The Freeman Report

SUMMARY OF RECOMMENDATIONS REGARDING FUTURE EXTENSIONS OF WATER SUPPLY FOR THE CITY OF SAN DIEGO, CALIFORNIA.

Abstracted from Report of About 250 Typewritten Pages

By JOHN R. FREEMAN
Consulting Engineer
San Diego, California,
May 16, 1924.

To His Honor, the Mayor,
The Common Council and the City Attorney, of the City of San Diego, California.

Gentlemen:

I give below, in briefest form, my recommendations for action by the city for obtaining with all practicable economy and with due regard to the city's future needs and its present financial resources, an additional supply from the San Diego River.

To these I have ventured to add a final paragraph, suggesting that the city now also look beyond the San Diego River to a future addition from the Santa Ysabel River, because of my firm conviction that the San Diego River, in addition to the fullest development of sources now owned by the city will become insufficient before many years, and that even with the Sutherland and Pamo waters added, the time will surely come when San Diego will have to stop growing in an attractive way because of lack of water.

It is in my judgment largely a case of now or never, about obtaining the surplus waters of the Santa Ysabel.

My recommendations are:

(1) That the city continue with utmost vigor the prosecution of its suits for confirming its ancient Pueblo water rights. With these rights soon confirmed (of which the City Attorney tells me the prospect has continually become strengthened), the fictitious swollen values now reported attached to certain dam sites and reservoir sites will quickly drop to little beyond the fair cash values for farm purposes.

(2) That the city immediately complete its purchase under present options of San Vicente Dam Site and Reservoir Site up to contour elevation 680. A reservoir flowing to contour 635 will surely be needed here and flowage to the higher level may in future be extremely useful for storing waters from the Santa Ysabel. This San Vicente reservoir site will give the smallest evaporation loss of any practicable site in San Diego County and therefore be particularly valuable for long-term storage for emergencies, as of drought.

(3) That the City immediately secure title to Dam Site No. 2 at head of Mission Gorge (or some other dam site of the several locations available within the gorge), and to the reservoir site up stream therefrom and build immediately the lower portion of a dam of the massive gravity arched concrete type, as shown in outline in my Sheet No. 23 of accompanying drawings for flowing to contour elevation 365, and which is to be provided with siphon spillways sufficient to hold water down to this level in a flood as great as that of January, 1916, and with auxiliary gates of 100 feet clear width and a depth of 10 feet below main crest, by which gates water can be kept down to contour 360 for the first few years in order to avoid flooding the concrete highway and the railroad until these have been relocated above contour 390.

Under certain contingencies of delayed purchase, litigation or action under Recommendation No. 11 construction of this Mission No. 2 dam above elevation 340, may be suspended several years.

(4) That the City systematically begin the purchase, through friendly negotiation, of all land lying below contour 392; offering immediately the price under the Herbert appraisal of 1922, and relying on legal condemnation only as a last resort.

(5) That for the second step forward in increasing San Diego's water supply, about 5 to 8 years hence, the dam at Mission No. 2 site be raised 25 feet to flow to contour elevation 390, as per my outline plan of Sheet No. 24 of accompanying drawings, thereby doubling the yield of Mission No. 2 reservoir, or making it in all 12 million gallons per day (with inclusion of reserve for a drought severe and prolonged as that of 1895-1904).

(6) That for the third step forward, about 10 to 12 years hence, San Vicente Reservoir be built, flowing to contour elevation 635.

The order of these three or four steps in building dams at Mission No. 2 site and at San Vicente, is conditioned upon facility and cost of obtaining land, and may be changed from that stated above as new conditions require. The dates for construction of these several steps are conditioned upon growth in consumption of water.

(7) If the City could purchase the Mission Gorge dam site No. 3 and also the lands between Mission 2 and Mission 3 sites up to about contour 320 for use in the distant future, say 20 years hence, at some moderate price not too largely in excess of their value for grazing purposes, it would be advisable to get them for possibilities of future use and to keep them from adverse possession.

After having secured Mission No. 2 dam and reservoir site for flowage to contour 390, the City has only the remote need perhaps 20 years hence of using this No. 3 site and the lands between it and No. 2 dam for a **reserve storage reservoir, to be drawn on only** during extreme drought in substitution for pumping from the Mission Valley gravels which after the dam at site No. 2 is built will receive a smaller water supply than now, although still fed by about 51 square miles of tributary drainage area downstream from Mission Gorge.

The El Capitan dam site should be purchased whenever it can be had at a reasonable price comparable with the prices recently paid by San Diego for lands in the El Capitan reservoir site in anticipation that, say 20 years hence, when water has become so extremely scarce that a much larger expenditure than proper today can be justified for saving 3 or 4 million gallons daily lost in evaporation from the broad area of Mission No. 2 reservoir by storing primarily in El Capitan behind a five million dollar dam, holding two-thirds as much water as Mission No. 2 at contour 390 and letting the surplus spill to Mission No. 2.

The value of the water thus saved combined with a sum obtained by compounding the principal and interest saved now in building Mission No. 2 instead of El Capitan would then justify this costly dam.

And, before that time the logic of events, the joining of the eastern suburbs with San Diego in water supply or some uniting of irrigators and municipalities with the Cuyamaca ownership, may make this feasible in course of time, with a new pipe from the dam shorter than the flume, conserving leakage, saving evaporation, waste of tearing out the Cuyamaca dam and abandoning all thought of building the Fletcher and South Fork Reservoirs.

(8) That the City at its early convenience have made a thorough and scientific ground water survey for learning of the actual resources available for pumping,

(a) In Mission Valley;

(b) Along the San Diego River above Mission Gorge;

(c) Along the Tijuana River north of the Mexican boundary,

with plans worked in a thorough and scientific way for development or obtaining these waters, either by infiltration galleries or by pumping from wells, and with a scientific study of the distances apart and number of wells, or form and location of gallery, needed in such locality.

Such study to give result of any real and certain value will require an appropriation of at least $25,000 for the driving of some hundreds of small pipe wells by the "wash-boring method" for learning of character and extent of substrata, and should be followed by at least two or three years of continuous observation (once a week) of height of the water table at many localities and by measurements of velocity of underflow by the Slichter and other methods. (Mr. C. H. Lee would be a competent engineer to make such a study.)

It is probable that those explorations would result in the "blocking out" of emergency water supplies worth say a million dollars to the City and would show the best means of working them and would be a measure of economy although the study cost $50,000.

These ground water prospects, each and all, if used like the Sunol and Pleasanton ground water supplies of San Francisco for certain localities, or with wells at other localities but with land above them used for restricted agriculture, promise to be of far greater value in safeguarding the domestic supply of the citizens in case of recurrence of another prolonged drought like that of 1895-1904, than for ordinary unrestricted agricultural use.

(9) My studies show that with a carefully planned development of reservoirs and ground water for safeguarding the supply in a severe and prolonged drought, such as may come only once in 20 or 50 years, there can be a safe surplus to be used for agriculture at all other times and the farmer's interests encouraged and safeguarded by reasonable rules and charges and remission of rates and taxes in those rare years when his supply has to be cut in half, after early notice given him in the spring.

(10) All along, there should be the cultivation of most friendly relations in water supply matters with the eastern suburbs, arranging to supply them, if need arise, in extreme droughts from the City's sources (they, of course, to bear the cost of extra pumping and pay normal city rates for this); also friendly relations with the farmers along the San Diego River and with the Cuyamaca Water Company.

Sooner or later, after the Pueblo water rights case is decided, and as previously suggested, the logic of events or the collapse of the Cuyamaca flume is likely to force an alliance of all these interests with the City of San Diego in the building of the El Capitan Dam rather than to build the inadequate and expensive structures now proposed at Fletcher Site, South Fork and El Monte.

If an emergency arises before the time comes (say 15 or 25 years hence) for building El Capitan, arrangements probably could be worked out for supplying these suburbs from the City's sources at an extra cost for pumping far less than interest and expenses of these structures proposed, coupled with the rebuilding of the flume.

The farm lands in El Monte and Mission Valleys could be supplied through pipes from a dam, with much greater economy of water than by releasing water from the dams for saturating the gravels and then having to pump it out. Water while percolating and flushing to surface in river bed, is subject to large evaporation loss.

(11) I am informed by Mr. John Treanor, vice-president and manager of the San Diego County Water Company, that conditions have greatly changed since my letter to him of October 24th, 1923, (of which you have a copy), in which I opposed the leasing of 10 million gallons of water daily for 30 years by the City from Lake Hodges and urged that his company substitute an offer to sell these works to the City of San Diego at their cost, plus a reasonable profit.

Mr. Henshaw, the chief owner of the company has since died, and certain settlements have been reached with the Santa Fe Railroad Company. Because of these and other changes they would now consider selling these works and appurtenant lands and water rights outright to the City and suspend leasing water to others.

He named to me a price that while not official and which, therefore, I am not free to quote, indicated a willingness to meet the City fairly, and sell outright (or with partly deferred payments);

All of the Lake Hodges and San Dieguito Reservoir Development;

Plus the dam and reservoir sites at Sutherland and Pamo;

Plus certain other reservoir sites on the Santa Ysabel River;

Plus extensive ownerships and options of a majority of all the lands in San Pasqual Valley, containing water-bearing gravels and underflow;

all for a price which probably could be brought within the financial means of the City (according to a plan which I partly developed last evening), after the City has also made a good beginning on the San Diego River by buying under its options at San Vicente and by building the first stage of the Mission No. 2 dam, flowing to contour 335 and constructing a pipe thence to University Heights and an appurtenant pumping plant.

The $73,000.00 per year which under Lake Hodges contract the City is now paying, and must continue paying seven years longer, would account for interest on nearly half the probable necessary expenditure for account of securing all this property, lands, structures and water rights named above.

I recommend that Mr. Treanor be at once called into conference with the Mayor and Common Council, in a friendly spirit of getting together, to see just what plan and price can be worked out.

I believe it **certain as the sunrise** that the prospective growth of San Diego will need this Santa Ysabel water relatively soon, probably within 15 or 20 years, **in addition to all that the San Diego River and all of the other sources now owned can furnish**, and meanwhile this possession of Lake Hodges, (which I see is now about 3 feet of full) and an enlargement of its present pipe and pumps, would remove all immediate possibilities of water famine should rainfall be small in the next few years; or should there be protracted litigation over any of the San Diego River water rights, Pueblo or others, or in acquisition of dam sites or reservoir lands.

If the City does not now secure this Santa Ysabel water, I believe it can never get any large part of it. Plainly, it is better for the whole county that this water be used in making possible the building of many more attractive homes in San Diego or in its suburbs than in growing oranges, avocados, etc.

Surely the day is not beyond foreseeing when San Diego will be forced to stop growing attractively by reason of lack of water.

I believe that for San Diego to rely upon obtaining water from the Colorado River and then pumping it up a grade 1,500 feet high over the mountains, through a ten million dollar tunnel about 18.5 miles long and in addition to the cost of structures and operation of pumps paying pro rata for Boulder Canyon Dam and the 150 miles of canal across Imperial Valley, is like reliance upon finding at some future day "the pot of gold at the end of the rainbow."

I believe that the region in and about San Diego presents greater charm of climate than any other region on this continent, better than the Riveria of France and Italy.

Under wise city planning and proper thought as to the personality of those to be attracted by factories, or by schools and culture; by green lawns, bright flowers, shade trees and parks, San Diego can grow as far as the water supply will allow and continue to retain its charm. It will be better for its future if there is not too much of a hurry to secure merely additional "population."

Plainly, the voters and the city government of San Diego are under a great responsibility as trustees for the next generation. I have never before seen so serious a case of future limitation by lack of water.

The total amount of water that can be had from present sources and from the San Diego River by utmost conservation of rainfall, flood discharge and by a transfer later of storage to reservoirs of smallest evaporation, **surely is inadequate for the probable future of San Diego.**

Every new ten-acre tract that is put under irrigation for intensive agriculture within 25 miles of San Diego lessens the number of future attractive homes that can be built and does not put this water to its "highest use." Two feet in depth on this ten acres, or 20 acre feet per year is equivalent to 19,250 gallons per 24 hours, or sufficient for 192 people at 100 gallons per capita; and would supply 40 families in city and suburbs, versus only one family on the ten-acre farm.

To buy water away from intensive agriculture in citrus groves, etc., after these have been brought to bearing has been found impossibly expensive.

(12) The principal direct question asked me by the Council was, in effect: "Which is the better dam and reservoir site, El Capitan or the dam at the upper end of the Mission Gorge, known as Mission Site No. 2 with flowage to contour 390 or 400 above sea?"

(I do not recommend flowage to 400 but believe flowage to 390 feasible and proper.)

As a reservoir site El Capitan is plainly superior but as a dam site Mission No. 2 is greatly superior.

The total costs of flowage to contour 390 above Mission Site No. 2 according to Mr. Herbert's appraisal (in which I am led to have confidence), is not nearly enough in excess of the cost of the reservoir lands above El Capitan after adding thereto the cost of removing the Indians therefrom (as estimated by the United States Department of the Interior) to offset the great difference in cost of these dams at El Capitan and Mission No. 2. El Capitan is a particularly expensive dam site by reason of width of bottom of gorge and because the sound rock is deeply covered with decomposed granite.

The Mission No. 2 has more than double the drainage area for gathering flood water (**San Diego must depend chiefly upon the great floods which have come at intervals of about ten years for filling its great reservoirs**) and has 70 per cent more storage capacity when built to flow to contour elevation 390, than has El Capitan reservoir built to flow to contour 750, the highest permissible, which is almost up to the bottom of the Cuyamaca Flume.

The result is, that notwithstanding the larger loss by evaporation from the Mission No. 2 Reservoir, its net yield to the city would be 12.2 million gallons daily for Mission No. 2 versus 11.6 million gallons daily for El Capitan or about 5 per cent greater safe yield from Mission No. 2 than from El Capitan, supposing that in both cases **the entire flow was conserved and none allowed to escape over the spillway or through waste gates to the valley below the dam during a period of 20 consecutive years** of small rainfall like those from 1895 to 1916.

Although such stoppage for 20 years of the entire flow under the city's paramount Pueblo rights would

be permissible under the law, it would not be to the interest of the city to do this. After its dam was built, the City would supply the water needed by the farmers through a pipe line far more economically and conveniently than they now obtain it and would thereby save much of the loss by evaporation which now occurs in saturating the gravel beds in El Monte and Mission Valleys.

As to the drain upon the storage in the City's new reservoirs required for supplying the irrigated lands in El Monte and Mission Valleys, the following computations are of interest. First, we may note that the drain from the reservoir at El Capitan would be more serious than from the reservoir at the head of the Mission Gorge, because the drainage area downstream from El Capitan dam tributary to the El Monte Valley above Lakeside is not more than about 13 square miles, while the Mission Valley tributary drainage area downstream from dam site No. 2 is about 51 square miles, or four times as large as that for the El Monte Valley. This 13 square miles in years of small rainfall would be utterly inadequate to supply the needs within the El Monte Valley and around Lakeside if the flow of the river were to be wholly diverted through the city conduit with no waste or overflow through the dam for twenty years.

The United States Geological Survey Water Supply Paper No. 446 (published in 1919) at page 154, etc., gives some extremely interesting data upon this situation. It states that the area of the valley filled with gravel below El Capitan and above Mission Gorge is about 2,180 acres, and that the average extraction of water by pumping in the three years covered in its investigation (1912 to 1915) was equivalent to 5,470 acre feet per year, or 4.9 million gallons per day, much of which obviously was taken out below Lakeside.

If we call the total irrigable area above Lakeside 1,000 acres (Planimetering Map XXII. gives 1,152 acres), and the average "duty" of 2.0 feet in depth, this calls for 2,000 acre feet per year, which, if drawn at a constant rate would be equivalent to a daily draft of 2.75 second feet or 1.77 million gallons daily.

To supply this by release from the dam to flow down the stream bed and percolate through the gravels would involve much additional waste. Delivery of this irrigation water through a pipe line would be more economical and more convenient and save the cost of pumping. The seepage from irrigation thus applied would percolate along down the valley to Lakeside and beyond.

To this 1.77 mgd. figured above there must be added the increased supply for the Cuyamaca Water Company at its El Monte pumps which they hope (without any real foundation for their estimate), will supply four million gallons per day continuously through year after year, during a severe drought.

Actually the average quantity diverted heretofore by the Cuyamaca Company's pumping station at El Monte has been very small and the expense of pumping it to the great height from the water table to the flume has tended to limit the draft to the few months of extreme need and to only a very few years in which rainfall was small.

It is stated that in October, 1919, pumping was maintained at the rate of 2.6 mgd. per day; and from computations of the rate of underflow down the valley, I believe this could not be largely exceeded and that this **rate of 2.6 mgd. could not be continued through a long period of** drought under the conditions of natural flow of water down the stream that have existed during the past 40 years.

Apparently, in estimating the quantity **that can be delivered to the** City after supplying the needs of the El Monte Valley and Lakeside, we will not be safe in making a smaller deduction than from 2.0 mgd. to 3.0 mgd. as an annual average through a long term of years.

The supply to irrigators anywhere in eastern suburbs or in these valleys seems contemplated by the words of the Act of Congress and the most economical and efficient way to deliver this water plainly is through a pipe line.

At Mission Gorge Site No. 2 the necessary release from the reservoir for supplying the needs of agriculture in the Mission Valley, some data is given in U. S. G. S. Water Supply Paper No. 446. This gives the total area of gravel filled valley supplied as 2,470 acres and that the average amount pumped as only 2.2 mgd. which is only little more than half that pumped during the same period from ground water in the valley between El Capitan and the head of the Gorge.

The fact that Mission Valley is fed by a water shed of 51 square miles, or four times the drainage area between El Capitan and Lakeside tends to lessen this demand; and it must be remembered that the city of San Diego owns and occasionally operates the largest pumping plant in Mission Valley.

The water for irrigation to be released from the dam at Mission Site No. 2 also would properly be conveyed through a pipe line as suggested above for the El Monte Valley, in order to save waste in evaporation and seepage. It appears that we may call this release from Mission No. 2 at least one million gallons daily smaller than from El Capitan.

Condensed into tabular form the comparison between the El Capitan Dam and the Mission Dam in safe yield and in cost stands as follows:

	Contour of flowage	Storage in acre feet	Full area acres	Safe yield (per Freeman) Mil. Gal. Daily	Approximate cost of dam only (exclusive of land filters and conduit
EL CAPITAN	750	134,000	1,750	11.6 (Subject to releases for irrigation and pumping at El Monte)	$4,775,000 (for earth and rock fill dam)
Release for agriculture and pumping 3.0 to 4.0 mgd. say 3.5 mgd.					
NET YIELD to CITY				8.1	
MISSION No. 2	390	228,000	6,200	12.2 (Subject to release for agriculture in Mission Valley)	$1,700,000 (for concrete dam, gravity arched type with siphons)
Release for agriculture and pumping 2.0 to 3.0 mgd. say 2.5 mgd.					
NET YIELD TO CITY				9.7	

The above estimates of yield assume that Cuyamaca Company's diversion will continue of the same quantity as in past 39 years and also assume climatic conditions the same as in past 39 years.

By the above comparison Mission No. 2 will furnish the City 0.6 of a million gallons daily more of safe yield of water than the El Capitan if no allowance whatever is made for the diversions or releases to agriculture and to the several pumping plants.

Or, if allowance is made for these diversions and releases the comparison shows Mission No. 2 giving 1.6 million gallons daily more water at $3,000,000 less total cost for dam alone.

After allowing liberally for extra cost of land above site No. 2 over that at El Capitan and allowing for difference in cost of pipe line, the cost of Mission No. 2 project would be about two and a half million dollars the smaller. If the difference in net safe yield or 12.2 minus 11.6 amounting to 0.6 mgd. is capitalized at average cost of about $500,000 per mgd. this adds $300,000 to the balance in favor of Mission Site No. 2.

These figures on net safe yield are very dependable, Mr. Savage and Mr. Freeman working by different methods being in close agreement. The figures above on costs of dams and upon quantity to be released are only roughly approximate, **but the balance against El Capitan plainly is too large to be turned by more precise figuring on these costs.**

There is a further possibility in favor of the Mission No. 2 site that by limiting the height of the first dam to contour 340, **the Santa Ysabel waters can also be secured within the present resources of the city** and before it is forever too late to get them.

Moreover, the El Capitan project, with cheaper earth dam flowing to contour 750 and cost of pipe line amounts to about $1,500,000 and an earth dam like this must be built at once while the concrete dam can be built in stages. This cost is hopelessly beyond the City's present resources, while the Mission Dam No. 2 and its reservoir can be built up to a flowage at contour 365 **within the present resources of the city** and leave a margin for securing the San Vicente lands and for beginning the acquisition of land between contours 365 and 392.

Although El Capitan's cost is plainly beyond the city's present resources, 20 years or more hence, when water becomes more scarce and valuable, **it may pay the City to buy out these farmers in the El Monte and Mission Valleys,** just as the Lake Hodges interests have recently been buying similar water bearing lands in the San Pasqual Valley and to lease back the land for agriculture with restrictions as to water rights during an extreme drought and long before that time probably the Cuyamaca Company will stand differently from today and all interests of suburbs and farmers in the valley may be joined in a water supply from one great reservoir to be built at El Capitan, while the Cuyamaca reservoir, with its wasteful evaporation, has its dam torn out and the dilapidated flume abandoned.

In fairness to the Cuyamaca Company in considering the smallness of the reservoirs proposed by these interests at South Fork and at the Fletcher Site, which together have only about one-seventh of the capacity proposed for the City at El Capitan, it must be remembered that perhaps they are designed primarily for irrigation uses to half their capacity and that a reservoir for irrigation need not be nearly so large as for municipal supply. The citrus grower can have his supply cut in half for several years in succession and the grower of lettuce, or celery or other annuals, can cease planting for one or two years while there is no water, but a city's domestic supply and its supply of water for steam boilers, cannot stand one or two years' interruption.

(13) Regarding the possibility of the lapsing of the rights given by Act of Congress to the City of San Diego to acquire lands in the Indian Reservation (which begins about one mile upstream from the proposed location of the El Capitan Dam), in case the City should defer action in proceeding to acquire the Indian lands at a total cost of about $362,000 and not build at least a low dam at El Capitan, within the time specified in said Act of Congress, which is many years earlier than would be economical or feasible to the City, it is my judgment the **City would run no substantial risk.**

The question seems to be as much one of engineering and cost of structures and of business judgment, as of law.

The Federal Government had no desire to move these Indians and consented only on the urgent petition of the City, which at that time was uninformed about costs. If the rights now lapse, Congress would, without doubt, revive them five, ten or twenty years hence.

In answer to the suggestion that should the City's present rights lapse, the Cuyamaca interests, or some other party might acquire them, the facts may be added that **this project is hopelessly without profit** to any and all possible operators, **unless the City of San Diego is their chief partner.**

Moreover, I am told the City has recently purchased the greater part of the lands in the reservoir bed within the mile between the dam site No. 2 and the Indian Reservation, thereby effectively blocking any scheme to secure an advantage over the City. I believe this recent purchase was wise.

(14) It has been suggested to me that unless the City of San Diego proceeds now with at least a small dam at El Capitan, and a pipe line thence to the City, that the Cuyamaca interests or their successors, the Irrigation District proceeding under recent option may build the dam at the Fletcher Site or Boulder Creek Site, which has been discussed for many years and thereby lessen the supply of water available to the City of San Diego. **The City's building at El Capitan could in no way prevent this.**

The extremely frank and luminous report of the California Railroad Commission Hydraulic Division, dated February 20, 1920, on application 4015 ROSS vs. MURRAY, which states in effect that the water so gained would cost more than it is worth, gives conclusive evidence which it seems certain would deter financiers from backing such an enterprise, with the million and a half dollars of new construction cost, in addition to the purchase price of about another million and a half dollars, or a total sum of about three million dollars, for a small additional quantity of water.

It is unbelievable that the farmers of the El Cajon Valley, La Mesa, Spring Valley and Lemon Grove would imperil their homesteads under a bond issue for this purpose after they have studied the circumstances and read this report of the Railroad Commission and it seems to me unbelievable that any substantial banker would back such a scheme with this report in hand (after an inspection of the flume, which says in effect, in unmistakable language that **the cost of the project would be more than the traffic can bear.**

Once more I urge that the day is coming when the **growth of** San Diego will **be limited because no more water can be had** and I would again counsel not being in too much of a hurry in purchasing any of the dam sites or reservoir lands at the grossly inflated prices now asked. After further conference with Messrs. Cosgrove and Higgins regarding progress in the Pueblo water rights suits, I believe these prices or the possible awards in condemnation, will suffer a severe drop within a year. Meanwhile, with careful use and by putting in now pumps or pipes for saving the half million gallons daily that the City is paying for and not getting from Lake Hodges, (equivalent to a year's growth) **the water now in storage can last safely six or seven years** and an excellent avenue of safety during delay can be had by the immediate purchase of the Lake Hodges System, including Sutherland and Pamo dam and reservoir sites, and its extensive lands and water rights, all capable of giving, according to Mr. Savage's careful estimates, throughout a drought severe as that of 1895-1904, a safe yield of 19.5 million gallons per day, which has not been yet half developed by sufficient dams and reservoirs.

The circumstances, the data, the estimates and the line of argument that have led me to these conclusions and to the recommendations stated above, are presented with much fullness of detail in the following report and its six appendices and in the sixty-seven sheets of design and diagrams which accompany this report.

Respectfully submitted,
(Signed) JOHN R. FREEMAN,
Consulting Engineer.

REPORT ON ADDITIONAL WATER SUPPLY FOR THE CITY OF SAN DIEGO

By JOHN R. FREEMAN,
Consulting Engineer
May 22nd, 1924

To the Honorable, the Mayor,
The Common Council and the City Attorney of the City of San Diego, California.

Gentlemen:

I herewith present my report upon the selection of the dam and reservoir site most advantageous to the city of San Diego, among the several possible sites on the San Diego River, and report also upon sundry other questions regarding your water supply, upon which you have asked my advice.

This choice of dam site and reservoir site involved consideration of:

(a) Structural designs and costs of dams;
(b) The flowage height to which these several dams should be built in order to best conserve the natural run-off for use by the City;
(c) A determination of the probable safe yield of each of said sources in time of prolonged drought;
(d) The design of siphon spillways for minimizing the flowage damages;
(e) Consideration of a total spillway capacity for passing floods enough larger than that of January, 1916, to give an ample factor of safety;
(f) The consideration of the vast differences in evaporation loss by the several reservoirs due to area in proportion to depth;

Also there were many subsidiary questions asked me by the individual members of your city government, to some of which the answers will be presented in the following pages.

COMPARISON OF DAM AND RESERVOIR SITES

I have carefully compared the respective merits and disadvantages of the well-known dam sites and reservoir sites, El Capitan No. 2, Mission Gorge No. 2, Mission Gorge No. 3, also the San Vicente site; after first becoming satisfied by personal inspection that these are the best dam and reservoir sites that the whole region offers.

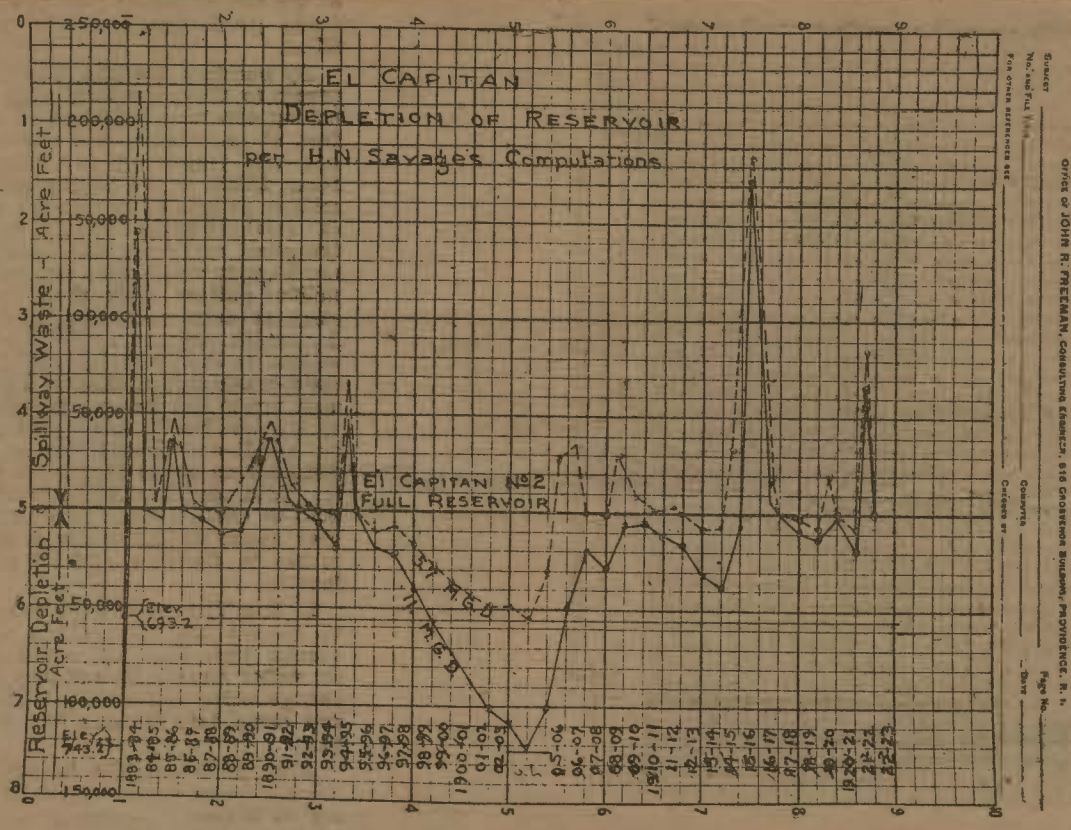
EL CAPITAN DAM AND RESERVOIR SITE

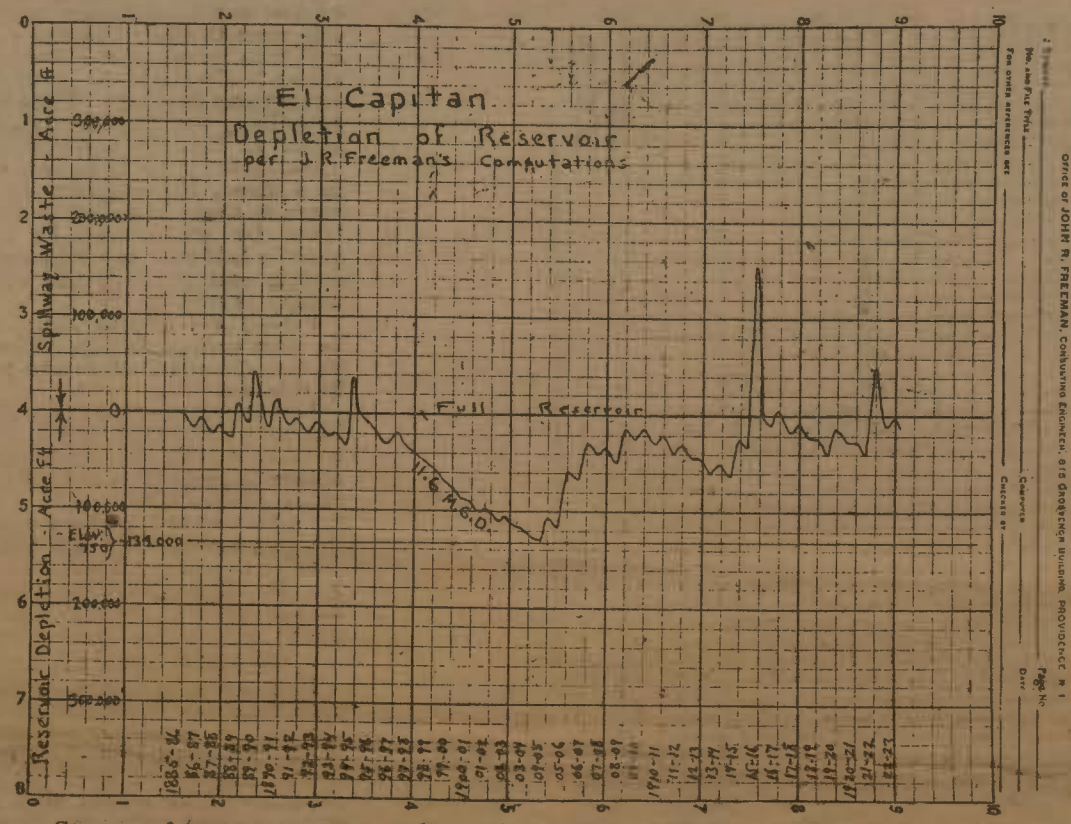
It is plain that El Capitan presents the **best reservoir site,** considering the natural conditions, small population of drainage area, great depth and relatively small area exposed to loss of water by evaporation and the large yield of the tributary water shed and an elevation that will convey its water to the city by gravity flow without pumping, but, at El Capitan, the dam site is particularly expensive by reason of width of valley and great depth of loose material above hard bed rock.

The El Capitan reservoir site, although containing little arable land, not already owned by the City of San Diego, would be particularly costly by reason of the large cost of moving the Indians from this Indian Reservation to another, which cost has been estimated by the U. S. Department of the Interior, including the government land, at about $362,000, exclusive of the cost of the dam site.

This dam site is said to be owned by Col. Ed Fletcher and to be obtainable only as a part of the Cuyamaca System, or at a very high price if purchased separately, or by slow process of legal condemnation and award of damages.

If the City builds a great dam at El Capitan before the City has reestablished its Pueblo rights to paramount ownership of all the waters of San Diego River, in the Court of last resort, and unless willing to exercise these rights with pitiless severity, it must release an amount from storage not now known precisely,—probably from 2.0 mgd. to 4.0 mgd. but possibly more, for satisfying the priorities and water appropriations





of the Cuyamaca Company for pumping at El Monte and for supplying the wells and pumps for irrigation all along the El Monte Valley.

Obviously, this water could be furnished with greater convenience and economy by a pipe from the dam than by turning it loose in the stream and the Act of Congress which gives the City the right to purchase this land plainly contemplates supply to be made to the riparian owners and others by this or other efficient means.

A dam at El Capitan would be of enormous benefit to all lands lying downstream by reason of the protection which it would give against the ravages of such floods as that of January, 1916, which laid waste much of the fertile agricultural land in El Monte Valley and between Lakeside and the Mission Gorge.

A dam at either site in Mission Gorge will similarly protect the Mission Valley, and at both sites these dams would also be of great benefit to riparian farmers in giving them a more certain supply of water in extreme and prolonged drought than they can depend upon from natural flow and the limited storage available in the porous gravels that fill these valleys to depth of from 40 feet to 100 feet, or perhaps more in spots.

A dam at the El Capitan site built to the greatest height permissible by the Cuyamaca flume, will store 140,000 acre feet and yield 11.8 million gallons per day throughout a series of years of the smallest rainfall experienced in the past 40 years.

It is an excellent reservoir site but requires an exceedingly costly dam; about $4,700,000 for dam alone, if of earth; or about $6,100,00 if of concrete gravity section, because of width of valley bottom and the great depth of decomposed granite overlying the hard rock.

MISSION GORGE SITE NO. 2

This site near the head of the Mission Gorge presents the best and cheapest dam site by reason of hard bed rock being exposed in plain sight in the bed of the river and by reason of the narrowness of the gorge and the extremely large storage that can be had by a dam of moderate height. Also it is much nearer to the City, thus saving about 16 miles of conduit which would cost about half a million dollars, as compared with El Capitan.

Its reservoir flowage is unfortunately shallow, particularly at the upper end; causing large evaporation waste and a considerable amount of good farm land would be flooded by this reservoir and put out of use.

Its location in proximity to the village of Lakeside brings more population on its water shed, but these are located a long distance from the outtake and this condition is not at all serious, particularly in view of the long detention, the germ-killing effect of sunlight and the intention to provide filtration.

This Mission No. 2 Site and Mission No. 3 Site each require the water to be pumped, while it will flow by gravity to the City distributing reservoir at University Heights either from El Capitan or San Vicente.

COST OF PUMPING FROM MISSION GORGE SITE NO. 2 VERSUS GRAVITY FLOW FROM EL CAPITAN

The interest and depreciation on the 16 miles of additional pipe line from El Capitan which would cost about a half million dollars more than the short pipe line from Mission Gorge, would offset the saving in cost of the pumping at small life from Mission Gorge Reservoir at University Heights.

The cost of pumping from Mission Site No. 2 would not be a serious matter, because when full the reservoir surface at elevation 365 is only 21 feet lower than the flow line at the distributing reservoir at University Heights (386).

Estimating that under average conditions for many years in succession the reservoir built to 365 might average 30 feet below high water, the static lift would average not more than 50 feet, to which must be added the friction loss in nearly ten miles of pipe when pumping at 50% above mean rate, say at most,—three feet per mile, giving a total lift of 80 feet, to which 20 feet may be added for loss in valves and pump connections, etc., giving with safe and liberal margin a total of 100 working head. (80 feet would be nearer the actual working head).

To pump all of six million gallons daily against this 100 feet head with an electric centrifugal pump, giving 60% average over all efficiency, would require 131.13 kilowatts constantly, or 1,150,000 kilowatt hours per year, which at 1¼c per kw. h. would amount to $14,400 per year for power alone, or double this for 12.2 million gallons daily.

Not all of the water delivered would have to be pumped,—much could flow by gravity to the lower zones of consumption in the city and some to irrigation. The total cost of pumping the whole future 12.2 million gallons daily with a first-class modern outfit would be surely less than interest and depreciation on an extra half million dollars in a 30 inch pipe line from El Capitan.

With depreciation and maintenance capitalized, the cost of this pipe line 25.4 miles long from El Capitan to University Heights probably would be above $1,500,000, if made 36 inch diameter so as to take in water from San Vicente and provide for emergency flow at a high rate. The distance from Mission No. 2 dam to University Heights is 9.3 miles; from Mission No. 3 dam 7.1 miles and from San Vicente dam about 20.8 miles.

A pump of the modern electric centrifugal type needs no constant attendant, and its cost for oil, supplies and depreciation is small. It can be stopped or started by throwing an electric switch 15 miles away, or made to stop automatically if anything goes wrong.

MISSION GORGE SITE NO. 3

This Site at the lower end of Mission Gorge has been looked upon with much favor because of the hard bed rock near the surface and the narrowness of the gorge.

As a dam site it is ideal, but unfortunately the storage is unprofitably small unless this dam is built of great height. The river bed here is of 144 feet elevation lower above sea level than that at Site No 2 at the head of the gorge and this extra height of dam required for sufficient storage to properly conserve the flood flow for use makes this site extremely expensive.

It has been studied in great detail by many engineers and for several different types and heights of dam.

SAN VICENTE DAM SITE

San Vicente also presents a remarkably good dam site with hard rock close to the surface and a narrow gorge permitting an arched concrete gravity type dam to be built in successive stages as funds permit, or an earth dam built to full height at once.

The San Vicente reservoir would be fed by a smaller and less prolific drainage area, capable of giving only about one-third the safe yield of El Capitan at Mission Gorge, the precise yield of each drainage area being dependent on height of dam.

Like El Capitan, San Vicente has a water shed very sparsely populated and as a whole is relatively deeper than the other reservoirs, with less exposed surface so that for same storage capacity, it would lose 20% less by evaporation than El Capitan. Like El Capitan it is at elevation suitable to deliver to the City without pumping. It appears better than any other large reservoir site in San Diego County for saving evaporation loss during long storage by reason of its steep rocky shores.

San Vicente presents one great advantage over all the others; that of freedom from legal complications and delays; and would present no such complications for release of stored water to feed the gravel beds as are presented at El Monte. Moreover, the City is in possession of options for the purchase of this San Vicente dam site and for much of its reservoir basin at a reasonable price, without controversy, delay or condemnation proceedings.

The San Vicente reservoir dam built at height flowing to contour 635 feet above sea will from its own water shed alone give long-term, steady, dependable yield of about 3.5 million gallons per day or about the same as Otay. San Vicente can be fed also from Sutherland and Pamo and from Santa Maria by either a side hill conduit or by a tunnel through rock apparently so strong that lining the tunnel with concrete is unnecessary. Therefore, San Vicente dam might well be built higher than 635, perhaps to 675, ultimately, and used for long-term storage of water from the Santa Ysabel with smaller waste by evaporation than in any other reservoir.

It makes little difference just where a reservoir is located within a watershed, if only it can be filled, and if the reservoir in question is to be part of a great system containing several reservoirs, it does not have to be drawn at a uniform rate, but can be held as a reserve for a great drought and the location and elevation of San Vicente are particularly favorable for such emergency use. It could even take a surplus from El Capitan in the distant future. If a flood comes to a full reservoir, the surplus can be caught by the dam further down.

POSSIBILITIES OF SAN VICENTE AS A RESERVE

At present, as in years past, pumping water out of the ground in the somewhat restricted gravel beds of the river valleys has been relied upon for safeguarding the domestic water supply in case of severe and prolonged drought.

If San Vicente were filled to 77,000 acre feet and held as a reserve and not drawn on at all in the first three years of a 7 year drought, as from 1897 to 1904, the evaporation loss, less the rain on its surface and some small inflow, might lower it say 10 feet, although its outlet gate was closed; leaving 67,000 acre feet in storage, which, drawn uniformly for the next four years, less 12 feet further allowance for evaporation, would leave 55,100 feet for delivery in the four years, or 14,000 acre feet per year, equivalent to 38.4 acre feet per day, which is equivalent to 19 cubic feet per Sec. or 12.5 millions gallons per day.

This addition from the reserve would give a big lift to the total safe yield of all of the other supply systems, Morena, Barrett, Otay, which is figured on the basis of maintenance at the constant rate of draft of 10 million gallons per day steadily through the great drought of 1895 to 1904. (See page ____)

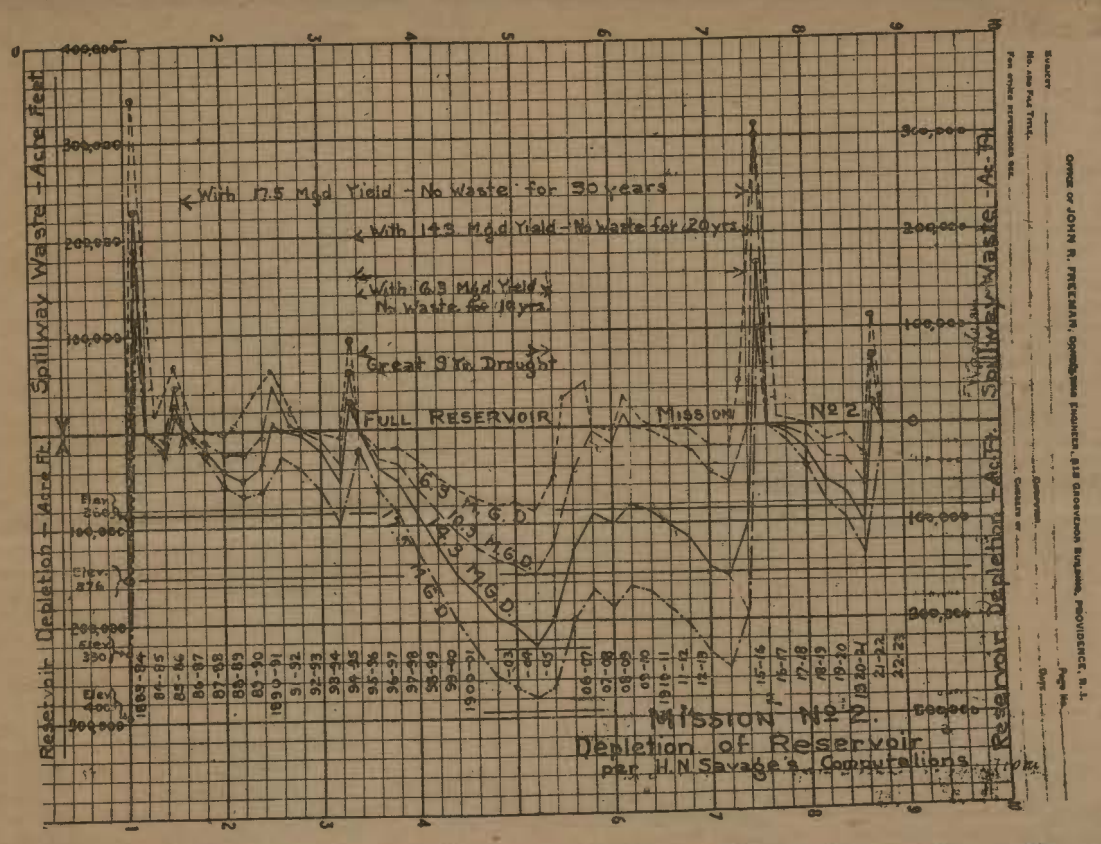
It would be filled from the surplus which otherwise would waste over the proposed dam at Mission Gorge, but might be slow in filling, or have to wait for one of the ten year floods on which all large reservoirs in San Diego County must chiefly depend.

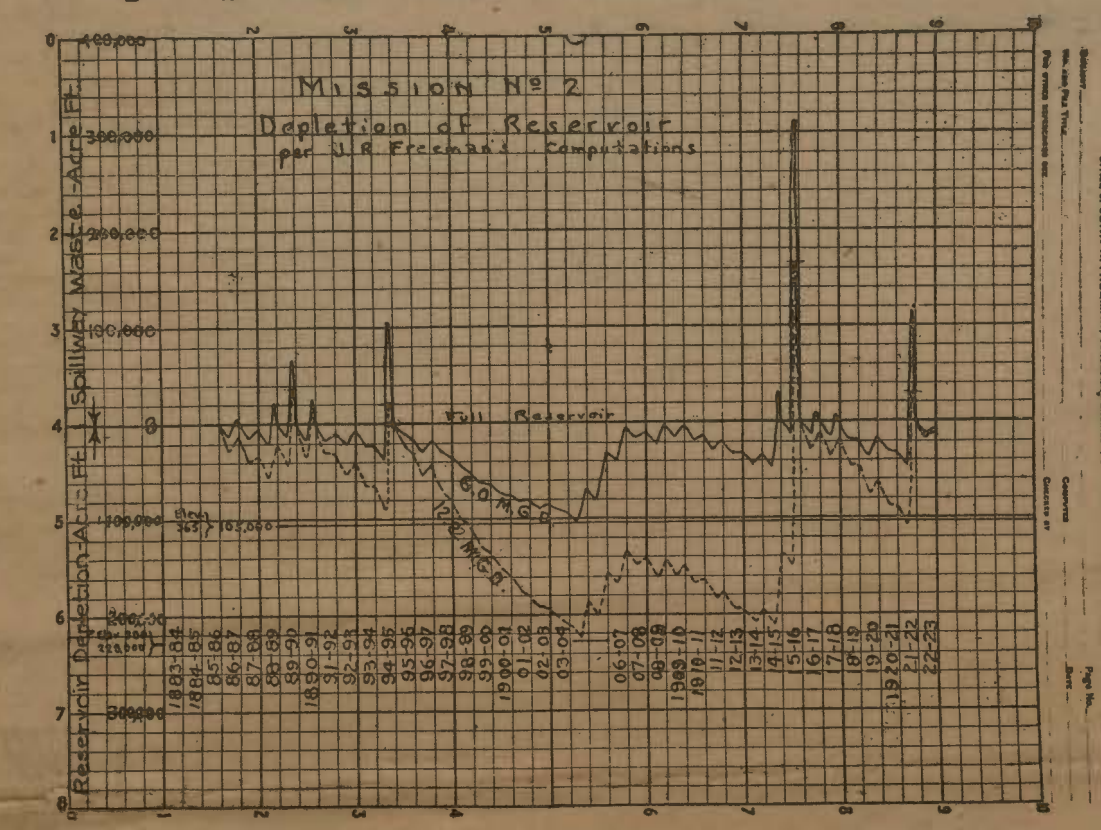
This San Vicente reservoir once filled would be visible and certain and far more dependable than the hope of pumping a sufficient supply out of the ground.

I have prepared plans for a higher earth dam at San Vicente shown on Sheet No. 16, which would be justified if water could be taken into it from Sutherland, Pamo, Etc.

I had opportunity on May 18th to inspect the quality of rock revealed at the San Vicente Dam Site and the exploration tunnels at both sides of the gorge, excavated subsequent to my visit of August, 1923. Also I inspected the test pits in the nearest material suitable for an earth dam and again inspected the rocky margins of the prospective reservoir and proceeded on to the Pamo Reservoir Site and dam site and followed down the Santa Ysabel River past sites for a diverting dam by a hillside conduit similar to the Escondido concrete-lined ditch (or by a straight tunnel) along routes recently surveyed at my request by Mr. J. W. Williams.

After again viewing local conditions, it appears probable, that an arched concrete dam of approximate-





ly a gravity section, will work out the best, because the situation favors building this in successive stages to 600-635-675 and simply letting water flow over the crest without incurring the expense of siphon spillways, and I will have designs and estimates worked out for this.

This inspection, the admirable dam site and reservoir site at Pamo, the apparent excellence of the rock formation for a tunnel of minimum practicable size, say 7 to 8 feet, that would safely stand without an expensive concrete lining, all strengthen my belief in the importance to San Diego of proceeding with all immediate diligence to work out a plan for acquiring, if practicable, the ownership of Pamo, Sutherland and all the water rights, lands and structures appurtenant to the Lake Hodges system and of immediately purchasing the San Vicente dam site and reservoir lands up to at least contour 680 or preferably 700, but of this more will be said elsewhere in this report.

To weigh all of the competing factors and correctly balance one merit or demerit against another is a slow, puzzling and tedious task, if done as accurately as required by a faithful regard for the many millions of dollars of expenditure involved in either case, and the amount of saving that may be made by surely finding the best.

Which dam site? And how high? Are far from being simple questions or questions to which a proper answer can be quickly given. I will save the reader's patience by stating briefly here in the beginning of this report, the chief conclusions that it has taken me several months to reach.

ESTIMATES OF COST AND YIELD PROVE MISSION GORGE DAM AND RESERVOIR SITE NO. 2 THE BEST

The dam site here is so much better and cheaper than any other for a reservoir of equal capacity or net safe yield that the saving which can be made in cost of dam far outweighs the extra cost of reservoir lands.

My investigations confirm those of Mr. H. N. Savage in showing that the Mission Gorge Site No. 2 with a dam at its first stage of construction about 121 feet high at the mid-stream with flowage to contour 365 above sea level, when reservoir is full and containing storage of about 105,000 acre feet, presents **by far the best combination of dam and reservoir site at lowest total cost.**

This first stage of Mission No. 2 development may be depended upon to yield

6.0 million gallons water per day

continuously through a series of years of low rainfall giving as severe and prolonged a drought as that which occurred in the great nine year cycle of scant rainfall from 1895 to 1904 and providing there is a repetition of the same conditions of climate and rainfall that have been experienced in the past 40 years.

Mr. Savage estimated that a dam at this Mission No. 2 Site 5.0 feet lower flowage (to contour 360) would yield continuously

5.0 million gallons water per day

This dam in its first stage, would be designed for an addition of 25 feet to its height somewhere from 5 to 10 years later. The foundation conditions here as already stated are remarkably good with hard bed rock bare in the stream and the height of dam required for large storage is remarkably small.

When raised to flow to contour 390, this Mission Site No. 2 would yield according to my estimates;

Thru a drought severe and prolonged as that of 1895-1904 ..... 12 mgd.

According to estimates of Mr. Savage ..... 14 mgd.

(See two diagrams on pages 87 and 88).

In all other ten year cycles of the past 40 years, outside of 1895 to 1904, and except for the necessity of holding a reserve for this drought, the draft from Mission No. 2 could have been much larger than 6 million gallons daily in the first stage, or 12 million gallons daily in the second stage, perhaps double; so that if the City could develop a "stand-by" ground water supply, by pumping from the saturated gravels of the river bed all along down-stream from Lakeside that could be depended upon for 1.5 million gallons per 24 hours steadily year after year **through the last 3 or 4 years** of such a drought, this new source built only to contour 365 with the aid of this new ground water could yield 7.5 million gallons daily in addition to present sources. (A supplementary reservoir at San Vicente to be drawn on only as a reserve would be much better than this ground water source, although of greater immediate cost).

This addition of Mission Site No. 2 flowing to 365 would probably be competent to meet the increase of population and consumption of San Diego and the probable demands of its suburbs for somewhat less than 10 years, considering that the lease of from 2.0 to 3.0 million gallons daily from the lake Hodges System has only about seven more years to run.

The recent yearly growth in consumption of about 0.5 million gallons per day per year, will increase from natural growth of city and by annexation of suburbs. **Also as luxury increases, the comsumption of water per capita is increasing in almost every city in the United States in each ten year period.**

But seven years, or ten years, is not nearly far enough into the future for a city to look which has the attractiveness of San Diego and has so great an opportunity for even more rapid growth than in the past. The consumption of water in San Diego has about doubled within the past ten years. If it doubles in the next ten years, this will find your city **using up to the limit** of all that the San Diego River can furnish after the necessary 2 to 4 million gallons daily has been supplied to the farmers in the El Monte and Mission Valleys.

After that you can raise the Barrett Dam and then get a little more by raising the Lower Otay,—but what next?

SAN VICENTE AS AN ALTERNATIVE FOR MISSION NO. 2

If there proves to be a great delay or excessive cost and difficulty in obtaining possession of Mission No. 2 dam site, for which an excessive price is reported asked, and in buying the lands for its reservoir site, which includes the Scripps Valley Ranch, an alternative means for promptly adding to the City's reservoir capacity exists in building the San Vicente dam flowing to contour 635, which, (whenever the flood comes) will supply about 60 percent as much water as Mission No. 2 in its first stage flowing to contour 365.

The city already has options such that this San Vicente reservoir could proceed without the delays noted above as possible. In the natural course of such operations it will take two years to get started and to complete this reservoir. Meanwhile there will be no diversion and long before two years are out the Pueblo water rights may be confidently expected confirmed and if the remarkable rule of the ten or eleven year flood cycle holds good the reservoir will be filled.

By building the San Vicente Reservoir to Elevation 625, with a dam having effective height of about 180 feet at midstream, and storing 77,000 acre feet when full, this, after being filled, would supply about 3:5 million gallons daily through a cycle of smallest known runoff, or about the same as Lower Otay and would not be very much more expensive per million gallons daily than the first stage of development in Mission No. 2, considering the respective values of land in the two reservoir beds and the possible cost of Mission No. 2 dam site; but if San Vicente is built prior to Mission No. 2, this would require an additional expenditure of about $400,000 in about 11.5 miles greater length of pipe line, which would pass near to Mission No. 2 dam and would cost about $730,000 for a pipe 30 inches in diameter and 20 miles in length.

If San Vicente is built subsequent to Mission No. 2, it would need no special pipe line but could deliver its water simply by opening its discharge valve and letting its outflow run down into Mission No. 2 reservoir.

Also, it is possible to build San Vicente in successive stages by adopting an arched concrete gravity type of dam and I am having designs for this made in order to make comparison with cost of the earth dams shown in Sheets 10 to 18 of the accompanying drawings. Since the cost of spillway and flood by-pass can be saved at the successive stages by allowing the dam to be overstopped in a flood, the concrete dam may prove as cheap as the earth dam, material for which must be brought about a half mile and with water for sorting and puddling the core unusually expensive.

Plainly the Mission No. 2 should be built earlier that San Vicente if its dam site and lands can be promptly obtained.

My recommendation telegraphed on February 27th, 1924, that San Vicente be built first, was based on probabilities of delay in securing dam sites at the Mission Gorge. (At that time my estimates had not been completed showing how greatly the cost of a dam at Site No. 3 exceeded that at Site No. 2 for anything like equal storage capacity and safe yield.)

SAFE YIELD OF SAN VICENTE COMPARED WITH EL CAPITAN

Fear has been expressed that the yield from San Vicente would be disappointingly small, because the flow in the bed of the stream during the recent March and April was zero, while about 20 second feet (or 13 million gallons daily) was for a brief time flowing down the El Capitan Gorge.

Therefore I hasten to call attention to the facts that this El Capitan flow of 20 second feet was nearly all being promptly absorbed into underground storage, sinking into the gravels near Lakeside to supply the pumps of irrigators or of the Cuyamaca Company a few months later (or being evaporated); **and hardly a gallon of it was reported reaching Mission Gorge.**

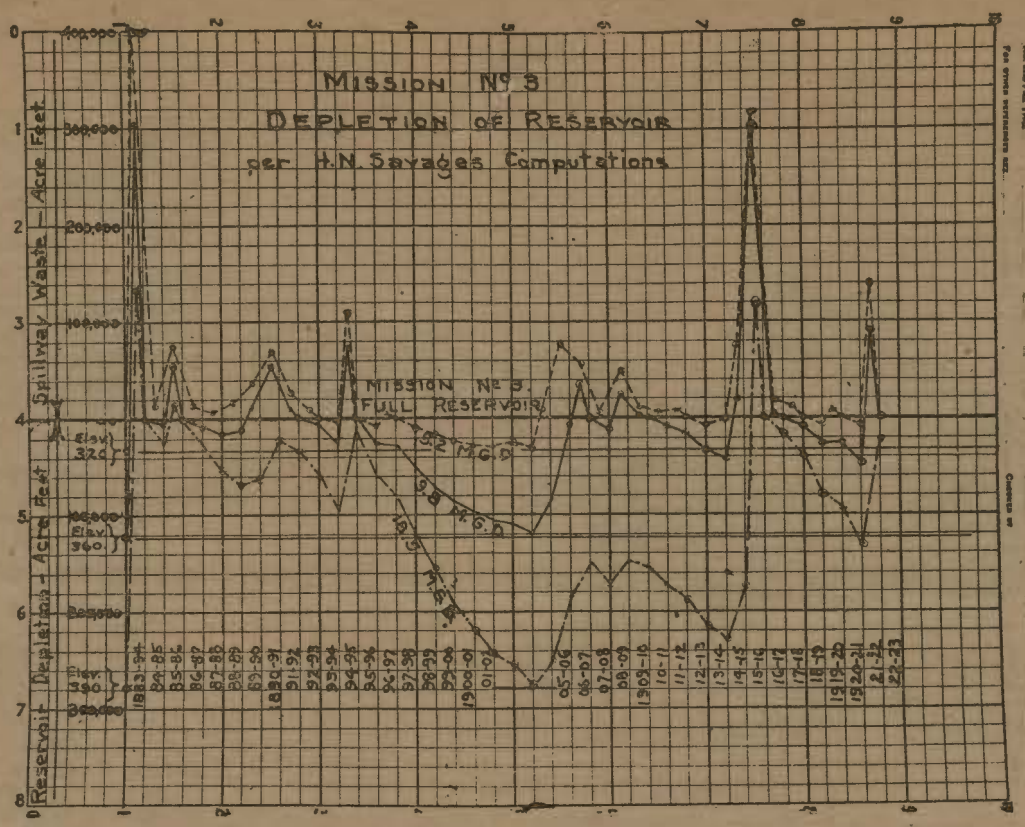
I regret that no systematic continuous gaugings have been maintained at or near the El Capitan dam site (also at San Vicente), for comparison with the gaugings maintained at the Old Mission Dam. These would give a definite conclusive measure of the absorption into these gravels combined with the loss from these gravels by evaporation (as later described).

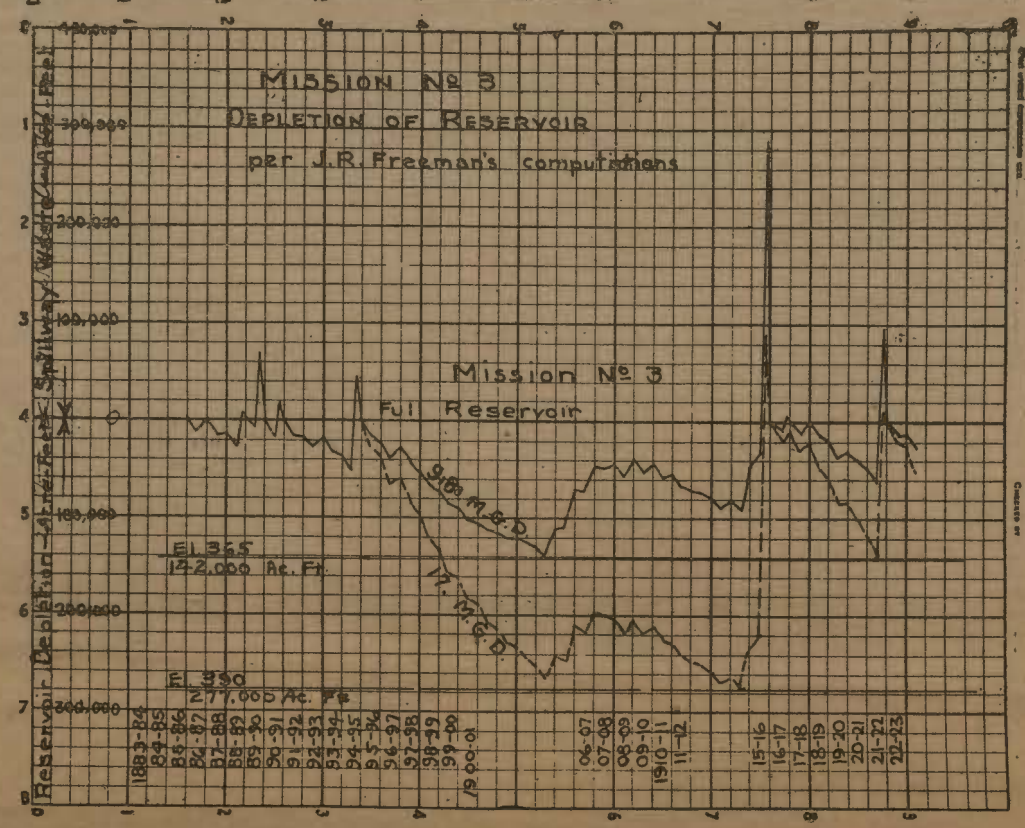
An approximate measure is given by the differences between the daily amounts gauged at Lakeside and that gauged at Old Mission dam site during those few years in which both stations were maintained, but this difference is less that the whole absorption because it fails to include the absorption between El Capitan Dam Site and Lakeside that sinks into the gravels of the En Monte Valley.

This question of feeding water into the gravel beds relates far more to the yield from El Capitan than to the yield from San Vicente, and will be discussed elsewhere in this report.

Constant gaugings at San Vicente have been maintained for only about two years, which is unfortunate. More are needed for a satisfactory answer to this question of how much San Vicente can yield and I recommend that the city immediately build the necessary weirs (of stone and cement) a short distance above or below both El Capitan and San Vicente and have gaugings maintained at both by the United States Geological Survey Hydrographer.

The most proper place for San Vicente in the sequence of dams now seem to come several years later than Mission No. 2 and after the completion of Mission No. 2 to its full height flowing to contour 390 and for use chiefly as a reserve for extreme drought; but San Vicente could be used advantageously as the second stage in increasing the water supply following Mission No. 2 at contour 365 if difficulties develop in purchase of land for extending Mission No. 2 reservoir to contour 390.





CHIEF SUPPLY COMES FROM FLOODS AT ABOUT TEN YEAR INTERVALS

These noteworthy great floods of the past 110 years have come as per the following schedule:

		(Interval)
1811	"Flood year in southern part of State" (per J. M. Quinn):	
1815	" " " 4 yrs.	11 yrs.
1822	" " 7 yrs.	
1832	(See next record)	10 years
1842	"Wettest year ever known, **similar to ten years before"** (Per J. M. Quinn)—10 years	
1849	"One of the wettest, most floody winters, well remembered by the Argonauts of '49." (Per J. M. Quinn): 4 yrs.	
1853	"Big floods" (Per A. Campbell) "3.6 inches rain in San Diego Dec. 22-26. equiv. to about 10 inches in mountains 7 yrs.	11 yrs.
	Great floods of January, 1862	9 yrs. interval
	(Nearly same magnitude as January, 1916)	
	Great floods of January, 1874	12 yrs. interval
	" " " " 1884	10 yrs. interval
	" " " " 1895	11 yrs. interval
	" " " " 1906	11 yrs. interval
	" " " " 1916	10 yrs. interval
	" " " " 1921	5 yrs. interval

The above shows eleven separate cycles of either ten or eleven years, and also shows three cases of an intermediate flood.

The great floods of the past 60 years are all well authenticated.

Surely the above is a remarkable sequence and curiously most of the floods have come within one or two years of the maxima of the sun spot cycle.

It is appreciated by very few that the water on which the City of San Diego must mainly depend for refilling its reservoirs **is the flood water of the great storms such as come only about once in ten years** and that water **must be held in storage during ten to twenty years!**

I know of no other populous region in the United States where such extreme conditions prevail. Estimates of water supply obtainable here can not be made on any such basis of relation of run-off to rainfall as prevails in most other parts of this country.

It is because of this fact that such enormously large reservoirs have to be built in order to provide any dependable number of gallons of water per day per 100 square miles of mountain water shed under the peculiar San Diego climate, with its scanty and capricious rains and its large evaporation.

If either one of the three reservoirs now under consideration at El Capitan, Mission Gorge or San Vicente could be finished tomorrow, **it might happen that it would not become filled for ten years to come,** although nothing was drawn out in the meantime.

We may reasonably hope that the curious ten year cycles of the past sixty years will hold their customary pace and give a great storm about the year 1926 or 1927.

THE NEXT INCREASE ABOUT 5 OR 8 YEARS HENCE

For the second step forward in obtaining an additional supply, after that from Mission Gorge No. 2 reservoir flowing to elevation 635 and adding 6.0 million gallons daily to sources at present in use has been absorbed by the growth of the City, there are three alternatives:

(1) Raise the Mission No. 2 dam at least 15 feet to elevation 380 (and preferably adding 25 feet to 390) thereby increasing its safe yield from 6 to 12.2 million gallons per day. (This raising Mission No. 2 to 390 would be the best and cheapest course unless there are difficulties about buying land not overcome 5 to 8 years hence.

(2) As an alternative, San Vicente can next be built flowing to elevation 635, and giving a safe yield of about 3.5 million gallons per day if drawn at a constant rate, and not held as a reserve in emergencies.

(3) A dam might be built at Mission Gorge Site No. 3 about 200 or even 225 feet high, which although expensive in proportion to yield, will be valuable sooner or later for catching the discharge spilled over from the dam at Mission Site No. 2 from the great storms.

This No. 3 site is so uncommonly favorable for building a high dam in hard bare bed rock and exceptional narrowness of gorge that a dam of the cellular or multiple arch type might be built here to the great height of 200 or 220 feet, which is about 70 feet higher than the Lake Hodges Dam and made more permanently safe than the Murray Dam or the Lake Hodges Dam, but in order to gain this safety and provide for great floods there should be a modification of the customary multiple arch design with ample steel reinforcement and impervious arches. **No safe dam of this height can be built cheaply** and its cost must be considered in relation to the increasing scarcity and value of water to be stored and conserved by it twenty years hence.

A dam in the Mission Gorge at Site No. 3, 320 feet high could store about three times as much as the Murray Dam and about one-half as much as the present Lake Hodges Dam, with remarkably small loss from evaporation because of the remarkably small area of its canyon reservoir and its great depth. The chief purpose of this reservoir would be that of a reserve against unusual drought, and seldom or never should it be drawn upon except in case of unusual need. The quantity of water remaining would be always in sight and more dependable than pumping water from uncertain substrata in the Mission Valley which after a dam is built in the Mission Gorge, will receive much less water than heretofore.

Further surveys, designs and estimates are required for determining precisely how high this dam should be built. 25,000 acre feet now seems to be the largest practicable size for its reservoir and 20,000 acre feet perhaps the largest economically.

In addition to this reserve in No. 3 there could still be some seepage and underflow and accumulation from previous years pumped from the Mission Valley sands and the sands or gravels in the partly vacant reservoir bed near Santee, but the ground water yield is likely to be smaller than heretofore in Mission Valley and the irrigation should be supplied by pipes from the conduit from the dam.

GROUND WATER STORAGE NEAR LAKESIDE

Water from the Mission No. 2 reservoir will seep back into the ground all around and become saturated to the flowage level but this will mostly percolate back into the reservoir as its surface is lowered and the net increase of capacity will not be noteworthy, but the underflow from El Capitan will continue and keep the ground saturated even after San Vicente Reservoir is built.

The ground water rights all along above and below Lakeside for pumping in last resort in a great drought might meanwhile become extremely useful, as were similar opportunities at Sweetwater in 1902, 1903 and 1904 and ultimately it will pay the City to buy all of these farm lands on the valley floor that can be had at a reasonable price, just as the Lake Hodges interests have been buying lands in the San Pasqual Valley.

The land could continue to be farmed where not flooded and much of it is already now in use for the County Farm. The use for agriculture could continue except that once or twice in say 25 years, when reservoirs had become half or two-thirds empty, on the first of March, the farmers would be notified that their irrigation water would be cut off and that the city proposed to pump the ground water.

FLOWAGE TO CONTOUR 390 IS NO GREAT OBSTACLE

From studying the map and from a brief personal inspection this flowage to elevation 390 does not appear a serious matter, **as such things commonly go in water works and water power development;** and after my conference with Mr. Herbert and again inspecting these valley lands I am strongly inclined to believe damages would not much exceed those estimated by Mr. Herbert and reported by Mr. Savage, **if purchased leisurely** by friendly negotiations without condemnation, or legal controversy.

All of this flowage is relatively simple and cheap in comparison with that done in several eastern cities in process of extending their water works and the value of the farm lands taken from agriculture is small and trivial compared with the values this water thus gained can create in city and suburban homes.

The strongest reason that I have found against flowing higher than contour 365 is not the cost of the land, but the excessive waste by evaporation, but for several years to come it will be much cheaper to thus waste water by evaporation than to save it by storage in a reservoir with smaller surface as by the more expensive dam at El Capitan before it is strongly needed.

The high cost of obtaining the Indian land in the El Capitan Reservoir, about $362,000, plus whatever has to be paid to Colonel Fletcher for the dam site, is a fair offset for high flowage cost within Mission Site No. 2.

My recommendation is that the City forthwith systematically and continuously purchase all land upstream from Mission Dam No. 2 lying below contour 392, acquiring these by friendly negotiation rather than by legal condemnation, notwithstanding this method of procedure is slow.

I advise that immediately cash offers, equal to the Herbert appraisal, be tendered to all these land owners coupled with from two to five years free use of the land, according to location.

After again viewing the premises and also because of my experience elsewhere in the acquisition of land for municipal reservoirs and notwithstanding the broad area of this flowage to contour 390, the concrete road near Lakeside and the re-location of the Lakeside Railroad, I recommend strongly that for the second stage of San Diego's water supply extension, the Mission No. 2 dam be carried to its full height, flowing to contour elevation 390, at which it would store 228,000 acre feet and yield, according to my own mass curve computations, safely in most severe and prolonged drought, 12.2 million gallons per day from the Mission No. 2 Reservoir alone.

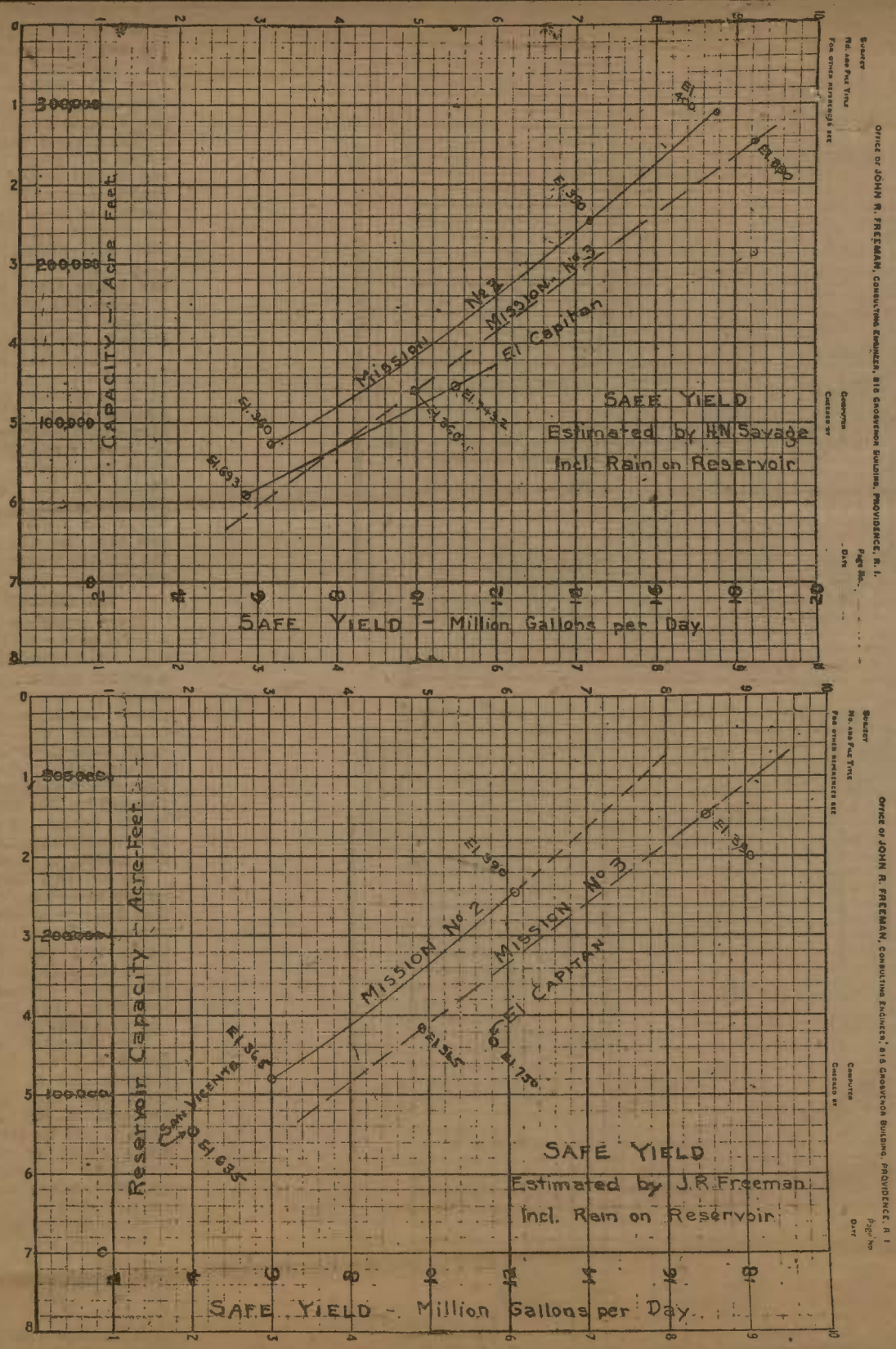
I present outline designs for the two stages of the proposed dam at Mission Gorge No. 2 in Sheets 23 and 24.

For each stage to 365 and 390, it is proposed to utilize **the full height of flowage in floods** for useful storage by means of syphon spillways.

In other words, 18 siphon spillways, sufficient in size and number are provided to discharge a quantity equal to that of the great flood of 1916 without raising the water level more than about one foot above normal. This flood discharge was the greatest of the past 60 years. Nevertheless, a greater may sometime come, and therefore a great length of open spillway crest is provided in addition to the siphons.

The raising of the dam from 365 contour to 390 would add 6.2 million gallons daily for the safe yield, according to my new mass curve computations, providing San Vicente had not first been built.

San Vicente may be considered as a partial substitute for the additional 10 feet in height of flowage between contour 390 and contour 400 proposed by Mr. Savage for the final stage of Mission Site No. 2. It adds much less acre feet of storage but does not disturb Lakeside and does not increase the broad area of shal-



low flowage which, when grown up with rank water weeds is extremely wasteful in evaporation, more so than an open water surface.

The dam suggested 20 years hence at the foot of Mission Gorge Site No. 3 also may be regarded as a partial substitute for this storage proposed by Mr. Savage between 390 and 400 contour.

In the pages following diagrams are presented showing the remarkable differences in mean depth and in area of water surface of the several present and prospective reservoirs, and thus indicating the remarkable superiority of the San Vicente Site over Mission Site No. 2 in saving of loss by evaporation during a long term of storage.

Because of depth, area and steep rocky shores, San Vicente is best reservoir site of all and Mission No. 2 the poorest reservoir site of all, but the vast difference in cost of the two dams controls the choice.

Under present conditions it is cheaper to waste some of this water in evaporation than to conserve it 20 years hence when water becomes more scarce, and after suburbs and city and agricultural interests and Cuyamaca have been united all these causes working together will make it profitable to build El Capitan and save a few million gallons daily from this evaporation loss.

WATER RATES

No good reason appears why San Diego should for an indefinite period supply water to its citizens at less than cost. Coal costs the householder more in Providence than in Scranton or Wilkes-Barrie, and it is proper that more should be paid for water in San Diego than in a city on the shores of the Great Lakes or on a great river.

What the citizens of San Diego save yearly in cost of fuel, winter clothing, food, fruit and vegetables compared with cities in a less favored climate, would offset many times over even a doubling of present water rates, but doubling them is not necessary.

Whatever increase may be needed in order to reach out for future sources before they are forever lost or needed in laying a present foundation for the utmost conservation of existing sources from waste by reservoirs of largest capacity and least evaporation, is true economy. It should be possible to find a better way of putting the burden of extending water mains past vacant lots held at speculative values than by selling water at insufficient rates and putting part of its cost into the general tax levy.

SOME DIFFICULTIES IN SAN DIEGO'S WATER PROBLEM

There is no large and rapidly growing city on the American continent where the problems of water supply for a long future seem so important to the public welfare and to the home life development as at San Diego; or where a mistake in present policy would be so difficult and expensive to remedy in future.

This is because the peculiar charm of San Diego rests upon climate and attractive homes, with ample water for flowers and for small kitchen gardens in which one seeks recreation rather than profit, and in parks, green trees and wayside flowers.

It has seemed to me that to rest content with now planning only the development of the total resources of the San Diego River—which will amount to only about 12.2 million gallons daily as estimated independently by Mr. Savage and myself for either El Capitan or Mission No. 2 to which about 3.5 mgd. from San Vicente, and of which 12.2 mgd. only 10 million gallons daily will reach the city after continuing the present necessary supply to the farmers, is like sleeping on the edge of a precipice. This added 10 mgd. will simply double the present supply. The consumption of water in San Diego has just about doubled in the past ten years by adding San Vicente and may serve only 15 years, or with Barrett and Otay dams raised the service may be extended to provide 20 years. But what next? Much depends on how fast the city grows.

I have felt that it was my plain duty not to "wear blinders" while I inspected the merits of the dam and reservoir sites only on the San Diego River but to try to look beyond, after sensing this impending shortage.

But first as to El Capitan Versus Mission Gorge

The possibility of future disaster lies in the fact that the whole country around is scantily fed by streamflow. There is more land for home sites than of water with which they can be supplied. The obtaining of water from beyond the mountains, from the Colorado River, or from Mexico is an idle dream.

If the problem of choice between these reservoirs at El Capitan and Mission Gorge, and their size, had been simple, this would have been settled long ago and discussion ended.

The outstanding difficulties of the problem of estimating the safe yield of a water shed in San Diego County for municipal purposes center around the following facts:

(1) That the rainfall throughout San Diego County is extremely capricious due to the region being on the outskirts of the main pathway of transcontinental storm centers;

(2) That the total inches of rainfall in a year, or in a season, is a very poor index of the quantity of water that will reach the streams. Whatever rain falls gently on dry ground is mostly absorbed as by a sponge and soon re-evaporated without any runoff reaching the main stream.

(3) The mountains, where the precipitation chiefly occurs, are covered largely with a mantle of decomposed granite in loose granular form, from two feet to twenty feet or more in depth, into which the rain is largely absorbed, but soon released to evaporation, except for the small proportion that seeps down along the surface of the underlying ledge into the talus. Over much of the area there is no sealing of the surface by frost in the rainy season, and consequently less spring run-off.

(4) Rainfalls averaging less than three to six inches in depth, seldom produce any important runoff. The stream flow does not begin after the winter rains until more than eight inches has fallen. **The water available for filling large storage reservoirs comes most in 10 years,** caused commonly by a succession of extremely heavy rains so timed that although the first rain is absorbed, the second rainstorm falls on wet ground. A heavy rain seldom produces much runoff unless it falls on ground thoroughly wet down by rain that has fallen within a few days previous or is itself of the exceptional magnitude of from 8 to 12 inches at the higher altitudes in the drainage area. (This is shown in the series of Rain Storm Diagrams, Sheets 38 to 41 attached to report.)

(5) The total depth of rain that fell in the month of January, 1916, which produced the greatest flood of 60 years, was not very much larger than that which fell in February, 1915, and produced no extraordinary flood. The great difference in result came from the timing of the rainfall.

In 1916, the second heavy rain fell on ground largely saturated by the heavy rain of a few days previous and it was the second of this prompt succession of two heavy rains that caused the great flood.

The annual evaporation is greatly in excess of the average annual rainfall on the same area, and therefore, in San Diego County there is great waste from long continued storage particularly in shallow reservoirs.

(6) The records plainly show that in the past 40 years, for which alone we here have accurate records of flood and stream flow, the chief opportunity for replenishing large reservoirs comes from the great floods, such as happen about once in 10 years. The less accurate records of great floods compiled from various sources for the past 110 years show the same general fact (see page 44) and for 60 years we have unquestionably accurate records of this remarkable series of 10-year floods.

For the largest economic conservation, the reservoirs must be large enough to hold water in storage for 10 or 15 years, perhaps for 20 years. The records show that a drought, or series of successive years of small rainfall has **continued for seven of nine successive years—or from 1895 to 1904—with no good reason why it may not ceme again.**

(7) In addition to the above severe conditions imposed here by nature, there are many difficult legal conditions of priority of water rights, and adverse water rights, and adverse ownership or occupancy of land in certain of the reservoir sites, particularly at El Capitan. Also there is a U. S. Government Indian Reservation in the upstream part of the El Capitan Reservoir Site that must be moved at a total estimated expense of $361,428.00, and also there are possible claims of extreme importance for release of water in large quantity to maintain the underflow in the gravels for the supply of wells and pumps at El Monte and for the needs of irrigation, all along down stream from the El Capitan Dam and to a less extent below the Mission Dam.

Above El Capitan are proposed two small reservoirs (of 17,805 acre feet at Fletcher Site and 3,116 acre feet at South Fork) for adding to the reservoirs of the Cuyamaca Company. **This detention and diversion obviously would detract from the quantity available at El Capitan or at a reservoir above Mission Gorge.**

There would, however, be sufficient of water left for filling El Capitan with flowage at 750 contour, in the course of the ordinary 10 year or 20 year flood cycles and for filling Mission No. 2 Reservoir.

At Mission Gorge No. 3, the owners of this dam site (allied to Cuyamaca) have proposed developing this site as a reservoir to supply the U. S. Government Military Station near San Diego, thus perhaps attaching a valuation much larger than ordinary land value to this No. 3 site, should the city seek to condemn it.

(8) Throughout southern California, in the past 30 years, along with the appreciation of opportunities for citrus cultivation and the recognition of the great value of irrigation there has been much studying of the conservation of stream flow and flood water; also much attention to the pumping of underground water.

Sometimes it seems there is hardly a hollow among the hills that has not been held for speculative value as a reservoir site, or a flowing stream that has not been covered with water-right filings, seemingly as numerous and overlapping as the shingles on a roof, totaling far beyond the yield of the stream.

The owners of the Cuyamaca System, and of the system projected on the Santa Ysabel and San Dieguito Rivers, and upon the San Luis Rey, have been particularly alert in spying out and trying to secure attractive water rights, while the city seems to have been slow in asserting its Pueblo rights and in seizing upon its various opportunities.

(9) In case of Mission Site 2 with flowage to elevation 390 there are difficulties and opposition about replacing or raising an excellent concrete paved highway and a few miles of railroad that has little traffic but might conceivably cause much trouble; and many home sites and farms would have to be displaced.

(10) The case before the public in relation to El Capitan is affected by the desire to have the City of San Diego provide protection against devastating floods for many miles along the valley below El Capitan, by their restraint in the proposed great reservoir.

(11) After one has worked out mass curves and tables of comparative yield for Mission Site No. 2 and El Capitan with reservoirs of equal capacity at each, there are found results that are at first view **unbelievable,** in which, for example, the project having more than double the tributary drainage area is found producing the **smaller yield;** simply because of the vastly greater evaporation in a shallow reservoir of about 3,700 acres compared with a deep reservoir of 1,500 acres.

However, the above difficulties all yield to patient analysis and study, **and I now have not the shadow of a doubt that the conclusion in favor of Mission Site No. 2 for the first reservoir to be built on the San Diego River is sound,** if its lands can be **promptly** acquired at a **reasonable** price. The demonstrations which have convinced me of this will be found **scattered** through many diagrams and computations presented with this report.

(12) The need of supplementing the surface storage in time of severe and prolonged drought by the addition of water pumped out of porous gravel beds along the river presents also some difficult questions, because while there is much optimism, there is little dependable data on precisely how large is this hidden underground supply, or how long it would hold out.

I believe its extent has been greatly over-estimated, and that the cost of getting the expected per cent out of the ground has been greatly under-estimated.

To assume because one well produces one million gallons daily for four months steadily, that eight wells or even eight pumping plants would produce 8 million gallons daily for four years, winter and summer continuously, may be wild of the mark.

To get at the truth would probably require a year of expert work and the putting down of say a hundred test wells of various kinds along the river bed between El Capitan and the sea.

And after the quantity and duration are known, the next question would be as to the rights and priorities pertaining to this water, and the resistance of those who think they have vested rights of which it is proposed to rob them.

EVAPORATION FROM UNDERFLOW

(13) One of the most puzzling problems of all, relates to conserving the natural yield of the water shels from loss by evaporation while in storage.

It often is stated that the water that soaks into the porous gravels of the river bed as at El Monte, Lakeside, Mission Valley, or San Pasqual "is safe against evaporation loss."

These basins filled with gravel are, at best, of small capacity compared with the reservoirs needed to store one of the great floods and slowly deliver it as needed through a 10 year cycle, **and only about 25 per cent of the gravel is pore space from which water can be gotten out,** (although theoretically there may be 40 per cent of pore space, or voids.)

Since water lying more than about four or five feet below the surface of medium coarse sand or gravel is safe from capillary attraction—to the surface, (as by a lamp wick) the ground water in storage below this five foot depth would be safely beyond **evaporation if the gravel bed and water table were level** so there was no underflow.

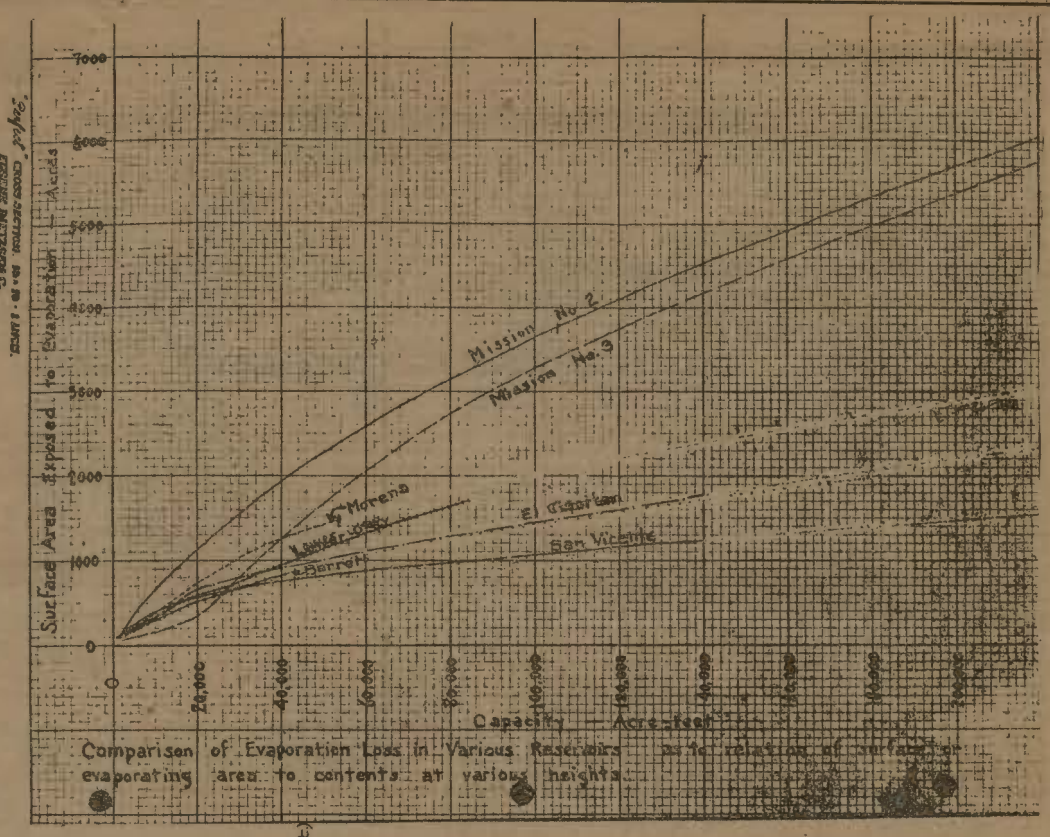
Unfortunately for present purpose of proposed storage, all of the gravel beds mentioned, slope toward the sea at an inclination which is much steeper than is appreciated by the eye unaided by an engineer's level.

El Monte Valley and all of the others mentioned, **slope seaward at from twenty-five feet to thirty feet to the mile.**

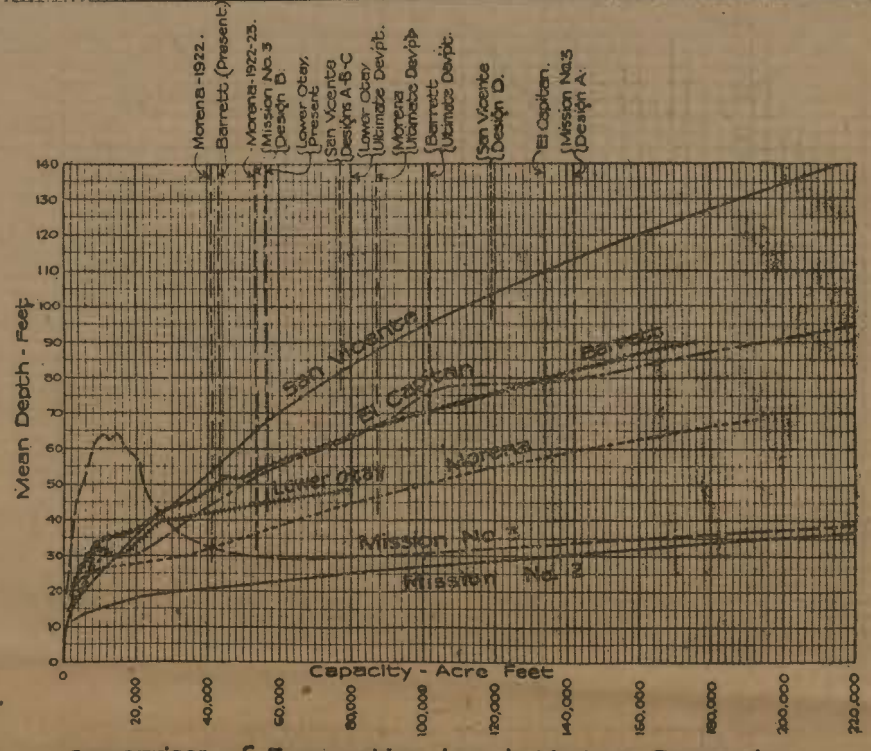
The result of this is a slow underflow, with a velocity varying with the coarseness of the gravel, sand or silt, but which Mr. C. H. Lee has estimated at an average of one-third mile per year, from very scant local data for his measurements by the Slichter Method and in another river valley further north. In the coarser gravels it may be at several times this rate, and may be much slower in fine sand, or in coarse gravel clogged with fine sand. Nevertheless, his figure of one-third mile per year is not discordant with the velocity of underflow found by many observations elsewhere.

This underflow causes a constant drainage from the upper end of these valleys toward the lower end, which is plainly shown by the lowering of the wells near the heads of the valleys when the inflow ceases in early summer.

If now, the inflow instead of being stopped only during a few months each year during the summer, **is all stopped for ten years continuously, or for twenty years,** as it would be by the great dam and storage reservoir proposed either at El Capitan or at Mission Gorge, those who now pump from the gravels would soon



Comparison of Evaporation Loss in Various Reservoirs as to relation of surface or evaporating area to contents at various heights.



Comparison of Evaporation Loss in Various Reservoirs as to relation of surface or evaporating area to contents at various hights.

get no supply.

The depletion diagrams on pages 115, etc., show that under both the Savage and the Freeman estimates, **for 20 years continuously** as from 1895 to 1916, no water whatever would pass the El Capitan Dam if built to elevation 743 and having storage capacity of 122,000 acre feet, after taking about 12.2 million gallons daily to the City of San Diego.

And nothing would pass Mission Dam No. 2 at elevation 390 **for 20 years** while 12.2 million gallons daily was sent to the city of San Diego.

And nothing would pass it for 10 (ten) years of next drought, 1895 to 1905, while its average of about 6.0 million gallons daily yield was being taken out by the city's pipe.

After the El Capitan Dam is built and this water diverted to the city, the future condition of water supply to the gravel beds in the El Monte Valley surely would be greatly changed because this valley has only about 13 square miles of tributary drainage area below the El Capitan Dam and year by year the gravel down stream from the El Capitan dam would drain to lower levels because of its slope of nearly 30 feet to the mile, and also because of the pumping by the farmers.

Since the gravel bed appears continuous down nearly to the head of Mission Gorge, although of variable width and perhaps of variable depth, (see Figure 13, page 116, U. S. G. S. Water Supply Paper 446), **the El Monte Basin would slowly become empty,** save for what little flows in from either side; and if also a dam is built at San Vicente, similarly holding back the natural discharge, these large gravel beds below Lakeside would slowly drain. If only San Vicente dam is built and El Capitan dam is delayed, there will be abundant flow to saturate these gravels.

These important facts about the gradual partial emptying of the underground reservoir have not been given sufficient attention in the several optimistic reports about yield from these gravel beds.

There is, however, still another important defect in conservation of the yield from a water shed by storage in the gravel beds which also has not been mentioned in the several publications, or considered in the several hopeful reports on ground water yield **near San Diego; where conditions are very different from those in the broad gravel filled valleys around Los Angeles and around San Francisco Bay.**

The water that is stored in the gravels in San Diego County **does not stay down beyond reach of capillarity and evaporation.**

By reason of the large inclination and underflow or slow percolation downstream, mentioned above, the water from the upstream portions of the San Diego Basin **is constantly draining off** and lowering at the upper end of the gravel filled basin, and tending to raise the water level at the lower end of the gravel basin, **and this constantly brings the underflow toward the surface** of the gravel beds so that it is **within reach of capillarity and evaporation** in the downstream portion of the basin; particularly where the underflow is obstructed by a deeply buried bar of fine sand, or silt, which is relatively impervious as compared with the coarse gravel.

Fortunately, in the state of nature the slow average rate of underflow, if at the rate of only one-third mile per year, or say 2,000 lineal feet per year, in a sand and gravel bed, say 100 feet deep and 1,600 feet wide (as at Cuyamaca's El Monte wells and pump), and assuming the **effective** voids in which the flow occurs are 25% of the sand mass, this underflow down the slope of 30 feet per mile produces a total discharge downstream of only

$$\frac{2000 \times 100 \times 1600 \times 25\%}{86400 \times 365} = 2.54 \text{ cubic feet}$$

per second, equivalent to about 5.0 acre feet per day or 1,825,000 acre feet per year, or to 1.65 million gallons per 24 hours.

The surface of the ground, and also of the water table at the lower end of the El Monte basin at the Lakeside gauging station, is about 90 feet lower than near head of the El Monte basin, therefore it is plainly evident that without replenishing the water-content of these gravel beds they would slowly drain away and would become empty. Probably this emptying would occur to a large extent from natural causes alone in a prolonged drought like that of 1895-1905 although no dam were built and after building the dam this slow continuous drainage during a 10 year stoppage of the stream flow by the dams plainly will cause a great change from natural conditions, and if there were to be no release at the dam, little if any reliance could be placed on the storage of water in the gravel beds below these great dams, for a reserve from which the city can be supplied in a recurrence of the drought of 1895-1904; or in one of only half that severity.

GROUND WATER FOR A DROUGHT RESERVE

The population of San Diego now is far larger than in the great drought 30 years ago, and its needs are far greater than when it worried through the drought of 1895-1904, by pumping from wells in the Mission Valley, and when it is said that water was sold in the streets of San Diego at 25 cents per bucket.

If to this increased demand, we add the effect of the lessened supply for saturating the gravels caused by the dam and by irrigating the farm lands in El Monte Valley, around Lakeside, and in Mission Valley by pipe delivery instead of by pumping from saturated gravels it becomes plain that something more reliable than pumping from ground water must be relied upon for carrying the city through a severe and prolonged drought.

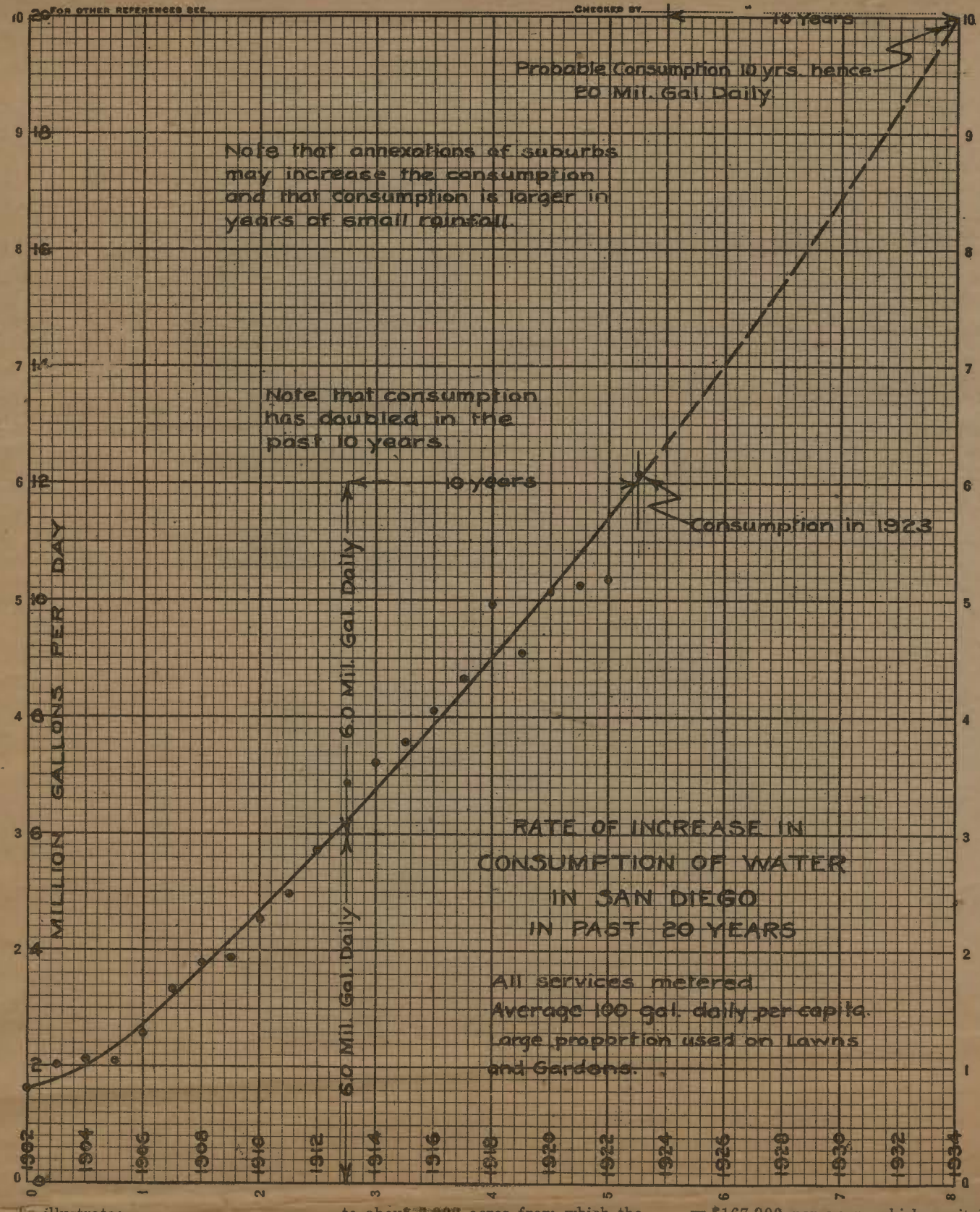
Mr. Savage and I have provided for this by increased reservoir storage. The estimates made for Mr. Fletcher of yield from the enlarged Cuyamaca —and Mr. Lippincott's estimates upon yield from Lake Hodges—rely upon relatively very small reservoirs and let the inhabitants take the risk of getting a plenty of water out of the ground or of again buying it at 25 cents per bucket for cooking and drinking, and taking only salt water baths.

CONSERVATION OF EVAPORATION WASTE

(14) There is still another important and extremely difficult problem in conserving the evaporation loss from the surface of the great reservoirs needed to impound the great floods of the ten year cycle.

Surely, the time is coming when there will not be in all the streams and all the reservoirs that may be built in San Diego County, water enough to supply the needs of the growing population.

To waste in evaporation more than is necessary, by developing for example, a hundred thousand acre feet of storage at a site where it covers 5,700 acres, when another site is available in which the same quantity could be stored with an exposure of only 1,000 acres, is like some of our wasteful processes in forestry, and in mining and in the old-style coke ovens.



To illustrate:

At the prospective reservoir sites the average gross evaporation probably averages about 56 inches per year over the Mission Gorge Reservoir Site No. 2; and about the same at San Vicente; with little variation from year to year.

The rainfall on the reservoir surface varies greatly from year to year, but averages about 12.4 inches per year at Mission Site No. 2 and about 15 inches per year at San Vicente, which is at a higher altitude.

I believe that over these broad surfaces the average loss will be a little smaller than that from the evaporating pan near the edge of the reservoir and I have estimated it at 95 per cent and 90 per cent but we seem to have yet no such data as might be obtained by careful study of effect on the several existing reservoirs, each as a whole. Thus the net loss from the reservoir surface averages about:

56 — 12.4 = 43.6 inches or 3.6 feet per year at Mission No. 2.

56 — 15 = 41.0 inches or 3.4 feet per year at San Vicente.

This is equivalent to 3.6 feet loss and on the 3,700 acres covered by a reservoir holding 105,000 acre feet at the 365 contour level above Mission Site No. 2, this depth lost from Mission Site No. 2 amounts each year (on the average, being more in years of small rainfall) to a loss of

3700 x 3.6 = 13,300 acre feet per year while reservoir is full;

equivalent to 36 acre feet per day; **equivalent to 11.9 million gallons daily.** In other words, **when reservoir is nearly full** to the 365 contour, **the daily average loss by evaporation is nearly double the estimated safe draft** of 6.0 million gallons daily taken away by the conduit to the city.

When raised 25 feet, flowing to contour 390, the area is increased to about 6,000 acres, upon which 3.6 feet net evaporation depth gives a loss of

6000 x 3.6 = 21,600 acre feet per year, when full.

Equivalent to 59 acre feet per day;

Equivalent to 19.3 million gallons daily; an increase from first stage of 7.7 million gallons daily to second stage (19.3—11.9=7.4.)

In midsummer the evaporation is much larger than this average figure.

Conversely, when half empty containing 114,000 acre feet the area of the final development is reduced to about 3,900 acres from which the mean yearly evaporation loss is 12.5 million gallons daily.

On the other hand, suppose the increase from first stage to second stage of Mission No. 2 giving increased storage of 94,000 acre feet, developed at San Vicente, which is feasible, the area for this quantity of storage in San Vicente is about 1,000 acres, from which the total yearly evaporation would be 1,000x 3.4=3,400 acre feet per year,

Equivalent to 9.3 acre feet per day; **Equivalent to 3.04 million gallons daily;** instead of the 7.7 mgd. loss in raising Mission No. 2 thus saving 4.6 million gallons daily.

This 4.6 million gallons daily saved would be worth at current costs of development of $500,000 per mgd., about **$2,300,000,** equal to the entire cost of San Vicente. Therefore, San Vicente is preferable if certain of being filled and well worth considering. The trouble with this computation is the small drainage area of San Vicente taking too long to fill or refill except in an exceptionally great storm.

The saving of water by developing this quantity in El Capitan would not be quite so large because it presents 20 per cent more evaporating surface and dam and reservoir cost about three times as much as San Vicente.

If we compare the first stage of Mission Site No. 2 with San Vicente, we find that to give same storage of 105,000 acre feet, would call for flowage to contour 650 and expose 1,080 acres and give about 3.1 million gallons daily total average evaporation loss instead of the 11.6 million gallons daily lost from Mission No. 2. This use of San Vicente would be all right if only it had the whole 375.59 miles of Mission No. 2 drainage area to feed it, but unfortunately, it has only 74.9 square miles and therefore, the Mission No. 2 project is preferable to San Vicente for the first step notwithstanding its waste in evaporation.

Calling water worth what the city pays at Lake Hodges nominally ten cents per 1,000 gallons, equivalent to $100.00 for each million gallons, or to $36,500 per year for each million gallons per day, the above saving of evaporation loss of about 4.6 million gallons daily in the deep San Vicente compared with the waste in the shallow Mission No. 2 reservoir between first and second stages of 365 and 390 contour amounts to 4,600 x 4.6 = $167,900 per year, which capitalized at 5 per cent is about $3,340,000 difference in real value after water in San Diego County becomes really scarce.

These figures, $2,300,000 on basis of construction cost and $3,340,000 on basis of wholesale purchase price, prove that it is now well worth while to provide for saving evaporation loss in the future when water becomes more valuable and it is largely for this reason that I recommend preparation for building El Capitan Dam about 20 or 30 years hence—after its cost can be had or can be regarded as obtained out of compounding with interest upon the sinking fund basis, the sum which the city now saves by building Mission No. 2 first.

Today under pressure of the city's bonding limit and its needs for many things besides water for adding to the attractiveness and prosperity of the city, it is profitable to be wasteful in evaporation but the time surely is coming when this needlessly large quantity of water wasted in evaporation will be very much needed.

Water that "wastes" over the spillway of a dam can be caught in another reservoir, upstream or downstream (it matters little which) but water that evaporates from the surface of a reservoir is completely lost.

This important matter of conservation of waste from evaporation does not appear to have been sufficiently considered in the previous reports about water storage in San Diego County.

By a similar line of reasoning it can be proved conclusively that the Cuyamaca dam should be torn out **at some future time** and its waters conserved in the deeper reservoir at El Capitan, and it can be shown that although the Mission No. 3 site requires too expensive a dam to be built in competition with Mission No. 2 to the full height of 365 contour, that this Mission Gorge Site No. 3 which, although too expensive and too small in yield for economy under constant draft, is, up to a certain depth, giving a volume of nearly 25,000 acre feet, superior to all of the other reservoir sites in saving evaporation loss, should be possessed by the city **and held for the future need.**

This dam site at No. 3 at the foot of the Mission Gorge and the canyon land within this small reservoir site is practically worthless to anyone else, or for any other use than as part of the city's future water supply system, to be used mostly as one of the last reserves in a prolonged drought.

Since one million dollars saved from expenditure in dams and reservoirs today would, in sinking fund, or in the city bonds at 5 per cent be equivalent to two million dollars 14 years hence and four million dollars 28 years hence, or at 4.5 per cent would amount to four million dollars 31.5 years hence and amount to eight million dollars about 47.3 years hence.

It is cheaper to now build the more wasteful but cheaper structure so long as there is enough more water flowing than is needed for consumption, and some must waste over the spillway of the dam anyway; **but the more economical reservoir should be planned now,** to be built when water becomes scarce and funds more easy and a long range consistent program should be kept constantly in view.

THE CUYAMACA RESERVOIR

(16) The present San Diego water supply situation has been further complicated by a proposal that the city should purchase the existing Cuyamaca Reservoir, diverting dams, flumes, terminal reservoirs (including Murray) and its water pipe distribution systems in the suburban municipalities of La Mesa, Lemon Grove, Spring Valley and East San Diego, together with the company's projected dam sites at Fletcher and South Fork and Mission Gorge No. 3, and all of the Fletcher and Cuyamaca priorities, water appropriations and a very complete series of releases for diversion by pumping at El Monte and perhaps also for future prospective dams at Fletcher site and South Fork, pertaining to most of the riparian lands all the way down from El Capitan to Mission Valley—all for a sum said to be $1,500,000; whereupon the city was to proceed to rebuild the old flume, build Fletcher and South Fork Reservoirs, build new wells and pumping station at El Monte gravel beds for "stand-by" purposes in drought and it was confidently (but erroneously) stated and doubtless sincerely believed by the vendor, Col. Fletcher, that these extensions to the Cuyamaca system could supply the growth in demand in San Diego from the surplus obtained in the added works, over and above the Cuyamaca Company's present obligations.

This project has been so elaborately and convincingly set forth, supported by sundry engineering reports, that this purchase and scheme of further development had been strongly recommended in an official communication made to the Mayor and Council by the City's Board of Water Commissioners dated December 29th, 1922, and printed and circulated.

(17) I was also asked to consider the acquisition of the Sutherland Reservoir Site and the diversion of all the water that it would furnish into the proposed Fletcher reservoir, or otherwise into the city system and a pipe line project was described and blue print of its survey shown me, whereby electric power could be generated from the great fall or hydraulic head in this pipe line.

I considered this carefully after visiting Sutherland reservoir site and dam site and viewing part of the conduit route, but found no promise of profitable return in such a small intermittent electrical power development.

The question of the value of the water which could be impounded in time of flood in the Sutherland reservoir Site is an entirely different matter and well worth further consideration.

Upon studying into this from the United States Geological Survey Topographic Maps I concluded that the city strongly needed to secure all water that could be had from Sutherland, Pamo and Santa Maria Creeks and reservoirs and that the supply from Sutherland, either with or without the others, could best be brought into the San Diego water supply system by a different route from that shown by Col. Fletcher. I sent sketches of this to the City Council via Engineer Williams and requested an accurate reconnoisance survey of this conduit line, which was duly made, and developed the fact that (when the time comes) a straight line tunnel, the smallest that it is practicable to drive, say seven feet high by eight feet wide, "horseshoe cross section," about eight miles long and in granite rock so strong and sound that very little timbering and probably no large amount of concrete lining would be necessary, could take the flood waters of the Santa Ysabel below Roden Canyon into storage in San Vicente reservoir. Whether side hill conduit or tunnel is final choice remains for the future after more complete surveys and estimates of costs are made.

From personal inspection on May 18th, 1924, I find the Pamo dam site and reservoir site thoroughly excellent and the whole situation very advantageous for developing by the

ly explained by Mr. Savage in his brief description.

The distinction as to which of Mr. Savage's two estimates of yield should be used, depends upon where and how the data for computing discharge into the proposed reservoir was measured and whether or not this data included the joint effect of evaporation and rainfall upon a reservoir surface.

This is discussed in Appendix No. 3 and it is there shown conclusively that the way this run-off data was prepared requires that the rain that falls throughout the year on these great areas of stored water be added and included.

If Mr. Savage's higher value, which includes the rain, be adopted, the comparison between the yield found by the Savage tabular computation and the Freeman Mass Curve computation comes out as follows:

	Per H. N. Savage (including rain)	Per J. R. Freeman (including rain)
EL CAPITAN, flowing to elevation 750	11.9	11.6
MISSION No. 2, flowing to elevation 365	7.4	6.0
MISSION No. 2, flowing to elevation 390	14.3	12.2

BEHAVIOR OF PROPOSED RESERVOIRS UNDER RAINFALL AND RUN-OFF CONDITIONS LIKE THOSE OF THE PAST THIRTY-NINE YEARS

Reservoir	Elevation of flow feet above sea	Full Storage capacity acre feet	Total inflow to reservoir acre feet	Total Evaporation Loss acre feet	Evaporation Loss % of inflow	Evaporation Loss M.G.D.	Draft by City Acre Feet	Draft by City % of inflow	Spillway waste Acre Feet	Spillway waste % of inflow	Net Gain in Storage Acre Feet	Net Gain in Storage % of inflow
EL CAPITAN No. 2—												
2nd stage	693.2	55,780	1,289,891	113,760	8.8	5.7	248,976	19.3	891,375	67.5	55,780	4.3
3rd stage	743.2	122,000	1,289,891	167,398	12.0	11.0	480,480	37.2	520,013	40.3	122,000	9.5
MISSION No. 2	360	87,000	1,929,781	368,524	19.1	6.3	275,184	14.2	1,199,073	62.2	87,000	4.5
	390	228,000	1,929,781	608,450	31.4	14.3	624,780	32.4	471,551	24.4	226,000	11.8
	400	295,000	1,929,781	659,480	34.2	17.5	764,400	39.6	227,610	11.8	278,291	14.4
MISSION No. 3	320	32,500	1,929,781	96,359	5.0	5.2	227,136	11.8	1,573,786	81.5	32,500	1.7
	360	121,000	1,929,781	393,701	20.4	9.8	428,064	22.2	987,016	51.1	121,000	6.3
	390	277,000	1,929,781	587,704	30.5	18.5	808,080	41.9	268,875	13.9	265,121	13.7

The above figures showing the total inflow that would have come into each reservoir during the whole period of 39 years since guagings on streams began, and showing also the portions of this total inflow available for draft by the city, loss by evaporation, wasted over spillway of dam are brought together from several tables in Mr. Savage's report for more convenient comparison. Mr. Freeman regards Mr. Savage's estimate of inflow in the early years as perhaps too large and this results in too small a value of percentages lost.

DETERMINATION OF SAFE YIELD

It was found on analyzing the computation sheets of Mr. Savage's and transforming them into the shape of diagrams of reservoir depletion, that for the entire period of about 40 years, the safe yield or draft could have been double the quantity shown by the computation which includes the nine consecutive years of scant rainfall from 1895 to 1904, which period of severe and prolonged drought presents the limiting conditions for all water supply studies for municipal purposes in San Diego County.

Evidently, it is important to explore all possible methods by which this gap or depression in the safe yield could be filled or lessened, either by a temporary pumpage of ground water, or by still larger storage by an auxiliary reservoir, which, after filling, should be held in reserve and seldom or never drawn upon except in the emergency of one of these unusual droughts, its cost being regarded as in the nature of insurance against water famine.

San Vicente offers an excellent example of a reservoir of that type by reason of its great average depth and its remarkably small evaporating surface and its sheltered location.

Obviously, the conditions of a severe and prolonged drought can be met and ameliorated, so far as household use is concerned, by imposing restrictions on the quantity drawn from week to week by various classes of consumers, after the first three or four years of drought have shown that the reservoirs are below the danger line, so that the normal rate of draft cannot be continued indefinitely in the absence of rain.

Such a condition must be met with the greatest skill and judgment lest the reservoirs be completely emptied and domestic consumption ultimately reduced to what little can be pumped out from the remaining underground storage.

The most obvious first precaution, is the shutting off of irrigation water for all annual crops, meanwhile making a proper compensation to the farmer for his loss of the water on which he had perhaps some vested right or reasonable expectation.

At the same time a limitation would be placed upon the use of garden hose, etc.

Next, the irrigation of citrus groves and other orchards would be limited much along the lines followed in the Sweetwater irrigation district during the great drought of 1895-1904; where it was found that half the normal quantity for several years in succession could keep citrus trees alive and that one-fourth the normal quantity would suffice in extreme cases.

These extreme measures, however, must be kept in the background, within the factor of safety, and as a provision against driving people out of town in case of the occurrence of a drought of equal or greater severity than that of 1895-1904.

The only reasonable basis for comparing the yield and value of the several sources, is that of finding, by means of the mass curve, **the safe yield that could be sustained throughout this period of extreme drought (1895-1904)**, and then adding whatever amount a further and more complete investigation may show could be depended on from pumping the ground water reserves, day after day, and year after year, throughout the last three or four years of such a drought after economies had begun.

REVIEW OF CONCLUSIONS

In my own investigations subsequent to this Savage report, I have found it necessary to go more deeply than Mr. Savage into the analysis of certain fundamental matters, such as the distribution of rainfall and its relation to altitude and locality as affecting the yield of one water shed in comparison with another. Also I have had to go further in analysis of relations of run-off to rainfall, and in consideration of ground water yields, but after so doing, I came out with a safe yield very nearly the same as Mr. Savage's minimum figure.

Also, I have felt in duty bound to try out other alternatives in types and heights of dams and reservoirs on the San Diego River differing from those presented by Mr. Savage in effort to find out if it were possible to get greater economy of first cost, particularly at El Capitan, and in view of the limited funds which the City of San Diego can now expend in water supply, in addition to other requirements of a rapidly growing city.

While I have been led to conclusions different in some respects from those of Mr. Savage, these differences result not from finding errors in his fundamental work but from business reasons as to the means by which the desired increase of water difference of personal judgment and can be most promptly and most cheaply obtained under the existing circumstances of adverse claims, adverse ownership and certain pending litigation.

I am pleased to find myself in agreement with Mr. Savage as to the need of reservoirs of vastly greater capacity in proportion to the mean annual run-off from the several water sheds here in San Diego County than are found necessary in other parts of the United States, but believe that he goes somewhat too far in increasing the size of Mission No. 2 reservoir to a flowage level at 400 feet above sea, because of its great waste by evaporation.

The chief difference between my conclusions and those of Mr. Savage are: (We agree completely in the choice of Mission No. 2.)

1. In a dam at either of the Mission Gorge sites, and for each stage, I would lessen the flood height by siphon spillways of total aggregate capacity to carry a flood canal equal to that of January, 1916.

I have tried (unsuccessfully thus far) to find a type of dam suited for these sites that would cost less than the almost universally approved type of gravity cross-section, built solidly of rubble concrete, which was recommended by Mr. Savage, but which should nevertheless be absolutely safe in stability, and safe against overtopping by even a greater flood than that of 1916 and in this search for economy I designed massive earth dams, deposited so far as practicable by hydraulic sluicing and heavily loaded by a loose rock-fill.

2. Although the earth dam proves to be the only type practicable within reasonable cost for El Capitan, my earth-type dam when designed for absolute safety at Mission Site No. 3 shows no gain in economy over the solid concrete because of local conditions.

For Mission Site No. 2, the dam is not the chief item of cost and the standard massive gravity type, is, in my judgment preferable.

3. I have been led to propose a different arrangement of the vast storage volume which we both believe is required for the largest reasonable conservation of the flood flows of the San Diego River in reservoirs above Mission Gorge placing a part of this storage at San Vicente because of the encroachment of flowage as proposed by Mr. Savage in his final stage of development to elevation 400 feet above sea level, upon the margins of the village of Lakeside, and because it seemed possible to lessen the evaporation loss that would be caused by his reservoir of the broad area of nearly 10 square miles covered at elevation 400, although it might stand near this high level for only about one year in ten.

4. From a study of the ground, I have concluded that elevation 365 is about the proper elevation for the first stage of flowage for a reservoir above Mission Gorge, this being 5 feet above the level proposed by Mr. Savage for the corresponding stage. This is made possible by the use of siphon spilling and by some raising of the railroad bed for about a mile or two, which will add more value in water than the cost of the changes.

5. I am convinced it would be a wise policy for the city to acquire all these valley lands up to contour 392, wherever practicable, and hold for future use, meanwhile leasing them for agriculture.

6. The vastly greater cost found of flowing to elevation 365 by the cheapest possible type at Mission No. 3 as compared with Mission Site No. 2 compels building the first dam at Site No. 2, buying whenever it can be had at not too much above value for grazing purposes the site at No. 3 for development in the distant future by a dam at lower elevation forming a reservoir of somewhere between 15,000 to 25,000 acre feet, to be drawn on only as the emergency of severe and prolonged drought. Its small evaporating surface fits it particularly well for such service.

7. I am certain that El Capitan also should at some time in the distant future be built to elevation 750 for full conservation of flood flow, and that this should serve in substitution for the present Cuyamaca reservoir and the proposed Fletcher and South Fork reservoirs, it being built for the joint use of all interests; irrigation, suburban, and city water supply, after the Indian lands can be had at a more reasonable total price than $361,500, and after the several interests have joined forces, although this may be 20 years hence.

In this final development by using El Capitan instead of Cuyamaca, Fletcher and South Fork in addition to using it ordinarily in substitution for storage in the upper portion of Mission No. 2 there will be a saving of evaporation loss. The time will surely come when such large loss by evaporation as is caused by the 3,700 or 6,200 acres of Mission Site No. 2 must be economized.

8. I am in hearty accord with Mr. Savage's recommendations for raising the Barrett dam, and later the Lower Otay dam, so that the water which now runs to waste at these dams may be conserved for the use of the city. This deeper storage also will make some small but noteworthy reduction in the evaporation loss, but I believe all such increase from Southern sources should wait while San Diego River water with those of the Santa Ysabel are being secured.

9. At the request of city officials I inspected portions of the old wood stave pipe leading from Lower Otay toward the city and while I am in accord with Mr. Savage's recommendation for an additional conduit here sooner or later, it seemed plain from the appearance of the portion inspected that the old pipe could be maintained with reasonable safety by constant, careful inspection and replacing of bands for several more years, and that the new pipe might wait pending the building of a new conduit to the city from the north, in view of the need of conserving the city's bond capacity.

10. It is my strong belief, based on much experience, that water rights and lands for reservoirs can be acquired at a vast saving of cost and of wasteful litigation, by proceeding to the greatest possible extent by friendly negotiation rather than by condemnation and litigation, and this leads to the suggestion that the acquisition of lands in and upstream from Mission Gorge, particularly above contour 367 proceed in a somewhat leisurely manner, by first bringing up to date the appraisal made by Mr. Herbert for Mr. Savage, and then making to each owner a cash offer on that basis accompanied by permission to occupy the land purchased, for say three years until needed, without rental until 1927 or even until 1930 and thereafter at a small rental not exceeding 5% interest on the purchase price.

(APPENDIX No. 3) INCLUSION OF RAINFALL ON RESERVOIR SURFACE

As stated on page — Mr. Savage presents two very different estimates of yield of each reservoir system; one as he says being based on the supposition that in the data from which he worked the effect of rain on the reservoir had been already included and the other value applied where rain on the surface had not been included. This makes so much difference that I have reviewed it as follows and find it seems certain that the value should be used which gives the larger yield and includes the rain.

Very curiously although I include the rain on reservoir surface, my results agree most closely with Mr. Savage's so-called conservative value which does not include the rain.

The rainfall at the Mission Gorge sites averages about 14 inches per year in depth, while the evaporation averages about 56 inches. The vast area of the Mission 3 reservoir at elevation 390 being 6,200 acres on which 14 inches of rain amounts to about 7,300 acre feet per year or 20 acre feet per day or 6.5 million gallons per day makes this rainfall on surface an element of great importance in the safe yield.

In estimating the safe yield of reservoirs on the San Diego River Mr. Savage used the daily gaugings by U. S. Geological Survey at Lakeside as his data for El Capitan yield—and the U. S. G. S. daily gaugings at old Mission dam as his data for the two Mission gorge projects—and there is no result of reservoir evaporation in these gaugings of the flow that would enter the new reservoir.

Therefore it is plain, that the proposed reservoir will regain about one-fourth part of its loss by evaporation from its surfaces from the rain that falls on the same surface. The evaporation loss will come chiefly in the summer and the gain from rain in the winter and the precise amount of the rain will vary largely while the evaporation will be nearly constant from year to year.

PECULIAR RELATIONS BETWEEN RUN-OFF AND RAINFALL

In making estimates of stream flow available for filling reservoirs to be constructed in San Diego County we are compelled to follow different lines from those commonly adopted in similar estimates in the eastern United States, or wherever from year to year the rainfall is comparatively uniform in total amount and exceeds the annual evaporation.

In San Diego County on lands not more than say 1,000 feet above sea level the rainfall (except that in heavy storms which falls on ground wet by previous rain) is all quickly lost by evaporation from the soil, or absorbed by plant growth, so that none reaches the stream.

The rain increases greatly with altitude as vapor laden winds cross the mountains but even in the mountains the ground is nearly always thirsty and evaporation loss is large and **the streams get very little except when a heavy rain falls on ground whose surface thoroughly wet by a previous storm.**

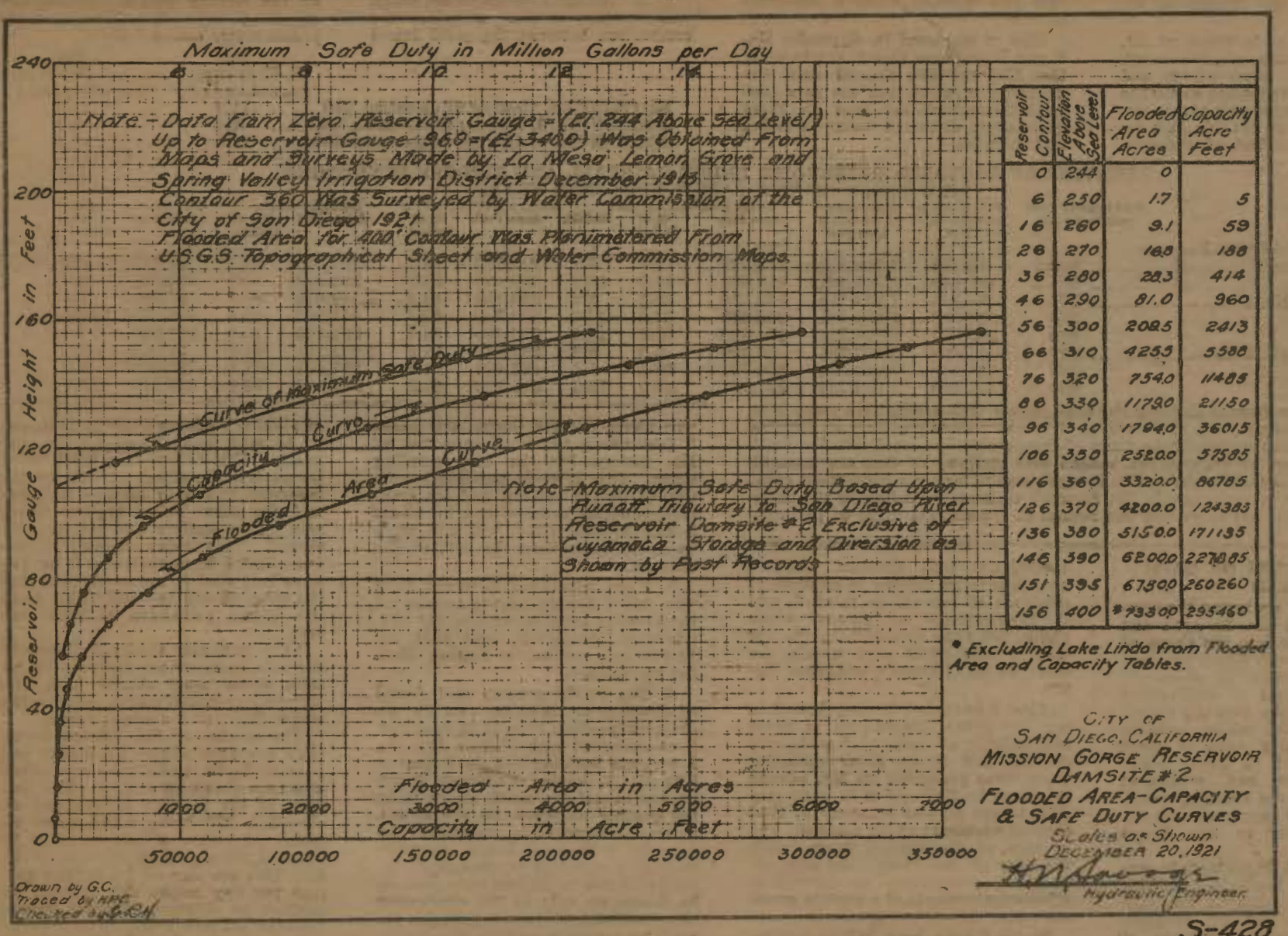
The chief reliance for refilling the great reservoirs **is the big storm that comes about once in ten years.**

Here in San Diego County the relations of rainfall and run-off are so extremely variable and uncertain that the discharge from a water shed cannot be estimated from data on the second-feet-per-square-mile basis, neither can it be deduced as a percentage of the annual rainfall. It can be deduced with reasonable **accuracy only by comparison of the run-off on the stream in question with the run-off found by actual gaugings for a long term of years on an adjacent stream.**

By far the best method of comparison and estimation is to first of all plot a **curve of relation of discharge,** month by month, for the two streams during the period when both have been observed. In other words a curve determined by plotting each calendar month as a point, using the measured discharge of that particular date found on one stream for the ordinate and that of the other stream for the abscissa.

Having obtained such a curve, the yearly and monthly discharge for the stream in question may be estimated, going backward through all the years in which records are available on the

(4)



Reservoir Contour	Elevation Above Sea Level	Flooded Area Acres	Capacity Acre Feet
0	244	0	
6	250	1.7	5
16	260	9.1	59
26	270	18.8	188
36	280	28.3	414
46	290	81.0	960
56	300	209.5	2413
66	310	425.3	5388
76	320	754.0	11485
86	330	1179.0	21150
96	340	1794.0	36015
106	350	2582.0	57585
116	360	3320.0	86785
126	370	4200.0	124383
136	380	5150.0	171135
146	390	6200.0	227885
151	395	6730.0	260260
156	400	*7330.0	295460

* Excluding Lake Lindo from Flooded Area and Capacity Tables.

CITY OF SAN DIEGO, CALIFORNIA
MISSION GORGE RESERVOIR DAMSITE #2.
FLOODED AREA-CAPACITY & SAFE DUTY CURVES
Scales as Shown
DECEMBER 20, 1921
H. M. Savage
Hydraulic Engineer

S-428

neighboring stream.

The present question about including the depth of rainfall on the reservoir surface as a part of the safe yield of the reservoir runs back to the question of **how the data on the neighboring stream, used for comparison, is obtained,** and whether this data included the effect of rain falling upon a reservoir.

Here on the San Diego River the data for our estimates for the discharge available for filling a reservoir at El Capitan, are almost wholly derived from those measurements of discharge at the Diverting Dam, which have been maintained with more or less precision during the past 30 years, or from gaugings made by the U. S. Geologic Survey at Lakeside or at old Mission dam, the effect of the discharge from the 12 square miles of Cuyamaca water shed being first eliminated from this record of discharge as measured at the Diverting Dam or Lakeside, or old Mission Dam.

This water shed of 90 square miles above the Diverting Dam (exclusive of 12 square miles of Cuyamaca drainage which is excluded from the data) contains no broad water surface, nor does that above Lakeside or old Mission Dam.

On the other hand, when we use for our data the recorded run-off from the Sweetwater system, the case is different because the published records of run-off from Sweetwater reservoir seems to be total that **ran out from** this reservoir—through valves and over spillway, and not the run-off from the drainage area **into** this reservoir.

This Sweetwater data of run-off in acre feet per square mile is derived by computation from data into which **both evaporation and rainfall upon the reservoir surface have** been incorporated and so this Sweetwater data contains already, in a measure, the net effect from both rain and evaporation upon this reservoir surface.

The question of inclusion or exclusion of rain on reservoir surface really turns **on the substitution of water surface** for the original dry land surface of equal area within the reservoir site. This water surface substituted amounts to only from ½% to about 1% of the total area of the water shed which feeds it and therefore its utmost influence on the data cannot be large.

Moreover, these reservoirs proposed on the San Diego River are each at comparatively low altitude where the rainfall is small and before flooding produced no noteworthy run-off which is included in the stream flow gaugings; these areas within the reservoir boundary save in the great storms which come at intervals of from five to ten years.

These particular areas which it now is proposed to cover with water have in past years contributed such a very small proportion to the discharge upon which we rely for replenishing the reservoir, that it seems plain to the writer that the larger figure for safe yields presented by Mr. Savage, which includes full allowance for the rainfall upon the surface of the reservoir, **is the sole and only one which should be used** for the El Capitan and Mission sites throughout all the years since data from the San Diego River itself is used.

In those early years when Sweetwater has to be our only recourse, prior to the recorded gaugings at Diverting Dam, and old Mission Dam the proper figure is somewhere between the two presented by Mr. Savage.

It should not be so low as his lowest figure, because the Sweetwater reservoir is of relatively small capacity and area in proportion to its drainage area, and is small in proportion to the great reservoirs now being planned on the San Diego River. Probably the correct figure to be used for these few years is much nearer the higher than the lower limit.

It will be near enough for all practical purposes for these few early years in which we are dependent on the Sweetwater data, to adopt a figure halfway between Mr. Savage's two figures, or to assume that an addition should be made of one-half the rainfall on the reservoir surface.

THE SWEETWATER, OTAY, MORENA, AND BARRETT RUN-OFF DATA

The Sweetwater data on run-off, month by month and year after year since October, 1887, seem without doubt the most accurately measured long term run-off records in San Diego County, but they seem to be estimated on the basis of **discharge out from the reservoir** instead of on the basis of discharge **into** the reservoir from the watershed, therefore, **the Sweetwater data show less than the true yield per square mile from the watershed,** because they have suffered loss by the excess of evaporation over rainfall on the reservoir surface.

I have none of the original notes or records at hand but this seems proved by internal evidence, as by the Sweetwater discharge being often smaller than that recorded for the Dehesa Gauging station on Sweetwater river a few miles upstream, and by the record of zero discharge out from Sweetwater shown as having been zero continuously for three years from January, 1901, to February, 1904, although there were heavy rains in 1903 which must have caused some discharge into the reservoir.

The run-off records for Otay, Barrett and Morena were worked up by Mr. Cromwell under Mr. Savage's supervision (see Savage report of August 8, page 264) on June 10, 1921, in his "study No. 12" and the details of computation for Otay are given step by step for each year from 1904 onward, and since the run-off from Barrett and Morena were worked up by the same engineer at the same time, it is almost certain wherever there was a reservoir surface involved, the same methods were used for each of these three.

These computations sought to obtain the run-off from the drainage area **into** the reservoir at Morena and Barrett (or into the reservoir site in case dam was not yet built.)

For example starting with the record of the depth and the surveyed capacity curve, the net inflow for a given month was deduced from the number of feet the water surface had risen. Next the draft measured out through delivery pipe to city was added, next the measured leakage or waste was added; and then the evaporation loss was estimated and added, and next the inflow to Otay from the Dulzura conduit was deducted. All checks out properly, except that for some unexplained cause **no deduction was made for the gain that had come from the rain on the water** surface. It might have been thought by the computer that the allowance for evaporation included the effect of rain; which would be true for the record **just as observed** in the floating evaporation pan; but this idea is precluded by the use of a constant average figure of 56.6 inches gross evaporation per year, in which five years' observations at Otay checked remarkably with five years' observation at Sweetwater; and at Sweetwater it is expressly stated that correction of observed evaporation was made by adding to it the depth shown by the rain gauge. Or it may have been argued that the same depth of rain would fall on this area whether the land was dry or flooded. True! but 90% or more of what fell on dry ground would be lost in prompt evaporation.

While if falling on water it is all clear gain, the evaporation from each acre of surface being the same whether it falls or does not fall, the mean annual rainfall here is about 14 inches or 25% of the evaporation.

"SAFE DUTY" CURVES FOR OTAY, BARRETT AND MORENA

In his estimates of the safe duty of these reservoirs, Mr. Savage includes the effect of rain upon the surface of Otay reservoir subsequent to 1904, on Morena subsequent to 1911 and on Barrett subsequent to 1922. At earlier dates the reservoir had not been built and the run-off gauged was the natural, unregulated flow of the stream. At Otay the reservoir had been put in service about seven years earlier than 1904. He follows in effect the line of argument that I have stated on the preceding page and I concur in his method of including the rain. His diagrams show two "duty curves" one including, the other excluding rain on surface but in his final estimates he adopts the curve which includes rain.

On page 709, Report of August 8, 1923, Mr. Savage states that his computations of safe yield proceed on basis that it is assumed that the data on run-off into Otay reservoir prior to 1904 **did not include** the rain on reservoir but that it is known that subsequent to 1904 the rain on reservoir was included in the data. He changes his method of figuring his depletion curve at the year 1904 and after that date in computing its run-off includes evaporation loss of 55.6 inches—the same figure in each year.

Prior to 1904 at Otay he uses a figure that varies year by year and is made up of an average evaporation loss of 56.2 inches lessened by rainfall on reservoir by whatever depth of rain actually fell as taken from his table on page 712. Rain thus not being incorporated in the run-off data he adds it when computing the yield. In that way he finds a safe yield of 3.8 million gallons daily with reservoir dam of present height providing 61,000 acre feet of storage. If Otay dam is raised to 160 feet high to contain 80,000 acre feet he finds a safe yield of 4.2 million gallons daily including rain on surface.

For Morena Reservoir, the run-off data had been figured by Mr. Wueste in "Study 12," along with the computation for Otay. Morena reservoir was under construction and being filled 1909 to 1911, the first stored water was drawn from it January, 1912, to set a gate. Its regular service began March, 1913. Prior to 1911 the run-off data used in his depletion studies for determining safe yield contained no increase for rain on reservoir because the reservoir had not been then built. The Morena run-off gaugings were ordinary stream flow gaugings. Wherefore in computing the rise and depletion of the reservoir for these early years, under various rates of draft he uses net evaporation by (in effect) adding the rainfall and thus gets a variable correction.

After the Morena reservoir was built and filled "the run-off values are known to include the rain on surface" and so now in computing the safe yield he does not add for it a second time.

At Barrett the run-off data on which this is based were part of "Study 12" and doubtless its computation was by same method described in detail for Otay. Barrett reservoir was not finished and put in service until 1921 and since in early years the run-off recorded was all natural flow without storage obviously no effect of rainfall on reservoir surface was included in this data. Mr. Savage (page 742 Report of August 8) says in effect that the run-off data on which reservoir performance is based prior to 1921-22 are not augmented by effect of rain on reservoir surface, therefore, the depletion is figured from net gross evaporation minus rain while after 1921-22 the run-off data is known to include rain on surface, therefore, no further addition for it is made.

It has seemed best to thus go into detail in clearing up this matter in order to make it evident that when the safe yield of the new reservoirs, it includes the effect of rain on the surface and that the use of Mr. Savage's larger figure is proper is thereby confirmed.

SUGGESTION OF GROUND WATER INVESTIGATION ON SWEETWATER

I am led to believe that it would be possible for a careful patient skillful engineering investigator to dig up from the old records and from the memories of men now easily accessible, who worked hard to keep things alive during the great drought, a more valuable record than any that I have yet seen regarding what can be practically obtained by pumping from the broad sandy river beds of San Diego county, in the later stages

of such a drought.

There are extant sundry typewritten reports containing estimates and computations of **what some hopeful individuals think might be done,** based upon the theoretic content of water within the pore space of a great mass of sand assumed to be uniformly open grained and freely permeable, but with no real proof, or any suggestion that it might take pumping plants spaced with something like the frequency and number of the oil wells at Signal Hill, to get out from the sand all of the quantity of water thus theoretically estimated as available.

Most of these valley-fills of sand have a slope seaward of from 20 to 50 feet to the mile and in the wet season the water table follows this slope closely. Obviously **if motion of the underflow was not extremely slow,** the water would drain out, and its surface drop at the upper ends of the valleys much faster than is shown by the few available records.

(APPENDIX No. 4)

SCOPE OF MR. FREEMAN'S INVESTIGATION IN SAN DIEGO

For the completeness of the record I append the following notes:

I arrived in San Diego on Saturday, August 4th, 1923, and was met by Councilman Don Stewart, City Manager Rhodes and the Consulting Engineer to the City Attorney's office, Mr. J. W. Williams. We proceeded immediately to a preliminary inspection of the dam sites on the San Diego River, reviewing successively, Mission No. 3, Mission No. 2, the lands that would be flooded by these dams, and then proceeded to the El Capitan dam sites.

Throughout the next three weeks, from eight A. M. to about ten P. M., Sundays and all, I was constantly busy, either on inspection or becoming familiar with the local water supply conditions, and the present reservoirs and their sources of supply, or in conference with officials or citizens who desired to explain their views and give the writer the benefit of their experience or their special knowledge of conditions affecting the City's Water Supply. Meanwhile, also, I met with the Water Supply Committee of the San Diego Chamber of Commerce for a discussion of the situation, and attended several day-time and evening meetings with the Mayor and Members of the City Council, the City Attorney, City Treasurer, City Engineer and others, at which I was questioned upon a wide range of topics relating to many phases of the City's water supply, and given much information.

Also I was in frequent conference with Colonel Ed. Fletcher, who was understood to be the principal owner of the Cuyamaca Water Company, with Mr. John Treanor, Vice-President of the San Diego County Water Company, with Mr. J. B. Lippincott, Consulting Engineer to the SAN DIEGO Water Company, who for many years also has had more or less to do as a consultant on various water problems in and about San Diego.

Also I passed an evening with Mr. John D. Spreckels, former owner of the present sources of supply and still deeply interested in all that pertains to the prosperity and future of San Diego, to learn of his views; also with Mr. Frederick M. White, formerly one of the city's Board of Water Commissioners. A conference also was had with the former City Attorney, Mr. T. B. Cosgrove, now Special Counsel and with City Attorney Higgins, regarding the suits for establishing the City's Public rights to the waters of the San Diego River. Conference also was had with Judge Haines, legal advisor on water supply matters to the eastern suburbs of San Diego, and with Mr. W. M. Herbert, an experienced realtor, who took the leading part in the appraisals of the lands that would be flooded by the Mission No. 2 Reservoir project.

Also I had extended conferences with Mr. Melville Klauber and other leading citizens, who were deeply interested in these questions of water supply and desirous of being helpful with explanation of conditions and statement of their conclusions. In every way I tried to collect all useful information bearing on these special problems, and to give a hearing to any official or any citizen who desired to present facts that he deemed helpful.

To help in estimates of cost, since the war, under local conditions, Mr. J. B. Lippincott, Consulting Engineer, responded with a copy of his analysis of unit costs on the Henshaw Dam and the Escondido Flume, which were most recent hydraulic structures in San Diego County, and the writer inspected these structures, and Mr. D. W. Albert, one of the most experienced builders of Hydraulic File Dams in America, was prevailed upon to come down to San Diego for two days from San Francisco, to add his judgment of fea ibility and cost of using this method t Mission Gorge or El Capitan, in building a cheaper dam than these previously proposed at these sites.

Mr. Rhodes, City Manager of Operation, devoted a large part of almost every day for about three weeks to taking me about on tours of inspection in his automobile, and Mr. J. W. Williams, C. E., worked early and late collecting information, supervising test pits at dam sites, etc., etc.

During the first two weeks, conferences of from one to three hours were held almost daily with Mr. H. N. Savage for the purpose of becoming familiar with the data on water supplies which he had collected.

I desire to express my special appreciation of the courtesy of Mr. **H. N. Savage, for many years the City's** Hydraulic Engineer, the builder of the Barrett Dam, and the rebuilder after the great flood, of the Lower Otay Dam, and also of long experience in studying San Diego's peculiar climatic conditions on the Sweetwater storage system; who although no longer in the City's employ, opened to me his notes and data and helped in every practicable way.

In particular he loaned to me his personal copy of the 836 page final report which he had filed with the Mayor and Council, on leaving the City's employ on August 8, 1923.

I have found this report, which Mr. Savage submitted on August 8th, in compliance with the Common Council's resolutions Nos. 26731 and 27239, extremely useful in my studies. I have admired its systematic and logical arrangement of data, the completeness with which he sets forth the essential facts and his conclusions.

This work of investigation described in these 814 pages, had, it is understood, been in progress for nearly two years, and preliminary reports containing a part of his conclusions had been filed, respectively, about one and one-half years, and about seven months previously, and to these preliminary reports this final report is stated to be fundamental and supplementary.

The brevity with which he outlines the problems and the brevity of his arguments make this volume difficult reading for one unskilled in water supply engineering; but I have found useful facts on almost every page, and wherever I have had occasion to check this data and results from other documents, I have found this presentation of Mr. Savage carrying internal evidence of the care with which his study was made. He gives, in many places, credit to his assistant, Mr. George Cromwell for the collection of data and for many of the computed tables.

Through it all there is apparent a freedom from personal prejudice and a desire to get at the truth and to serve the public. Its brevity of descriptions seems to me its chief fault.

Mr. Savage also gave me copies of his cost analsysis on Barrett Dam and various other useful papers, including a copy of Mr. Cosgrove's opinion on the legal status of the Public Water Rights.

Mr. Savage, with great courtesy, remained in San Diego for about two weeks after terminating his official connection with the City as its Hydraulic Engineer, in order that in response to my request transmitted thru the Mayor and the City Attorney, he might answer my many questions and assist me in rapidly understanding his reasons for the conclusions that he stated, based on engineering estimates.

I desire to particularly express my appreciation of the courtesy and promptness with which Col. Ed. Fletcher produced reports on the yield of the San Diego River made for his own use in previous years and the cheerful way in which he tendered the services of his engineering assistants, Mr. K. Harritt, Mr. F. E. Green and Mr. T. H. King, and procured a report based on experience with Cuyamaca from his former Manager, Mr. Fauds, now an Engineer of the Califronia Railroad Commission.

Also I desire to express appreciation of the courtesy of the Manager of the Sweetwater Company for opportunity to inspect their works and for useful data furnished, also to Mr. Allen who related his experiences on the Sweetwater System with keeping citrus groves, etc., alive in the great drought of 1895-1904.

As a result of this general willingness of citizens and officials to provide me with data, I brought east for further study several thousand pages of typewritten material and a hundred or more maps and diagrams and many photographic copies of reports, and also sundry copies of decisions by California Railroad Commission, etc., all of which I have tried to faithfully study.

In brief, I endeavored in every way, to become familiar with all phases of the special problems in hand, and desire to express my appreciation of the courtesy with which I was met on every side and my appreciation of the patience with which my many questions were answered.

While it was made plain in conferences with the City Officials that the question of first importance was the relative merits of the three dam sites on the San Diego River which had long been under discusssion and about which intense differences of opinion had developed—Mission No. 2 and Mission No. 3 and El Capitan—it soon became plain that a wise decision as to which of these three sites was preferable in first cost and in ultimate conservation and economy of operation as by avoiding pumping, involved some extremely complicated problems, such as:

(a) The storage capacity needed to properly conserve the flow of the river.
(b) The length of time that water must be held in storage.
(c) The loss by evaporation meanwhile in reservoirs of very different area and exposure.
(d) Also there were painstaking studies required of the type of dam best adapted to each particular site.
(e) The methods by which the dam could be built with greatest economy in stages so as to keep within available funds.
(f) Depletion diagrams had to be constructed showing how each prospective reservoir would behave as to lowering and refilling under a repetition of such climatic conditions as have occurred in the past 40 or 50 years; for it seems that in this region large reservoirs can only be refilled by catching and holding the big rainfalls that occur about once in ten years.
(g) The question of the probability of the recurrance of severe and prolonged drought like that which held the region around San Diego in its grip during the nine consecutive years of low rainfall from 1895 to 1906.
(h) The extent to which underground sources for temporary supply during prolonged drought could be developed by pumping from the deep beds of saturated gravel in Mission Valley, in the Valley above Mission Gorge, near Lakeside and near El Monte, and the number of months or years before these would practically be pumped dry.

In many years of experience upon water supply problems in the United States, Canada and Mexico, including many studies in Central California, I have never found such puzzling conditions as those presented here by the small and extremely variable rainfall, and the fact that the main dependence for refilling the Water Supply Reservoirs must be on the great floods which come only about once in ten years, and that, if the rate of growth for the past ten years continues for twenty years there will be no water available from anywhere with which more homes can be assured of green lawns and well watered gardens impressed me profoundly as to the responsibilities involved in studying these questions with the greatest care.

(APPENDIX No. 5)

BRIEF NOTES ON SAN DIEGO'S PRESENT SUPPLY

In the course of my studies as a means of learning the general trend of affairs in the past and their probable trend in the future, I compiled from time to time the following description of the present sources of water supply to the city of San Diego and the brief description of sources used in earlier years and of the events that have led up to the present recent determination to develop new sources. I found these notes useful and have thought it worth while to have them copied here for the purpose of making this record more complete.

The sources of the municipal water supply now owned by the city of San Diego consist mainly of four large reservoirs — MORENA, BARRETT, UPPER and LOWER OTAY; in which the flood run-off from drainage areas aggregating 349.2 square miles, is impounded and held, some of it for five, or it may be for ten years; subject to large evaporation loss before withdrawn for use in the city, through pipes nearly 20 miles long.

The capacities of the several reservoirs are given in the table on the following page, and their positions are shown in the outline index map, Sheet No. 0, along with various other sources that have been proposed.

PRESENT CATCHMENT AREAS AND STORAGE RESERVOIRS

Name of Reservoir	Catchment or drainage area Sq. miles	Total capacity of present reservoir Acre feet	In storage on April 1st 1923 Acre feet	In storage on April 1st 1924 Acre feet	Estimated continuous supply with present reservoirs, rain, flood, drought as in past 35 years (per Savage) (mgd.)	Maximum storage obtained after proposed Increase in height of dam	Probable continuous yield after enlargement and filling (per Savage) (mgd.)
Upper Otay	12.6	2,360	2,093	1,611	3.8	———	4.2
~~Lower Otay~~	85.7	58,200	55,554	52,267	3.8	80,000	4.2
Morena	119.5	53,680	31,473	31,848	3.5	61,000	4.5
Barrett	130.0	42,899	41,865	30,567	4.3	150,387	10.0
Mission Valley Subterranean					3.7 to 4.3	192,500 (in new dam only)	14.0 to 19.5 (Inc. Sutherland & Pamo)
Lake Hodges	299.0	37,700	37,647	32,421			
Cuyamaca Reservoir only	12.0	12,144	10,676	6,658	0.9	———	———
Whole Cuyamaca System	———	20,244	———	———	3.1	———	———
Fletcher and South Fork			0	0			
Murray Terminal Reservoir	4.0	6,100					

PRESENT UNDERGROUND SOURCES

Also the city owns water rights, wells and pumping stations within the Mission Valley, from which, in times of prolonged drought, when the reservoirs threaten to become empty, water in limited quantity (perhaps two or three million gallons per 24 hours during the dryest part of the year for from three to five years in succession) can be sucked out of subterranean storage in the pores of the sand and gravel deposits which fill, more or less, of the bottom of a space in the bed rock formed in past geologic ages, now known as the Mission Valley. The area of these gravel deposits in Mission Valley may have a total area of 2,000 acres and average 50 to 60 feet deep; and thus at most are not a very large reservoir, since 2,000 acres of saturated sand 60 feet deep would at best yield only 25% of its volume in water, amounting to 30,000 acre feet. But, **not all of this** can be extracted by pumps, **unless wells are scattered over the whole area with a profusion never yet attempted.**

There is much of misinformation and exaggeration and of false hopes prevalent about the maximum quantity that could be obtained from wells in the valley gravel beds in San Diego County, and the matter is worthy of more scientific investigation, although an admirable beginning has been made in U. S. Geological Survey Water Supply Paper No. 446, published in 1919.

LEASED SUPPLY FROM LAKE HODGES

Also, the northern districts of the municipality now have a temporary supply, leased about three years ago from the owners of Lake Hodges on the San Dieguito River, for a ten year term. The City now has the right to draw two million gallons per 24 hours—"when available"—in return for its payment of about $73,000 per year, or at a nominal rate of 10c per 1,000 gallons for the right to draw 2.0 mgd; although the City is reported to now draw only about 1.5 million gallons daily. This is for the water as delivered by gravity flow at the northern boundary of the Pueblo. The cost of pumping by the City has to be added in order to get the total cost.

This lease also gives the right to draw up to three million gallons daily, at 10c per thousand gallons. Although there is no question of the company's good faith and the confidence of its managers about ability to supply this 3.0 mgd. through a severe and prolonged drought, **it is to be noted that the words "when available"** appear in the lease, and that prospective leases for irrigation to the extent of 10,000 acre feet of water per year, with only "half-service" for irrigation when reservoir level has sunk below a certain quantity, **may lead to demands which cannot be satisfied,** if another drought severe as that of 1895-1904 should occur.

It is worth noting that 10,000 acre feet is equivalent to a continuous draft throughout the year of 8.9 mgd. adding that leased by San Diego ——— 2.0 mgd. making a total draft of 10.9 mgd. while Mr Savage estimates that the safe yield from Lake Hodges is only from 3.7 to 4.3 million gallons daily.

LEASED FROM CUYAMACA

Also, until within two years, a million gallons daily, more or less, from the Cuyamaca Water System is reported to have been delivered into

San Diego at 10c per thousand gallons, by gravity flow, and at an elevation that could deliver into the main distribution reservoir at University Heights without pumping.

SUMMARY OF YIELDS OF PRESENT SOURCES

It has been estimated by Mr. H. N. Savage that all of the sources and reservoirs now in use by the City (including the 2 mgd. from Lake Hodges) can supply within the municipal limits of San Diego, throughout any ordinary drought, a total of eleven million gallons daily, which is very nearly the average rate of consumption by the present population, exclusive of suburbs, and gives no margin whatever for increase of population.

If another prolonged drought like that of 1895 to 1904 should occur before new sources are added, there would be a decided shortage of supply such that use of garden sprinklers and irrigation, and perhaps also domestic uses, would have to be seriously curtailed.

In reply to inquiry from the City Council on January 23, 1923, Mr. Savage presented a statement of amount of Water in storage and states that **after the recent addition to Morena reservoir** has become filled, the yield of sources owned by the City will be increased about 1.0 mgd. or from 9 to 10 mgd. Mr. Savage estimated about a year ago (April 1, 1923) that there was then in storage the amounts given below. The amounts on April 1, 1924 have been added.

	Total Capacity Acre Feet	Acre Feet in Storage April 1st 1923	1924
MORENA	43,800	30,700	31,848
BARRETT	44,600	41,500	30,567
UPPER OTAY	2,500	2,200	1,611
LOWER OTAY	56,300	55,600	52,267
TOTAL	147,200	130,000	116,293

CONSUMPTION

The average throughout the year, of consumption **from city sources** (exclusive of Lake Hodges) is now about 9.5 million gallons daily, equivilent to 29 acre feet daily, or about 10,000 acre feet yearly. (Note that the shrinkage was 13,700 during the past year. Evaporation loss from these reservoirs is so extremely large that to assume that because this 116,300 acre feet now in storage is eleven times the present yearly consumption, it would last eleven years, would be very far outside the possibilities. Judging from the rate of shrinkage shown above, it should last 116,293/13,700=8.5 years, but some margin must be allowed for the City's growth and for the possibility of Lake Hodges water being "not available."

On August 8, 1923, Mr. Savage estimated this storage, with some small natural inflow from the four tributary drainage areas, after allowing for loss by evaporation and the small rainfall on the surface, could supply the consumption for only about **5 years of drought** before exhaustion, and he recommended that new storage works should be completed not later than 1926. Two years of his five are gone, but they have not been "years of drought." My own opinion is that the supply now in storage, April 1st, 1924, is safe for a longer period, say for fully five or six years from the present time and with more than an even chance that they will be filled to overflowing by a great storm two or three years hence (one of the 10 year cycle.)

There were nine years in succession from 1896 to 1905 in which rainfall and run-off were abnormally small and practically nothing ran into the reservoirs at Sweetwater during the last five years of this period; and almost nothing ran into Cuyamaca reservoir, high in the mountains in a region ordinarily of high rainfall, during the last three years of this period.

The diagram and table on the following page show the rate of increase in consumption for the past 20 years. All services are said to be metered and therefore presumably the amount of waste thru leakage is a minimum, or cannot be reduced to any important amount for increasing the quantity to be supplied to consumers in time of shortage.

(See Plate on Page 8)

The sunny climate, the long dry season from May to October, the high average standards of home life, with many home gardens, all lead to an uncommonly large per capita demand, compared with other American cities.

The draft was doubled in about 11 years and the present rate of increase in population and in the various demands for public service, together with probable annexations of suburbs, indicate the requirements for water will double within the next 15 or 20 years at most; and will continue to increase indefinitely, until sooner or later the growth of the City will have to stop because **the peculiar charm of the city will be lost when there is insufficient water for verdure of parks and gardens.**

Whether this limit to growth is to come in 25 years, or in 50 years, depends upon the amount of water that is firmly secured.

Plainly the region around about San Diego **contains more attractive sites for homes than of water to supply them,** and the municipality of San Diego itself is owner of a vast area of the old pueblo lands, beautifully located for home sites, near the sea, which, if well laid out and skillfully sold, will go far toward re-imbursing the city for cost of all the additional water needed.

IMPRACTICABILITY OF THE NEW SUPPLY FROM OUTSIDE SAN DIEGO COUNTY

Water from east of the mountains or from north of the county line may be regarded as utterly beyond reasonable limits of cost. Water from the Garcia Site on the Tia Juana River 7 miles south of the Mexican Border also may be regarded as impracticable for many years to come and if obtainable at best would be relatively small in quantity.

NONE FROM MEXICO

From inspecting flood marks and reservoir site at Garcia, Mexico, I believe that its capacity for sustained delivery has been greatly exaggerated. The rainfall and run-off diminish as we move south and Mexico may vary naturally desire to reserve this for irrigation of certain Mexican lands that are said to be favorably located for receiving this water.

NONE FROM THE COLORADO RIVER

Some wild dreams have been published about bringing water to San Diego from the Colorado River from above Yuma, but one only has to remember the difficulties of building and the cost per mile of the San Diego & Arizona Railroad to cross these same mountains.

Mr. Williams has taken off from the U. S. G. S. Topographic maps the heights and lengths of tunnel required by the shortest route across the mountains from the end of the proposed canal crossing Imperial Valley.

The present writer was a member of the Board of Engineers that planned and favored bringing the Owens River Supply to Los Angeles, and the Catskill supply to New York, and the Nashua River Supply to Boston, thus has experience of cost and difficulties of such long distance conveyance of water. The available resources of San Diego for a quarter of a century, or even half, will never permit reaching out with an aqueduct or pipe line more than fifty miles from the City Hall. The problem is **to conserve to the utmost THE SOURCES NEAR AT HAND.**

SUBURBAN NEEDS

There are rapidly growing suburbs outside of the present city limits, all of which probably will become annexed sooner or later, or will look to San Diego for their water supply. These comprise East San Diego, La Mesa, Lemon Grove and Spring Valley, now supplied from the Cuyamaca Company, and said to be uneasy about their present supply and largely desirous of annexation, meanwhile across the harbor Coronado is rapidly growing.

To the south are Chula Vista and National City, now supplied from the Sweetwater Reservoir, which now has limitations, as was proved in the prolonged drought from 1895 to 1904, but which could be doubled in capacity by liberal expenditure in increasing the height of the present dam, or by one or more new reservoirs further back in the hills.

It has been estimated that the outside populations in those suburbs, exclusive of those supplied from Sweetwater, that may look to San Diego for their future supply, is now about 15,000 and that they now require for domestic purposes, exclusive of irrigation, about 1.5 million gallons daily. The needs of these suburban communities will surely increase and San Diego is certain to be called on to supply some of these demands.

The Geographic situation is shown by the map index given on Sheet No. 0 of accompanying drawings.

OBLIGATIONS TO THE CITY OF CORONADO

The City of Coronado now is reported as having a population of about 5,000 and growing. The greatest chance of large future growth and demand for water in this direction seems to have been removed by the recent taking by the United States for an aviation base the large promontory, equal in area to Coronado, lying just beyond, but there is still ample vacant space on which hundreds of new homes could be built in Coronado.

I am informed that the City of San Diego is under contract to supply water for municipal purposes to Coronado perpetually on demand and that Coronado has been supplied from the same sources which now supply San Diego for about 25 years (Savage Report page 806.)

INCREASE FROM TIA JUANA SANDS

I am not fully informed about the extent to which water has been pumped from the saturated sands in the bed of the Tia Juana River northerly from the Mexican Boundary.

From a study of the geologic maps and brief inspection of the surroundings, I am led to believe that under skillful planning and supervision, a large temporary emergency supply for use in prolonged drought or other emergency could be obtained here. Skillful scientific supervision would be needed in order to avoid contamination and permanent injury by sucking in salt water in pumping from any of these gravel beds lying at low altitude near the sea.

SOME HISTORICAL NOTES ON THE PRESENT SAN DIEGO WATER SUPPLY

The history of San Diego's water supply begins with the establishment of the Pueblo of San Diego by the Mission Fathers. They built a dam in Mission Gorge about 125 years ago and a conduit about 4 or 5 miles long was built for diverting the water of the San Diego River to the pueblo lands in the upper end of Mission Valley where their farm lands mostly were. This conduit did not extend down to the main settlement, mission and fort, but the agricultural lands at the "Ex Mission" were a part of the Pueblo. The main mission and the fort were located at the southerly downstream corner of Mission Valley, close beside the course of the San Diego River from which perhaps they brought their water in buckets. The location of the river here has since been changed. Under the Spanish law, the Pueblo owned the exclusive right to the waters of the San Diego River. The city claims it has succeeded the Pueblo in this ownership of a prior right to all the waters of the San Diego River.

LITIGATION FOR PUEBLO WATER RIGHTS

At Los Angeles, under somewhat similar conditions, it has been decreed by the highest courts that the municipality was successor in ownership of the Pueblo water rights, and legal proceedings to establish prior title of the City of San Diego to all the waters of the San Diego River were begun about ten years ago by the then City Attorney, T. B. Cosgrove, whose views were set forth in a printed pamphlet published at that time. This matter is still more or less active in the courts and Mr. Cosgrove is still conducting the case as counsel for San Diego, with the assistance of the present City Attorney, S. J. Higgins.

The ownership or priority of the City is vigorously disputed by the owners of the Cuyamaca Water Company and perhaps by others in the valley who pump or otherwise divert this water, and the matter has now been in active litigation for ten years. Both parties have recently filed new briefs and Mr. Cosgrove and Mr. Higgins believe rapid progress has recently been made, all favorable to the city and that a decision completely in favor of the city will be reached before the end of the present year, and that it is not a matter that can be put before the U. S. Supreme Court in Washington. They hope and believe that the suits will be concluded this year.

(For Foot Note): Notes from "Final Report Los Angeles Water Works."

Los Angeles was founded as a Spanish Pueblo in 1781, "established primarily by Spanish Crown to furnish subsistence for a small army of occupation. The Spaniards came from a country that thrived by irrigation." Water was the element that determined the location of a pueblo and area of grant was generally adjusted to the available supply.

The Los Angeles grant was one league square and Los Angeles River became appurtenant to pueblo by Spanish authority in 1781. The water was diverted on agricultural lands and used for irrigation purposes. Holdings were communistic and no lands separately held until after American occupation and treaty of Guadelupe Hidalgo in 1848.

Relative to the City's paramount ownership of the waters of the Los Angeles River it is stated in the First Annual Report of the Los Angeles Aqueduct;

> "Men on the small farms in the San Fernando Valley overlying the ground waters of the Los Angeles River put down wells upon their own lands and pumped therefrom and applied the waters to the lands which they owned. The City was obbliged to procure injunctions against these intrusions but enforcement of the orders of the Court would be so disastrous to those who had built small homes, that it was deemed inexpedient to apply them, unless actual water shortage should make such action imperatively necessary, although the City had spent $150,000 in establishing its rights to this water."

WORKS PUMPING FROM SAN DIEGO MISSION VALLEY

The dispersion of the Mission Settlement led to the disuse of the old Mission Dam and its conduit and the founding of the new City of San Diego and the building at other localities within the Pueblo lands caused various other means for water supply to be developed. In 1873 a private company developed wells and a pumping station near the lower end of the Mission Valley which pumped from the saturated sands, but was long ago abandoned and replaced by the present pumping station located several miles upstream on the south side of Mission Valley.

As illustrating the early small beginnings of the San Diego Water Works in comparison with the later growth, it is of interest to note the following statistics from the "Manual of American Water Works" for the year 1869, or 35 years ago:—

Estimated population of San Diego 25,000

Water works built in 1873 by San Diego Water Company, formerly known as San Diego and Coronado Water Company. President, E. S. Babcock; Designing Engineer, H. M. Covert.

Supply pumped from 14 wells to reservoir, 3,850,000 Gal. Cap. Wells from 24 feet to 30 feet in diameter and 15 to 25 feet deep.

Pumps:

Worthington	1 million gallons daily
Holly	2 million gallons daily
Gaskell	3 million gallons daily
Dow	.5 million gallons daily
TOTAL	6.5 million gallons daily

Distributing mains, rivetted wrought iron, 54.75 miles. Services of wrought iron taps, 1801, meters, 1,000. Hydrants, 100. average hydrant rental $50 each.

Average consumption 0.9 m.g.d. in summer, 1.5 m.g.d. in winter, total average, 1.2 m.g.d

Reported cost of works	$710,000
Capital in 1888, subscribed or issued	125,000
Authorized, $500,000, Debt $250,000, 6% Bonds; $17,000, 8% Bonds,; $4,000, 10% Bonds.	
Annual operating expenses	$ 61,000
Annual revenue	110,434

CITY'S GROWTH LIMITED YEARS AGO BY SCANT WATER SUPPLY

For many years, and up to the time within the memory of many citizens still active, it is said the supply for domestic purposes within some parts of the City of San Diego was extremely precarious and that 20 or 25 years ago, in time of severe drought, water was regularly sold in the streets at 25c per bucket.

Mr. John D. Spreckels has told me that when he became interested in promoting the growth of San Diego, he saw that its greatest obstacle to growth was lack of good water supply, and that one of his first steps was to give financial assistance to the private system which he found here, and which he subsequently purchased, greatly enlarged and finally sold to the municipality in 1913.

BRIEF NOTES ON PRESENT DEVELOPMENTS

THE CUYAMACA COMPANY

The earliest modern water supply by gravity flow to the new city of San Diego was brought in through the present Cuyamaca Water Company which had its origin in the San Diego Flume Works or Company, incorporated May 14, 1888 or about 15 years later than the building of the pumping station of the works in Mission Valley described on page 219, with a capital of $1,000,000. This incorporation was amended May 25th, 1895, and the original cost was probably much more than the sum stated.

The preliminary estimates of water available made by its promoters seem to have been far too optimistic. Much water sold originally with land as "irrigation rights" could not be delivered and the Company is said to have particularly failed in meeting its obligations in the great drought of 1895-1904.

The Company's property was sold out for $150,000 in 1910 (Savage p. 413) and bought by the present owners who made more or less repairs and improvements and extension of pipes for domestic supply to the communities of La Mesa, Lemon Grove, Spring Valley and East San Diego, etc. The operation and main-

tenance of the depreciated structures has been carried on with remarkable skill and efficiency by the Superintendent, Mr. Harritt and undoubtedly the general status of the works has been much improved.

The most important and costly improvement by the new owners of Cuyamaca was the building of the Murray dam in 1917. This was a new concrete dam of the multiple arch type, having its flowage line at greater elevation than that of the original terminal reservoir known as La Mesa reservoir, which it flowed over, giving increased capacity for storing up the surplus of flume delivery in the wet season.

Relieved of many of its irrigation demands, and no longer a main source of supply to the city of San Diego, the company, under its new ownership, claims to have met all obligations for supplying water to the suburban communities (now said to contain nearly 15,000 population) and to its present line of customers for irrigation water (now said to cover 4,000 acres) during the past 15 years, and claims to have present and undeveloped resources from which it could largely increase the supply to the city of San Diego.

It is obvious from inspection of its maps of distribution pipes and from riding through the thrifty suburbs, which these distribution pipes serve that the Cuyamaca System, in spite of certain defects possesses much property of great present and potential value and that it certainly is now performing a valuable service to many people.

On the other hand, current reports, certain testimony of record before the California Railroad Commission, and the dilapidated appearance of the El Monte Pumping Station, the badly decayed main flume and some of its siphons, would lead to an impression that the whole enterprise is still in a precarious condition, although it is associated in possession with valuable dam sites at El Capitan and Mission Site No. 3 and has water rights that will be valuable if the city loses its Pueblo suits.

THE CUYAMACA DAM AND RESERVOIR

The construction of Cuyamaca dam and reservoir and flume was begun in 1887 and the works, substantially of present capacity, were completed in 1889.

These are reported to have consisted of an earth dam about 35 feet high and 635 feet long, said to impound about 6,452 acre feet.

This dam was raised 6.5 feet in 1895 to elevation 4,630.5 and is said to now impound 11,410 acre feet at level of spillway crest, and 2,734 acre feet more if filled to the top of the temporary flashboards sometimes placed in the spillway, thus making its total capacity 14,144 acre feet (according to Mr. Savage's report.)

This Cuyamaca reservoir receives drainage of 12 square miles, having an average altitude of 4,870 feet above sea level, and having a remarkably large run-off per square mile.

Since the reservoir is shallow (average depth when full being only 12.9 feet), the evaporation loss is very large, this apparently being increased by proximity to the desert. I have been told that whenever a strong wind blows from the east from across the desert, the reservoir gauge shows that the lowering of the water surface by evaporation becomes largely increased.

Probably this evaporation loss is so great that when the time comes for conserving water resources of the San Diego River to the utmost, it would be true economy to tear out this Cuyamaca dam and merge its storage in some much larger future reservoir further down the river.

The Cuyamaca reservoir is drawn upon only during the dry months of the year, at those times when flow in the San Diego River becomes small or ceases entirely, and when this reservoir and the river flow both fail, recourse is had to the surplus stored in the Murray reservoir and to pumping from the underflow found in the saturated gravels of the San Diego River bed at El Monte.

The discharge for Cuyamaca reservoir runs about 14 miles down the bed of Boulder Creek into the main San Diego River and this discharge flowing down this 14 miles of creek bed containing some expanses of sand and much vegetation, in the dry season is partially lost by seepage and evaporation, at times to the extent of 25% of the whole. The lessening of this loss by conveying the water in a pipe and utilizing the fall to produce power and electric current has been discussed, but I judge this would be impracticable commercially, because of the small amount of power, its intermittent uncertain character and its remoteness and the large cost.

This further loss of the stored water, by seepage and evaporation along Boulder Creek is another reason for the future abandonment of Cuyamaca reservoir and merging with a deeper future reservoir downstream.

THE DIVERTING DAM

A diverting dam was built upon the main San Diego River at a short distance below the entrance of Boulder Creek down which flows the reservoir discharge. This dam has no considerable storage, but is for the sole purposes of diversion of flow from river into the Cuyamaca flume and for providing a somewhat crude gauging weir by which the discharge of the river, in excess of what is taken by the flume, can be measured approximately. This dam is understood to have been largely rebuilt and now it appears to be a substantial structure, suited to its present purpose.

THE CUYAMACA FLUME

This flume extends 35¾ miles along the hillsides on a slope of about 4.75 feet per mile. On this total length about 0.8 miles are tunnel. The Cuyamaca flume is mostly constructed of wood, is now 37 years old and much decayed, but has been made tolerably tight, temporarily, by means of lining of rubberoid roofing felt.

When running full the flume is said to have a capacity of 31 cubic feet per second, or 5,000 miner's inches, or the equivalent of 20 million gallons per 24 hours.

There are possibilities of temporary interruption of service in several high wooden trestles, subject to fire or other damage, and also risks in certain scantily protected fragile siphon pipes across branch streams, nevertheless safeguards for maintaining delivery to consumers during temporary interruption have largely been provided in the excellent main terminal reservoirs at Murray Dam and the small reservoirs, Eucalyptus and Grossmont.

THE CUYAMACA RECORDS ARE VALUABLE

The daily records of river flow past this diverting dam, and of discharge into the flume, which have been continuously maintained for the past 31 years, are one of our chief means of estimating the run-off of the San Diego River and neighboring streams, and have been the subject of review and recomputation by several engineers.

SOUTH FORK DIVERSION

The Cuyamaca Flume also is fed by another diverting dam of small size, built across the South Fork of the San Diego River, which enters the main river 7 miles downstream from the main diverting dam, a length of about 1.3 miles to its junction with the main Cuyamaca Flume.

VARIABLE DELIVERY OF THE CUYAMACA FLUME

The main Cuyamaca flume throughout the year gathers in time of flood all the water that it can hold or can carry and after the flood has passed takes in substantially all the water that it finds flowing in the stream at diverting dam. Obviously, during the winter months, while the natural flow of the river is greatest, there is small need for irrigation and so this surplus is brought down to the end of the flume and put into storage reservoirs, mostly into Murray Reservoir of about 6,000 acre feet capacity and with limited storage in the small Eucalyptus and Grossmont Reservoirs. This flume is kept working continuously to as near full capacity as the main river and South Fork can supply.

THE MURRAY RESERVOIR

Originally this reservoir was known as the La Mesa Reservoir. It is located about 8 miles easterly from San Diego and was formed by an earth dam 66 feet high, built across Alvarado Canyon, impounding about 1,110 acre feet (from Savage curve).

In 1917, a little farther down the Canyon, there was built the Murray Dam, already mentioned, a multiple arch concrete dam, 127 feet high, having its high water level at elevation 530 feet above sea level, or 36.5 feet higher than the former La Mesa Reservoir, thus drowning out the old earth dam and increasing the water storage to 6,085 acre feet.

This Murray reservoir conserves much water discharged by the San Diego River and brought down by the flume in winter and early spring, when flow is large and use for irrigation is small, that otherwise would be lost, and it also serves to safeguard the domestic supply furnished to the communities of La Mesa, Lemon Grove and Spring Valley in time of drought and in case of accident to the old weakened flume.

Its location and elevation also makes it available for delivering water to the city of San Diego, so far as permitted by its supply and its capacity over and above the prior demands for these communities with population variously estimated at from 10,000 to 15,000 or about 1/7 the number in San Diego and for prior irrigation demands.

DEFICIENCIES IN ORIGINAL WATER RIGHTS

The yield of the Cuyamaca watershed, reservoir and flume, seems to have been largely overestimated at the time of the original promotion of the Cuyamaca enterprise, and it has been said many more water rights for irrigation were sold appurtenant to sales of land, than could be supplied throughout dry seasons.

Many of these rights are said to have lapsed or been extinguished by the failure of the original company, but it has been stated there is danger that in case the city of San Diego should purchase these works and build new dams and thus increase the water supply, there would be priorities claimed under these old grants.

PROPOSED EXTENSION OF CUYAMACA SYSTEM:

For a long time past the owners of the Cuyamaca System (Principally Col. Ed Fletcher) have been having engineers study the possibilities of greatly enlarging the permanent yield of the Cuyamaca System by means of constructing an additional storage reservoir near the junction of Boulder Creek with the San Diego River having a drainage area of about 90 square miles and a storage capacity of 5 billion gallons equivalent to 17,800 acre feet, also a new diverting dam and small reservoir on South Fork having a drainage area of 44.5 square miles, and a storage of about one billion gallons, equivalent to 3,120 acre feet, or 20,900 acre feet in both, both of which would feed into the present flume or a new flume or pipe line on about the same location.

It is to be noted that these reservoirs are very small in proportion to those found necessary by Mr. Savage and Mr. Freeman for storing water to carry through a long drought. Both the Fletcher reservoir and the South Fork reservoir as proposed have a combined capacity of only one-tenth part of Mission No. 2 site at contour 390, and only one-seventh part of that proposed for El Capitan.

Mr. Fletcher and his engineers hope to fill this gap by pumping water that may be needed to maintain the supply from the saturated gravels in the bed of the San Diego River near El Monte.

Mr. Fletcher also is understood to own much of the area of the El Capitan Dam Site proposed by the City and owns the land at Mission No. 3 for a relatively low reservoir for storing water and supplying the U. S. Government Military Stations, or possibly other customers.

There appear still to be strong differences of opinion about the possibility of legal opportunity for revival of some of these old claims adversely to the granting of new rights, in case of increase in discharge of the flume, by the building of new or larger reservoirs appurtenant to it.

SAFE YIELD OF THE PRESENT CUYAMACA SYSTEM:

Mr. H. N. Savage, while Hydraulic Engineer for the City, made a careful estimate of the total capacity of the present Cuyamaca System for supplying water for all purposes in time of drought (page 393) and found 3,417 acre feet per year, equivalent to 3.1 mgd. was the safe continuous average yield throughout the year.

No substantial amount of water flows down the channel of the San Diego River at the Diverting Dam during the dry months in almost every year and none flows down the South Fork, therefore, at such times the supply to the Cuyamaca Flume depends primarily upon the discharge of water stored in the Cuyamaca Reservoir. This storage is not large, and in some years of small rainfall, as, for example 1900-1902, **evaporation has left nothing in the reservoir** available for discharge into the flume.

SUPPLY PUMPED FROM EL MONTE GRAVELS

At such times, or whenever the natural flow in the river has stopped and the Cuyamaca Reservoir has been exhausted, recourse is had to pumping from the underground storage in the sands and gravels of the San Diego river bed near El Monte, about two miles above Lakeside, from a line of about six wells, each said to be about 80 feet deep, arranged in a line across the valley so as to intercept the slow underflow down the slope of this valley.

This valley averages about .37 mile wide above El Monte wells and extends about 3¼ miles upstream from the wells. The depth of the deposit of gravel and sand is not definitely known, but probably averages 80 feet to 100 feet, being less deep near the head. Nor is it known what proportion of the substrata is coarse and pervious, or what is fine and almost impervious, but since the general surface of this broad deposit slopes downstream at the rate of about 26 feet to the mile with the top surface at the downstream end, at wells, 90 feet lower than the surface at the upstream end of the valley, it is plain, beyond all doubt, that the average rate of underflow must be extremely slow, or the water would nearly all soon drain away, just as from a small basin of saturated gravel held in the hand and tilted at an angle, and the elevation of the water table at the head of the valley would become thereby greatly lowered in six months of drought, after inflow to these gravels from the canyon above Cape Horn had ceased. Actually, this lowering is remarkably small proving the slow movement of the seepage downstream.

Mr. C. R. Lee, who has studied these matters more than any other engineer in California, has estimated the average rate of underflow at 1/3 of a mile per year. (See U. S. Geological Survey Water Supply, Paper 446, page 146.) To illustrate that the limitations in this underflow are many, note that at this rate in a valley 1,600 feet wide and 100 feet deep, having thus a cross section of 160,000 square feet and a velocity of 1/3 mile or 1,780 feet per year, or about 4.8 feet per day, and with water in motion being 25% of the total volume of gravel or sand, the product would be only 40,000x4.8x 7.48 = 1.6 million gallons per day flowing down toward the line of wells, some little quantity could be drawn upstream and the deep pumping would increase the slope materially, but only near the wells.

It is reported that as much as 2.5 million gallons per 24 hours was pumped for several months in succession from these gravels in the year 1900, into the Cuyamaca Flume, and the officials of the Cuyamaca Company plainly are sincere in the belief that a much larger quantity, or 4 million gallons daily, could be steadily pumped throughout several dry years in succession. This, however, is open to serious question and I am inclined to believe that the past rates of yield are about as great as could be maintained steadily through a single long dry season.

The owners of the Cuyamaca Company are said to have acquired the riparian rights necessary to almost unlimited pumpage throughout most of the distance downstream along the San Diego River and along the valley lands that might be adversely affected.

They are also said to own the sites for the proposed dams at El Capitan and the Mission Dam Site No. 3 and to have fortified their own water rights all along the San Diego River so very carefully that it is difficult or impossible for any other interest, or for the City of San Diego to build a dam or to conserve flood discharge by storage for diversion and use, without first making terms with the owners of the Cuyamaca interests, or a legal taking under right of eminent domain.

It is currently reported that the entire Cuyamaca System has been offered for sale to the City of San Diego for the lump sum of $1,500,000.

A few years ago, the purchase of the Cuyamaca System by an irrigation district to be formed of La Mesa, Lemon Grove, Spring Valley was under active consideration and a report on its water resources and an appraisal of its property was made for the California Railroad Commission by Mr. William L. Huber, Civil Engineer, which report I have carefully studied.

The purchase of the entire Cuyamaca Water System by the City of San Diego has been strongly urged, and the question of **just how much water it could furnish above its present obligations**, the possibilities of increase and the total cost of necessary additions all are matters about which there are extremely wide differences of opinion.

I have been told the Cuyamaca Company has furnished no water to the City of San Diego for a year or more past, but that not so very long ago it was receiving from the city of San Diego for water purchased nearly $40,000 per year.

In the California Railroad Commissioners' Decision 4058, it is stated:

> "For many years the Cuyamaca Company's main source of revenue was the sale of water in the city of San Diego, until the city of San Diego purchased the local water distributing system and turned from the Cuyamaca Company to the so-called 'Spreckels System' for its supply and that 'without the city of San Diego as a prospective customer,' the construction of this system would not have been justified and probably would not have been undertaken."

The Savage report of August 8, 1923, page 453, states that during the six years 1914 to 1919, inclusive, the sales of water for the Cuyamaca System to the city averaged about $27,000 per year. Of course, the public records will show what support the Cuyamaca System has had from the city of San Diego from earliest to latest times.

The chief income of the Cuyamaca System in recent years is understood to have come from the sale of water for domestic purposes in the suburbs of East San Diego, La Mesa, Lemon Grove and Spring Valley, but of all of this matter of revenue, cost of upkeep and profit or loss, the present writer has no precise information and does not consider this necessary to a determination of the

question of the purchase of the Cuyamaca System by the city of San Diego.

This decision must turn on the **quantity of water** that the Cuyamaca System could be depended on to supply throughout a severe and prolonged drought **over and above present obligations, available to San Diego** and what it would cost to put the dilapidated works into good condition, and the cost of building new dams.

The present situation as the next extension of the city's supply is complicated by this historical background as by the disuse of the early pueblo rights, by the supply of the city from wells in the Mission Valley, by supply from the Cuyamaca System, and by the change to the so-called "Spreckels System" and the subsequent purchase of this by the city and by the recent contracts for a supplementary supply from Lake Hodges.

The present writer is not informed as to the successive steps by which the city of San Diego developed its pumped well supplies from the saturated sands along the San Diego River in Mission Valley, or the moves and causes by which the city began and ceased to be supplied from Cuyamaca sources, or under precisely what conditions the city came to be supplied from its present sources, the Otay River and Cottonwood Creek and while the whole would be of interest historically for completing this record, additional information on this topic bey nd that already stated does not seem essential to the problem now before us.

DATA ON YIELD OF DRAINAGE AREAS AND RESERVOIRS OF PRESENT SUPPLY

It has been found important to study the records of these present supplies and their actual yields carefully in order to estimate with all practicable accuracy the quantity of water that could be derived for the city's use from the several drainage areas of the San Diego River, above the several dam sites, and it was necessary to study the effects of long term storage and evaporation loss in the existing reservoirs, and particularly to gather all possible data from these present sources, about the relative yield from ordinary natural flow and the addition obtainable by large reservoirs for conserving the great floods such as come about ten years apart.

THE OTAY, BARRETT AND MORENA SYSTEMS:

The Southern California Mountain Water Company built, owned and operated, until 1912, the works which are now owned by the city and which provide nearly all of the present supply; the only water not now supplied by Morena, Barrett and Otay being the 1.5 million gallons daily taken from Lake Hodges under the lease for 2 million gallons daily, and also the additional 2 million gallons daily more or less which in emergencies of drought or accident is pumped from the city's line of wells at Mission Valley.

OTAY DAMS

The Lower Otay Dam, the first in a series of four dams projected by this company for the water supply of San Diego and Coronado and for the irrigation of lands in the mesa devoted to citrus fruit culture, was completed in 1897. It was of the rock fill type with a sheet steel core, about 182 feet high and impounded 37,400 acre feet of water.

This dam was destroyed by overtopping in the great flood of January, 1916, because of an inadequate spillway. Prior to this flood, the run-off from the watershed, during the 18 years since it was completed, never had exceeded the draft sufficiently to fill the reservoir.

Subsequent to the flood, this dam was rebuilt in excellent form as a massive arched concrete dam of gravity type, under the design and supervision of Mr. H. N. Savage.

The Upper Otay Dam is understood to have been completed in 1901. It is a remarkably thin masonry or concrete arched dam, about 77 feet high, and impounds the flow from a relatively small drainage area and its reservoir has a capacity of only 2,793 acre feet. Its surface, when full, is 64 feet higher than Lower Otay and formerly a wood stave pipe 36 inches in diameter led from it.

At present Upper Otay discharges into Lower Otay, either over its spillway when it has a surplus, or through a sluice gate, which is seldom opened. Its storage is held in reserve according to a rule.

Apparently, the seepage through ledge or earth around it, or beneath, is insignificant and it presents an excellent site and opportunity for some large scale and precise observations upon the effects of rainfall, run-off and evaporation under these conditions of soil and climate, which would be very useful.

MORENA DAM

The Morena Dam was next in order of construction. This was begun in 1896, but work was suspended, because of difficulties in foundations, until 1912, when it was completed under the engineering designs and supervision of Mr. M. O'Shaughnessy, to a flowage height of 146 feet above sea level and storage capacity of 41,254 acre feet.

This was raised 9 feet during the summer of 1923 under the designs of Mr. H. N. Savage, so as to increase the total storage capacity of 61,300 acre feet (see Savage Report, page 730), which **after being filled** will increase its long term average safe yield by about 1.0 million gallons per day, per Mr. Savage's figures.

BARRETT DAM

A dam at the Barrett Site, the middle one of the chain of three great reservoirs projected by the Southern California Mountain Water Company, was begun in 1897, but work stopped with the completion of a small masonry base, which served merely as a diverting dam to take the natural flow of the stream, and also bring the discharge from Morena into the Dulzura Pass Conduit, which was built about the same time.

The discharge from the Morena Reservoir all passes through the Barrett Reservoir.

In 1898 a new Barrett Dam was begun 1,000 feet downstream from the original location but work on this stopped after the foundation block of masonry, about 35 feet high, had been built. Nothing further was done here until subsequent to the purchase by the city and subsequent to the great flood of 1916.

A new and radically different design was then prepared by Mr. H. N. Savage and the present dam completed under his supervision in 1922, to a flowage height of 1,615 feet above the sea level, providing storage of 42,899 acre feet, but with designs and structures left in readiness for raising its flowage height 81 feet to 1,696 feet above sea level, giving a dam having an extreme height of 250 feet and storing a total of 150,387 feet.

One of Mr. Savage's latest recommendations was that this work of raising the Barrett Dam should be carried forward immediately, if there was to be delay in developing a new source on the San Diego River as affording the quickest and probably the cheapest means for safety against an impending shortage of supply of water to the city of San Diego.

This addition in the height of Barrett Dam seems entirely practicable, but before doing this there also is good reason for safeguarding the supply to San Diego as a whole by bringing in the next supply through a new conduit from the opposite direction and this reason points very strongly to the San Diego River for the next source.

Mr. Savage and Mr. Cromwell estimate from what is practically a mass curve computation in tabular form, that the safe yield for these Morena, Barrett and Otay sources, as at present developed, and with the enlargements proposed, under the same average conditions of rainfall and run-off, storm and drought, as have actually been recorded at Sweetwater, Otay, Barrett, etc., during the past 38 years would be as follows:

PROJECT	With present storage		With ultimate future storage		
	Acre feet capacity.	Safe yield Mil.Gal.Dal.	Acre feet capacity	Safe yield Mil. Gal. Dly.	
MORENA	61,000	4.5	61,000	4.5	4.5
		(a)	102,000	8.6	
BARRETT	43,000	4.3(b)	150,380		10.0
UPPER AND LOWER OTAY	61,000	3.8	80,000	4.2	4.2
Total	165,100	12.2	317,380	17.3	18.7
Loss in Dulzura Creek by seepage and evaporation		1.2			
Net		11.0			

This yield from Morena will be about one million gallons daily smaller until the Morena Reservoir, as increased by last year's raising of dam, has become filled.

It is proposed that Barrett Dam may be raised in two stages (see Savage Report August 8, page 759), with following costs and results:

RESULTS OF PROPOSED INCREASE OF HEIGHT OF BARRETT DAM

	AS NOW	2nd STAGE	3rd STAGE
Storage to Reservoir Gauge	160 ft.	220 ft.	250 ft.
Flooded area (acres)	862	1,445	1,794
Mean depth of full Res. (feet)	47.8	70.5	83.3
Full storage capacity, ac. ft	42,900	101,812	150,380
Maximum safe duty, Mil. Gal. daily	4.3	8.6	10.0
*Excavation quantity Cu. Yds.	75,172	179,172	135,172
Concrete masonry Cu. Yds	138,848	308,843	368,848
Estimated total cost to City	$2,219,000	$3,719,000	$4,219,000
Estimated cost per Mil. Gal. daily duty	517,000	433,000	422,000
Cost of additions per Mil. Gal. Daily		$350,000	$350,000

*These estimates of construction, quantities and costs are very rough.

DULZURA CONDUIT:

The combined discharge from Morena and Barrett is discharged into Dulzura conduit, which is compressed in 1.75 miles of tunnel and about 14.5 miles of ditch out in the hillside and lined with concrete, having a slope of 4.22 feet per mile and a capacity of 37 million gallons daily.

It crosses the watershed boundary into Dulzura Creek which empties into the Lower Otay Reservoir and loses some water by seepage and evaporation on the way down the bed of the creek. Because of this loss, the withdrawals from Barrett into Lower Otay reservoir are made largely in the wet season and this water stored in Otay until sent into the city.

Mr. Savage reports (page 267) an investigation by Engineer Wueste, admittedly very crude which showed that 10% of the water discharged by the conduit was lost in the creek bed and Mr. Cromwell and Mr. Savage call this loss an average of 1.2 million gallons per day. It has been proposed to save this loss by conveyance in a pipe line which should yield electric power from the fall of 800 feet but the flow is so intermittent and small that the power obtained would not reimburse for the cost and maintenance.

Nevertheless, at some future time, as water becomes scarce and valuable, a pipe should surely be put in to prevent this loss. The value of the water wasted, if 1.2 m. g. d., 1.2x365x10c = $43,000 per year, if valued at price paid for Lake Hodges water.

This indicates that the value lost is surely enough to pay interest and depreciation on cost of a pipe, even if the quantity lost is much less than 1.2 million gallons daily, and notwithstanding a power plant on this pipe would not pay.

TRANSPORTATION TO CITY

The water thus gathered on Lower Otay Reservoir is transported to San Diego by wood stave pipes 36 inches in diameter, mostly built in 1901 and therefore beginning to show age, particularly in the rusting away of the iron hoops which confine the wood staves, but capable, with careful watching and frequent repairs, of good service for many years longer, although an alternative supply line into the city from another direction plainly is desirable.

TERMINAL DISTRIBUTION RESERVOIRS

The city plat of San Diego contains a wide range of altitudes from sea level to elevation 400 above.

The main distributing reservoir is that at University Heights with high water at elevation 386.

There are several supplementary reservoirs and the city can be divided into the zones of altitude for water distribution.

If water is stored in Mission Site No. 2, this could at all ordinary heights in reservoir be delivered to large sections of the city by gravity flow, but for higher sections would have to be pumped.

Water from El Capitan or San Vicente can flow by gravity into the reservoir at University Heights without pumping.

DEVELOPMENT IN MEXICO

Farther downstream, below Morena and Barrett, within the same valley and drainage system of Cottonwood Creek, close to the Mexican border, lies the Marron Reservoir site owned by the City of San Diego, understood to have been purchased at the same time as Morena and Barrett, as a part of the so-called "Spreckels System" and awaiting development by San Diego whenever the time is ripe.

This dam site and reservoir site has been surveyed. Although the dam site has not been thoroughly explored by borings, the surface indications are favorable for the construction of a dam of the earth or rock fill type, of almost any desirable height up to 150 feet or more.

The surveys show that a dam 150 feet high would store about 77,530 acre feet of water with surface at elevation 656.5. The dam as heretofore planned would have its southerly end barely across the international boundary within Mexico, and a considerable part of the ground flooded by the reservoir would be across the international boundary.

The delivery pipe to San Diego would necessarily traverse several miles of Mexican soil, unless a tunnel should be built all within the United States at a cost which now seems utterly beyond reason.

It would be feasible to build the Marron dam all on American soil, at somewhat greater cost, but flowage would extend unavoidably into Mexico.

Various difficulties, some of them international, seem to surely put this project far in the future and last in the series, but I have no doubt that it will be needed by the City of San Diego at some future time and all rights pertinent to it should be steadfastly conserved and strengthened whenever opportunity offers. When the time comes for building the Marron reservoir, it is probable that a branch line into the small Mexican city of Tijuana would be helpful in securing rights of way.

DUPLICATE CONDUITS

As already suggested, it now seems highly important for safety from earthquake and other possible accidents or emergencies, that the next sources to be developed should be north of San Diego and that the new main conduit should be independent from the present conduit and come from the opposite direction.

GARCIA SITE IN MEXICO

Before proceeding to the northern sources, here is as good a place as any, to mention the possibilities of the Garcia site. This dam and reservoir site lie about seven miles south of the international boundary, on the Tijuana River which has a large drainage area, mostly unsurveyed but in a land of little rain, where there are few, if any, records of either rainfall or run-off.

From the study of the many records of rainfall and run-off in San Diego County, the rainfall surely diminishes to the south and from a personal inspection of the dam site and such old and recent flood marks as can now be seen, I concluded that the flood volume here was much smaller than one would expect from the reported size of the watershed and by analogy from the records on the San Diego River.

The dam site has been surveyed in outline and I find that it looks fairly good, with hard bedrock showing on both sides of the narrow, sand-filled gorge. No one knows the depth to hard rock in midstream. It may be very deep. This site is very conveniently accessible from the railroad.

The reservoir volume has been surveyed and by inspection from the high hill near its northwestern end it also looked fairly good, although evaporation would be large.

As a whole from one-half day's examination I found the Garcia Site less attractive than several sites within San Diego County. It seems highly probable that the Mexicans would feel that at some future time they would themselves want to develop this site for irrigation, and that the international complications about taking this water away from Mexico and into the United States must be reckoned as placing it beyond reach.