered that city six tenths of a cent per kilowatt hour for all the power that may be delivered by the power plants on the Los Angeles Aqueduct. This is a low wholesale rate, but if it would be accepted as governing in this case, the earning power for this plant would be $79,000. per annum. Considering the fact that the plant is wholly undeveloped and also allowing for operating charges, which would be small, the capitalized valuation in this report is considered at but $600,000., which is approximately one half its ultimate value to the city.

It is to be noted that an additional area of 1095 acres of land, estimated value of $54,750., should be obtained at Warner's and that 72 acres, at not to exceed $150. per acre, should be also obtained for a similar reason at San Clemente, in order to get full reservoir use.

While your Board recommends the development of the most available reservoirs, we consider it good business policy to acquire all other lands in all reservoir sites, outlined in the schedule.

Second: "The available water supply of said system."

An hydrographic study of all available data has been made considering this question in its various phases. On the San Luis Rey River an investigation has been made of the safe net dependable yield from the Warner Reservoir, with a storage capacity of 117,000 acre feet, which results in a safe net yield of 11.6 million gallons daily. Four thousand acres will be flooded which is 1040 acres in excess of the area contemplated to be transferred under the option. The company, however, has agreed to transfer the floodage rights for the additional lands for $50. per acre. This agreement of transferring additional lands to be flooded at $50. per acre applies also in the case of the Pamo reservoir site.

There are three reservoir sites on the Santa Ysabel River - one at Sutherland, one at Pamo, and the third at Carroll.

The net safe yield from the Sutherland Reservoir, considering it as the only regulation upon this stream, is about 3.2 million gallons daily.

If the Pamo reservoir be constructed without other regulation on the river the yield would be 7.0 million gallons daily.

If both the Sutherland and Pamo reservoirs were built, the safe net yield from the upper portion of the stream would be 8.0 million gallons daily.

Studies of the Carroll reservoir were made under the conditions of no storage regulation on the upper river, and with reservoir capacities of 34,800 acre feet and 66,000 acre feet, a safe net yield of 5.7 million gallons daily is obtained in the first instance and 7.1 million gallons daily in the latter.

Studies have also been made of the Carroll reservoir under the assumption that the Sutherland reservoir was built, under which assumption a yield of 3.1 million gallons daily could be obtained from the Carroll reservoir.

Similarly a study has been made of the Carroll with both the Sutherland and Pamo reservoirs built, under which condition 1.34 million gallons daily may be obtained from Carroll.

The complete development of this system, which we would recommend, would yield a total of 19.05 million gallons per day, made up from the several sources in the following amounts:-

Warner Reservoir,	11.6 million gallons daily
Pamo	7.0 " " "
Additional from Warner's and Pamo combined, with elimination of portion of evaporation losses,	0.45 " " "
TOTAL	19.05 " " "

In the operation of this system it will be advisable to transfer stored water from the Warner's into the Pamo reservoir whenever storage capacity is available in the latter, as the area exposed to evaporation per acre foot of storage in this reservoir is less than that in Warner's. By a judicious handling of the stored water the safe net yield from this portion of the system may possibly be increased 0.45 million gallons daily.

Third:- "The development of said system which said engineers would recommend and which would safely guarantee the delivery of ten million gallons of water from said system to said city per day, together with the cost of such development, setting forth in detail to such extent as the time available will permit, the number, character and extent of structures advisable in such work and the time required to develop said system and to construct said structures to make available delivery to said city of ten million gallons of water daily."

A summarized statement of the cost of the structures hereafter follows. It is not recommended, however, to make an immediate expenditure of the entire amount, but complete to the fullest extent in the initial stages of development only such structures as may be required to meet such reasonable demands as the growth of the City of San Diego may warrant, including, however, development of 10 million gallons daily as a first unit of construction.

From careful consideration of the findings and the hydrographic studies made it is recommended that the following plan of development be allowed:-

A. That the Pamo conduit (capacity of 54 second feet) and the San Clemente reservoir be first constructed so that portion of the flood waters of the Santa Ysabel River may be immediately diverted to the city.

B. That the Warner Dam be completed to such a height as to provide a depth of 90 feet of water.

C. That the conduit from the Warner reservoir (capacity 100 second feet) be built through a divide from the San Luis Rey River into the Pamo drainage. This development will guarantee to the city the delivery of at least 10 million gallons daily and its estimated cost $2,871,950.; if built on a cash basis under efficient management, it is estimated that it will require two years to complete this portion of the system.

It is our opinion that the completion of the above works and the diversion of water as outlined in this report will not be in the least injurious to any existing interests upon the Santa Ysabel River, but that, on the other hand, an economic waste will be arrested by the storage of much needed waters in the proposed reservoirs, which can be applied for the use of the people in San Diego and vicinity.

A further development of the system by the completion of the Pamo Dam and other work should be made in such order as the needs of the population may warrant. It can be emphatically stated that the greatest advantage to the material interests of San Diego will follow from the sane and continuous policy of constructing storage dams and impounding flood waters. The fact that the population of San Diego has increased three-fold in the last ten years should be sufficient incentive to the proper officials to

have an adequate realization of the importance of this development.

The following work should be done to procure the economic output of the system ultimately:-

D. Construct the Pamo Dam to a full height of 170 feet, or if unforeseen complications should arise, build this dam to a lesser height and complete the Sutherland Dam to a height of 160 feet.

E. Construction of conduit so that water from the Warner reservoir power drop may be conveyed into Pamo reservoir with minimum evaporation losses.

F. Construct a power plant on the Warner conduit above Pamo. No cost estimate included in this report.

The safe dependable yield from the Carroll reservoir with the complete regulation of the upper river is only 1.34 million gallons daily. The cost of this development and delivery to the city is so great that your engineers do not believe it advisable at present to consider construction of this portion of the system.

The total annual charges for a dam at Carroll, pumping costs, cost of pipe line to San Diego and depreciation for the same for a maximum capacity of 10 million gallons daily would amount to $137,500.00. While this plant would require a 10 million gallon daily capacity to meet fluctuating load conditions, the estimated average available supply of water from

the Carroll reservoir with no other structures built on this stream is but 7.10 million gallons daily. Ten million gallons daily of water can be obtained at higher levels by gravity by the installation of the first unit of the system as above recommended, and since this unit is capable of expansion to practically 20 million gallons daily as the needs of the city dictate, it is believed to be the better policy to concentrate all efforts at present on this portion of the project, and leave the construction of Carroll reservoir to some future date.

G. Further hydrographic studies should be made along the Santa Ysabel River to determine accurately the potentialities of the gravel and sand strata along this stream. It is our judgment that considerable water could be obtained from this formation to supplement the supply in case of emergencies or droughts, when this water could be delivered by pumping from the Santa Ysabel River into the Pamo conduit.

H. For an expenditure of $125,000. an adequate pipe line could be laid to connect the San Clemente distributing reservoir with the city distributing system at a point south of the river. It should be the policy of the city, if it contemplates the acquisition of this source, to extend its service mains, of a large size, northerly, across the San Diego River, so as to be able to make this connection and work the supply to an advantage.

To summarize, the cost of development to guarantee a minimum delivery of 10 million gallons daily is $2,871,950., or 7.9 cents per 1000 gallons delivered to the city.

The cost of developing the entire system to a safe yield of 19.05 million gallons daily (exclusive of Carroll Reservoir) is practically $6,500,000., or a cost per 1000 gallons of 6.8 cents for structures.

The estimates for structures presented in this report are largely based on preliminary surveys that have been made by the Volcan Land & Water Company and which have been kindly presented to your engineers. The figures here used should be taken as preliminary and for the purpose of guiding the judgment of the people of San Diego in the determination of the advisability of proceeding with the construction of this system. Before construction is undertaken, it will be necessary to make more detailed surveys and engineering plans, as usual in works of this magnitude. The figures presented are believed to be liberal and are based upon protracted experience in construction of similar works in this neighborhood. The plans are for permanent construction of a substantial nature along conservative designs as shown in the numerous engineering drawings that accompany the report. The estimate of $2,871,950., is for structures to bring water from the Warner reservoir to the San Clemente reservoir, which is ten miles north of the University Heights reservoir and at a commanding position for the distribution of water on the Pueblo lands as well as to the City of San Diego itself.

If it is desired to connect this San Clemente reservoir with the University Heights reservoir an additional expenditure of $125,000. will be required. These figures are for construction charges and do not include payments that will be required for lands, rights of way and water rights to the Volcan Company, which latter amounts would be an additional charge on the system.

From the hydrographic study and the estimates, the Pamo reservoir was shown to be more efficient than either the Sutherland or the Carroll reservoirs on the Santa Ysabel River. Its construction is an essential portion of this enterprise. The elevation of the outlet of this reservoir is 850 feet and because of the great extent of higher intervening country between Pamo reservoir and the Cuyamaca Flume, it would not be feasible to divert water therefrom to the flume. It is our judgment that considering the entire group of reservoirs and the area to be served, that the most effective system that could be designed would be to build the Warner reservoir, develop the power from the Warner water through some 1400 feet of drop into the Pamo reservoir and to convey the waters of the combined reservoirs by means of the Pamo-Clemente Canal as outlined on the accompanying map. This will deliver water at such elevation as to command by gravity your city.

Respectfully submitted,

The detailed studies following are divided into two sections, namely, (1) HYDROGRAPHIC studies showing the quantities of water that can be developed from the different portions of the system, after a most rigid analysis; and (2) STRUCTURAL studies showing the cost of the proposed dams and conduits.

Considerable more time has been devoted to those subjects than was contemplated when undertaking this study, as both problems are far more intricate and involved than either your Water Department or your Board of Engineers had assumed.

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(1) HYDROGRAPHIC STUDIES.

SAN LUIS REY RIVER

The San Luis Rey River drains the west slope of the Coast Range in a portion of San Diego County, discharging into the Pacific Ocean at Oceanside. The drainage basin back of Warner's dam site includes 210 square miles, all lying within the Cleveland National Forest Reserve. About 80 square miles of this area is a broad valley with gentle slopes in which there are numerous swamps and two small lakes. The surrounding mountain slopes have a dense brush cover with scattered oak and pine near the crest. The elevation ranges from 2620 feet above sea level at the dam site to 6126 feet at the summit of Palomar Mountain.

While the rainfall along the seaboard in San Diego County is light (9.62 inches at San Diego), it is substantial on the high mountain elevations. At Cuyamaca, at elevation 4600 feet, a twenty-six year record gives a mean of 40.21 inches per annum. At Julian, elevation 4500, a twenty-eight year record has a mean of 28.19 inches. The Volcan Land & Water Company have established a large number of rainfall stations throughout the upper portion of the drainage basins of the San Luis Rey and the Santa Ysabel Rivers, and the records at these stations are available for the past three years. The precipitation on the basin east of the Warner's dam site ranges from about fourteen inches on the extreme eastern edge to between thirty and thirty-five inches along the eastern face of the Volcan Mountains. A study of the isohyetals

projected from long period means over this drainage basin shows the average intensity of rainfall to be 22.52 inches per annum.

STREAM FLOW:

We are fortunate in having available an unusual amount of data on the flow of streams in this vicinity, and it is believed that deductions therefrom are more reliable in determining the available water crop than those based upon a study of the rainfall.

The Sweetwater River has been measured at the reservoir without interruption since the season 1887-88. The record is given in Table No. I, together with the percentage ratio of the annual to the mean annual discharge. The basin of the Sweetwater River adjoins that of the San Diego River, has 186 square miles of drainage area, and its lower reaches have light rainfall and long sandy channels. The record on this stream at the Sweetwater Reservoir is not used in computing the flow of the San Luis Rey at Warner's as the drainage basins are distinctly different. This is clearly evident from a study of Diagram No. 1, which shows graphically a comparison of the percentages of the mean annual flow for several Southern California streams. This diagram is explained further below.

The San Diego River at Cuyamaca drains a high mountainous basin of 12 square miles. Its exposure is favorable to a high precipitation and the basin is unusually productive of runoff. The stream has been measured by the

Cuyamaca Flume Company since 1893-4. This record, together with the annual percentages of the mean flow are shown on Table No. I. A record has been maintained on the San Diego River at the Diversion Dam of the Cuyamaca Flume Company by the company, and the U. S. Geological Survey since 1898-99. The flow at this point, together with the measured flow into the Cuyamaca Reservoir give the total runoff of the 104 square miles back of the Diversion Dam. This total, together with the percentage ratios of the mean annual runoff, are also shown in Table No. I.

The San Gabriel River drains a high mountainous area of 222 square miles above Azusa. The U. S. Geological Survey have maintained a record on this stream since 1895-96. The annual discharge of this stream, together with the percentage ratio to the mean, are shown on Table No. I.

Diagram No. 1 has been prepared from Table No. I. The yearly percentages of the mean annual flow have been plotted as abscissa against the years of record as ordinates for the Sweetwater, Cuyamaca, San Gabriel, and the San Diego River at the Diversion Dam. This diagram shows that, with the exception of the Sweetwater River, the regimen of these streams during the years of record is similar. From a comparison of the drainage basins tributary to the several streams, it is believed that a good index of the regimen of the San Luis Rey River at Warner's is obtained by averaging the percentages of the mean annual runoff of the Cuyamaca and San Diego River at the Diversion Dam, and averaging this

mean with the percentages of the mean annual runoff of the San Gabriel River. The resulting percentages are shown in Table No. I, Columns 5 and 6. This diagram is used in establishing the regimen for the estimated runoff at Warner's only for the period 1893-94 to 1903-04 inclusive.

GAGINGS ON THE SAN LUIS REY RIVER:

The U. S. Geological Survey have measured the flow of this river at a point four miles above Pala since 1903-04, with the exception of the year 1911-12, when no record is available. The drainage area above this point is 318 square miles. Twelve miles above this gaging station, the Escondido Ditch diverts water from the river during its higher stages. A record of the diversion of this channel is available since 1904-05. Table No. II shows the discharge measurements at Pala and the diversions by the Escondido Ditch. The sum of these two quantities gives the total runoff of the river for the 318 square miles above Pala.

The Volcan Land & Water Company, in conjunction with the U. S. Geological Survey, have measured the discharge of the San Luis Rey River at Warner's dam site for the years 1905-06 and 1911-12 to date. The drainage area back of this point is 210 square miles, or 64 per cent of the drainage area back of Pala. A comparison of the runoff of the entire river at Pala with the discharge at Warner's during those years in which synchronous measurements were made at both points, indicates that the runoff at Warner's is 61.4 per cent of the entire river at Pala. Table No. II is constructed by

applying this ratio to the combined flow of the river at Pala plus the Escondido diversions. This table shows the estimated runoff at Warner's for the period when measurements were made at Pala only and also the actual measurements at Warner's. The estimated mean runoff for the period during which measurements were made either at Warner's or Pala (1904-5 to 1913-14) is 28,981 acre-feet per annum. The percentages of the annual runoff given in Column 6, Table No. I, show the mean for this period to be 145 per cent of that of twenty-one years. Making this adjustment a mean annual runoff at Warner's of 20,000 acre-feet per annum is obtained. Applying the estimated percentages as given in Column 6, Table No. I, to this mean annual runoff of 20,000 acre-feet, the runoff of the San Luis Rey River at Warner's for the years 1893-94 to 1903-04 inclusive, is estimated. This is shown in Table No. I, Column 7. The period considered (1893-94 to 1913-14) includes the driest group of years indicated either by the oldest stream flow records of the state or by the records of precipitation at San Diego, which extend back to 1849-50.

Mass curve studies have been made of the San Luis Rey River with storage capacity at Warner's to the extent of 120,000 acre-feet and 117,000 acre-feet, and the safe dependable yield of the stream computed in each instance. In the preparation of this mass curve certain losses and accretions in the reservoir have been considered which will be taken up in detail.

RELINQUISHMENTS TO SATISFY RIPARIAN RIGHTS ON THE LOWER RIVER:

The Volcan Land & Water Company have acquired practically all the riparian lands on the San Luis Rey River from the Warner's dam site to the ocean. The only priorities on the stream which have to be considered are those of the Pala Indians, the Rincon Indians and the Escondido Mutual Water Company. The City of Oceanside at the mouth of the San Luis Rey River, has protested against the construction of a dam at Warner's, but this protest is not here considered well founded from a physical standpoint. The Pala Indians claim a perennial flow of 6 second-feet. Their diversion is just below the Pala gage. The large porous gravel area above the diversion acts as a regulating reservoir, storing the winter flood waters and yielding them in quite a constant flow. The Pauma Creek with a drainage area of 12 square miles is a perennial stream and has its confluent with the main river above the Pala diversion. This creek and the tributary drainage below the Escondido diversion will provide for the diversions of the Pala Indians. No further provision is made in this study for this diversion.

RINCON INDIANS:

The U. S. Indian Service has a contract with the Escondido Mutual Water Company to supply a stipulated flow of water to the Rincon Indian Reservation. Judge F. W. Henshaw, in a written opinion on the Escondido-Indian Service contract states that the Escondido Mutual Water Company are between the Indian Service and the Volcan Land & Water Company. He states that the Escondido Mutual Water

Company must satisfy the claims of the Rincon Indian Reservation. The practice in the past has been for the Escondido Mutual Water Company to stop its diversions in the summer time and the Indians to take the entire summer flow, of the San Luis Rey River, which normally amounts to about 75 miner's inches. Warner's Dam is about ten miles above the Escondido diversion. The stream goes dry during the summer months about three miles below the dam site. It is not probable that the water passing Warner's during the summer is the same water diverted by the Indians during the same year, as this summer water goes down stream as an underflow and probably would not travel a distance of seven miles in two or three months. There are several perennial streams flowing from the Pala Mountains which probably sustain the summer flow of the river at the Escondido diversion point. No water is estimated in this report as released at Warner's to provide for the Rincon Indian Reservation.

ESCONDIDO MUTUAL WATER COMPANY:

The Volcan Land & Water Company have entered into a contract with the Escondido Mutual Water Company under date of June 21st, 1912, a copy of which contract is herewith attached as Appendix No. 1. This contract provides that the Escondido Mutual Water Company is entitled to an annual diversion of 1,350,000,000 gallons, that the water may be diverted between November 1st and July 1st, that the maximum rate of diversion shall be 27,000,000 gallons per day, and further that whenever this amount of water is available in the river between the dates mentioned it shall be considered as contributing toward

the diversions of the Escondido Mutual Water Company, irrespective of whether such diversion is made or not. There is a further provision that if at any time between November 1st and July 1st, prior to July 1st, 1917, the flow of the river is less than 200 miner's inches, plus the amount required by the Indians, then the said 200 miner's inches or less which shall be flowing in said river shall not be included in making up the annual quantity of 1,350,000,000 gallons. If at any time after the first of July, 1917, between November 1st and July 1st, the water flowing in the river shall not exceed 100 miner's inches plus the amount required by the Indians, then the said 100 miner 's inches shall not be considered as included in making up the total diversions to which the Escondido Mutual Water Company are entitled. It is also provided that the Escondido Mutual Water Company shall not be entitled to more water or to have delivered to it more water in any year than the actual runoff of the river at its point of diversion during such year, or more water than could be diverted by the Escondido Ditch if the Warner Dam were not constructed.

There are 33 square miles of drainage area above the Escondido diversion point and below the Warner dam site. The West Fork of the San Luis Rey River which is tributary above the Warner Reservoir has 24.4 square miles of drainage area. A study of the isohyetals projected from long period means upon the drainage areas shows the average intensity of rainfall upon the 33 square miles below the Warner dam site

and above the Escondido diversion to be 31.8 inches, and that upon the 24.4 square miles of drainage area tributary to the West Fork to be 32.7 inches. The runoff per square mile from these drainage basins is assumed to be the same.

Table No. III shows the runoff of the West Fork for eighteen months and the runoff of the San Luis Rey River at Warner's Dam for the same period. The total runoff of the West Fork for these eighteen months is 32.5 per cent of the total runoff at Warner's. Adjusting this percentage by the ratio of the areas of the Escondido and the West Fork drainage areas results in the runoff of the 33 square miles tributary to Escondido, being 44 per cent of the runoff at Warner's. This ratio of 44 per cent was used in determining the available supply at the Escondido Diversion points.

A study has been made to determine under the conditions of the Escondido contract, first the amount of water that could have been diverted each seasonal year by the Escondido Ditch if there were no regulations of the river, and second, the amount that could have been diverted each seasonal year from the runoff of the 33 square miles below Warner's and above the Escondido Diversion point. If this latter amount is not equal to 1,350,000 gallons, then it is necessary under the provisions of the contract to release at Warner's Dam sufficient water to bring the total diversions up to the amount which could have been diverted if the dam were not constructed. Table No. IV shows the quantity of water in acre-feet it is necessary to release each seasonal

year at Warner's to satisfy the conditions of the Escondido contract. It is seen from this table, that upon critical years, or years of little runoff at Warner's, the necessary relinquishments for the Escondido diversion are greatest and upon years of large runoff none have to be made.

EVAPORATION:

The Volcan Land & Water Company have been carrying on a series of observations since January 1913, to determine the evaporation from a water surface in the vicinity of their proposed reservoirs. There are four stations in the vicinity of Warner's reservoir from which records are available for the past two years. Pan No. 3 is set on a knoll adjacent to the Warner dam site and is elevated about five feet above the ground surface. The average evaporation from this pan has been 75.16 inches per annum. Pan No. 4, located at the Warner dam site in a pool adjacent to the dam, shows an average evaporation for the past two years of 56.20 inches. Pan No. 5 which is floating in Big Lake near the Warner reservoir site shows an average depth of evaporation of 61.51 inches per annum. Pan No. 6 is situated in moist ground near the margin of Big Lake and shows an average evaporation of 48.10 inches per annum. It is considered that Pan No. 3 is not indicative of the conditions existing on the surface of a reservoir and the determinations from this pan are excluded as excessive. The average of the other three pans is 55.27 inches and the gross evaporation used in these studies has been taken as an average of 55 inches. From this total evaporation 90 per cent of the rainfall occurring on the reservoir surface is subtracted. Ten per cent of the

rainfall is considered as already accounted for in stream flow.

RAINFALL:

There are available records of precipitation for the past three years on five stations adjacent to the Warner Reservoir. Three of these stations are within the area flooded. A table showing a seasonal variation of precipitation expressed as percentage of the mean observed precipitation for eight base stations in San Diego County has been prepared by Mr. C. H. Lee, Associate Member of the American Society of Civil Engineers. The yearly averages of all the stations are given in Column 2, Table No. V, for a period of twenty-one years. This period is 94.6 per cent of the mean for the forty-one year period of observation. These percentages are expanded to a hundred per cent basis in Column 3. The three years of measurement on the five stations in Warner reservoir, expressed as the yearly average, give a mean precipitation of 19.45 inches, but these three years, according to the adjusted percentages, is a 97.6 per cent period as compared to the twenty-one years. The mean rainfall then on 100 per cent basis is 19.45 divided by 97.6 equals 19.94 inches. In Table No. V, Column 4, the rainfall on the reservoir surface is computed, from these measurements. The evaporation and rainfall should be considered as a yearly condition rather than an average condition extending over a period of years, as during dry years there is little rainfall and consequently a larger evaporation than upon wet years when the reverse is true. This condition militates against the safe dependable yield of the stream.

CONSERVED EVAPORATION FROM SUBMERGED MOIST LANDS:

There is a total area of 1740 acres of moist land lying within the Warner reservoir site. A portion of this land is kept moist by springs. The bulk of it, however, becomes charged with water during the rainy season and this retarded water evaporates and drains out to a depth of probably six feet during the summer. The water that is at present lost by evaporation from these lands will be conserved when this area is submerged. It is considered that the evaporation losses occurring on these lands are equal to a depth of water of 19 inches per annum over the moist area. Diagram No. 2 has been prepared with this as a basis. It shows the volume impounded in the reservoir plotted in thousands of acre-feet as ordinates and the evaporation losses from the submerged moist land in hundreds of acre-feet, as abscissa.

Table No. VI shows the mass curve tabulation for Warner reservoir computed under the conditions heretofore set forth. The maximum capacity of the reservoir is taken at 117,000 acre-feet, which would necessitate a dam 105 feet high with a maximum depth of 90 feet of water. The reservoir is assumed to contain 80,000 acre-feet at the beginning of the study. It would probably take two years to construct the dam and the reservoir would have the benefit of at least one winter's runoff before any withdrawals were made, and experience has shown that the use of water from a newly constructed system is almost invariably below normal for the first two or three years of its operation, so that this assumption is justified.

This tabulation is a study of the seasonal conditions of the reservoir. The runoff year is from July 1st to June 30th, but the major portion of the runoff actually occurs during the winter months. The yearly draft is assumed to be made in about the ratio of one third in the winter months and two thirds in the summer months. All the evaporation is considered to occur during the summer months.

Column 1, of Table No. VI shows the volume impounded in the reservoir at the beginning of the wet season. Column 2, shows the estimated runoff in acre-feet occurring during the winter months. Column 3 is the draft assumed to occur during the winter months. Column 4 gives the volume in the reservoir at the end of the wet season. This volume determines the necessary size and the amount of waste from the reservoir. Column 5, shows the conserved evaporation from moist lands as heretofore outlined. Column 6, shows the quantity of water in acre-feet it would have been necessary to release at Warner's to satisfy the Escondido diversion. Column 7, is the mean area flooded. Column 8, shows the net evaporation from the reservoir surface in feet. These quantities are determined by subtracting 90 per cent of the rainfall as given in Column 5, Table V, from the gross evaporation of 55 inches as deduced above. Column 9 gives this evaporation in acre-feet. Column 10, shows the total useful draft of 13,000 acre-feet per annum. This figure includes the 4000 acre-feet occurring during the winter months. Column 11, shows the waste that would have occurred.

It will be seen that a net annual draft of 13,000 acre-feet, or 11.6 million gallons per day, can be sustained throughout the twenty-one year period considered, except during the season 1903-04, when a deficiency of 3685 acre-feet, or 28 per cent of the draft occurs.

Similarly Table No. VII is a mass curve study for Warner's reservoir with a storage capacity of 120,000 acre-feet, and assuming 90,000 acre-feet in the reservoir at the beginning of the study. Under these conditions a draft of 13500 acre-feet per annum, or 12.05 million gallons per day could be sustained, except during the year 1903-04, when a deficiency of 3185 acre-feet would have occurred. This amounts to 23-1/2 per cent of the annual draft. The shortage, however, in both will be modified by water leaching from the surcharged banks of the reservoir. The deficiency would probably have occurred but once in the past fifty years. It should be noted that there is a period of nine successive years which are all below normal in runoff in the twenty-one year period under consideration. This is an extremely severe condition to adopt as limiting the safe dependable yield of any stream regulated entirely by surface storage. It is desirable to supplement the surface storage system with pumping plants drawing on underground supplies.

If the water supply from this reservoir is devoted to an irrigation use, the larger draft may be safely contemplated. If, however, the water is to be used for the domestic water supply of a great city, as in the case of San Diego, the smaller draft should be used.

The offer of sale by the Volcan Land & Water Company to the City of San Diego contemplates the transfer of 2960 acres in the Warner reservoir. The reservoir of 117,000 acre-feet capacity here contemplated will flood an area of 4000 acres. The floodage rights for the additional area flooded may be obtained for $50.00 per acre.

SANTA YSABEL RIVER

The Santa Ysabel River drains the territory immediately south of the San Luis Rey River and flows through the Sutherland and Pamo reservoir sites. The 53 square miles tributary to the Sutherland reservoir are rough and mountainous, ranging in elevation from 1940 feet at the dam site to 5570 feet at the summit of the Volcan Mountain. The canyons are box-like with steep side hills densely covered with brush and studded with oak and pine trees. There are no lateral valleys of any size. The rainfall on this area is abundant.

The drainage area of 57 square miles between the Sutherland and Pamo reservoirs is very similar in character, though somewhat lower in elevation, ranging from 890 feet at the dam site to about 4000 feet at the summit of Pine Mountain. From a study of maps of these drainage basins, prepared by the Volcan Land & Water Company, showing isohyetals it may be seen that in a general way the rainfall on the lower basin is not so great as that upon the upper one.

GAGINGS ON THE SANTA YSABEL RIVER:

The U. S. Geological Survey have measured the flow of this stream at the Pamo Gage, a point about four miles below the Pamo dam site, from January 1906 to July 1912. There are 128 square miles of drainage basin back of this gaging station. From February 1912 to date the stream has been measured at the Pamo dam site by the same authority. Measurements have also been made at the Sutherland dam site

for the past twenty-five months. During the period of synchronous measurements at Sutherland and Pamo dam site the total volume of water passing Sutherland was 57 per cent of the runoff at Pamo dam site. An exhibit of these measurements is shown in Table No. VIII. The ratio of 57 per cent has been adopted and is used in the estimates for the available water supply at the Sutherland reservoir.

Table No. IX shows the relation of the measured runoff of the Santa Ysabel River at Pamo Gage to the measured runoff of the San Luis Rey River at Pala, together with the same ratio to the estimated flow of the San Luis Rey River at Warner's, all for the period of measurement at Pamo Gage. The Santa Ysabel River at Pamo Gage is an average of 59 per cent of the measured flow of the San Luis Rey River at Pala, and 96 per cent of the estimated flow of the San Luis Rey River at Warner's. The runoff of the Santa Ysabel River at the Pamo Gage has been estimated as 96 per cent of the runoff of the San Luis Rey River at Warner's. The regimen of the streams is taken to be the same.

The drainage area of the Santa Ysabel River back of the Pamo dam site is about 90 per cent of that back of Pamo Gage. The intervening area is not as productive in runoff as that above the Pamo dam site. The runoff at the Pamo dam site has been taken as 95 per cent of that at the Pamo Gage.

Table No. X shows the estimated runoff of the Santa Ysabel River at several points on the stream. Column 2 shows the estimated runoff of the San Luis Rey River at

Warner's. Columns 3 and 4 show the estimated runoff of the Santa Ysabel River at Pamo Gage and at Pamo dam site respectively, estimated in accordance with the theory outlined above. Column 5 shows the estimated runoff of the Santa Ysabel River at Sutherland estimated as 57 per cent of the runoff at Pamo dam site. Column 6 shows the runoff of the tributary drainage area between Sutherland and Pamo.

MASS CURVE STUDIES FOR PAMO AND SUTHERLAND RESERVOIRS:

Several studies to determine the safe net yield from the upper portion of the Santa Ysabel River have been made. First, considering only the Pamo reservoir constructed, and second, considering both the Sutherland and Pamo reservoirs built. There are certain factors entering into these studies that are identical, as for example the evaporation, rainfall, and relinquishments necessary for priorities on the lower river.

EVAPORATION AND RAINFALL:

The gross evaporation at the Warner reservoir has been determined as 55 inches in depth. Observations maintained by the Volcan Land & Water Company upon the evaporation from a pan (No. 9) located at Sutherland dam site, show a gross evaporation for the year 1914 of 55.98 inches. This is in fair accord with the amount found at Warner's. The gross evaporation for Sutherland and Pamo reservoirs has been taken as 55 inches, and the rainfall on the reservoir surface is assumed to be the same as that estimated for Warner reservoir.

PRIORITIES IN THE SAN PASQUAL VALLEY:

There are about 3880 acres of bottom lands riparian to this stream from the head of the San Pasqual Valley to Bernardo. These lands are composed of detrital fill, are porous and have great absorbent capacity. They are fertile and a large proportion of them are already under irrigation. It is estimated that a gross duty of water may obtain throughout this valley of three acre-feet per annum and that a third of this amount may be considered as return water through the gravels. This leaves a net loss in the valley of two acre-feet per annum, which, over the 3880 acres, is a total loss of 7760 acre-feet per annum.

There is tributary to this area below Pamo dam site 130 square miles of drainage area whose runoff goes toward replenishing these losses.

The average runoff of the Sweetwater River for a period of twenty-sevem years has been measured as 60 acre-feet per square mile from a drainage area of 186 square miles and the runoff of 104 square miles tributary to the San Diego River below the diverting dam and above Lakeside has been estimated as an average for a twenty year period of 76 acre-feet per square mile. The runoff noted of both these rivers occurs at the end of long absorbent channels.

Santa Maria Creek, a tributary of the Santa Ysabel River having its confluent with the river in the San Pasqual Valley, has been measured by the U. S. Geological Survey in co-operation with the Volcan Land & Water Company for the past three years. The average runoff of the 56 square

miles tributary to this stream, when adjusted to a twenty-one year mean on the basis of the Sweetwater percentages, is 112 acre-feet per square mile, and when adjusted in accordance with the Pamo percentage is 100 acre-feet per square mile. The Santa Maria Valley, which composes the greater part of the drainage area, is flat but not highly absorbent. During years in which the precipitation is above normal, this drainage area produces a substantial runoff and in years below normal little runoff occurs. This area is not the most productive part of the 130 square miles tributary to the San Pasqual Valley below Pamo dam site.

In the case of the Sweetwater and the San Diego Rivers the runoff from the mountains has been reduced and regulated by the absorbent channels. The runoff of the 130 square miles tributary to the San Pasqual Valley is not so regulated as it is considered as flowing directly upon the absorbent gravels whose area of 3880 acres is not included in the above mentioned 130 square miles. It is estimated that the runoff from the drainage area tributary to the San Pasqual Valley will average 100 acre-feet per square mile, and that this average should be projected back in accordance with an annual percentage that is a mean of the Sweetwater and Pamo annual percentages. Table No. XI shows the estimated runoff of this area.

SAFE NET YIELD FROM PAMO RESERVOIR:

This mass curve study is made under the assumption of 47,500 acre-feet storage capacity requiring 156 feet depth of water at the dam, in the Pamo reservoir, and is no

regulation of the stream above Pamo, and that the regulating reservoir at San Clemente is built to a capacity of 8570 acre-feet. The storage capacity in the San Clemente reservoir acts virtually as an increase to the capacity in Pamo as the winter waters may be passed directly into San Clemente so that it shall always be filled at the beginning of the draft season.

Table No. XII shows the estimated net runoff into Pamo reservoir from the total drainage back of Pamo dam site, and relinquishments at Pamo for losses in the San Pasqual Valley. Column 2 of this table shows the estimated runoff of the 130 square miles of drainage area tributary to the San Pasqual Valley below Pamo dam site. When this runoff is in excess of 7760 acre-feet the losses in the valley are satisfied and it is not necessary to relinquish anything from storage above. When the runoff onto the valley does not equal 7760 acre-feet the difference is released at Pamo reservoir, providing that the unregulated stream flow above Pamo during that year is sufficient to make up this amount. If the runoff is not sufficient, only such water as the stream produces during that year is released. Column 3 shows the estimated runoff at Pamo. Column 4 shows the amount necessary to release at Pamo dam site to satisfy the San Pasqual Valley losses and Column 5 shows the net amount available for storage regulation in Pamo reservoir. These last three columns are transferred to Table No. XIII as Columns 3, 4, and 5.

Table No. XIII is the mass curve tabulation for

Pamo reservoir and it is constructed in a manner similar to those heretofore described. The results of this study show that a dependable safe yield of 7800 acre-feet per annum, or seven million gallons per day may be obtained from this reservoir; that the reservoir contained 485,000 acre-feet in 1904 after a series of seven dry years. It is also seen that waste occurs on seven years. This waste accrues from the fact that the storage capacity of the reservoir is not sufficient to regulate maximum runoff of the stream.

SAFE NET YIELD WITH BOTH SUTHERLAND & PAMO RESERVOIRS CONSTRUCTED:

This study is made upon the assumption that both the Sutherland and the Pamo reservoirs are constructed, the Sutherland reservoir to have a storage capacity of 18400 acre-feet, and the Pamo of 47500 acre-feet, and the additional storage of 8570 acre-feet in San Clemente regulating reservoir. A mass curve tabulation was first made for the Sutherland reservoir assuming that all relinquishments for the San Pasqual Valley would be made from Pamo reservoir. This tabulation is in every way similar to that described for Warner's reservoir. It shows that a draft of 5000 acre-feet per annum, or 4.45 million gallons per day, could be maintained except during the year 1903-04 when a deficiency of 380 acre-feet would have occurred. This tabulation is shown as Table No. XIX.

Similarly Table No. XV is a mass curve tabulation for Pamo reservoir, considering the runoff below Sutherland, the waste past Sutherland and the relinquishments necessary for the San Pasqual Valley. The results of this study show that under these conditions a draft of 4000 acre-feet per

annum, or 3.57 million gallons per day could be maintained except during the year 1903-04 when a deficiency of 675 acre-feet (17 per cent) would have occurred.

Thus the safe net yield from both reservoirs would have been 4000 plus 5000 or 9000 acre-feet per annum, or 8 million gallons daily.

The area exposed to evaporation per acre-foot of storage in the Pamo reservoir is less than that in the Warner reservoir. A study has been made to determine how much the safe net yield of the Warner reservoir could be increased if it were operated in conjunction with the Pamo reservoir. Table No. XVI is a tabulation of this study. The Sutherland reservoir is built and Pamo reservoir is assumed to have the benefit of the storage capacity in the San Clemente regulating reservoir and winter water is passed from Warner's into Pamo so that the Pamo-San Clemente reservoirs shall be not more than two thirds full, or contain not more than 37,000 acre feet at the beginning of the runoff season. This tabulation is in effect a mass curve tabulation for these reservoirs, and is similar in its construction to those heretofore described. Under the conditions outlined above the yield from Warner's reservoir could be increased to 13500 acre-feet per annum, or 12.05 million gallons per day.

LOWER SANTA YSABEL OR SAN DIEGITO RIVER

GAGINGS:

The U. S. Geological Survey in co-operation with the Volcan Land & Water Company have measured the runoff for the San Diegito River at Bernardo since January 1913. Table No. XVI shows these measurements and synchronous measurements at Pamo for the same period. The ratio between the runoff at Bernardo and the runoff at Pamo is also shown in this table. Diagram No. 3 has been prepared with the runoff in thousands of acre-feet as ordinates and the percent runoff year at Pamo as abscissa. The runoff at Pamo was plotted and shows as a straight line. The data given in Table No.XVII was then plotted upon this diagram and the lower portion of the runoff curve for Bernardo determined. To serve as an indication of the shape of the upper portion of the Bernardo curve, the runoff of the Sweetwater River at the Sweetwater Dam has been plotted against the percentage runoff year at Pamo. The regimen of these two streams are analogous and their drainage basins are quite similar, although that of the Santa Ysabel River is almost twice as large as that of the Sweetwater.

A study of the isohyetals projected from long period means upon the drainage basin of the Santa Ysabel River has been made which indicates a mean rainfall upon that portion of the basin above Pamo dam site of 26.8 inches, or a total of 157,000 acre-feet. For the part of the basin below the

Pamo dam site and above Bernardo, the average intensity of precipitation was found to be 18.6 inches, or a total of 152,600 acre-feet. The total average rainfall per annum over the whole basin is then 309,600 acre-feet. Under normal conditions then the total volume of rainfall upon all of the basin is 196 per cent of that occurring upon the area above Pamo. It follows than that the runoff from the total drainage area can at no time be more than 196 per cent of the runoff of the Pamo watershed and approaches 196 per cent as a maximum. This maximum is assumed to occur on a 300 per cent runoff year at Pamo. Upon such a year the flow at Pamo would have been 54,400 acre-feet and the flow at Bernardo 106,400 acre-feet. This locates a high point upon the Bernardo runoff curve on Diagram No. 3. The curve beyond this point has an inclination such that the runoff at Bernardo is 196 per cent of the runoff at Pamo. With Diagram No. 3 as a basis, Diagram No. 4 was constructed, showing the percent ratio between the runoff at Pamo and the runoff at Bernardo. From this latter diagram the runoff of the San Diegito River at Carroll was estimated. This runoff is estimated upon the assumption that there is no storage regulation on the upper river. The details are shown in Table No. XVIII. Columns 2 and 3 of this table show the seasonal runoff of the Santa Ysabel River at Pamo, and the percentage of the mean. Entering Diagram No. 4 with percentage runoff year at Pamo, the ratio of the runoff at Bernardo to that at Pamo is found and shown in Column No. 4. Column 5 is computed from Columns 2 and 4.

The Carroll dam site is about four miles below Bernardo, the point of measurement, and there are 36 square miles of drainage area tributary below Bernardo, making the total drainage area above the Carroll dam site 114 per cent of the drainage area back of Bernardo. The runoff per square mile for the 36 square miles below Bernardo is probably not so great as the average runoff per square mile for the tributary drainage above Bernardo. With this in mind, the runoff of the San Diegito at Carroll dam site is taken as 110 per cent of the runoff at Bernardo. This is shown in Column 6 of Table No. XVIII. Column 7 shows the per cent runoff year at Carroll dam site.

LOSSES IN SAN PASQUAL VALLEY:

The runoff of the San Diegito at Bernardo has been computed on the assumption of no storage on the upper river and is based on the present conditions of the use and loss of water in the San Pasqual Valley. Table No. XIX has been constructed to determine the average amount of these losses under present conditions. Column 2 shows the estimated run-off at Pamo. Column 3 shows the estimated runoff at Bernardo, upon runoff years that are below normal. Column 4 shows the shrinkage in the runoff between these two points. Column 5 shows the estimated runoff of 130 square miles tributary to the San Pasqual Valley. Column 6 shows the total of the losses in the valley, which is the sum of Columns 4 and 5. The average loss of the period considered amounts to 5960 acre-feet. This loss obtains under the present condition of agricultural development in the valley. There are 3880

acres of bottom land riparian to this stream above Bernardo and below the head of the San Pasqual Valley and it has been estimated that ultimately there may be a net loss of water upon this land amounting to 2 acre-feet per annum, or 7760 acre-feet in total. Deducting the 5960 acre-feet loss occurring at present, leaves a probable future loss in this valley of 1800 acre-feet. This amount is deducted from the estimated runoff at Carroll to provide for additional losses which may occur in the future.

RIPARIAN PRIORITIES BELOW CARROLL:

A large portion of the San Diegito Ranch is riparian to the river below Carroll. This ranch has a contract with the town of Del Mar to supply a constant flow of 50 miner's inches or one second foot. There are about 300 acres of bottom land in this ranch that are susceptible to irrigation by gravity from the river. In order to irrigate the higher mesa lands water would have to be pumped about 150 feet. It is estimated that the riparian priorities below Carroll will be satisfied if 1000 acre-feet per annum is released from the Carroll reservoir on all years except those in which this amount of water would not have passed Carroll dam site, had no dams been constructed on the river.

The deductions just described for the San Pasqual Valley and the priorities below Carroll are shown in Columns 8 and 9 respectively of Table No. XVIII. Column 10 of this table shows the net runoff available for storage regulation in the Carroll reservoir, provided there is no reservoir on the stream above.

EVAPORATION:

The Sweetwater reservoir and the La Mesa reservoir are approximately the same distance inland as the Carroll reservoir, and the mean of their elevations is about the same as the elevation at Carroll. There are records of evaporation from the Sweetwater reservoir extending over a period of six years and similar records for the past two years at La Mesa. The six years of measurement at Sweetwater give an average of 59.09 inches in depth annually; that at La Mesa reservoir an average of 71.96 inches in depth annually. A weighted average between these two amounts is equal to 62.31 inches. A gross evaporation of 62 inches has been used in the study of the Carroll reservoir.

RAINFALL:

The City of San Diego at the sea coast has a 42 year average annual precipitation of 9.62 inches. The precipitation at the Sweetwater reservoir is an average of 10.70 inches for a period of 26 years. Escondido has a 39 year mean rainfall of 15.25 inches. The average of all these stations is 11.86 inches. The elevation of San Diego is taken as zero. The elevation of Sweetwater is 250 feet and the elevation of Escondido 654 feet. Considering the relative increase in precipitation at these stations together with their elevations indicates an average increase of 0.78 inches of rain per 100 feet rise in elevation. The elevation of Carroll reservoir is 315 feet and computing the rainfall at this point on the basis of its elevation above San Diego,

results in a mean rainfall of 12.08 inches. The Carroll reservoir lies between San Diego and Escondido and is a bit nearer the coast than Escondido. The average between the rainfall at San Diego and at Escondido is 12.43. We have then the rainfall at Carroll computed as an average between San Diego, Sweetwater and Escondido equals 11.88 inches; computed as an average between San Diego and Escondido 12.43 inches; computed on a basis of its elevation above San Diego as a base, 12.08 inches. The mean rainfall upon the Carroll reservoir has been taken as 12 inches and is extended back in accordance with the Escondido annual percentages of the mean rainfall. Table No. XX shows this extension. The gross evaporation from the Carroll reservoir is considered to be reduced by 90 per cent of the rainfall as about 10 per cent of it has already been accounted for in the estimated runoff.

MASS CURVE STUDIES:

Studies of the safe net yield of the Carroll reservoir have been made under the assumption of, first, no regulation on the upper river, second, the Sutherland and Pamo reservoirs built. These studies are shown on Tables Nos. XXI and XXII. The detail of their computation is similar to that heretofore described in connection with the Warner, Sutherland and Pamo reservoirs.

With no regulation on the upper river, and a storage capacity in Carroll reservoir of 34,800 acre-feet, requiring a depth of water of 100 feet at the dam, a draft of 6400 acre-feet per annum, or 5.71 million gallons per day can be maintained, except during the years 1899-1900, when there would have been a deficiency of 1030 acre-feet, and the year 1901-02 when

A deficiency of 1270 acre-feet would have occurred. These deficiencies probably could have been met by water leaching from the walls of the reservoir and by pumping from its bed. The details of this study are shown in Table No. XXI.

A similar study has been made of the Carroll reservoir under the assumption that the Pamo and Sutherland reservoirs are constructed, and that the Carroll reservoir has a storage capacity of 23,000 acre-feet. Table No. XXIII shows the estimated runoff at Carroll with the Pamo and Sutherland reservoirs constructed. This table is self explanatory, except that during those years in which the runoff at Pamo reservoir exceeded that at Carroll, the runoff at Carroll is estimated from Diagram No. 4. Columns 4, 5, and 6 of Table No. XXIII have been transferred to Table No. XXII which is the mass curve table for the Carroll reservoir under these assumptions. The balance of this mass curve table is computed in a manner similar to those heretofore described. The results of this tabulation show that a constant draft of 1500 acre-feet per annum or 1.34 million gallons daily could be maintained, except during the year 1901-02 when a deficiency of 153 acre-feet would have occurred, and the year 1903-04 when a deficiency of 207 acre-feet would have occurred. These deficiencies may have been modified by water leaching from the walls of the reservoir.

Summarizing the results of this study we have the following:

	M.G.D.
San Luis Rey River - Warner's Reservoir	
Safe Dependable Yield	11.6
Santa Ysabel River	
Pamo Reservoir only constructed	7.0
Pamo & Sutherland Reservoirs Constructed	8.0
Carroll Reservoir only constructed	5.71
Carroll, Pamo & Sutherland Reservoirs Constructed	1.34
Total Yield of System including Warner's, Carroll, Pamo and Sutherland Reservoirs	20.94
Additional from Warner's when considered with Pamo	0.45
TOTAL	21.39

It must be borne in mind that the above safe dependable yields are computed upon the assumption that the priorities in the San Pasqual Valley could be satisfied in the way outlined. This is an uncertain factor and before any definite steps are taken for construction of any dams on this stream above the San Pasqual Valley, these priorities should be definitely adjusted. Under the offer of Mr. Henshaw the riparian rights on about 300 acres of land in the San Pasqual Valley are to be transferred. This, however, is only about ten per cent of the total.

DIAGRAM No 1
COMPARISON OF REGIMEN OF FIVE SOUTHERN CALIFORNIA STREAMS TO ACCOMPANY REPORT ON VOLCAN LAND & WATER COMPANY TO THE CITY OF SAN DIEGO CALIFORNIA OF M.M O'SHAUGHNESSY & J.B. LIPPINCOTT

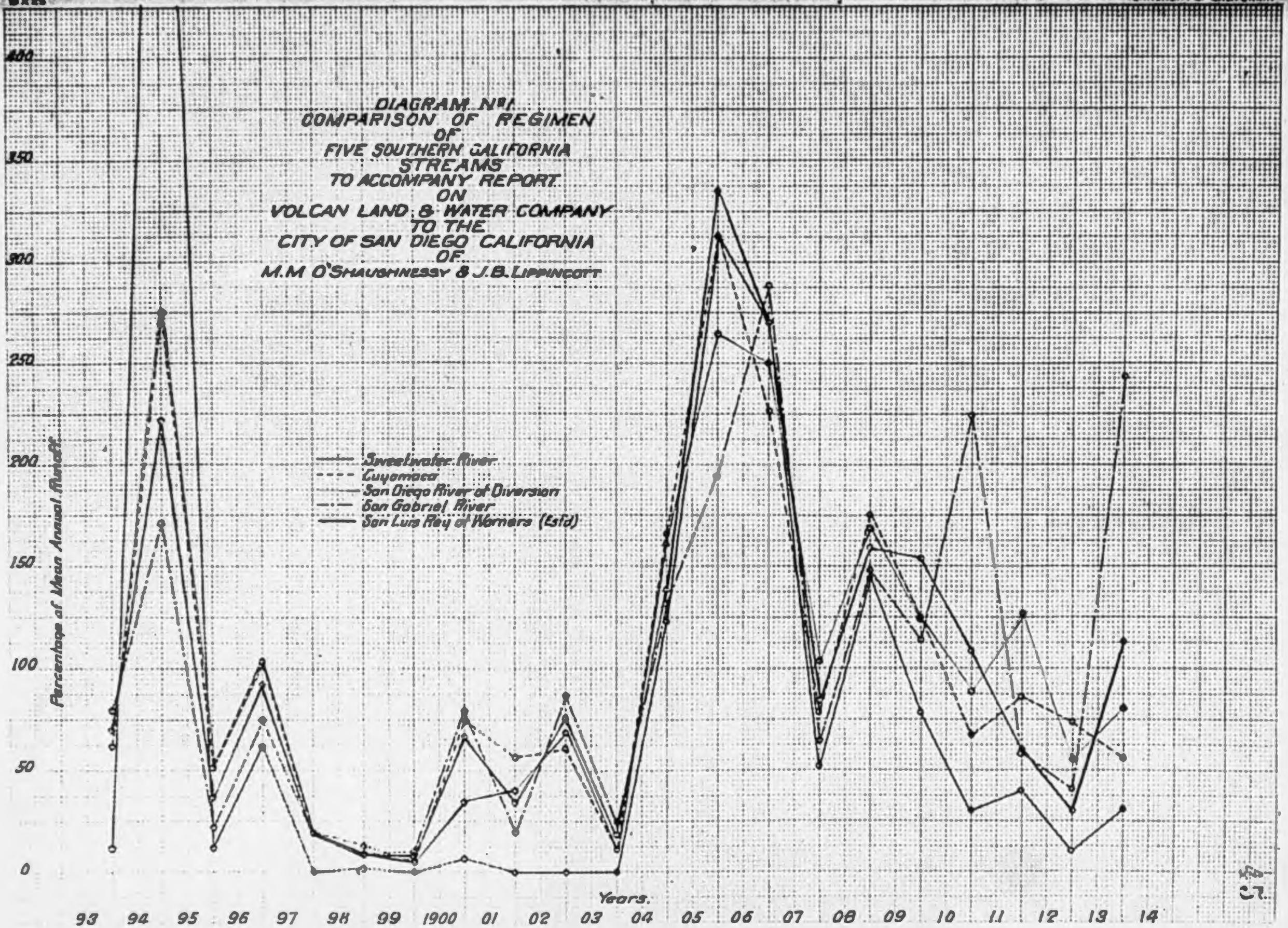

DIAGRAM NO 2
SHOWING EVAPORATION
FROM MARSH LANDS
IN
PROPOSED WARNER RESERVOIR
TO ACCOMPANY REPORT
ON
VOLCAN LAND & WATER COMPANY
TO THE
CITY OF SAN DIEGO CALIFORNIA
OF
M.M.O'SHAUGHNESSY & J.B. LIPPINCOTT

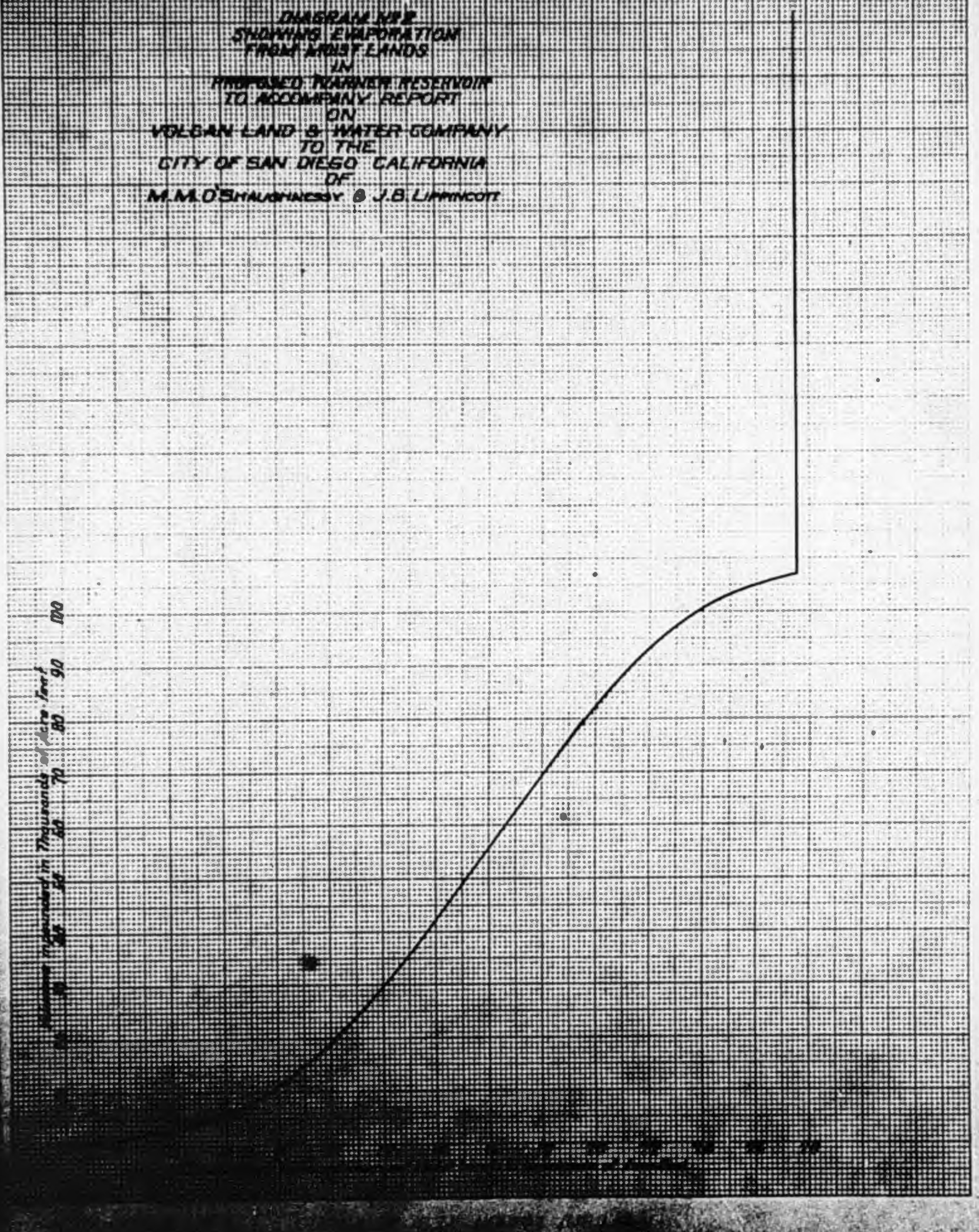

DIAGRAM. Nº 3
SHOWING RELATION BETWEEN
THE PERCENTAGE RUNOFF YEAR OF THE
SANTA YSABEL RIVER
AT PAMO AND THE RUNOFF OF THE
SAN DIEGUITO RIVER
AT BERNARDO
TO ACCOMPANY REPORT
ON
VOLCAN LAND & WATER COMPANY
TO THE
CITY OF SAN DIEGO CALIFORNIA
OF
M.M. O'SHAUGHNESSY & J.B. LIPPINCOTT

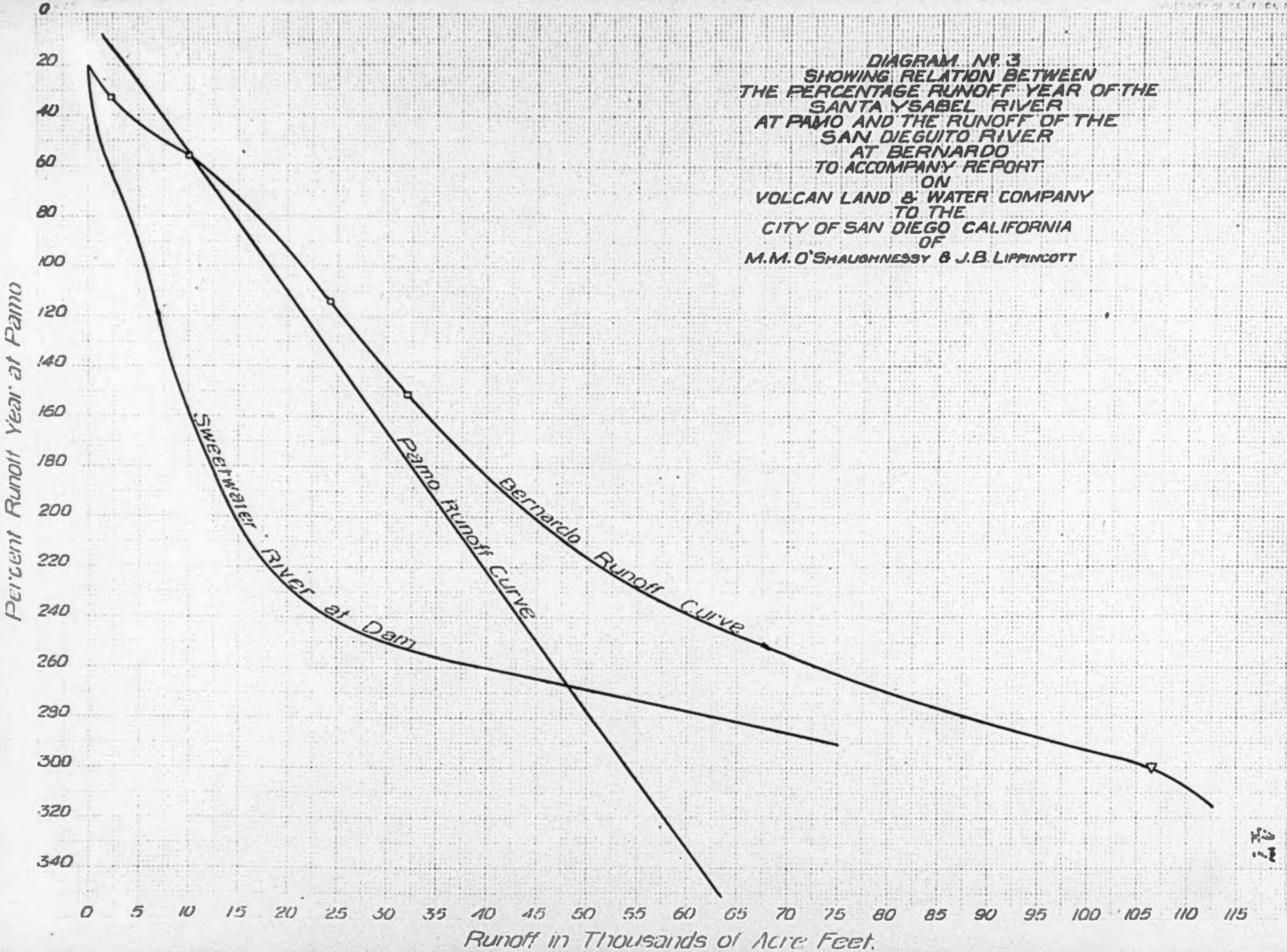

DIAGRAM No 4
SHOWING PERCENTAGE RELATION BETWEEN THE RUNOFF OF THE SANTA YSABEL RIVER AT PAMO AND AT BERNARDO
TO ACCOMPANY REPORT
ON
VOLCAN LAND & WATER COMPANY
TO THE
CITY OF SAN DIEGO CALIFORNIA
OF
M.M. O'SHAUGHNESSY & J.B. LIPPINCOTT

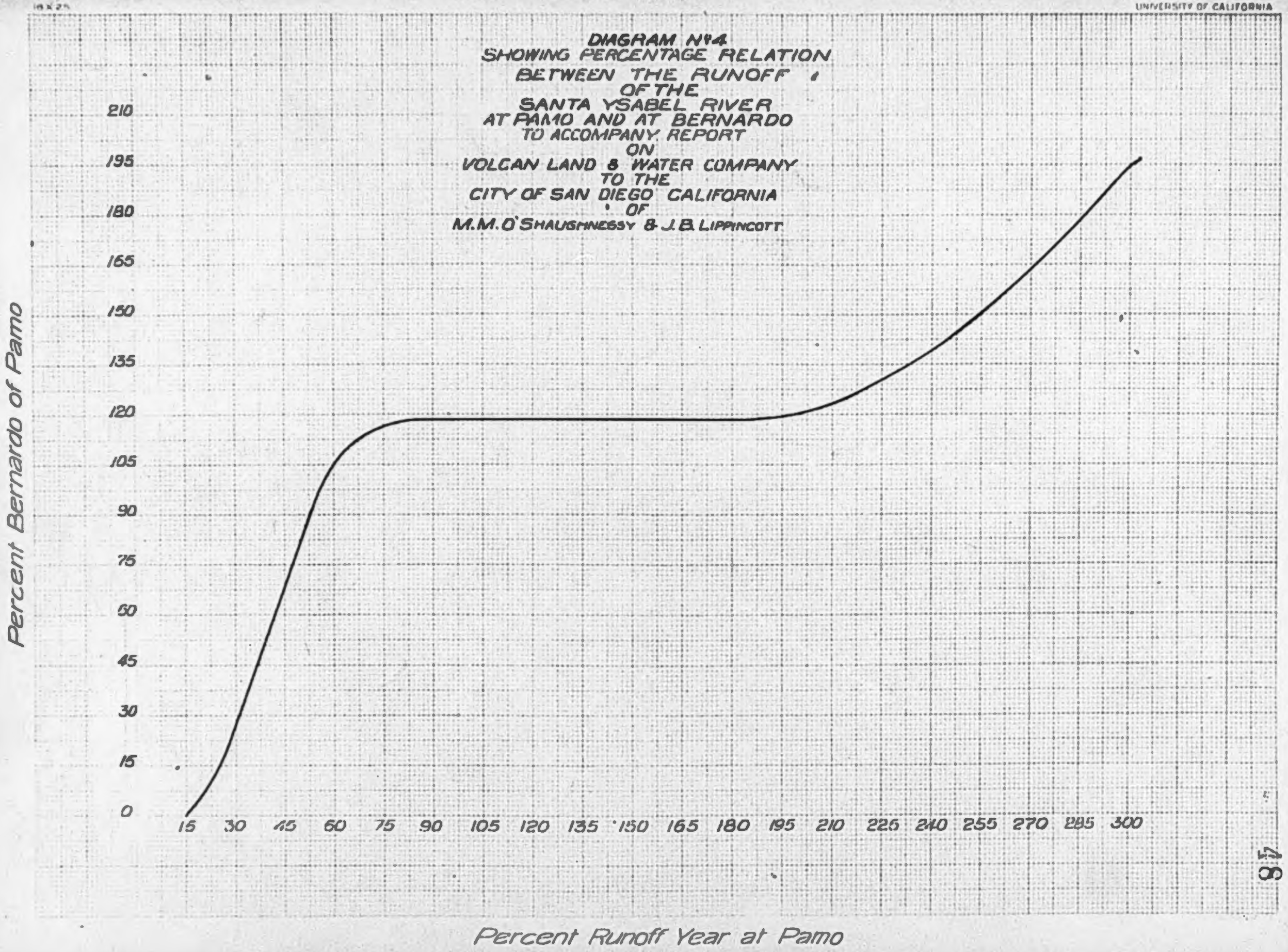

Table No. I

RUN-OFF OF FIVE SOUTHERN CALIFORNIA STREAMS

SHOWING THE ANNUAL PERCENTAGE OF THE MEAN ANNUAL RUN-OFF

Year	(1) Sweetwater 186 sq.mi. A. Ft.	Per Cent Mean	(2) Cuyamaca 12 sq.mi. A. Ft.	Per Cent Mean	(3) San Diego at Diversion 104 sq.mi. A. Ft.	Per Cent Mean	(4) San Gabriel 222 sq. mi. A. Ft.	Per Cent Mean	(5) Percentage Mean Cuyamaca & San Diego	(6) Percentage Mean Cuyamaca & San Diego With San Gabriel	(7) Estimated at Warner's A. Ft.	Adjusted Mean =19,987 Percentage of mean from Pala records.
87-88	7048	63										
88-89	25253	225										
89-90	20532	183										
90-91	21565	192										
91-92	6198	55										
92-93	16260	145										
93-94	1338	12	2563	62	8560°	62	96000°	79	62	70	14000	
94-95	73412	655	11279	275	37700°	274	208500°	171	274	222	44400	
95-96	1321	12	2153	52	7190°	52	27100	22	52	37	7400	
96-97	6892	62	4216	103	14080°	103	90900	75	103	89	17800	
97-98	4	0	834	20	2785°	20	23000	19	20	20	4000	
98-99	245	2	472	13	1218	9	9630	8	11	9	1800	
99-00	0	0	260	6	665	5	12100	10	6	8	1600	
00-01	828	7	3031	74	4700	34	96200	79	54	67	13400	
01-02	0	0	2351	57	5456	40	23800	20	49	34	6800	
02-03	0	0	2516	61	9304	68	106000	87	65	76	15200	
03-04	0	0	492	12	1672	12	28700	24	12	18	3600	
04-05	13760	123	6831	166	22081	161	160000	132	164	148	27500(3)	138
05-06	35000	312	12780	313	36275	264	236000	194	289	241	66957 M	335
06-07	30000	268	9259	226	34313	250	350000	288	238	263	54000(3)	270
07-08	5787	52	3201	78	14124	103	77500	64	91	77	16900(3)	84
08-09	16126	144	7172	175	23160	168	180000	148	172	160	31700(3)	159
09-10	8775	78	5134	125	16963	124	139000	114	125	119	30560(3)	153
10-11	3363	30	2765	67	12124	88	273000(2)	224	78	151	21600(3)	108
11-12	4463	40	3520	86	17412	127	70700	58	107	82	12030 M	60
12-13	1077	10	2982	73	7534	55	50300	41	64	53	6042 M	30
13-14	3525	31	2304	56	11074	81	296000	243	69	156	22521 M	113
Total	302772		86115		288390		2554430				419810	
Mean	11214		4101		13733		121640				20000	

° Estimated from Cuyamaca (San Diego - Cuyamaca x 3.34
(San Gabriel 93-94 = Cuyamaca x 37.48
(San Gabriel 94-95 = Cuyamaca x 18.47

(2) February flood of 122,000 a.f. not apparent in Southern California Streams.

(3) Computed from total river at Pala.

M Measured flow at Warner.

Note: Subsequent to the preparation of the table the runoff of the San Diego River at the Diversion Dam was revised and corrected by the Volcan Land & Water Co., but the changes are such that the results of this study are not appreciably affected and the table has not been changed to agree with the revised runoff.

Table No. II

RUN-OFF OF SAN LUIS REY RIVER AT WARNERS

FOR PERIOD OF MEASUREMENT AT PALA

	Measured at Pala A. Ft.	Escondido Ditch at Intake A.Ft.	Total River at Pala A. Ft.	River at Warner A. Ft.	Warner in Per Cent Total River at Pala (4)	Estimated Adjusted Annual Percentages
1904-05	41868	2937	44805	27500 (3)		138
05-06	106302	1742	108044	66957 M	61.9	335
06-07	84571	3319	87890	54000 (3)		270
07-08	24850	2705	27555	16900 (3)		84
08-09	48120	3488	51608	31700 (3)		159
09-10	47086	2686	49772	30560 (3)		153
	:31000(1)					
10-11	: 1000	3212	35212	21600 (3)		108
11-12		2562	20100(2)	12030 M		60
12-13	6551	4256	10807	6042 M	55.8	30
13-14	28089	5783	33872	22521 M	66.5	113
Total				289810		1450
Mean				28981	61.4	145
Adjusted Mean (5)				19987		

(1) Add 1000 a.f. estimated for July to December 1910 inclusive account of no record.
(2) Computed from measured flow at Warner
M Measured flow at Warner
(3) Estimated by multiplying Total River at Pala by 61.4 per cent.
(4) Drainage area back of Warner = 64 per cent of drainage area back of Pala.
(5) The period 1904-05 to date is 145 per cent period as compared to a twenty-one year average of the Cuyamaca, San Diego River at diversion, and San Gabriel River.

Table No. 3

MEASURED RUN-OFF OF THE WEST FORK OF THE SAN LUIS REY RIVER AND OF THE SAN LUIS REY RIVER AT WARNER DAM

Month	West Fork a.f.	San Luis Rey a.f.	Ratio
1913			
Jan.	61	443	
Feb.	555	2008	
Mar.	763	1758	
April	368	744	
May	117	252	
June	23	94	
Total	1887	5299	35.6
1913-14			
July	7	54	
Aug.	0	138	
Sept.	0	56	
Oct.	0	61	
Nov.	10	111	
Dec.	55	200	
Jan.	1220	4740	
Feb.	3330	12300	
Mar.	1050	2210	
Apr.	809	1313	
May	448	795	
June	146	243	
Total	7075	22221	32
Total for period of measurement	8962	27520	32.5

$$32.5\% \times \frac{33}{24.4} = 44\%$$

Table No. IV

ESTIMATED RELINQUISHMENTS AT WARNERS TO SATISFY ESCONDIDO DIVERSIONS

Year	Estimated Run-off at Warners a. f.	Estimated Relinquishments for Escondido a.f.
1893-94	14000	960
94-95	44400	0
95-96	7400	1897
96-97	17800	460
97-98	4000	2451
98-99	1800	1350
99-00	1600	723
1900-01	13400	1048
01-02	6800	1497
02-03	15200	404
03-04	3600	1505
04-05	27500	0
05-06	66957	0
06-07	54000	0
07-08	16900	0
08-09	31700	0
09-10	30560	0
1910-11	21600	0
11-12	12030	833
12-13	6042	2028
13-14	22521	457
	419810	15613

Table No. V

RAINFALL ON SURFACE OF RESERVOIR AT WARNERS

Year	(2) Average Annual Percentages of Mean Rainfall for County 41 Year Period	(3) Adjusted Percentages for 21 Year Period	(4) Estimated Rainfall on Reservoir Surface	(5) 90 Percent of Rainfall
1893-94	65	69	13.76	12.38
94-95	131	138	27.51	24.76
95-96	60	63	12.57	11.31
96-97	111	117	23.33	21.00
97-98	61	64	12.77	11.49
98-99	55	58	11.57	10.41
99-00	73	77	15.36	13.82
1900-01	96	102	20.34	18.31
01-02	75	79	15.75	14.18
02-03	112	118	23.52	21.17
03-04	53	56	11.17	10.05
04-05	146	154	30.71	27.64
05-06	155	164	32.70	29.43
06-07	116	123	24.53	22.08
07-08	89	94	18.75	16.88
08-09	113	120	23.92	21.54
09-10	97	103	20.53	18.48
10-11	102	108	21.53	19.38
11-12	98	104 (97.6%	18.72(1)	16.85
12-13	70	74(of	15.22(1)	13.70
13-14	109	115(mean	24.40(1)	21.96
Total	1987		418.67	
Mean	94.6		19.94	

(1) Average of measured rainfall on five stations.

Table No. VI

MASS CURVE STUDY FOR WARNER RESERVOIR

Capacity 117000 a.f.

Year	(1) Volume in Reservoir at beginning of wet Season	(2) Estimated run-off	(3) Draft During Wet Season	(4) Volume in Reservoir at end of Wet Season	(5) Conserved Evaporation from Submerged Moist Lands	(6) Released for Escondido	(7) Mean Area Flooded	(8) Net Evaporation Feet	(9) Evaporation Acre Feet	(10) Total Draft	(11) Waste
1893-94	80000	14000	4000	90000	1900	960	2870	3.6	10300	13000	
94-95	71640	44400	4000	112040	2040	0	3100	2.5	7760	13000	
95-96	97320	7400	4000	100720	2100	1897	3160	3.7	11680	13000	
96-97	80243	17800	4000	94043	1950	460	2960	2.8	8300	13000	
97-98	78233	4000	4000	78233	1790	2451	2670	3.7	9900	13000	
98-99	58672	1800	4000	56472	1500	1350	2160	3.75	8100	13000	
99-00	39522	1600	4000	37122	1220	723	1670	3.4	5670	13000	
1900-01	22949	13400	4000	32349	1050	1048	1420	3.1	4400	13000	
01-02	18951	6800	4000	21721	880	1497	1150	3.4	3900	13000	
02-03	8234	15200	4000	19434	690	404	900	2.8	2520	13000	
03-04	8200	3600	4000	7800	500	1505	400	3.7	1480	13000	°
04-05	0	27500	4000	23500	620	0	800	2.2	1760	13000	
1905-06	13360	66957	4000	76317	1320	0	1850	2.2	4070	13000	
06-07	64567	54000	4000	114567	2000	0	3050	2.75	8400	13000	
07-08	99167	16900	4000	112067	2100	0	3450	3.2	11000	13000	
08-09	94167	31700	4000	117000	2260	0	3420	2.75	9420	13000	4867
09-10	100840	30560	4000	117000	2300	0	3550	3.1	11000	13000	10400
10-11	99300	21600	4000	116900	2360	0	3500	3.0	10500	13000	
11-12	99760	12030	4000	107790	2260	833	3400	3.2	10850	13000	
12-13	89367	6042	4000	91409	2000	2028	3040	3.4	10300	13000	
13-14	72081 75305	22521	4000	90602	1860	457	2800	2.75	7700	13000	
Total		419810			34700	15613			159010	273000	15267

° Deficiency 3685 acre-feet or 28 per cent.

Table No. VII

MASS CURVE STUDY FOR WARNER RESERVOIR

Capacity 120000 a.f.

Year	(1) Volume in Reservoir at beginning of wet Season	(2) Estimated Run-off	(3) Draft During Wet Season	(4) Volume in Reservoir at end of Wet Season	(5) Conserved Evaporation from Submerged Moist Lands	(6) Released for Escondido	(7) Mean Area Flooded	(8) Net Evaporation Feet	(9) Evaporation Acre Feet	(10) Total Draft	(11) Waste
1893-94	90000	14000	4500	99500	2040	960	3120	3.6	11200	13500	
94-95	80380	44400	4500	120280	2180	0	3300	2.5	8260	13500	
95-96	105200	7400	4500	108100	2240	1897	3400	3.7	12600	13500	
96-97	86843	17800	4500	100143	2030	460	3100	2.8	8600	13500	
97-98	84113	4000	4500	83613	1870	2451	2850	3.7	10500	13500	
98-99	63532	1800	4500	60832	1560	1350	2250	3.75	8450	13500	
99-00	43592	1600	4500	40592	1290	723	1760	3.4	6000	13500	
1900-01	26259	13400	4500	35159	1100	1048	1500	3.1	4650	13500	
01-02	21561	6800	4500	23861	920	1497	1250	3.4	4250	13500	
02-03	10034	15200	4500	20734	740	404	900	2.8	2520	13500	
03-04	9550	3600	4500	8650	520	1505	500	3.7	1850	13500	°
04-05	0	27500	4500	23000	620	0	800	2.2	1760	13500	
05-06	12860	66957	4500	75317	1320	0	1850	2.2	4060	13500	
06-07	63577	54000	4500	113077	1960	0	3000	2.75	8260	13500	
07-08	97777	16900	4500	110177	2200	0	3360	3.2	10075	13500	
08-09	93302	31700	4500	120502	2300	0	3470	2.75	9550	13500	
09-10	104252	30560	4500	120000	2460	0	3600	3.1	11100	13500	10312
10-11	102360	21600	4500	119460	2390	0	3550	3.0	10650	13500	
11-12	102200	12030	4500	109730	2300	833	3450	3.2	11000	13500	
12-13	91197	6042	4500	92739	2000	2028	3050	3.4	10400	13500	
13-14	73311 75685	22521	4500	91332	1860	457	2820	2.75	8050	13500	
Total		419810			35900	15613			163785	283500	10312

° Deficiency 3185 a.f. or 23-1/2 per cent.

Table No. VIII

RELATION BETWEEN RUN-OFF OF SANTA YSABEL RIVER AT PAMO DAM SITE & AT SUTHERLAND

Date	At Pamo Dam Site 110 sq.mi. A. ft.	At Sutherland 53 sq.mi. A. ft.	Percentage Sutherland of Pamo Period
1912-13			
Dec.	225	163	
Jan.	460	410	
Feb.	1355	841	
Mar.	1828	1426	
Apr.	902	696	
May	418	370	
June	171	178	
Total	5359	4084	76
1913-14			
July	13	39	
Aug.	4	4	
Sept.	10	4	
Oct.	3	14	
Nov.	175	123	
Dec.	296	229	
Jan.	5400	2890	
Feb.	9150	4100	
Mar.	2500	1440	
Apr.	1560	875	
May	1080	593	
June	488	231	
Total	20679	10542	51
1914			
July	19	23	
Aug.	6	1	
Sept.	6	5	
Oct.	33	33	
Nov.	99	66	
Dec.	358	270	
Total	521	398	76
Total Run-off for Period	26559	15024	57

Table No. IX

RELATION OF THE RUN-OFF OF THE SAN LUIS REY RIVER AT WARNERS AND PALA TO THE RUN-OFF OF THE SANTA YSABEL RIVER AT PAMO GAGE FOR THE PERIOD OF MEASUREMENT AT PAMO GAGE

Year	San Luis Rey River at Pala(1)	Estimated at Warner	Santa Ysabel Measured at Pamo Gage	Percentages Pamo of Pala	Pamo of Warner
1905-06	108044	66957 M	60471 (3)	56	90
06-07	87890	54000	35756	41	66
07-08	27555	16900	12389	45	73
08-09	51608	31700	45765	89	144
09-10	49772	30560	35191	71	115
10-11	35212	21600			
11-12	20100 (2)	12030 M	10705	53	89
				355	577
				59	96

(1) Measured run-off at Pala plus Escondido Ditch Diversion

(2) Computed from measured flow at Warners

(3) January to June 1906 inclusive

M Measured run-off

Note: The run-off of the Santa Ysabel at Pamo Gage is taken as 96 per cent of the run-off of the San Luis Rey River at Warners for those years during which there is no record at Pamo Gage.

Table No. X

ESTIMATED RUN-OFF OF SANTA YSABEL RIVER

Year	(2) San Luis Rey River Estimated at Warners		(3) Santa Ysabel River Estimated at Pamo Gage (1)		(4) Santa Ysabel River Estimated at Pamo Dam Site (3)		(5) Santa Ysabel River Estimated at Sutherland (4)		(6) Santa Ysabel River Run-off between Sutherland & Pamo Dam Site
	A. Ft.	Percent of Mean	A. Ft.	Percent of Mean	A. Ft.	Percent of Mean	A. Ft.	Percent of Mean	
1893-94	14000	70	13440	71	12770	71	7280	71	5490
94-95	44400	222	42650	224	40520	224	23100	224	17420
95-96	7400	37	7100	38	6740	38	3840	37	2900
96-97	17800	89	17080	90	16230	90	9310	90	6920
97-98	4000	20	3840	20	3650	20	2080	20	1570
98-99	1800	9	1728	9	1640	9	940	9	700
99-00	1600	8	1536	8	1460	8	830	8	630
1900-01	13400	67	12860	68	12220	68	6970	68	5250
01-02	6800	34	6530	34	6200	34	3540	34	2660
02-03	15200	76	14590	77	13860	77	7900	77	5960
03-04	3600	18	3457	18	3280	18	1870	18	1410
04-05	27500	138	26400	138	25090	138	14300	139	10790
05-06	66957 M	335	60471 M	317	57450	317	32750	318	24700
06-07	54000	270	35756 M	187	33970	187	19370	188	14600
07-08	16900	84	12389 M	65	11870	65	6760	66	5110
08-09	31700	159	45765 M	240	43480	240	24790	241	18690
09-10	30560	153	35191 M	184	33430	184	19060	185	14370
1910-11	21600	108	20730	109	19700	109	11230	109	8470
11-12	12030 M	60	10705	56	10170	56	5800	56	4370
12-13	6042 M	30	6390(2)	33	6071 M	33	4084 M	40	1987
13-14	22521 M	113	21760(2)	114	20679 M	114	10542 M	102	10137
Total	419810		400368		380480		216346		164134
Mean	20000		19065		18118		10302		

M Measured run-off
(1) Santa Ysabel at Pamo Gage estimated as 96 per cent of run-off of San Luis Rey River at Warners.
(2) Estimated as 105.3 per cent of measured run-off at Pamo Dam site
(3) Estimated as 95 per cent of run-off at Pamo Gage
(4) Estimated as 57 per cent of run-off at Pamo Dam site

Table No. XI

ESTIMATED RUN-OFF OF 130 SQUARE MILES TRIBUTARY TO SAN PASQUAL VALLEY BELOW PAMO DAM SITE

Year	Sweetwater Percentages	Pamo Dam Percentages	Average Percent	Run-off of 130 sq. mi. tributary to San Pasqual Valley Mean =130 x 100 =13000 acre-feet
1893-94	12	71	42	5460
94-95	655	224	439	57100
95-96	12	38	25	3250
96-97	62	90	76	9880
97-98	0	20	10	1300
98-99	2	9	6	780
99-00	0	8	4	520
1900-01	7	68	38	4940
01-02	0	34	17	2210
02-03	0	77	38	4940
03-04	0	18	9	1170
04-05	123	138	130	16900
05-06	312	317	314	40830
06-07	268	187	227	29500
07-08	52	65	58	7540
08-09	144	240	192	24950
09-10	78	184	126	16380
10-11	30	109	70	9100
11-12	40	56	48	6240
12-13	10	33	22	2860
13-14	31	114	73	9490

ESTIMATED NET RUN-OFF INTO PAMO RESERVOIR

FROM TOTAL DRAINAGE BACK OF PAMO DAM SITE

CONSIDERING RELINQUISHMENTS AT PAMO FOR LOSSES IN THE

SAN PASQUAL VALLEY

TO THE EXTENT OF 7760 a. f. PER ANNUM IF AVAILABLE IN

THE STREAM

Table No.XII

YEAR	(2) Estimated Run-off of 130 sq.mi. below Pamo Dam Site tributary to San Pasqual Valley a. f.	(3) Run-off Above Pamo Dam a.f.	(4) Released at Pamo Dam Site	(5) Net Run-off Above Pamo
1893-94	5460	12770	2300	10470
94-95	57100	40620	0	40620
95-96	3250	6740	4510	2230
96-97	9880	16230	0	16230
97-98	1300	3650	3650	0
98-99	780	1640	1640	0
99-00	520	1460	1460	0
1900-01	4940	12220	2820	9400
01-02	2210	6200	5550	650
02-03	4940	13860	2820	11040
03-04	1170	3280	3280	0
04-05	16900	25090	0	25090
05-06	40830	57450	0	57450
06-07	29500	33970	0	33970
07-08	7540	11870	220	11650
08-09	24950	43480	0	43480
09-10	16380	33430	0	33430
10-11	9100	19700	0	19700
11-12	6240	10170	1520	8650
12-13	2860	6071	4900	1171
13-14	9490	20679	0	20679

Table No. XIII

MASS CURVE STUDY FOR PAMO RESERVOIR

NO REGULATION ON RIVER ABOVE PAMO

Reservoir Capacity Pamo 47500
San Clemente 8570
Total Effective Storage Cap. 56070 a.f.

Year	(2) Volume in Reservoir at beginning of wet Season	(3) Estimated Run-off	(4) Relinquishments for San Pasqual Valley	(5) Net Run-off into Pamo Reservoir	(6) Draft During Wet Season	(7) Volume in Reservoir at end of Wet Season	(8) Mean Area Flooded Acres	(9) Net Evaporation Feet	(10) Evaporation Acre Feet	(11) Total Draft	(12) Waste
1893-94	25000	12770	2300	10470	2500	32970	610	3.6	2200	7800	
94-95	25470	40520	0	40520	2500	56070	800	2.5	2000	7800	7420
95-96	48770	6740	4510	2230	2500	48500	950	3.7	3500	7800	
96-97	39700	16230	0	16230	2500	53430	940	2.8	2620	7800	
97-98	45510	3650	3650	0	2500	43010	900	3.7	3330	7800	
98-99	34380	1640	1640	0	2500	31880	700	3.75	2620	7800	
99-00	23960	1460	1460	0	2500	21460	500	3.4	1700	7800	
1900-01	14460	12220	2820	9400	2500	21360	410	3.1	1270	7800	
01-02	14790	6200	5550	650	2500	12940	340	3.4	1150	7800	
02-03	6490	13860	2820	11040	2500	15030	275	2.8	770	7800	
03-04	8960	3280	3280	0	2500	6460	180	3.75	675	7800	
04-05	485	25090	0	25090	2500	23075	290	2.25	650	7800	
05-06	17125	57450	0	57450	2500	56070	750	2.2	1650	7800	16005
06-07	49120	33970	0	33970	2500	56070	1060	2.75	2920	7800	24520
07-08	47850	11870	220	11650	2500	56070	1030	3.2	3300	7800	930
08-09	47470	43480	0	43480	2500	56070	1030	2.75	2830	7800	32380
09-10	47940	33430	0	33430	2500	56070	1030	3.1	3200	7800	22800
10-11	47570	19700	0	19700	2500	56070	1030	3.0	3090	7800	8700
11-12	47680	10170	1520	8650	2500	53830	1010	3.2	3240	7800	
12-13	45290	6071	4900	1171	2500	43961	900	3.4	3060	7800	
13-14	35601	20679	0	20679	2500	53780	900	2.75	2470	7800	
	46010										
Total		380480	34670	345810					48245	163800	112755

Table No. XIV

MASS CURVE STUDY FOR SUTHERLAND RESERVOIR

PAMO RESERVOIR CONSTRUCTED

San Pasqual Valley Demands Met from Pamo Reservoir

Capacity of Sutherland Reservoir 18400 a.f.

Year	(2) Volume in Reservoir at beginning of wet Season	(3) Estimated Run-off Acre-feet	(4) Draft During Wet Season	(5) Volume in Reservoir at end of Wet Season	(6) Mean Area Flooded	(7) Gross Evaporation Inches	(8) 90 Per Cent Rainfall Inches	(9) Net Evaporation Inches	Feet	(10) Evaporation Acre Feet	(11) Draft Acre Feet	(12) Waste Acre Feet
1893-94	9000	7280	1000	15280	260	55	12.38	43	3.6	935	5000	
94-95	10345	23100	1000	18400	300	55	24.76	30	2.5	750	5000	14045
95-96	13650	3840	1000	16490	320	55	11.31	44	3.7	1180	5000	
96-97	11310	9310	1000	18400	320	55	21.00	34	2.8	900	5000	1220
97-98	13500	2080	1000	14580	300	55	11.49	44	3.7	1100	5000	
98-99	9480	940	1000	9420	220	55	10.41	45	3.75	825	5000	
99-00	4595	830	1000	4425	100	55	13.82	41	3.4	340	5000	
1900-01	85	6970	1000	6055	40	55	18.31	37	3.1	120	5000	
01-02	1935	3540	1000	4475	45	55	14.18	41	3.4	150	5000	
02-03	325	7900	1000	7225	90	55	21.17	34	2.8	250	5000	
03-04	2975	1870	1000	3845	60	55	10.05	45	3.75	225	5000	
04-05	0	14300	1000	13300	170	55	27.64	27	2.25	380	5000	22870
05-06	8920	32750	1000	18400	300	55	29.43	26	2.2	660	5000	22270
06-07	13740	19370	1000	18400	340	55	22.08	33	2.75	935	5000	13725
07-08	13465	6760	1000	18400	340	55	16.88	38	3.2	1090	5000	18825
08-09	13310	24790	1000	18400	340	55	21.54	33	2.75	935	5000	18705
09-10	13465	19060	1000	18400	340	55	18.48	37	3.1	1050	5000	15125
1910-11	13350	11230	1000	18400	340	55	19.38	36	3.0	1020	5000	5180
11-12	13380	5800	1000	18180	335	55	16.85	38	3.2	1070	5000	
12-13	13110	4084	1000	16194	310	55	13.70	41	3.4	1050	5000	
13-14	11144	10542	1000	18400	310	55	21.96	33	2.75	850	5000	* 2286
		216346								15815	105000	91361

* Deficiency of 380 acre-feet.

Table No. XV

MASS CURVE STUDY FOR PAMO RESERVOIR

SUTHERLAND RESERVOIR CONSTRUCTED

Reservoir Capacity Pamo 47500
San Clemente 8570
Total Effective Storage Cap. 55070 a.f.

Year	(2) Volume in Reservoir at beginning of wet Season	(3) Estimated Run-off Below Sutherland	(4) Waste From Sutherland	(5) Relinquishments for San Pasqual Valley	(6) Estimated Net Run-off Into Pamo Reservoir	(7) Draft During Wet Season	(8) Volume in Reservoir at end of Wet Season	(9) Mean Area Flooded Acres	(10) Gross Evaporation Inches
1893-94	25000	5490		2300	3190	1000	27190	560	55
94-95	22190	17420	14045	0	31465	1000	52655	800	55
95-96	47655	2900		4510	1610	1000	45045	920	55
96-97	38645	6920	1220	0	8140	1000	45785	840	55
97-98	40445	1570		3650	2080	1000	37365	800	55
98-99	31405	700		1640	940	1000	29465	650	55
99-00	24065	630		1460	830	1000	22235	520	55
1900-01	17475	5250		2820	2430	1000	18905	400	55
01-02	14665	2660		5550	2890	1000	10775	320	55
02-03	6695	5960		2820	3140	1000	8835	150	55
03-04	5415	1410		3280	1870	1000	2545	60	55
04-05	0	10790		0	10790	1000	9790	100	55
05-06	6565	24700	22270	0	46970	1000	52535	650	55
06-07	48105	14600	13710	0	28310	1000	56070	1080	55
07-08	50110	5110	825	220	5715	1000	54825	1080	55
08-09	48365	18690	18700	0	37390	1000	56070	1080	55
09-10	50110	14370	13125	0	27495	1000	56070	1080	55
10-11	49720	8470	5180	0	13650	1000	56070	1080	55
11-12	49830	4370		1520	2850	1000	51680	1050	55
12-13	45320	1987		4900	2913	1000	41407	900	55
13-14	35347	10137	2286	0	12423	1000	46770	840	55
Total		164134	91361	34670	220825				

(11) 90 Per Cent Rainfall Inches	(12) Net Evaporation Inches	Feet	(13) Evaporation Acre-feet	(14) Total Draft	(15) Waste	
12.38	43	3.6	2000	4000		
24.76	30	2.5	2000	4000		
11.31	44	3.7	3400	4000		
21.00	34	2.8	2340	4000		
11.49	44	3.7	2960	4000		
10.41	45	3.75	2400	4000		
13.82	41	3.4	1760	4000		
18.31	37	3.1	1240	4000		
14.18	41	3.4	1080	4000		
21.17	34	2.8	420	4000		
10.05	45	3.75	220	4000		Deficiency 675 a.f. = 17%
27.64	27	2.25	225	4000		
29.43	26	2.2	1430	4000		
22.08	33	2.75	2960	4000	19345	
16.88	38	3.2	3460	4000		
21.54	33	2.75	2960	4000	28685	
18.48	37	3.1	3350	4000	20535	
19.38	36	3.0	3240	4000	6300	
16.85	38	3.2	3360	4000		
13.70	41	3.4	3060	4000		
21.96	33	2.75	2300	4000		
			46165	84000	74865	

Note: Sutherland Reservoir constructed to a capacity of 18400 a.f.

Table No. XVI

MASS CURVE STUDY FOR WARNER AND PAMO RESERVOIRS COMBINED

SUTHERLAND RESERVOIR CONSTRUCTED

Capacities

Warner			117000 a.f.
Pamo			
	Pamo	47500	
	SanClemente	8570	56070

WARNER'S --

Year	Volume in Reservoir at beginning of wet Season	Estimated Run-off Acre Feet	Passed to Pamo During Wet Season	Draft During Wet Season	Volume in Reservoir at end of Wet Season	Conserved Evaporation	Released for Escondido	Mean Area Flooded	Net Evaporation Feet	Evaporation Acre Feet
1893-94	80000	14000	0	4500	89500	1860	960	2800	3.6	10000
94-95	67400	44400	0	4500	107300	1950	0	2950	2.5	7350
95-96	92900	7400	0	4500	95800	2040	1897	3100	3.7	11400
96-97	75543	17800	0	4500	88843	1860	460	2820	2.8	7900
97-98	73343	4000	0	4500	72843	1680	2451	2480	3.7	9200
98-99	50872	1800	0	6000	46672	1320	1350	1820	3.75	6800
99-00	24342	1600	0	6000	19942	800	723	1100	3.4	3700
1900-01	2819	13400	13500	0	2719	0	1048	200	3.1	620
01-02	1051	6800	5000	0	2851	0	1497	30	3.4	100
02-03	1254	15200	16000	0	1454	0	404		2.8	50
03-04	0	3600	2095	0	2505	0	1505		3.7	0
04-05	0	27500	27500	0	0	0	0		2.2	0
05-06	0	66957	0	0	66957	1220	0	1670	2.2	3680
06-07	64497	54000	0	0	117000	2020	0	3200	2.75	8800
07-08	110220	16900	10000	0	117120	2750	0	3800	3.2	12200
08-09	107670	31700	0	4500	117000	2420	0	3640	2.75	10000
09-10	100420	30560	0	4500	117000	2360	0	3500	3.1	10800
10-11	99560	21600	0	4500	116660	2340	0	3480	3.0	10400
11-12	99600	12030	0	4500	107130	2200	833	3350	3.2	10700
12-13	88797	6042	0	4500	90339	1960	2028	2960	3.4	10000
13-14	71271	22521	0	4500	89292	1820	457	2750	2.75	7600
Total		419810				30600	15613			141300

Note: About one third of draft is considered as being taken out during "wet" season.

P A M O

Total Passed to Storage In Pamo	Total Draft	Waste	Volume in Reservoir at beginning of Wet Season	Estimated Run-off Below Sutherland Acre-feet	Waste from Sutherland	Passed from Warner's During Wet Season	Draft During Wet Season	Released for San Pasqual Valley	Volume in Reservoir at end of Wet Season
4000	13500		25000	5490	0	0	1000	2300	27190
0	13500		26040	17420	14045	0	1000	0	56505 °
0	13500		51385	2900	0	0	1000	4510	48775
0	13500		42005	6920	1220	0	1000	0	49145
3000	13500		43485	1570	0	0	1000	3650	40405
4000	17500		37105	700	0	0	0	1640	36165
2000	17500		36985	630	0	0	0	1460	36155
13500	0		35255	5250	0	13500	6000	2820	45185
5000	0		31335	2660	0	5000	6000	5550	27445
16000	0		14075	5960	0	16000	6000	2820	27215
2095	0		14595	1410	0	2095	6000	3280	8820
27500	0		0	10790	0	27500	6000	0	32290
0	0	0	20025	24700	22270	0	6000	0	56070
0	0	1497	42970	14600	13710	0	6000	0	56070
10000	0	0	41960	5110	825	10000	6000	220	51675
0	13500	17870	37475	18690	18700	0	1000	0	56070
0	13500	9480	50430	14370	13125	0	1000	0	56070
0	13500	0	49670	8470	5180	0	1000	0	56070
0	13500	0	49830	4370	0	0	1000	1520	51680
0	13500	0	45380	1987	0	0	1000	4900	41467
0	13500	0	35407	10137	2286	0	1000	0	46830
87095	183500	28847		164134	91361			34670	

° Slightly in excess of maximum capacity.

in oir of n	Total Transferred from Storage at Warners to Pamo	Mean Area Flooded	Net Evaporation Feet	Evaporation Ac. Ft.	Total Draft	Waste	Combined Draft Acre-ft. Warners	Pamo	Total	
	4000	600	3.6	2150	4000	0	13500	4000	17500	
•	0	850	2.5	2120	4000	0	13500	4000	17500	
	0	1020	3.7	3770	4000	0	13500	4000	17500	
	0	950	2.8	2660	4000	0	13500	4000	17500	
	3000	900	3.7	3300	4000	0	13500	4000	17500	
	4000	850	3.75	3180	0	0	17500	0	17500	
	2000	850	3.4	2900	0	0	17500	0	17500	
	13500	760	3.1	2350	17500	0	0	17500	17500	
	5000	550	3.4	1870	17500	0	0	17500	17500	
	16000	400	2.8	1120	17500	0	0	17500	17500	
	2095	200	3.75	750	17500	0	0	17500	17500	Def.3430 a.f.or 19¼%
	27500	340	2.25	765	17500	0	0	17500	17500	
	0	730	2.2	1600	17500	4925	0	17500	17500	
	0	950	2.75	2610	17500	9210	0	17500	17500	
	10000	850	3.2	2700	17500	0	0	17500	17500	
	0	960	2.75	2640	4000	17795	13500	4000	17500	
	0	1100	3.1	3400	4000	20855	13500	4000	17500	
	0	1080	3.0	3240	4000	6250	13500	4000	17500	
	0	1030	3.2	3300	4000		13500	4000	17500	
	0	900	3.4	3060	4000		13500	4000	17500	
	0	850	2.75	2340	4000		13500	4000	17500	
	87095			51825	184000	59035				

Waste is not passed from Warners to Pamo to more than two thirds of Pamo capacity or 37000 a.f.

Table No. XVII

MEASURED RUN-OFF OF SANTA YSABEL RIVER

AT PAMO DAM SITE AND BERNARDO

Date	Run-off at Pamo Dam Site		Run-off at Bernardo	Per Cent Bernardo of Pamo
	Acre feet	Per Cent Mean a.f.		
March to June 1912	9740	56	9973	102.3
1912-13	6071	33	2218	36.5
1913-14	20679	114	24269	117.3
1914-15 +	27627	152	32473	117.5

+ July to March

Table No.XVIII

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 110% 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

Table No. XIX

ESTIMATED SAN PASQUAL VALLEY LOSSES

Year	(2) Estimated Run-off Pamo Dam a.f.	(3) Estimated Run-off Bernardo a.f.	(4) Direct Loss a.f.	(5) Estimated Run-off 130 sq.mi. tributary to S.P.Valley a.f.	(6) Estimated Total Losses
1895-96	6740	3370	3370	3250	6620
1897-98	3650	260	3390	1300	4690
1898-99	1640	0	1640	780	2420(1)
1899-00	1460	0	1460	520	1980(1)
1901-02	6200	2360	3840	2210	6050
1903-04	3280	160	3120	1170	4290
1911-12	10170	9970	200	6240	6440
1912-13	6071 M	2218 M	3850	2860	6713
					34803
				Mean	5960

M Measured run-off

(1) During these years the uses in the San Pasqual Valley are probably not entirely satisfied and these years have been excluded in making up the average.

Ultimate use in San Pasqual Valley	7760
Present use in valley	5960
Probable future use	1800 a.f.

Table No. XX

ESTIMATED RAINFALL ON CARROLL RESERVOIR

Year	Escondido Percentage of Mean	Adjusted Percentages	Estimated Annual Rainfall On Carroll Mean = 12.0"	90 Percent Rainfall
1893-94	39	41	4.92	4.43
94-95	122	127	15.24	13.72
95-96	52	54	6.48	5.83
96-97	102	106	12.72	11.45
97-98	57	59	7.08	6.37
98-99	62	65	7.80	7.02
99-00	90	94	11.28	10.16
1900-01	95	99	11.88	10.69
01-02	76	79	9.48	8.53
02-03	115	120	14.40	12.96
03-04	53	55	6.60	5.94
04-05	153	160	19.20	17.28
05-06	164	171	20.52	18.47
06-07	116	121	14.52	13.07
07-08	88	93	11.16	10.05
08-09	118	123	14.76	13.29
09-10	122	127	15.24	13.72
1910-11	101	105	12.60	11.34
11-12	96	100	12.00	10.80
12-13	68	71	8.52	7.67
13-14	125	130	15.60	14.04
	2014	2100	252.00	226.83
	96%	100	12.00	10.80

Table No.XXI

MASS CURVE STUDY FOR CARROLL RESERVOIR

NO REGULATION ON UPPER RIVER

Capacity 34800 a.f.

Year	(2) Volume in Reservoir at beginning of wet Season	(3) Estimated Run-off	(4) Estimated Future Loss in San Pasqual Valley	(5) Released for Priorities Below Carroll	(6) Estimated Net Run-off Into Carroll	(7) Draft During Wet Season	(8) Volume in Reservoir at end of Wet Season	(9) Mean Area Flooded	(10) Net Evaporation Feet	(11) Evaporation Ac.Ft.	(12 Total Draft	(13) Waste	
1893-94	10000	16150	1800	1000	13350	2000	21350	600	4.8	2880	6400		
94-95	14070	57700	1800	1000	54900	2000	34800	900	4.0	3600	6400	32170	
95-96	26800	3710	1800	1000	910	2000	25710	950	4.7	4450	6400		
96-97	16860	21100	1800	1000	18300	2000	33160	930	4.2	3900	6400		
97-98	24860	282	282	0	0	2000	22860	860	4.6	3960	6400		
98-99	14500	0	0	0	0	2000	12500	500	4.6	2300	6400		
99-00	5800	0	0	0	0	2000	3800	100	4.3	430	6400		Deficiency 1030 a.f. or 16%.
1900-01	0	15210	1800	1000	12410	2000	10410	100	4.3	430	6400		
01-02	5580	2600	1800	800	0	2000	3580	100	4.5	450	6400		" 1270 " " 20%.
02-03	0	17870	1800	1000	15070	2000	13070	230	4.1	945	6400		
03-04	7725	176	176	0	0	2000	5725	230	4.9	1130	6400		
04-05	195	32600	1800	1000	29800	2000	27995	500	3.7	1850	6400		
05-06	21745	124000	1800	1000	121200	2000	34800	1030	3.6	3700	6400	106145	
06-07	26700	44500	1800	1000	41700	2000	34800	1080	4.1	4430	6400	31600	
07-08	25970	14500	1800	1000	11700	2000	34800	1080	4.3	4650	6400	870	
08-09	25750	66000	1800	1000	63200	2000	34800	1080	4.1	4430	6400	52150	
09-10	25970	43400	1800	1000	40600	2000	34800	1080	4.0	4320	6400	29770	
10-11	26080	25600	1800	1000	22800	2000	34800	1080	4.2	4550	6400	12080	
11-12	25850	10950	1800	1000	8150	2000	32000	1030	4.3	4430	6400		
12-13	23170	2341	1800	541	0	2000	21170	830	4.5	3720	6400		
13-14	13050	26950	1800	1000	24150	2000	34800	860	4.0	3440	6400	400	
		525639	31058	16341	478240					63995	134400	265185	

Table No.XXII

MASS CURVE STUDY FOR CARROLL RESERVOIR

PAMO AND SUTHERLAND RESERVOIRS CONSTRUCTED

Year	(2) Volume in Reservoir at beginning of wet Season	(3) Estimated Run-off Below Pamo	(4) Wasted from Pamo	(5) Total Estimated Run-off Into Carroll	(6) Future Use In San Pasq. Valley	(7) Deducted from Run-off for Priorities Below Carroll	(8) Net Estimated Run-off Into Carroll	(9) Volume in Reservoir at end of Wet Season	(10) Mean Area Flooded
1893-94	10000	3380	0	3380	0	1000	2380	12380	475
94-95	8600	17180	0	17180	1800	1000	14380	22980	640
95-96	18920	42	0	42	0	42	0	18920	750
96-97	12962	4870	0	4870	1800	1000	2070	15032	600
97-98	11032	0	0	0	0	0	0	11032	450
98-99	7482	0	0	0	0	0	0	7482	310
99-00	4582	0	0	0	0	0	0	4582	170
1900-01	2352	2990	0	2990	0	1000	1990	4342	130
01-02	2282	0	0	0	0	0	0	2282	30
02-03	0	4010	0	4010	0	1000	3010	3010	30
03-04	1387	0	0	0	0	0	0	1387	20
04-05	0	7510	0	7510	1800	1000	4710	4710	100
05-06	2840	66550	4925	71475	1800	1000	68675	23000	550
06-07	19520	10530	9210	19740	1800	1000	16940	23000	850
07-08	18000	2630	0	2630	0	1000	1630	19630	770
08-09	14830	22520	17795	40315	1800	1000	37515	23000	760
09-10	18400	9970	20855	30825	1800	1000	28025	23000	830
10-11	18200	5900	6250	12150	1800	1000	9350	23000	830
11-12	18000	780	0	780	0	780	0	18000	750
12-13	13080	0	0	0	0	0	0	13080	560
13-14	8499	6271	0	6271	1800	1000	3471	11970	460
Total		165133	59035	224168	16200	13822	194146		

(11) Net Evapor-ation Feet	(12) Evapor-ation Acre Feet	(13) Draft	(14) Released from Storage for Priorities Below Carroll	(15) Waste
4.8	2280	1500	0	
4.0	2560	1500	0	
4.7	3500	1500	958	
4.2	2500	1500	0	
4.6	2050	1500	0	
4.6	1400	1500	0	
4.3	730	1500	0	
4.3	560	1500	0	
4.5	135	1500	800	
4.1	123	1500	0	
4.9	94	1500	0	
3.7	370	1500	0	
3.6	1980	1500	0	48515
4.1	3500	1500	0	13460
4.3	3300	1500	0	
4.1	3100	1500	0	29345
4.0	3300	1500	0	23425
4.2	3500	1500	0	4550
4.3	3200	1500	220	
4.5	2540	1500	541	
4.0	1840	1500	0	
	42562	31500	2519	119295

Deficiency 153 a.f.

" 207 "

<u>Capacities</u>

Carroll	23000 a.f.
Pamo	47500 "
San Clemente	8750 "
Sutherland	18400 "

Table No.XXIII

ESTIMATED RUN-OFF AT CARROLL

WITH SUTHERLAND AND PAMO RESERVOIRS BUILT

Year	(2) Total Run-off at Carroll	(3) Total Run-off at P a m o	(4) Run-off Between Carroll & Pamo	(5) Wasted from Pamo
1893-94	16150	12770	3380	0
94-95	57700	40520	17180	0
95-96	3710	6740	42	0
96-97	21100	16230	4870	0
97-98	282	3650	0	0
98-99	0	1640	0	0
99-00	0	1460	0	0
1900-01	15210	12220	2990	0
01-02	2600	6200	0	0
02-03	17870	13660	4010	0
03-04	176	3280	0	0
04-05	32600	25090	7510	0
05-06	124000	57450	66550	4925
06-07	44500	33970	10530	9210
07-08	14500	11870	2630	0
08-09	66000	43480	22520	17795
09-10	43400	33430	9970	20855
10-11	25600	19700	5900	6250
11-12	10950	10170	780	0
12-13	2341	6071	0	0
13-14	26950	20679	6271	0
Total	525639	380480	165133	50935
Mean	25034	18118	7860	

(2) STRUCTURAL STUDIES.

DESCRIPTION OF SYSTEM

The project as proposed by the Volcan Land & Water Company consists essentially of the following:-

Construction of a dam at Warner Ranch on the San Luis Rey River. The water stored in this reservoir is to be diverted by means of a canal into the Santa Ysabel River, upon which three reservoirs are proposed. The first is the Sutherland reservoir, the second (about five miles below) the Pamo reservoir, and the third (below Bernardo) is the Carroll reservoir.

The water in Warner reservoir in passing into the Santa Ysabel drainage area may be distributed either to the Sutherland or Pamo reservoirs, from which the combined waters of Warner, Sutherland and Pamo are to be carried in a canal about 25 miles to San Clemente regulating reservoir, which is about 13 miles from the center of San Diego. This reservoir is merely required to carry sufficient storage to provide against any temporary interruption in the supply from the reservoir above.

From San Clemente reservoir the water will flow by gravity into the University Heights reservoir in the northeasterly portion of the City.

The Santa Maria reservoir lies within the Carroll watershed, and no special study of its development has been made, although it may be advisable to utilize this storage site in the future.

The water from Carroll reservoir will be pumped against a head of 250 feet and carried by an independent pipe line to San Diego.

The general scheme as outlined above is shown on Sheet No. 1.

SOUTHERN CALIFORNIA
SHEET NO. 2

MARNER WATERSHED

CARROLL WATERSHED SYSTEM

SHEET No. 1
TO ACCOMPANY REPORT
ON
VOLCAN WATER CO.
TO THE
CITY OF SAN DIEGO CALIFORNIA

M.M. O'SHAUGHNESSY.... MEM. AM. SOC. C.E.
J.B. LIPPINCOTT..... " " " "

Scale 1/125000
2 0 2 4 6 8 10 Miles
2 0 2 4 6 8 10 Kilometers
Contour interval 250 feet
Datum is mean sea level.

Edition of June 1904 reprinted June 1909

SOUTHERN CALIFORNIA
SHEET NO. 2

SHEET No. 1
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VOLCAN WATER CO.
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2 0 2 4 6 8 10 Miles
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Contour interval 250 feet
Datum is mean sea level.

Edition of June 1904 reprinted June 1909

VOLCAN LAND & WATER COMPANY

CAPACITIES OF RESERVOIRS

Surveys by W. S. Post — May 14, 1914.
Acre Feet Computed by M.M. O'SHAUGHNESSY and J. B. LIPPINCOTT.

	WARNER			SUTHERLAND			PAMO		
	Drainage Area 210 Sq.Mi.			Drainage Area 53 Sq.Mi.			# Drainage Area 110 Sq. Mi.		
Depth Ft.	Acres Flooded	Capacity M.G.	Capacity Ac. Ft.	Acres Flooded	Capacity M.G.	Capacity Ac. Ft.	Acres Flooded	Capacity M.G.	Capacity Ac. Ft.
10	17	18.9	58.1	1	1.3	4.0	3	4.9	15.1
20	58	141.0	433.1	4	10.0	30.7	9	23.4	71.9
30	260	660.0	2028.0	16	44.0	135.2	21	71.5	219.6
40	875	2510.0	7712.0	36	130.0	399.2	63	206.0	633.0
50	1405	6220.0	19100.0	62	291.0	894.0	103	477.0	1465.0
60	1822	11490.0	35300.0	97	552.0	1696.0	147	882.0	2710.0
70	2300	18200.0	55900.0	138	930.0	2858.0	184	1420.0	4360.0
80	2960	26780.0	82250.0	173	1440.0	4422.0	245	2120.0	6515.0
90 X	4055 X	38210.0 X	117600.0	219	2080.0	6392.0	303	3000.0	9218.0
100	5300	53460.0	164200.0	268	2870.0	8820.0	362	4120.0	12660.0
110				318	3830.0	11865.0	443	5420.0	16650.0
120				373	4950.0	15200.0	539	7000.0	21500.0
130			X	434 X	6000.0 X	18430.0	662	9000.0	27650.0
140				510	7800.0	23960.0	805	11370.0	34900.0
150				568	9560.0	29390.0			
156							X 1050 X	15480.0 X	47500.0
160				630	11410.0	35050.0			
170				692	13660.0	41950.0			
180				752	16020.0	49200.0			
190				797	18540.0	59960.0			

X Indicate the quantities referring to the reservoirs as resommended in this report.
This drainage area includes the 53 sq.mi. given for Sutherland.

VOLCAN LAND & WATER COMPANY

CAPACITIES OF RESERVOIRS

Surveys by W. S, Post, May 14, 1914.
Acre Feet Computed by M. M. O'SHAUGHNESSY and J.B. LIPPINCOTT

	CARROLL			SANTA MARIA			SAN CLEMENTE		
	Drainage Area 195 sq. mi.			Drainage Area: Included in Carroll			Drainage Area: Small and Unimportant		
		Capacity			Capacity			Capacity	
Depth Ft.	Acres Flooded	M.G.	Ac. Ft.	Acres Flooded	M.G.	Ac. Ft.	Acres Flooded	M.G.	Ac. Ft.
10	4	6.5	20.0	1	0.3	0.9	8	0.6	1.8
20	20	45.7	140.5	8	14.6	44.9	23	4.9	15.1
30	65	100.0	307.0	23	32.6	100.2	60	140.0	430.0
40	133	480.0	1475.0	41	170.0	522.5	79	350.0	1075.0
50	220	1070.0	3287.5	80	360.0	1106.0	93	630.0	1935.0
60	336	1950.0	6990.0	154	752.0	2310.0	129	1000.0	3070.0
70	490	3320.0	10200.0	286	1460.0	4485.0	166	1470.0	4515.0
80	720	5270.0	16190.0	561	3000.0	9218.0	201	2080.0	6390.0
90	X 980	X 7500.0	X 23030.0				X 238	X 2790.0	X 8574.0
100	X 1308	X11300.0	X 34680.0				277	3630.0	11150.0
110							317	4600.0	14130.0

X indicate the quantities referring to the reservoirs as recommended in this report.

In the case of Carroll Reservoir it is not recommended that the dam be built at present, but that further hydrographic studies be made on this drainage area in order to determine the economic possibilities of a reservoir at this place. From the data at hand it appears that the economic height, when built, would be 90 or 100 feet.

DESIGN - GENERAL

EARTH DAMS:

These dams are to be constructed by the hydraulic fill process. A central core trench from 60 to 75 feet wide and extending 20 feet into the solid rock is to be excavated for practically the entire length of the dam. The hydraulicing is to be carried on in such a manner that the resulting dam will be composed approximately of layers as shown in the plans - that is, the interior or central portion will be fine clay to form the impervious core. On the upstream and downstream sides of this core the material will be of a semi-porous nature. Beyond this will be a layer of porous material, next a layer of very coarse material; and finally, on the water face, a course of heavy stone rip-rap, hand laid, as protection against wave action. The downstream face will be covered with a heavy layer of large loose stones, 15 to 20 feet deep. This rock will be merely dumped into place, its chief function being to give added weight, and help compact the interior of the structure.

The general scheme of flood control during construction is by means of a large reinforced concrete pipe or conduit running through the dam, its lower side resting on bed rock. The entrance to this pipe will be in the shape of a vertical well rising into the reservoir. The height of the well, as shown on the plans, is the ultimate height to which it will be built. At first it should be raised simply enough to keep the pipe from being filled with sediment. As the work goes on, the pipe is to be raised in order to create a small reservoir to furnish water for hydraulicing. Later on, this well entrance can be either plugged up, or if desired, it can originally be made of the necessary size to form the lower portion of a reinforced concrete outlet tower.

After the structure is completed the above mentioned flood control pipe can be readily changed so as to be used as the conduit for the permanent outlet pipes.

In the center of the clay core wall trench, there will be a concrete cut-off wall, extending usually 8 or 10 feet into the solid rock and rising approximately to the original ground surface. This cut-off wall will have a thickness of 3 feet on the bottom and one foot on the top. When the construction starts it may be found that it is not necessary to continue this wall beyond 4 or 5 feet above the bottom of the trench, instead of the ground surface, as shown on plans.

MASONRY DAMS:

For the masonry dam at Sutherland reservoir, the arched gravity section is used. This requires no particular comments since

The design was made according to standard engineering practice as it is known today.

The masonry dam at Carroll reservoir is an overflow structure. This, as in the case of the Sutherland dam, was designed according to the most recent practice of considering the upward pressure of water under all horizontal sections and the base. Also the curve of the downstream face is made in such manner and of such shape that it will at all points project inside of the lower nappe of the overflowing sheet of water, thus preventing any possible formation of a vacuum.

OUTLINE OF GENERAL METHOD OF HYDRAULICING:

The detail arrangement of the plant for hydraulicing material into place in the case of the earth fill dams will, of course, depend largely upon the different conditions to be met at each site. The general method used is here given.

The material will be sluiced from borrow pits down open channels on about a 6% grade, emptying into a concrete lined sump. Monitors having a discharge that can be fitted with nozzles of 4 or 5 inch diameter will be used to loosen and wash the material from the pits. They will be operated at a discharge rate of about 8 second feet and under pressure of approximately 100 pounds per square inch. Smaller jets can be used for large pockets where very soft material is encountered. The monitors will be supplied with water by two-stage 10-inch pumps. These pumps should operate at a speed of from 575 to 600 r.p.m., and be driven by 25o or 300 H.P. electric motors.

From the sump the solution will be raised to the dam by means of 10 or 12 inch mud pumps. These pumps are to be driven by 250 H.P. motors at such a speed that the velocity of the mixture in the discharge pipes will be at least 10 feet per second in order that no heavy gravel will deposit in the pipes. In order to secure this speed and steady flow, as the dam is raised, it will be necessary to install booster pumps, especially for the portions of the dam most remote from the sump.

The sluiced material will be discharged at the upper and lower faces of the dam and allowed to run on natural grades toward the center, where a pool of still water is to be maintained. By this means all the large or porous material is deposited on the slopes approaching the pool and is graded down from the small rocks, through sand, to practically sedimentary clay in the central part of the pool. By regulating the size and elevation of the water in the pool, the limit of the central clay core may be changed at will.

During the summer months the water supply necessary to operate the above described system may become an important factor, and for this reason none should be wasted, except that which naturally is lost by seepage through the downstream face direct from the sluicing pipes.

The drainage from the center pool should be conveyed by say, a 24 inch pipe back to the sump, thus enabling the greater portion of it to be used repeatedly

In the following paragraphs the individual structures, together with their cost estimate, are considered in more detail.

WARNER'S DAM:

The nature of the sight and character of the materials at this reservoir are exceptionally well adapted to the construction of an earth fill dam by the hydraulic process, and this type is here recommended. The drainage area is 210 square miles, the capacity of the reservoir (with water at a depth of 90 feet) is 117,500 acre feet, and the area covered is 4055 acres.

The top of the dam is at elevation 2725 feet, the valley floor being at elevation 2620 feet. This gives the height of fill, excluding the core wall trench, of practically 105 feet. The water surface is at elevation 2710 feet, giving 15 feet freeboard.

The upstream slope is 2½ to 1, and is to be covered with heavy stone rip-rap, hand laid, to 5 feet above the water surface (i.e. to elevation 2750). In preparing detail plans for construction it may be found advisable to substitute a face slab covering of concrete instead of rip-rap in all the earth dams here discussed. The downstream slope is 3 to 1 and covered with a layer of large rock to a depth of about 15 feet. The dam is 25 feet wide on top and practically 600 feet thick at the bottom, the volume being 475,900 cubic yards.

A foundation trench, about 60 feet wide on the bottom, and extending 20 feet into the solid rock, is to be excavated for practically the entire length of the dam. From the bottom of this a concrete core wall, 3 feet thick at the base and one foot thick at the top, will be built up to the original ground surface. A few feet upstream from this core wall there will be a line of grout holes 3 inches in diameter, 10 feet center to center, and from 40 to 75 feet deep, through which cement grout under a pressure of 100 pounds to the square inch will be forced. This is necessary in order to solidify the underlying rock, since the test holes show it to be badly broken, and unable to offer resistance to the seepage of water from the reservoir.

The outlet control is a reinforced concrete tower with gates and valves at four different elevations between the bottom and the water surface. This tower connects directly with the flood control conduit described below.

The floods to be handled during the earlier period of construction will be discharged through a 13 foot reinforced concrete pipe, with a well entrance; the lower side of this pipe rests in a trench cut into bedrock. There will be concrete collars 1½ feet by 3 feet, surrounding the pipe at intervals of 30 feet, in order to prevent seepage along the outside face of the conduit, (see sketch on sheet No. 4). A more detailed study and design may possibly show that a saving could be made by designing all flood control pipes to withstand compressive stresses only, thus materially increasing its thickness, but omitting the steel reinforcement. When the structure is completed this pipe can be used as a conduit for the permanent outlet pipes, or, if found more desirable, it can be plugged and the 5 by 7½ foot tunnel, which is already constructed, made to answer this purpose. However, before being thus used it will be necessary to re-line the tunnel with 12 inches of first class concrete, as the formation is very broken and offers little resistance to water pressure.

It will be necessary during the earlier stages of construction to keep the upstream toe somewhat higher than the remainder of the dam, in order to provide sufficient head on the flood control pipe. This can be accomplished by means of scrapers and teams.

The maximum flood of this site may, during severe floods, reach 3 or 4 times the amount provided for above, and special precautions must be taken to handle this water until the dam has reached a height sufficient to give reservoir storage capable of handling the entire flood without any possible danger of a break occurring in the structure. This can probably best be handled by leaving an opening through one abutment of the dam, in which a large flume, built in sections, can be placed, and raised along with the dam. Another method would be to materially increase the size of the flood control pipe. Before construction is started, a detailed economic study of this feature would be advisable.

The permanent spillway for the dam can be provided by a cut through the rim on the south side, as indicated by Mr. Post. It may be necessary, in addition to the main dam, to build a small embankment at the spillway section, since the natural ground at this point is only 7 or 8 feet above the water line. The cost would be small.

The above observations applying to the additional precautions necessary for flood protection (namely, keeping the upstream too high, together with an extra opening through one abutment of the dam), applies with equal force to all of the earthmstructures hereinafter described.

The permanent spillways must be large enough to handle the entire maximum flood after the dam is completed, and it is essential that this detail receive close study in order to insure the safety of the structure.

PAMO DAM:

This is to be an earth fill structure, similar in all respects to the Warner dam described above. It will be formed by the hydraulic process, and have the water face rip-rapped, and the downstream face covered with a heavy layer of loose rock. The preparation of the foundations and the general scheme of flood control is identical with that previously describedm the foundation being thoroughly grouted under pressure.

The storm waters to be cared for by the flood control conduit require a pipe 14½ feet in diameter, reinforced against both internal and external pressures as shown on the sketch.

The drainage area is 110 square miles, and the reservoir covers 1050 acres, and has a storage capacity of 47,500 acre feet.

The elevation of the top of the dam is 1020 feet, while the floor of the valley is at elevation 850, the resulting height of the earth fill (exclusive of core wall trench) being 170 feet. The water surface is at elevation 1006, giving a freeboard of 14 feet.

The top width of the dam is 25 feet, bottom width 1000 feet, length of crest 1065 feet, requiring 1,961,800 cubic yards of earth in its construction.

SUTHERLAND DAM:

For the Sutherland dam, studies of two separate types were made, one for an earth fill structure, the other for a masonry arched structure, with a gravity section.

Earth Fill Type: This dam differs from the Warner and Pamo, above described, only in dimensions. The elevation of the crest is 2065 feet, elevation of bottom 1925 feet, giving a height of fill (exclusive of trench) of 140 feet. The water surface is at elevation 2055, the freeboard being 10 feet.

The top width is 25 feet, bottom width 700 feet, and the length on the crest 900 feet. The amount of earth required for its construction is 930,800 cubic yards.

The drainage area is 53 square miles, which is, however, included in the 110 square miles given for the Pamo watershed. The reservoir at a depth of 130 feet, has a capacity of 18,400 acre feet, and covers 434 acres.

The flood control conduit for this dam will be a reinforced concrete pipe 12 feet in diameter, and 900 feet long, constructed in the same manner as for Warner's dam.

The nature of the foundation and exposed bedrock at this site would seem to indicate that there is no need for grouting, and none has been included in the cost estimate.

Masonry Type: About 3/8 ths of a mile below the site of the earth dam, described above, the canyon narrows down decidedly, and offers a favorable opportunity for the construction of an arched masonry dam. Below the earth dam, however, the stream bed falls rather rapidly and the height of the masonry dam (from bedrock) will be 20 feet greater than the earth dam, excluding the depth of foundation trench. The elevation of the crest is 2065, as for the earth dam.

The structure is to be built of Cyclopean concrete, with approximately 20 per cent of the entire mass consisting of large rock plums; it is curved in plan, the radius of the crest being 400 feet.

There will be no special flood control preparations necessary for this structure, beyond the construction of the permanent outlet tunnel, since, after the dam reaches a height of a few feet above the foundation, the flood waters can pass over the top without causing any considerable damage. It will be necessary to provide spillways around the ends of the dam, however, to handle excess flood waters when the dam is completed.

The outlet control will be a reinforced concrete tower, connecting to an outlet tunnel 5 feet by 7½ feet, and 200 feet long, driven through the solid rock, and lined with concrete, if found necessary.

SAN CLEMENTE DAM:

This dam will be an hydraulic, earth fill structure, 90 feet in height, forming the San Clemente regulating reservoir. It is intended that this reservoir be used merely to regulate the flow from the Pamo and Warner reservoirs and have an area of 238 acres, capacity of 8570 acre feet. It differs in no wise from the other earth dams described above. The total volume of earth required for its construction is 984,400 cubic yards. Here, as for the other dams, it will be necessary to provide ample spillways.

UPSTREAM SLOPE 2:1

DOWNSTREAM SLOPE 2:1

HYDRAULIC GRADIENT

T. 15 S. - R. 8 W.

SAN G[illegible]

REGULATING RESERVOIR

AREA = 2.38 Ac.

CAPACITY = 8.570 Ac.-Ft.

Ex Mission North Line

4 3 2 1

9 10 11 12

16 15 14 13

UPSTREAM SLOPE 2½:1

DOWNSTREAM SLOPE 3:1

HYDRAULIC EARTH FILL DAM

T. 15 S. - R. 2 W.

SAN C...
REGULATING RESERVOIR
AREA: 8.38 AC.
CAPACITY: 85.70 AC.FT.

...SURVEY
TO ACCOMPANY REPORT
ON
YOLO...
TO THE
CITY OF SAN FRANCISCO
...
J.D. LIPPINCOTT

SCALE:

Ex Mission North Line

However, the flood control conduit is not of so much importance, and possibly could be handled by means of a temporary flume during the entire period of construction.

The crest elevation is 690, the top width 20 feet, upstream slope 2½ to 1, downstream slope 3 to 1.

It is from this reservoir that it is recommended a pipe line be built connecting with the city distributing system at a point on the north side of the San Diego River.

CARROLL DAM:

This structure differs from any of the dams previously described. It is of the type known as a masonry overflow dam, the flood waters passing over the entire crest length, thus requiring no special permanent spillway construction.

The maximum height above the foundation is 110 feet, the elevation of the crest being at 306. This height is only tentative, and further hydrographic data will have to be collected before it can be definitely stated what height will make this dam the most economic unit of the entire system. The length along the crest is 720 feet. The curve of the downstream face is made of such shape as to project within the overflowing sheet of water at all points, thus eliminating any possibility of the formation of a vacuum.

As in the case of the masonry dam at Sutherland reservoir, this structure is to be built of Cyclopean concrete, 20 per cent of the entire mass being large rock plums, the total yardage of the structure is 93,800.

The drainage area below Pamo is 196 square miles. The area of the reservoir 1308 acres, and the capacity 34,680 acre feet.

The outlet control is by means of a reinforced concrete tower, connecting with a 5 by 7½ foot tunnel, concrete lined, 225 feet long.

CARROLL PUMPING PLANT:

In addition to the dam there will be required a pumping plant capable of handling 10 million gallons daily, against an actual head of 250 feet (or about 310 feet including friction). If the Carroll dam, together with this plant, should be built before the power station on the Warner Canal, it would probably be advisable to use steam for pumping purposes, in which case there would be required about an 800 horse power steam turbine, direct

connected to a three stage centrifugal pump, together with 1000 horse power steam boiler, the necessary condensing apparatus, buildings, etc., From the power plant on Warner's canal there can be developed from the Warner waters alone sufficient electrical power to operate the pumping station at the Carroll reservoir, and still leave a material excess. The construction of this power plant, however, is not recommended until some time in the future. If it is decided that the Carroll Pumping Plant, when built, should be operated by electrical power, there would be needed three 300 horse power motors, 2 high duty pumps, direct connected, and operated at about 1000 revolutions per minute. One pump and one motor could be used as "spares" for emergency purposes.

WARNER'S CANAL:

This canal will convey the water from Warner's reservoir along the San Luis Rey River for a short distance, and then by means of a tunnel through the divide divert it into the Santa Ysabel drainage basin, finally delivering it to the natural channel of Temescal Creek, from which it can be distributed to the Pamo or Sutherland reservoirs. The total length is 6.6 miles, of which 6200 feet will be 6 x 7 foot concrete lined tunnel. The canal proper will be lined with 4 inches of concrete, and have a 4 inch reinforced concrete slab roof through its entire length.

It will be necessary to take special sanitary precautions along the portion of the canal which is formed by the natural channel of Temescal Creek, and it may be found advisable to continue the concrete lined and covered canal over this section also.

It is believed that this canal, as shown in Mr. Post's report, should be lowered 15 or 20 feet, in order to collect any seepage which might occur around or under the dam, without having to resort to pumping, as would be necessary with the canal in its present location. This change is recommended.

As previously noted under the description of Pamo Dam, The capacity of Warner's canal will be 100 second feet in order to rapidly conduct Warner waters to Pamo reservoir, when the storage in the latter is low, and save a substantial amount which would otherwise be lost by evaporation. There is, however, a second important reason for making the canal of this capacity. The Volcan Land & Water Company, by an agreement with the Escondido Mutual Water Company, is required to deliver a certain quantity of water to the latter, at the Escondido Intake, several miles below Warner's dam. This water is conveyed to the intake by means of the natural channel of the San Luis Rey River, and consequently there is a very considerable quantity of it lost by evaporation, percolation, and diffusion over the sandy stream bed. By making the canal larger (100 second feet capacity), this Escondido water can be carried in addition to the regular yield of Warner's reservoir and the above

noted loss through the natural stream bed eliminated over a part of the course of the Intake. For the same reason it is believed that the saving which would result from extending the conduit, or a smaller branch canal, farther down the San Luis Rey River before discharging the Escondido water into the natural stream channel, would be worthy of serious consideration. The exact length of this extension can only be determined from an economic study, whereby the cost and annual charges on upkeep of the canal are balanced against the cost of the loss of water resulting from using the natural stream channel. In such a study there will be a point reached where the above two costs will be practically equal. With this knowledge it will be possible to construct the canal in such a manner as to make it most economic as a unit of the entire completed system.

PAMO CANAL:

This canal will have a capacity of 54 second feet or 35 million gallons daily, and will be used to convey at first the Santa Ysabel flood waters and later the combined waters of Warner, Pamo and Sutherland reservoirs to the San Clemente regulating reservoir near San Diego.

Its length will be about 25 miles, consisting mainly of three types of construction, namely the concrete lined and covered canal, steel flume, and concrete lined tunnel. The detail lengths of each class of construction are shown in the cost estimate given later in this report.

CARROLL - UNIVERSITY HEIGHTS PIPE LINE:

The pumping plant at Carroll reservoir will deliver the water against a 250 foot actual head to elevation 512, from which point it will flow by gravity through a riveted steel pipe line (diameter 30 and 34 inches), in a more or less direct line across the Linda Vista Mesa to the University Heights Reservoir, elevation 400.

A short section at the beginning of this line will be a concrete lined canal. There are no special features of construction which need to be commented upon.

CONCRETE COSTS

The concrete to be used in the dams as herein shown, is to consist of a 1:2½:5 mixture, for which the unit costs given below were estimated.

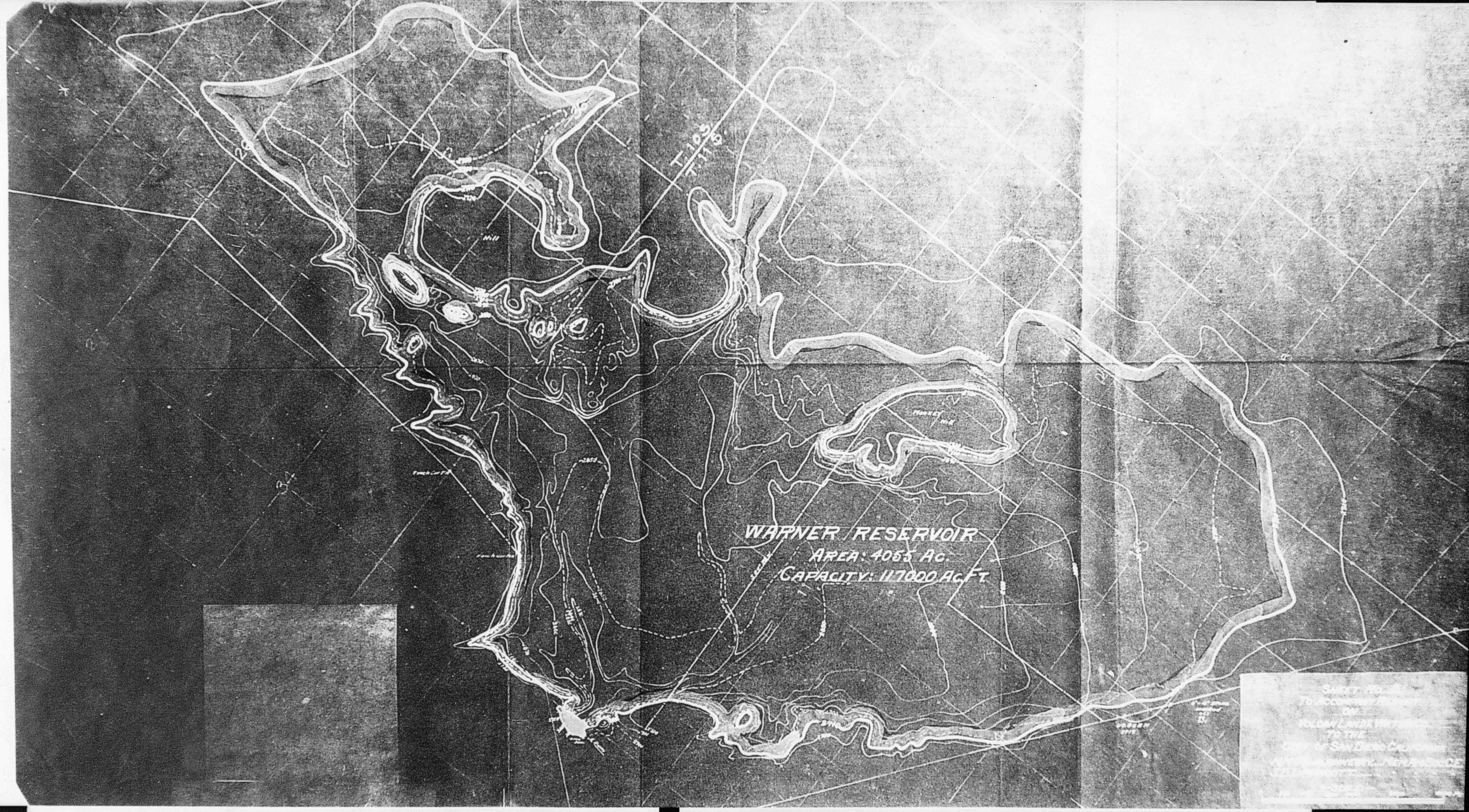
The cost of cement per barrel in San Diego is $2.00. The remainder of the cost is made up from the cost of sand, crushed rock, lumber and bolts for forms, carpenter work on form setting, mixing and placing concrete, and the charges for hauling, of which an analysis was made including the relative distances both by rainway and by wagon.

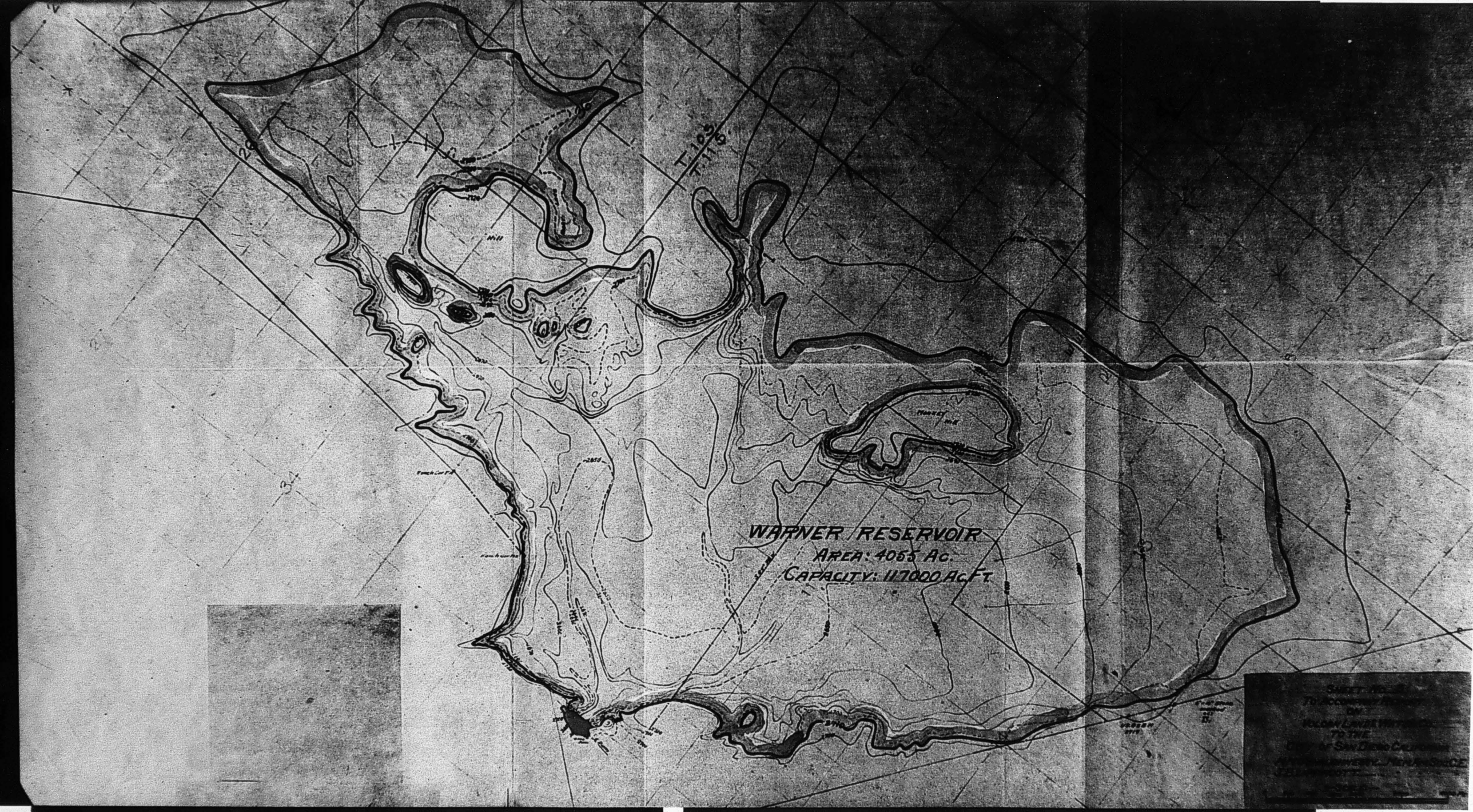
The costs as given are for concrete in place in the dam, but do not include the cost of quarrying the necessary rock for crushing, a separate figure being given for this item in the cost estimates.

Dam	Concrete Cost per Cu. Yd.
Sutherland	$6.30
Pamo	6.10
Warner's	7.80
Carroll	5.85

STEEL REINFORCEMENT:

The reinforcement to be used in the Flood Control conduits will consist of square corrugated bars, the price being $71.50 per ton in place. This is equivalent to $0.036 per pound.


T.10S.
T.11S.
WARNER RESERVOIR
AREA: 4065 Ac.
CAPACITY: 117000 Ac.Ft.


T.10S.
T.11S.
WARNER RESERVOIR
AREA: 4055 AC.
CAPACITY: 117000 AC. FT.

ESTIMATE OF COST

WARNER'S DAM

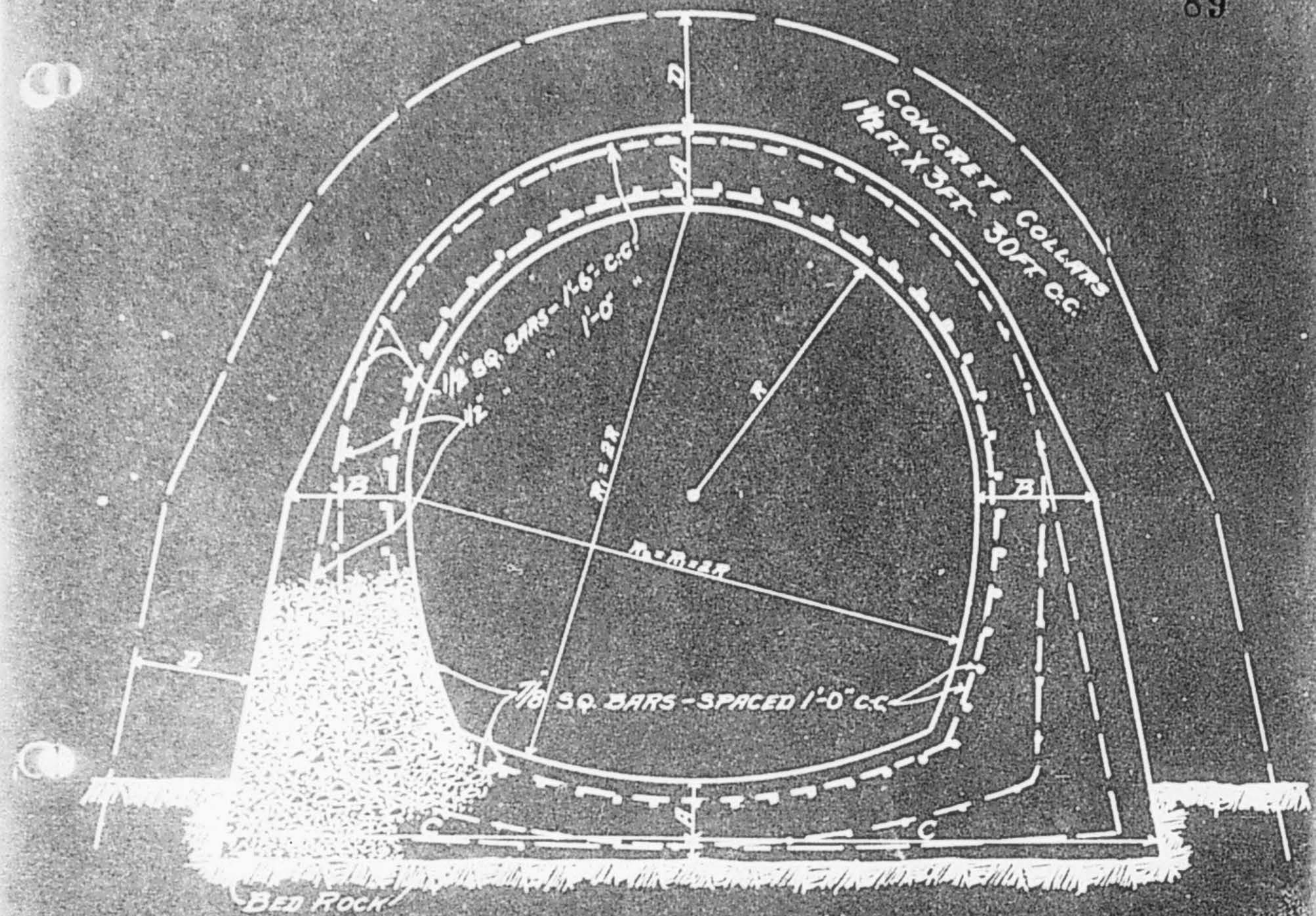
(Hydraulic Earth Fill Type)

VOLCAN LAND & WATER CO.

475,900 Cu.Yds.	of earth (allowing 10% shrinkage) @ $0.27 per cu.yd.,	$128,300.
3,000 " " " "	stripping on dam site @ $0.40 per cu.yd.,	1,200.
17,500 " " " "	excavation core wall trench @ $0.25 per cu.yd.,	4,400.
26,000 " " "	rock and decomposed granite excavation in core wall trench @ $2.50 per cu.yd.	65,000.
Note:	The test borings indicate that probably 18,000 cu.yds. of this rock excavation can be used for loose rock fill on down-stream slope and crushing for concrete.	
1,950 Cu.Yds.	of concrete in core wall @ $7.80 cu.yd.	15,200.
1,700 " " "	rock for crushing for concrete (re-handling from trench excavation) @ $0.60 per cu.yd.,	1,000.
16,000 " " "	loose rock fill on downstream slope (rehandling from trench excavation) @ $0.80 per cu.yd.,	12,800.
3,800 " "	"mhand laid riprap @ $2.80 per cu.yd.,	10,600.
4,200 " "	reinforced concrete in "Flood control conduit" 13 ft. diam. 650 ft.long @ $19.40 per cu.yd., including reinforcement,	81,500.
3,700 " "	rock for crushing for concrete @ $1.75 per cu.yd.,	9,100.
	Clearing Reservoir Site: say,	5,000.
	Outlet Tower, gates, pipes, etc.(including bridge),	17,800.
#	Spillways,	13,500.
	100 Grout holes, average depth 90 ft.,	11,300.
	Camp buildings, sheds, shops, water supply, sewerage etc,	6,000.
	" Maintenance and Repairs,	750.
	Plant " " "	3,300.
	Local Engineering and Superintendence - 2%,	7,700.
	Heavy Plant, allowing 20% salvage value,	20,000.
	Loss on Labor Transportation,	1,500.
	Contractor's Profit - 15%,	62,400.
	Interest during construction @ 4½% on one half the above amount for 2 years	21,500.
	TOTAL COST OF STRUCTURE,	$ 499,850.

The greater part of the spillway excavation should be accomplished in obtaining earth for the dam proper. The figure here given allows for finishing, trimming, and lining, together with special concrete slab protection at entrance and emptying ends, if found necessary.

EARTH FILL ABOVE & ON SIDES OF PIPE.
(WET EARTH & WATER ON UPSTREAM SIDE OF CORE WALL)



—CROSS SECTION—
FLOOD CONTROL TUNNEL

—SCALE—

0 1 2 3 4 5 10 FT

DATA & QUANTITIES

RESERVOIR	FLOOD SEC. FT.	*PIPE DIAM. FT.	R	R=R1 FT.	A FT.	B FT.	C FT.	D FT.	CONCRETE PER. FT.	STEEL PER FT.	COST PER CU. YD.
SUTHERLAND	2650	12	6	12	2'-0"	3'-0"	11'-0"	3'-0"	5.7 Cu Yds.	0.132 TONS	$17.15
WARNER'S	3000	13	6½	13	2'-3"	3'-3	11'-4"	3'-0"	6.5 "	0.162 "	$19.40
PALMO	4000	14½	7¼	14½	2'-6"	3'-6	12'-0"	3'-0	7.8 "	0.180 "	$18.95

* SLOPE: S = 0.00833

SHEET NO. 4
TO ACCOMPANY REPORT
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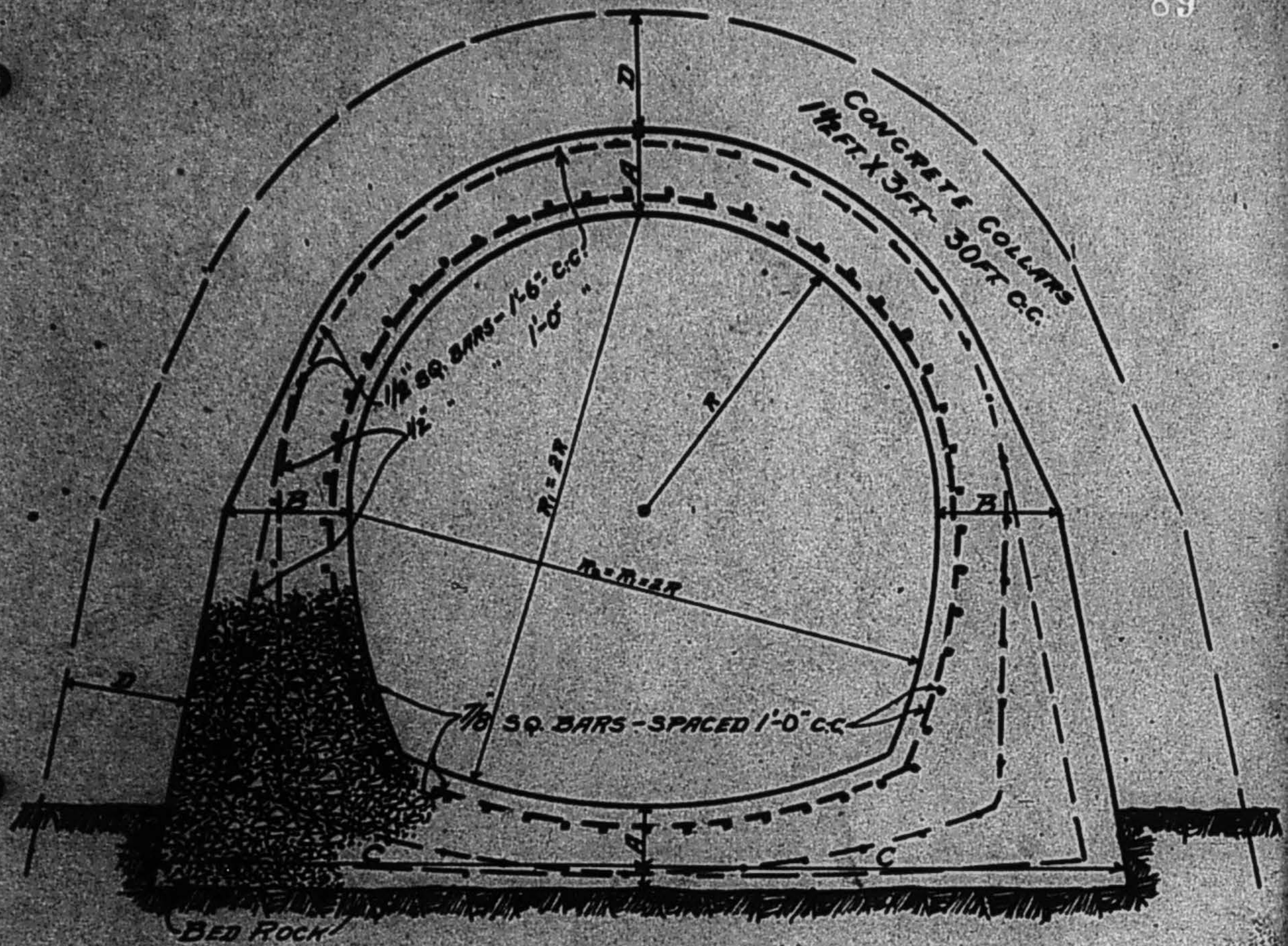
TO THE
CITY OF SAN DIEGO CALIFORNIA

M.M. O'SHAUGHNESSY..... MEM. AM. SOC. C.E.
J.B. LIPPINCOTT..... " " " "

EARTH FILL ABOVE & ON SIDES OF PIPE.
(WET EARTH & WATER ON UPSTREAM SIDE OF CORE WALL)



—CROSS SECTION—
FLOOD CONTROL TUNNEL

—SCALE—

0 1 2 3 4 5 10 FT

DATA & QUANTITIES

RESERVOIR	FLOOD SEC. FT.	*PIPE DIAM. FT.	R FT.	R = R₁ FT.	A FT.	B FT.	C FT.	D FT.	CONCRETE PER. FT.	STEEL PER FT.	COST PER CU. YD.
SUTHERLAND	2650	12	6	12	2'-0"	3'-0"	11'-0"	3'-0"	5.7 CU. YDS.	0.132 TONS	$17.15
WARNERS'	3000	13	6½	13	2'-3"	3'-3"	11'-4"	3'-0"	6.5 "	0.162 "	$19.40
PAMO	4000	14½	7¼	14½	2'-6"	3'-6"	12'-0"	3'-0"	7.8 "	0.180 "	$18.95

* SLOPE: S = 0.00833

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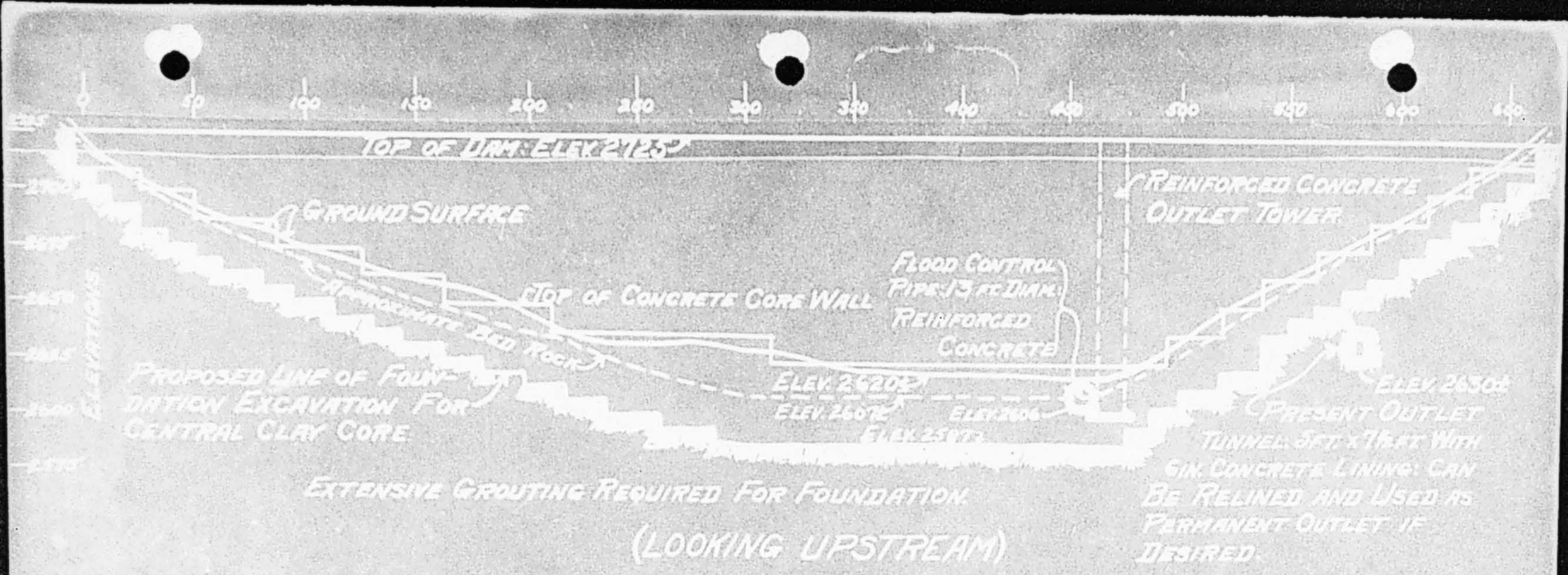

(LOOKING UPSTREAM)

—SECTION ALONG CENTER LINE—

WARNERS' DAM (A)

—EARTH TYPE—

DATA & QUANTITIES

TYPE OF DAM: HOMOGENEOUS EARTH FILL.

LENGTH: 725

ELEVATION OF TOP SURFACE: 2710.

MAXIMUM HEIGHT: 88 FT.

EXCAVATION (CUTTING TRENCH): 105 FT.

CONCRETE: REINFORCED CONCRETE.

OUTLET: REINFORCED CONCRETE PIPE: 13 FT. DIAM. 650 FT. LONG.

ELEV. OF BOTTOM: 2606.

EXCAVATION: 50 CU.YDS.

(UNCLASSIFIED): 3 100 CU.YDS.

ROCK: 2600 CU.YDS. EARTH: 17500 CU.YDS.

EXCAVATION (CUTTING TRENCH): 32600 CU.YDS. (+) or SHRINKAGE)

WATER SHED: 20 SQ. MI.

RESERVOIR CAPACITY (DEPTH 90 FT.): 117600 Ac. Ft.

" " : 4055 ACRES.

AVERAGE DEPTH 90 FT. DIAM 3"

SCALE:

0 50 100 150 200 250 300 FEET

SHEET No. 5.

TO ACCOMPANY REPORT

OF

VOLCAN LAND & WATER CO.

TO THE

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M. M. O'SHAUGHNESSY, MEMAM Soc CE

J.B. LIPPINCOTT

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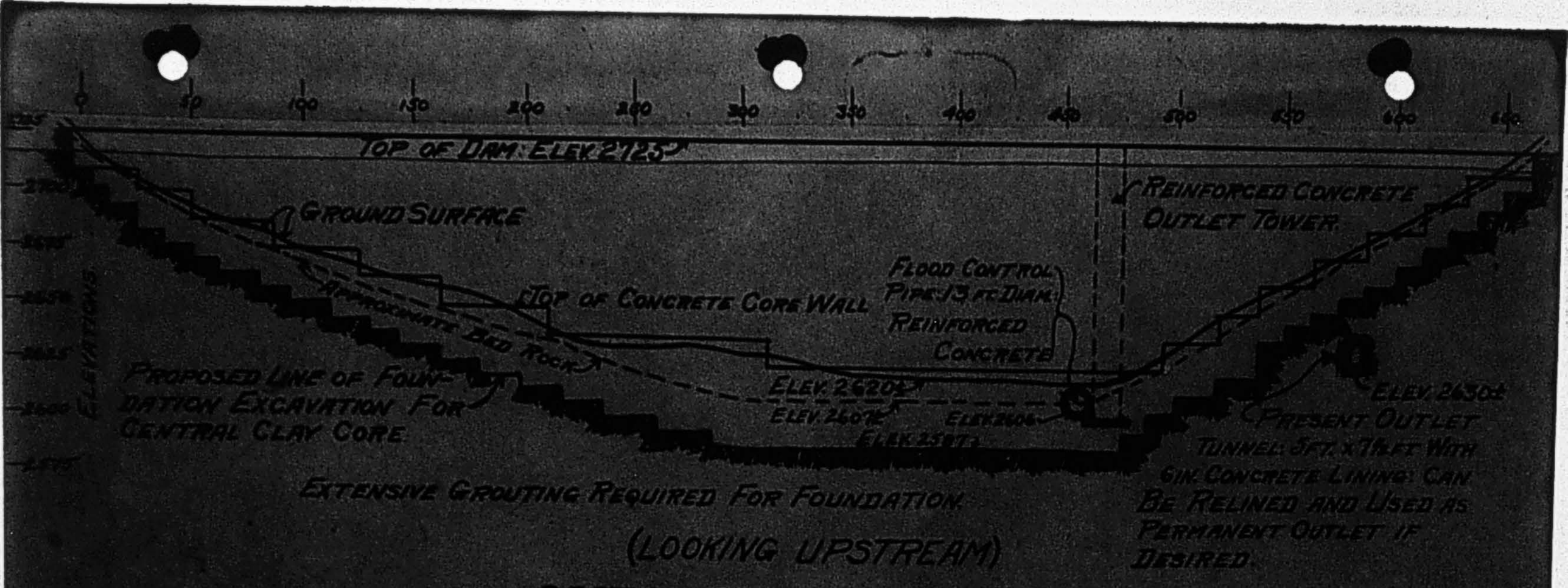

(LOOKING UPSTREAM)

—SECTION ALONG CENTER LINE—

WARNERS' DAM (A)

—EARTH TYPE—

SCALE:

0 50 100 200 300 400 FT.

DATA & QUANTITIES.

TYPE OF DAM: HOMOGENEOUS EARTH FILL.

ELEV. OF CREST: 2725

ELEV. OF GROUND SURFACE: 2710.

LENGTH ON CREST: 650 FT.

TOP WIDTH: 20 FT.

MAXIMUM HEIGHT (EXCLUDING TRENCH): 105 FT.

OUTLET WORKS: REINFORCED CONCRETE.

FLOOD CONTROL: REINFORCED CONCRETE PIPE: 13 FT DIAM. 650 FT LONG.

PIPE: ELEV. OF BOTTOM: 2606.

CONCRETE IN CORE WALL: 1850 CU.YDS.

EARTH STRIPPING (OVER DAM): 3000 CU.YDS.

EXCAVATION: ROCK 26000 CU.YDS.; EARTH 17500 CU.YDS.

EARTH FILL (EXCLUDING TRENCH) 132600 — CU.YDS. (+10% SHRINKAGE)

DRAINAGE AREA: 210 SQ. MI.

RESERVOIR CAPACITY (DEPTH 90 FT): 17600 AC. FT.

" AREA: " : 4055 ACRES.

100 GROUT HOLES: AVERAGE DEPTH 90 FT: DIAM 3"

SHEET NO. 5.

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VOLCAN LAND & WATER CO.

TO THE

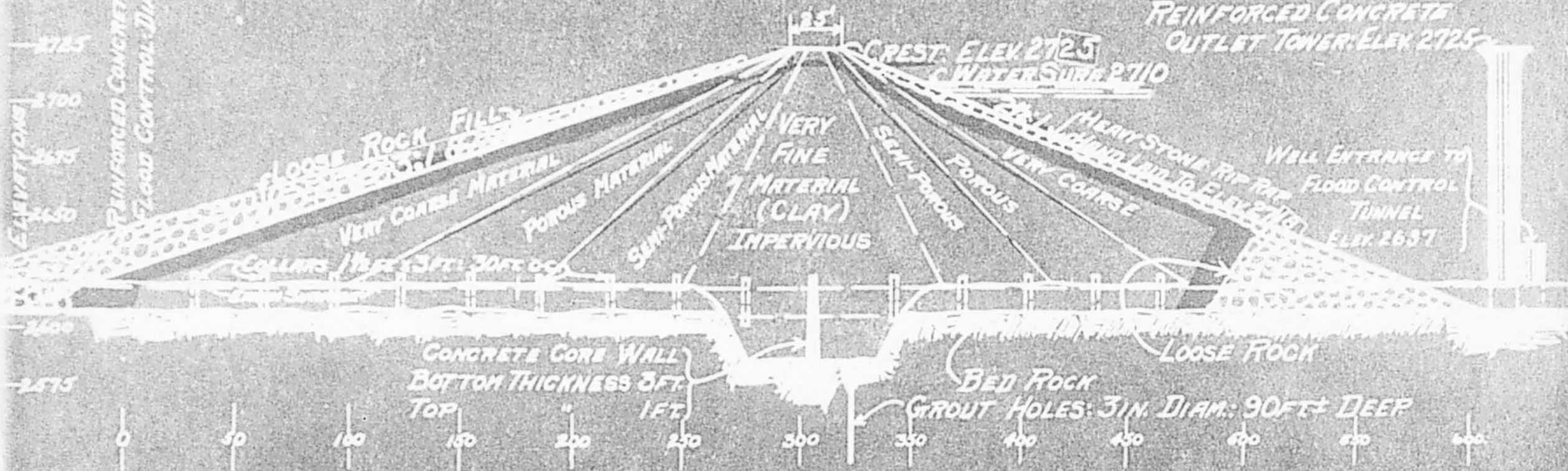
CITY OF SAN DIEGO, CALIFORNIA

M.M. O'SHAUGHNESSY, MEM. AM. SOC. C.E.

J.B. LIPPINCOTT, " " "

13

NOTE: MATERIAL ON UPSTREAM AND DOWNSTREAM FACES TO BE KEPT 3 OR 4 FT. HIGHER THAN INTERIOR, BY MEANS OF SCRAPERS.



—MAXIMUM SECTION—

WARNERS DAM. (B)

—HYDRAULIC EARTH FILL TYPE—

SCALE:

SHEET NO. 5 1/2
TO ACCOMPANY REPORT
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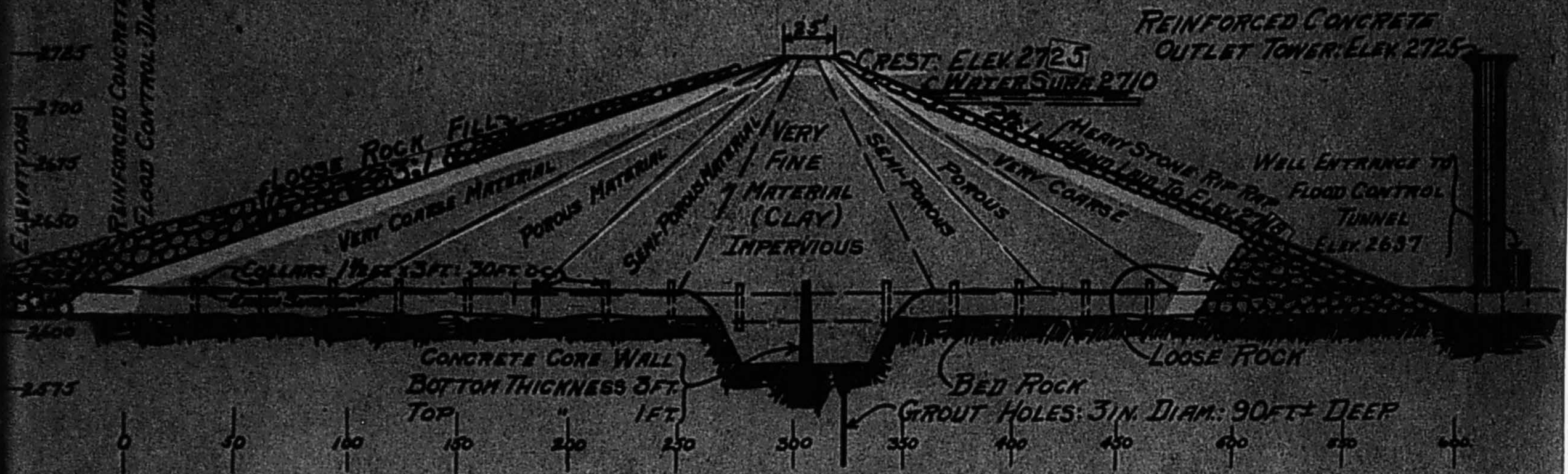
CITY OF SAN DIEGO CALIFORNIA

M.M. O'SHAUGHNESSY.... MEM. AM. SOC. C.E.
J.B. LIPPINCOTT..... " " " "

13

NOTE: MATERIAL ON UPSTREAM AND DOWNSTREAM FACES TO BE KEPT 3 OR 4 FT HIGHER THAN INTERIOR, BY MEANS OF SCRAPERS.

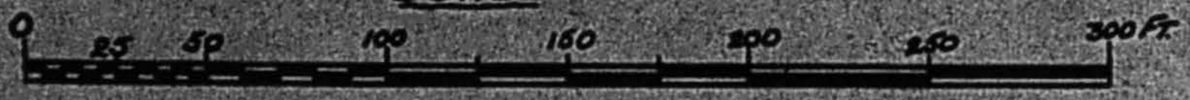


—MAXIMUM SECTION—

WARNERS DAM. (B)

—HYDRAULIC EARTH FILL TYPE—

SCALE:



SHEET NO. 5 1/2
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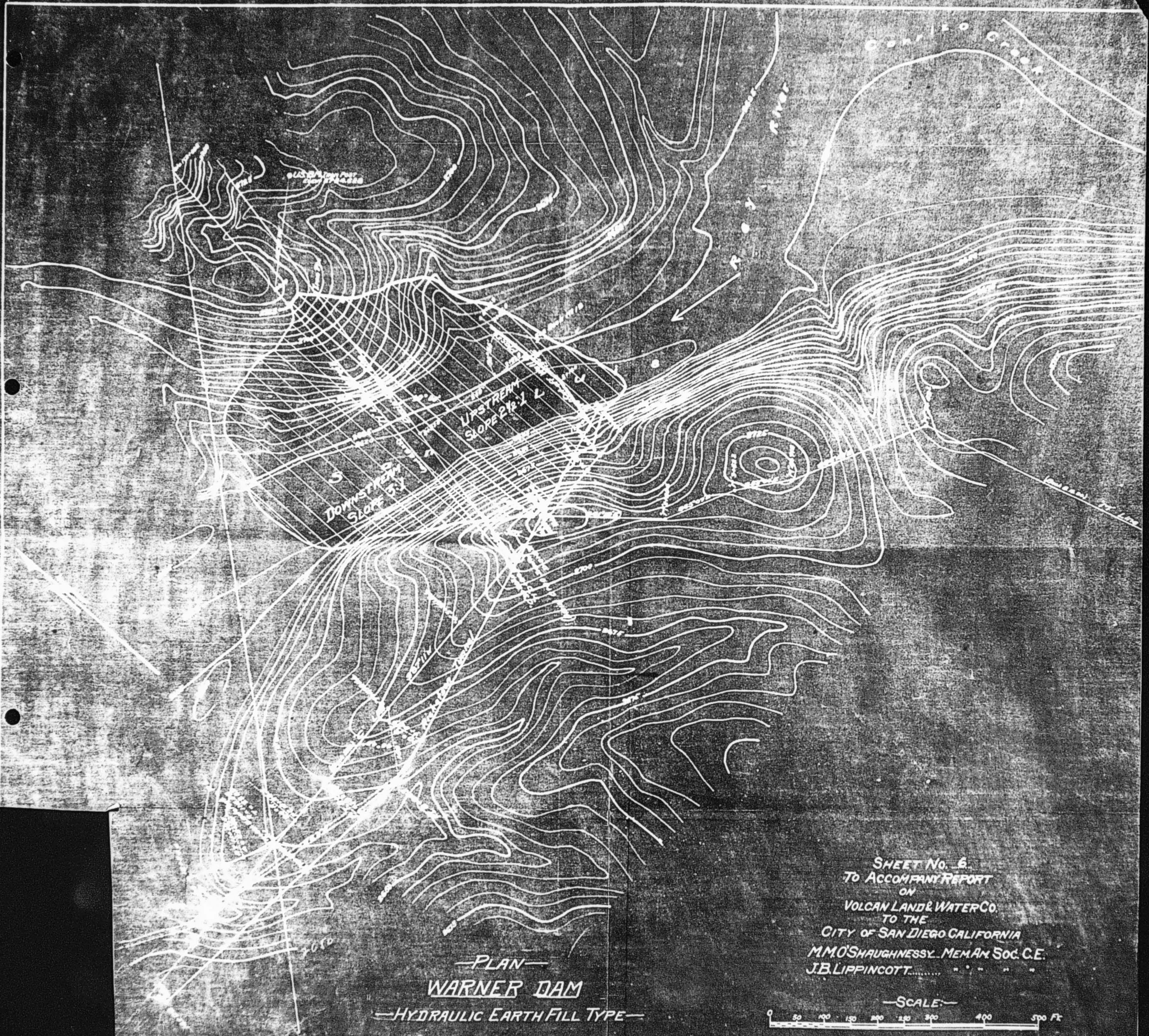

—PLAN—

WARNER DAM

—HYDRAULIC EARTH FILL TYPE—

SHEET No. 6.
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—PLAN—

WARNER DAM

—HYDRAULIC EARTH FILL TYPE—

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J.B.LIPPINCOTT..... " " " "

—SCALE:—

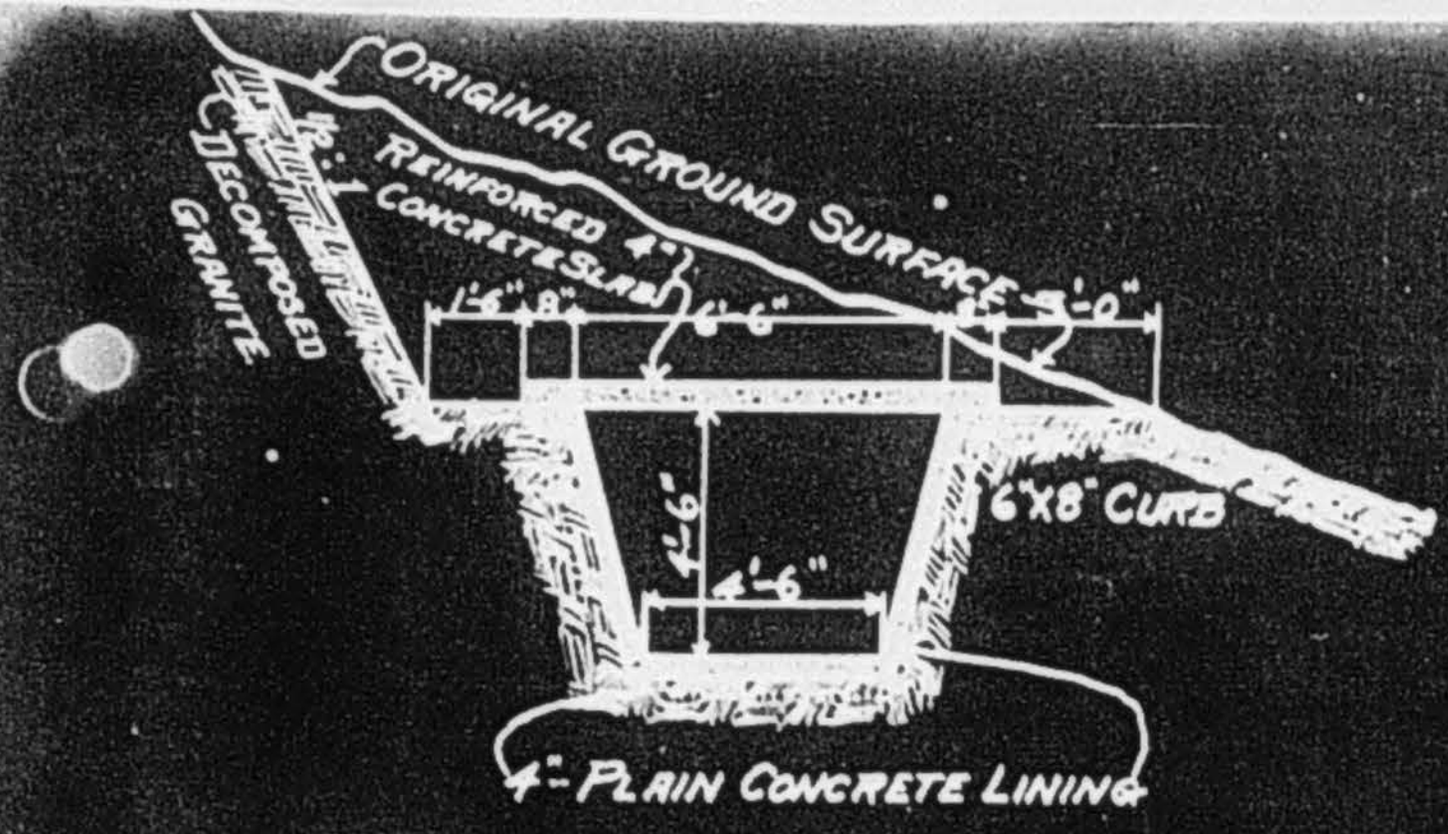
0 50 100 150 200 250 300 400 500 Ft

COST ESTIMATE

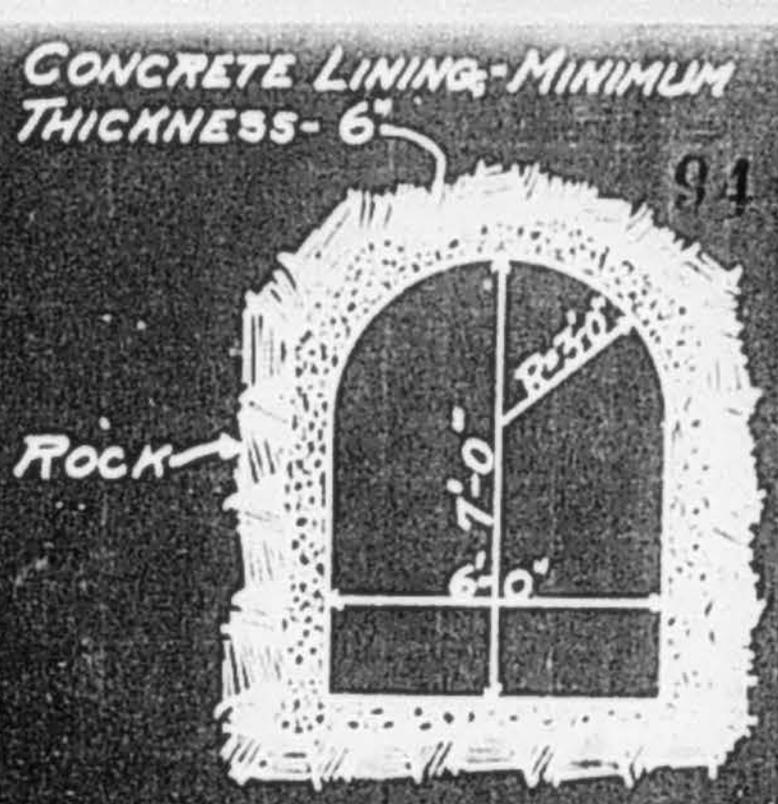
WARNER'S CONDUIT

VOLCAN LAND & WATER COMPANY

22,250 lin.ft. of canal excavation (1-1/9 cu.yds. per ft. @ $0.75 per ft., ...	$16,700.
Benching @ $0.60 per ft., ...	13,300.
4" Concrete lining and 4" reinforced concrete roof (0.293 cu.yds. concrete per ft.), at an average for the entire length, including reinforcement, of $8.10 cu.yd., ...	52,800.
850 lin.ft. of steel flume on trestles @ $7.10 per ft.,	6,000.
Construction roads, ...	4,000.
County Road Changes	2,000.
10,100 lin.ft. of 6' x 7' tunnel (concrete lined) . . .	211,100.
Total overhead charges: including engineering and contingencies, contractor's profit @ 15%, extras, interest, during construction @ 4½% on one half the total amount for one year, etc., -- 30%	91,700.
TOTAL COST OF CONDUIT, . .	$397,600.



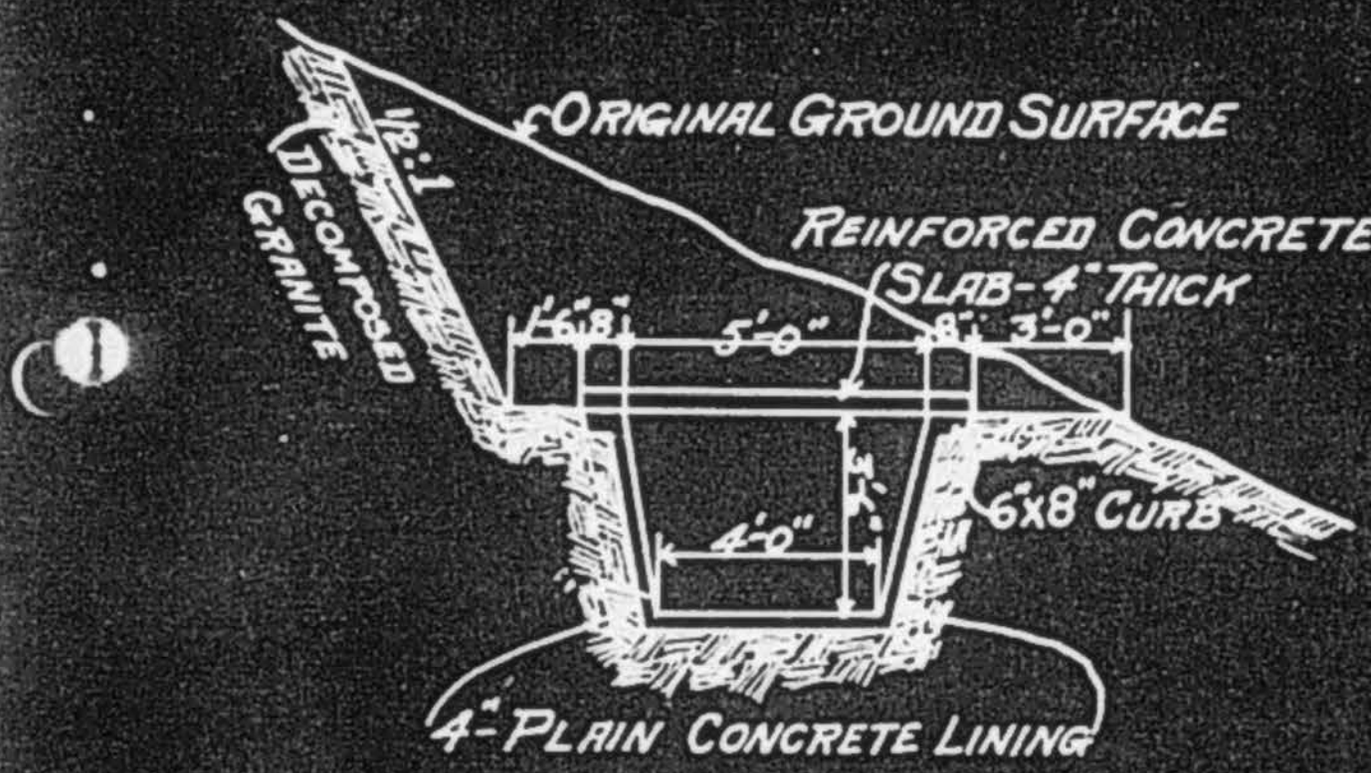
—CANAL SECTION—



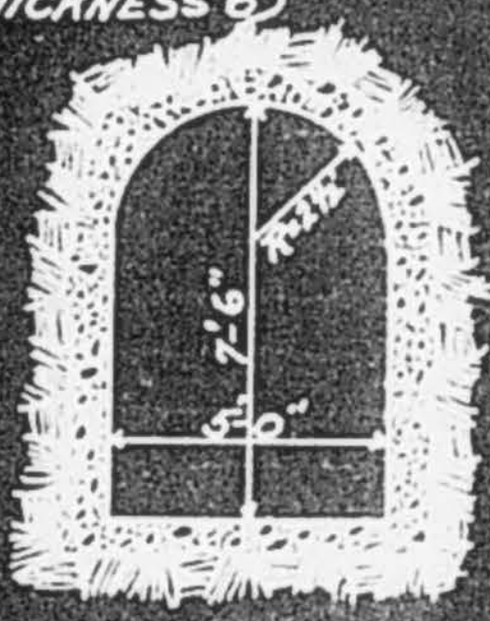
—TUNNEL SECTION—

WARNER'S CANAL

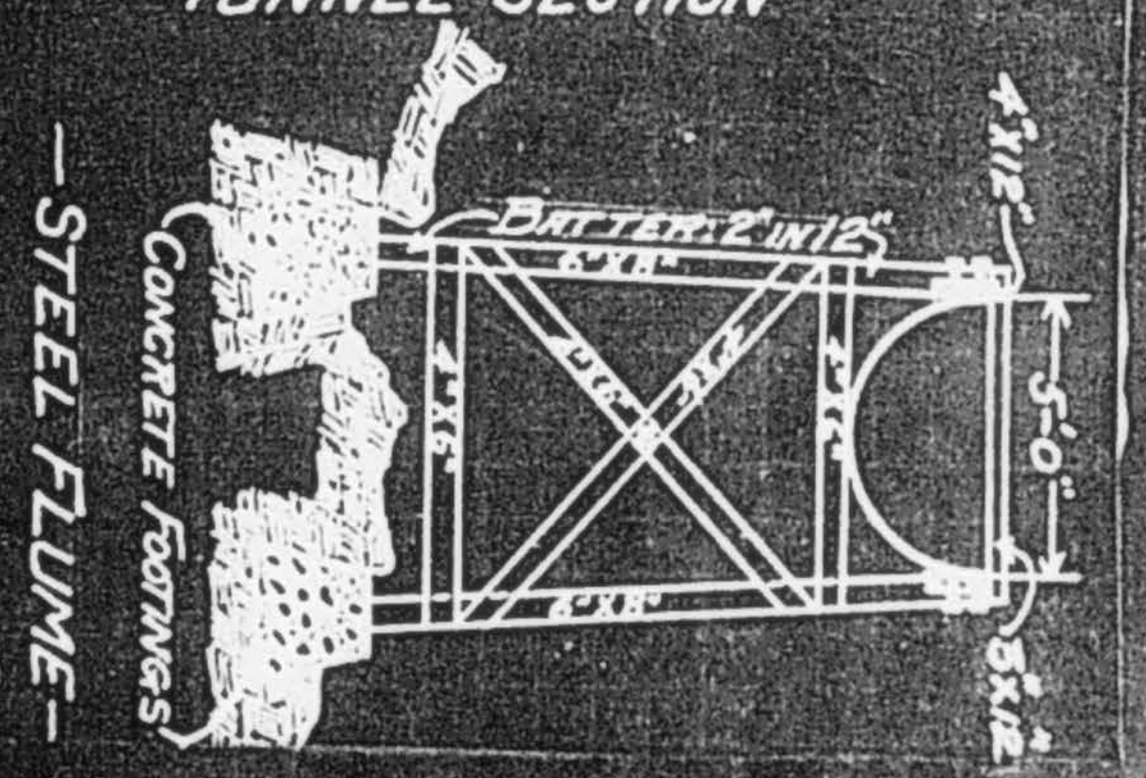
GRADE: 1 IN 1000.; CAPACITY: 100 SEC. FT.



—CANAL SECTION—



—TUNNEL SECTION—



PAMO CONDUIT

GRADE: 1 IN 1000
CAPACITY: 54 SEC. FT.

SHEET NO. 6½
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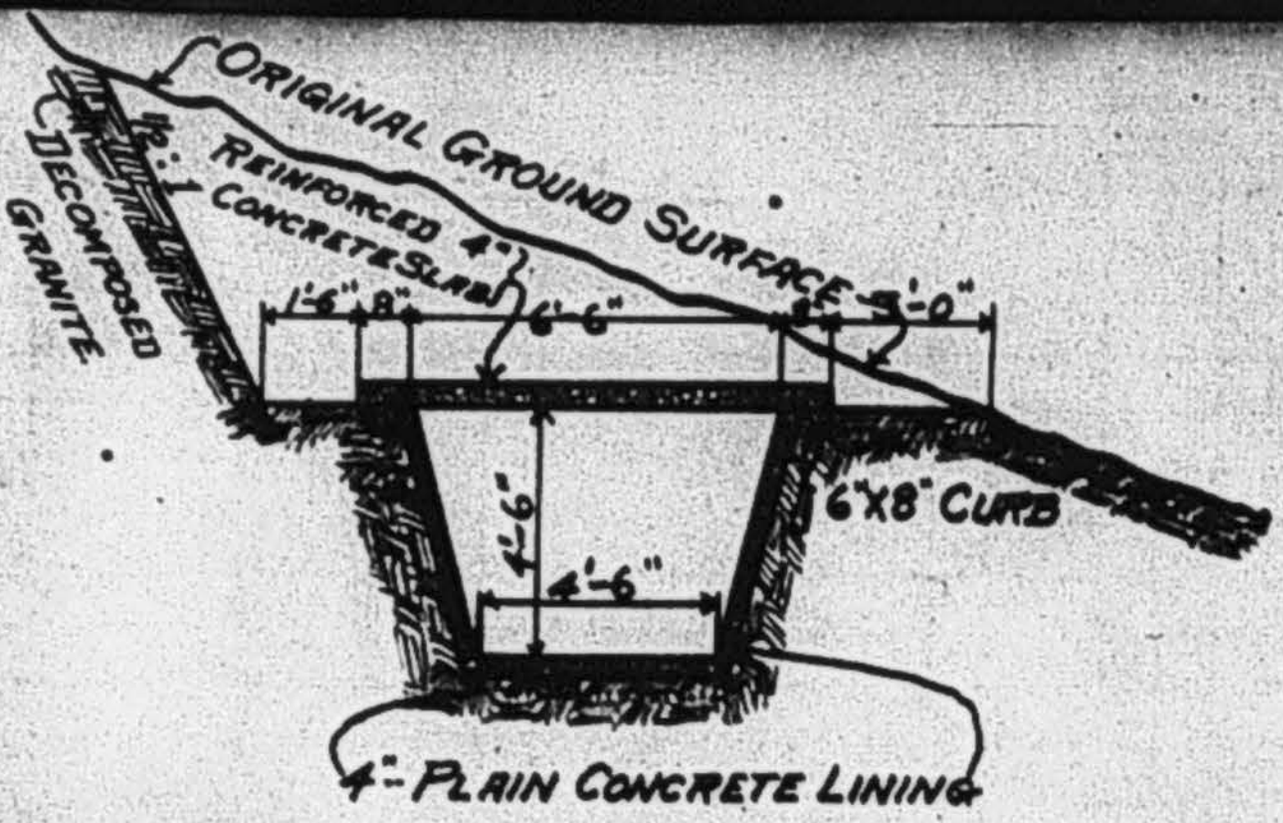
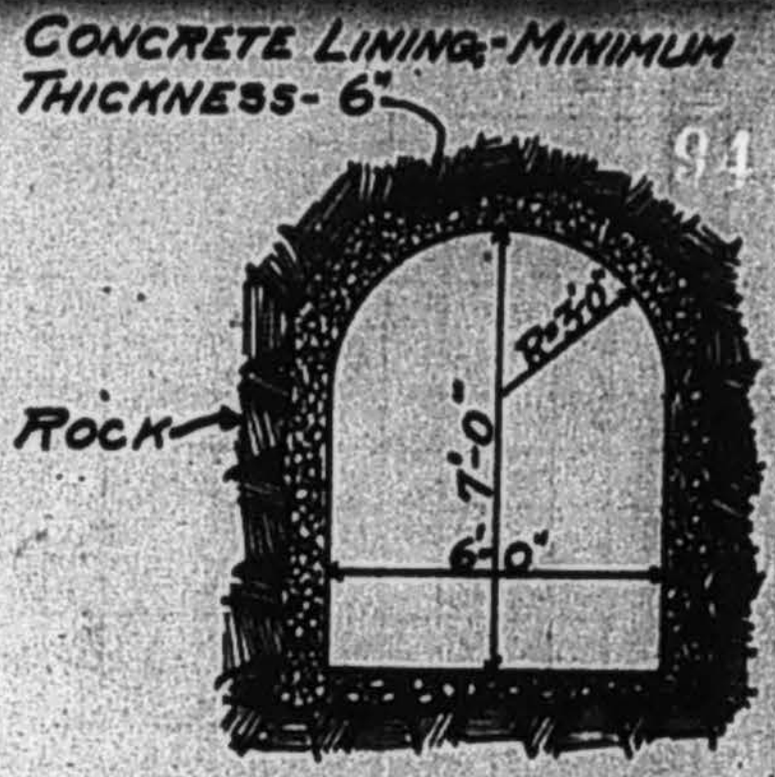


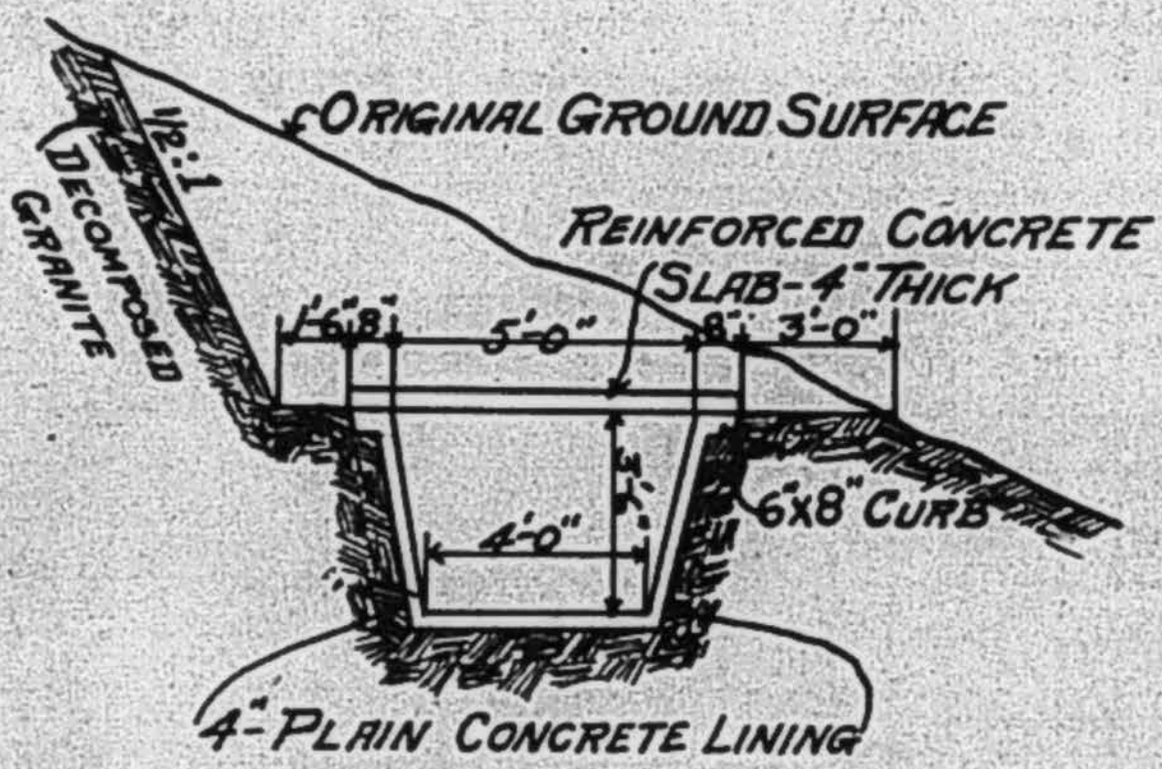
—CANAL SECTION—



—TUNNEL SECTION—

WARNER'S CANAL

GRADE: 1 IN 1000.; CAPACITY: 100 SEC. FT.

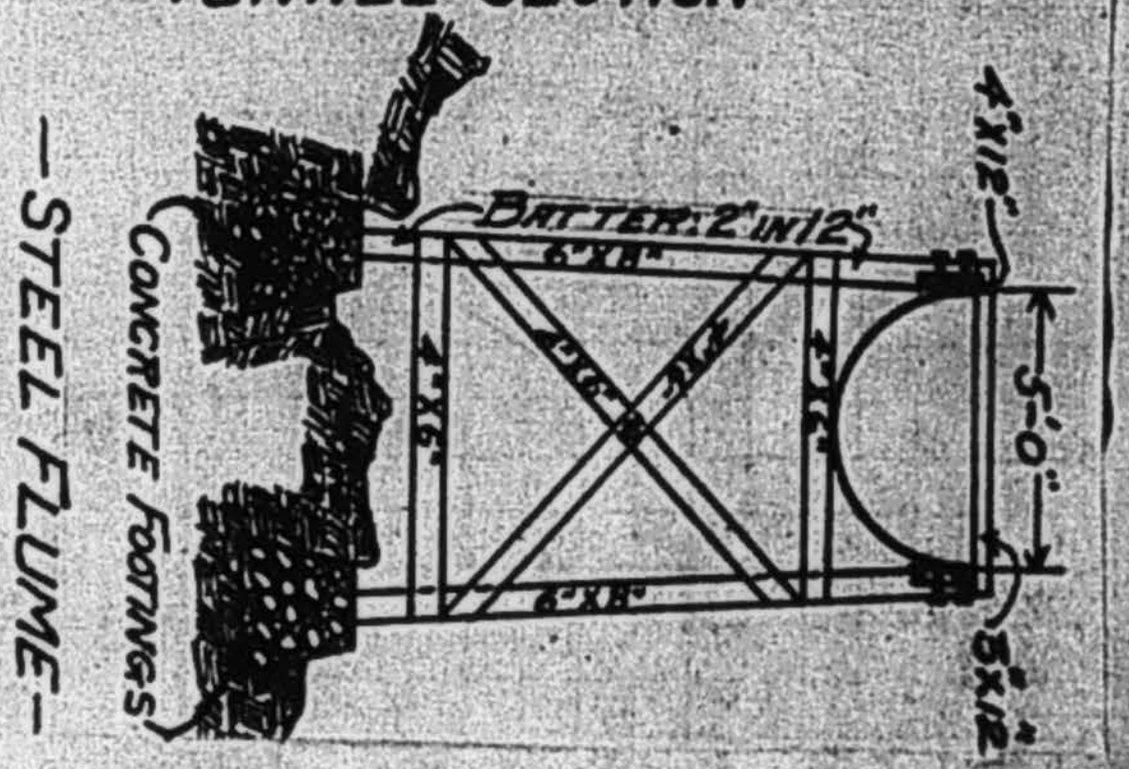


—CANAL SECTION—

—TUNNEL SECTION—

PAMO CONDUIT

GRADE: 1 IN 1000
CAPACITY: 54 SEC. FT.



—STEEL FLUME—

SHEET NO. 6½
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M.M. O'SHAUGHNESSY.... MEM. AM. SOC. C.E.
J.B. LIPPINCOTT..... " " " "

ESTIMATE OF COST

PAMO DAM
(Hydraulic Earth Fill Type)

VOLCAN LAND & WATER COMPANY

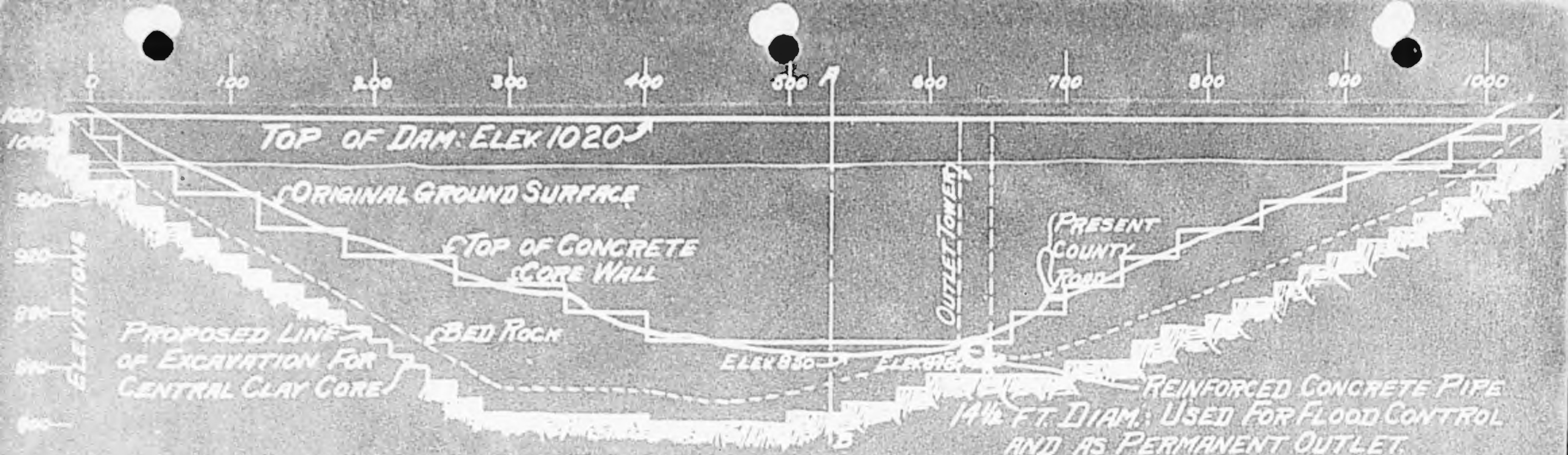
1,961,800	Cu.Yds.	of earth (allowing 10% shrinkage) @ $0.26 per cu.yd., ...	$509,900.
10,000	"	" " stripping on dam site, @ $0.40 per cu.yd., ...	4,000.
120,000	"	earth hardpan, decomposed granite,etc., excavation in core wall trench, @ $0.85 per cu.yd., ...	102,000.
48,000	"	rock excavation in core wall trench, @ $2.70 per cu.yd., ...	129,500.

NOTE: The test borings seem to indicate that probably 40,000 cu.yds. of this rock can be used for the loose rock fill on downstream slope and crushing for concrete.

5,300	Cu.Yds.	of concrete in core wall, @ $6.10 per cu.yd., ...	32,300.
4,700	"	" rock for crushing for concrete (rehandling from trench excavation, @ $0.60 per cu.yd., ...	28,200.
26,000	"	loose rock fill in downstream face,)rehandling from trench excavation, @ $0.80 per cu.yd., ...	20,800.
9,700	"	riprap,hand laid (stone from trench excavation),@ $1.35 per cu.yd., ...	13,100.
8,500	"	reinforced concrete in "Flood Control Conduit" 14½ ft. diam., 1100 ft.long, @ $18,95 per cu.yd., including reinforcement, ...	161,000.
4,400	"	rock for crushing for concrete, @ $1.75 per cu.yd., ...	7,800.
		Clearing reservoir site, say	3,500.
		Outlet Control,gates,pipes,etc.(including bridge).....	18,300.
#		Spillways, ...	13,000.
		200 Grout holes, average depth 60 ft., ...	15,000.
		Camp buildings,sheds,shops,water supply,sewerage,etc.,	7,000.
		Camp Maintenance and repairs,.....	3,500.
		Plant " "	4,000.
		Local Engineering and Superintendence - 2%, ...	21,400.
		Heavy Plant, allowing 20% for salvage value, ...	25,000.
		Loss on labor transportation, ...	1,800.
		Contractor's profit - 15%, ...	168,300.
		Interest during construction @ 4½% on one half the above amount for 2½ years, ...	72,500.
		TOTAL COST OF STRUCTURE, ...	$1,361,900.

NOTE: If the entire expense of changing the County Road,which at present traverses the reservoir, is added to the above estimate, it might easily cause an additional expense of $15,000.

The greater part of the spillway excavation will be accomplished in obtaining earth from the dam proper. The figure here given allows for finishing,trimming,and lining,together with special concrete slab protection at entrance and emptying ends, if found necessary.



—SECTION ALONG CENTER LINE—
LOOKING UPSTREAM

PAMO DAM (A)

NOTE. TEST BORINGS SHOW THAT VERY GENERAL GROUTING OF FOUNDATION WILL BE REQUIRED, ESPECIALLY BETWEEN STA. 600 & 800. GROUT HOLES 10 FT. C-C. AND 40 TO 75 FT. DEEP.

DATA & QUANTITIES

TYPE OF DAM: HYDRAULIC EARTH FILL.
ELEK. OF CREST: 1020
" " WATER SURF: 1006
LENGTH ON CREST 1050 FT.
TOP WIDTH: 25 FT.
MAXIMUM HEIGHT OF FILL: 170 FT.
OUTLET TOWER: REINFORCED CONCRETE.
FLOOD CONTROL: " " PIPE: 14½ DIAM: 800 FT. LONG.
" " PIPE: ELEV. OF BOTTOM: — 848.
CONCRETE IN CORE WALL: 5300 CU. YDS.
EARTH STRIPPING: 10000 CU. YDS. (1 FT. OF TOP SOIL)
ROCK EXCAVATION: CORE WALL TRENCH: 48000 CU. YDS.
EARTH " " " " : 120,000 CU. YDS.
CEMENT GUN FOUNDATION: 200 HOLES - 60 FT. AVERAGE DEPTH.
EARTH DAM (INCLUDING TRENCH): 1961800. CU. YDS.
DRAINAGE AREA: 110 SQ. MI.
RESERVOIR CAPACITY: (DEPTH 156 FT.): 47500 AC. FT.
" AREA: (" " "): 1050 ACRES.

SCALE:
0 50 100 150 200 250 300 400 500 FT.

SHEET NO. 1.
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J.B. LIPPINCOTT..... " " " "

NOTE: MATERIAL ON UPSTREAM AND DOWNSTREAM FACES TO BE KEPT 3 OR 4 FT. HIGHER THAN INTERIOR, BY MEANS OF SCRAPERS.

CONCRETE CORE WALL
BOTTOM THICKNESS 3 FT.
TOP " 1 FT.

—SECTION A-B—

PAMO DAM (2)

—HYDRAULIC EARTH FILL TYPE—

SCALE:

100 75 50 25 0 100 200 300 400 600 FT.

SHEET NO. 8
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J.B. LIPPINCOTT..... " " " "

ESTIMATE OF COST

PAMO CONDUIT

VOLCAN LAND & WATER COMPANY

47,951 lin. ft. of canal excavation (0.80 cu.yds. per ft.) @ $0.55 per ft.,.....						$ 26,400.
Benching @ $0.50 per ft., ...						24,000.
4" concrete lining and 4" reinforced concrete roof (0.24 cu.yds. per ft.) at an average price for the entire length, including reinforcement, of $5.80 per cu.yd., ...						66,700.
37,080	lin.ft.	of	steel flume	on bench	@ $3.85 per ft.	142,800.
6,576	"	"	"	" " trestle	5.75 "	37,800.
24,386	"	"	5 ft.x 7½ ft. tunnel, concrete lined, @ $20.00 per ft.			487,700.
8,737	"	"	low head siphons	@	6.70 "	58,500.
5,990	"	"	high " "	@	7.90 "	47,300.
130,720 lin.ft. = 24.8 miles, ...						$ 891,200.
Total Overhead Charges; including engineering and contingencies, contractor's profit @ 15%, extras, interest during construction @ 4½% on one-half the total amount for 2 years, etc. -- 30%, ...						$ 267,300.
TOTAL COST OF CONDUIT, ...						$1,158,500.

SUMMER AND RESERVOIR
AREA: 434 AC.
CAPACITY: 18,000 M.G.

SEC. 15
SEC. 22
SEC. 21
SEC. 28
SEC. 27

2000
2100
2150
2200
2055

SHEET. NO. 9
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M.M. O'SHAUGHNESSY MEM. AM. SOC. C.E.
J.B. LIPPINCOTT

SEC. 15

SEC. 22

SEC. 21

SEC. 28

SEC. 27

SWEETWATER RESERVOIR
AREA: 434 AC.
CAPACITY: 18,000 AC. FT.

SHEET. NO. 9
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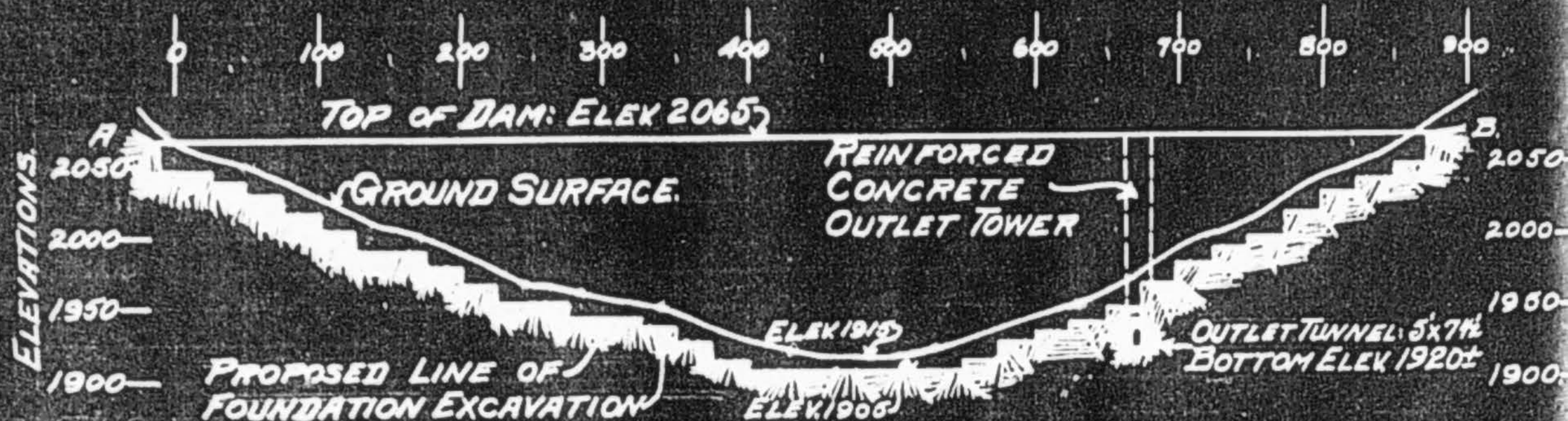
J.B. LIPPINCOTT

COST ESTIMATE
SUTHERLAND DAM
(Masonry Gravity Arched Type)
VOLCAN LAND & WATER COMPANY

92,500 Cu.Yds.	of 1:2½:5 Concrete @ $6.30 per cu.yd.		$582,700.
23,000 "	" "Rock Plums" @ 2.25 " "		51,700.
48,000 "	" Rock for crushing for concrete, @ $1.75 per cu.yd.		84,000.
7,400 "	" " stripping on foundation,etc., @ $2.70 per cu.yd.		20,000.
11,300 "	" Earth " on foundation,etc., @ $0.25 per cu.yd.		2,800.
Clearing reservoir site			3,000.
Outlet Tower, gates, pipes, etc., ...			16,500.
Outlet Tunnel 5 ft. x 7½ ft. 200 ft. long, @ $20.per lin.ft			4,000.
Bridge to Outlet Tower, ...			300.
# Spillways, ...			7,500.
Camp Buildings,sheds,shops,water supply,sewerage,etc.,			8,000.
" Maintenance and Repairs, ...			1,800.
Plant " "			5,000.
2 miles of road for hauling to dam site @ $5000 per mile			10,000.
Local Engineering and Superintendence - 2%			15,900.
Heavy Plant, allowing 40% salvage value, ...			22,500.
Loss on Labor Transportation, ...			1,200.
Contractor's Profit - 15%			125,400.
Interest during construction @ 4½% on one half the above amount for one year, ...			21,600.
	TOTAL COST OF STRUCTURE, ...		$983,900.

The greater part of the excavation for the spillways should be accomplished in the regular quarry work of obtaining rock for the dam.



—SECTION ALONG CENTER LINE—
(LOOKING UPSTREAM)

SUTHERLAND DAM (A1)

—SCALE—
100 50 0 50 100 150 200 300 400 500 Ft.

DATA & QUANTITIES

TYPE OF DAM: CYCLOPEAN CONCRETE: GRAVITY SECTION, ARCHED.
ELEV. OF CREST: 2065
" " WATER SURF.: 2055
LENGTH ON CREST: 875 FT.
MAXIMUM HEIGHT: 160 FT.
OUTLET TOWER: REINFORCED CONCRETE.
" TUNNEL: 5FT. X 7½ FT.: LENGTH: 200 FT.
" " : ELEV. OF BOTTOM: 1920.
CONCRETE IN DAM: 92500 CU. YDS.; ROCK PLUMS: 23000 CU. YDS.
STRIPPING { EARTH: 11400 CU. YDS.
ROCK: 7600 " "
DRAINAGE AREA: 53 SQ. MI.
RESERVOIR CAPACITY: (DEPTH 130 FT.): 18400 AC. FT.
" AREA: (" " "): 434 ACRES.
RADIUS OF CREST: 400 FT.
(SEE ALSO EARTH TYPE)

SHEET NO. 10
TO ACCOMPANY REPORT
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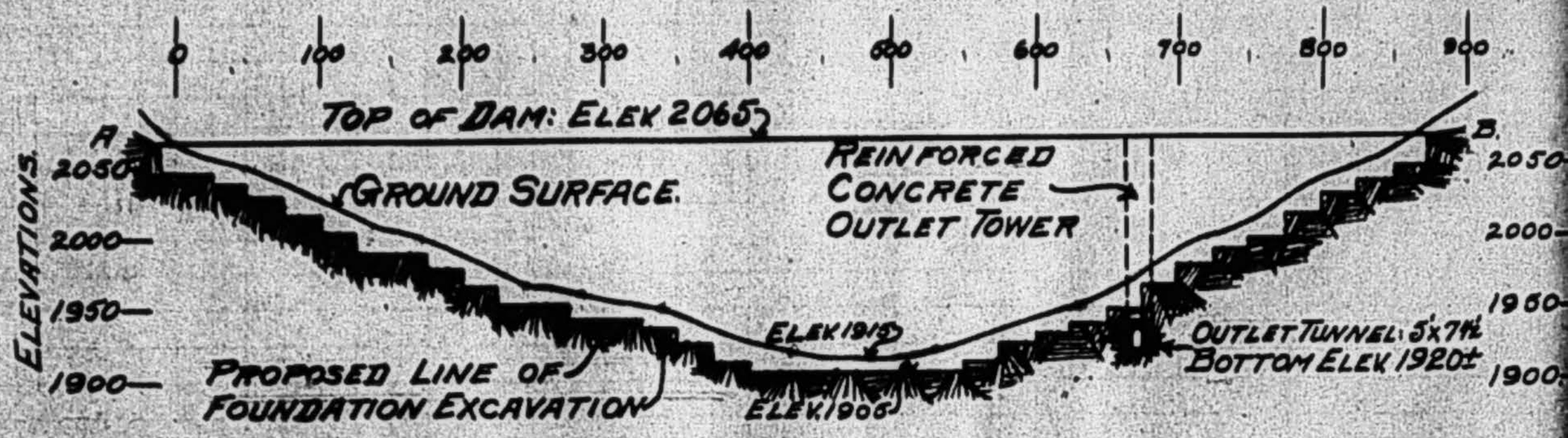
VOLCAN LAND & WATER CO.
TO THE
CITY OF SAN DIEGO CALIFORNIA.

M. M. O'SHAUGHNESSY.... MEM. AM. SOC. C. E.
J. B. LIPPINCOTT..... " " " "



—SECTION ALONG CENTER LINE—
(LOOKING UPSTREAM)

SUTHERLAND DAM (A1)

DATA & QUANTITIES

TYPE OF DAM: CYCLOPEAN CONCRETE: GRAVITY SECTION, ARCHED.
ELEV. OF CREST: 2065
" " WATER SURF: 2055
LENGTH ON CREST: 875 FT.
MAXIMUM HEIGHT: 160 FT.
OUTLET TOWER: REINFORCED CONCRETE.
" TUNNEL: 5FT. X 7½FT.: LENGTH: 200FT.
" " : ELEV. OF BOTTOM: 1920.
CONCRETE IN DAM: 92500 CU.YDS.; ROCK PLUMS: 23000 CU.YDS.
STRIPPING { EARTH: 11400 CU.YDS.
ROCK: 7600 " "
DRAINAGE AREA: 53 SQ.MI.
RESERVOIR CAPACITY: (DEPTH 130 FT.) 18400 AC.FT.
" AREA: (" " "): 434 ACRES.
RADIUS OF CREST: 400FT.
(SEE ALSO EARTH TYPE)

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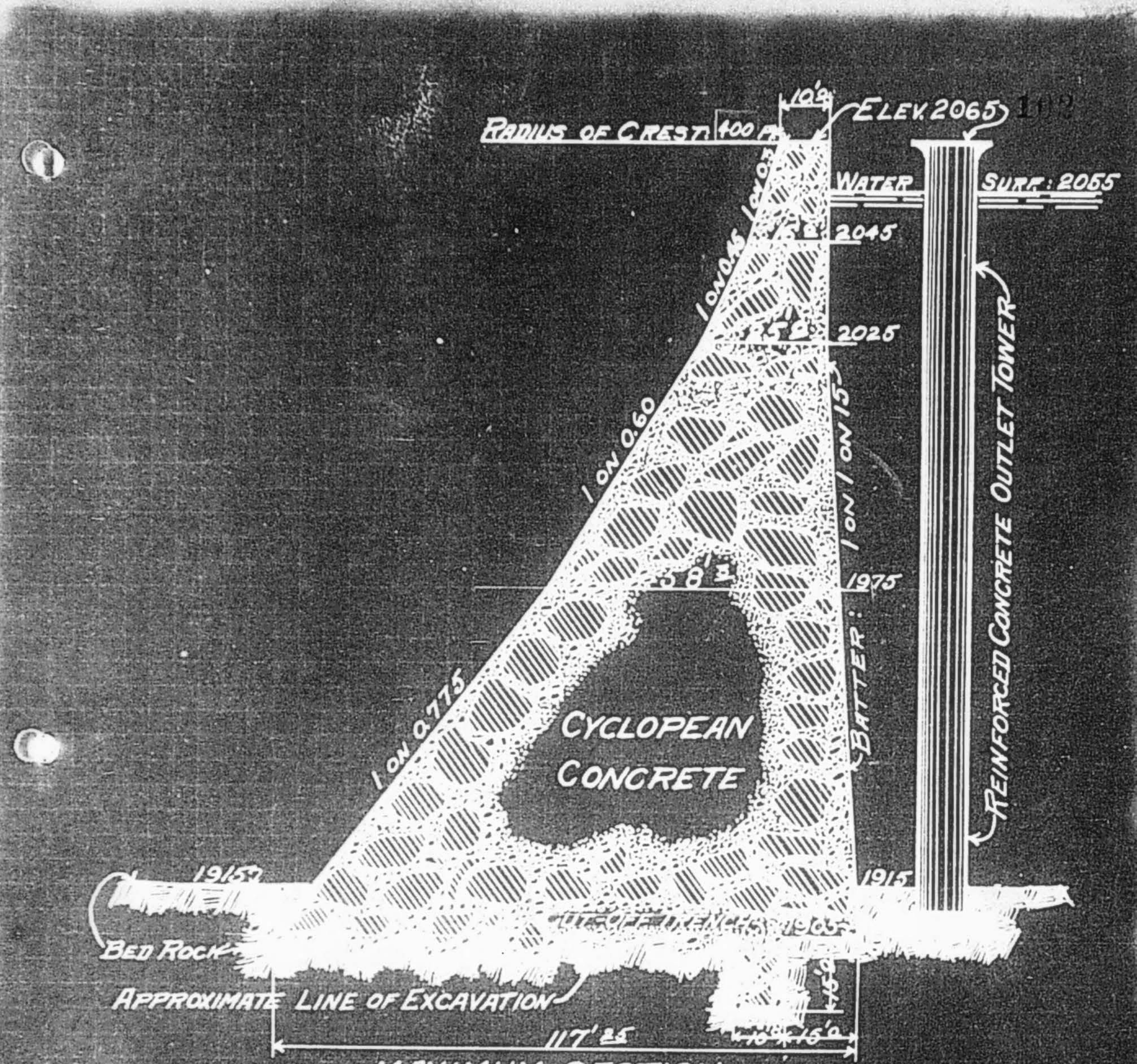
J.B.LIPPINCOTT..... " " " "



—MAXIMUM SECTION—
SUTHERLAND DAM (B.)
—ARCHED GRAVITY TYPE—

SCALE 10 5 0 10 20 60 100 Ft.

SHEET NO. 11.
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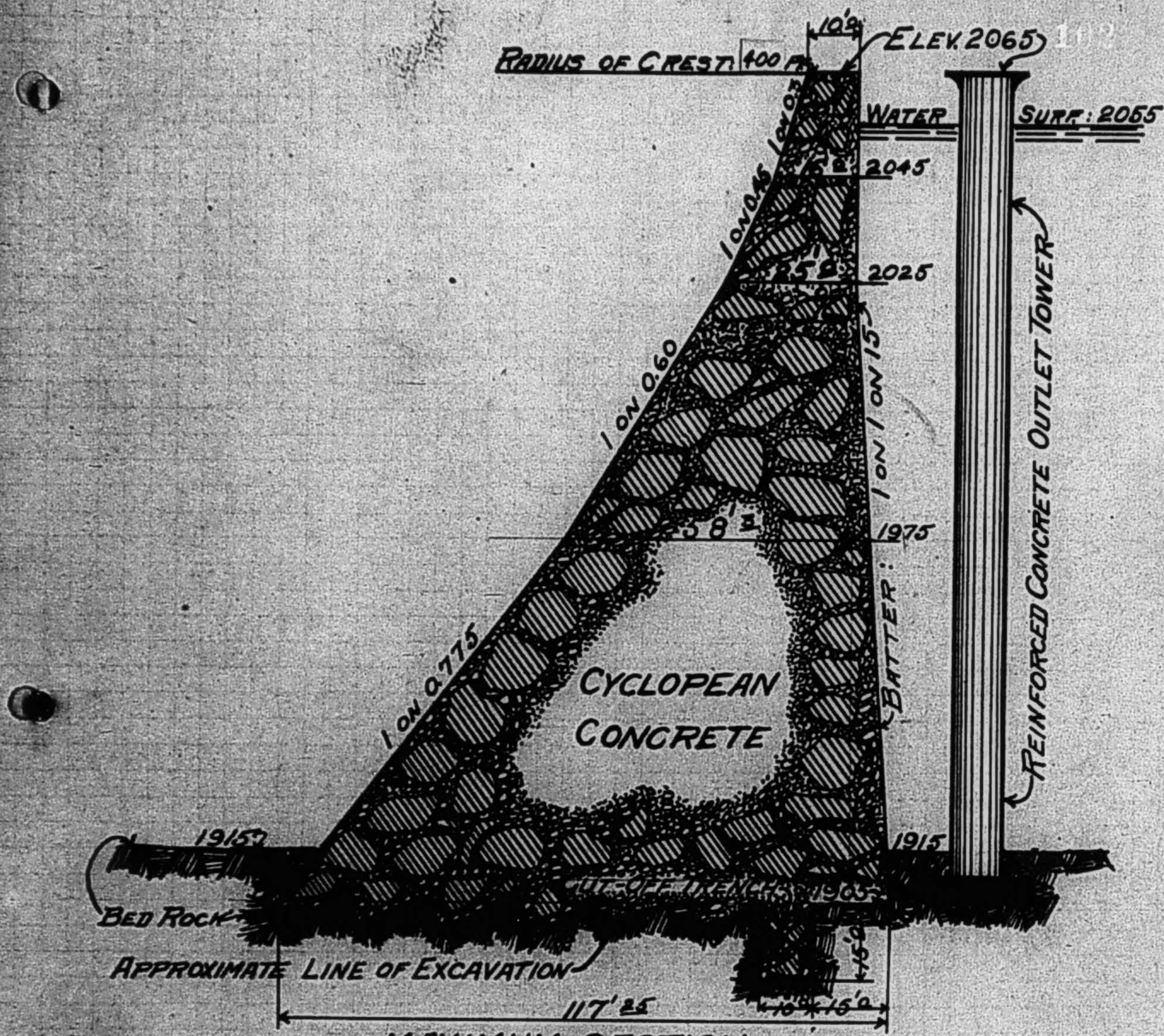

—MAXIMUM SECTION—
SUTHERLAND DAM (B)
—ARCHED GRAVITY TYPE—

SCALE 10 5 0 10 20 60 100 Ft.

SHEET NO. II.
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CITY OF SAN DIEGO CALIFORNIA

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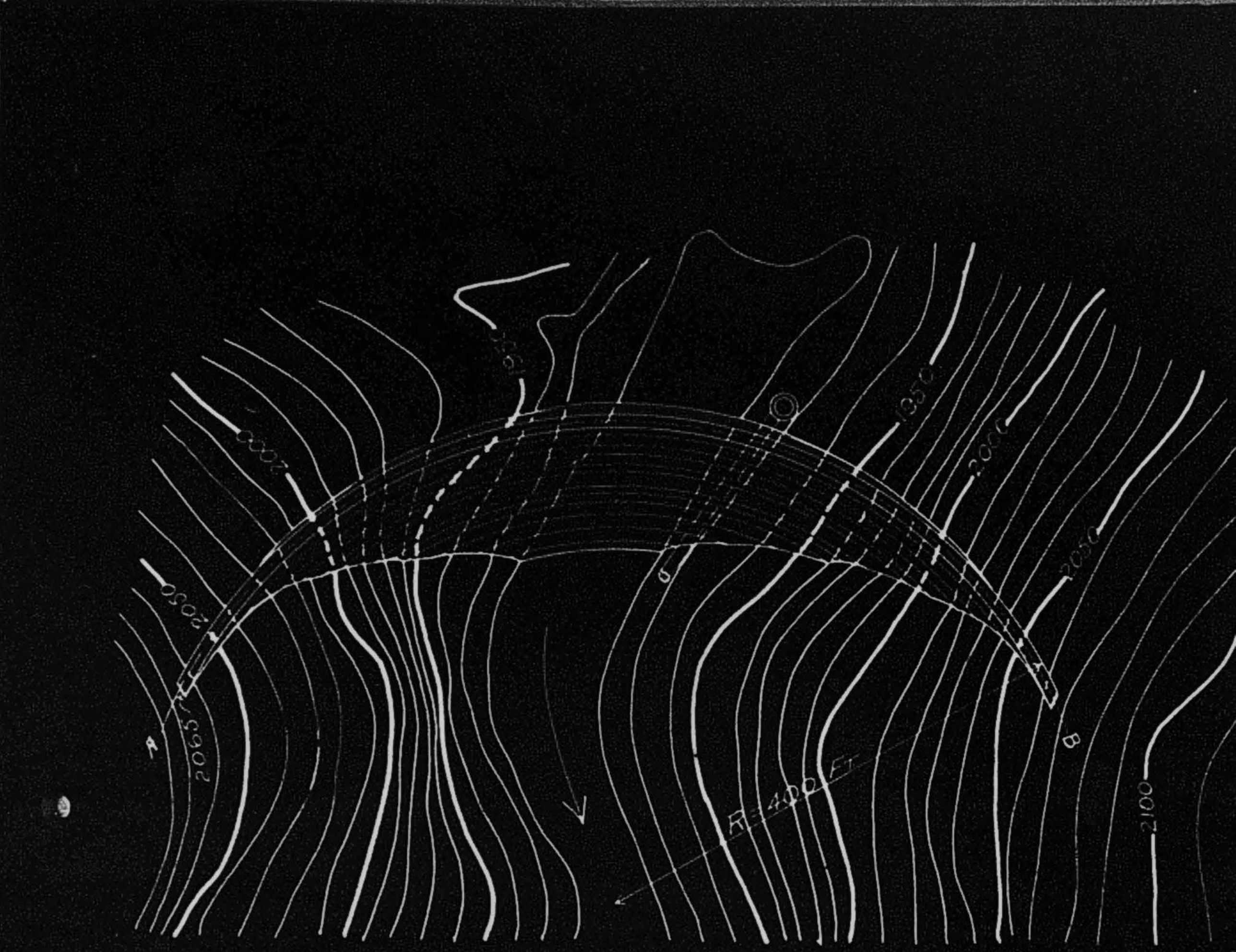
J.B. LIPPINCOTT..... " . " " "



PLAN

SUTHERLAND DAM (C.)

MASONRY ARCHED GRAVITY TYPE

SCALE

0 50 100 150 200 250 300 400 500 FT.

SHEET NO. 12
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CITY OF SAN DIEGO CALIFORNIA

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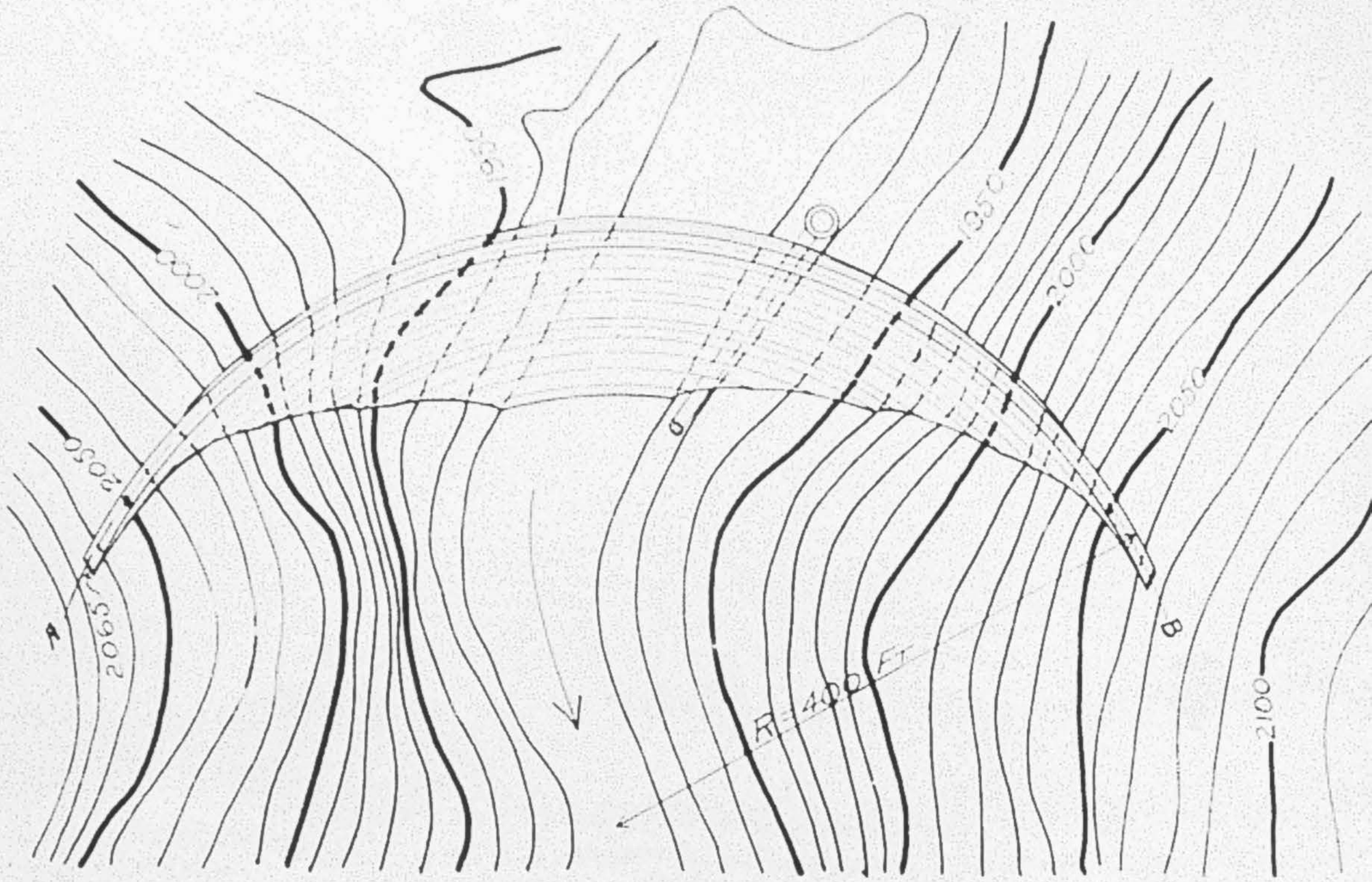
J.B. LIPPINCOTT



PLAN

SUTHERLAND DAM (C.)

MASONRY ARCHED GRAVITY TYPE

SCALE

0 50 100 150 200 250 300 400 500 Ft.

SHEET NO. 12
TO ACCOMPANY REPORT
ON
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TO THE
CITY OF SAN DIEGO CALIFORNIA

M.M. O'SHAUGHNESSY. MEM AM SOC C.E.
J.B. LIPPINCOTT. " "

ESTIMATE OF COST

SUTHERLAND DAM
(Hydraulic Earth FILL Type)

VOLCAN LAND & WATER COMPANY

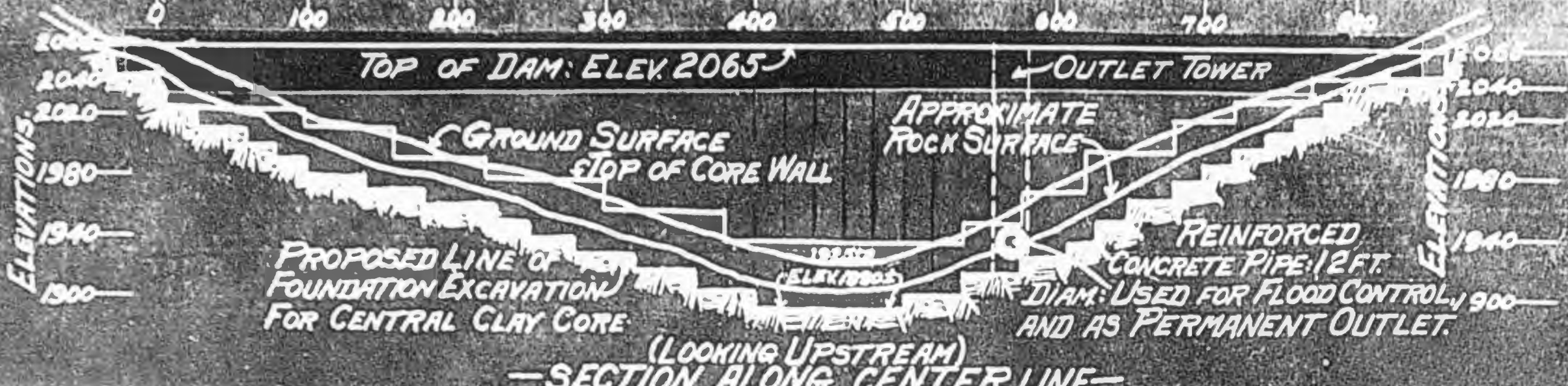
930,800 Cu.Yds.		of earth in dam (allowing 10% for shrinkage), @ $0.26 per cu.yd., ...	$242,000.
3,200	"	of earth stripping on dam site, @ $0.40 per cu.yd., ...	1,300.
35,000	"	" " and decomposed granite excavation in core wall trench, @ $0.75 per cu.yd.	26,100.
33,000	"	of rock excavation in core wall trench, @ $2.70 per cu.yd., ...	89,100.

NOTE: Probably 20,000 cu.yds. of this rock can be used for the loose rock fill on downstream slope, and crushing for concrete.

3,200 Cu. Yds.		of concrete in core wall @ $6.30 cu.yd.,	20,100.
2,900	"	rock for crushing for concrete (rehandling from trench excavation) @ $0.60 per cu.yd., ...	1,700.
18,000	"	of rock for fill downstream face (rehandling from trench excavation) @ $0.80 per cu.yd., ...	14,400.
7,100	"	of hand laid riprap @ $2.80 per cu.yd.	19,900.
5,150	"	of reinforced concrete in "Flood Control Conduit" 12 ft. diam., 900 ft.long, @ $17.15 per cu.yd., including reinforcement, ...	88,200.
2,700	"	rock for crushing for concrete, @ $1.75 per cu.yd., ...	4,700.
Clearing reservoir site, say, ...			3,000.
Outlet Control,gates,pipes,etc.(including bridge),..			16,300.
# Spillways, ...			10,500.
Camp buildings,sheds,shops,water supply,sewerage,etc.,			6,000.
" Maintenance and Repairs, ...			3,600.
Plant " " "			4,200.
2 miles of road for hauling to dam site @ $5000 per mi.			10,000.
Local Engineering and Superintendence - 2%, ...			11,200.
Heavy Plant, allowing 20% salvage value, ...			20,000.
Loss on Labor Transportation, ...			1,500.
Contractor's Profit - 15%, ...			89,000.
Interest during construction at 4½% on one-half the above amount for 2½ years, ...			38,400.
TOTAL COST OF STRUCTURE, ...			$ 721,200.

The greater part of the spillway excavation should be accomplished in obtaining earth for the dam proper; the figure here given allows for furnishing,trimming, and lining,together with special concrete slab protection at entrance and emptying ends if found necessary.

NOTE: If entire expense of changing the country road, which now runs across reservoir site, is added to the above estimate, (assuming 3 miles of road to be built @ $3100 per mile) it will increase the total cost to $733,500.



(LOOKING UPSTREAM)

—SECTION ALONG CENTER LINE—

SUTHERLAND DAM (A.)

—EARTH TYPE—

DATA & QUANTITIES

TYPE OF DAM..... EARTH FILL: HYDRAULIC.
ELEV. OF CREST: 2065
" " WATER SURFACE: 2055
LENGTH ON CREST: 900 FT.
TOP WIDTH: 25 FT.
MAXIMUM HEIGHT: 140 FT. (EXCLUDING TRENCH)
OUTLET TOWER: REINFORCED CONCRETE.
FLOOD CONTROL: " " PIPE: 12 FT. DIAM, 900± FT LONG.
" " PIPE: ELEV. OF BOTTOM: 1925.
CONCRETE IN CORE WALL: 3200 CU. YDS.
EARTH STRIPPING: 3200 CU. YDS: (TRENCH 35000 CU. YDS.)
ROCK EXCAVATION: CORE WALL TRENCH: 35000 CU. YDS.
MAIN DAM: 846200 CU. YDS. NET: (SHRINKAGE; 10% ±)
(SEE ALSO MASONRY TYPE).

SCALE:
0 50 100 150 200 250 300 400 500 FT.

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TO ACCOMPANY REPORT
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VOLCAN LAND & WATER CO.
TO THE
CITY OF SAN DIEGO CALIFORNIA

M. M. O'SHAUGHNESSY.....MEM. AM. SOC. C.E.
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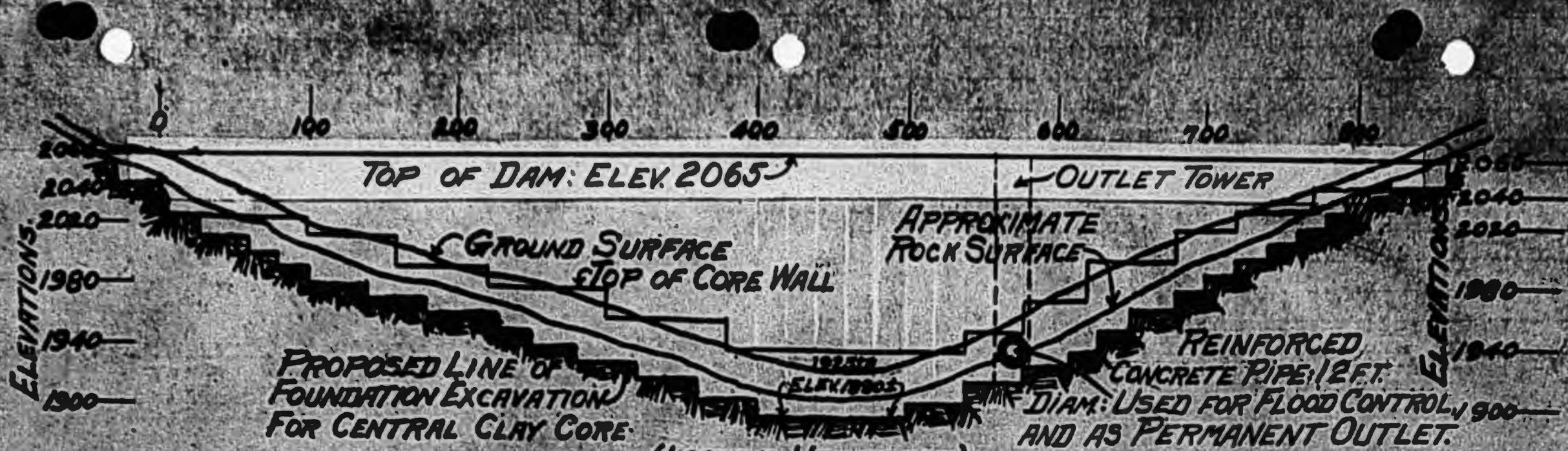

SUTHERLAND DAM (A.)

—EARTH TYPE—

DATA & QUANTITIES

TYPE OF DAM..... EARTH FILL: HYDRAULIC.
ELEV. OF CREST: 2065
" " WATER SURFACE: 2055
LENGTH ON CREST: 900 FT.
TOP WIDTH: 25 FT.
MAXIMUM HEIGHT: 140 FT. (EXCLUDING TRENCH)
OUTLET TOWER: REINFORCED CONCRETE.
FLOOD CONTROL: " " PIPE: 12 FT. DIAM, 900± FT. LONG.
" " PIPE: ELEV. OF BOTTOM: 1925.
CONCRETE IN CORE WALL: 3200 CU. YDS.
EARTH STRIPPING: 3200 CU. YDS: (TRENCH 35000 CU. YDS)
ROCK EXCAVATION: CORE WALL TRENCH: 35000 CU. YDS.
MAIN DAM: 846200 CU. YDS. NET. (SHRINKAGE; 10% ±)
(SEE ALSO MASONRY TYPE).

SCALE:
0 50 100 150 200 250 300 400 500 FT.

SHEET NO. 13
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TO THE
CITY OF SAN DIEGO CALIFORNIA

M. M. O'SHAUGHNESSY..... MEM. AM. SOC. C.E.
J. B. LIPPINCOTT..... " " " "

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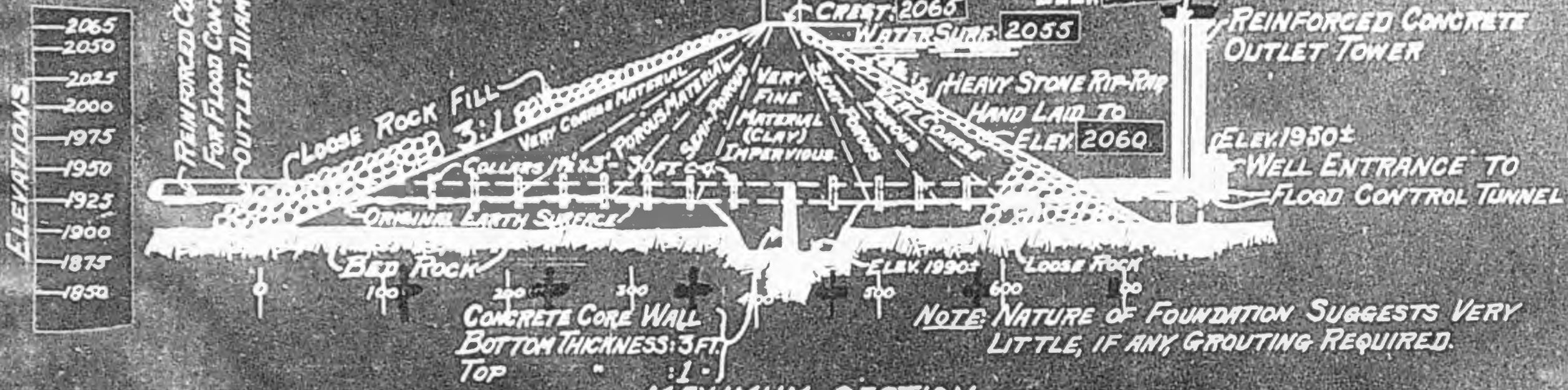
NOTE: MATERIAL ON UPSTREAM AND DOWNSTREAM FACES, TO BE KEPT 3 OR 4 FT. HIGHER THAN INTERIOR, BY MEANS OF SCRAPERS.



NOTE: NATURE OF FOUNDATION SUGGESTS VERY LITTLE, IF ANY, GROUTING REQUIRED.

—MAXIMUM SECTION—

SUTHERLAND DAM. (B.)

— HYDRAULIC EARTH FILL TYPE —

SHEET NO. 14.
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TO THE
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M.M. O'SHAUGHNESSY.....MEM. AM. SOC. C.E.
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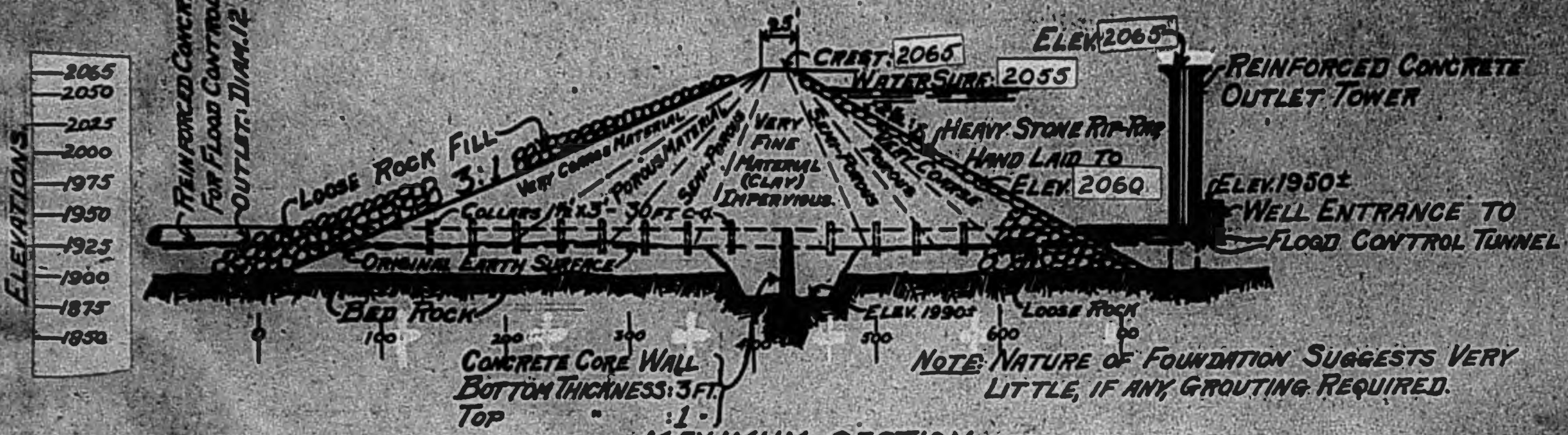
NOTE: MATERIAL ON UPSTREAM AND DOWNSTREAM FACES, TO BE KEPT 3 OR 4 FT HIGHER THAN INTERIOR, BY MEANS OF SCRAPERS.



NOTE: NATURE OF FOUNDATION SUGGESTS VERY LITTLE, IF ANY, GROUTING REQUIRED.

—MAXIMUM SECTION—

SUTHERLAND DAM. (B2)

—HYDRAULIC EARTH FILL TYPE—

SHEET NO. 14.
TO ACCOMPANY REPORT
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VOLCAN LAND & WATER CO.
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CITY OF SAN DIEGO CALIFORNIA

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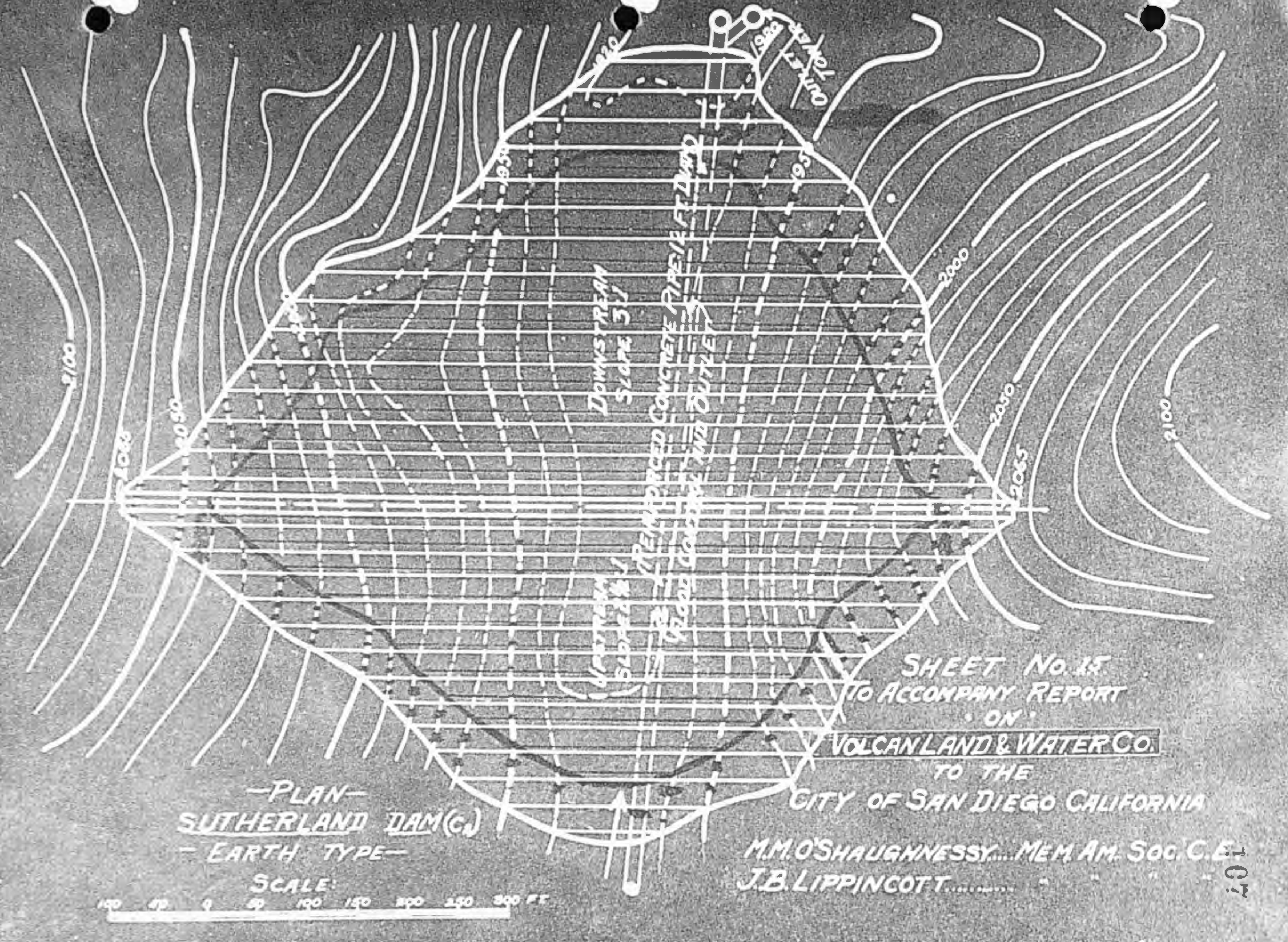
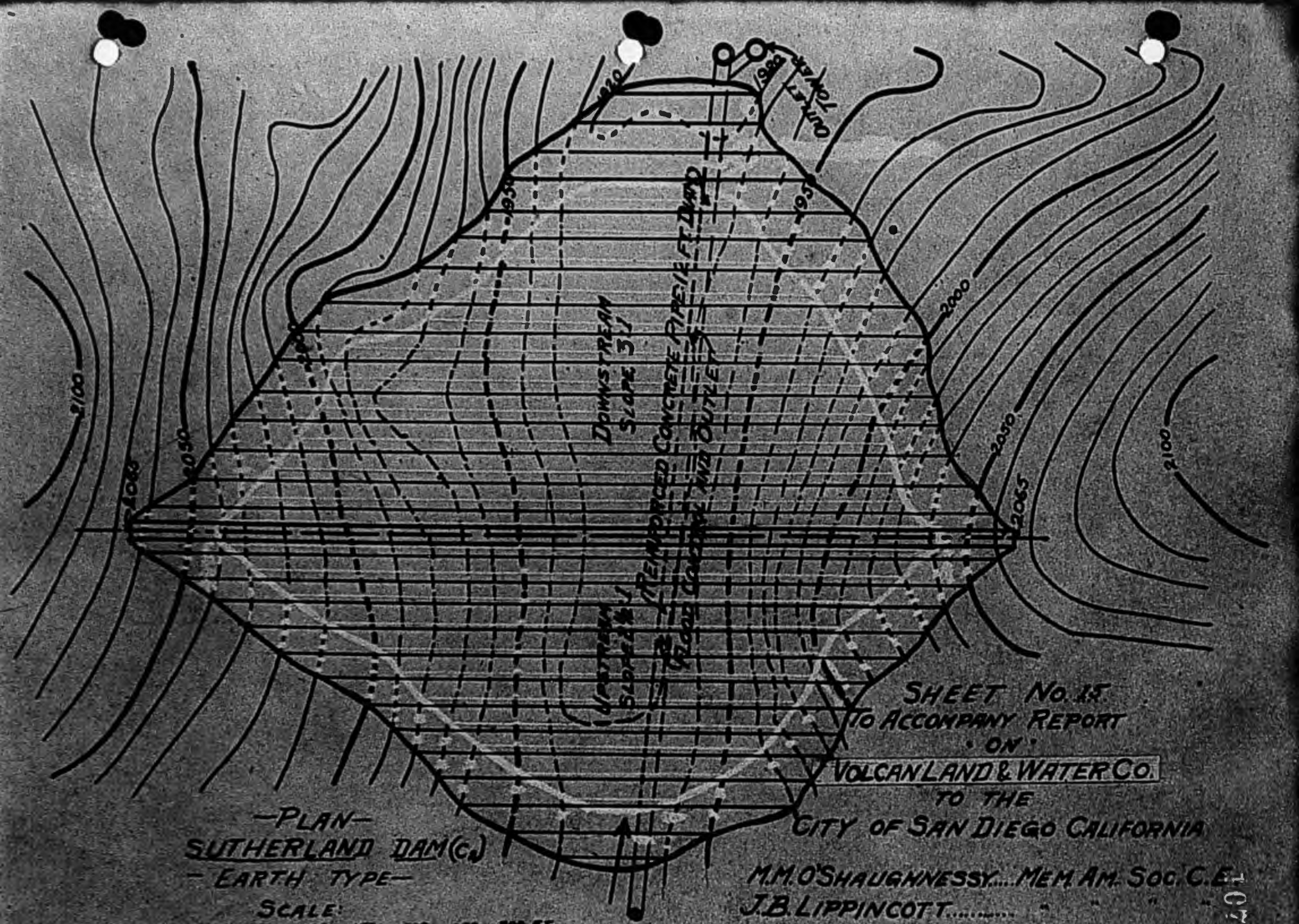

OUTLET TOWER
DOWNSTREAM SLOPE 3:1
REINFORCED CONCRETE PIPE 6 FT. DIAM.
FLOOD CONTROL AND OUTLET
2100
2050
2000
2065
2100
2050
1950
1850
SHEET No. 15
TO ACCOMPANY REPORT
· ON ·
VOLCAN LAND & WATER CO.
TO THE
CITY OF SAN DIEGO CALIFORNIA
M.M. O'SHAUGHNESSY.... MEM. AM. SOC. C.E.
J.B. LIPPINCOTT........ " " "
-PLAN-
SUTHERLAND DAM (C1)
- EARTH TYPE -
SCALE:
100 50 0 50 100 150 200 250 300 FT.



SHEET No. 15.
TO ACCOMPANY REPORT
ON
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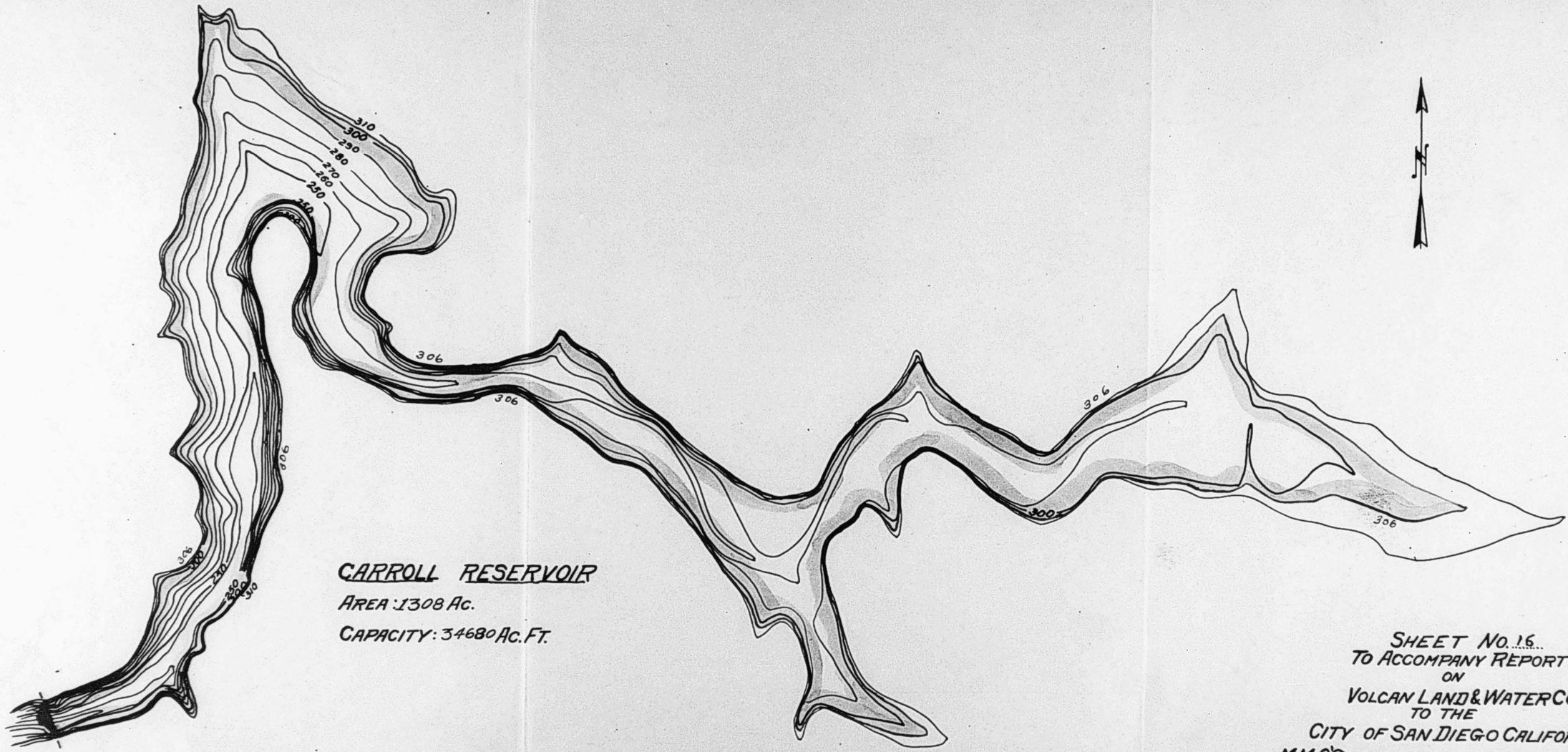
TO THE
CITY OF SAN DIEGO CALIFORNIA

M.M. O'SHAUGHNESSY.... MEM. AM. SOC. C.E.
J.B. LIPPINCOTT..... " " " "

-PLAN-
SUTHERLAND DAM (C.)
- EARTH TYPE -

SCALE:
100 50 0 50 100 150 200 250 300 FT.

107



CARROLL RESERVOIR

AREA: 1308 Ac.

CAPACITY: 34680 Ac. Ft.

SHEET No. 16.
TO ACCOMPANY REPORT
ON
VOLCAN LAND & WATER CO.
TO THE
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M.M. O'SHAUGHNESSY.... MEM. AM. SOC. C.E.
J.B. LIPPINCOTT..... " " " "

SCALE: 0 1/8 1/4 3/8 1/2 3/4 1 MILE.

ESTIMATE OF COST

CARROLL DAM
(Masonry Overflow Type)

VOLCAN LAND & WATER COMPANY

75,100 Cu.Yds. of concrete in place (exclusive of quarrying the rock) @ $5.85 per cu.yd., ...	$439,000.
Quarrying 38,800 cu.yds. of rock for crushing @ $1.75 per cu.yd., ...	67,900.
18,700 Cu.Yds. of Rock Plums in place @ $2.25 per cu.yd.	42,100.
Outlet Tower and Appurtenances,pipes,gates, etc., ...	14,800.
Outlet Tunnel 5 ft.x 7½ ft.,225 ft.long,@ $20.00 per ft.,	4,500.
Bridge from Outlet Tower to side of reservoir, ...	600.
Clearing reservoir site, ...	3,000.
Stripping (26300 Cu.Yds.Earth @ $0.25 per cu.yd., ...	6,600.
(18200 " Rock @ $2.70 " "	49,100.
Camp buildings, sheds, shops, water supply,sewerage,etc.	5,500
" Maintenance and Repairs, ...	3,000.
Plant " " "	5,000.
Local Engineering and Superintendence - 2%, ...	12,800.
Heavy Plant, allowing 40% salvage value, ...	22,500.
Loss on Labor Transportation, ...	1,200.
Contractor's Profit - 15%, ...	101,700.
Interest during construction @ 4½% (on one half of the above amount for one year),.....	17,500.
TOTAL COST OF DAM, ...	$796,800.

NOTE: (1) The above estimate is based upon the assumption that there is plenty of rock economically available to allow the structure to be made "Cyclopean Concrete", approximately 20% of the dam being "rock plums".

(2a) In addition to the dam there will be required a pumping plant to handle 10 million gallons daily against an actual head of 250 feet, or 310 feet including friction. The cost of this plant, including 3-300 H.P. Motors, 2 High Duty Pumps, direct connected, and operated at about 1000 revolutions per minute (one motor and pump to be used only in case of emergency) together with the building, piping and other appurtenances, will cost, ... 42,000.

TOTAL COST OF COMPLETE STRUCTURE .....$ 838,800.

(2b) Should it be found more desirable to install a steam pumping plant at first, from the economic standpoint of fuel and other operating expenses, there will be required 800 H.P. steam turbine, direct connected to 3 stage centrifugal pump; 1000 H.P. steam boiler, together with the condensing machinery; 30" steel pipe from reservoir to pumps and from pumps to canal sump, buildings, and all other appurtenances. Cost, erected and ready for operation, ... 56,000.

TOTAL COST OF COMPLETE STRUCTURE WOULD THEN BE $ 852,800.

—SECTION ALONG CENTER LINE—
(LOOKING UPSTREAM)

CARROLL DAM. (A)

DATA & QUANTITIES.

TYPE OF DAM: OVERFLOW:- CYCLOPEAN CONCRETE.
ELEV. OF CREST: 306.
LENGTH ON CREST: 720 FT.
MAXIMUM HEIGHT: 110 FT.
OUTLET TOWER: REINFORCED CONCRETE.
" TUNNEL: 5FT. X 7½FT. LENGTH 225FT.
" : ELEV. OF BOTTOM: 220.
CONCRETE IN DAM: 75100 CU YDS.: ROCK PLUMS: 18700 CU.YDS.
STRIPPING: { EARTH: 26300 CU. YDS.
ROCK: 18200 " "
DRAINAGE AREA: 196 SQ. MI.
RESERVOIR CAPACITY: (DEPTH 100FT): 34680 AC. FT.
" AREA: (" ") 1308 ACRES.

SCALE:
100 80 60 40 20 0 50 100 150 200 300 FT.

SHEET NO. 17.
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CITY OF SAN DIEGO CALIFORNIA

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J.B. LIPPINCOTT..... " " "

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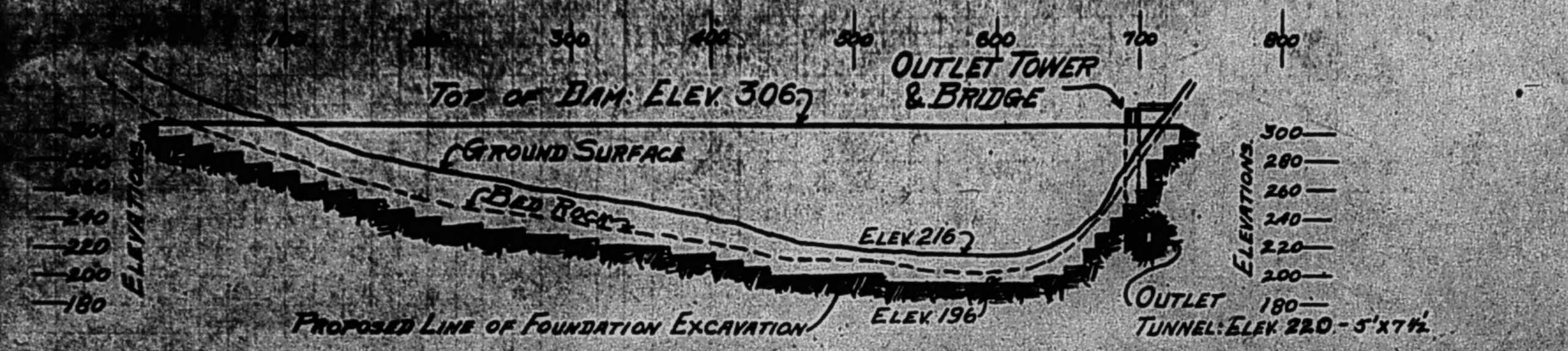


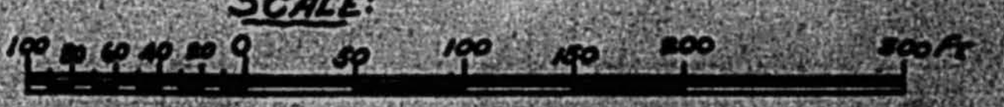
—SECTION ALONG CENTER LINE—
(LOOKING UPSTREAM)

CARROLL DAM. (A)

DATA & QUANTITIES.

TYPE OF DAM: OVERFLOW:- CYCLOPEAN CONCRETE.
ELEV. OF CREST: 306.
LENGTH ON CREST: 720 FT.
MAXIMUM HEIGHT: 110 FT.
OUTLET TOWER: REINFORCED CONCRETE.
" TUNNEL: 5FT. x 7½FT. LENGTH: 225FT.
" : ELEV. OF BOTTOM: 220.
CONCRETE IN DAM: 75100 CU YDS. ROCK PLUMS: 18700 CU.YDS.
STRIPPING: { EARTH: 26300 CU. YDS.
ROCK: 18200 " "
DRAINAGE AREA: 196 SQ. MI.
RESERVOIR CAPACITY: (DEPTH 100FT): 31680 AC. FT.
" AREA: (" ") 1308 ACRES.

SCALE:



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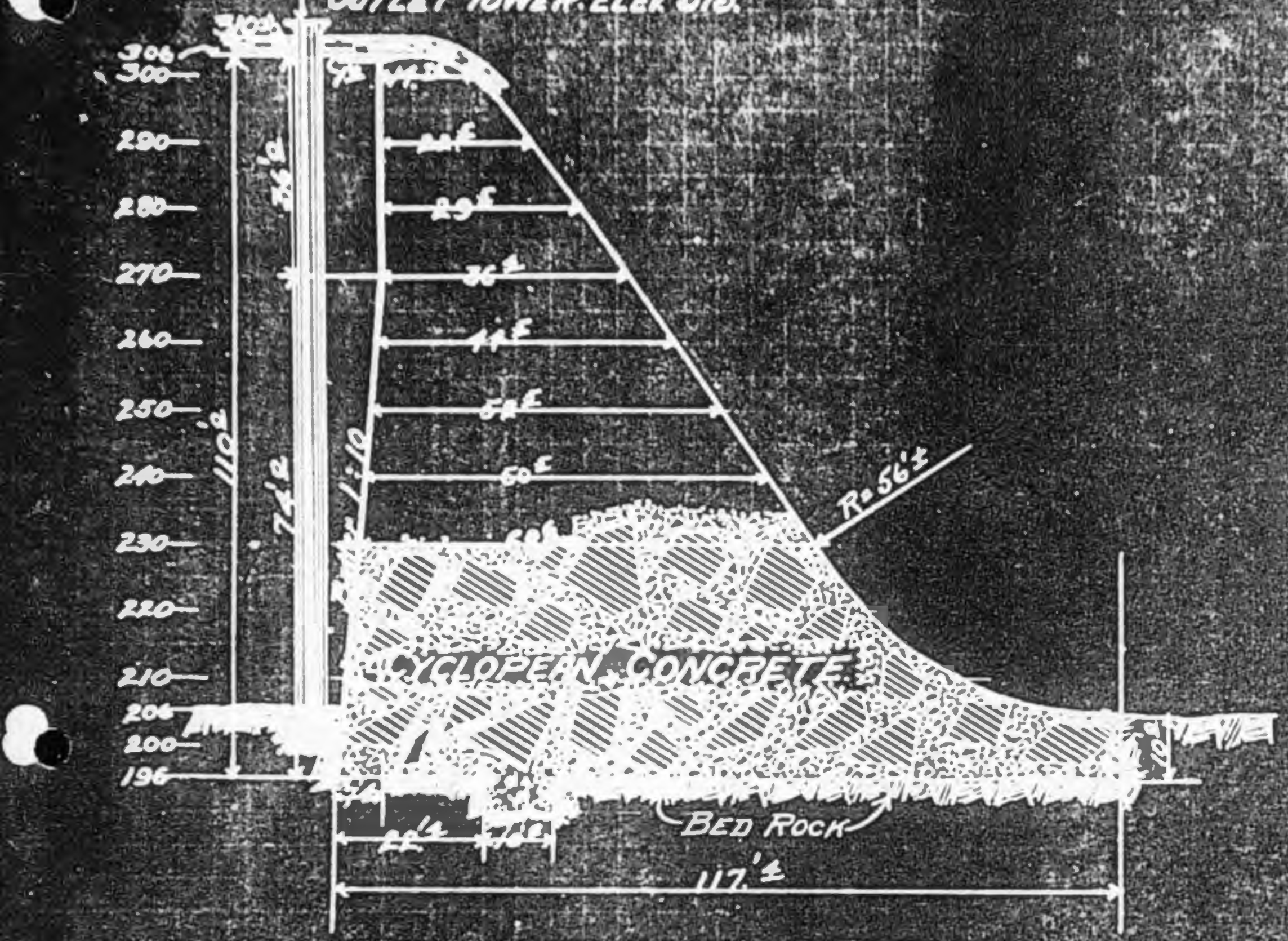
J.B. LIPPINCOTT..... " " " "

17.



—MAXIMUM SECTION—
CARROLL DAM (B)

SCALE:
0 5 10 15 20 25 30 40 50 60 70 80 90 100 Ft

SHEET No. 18
TO ACCOMPANY REPORT
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CITY OF SAN DIEGO CALIFORNIA

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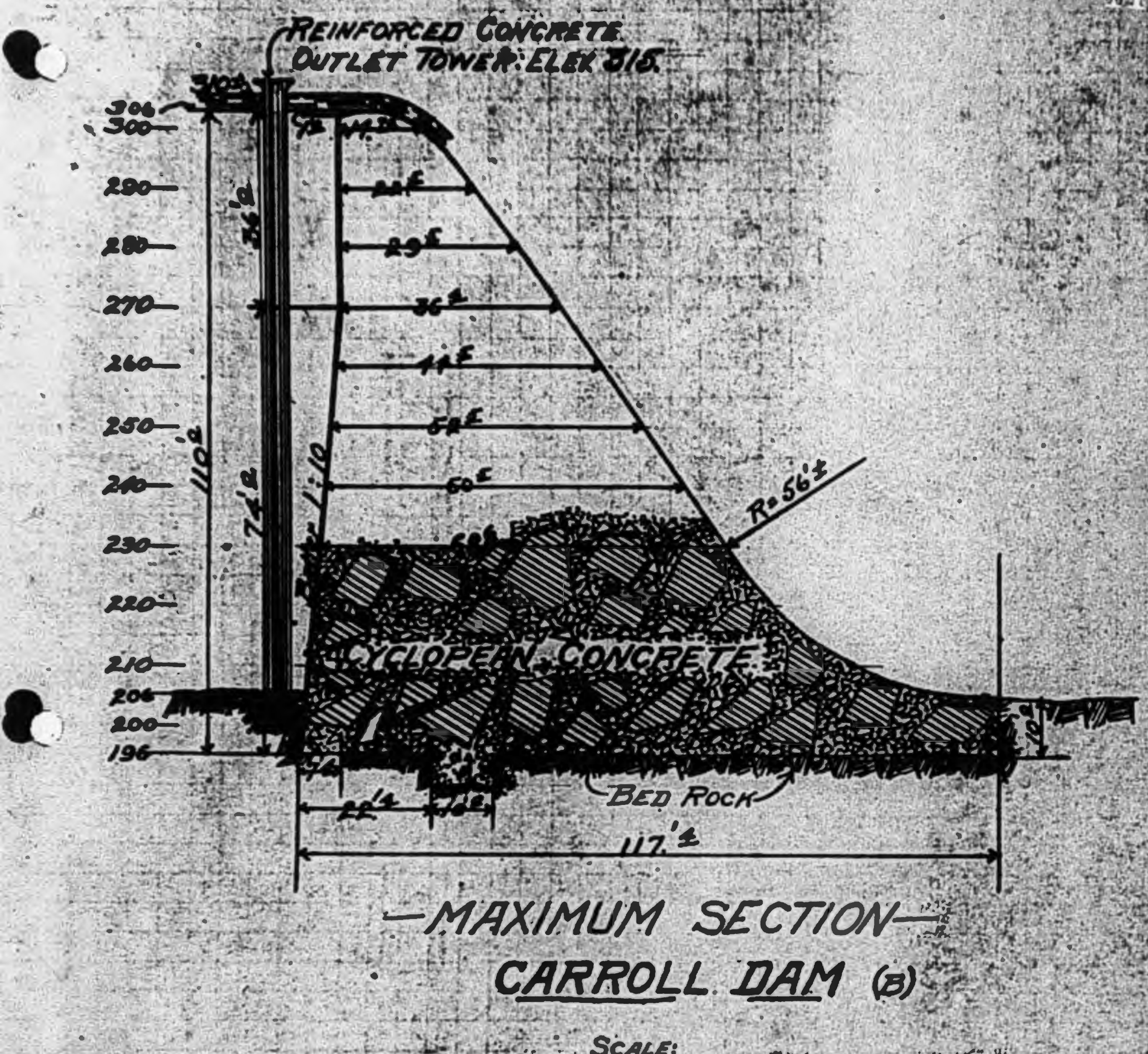
J.B. LIPPINCOTT..... " " " "



MAXIMUM SECTION

CARROLL DAM (B)

SCALE:
0 5 10 15 20 25 30 40 50 60 70 80 90 100 Ft

SHEET NO. 18
TO ACCOMPANY REPORT
ON
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CITY OF SAN DIEGO CALIFORNIA

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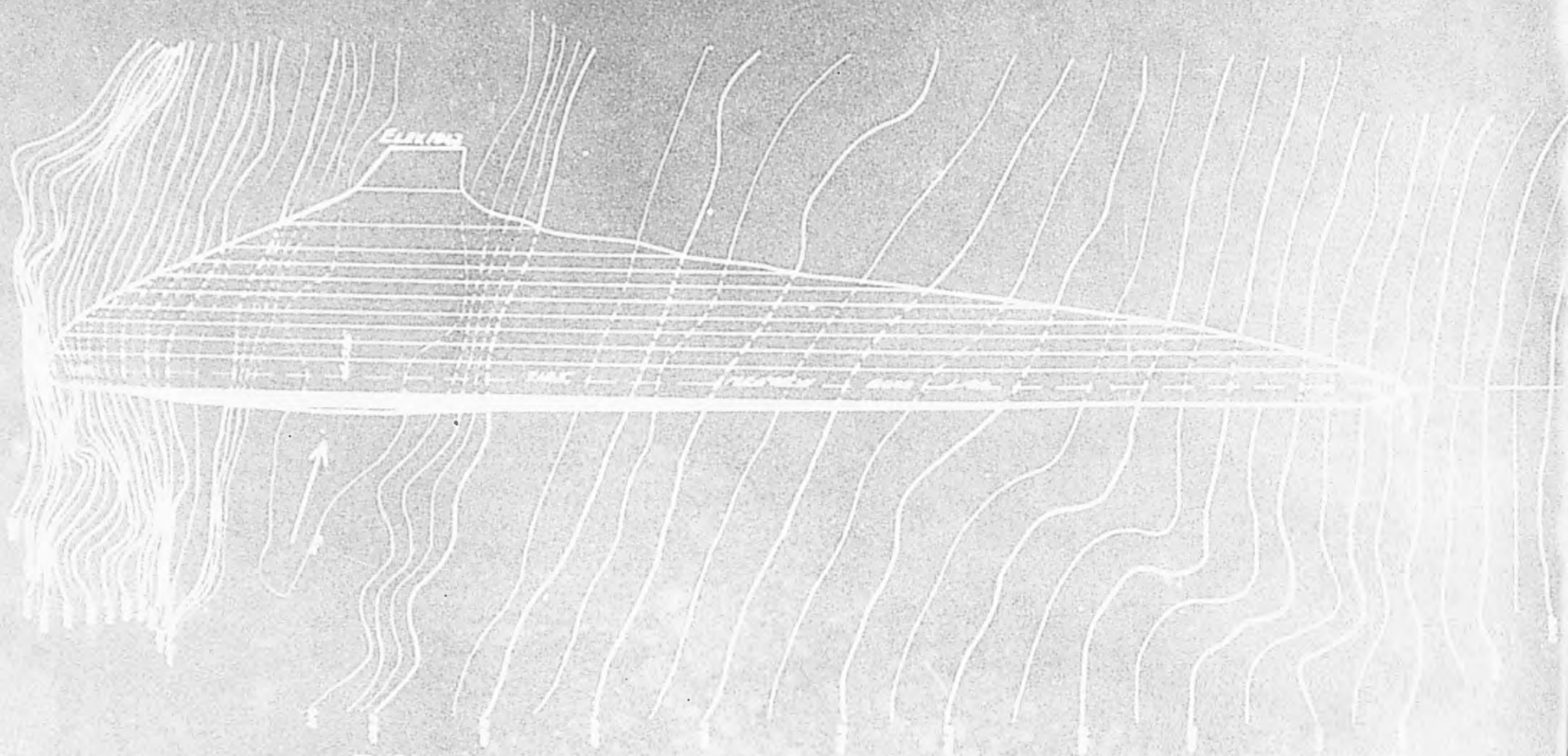
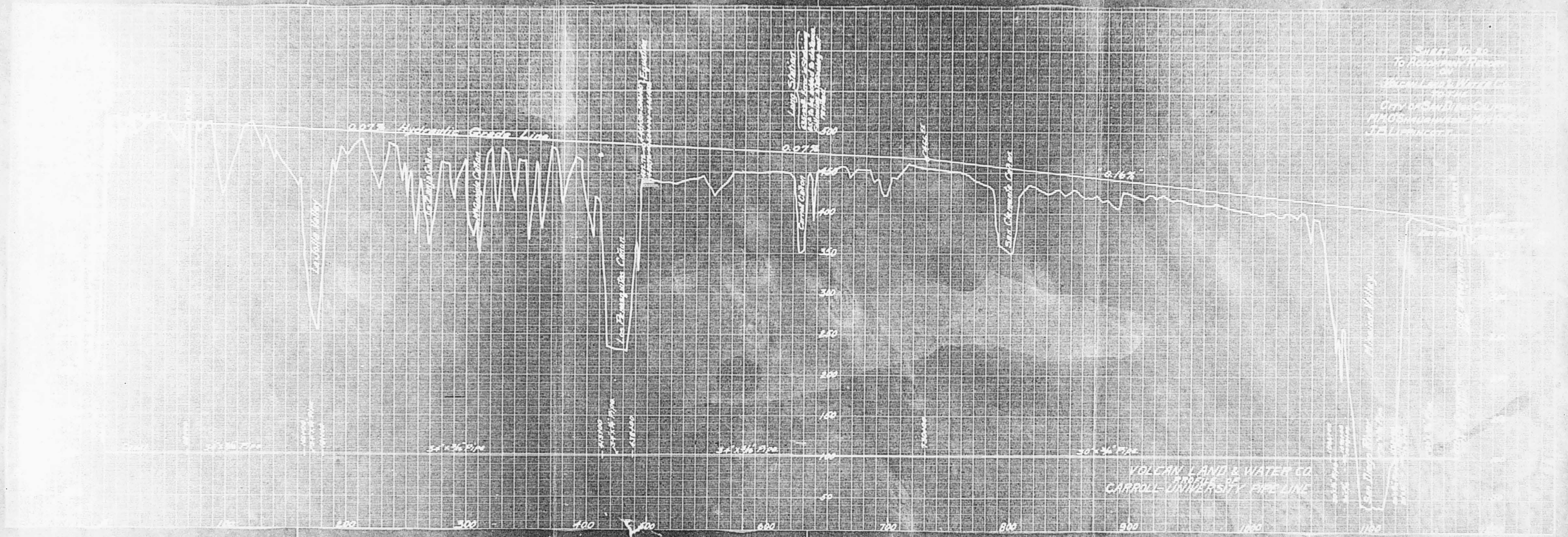
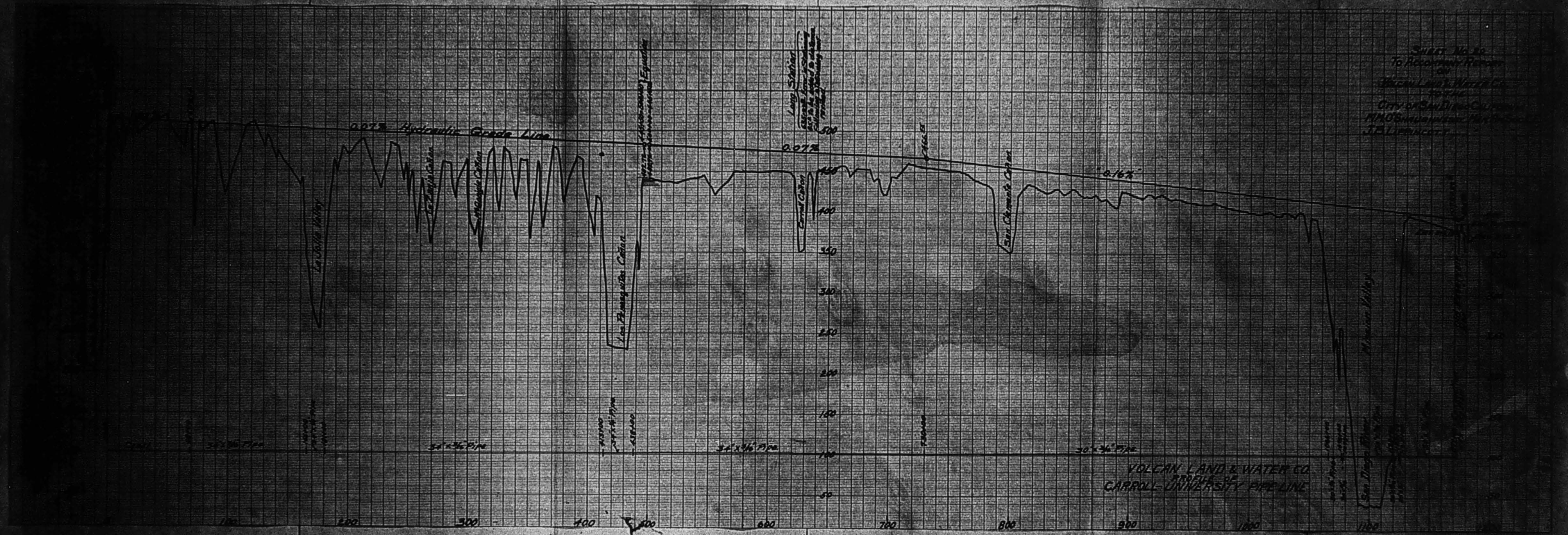
J.B. LIPPINCOTT..... " " " "



—PLAN—
CARROLL DAM


0.07%
0.16%
VOLCAN LAND & WATER CO.
PROFILE OF
CARROLL-UNIVERSITY PIPE LINE


0.21% Hydraulic Grade Line
0.07%
0.16%
VOLCAN LAND & WATER CO.
ACROSS
CARROLL-UNIVERSITY PIPE LINE

COST ESTIMATE

CARROLL-UNIVERSITY PIPE LINE

VOLCAN LAND & WATER COMPANY

6,800 ft. Canal with 4" concrete lining on sides and bottom and 4" reinforced concrete slab roof- 2½ ft. deep and 3 ft. wide (depth of flow 2 ft., giving a capacity of 13.5 M.G.D.) @ $2.95 per foot of completed structure, ...		$20,000.
NOTE: Costs of excavation and backfill are included in unit pipe costs given below.		
62,200 lin.ft. of 34" x 3/16" pipe - 4,179,800 lbs. @ $0.05 per lb., ...		209,000.
4,000 " " " 34" x 1/4" pipe - 364,000 lbs. @$0.05		18,200.
38,300 " " " 30" x 3/16" " - 2,317,200 " " "		115,900.
1,200 " " " 30" x 1/4" " - 96,900 " " "		4,800.
500 " " " 30" x 5/16" " - 50,500 " " "		2,500.
4,200 " " " 30" x 5/8" " - 847,600 " " "		42,400.
The above is for straight lengths as given between stations; it will be necessary to add approximately 10% to this in order to take care of the increased length up and down canyon sides, and other irregularities, ...		39,200.
Bridges, trestles, specials, bends, blow-offs, air valves, pipe, leading, extra charges for certain portions with long haul, and incidentals - 15%, ...		67,800.
San Diego River crossing, ...		3,800.
Rights of Way, 70 acres @ $50.00 per acre, ...		3,500.
Acquiring permits along 10 miles of county road @ $100. per mile, ...		1,000.
Local Engineering and Superintendence - 2%, ...		10,600.
Contractor's Profit - 6% (including plant,repairs,etc.)		32,300.
NOTE: This value, instead of the 15% as in the dams, is here used on account of the large proportion of the total cost being for the steel pipe itself, and not for the contractor's labor or plant.		
Interest during construction - 4½% on one half the above amount for one year, ...		12,900.
TOTAL COST OF PIPE LINE, .		$ 583,900.

COST OF WATER FROM CARROLL RESERVOIR

(Pumping with Electrical Power)

Cost of Dam and Pumping Plant and Pipe Line, ...	$1,422,700.
Interest on $1,422,700. @ 4½% for one year, ...	$ 64,500.
Cost of Pumping 10 million gallons daily against a 250 foot head, for one year (@ $0.035 per M.G. per day per foot of lift),.....	32,000.
# Depreciation, general repairs and maintenance, including such items as pipe walking, telephone service, boat for reservoir, necessary tools, wagons and teams, occasional extra labor, etc., ...	19,600.
General Supervision of this portion of the system -- about 3% of the operating expenses, ...	3,500.
Taxes @ $2.50 per $100. (on ½ the value), ...	17,900.
TOTAL ANNUAL CHARGES, ...	$137,500.

The above is based on the Straight Line Depreciation Method, with a life for steel pipe of 50 years; pumping machinery, bridges, etc. 30 years; electrical machinery, 20 years, and buildings of wood, 40 years.

This amounts to a cost of 3.77 cents per thousand gallons delivered. This figure should be increased somewhat, since no allowance has been made for the value of water rights, lands, and rights of way. With these items (amounting to practically $845,000. on a 10 million gallon daily basis, with water rights at $1,000 per miner's inch), properly included, the cost would be 5.1 cents per 1000 gallons.

It is to be noted that the annual cost of pumping 10 million gallons daily from this course is in itself equivalent to 4½% on $711,000.

If the steam pumping plant is used the above charges would be increased slightly; however, the cost of water per 1000 gallons, delivered to San Diego, would remain practically the same.

COST OF WATER DELIVERED

The following cost is based on the development of the collecting system necessary to guarantee the delivery of at least 10 million gallons daily to the City of San Diego, as recommended in this report.

Structures:

Pamo Conduit, ...	$1,158,500.
San Clemente Dam, ...	691,000.
Warner Dam, ...	499,850.
Warner Conduit, ...	397,600.
Pipe line to connect San Clemente Reservoir with city distributing system, point north of the river	125,000.
Water rights, rights of way, reservoir lands, etc., for the entire system, including additional reservoir lands, (as recommended on page 2),	2,346,200.
	$ 5,218,150.

Annual Charges:

Interest at 4% per annum, ...	$ 234,650.
Depreciation, general repairs and maintenance, including such items as pipe walking, telephone service, boats at reservoirs, necessary tools, wagons, teams, occasional extra labor, etc.etc.	26,700.
General supervision of system at 3% of operating expenses, ...	7,850.
Taxes, $2.50 per $100. on one half the value, ...	65,200.
	$ 334,400.

On the basis of the yield of Warner's Reservoir alone (11.6 million gallons daily) the cost per 1000 gallons delivered is 7.9 cents.

SUMMARY OF STRUCTURES

STRUCTURE	TYPE	HEIGHT OR DEPTH OF STRUCTURE	VOLUME OR CAPACITY	LENGTH	SLOPE	AREA OF WATERSHED (Sq. Mi.)	RESERVOIR AREA (Acres)	RESERVOIR CAPACITY (Ac. Ft.)	COST
Warner's Dam (A)	Earth Fill	105 ft.	475,900 Cu. Yds.	660 ft. on crest	Upstream 2½:1 Downstream 3 :1	210	4055	117,600	$499,850
Sutherland Dam	Earth Fill	140 ft.	930,800 Cu. Yds.	900 ft. on crest	Upstream 2½:1 Downstream 3 :1	53	434	18,400 (1)	721,200.
	Cyclopean Masonry	160 ft.	115,500 Cu. Yds.	875 ft. on crest	Variable (See Sheet #)	53	434 +	18,400 +(2)	983,900.
San Clemente Dam (B)	Earth Fill	90 ft.	984,400 Cu. Yds.	1970 ft. on crest	Upstream 2½:1 Downstream 3 :1	--	238	8,570	691,000.
Pamo Dam	Earth Fill	170 ft.	1,961,800 Cu. Yds.	1050 ft. on crest	Upstream 2½:1 Downstream 3 :1	110	1050	47,500	1,361,900.
CARROLL Dam	Cyclopean Masonry	110 ft.	93,800 Cu. Yds.	720 ft. on crest	Variable (See Sheet #)	196	1308	34,680	796,800.
Warner's Conduit (C)	Concrete lined and covered; partly steel flume	(See Cost Estimate pg.)	100 Sec.ft. or 64.6 M.G.D.	6.6 miles	1 ft. in 1000 ft.	--	--	--	397,600.
Pamo Conduit (D)	Concrete lined and covered; partly steel flume	(See Cost Estimate pg.)	54 Sec.ft. or 35 M.G.D.	24.8 miles	1 ft. in 1000 ft.	--	--	--	1,158,500.
Carroll Pumping Plant	Electric Driven Steam Driven +	Hydraulic head of 250 ft. 60 ft. friction	10 M.G.D.	---	--	--	--	-- (3)	42,000.
Carroll Pipe Line	Steel	30" and 34" diam.	10 M.G.D.	22.25 miles	Varies from 0.7 to 1.6 ft. per 1000 ft. (See Sheet No.)			(4)	56,000. 583,900.
Connection to extension of City Distributing System (E)	Steel Pipe	24"	10 M.G.D.	about 6 miles	Variable	--	--	--	125,000.

NOTE: In this tabulation no allowance has been made for the costs of water rights, lands and rights of way. The proper consideration of these items will add practically $3,000,000. to the cost estimate as here given.

THE COST OF THE STRUCTURES necessary to deliver 10 million gallons daily to San Diego, as recommended in this report is (exclusive of lands, rights of way, and water rights) (A) + (B) + (C) + (D) + (E) = $2,871,950.

TOTALS

Using (1) & (3)	$6,377,750.
Using (1) & (4)	6,391,750.
Using (2) & (3)	6,640,450.
Using (2) & (4)	6,654,450.

Ed Fletcher Papers

1870-1955

MSS.81

Box: 40 Folder: 5

Business Records - Reports - O'Shaughnessy, M.M - "Report on Volcan Land and Water Company to the City of San Diego, California [with J. Lippincott]"