RETURN TO:
Ward Engineering Company,
315 Montgomery Street,
San Francisco, California.

OCTOBER 17, 1936

REPORT

ON

CLEAR LAKE WATER COMPANY PROJECT

WOODLAND, YOLO COUNTY, CALIFORNIA

CLEAR LAKE WATER SUPPLY

INDIAN VALLEY RESERVOIR WATER SUPPLY

INDIAN VALLEY STORAGE DAM COST ESTIMATES

VALUATION - CLEAR LAKE WATER COMPANY PROPERTIES

PROJECT REPORT NO. 1

FRED H. TIBBETTS
CIVIL ENGINEER
SAN FRANCISCO

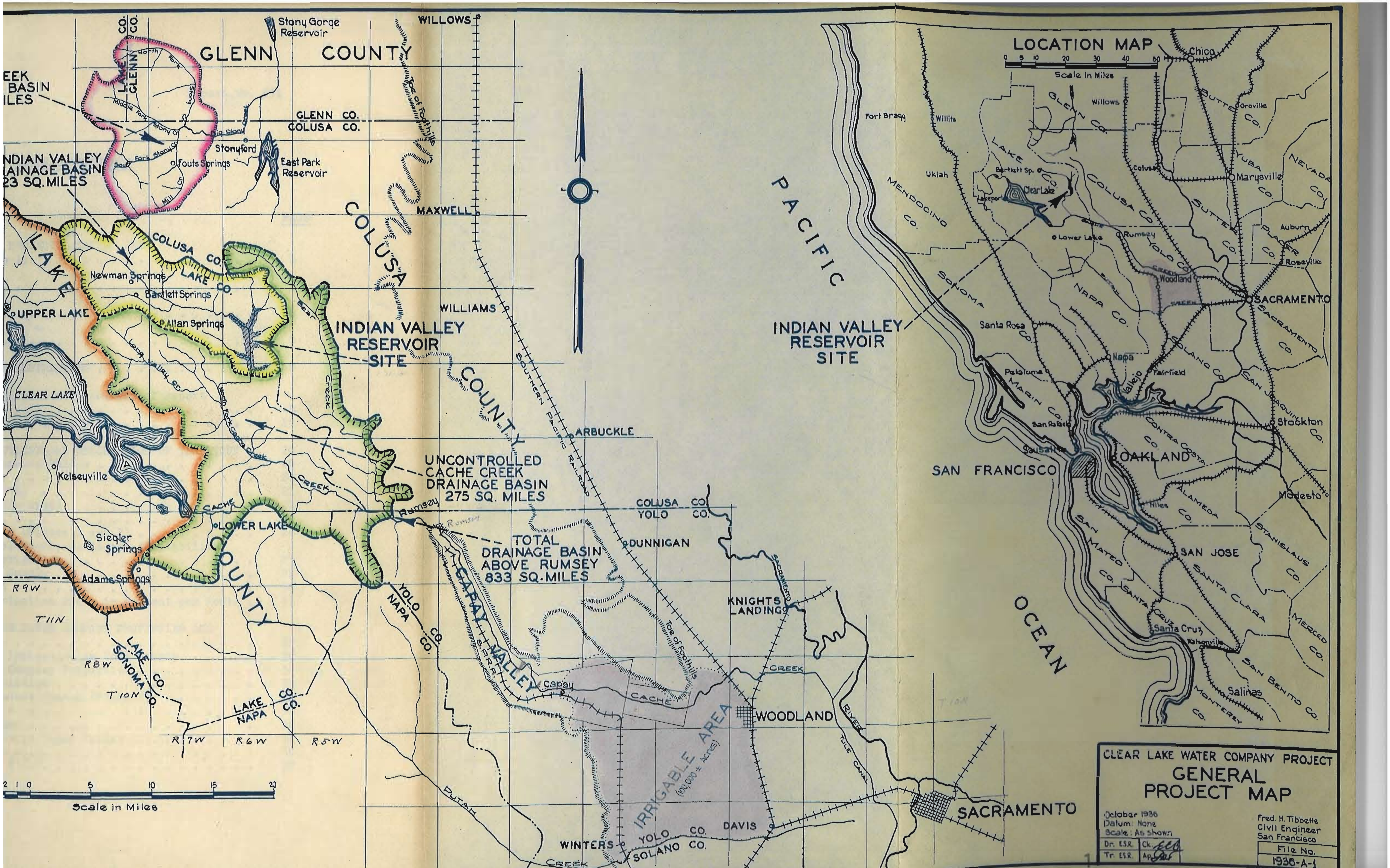
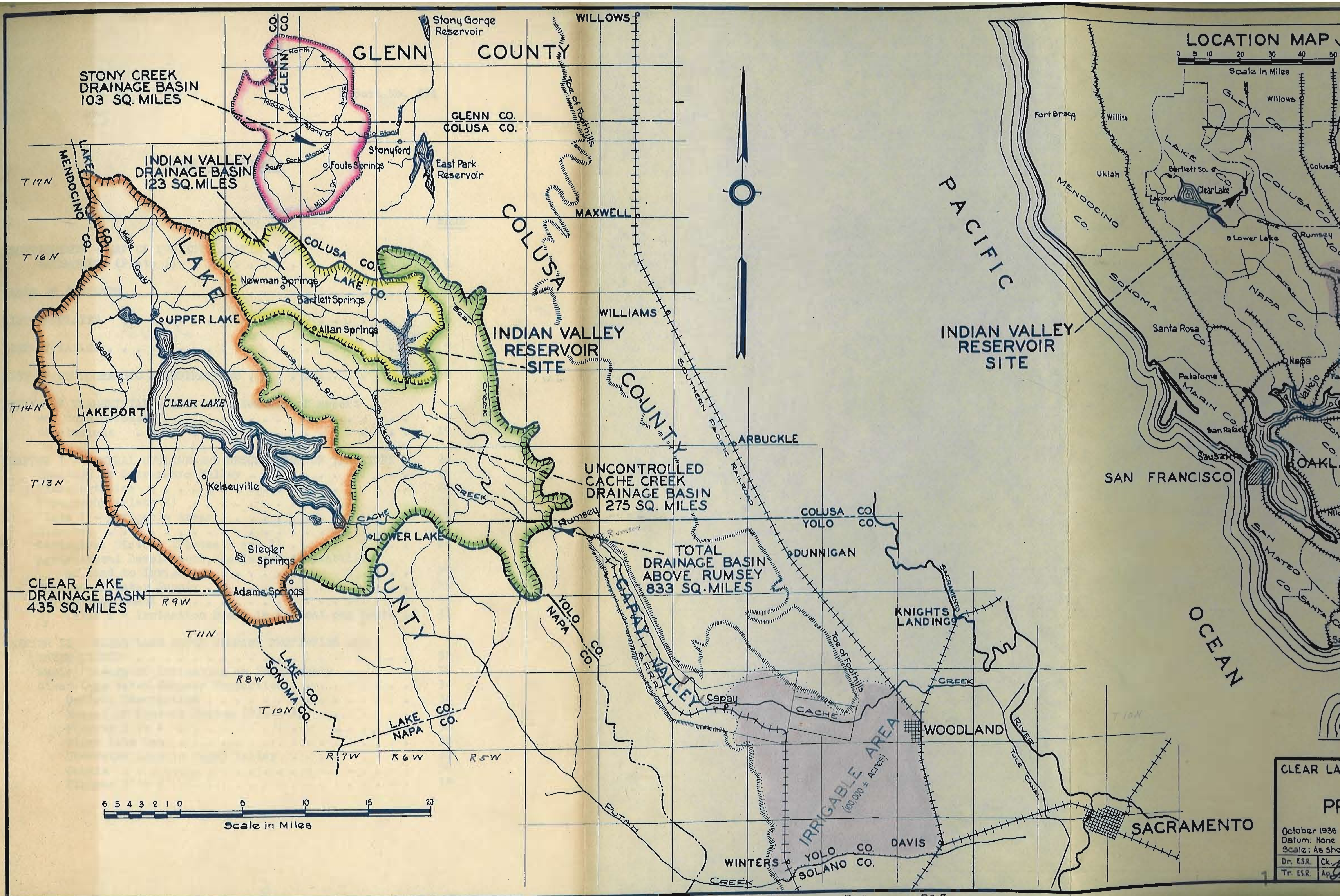

CLEAR LAKE WATER COMPANY PROJECT
GENERAL PROJECT MAP
October 1936
Datum: None
Scale: As shown
Dr. ESR.
Tr. ESR.
Fred. H. Tibbetts
Civil Engineer
San Francisco
File No.
1936-A-1
LOCATION MAP
Scale in Miles
GLENN COUNTY
COLUSA COUNTY
LAKE COUNTY
YOLO CO.
NAPA CO.
Stony Gorge Reservoir
East Park Reservoir
Stonyford
Fouts Springs
INDIAN VALLEY DRAINAGE BASIN 23 SQ. MILES
INDIAN VALLEY RESERVOIR SITE
UNCONTROLLED CACHE CREEK DRAINAGE BASIN 275 SQ. MILES
TOTAL DRAINAGE BASIN ABOVE RUMSEY 833 SQ. MILES
CLEAR LAKE
UPPER LAKE
Newman Springs
Bartlett Springs
Allan Springs
Kelseyville
Siegler Springs
Adams Springs
LOWER LAKE
Rumsey
CAPAY VALLEY
Capay
IRRIGABLE AREA (100,000 ± Acres)
WOODLAND
DAVIS
WINTERS
SACRAMENTO
KNIGHTS LANDING
DUNNIGAN
ARBUCKLE
WILLIAMS
MAXWELL
WILLOWS
SOUTHERN PACIFIC RAILROAD
Toe of Foothills
CACHE CREEK
PUTAH CREEK
SACRAMENTO RIVER
TULE CANAL
COLUSA CO. YOLO CO.
GLENN CO. COLUSA CO.
YOLO CO. SOLANO CO.
LAKE NAPA CO.
LAKE SONOMA CO.
Scale in Miles
R9W R8W R7W R6W R5W R4W R3W R2W R1W R1E R2E
T11N T10N
PACIFIC OCEAN
SAN FRANCISCO
OAKLAND
SAN JOSE
Stockton
Modesto
Chico
Oroville
Marysville
Auburn
Roseville
Santa Rosa
Napa
Petaluma
Vallejo
Fairfield
San Rafael
Sausalito
Santa Cruz
Salinas
Fort Bragg
Willits
Ukiah
Lakeport
Rumsey
Lower Lake
Colusa
Woodland

PLATE I



GLENN COUNTY
Stony Gorge Reservoir
WILLOWS
STONY CREEK DRAINAGE BASIN 103 SQ. MILES
LAKE CO.
GLENN CO.
GLENN CO.
COLUSA CO.
Stonyford
East Park Reservoir
Fouts Springs
INDIAN VALLEY DRAINAGE BASIN 123 SQ. MILES
MENDOCINO CO.
LAKE CO.
T17N
T16N
T14N
T13N
T11N
T10N
COLUSA CO.
LAKE CO.
COLUSA
MAXWELL
Toe of Foothills
Newman Springs
Bartlett Springs
Allan Springs
UPPER LAKE
LAKE
WILLIAMS
INDIAN VALLEY RESERVOIR SITE
CLEAR LAKE
LAKEPORT
Kelseyville
COUNTY
SOUTHERN PACIFIC RAILROAD
ARBUCKLE
UNCONTROLLED CACHE CREEK DRAINAGE BASIN 275 SQ. MILES
CACHE
CREEK
Rumsey
COLUSA CO.
YOLO CO.
LOWER LAKE
TOTAL DRAINAGE BASIN ABOVE RUMSEY 833 SQ. MILES
DUNNIGAN
Siegler Springs
CLEAR LAKE DRAINAGE BASIN 435 SQ. MILES
Adams Springs
R9W
COUNTY
YOLO CO.
NAPA CO.
CAPAY VALLEY
KNIGHTS LANDING
SACRAMENTO
LAKE CO.
SONOMA CO.
R8W
LAKE CO.
NAPA CO.
R7W
R6W
R5W
Capay
CACHE
CREEK
WOODLAND
IRRIGABLE AREA (100,000 ± Acres)
TULE CANAL
RIVER
PUTAH
6 5 4 3 2 1 0 5 10 15 20
Scale in Miles
WINTERS
YOLO CO.
SOLANO CO.
DAVIS
CREEK
SACRAMENTO
R4W
R3W
R2W
R1W
R1E
R2E
T10N
PACIFIC
OCEAN
INDIAN VALLEY RESERVOIR SITE
SAN FRANCISCO
OAKLAN
LOCATION MAP
0 5 10 20 30 40 50
Scale in Miles
Willows
GLENN CO.
Fort Bragg
Willits
LAKE CO.
COLUSA CO.
Colusa
Ukiah
Bartlett Sp.
Clear Lake
Lakeport
MENDOCINO CO.
Lower Lake
Rumsey
YOLO
SONOMA
NAPA CO.
Santa Rosa
Napa
Petaluma
Vallejo
MARIN CO.
San Rafael
Sausalito
CONTRA CO.
Niles
SAN MATEO CO.
SANTA CRUZ
CLEAR LAKE
PRO
October 1936
Datum: None
Scale: As Shown
Dr. ESR
Tr. ESR

FRED. H. TIBBETTS
CIVIL ENGINEER

Report No. 531.

REPORT

on

CLEAR LAKE WATER COMPANY PROJECT

Woodland, Yolo County, California

-oOo-

Clear Lake Water Supply
Indian Valley Reservoir Water Supply
Indian Valley Storage Dam Cost Estimates
Valuation - Clear Lake Water Company Properties

-oOo-

PROJECT REPORT NO. 1
October 17, 1936

-oOo-

Fred. H. Tibbetts
Civil Engineer
San Francisco

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TELEPHONE SUTTER 5728

MEM. AM. SOC. OF CIVIL ENGS.
MEM. AM. INST. OF ELEC. ENGS.

FRED. H. TIBBETTS
CIVIL AND
CONSULTING ENGINEER
ALASKA COMMERCIAL BUILDING
SAN FRANCISCO, CALIF.

SUBJECT REPORT ON CLEAR LAKE WATER COMPANY PROJECT FOR IRRIGATION OF LANDS IN YOLO COUNTY, CALIFORNIA

LETTER OF TRANSMITTAL
(CONTAINING SUMMARY OF REPORT AND RECOMMENDATIONS)

October 17, 1936

E. R. Chambers, Esquire,
1428 Franklin Street,
Oakland, California.

Dear Sir:

The accompanying preliminary report contains a general description and appraisal of the operating properties of the Clear Lake Water Company serving irrigation water for lands in Yolo County, California. It also contains a preliminary report with preliminary designs and cost estimates for augmenting the present water supply by the construction of large new storage facilities at Indian Valley, on the North Fork of Cache Creek. A study is then made of the combined water supply which might be available to the Clear Lake Water Company from:

1. Releases from Clear Lake during the irrigation season as they have actually been made in recent years, under existing legal decisions limiting use of Clear Lake for storage.

2. Additional amounts which might be obtained from a relatively large storage reservoir (157,000 acre feet) at Indian Valley, designed to be operated for cyclic or carry-over storage.

3. Additional water which might be obtained during the irrigation season from the natural runoff of the large area above the head of Capay Valley and below the points of storage control at Clear Lake outlet and Indian Valley Reservoir.

It is concluded that there is sufficient water to justify placing under irrigation about 75,000 acres of the approximately 100,000 acres now fairly well covered by the existing irrigation distribution system diverting water through the Company's canals. This is one of the finest bodies of land in the entire State of California, both from the standpoint of location, productivity, accessibility, climate and transportation. A considerable portion of it should eventually go into fruit or vines, and most of the balance to alfalfa, as a basis for dairying and stock production, and to irrigated field crops. In normal years there will be sufficient water available for a considerable area in rice, in addition. The development of 75,000 acres of irrigated land is based upon a duty of water of two feet at the irrigated fields, this relatively high duty of water being justified by the probability that a considerable portion of the area will be in fruit and vines.

It is estimated that of the 75,000 acres to be developed as irrigated land, 20% in any one year would be unirrigated, much of this being in roads, rights of way, building areas and dry farmed. This would indicate a delivery at the fields for sale of 60,000 acres at 2 acre feet per acre, or 120,000 acre feet per year. If the recommended developments by the Company could insure certain delivery, the water should be worth at least $2.00 per acre foot, giving a gross revenue of $240,000. per year.

Some of the largest canals are now lined with concrete in porous areas, and the total distance to delivery points will not average more than about ten miles, so that it is believed that 15% should be ample for transit and regulating losses, requiring at the diversion points 141,000 acre feet per year for normal full irrigation demand. The plan here proposed would have given an average amount of surface water available at diversion points on Cache Creek during irrigation seasons, of about 130,000 acre feet or 92% of full requirements per year in the last twenty years, which last twenty years constitutes a long dry cycle with average water production apparently between 85% and 90% of the normal of the past sixty years.

The area of 75,000 acres proposed for irrigation is further based upon the assumption that on occasional dry cycles a shortage of about one-third could be tolerated. In the practical working out of agricultural operations in a semi-arid country such as this, a shortage as much as indicated would mean only reduced water supply with somewhat reduced production, usually more than compensated by higher prices because of the more or less complete failure of crops in unirrigated areas.

There appear to have been three years in the last sixty, all of them coming in extraordinarily dry cycles of about five years duration, in which there could not have been produced sufficient surface runoff to furnish even two-thirds of the normal supply. The worst drought of this period was the recent one of 1930-34, for which full and accurate records are available. For over fifty years back to 1884 the works here proposed would have given sufficient surface runoff to provide for the 75,000 acre project.

The low record of the Clear Lake Water Company sales occurring in this period shows, according to the Railroad Commission reports, that in 1931 and 1933, both with no water released during the irrigation season from Clear Lake, the Company sold but 7,130 and 6,654 acre feet, respectively, in these two years. With the project herein proposed, there would have been available surface water during even these two years, principally from Indian Valley Reservoir releases, of 126,369 acre feet in 1931 and 33,850 acre feet in 1933. In such rare, very dry years, it is suggested that the deficiency could readily be met by auxiliary pumping, i.e., by the use of accumulated underground storage. This involves a principle relatively new in irrigation, but recently widespread in many parts of the West, especially California and Arizona. Underground storage is the sole source of water supply in many of the most prosperous regions of California, such as the Santa Clara Valley. Unusually good facilities apparently exist in this section for drawing on underground storage. The entire area of Capay Valley immediately above the Company's diversion points, and a large area below the mouth of the Capay Valley, is evidently composed in considerable part of water-bearing gravels and sands and the most ideal conditions exist for replenishment of underground storage directly from the river and from the adjacent irrigated areas.

That there is abundant water to completely replenish the underground storage in this vicinity is well indicated by the classic Bulletin No. 5 of the State of California Public Works, "Flow in California Streams," page 205, where the mean seasonal runoff of Cache Creek is given as 586,000 acre feet and the minimum as 174,600 acre feet. This is down to 1921 and does not include the recent twenty year dry cycle in which our estimates indicate an average runoff wasted past Yolo of about 153,000 acre feet, or a waste alone, more than sufficient for the irrigable area of Cache Creek.

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Recent developments have indicated that underground storage, within the limits of economical pumping, can, if properly developed, be relied upon to equalize the dry seasons of twenty years or more.

The development of irrigation from Cache Creek started over three-quarters of a century ago. It has one of the most fascinating and interesting histories of any agricultural enterprise in California. There is an abundance of historical data and engineering skill of record to draw upon, with which are connected the names of a number of the most eminent engineers of California, including some of international reputation.

Normal or wet cycles in the past have evidently produced an abundant runoff from Cache Creek, partially under natural regulation at Clear Lake, and resulted in over-optomistic enterprises being proposed. In a report of the California State Engineer as early as 1880, a very prominent hydraulic engineer describes a projected canal from Cache Creek to be large enough to be navigable, and "to extend to deep water in Suisun Bay or elsewhere." A study of the records shows that 1880 had been preceded by some very wet years. In 1901, two very excellent reports appear by some of the best engineering talent of that period. One of these is the U. S. Department of the Interior Water Supply and Irrigation Paper No. 45, "Water Storage on Cache Creek, California," by A. E. Chandler, later State Water Commissioner of California. This contains a very excellent preliminary report on the proposed Indian Valley reservoir project, designed for a storage much less than now proposed, but in those days it must be remembered that the science of dam building was in its early stages, and that the periodic occurrence of weather cycles as dry as have occurred in the last five and in the last twenty years was not then fairly appreciated.

About the same time appears a report prepared by Elwood Mead, distinguished engineer of international reputation, and later Director of the United States Reclamation Service, this being Bulletin No. 100 of the United States Department of Agriculture, containing an excellent and comprehensive article on irrigation investigation on Cache Creek by J. M. Wilson, Civil Engineer and agricultural expert. Much of the volume of Wilson's report is occupied by criticism of the unfortunate condition in which the water rights were at that time.

The writer also has the advantage of a report prepared in 1914 on the little Indian Valley reservoir site by the late C. E. Grunsky, Past President of the American Society of Civil Engineers. We are also fortunate in having at hand a "Geological

Report on the Indian Valley Reservoir and Dam Site," by an eminent geologist, Chester Marliave, now Chief Geologist of the Department of dams of the State of California.

Even the writer of this report, youthful and inexperienced in comparison with the great engineers of the past mentioned above, who have studied this problem, had his first connection with irrigation from Cache Creek, when during a summer college vacation in 1904 he operated a pumping plant, which at that time was able to pump water all summer long, at Yolo. On a former occasion a few years ago, we also made a professional investigation and report on the Indian Valley Reservoir Project.

We also have a very excellent report and very detailed appraisal of the properties of the Clear Lake Water Company made in 1925 by Walter H. Davis, then Consulting Engineer of the Clear Lake Water Company. The construction features of the Clear Lake Water Company, quantities, etc., are very completely and accurately described, listed and tabulated by Mr. Davis, and as there has been little additional construction since that time, these quantities, together with the condition of the dams and canals as checked up during the preparation of this report by the writer and his assistants, have formed an excellent basis for an appraisal of the present properties. During the preparation of this report the

Indian Valley Reservoir site has been again examined by Mr. H. I. Wood, Chief Field Engineer of the writer's staff and an expert who has supervised for us the construction of about twenty dams of varied types. The operating properties in Yolo County have also been examined in detail by Mr. R. P. Bryan, an engineer of wide experience in the construction and valuation of irrigation properties.

CONCLUSIONS

It is concluded that sufficient water can be developed for the irrigation from surface supply of about 75,000 acres of some of the best land in California, in Yolo County. Once in about fifteen years there would be shortages in the normal supply of as much as one-third, and three years in the last sixty it would have been desirable and entirely practical to supplement the unusually meager surface runoff by pumping from accumulated underground water storage. As this would have to be done only at rare intervals, the total cost would not be great.

During normal seasons the Company would know in advance, and in ample time for planting rice, that it would also have additional water which it could guarantee for delivery to a considerable acreage of rice, and the additional revenue therefrom should be sufficient to meet the probable cost of the very rare occasions in which the irrigation supply for the 75,000 acres should be supplemented by pumping.

These rare occasional super-shortages could be made up in part by increasing the proposed storage at Indian Valley, a construction operation which would be simple, which could be performed in one season, and which would be relatively inexpensive. It should be delayed until the extension of irrigation in the project had developed the full irrigation demand and the exhaustion of storage in the reservoir had forecast the probable advance of another very dry cycle. The years of extra meager runoff on a watershed of this type must always be preceded by one or two subnormal seasons.

The project herein proposed should be able to offer for sale an average of 120,000 acre feet per year at the fields, in most years which at $2.00 per acre foot should yield an average gross revenue of $240,000. per year.

The present distribution system is so comprehensive, and the main canals in such excellent shape, that only nominal additions would be required for distribution facilities. Based upon operating costs as of record in Railroad Commission annual reports, it is estimated that the normal cost of operation and maintenance, including depreciation, of the proposed system to deliver the quantities as above would be $60,000. per year.

The estimated reproduction cost of the existing facilities of the Company, including the actual costs of acquiring the Company's valuable water rights, is $1,643,000. The estimated cost of the Indian Valley storage project as herein recommended, with 157,000 acre feet of storage, is $841,000., and of the auxilliary pumping works $250,000.

Total New Construction		$1,091,000.
Value of Present System		1,643,000.
	Total	$2,734,000.

Estimated Net Annual Revenue $180,000. = 6.6%

Irrigation development on Cache Creek has been intensively studied for many years by many very eminent engineers, so that ample and authoritative data are available upon which to base the foregoing conclusions.

Respectfully yours

[signature]

Civil Engineer

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CLEAR LAKE WATER COMPANY PROJECT

CHAPTER I. GENERAL OUTLINE AND DESCRIPTION OF TERRITORY

LOCATION IN SACRAMENTO VALLEY (PLATE 1.)

The project of the Clear Lake Water Company, the subject of this preliminary report, while it derives its water supply principally from Lake County, is intended to irrigate a large body of extraordinarily fine land in Yolo County, comprising some of the best land in the southern portion of the west side of the Sacramento Valley.

The 75,000 acres proposed for irrigation under this project centers a few miles southwest of Woodland, the county seat of Yolo County, which is about 15 miles northwest of Sacramento, the State Capitol, and about 70 miles northeast of the metropolitan area of San Francisco Bay. It occupies one of the most favorable locations in the great central valley of California.

TRANSPORTATION (PLATE 1.)

This area has been well developed for over a half century and already has excellent transportation facilities. The main line

(Shasta Route) of the Southern Pacific Railroad extends through the easterly portion of the area, Woodland being a junction point of the railroad with a branch line extending northeasterly up the east side of the Sacramento Valley. The Sacramento-Northern Electric Railroad, affiliated with another transcontinental line, the Western Pacific Railroad, has a branch line terminating at Woodland. The main route of the State Highway from San Francisco to Oregon and Washington extends through the western portion of the area, with numerous other paved roads extending to Sacramento and through the entire area and through Capay Valley westerly from Woodland. Water transportation of freight on the Sacramento River is but a few miles to the eastward.

TOPOGRAPHY (PLATE 2.)

The topography of most of the entire area is ideal for irrigation development. Two large tributaries of the Sacramento River from the west, Cache Creek and Putah Creek, run through the northerly and southerly edges of the tract, and each have built up broad, smooth, alluvial ridges of excellent soil. The main slope of the entire area, however, is gently toward the east, that is, from the foothills toward the axis of the Sacramento Valley. Much of the area to be irrigated has a slope of about 10 feet to the mile, which is ideal for the development of irrigated agriculture, giving economical grades for irrigation distributing ditches and at the same time leaving ample slope for proper drainage. The

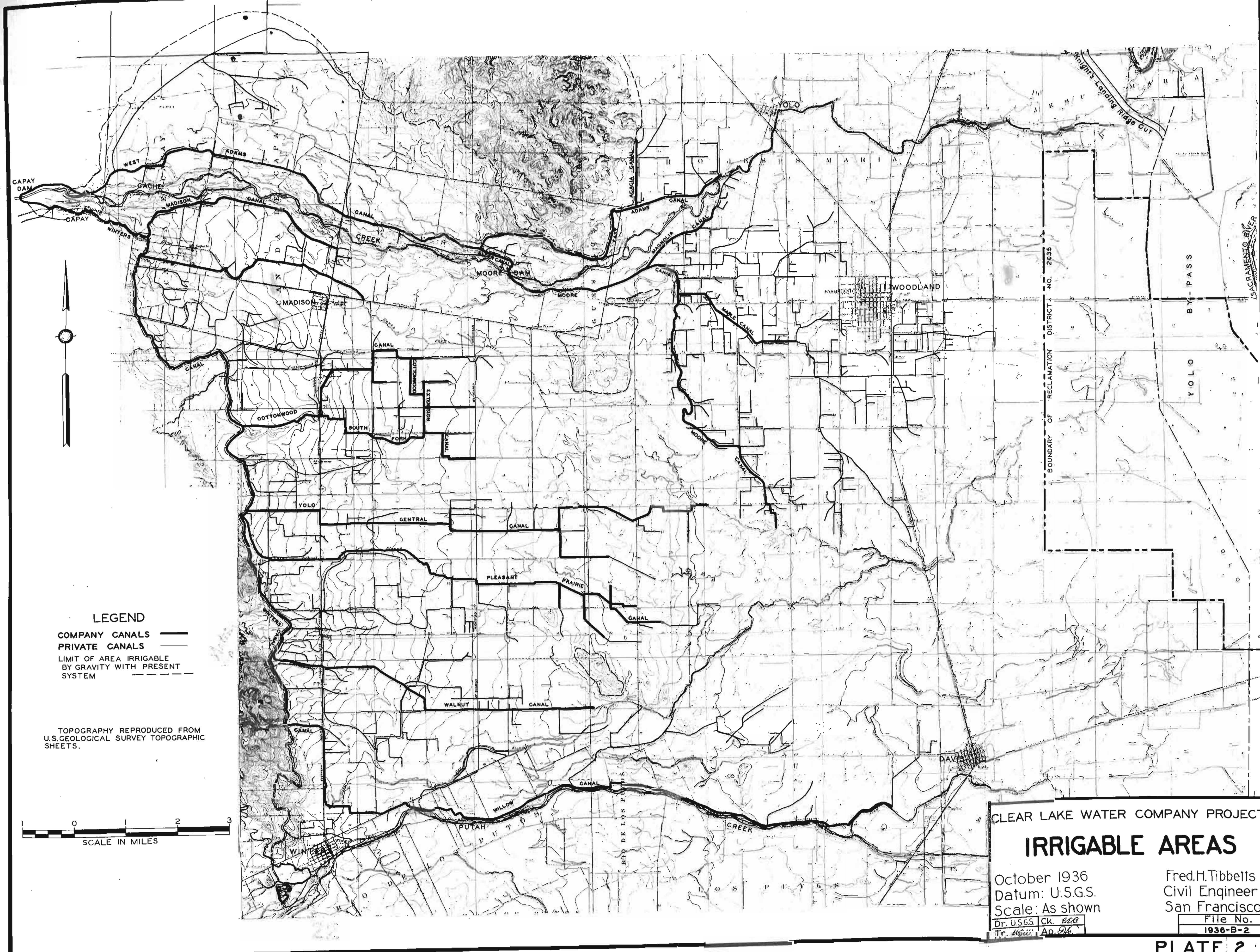
CLEAR LAKE WATER COMPANY PROJECT
IRRIGABLE AREAS
October 1936
Datum: U.S.G.S.
Scale: As shown
Fred. H. Tibbetts
Civil Engineer
San Francisco.
Dr. U.S.G.S.
Ck.
Tr.
Ap.
File No.
1936-B-2
LEGEND
COMPANY CANALS
PRIVATE CANALS
LIMIT OF AREA IRRIGABLE BY GRAVITY WITH PRESENT SYSTEM
TOPOGRAPHY REPRODUCED FROM U.S. GEOLOGICAL SURVEY TOPOGRAPHIC SHEETS.
SCALE IN MILES
1
0
1
2
3
CAPAY DAM
CAPAY
WEST
ADAMS
CACHE
MADISON
CANAL
WINTERS
CREEK
MOORE DAM
MADISON
YOLO
WOODLAND
ACACIA CANAL
MAPLE CANAL
MAGNOLIA
MOORE
COTTONWOOD
SOUTH
FORK
EXTENSION
CENTRAL
PLEASANT
PRAIRIE
WALNUT
WILLOW
PUTAH
DAVIS
RIO DE LOS PUTOS
Knights Landing Ridge Cut
SACRAMENTO RIVER
YOLO BY-PASS
BOUNDARY OF RECLAMATION DISTRICT NO. 2035

PLATE 2

existing distribution ditches covering most of this area are the result of a long period of development of irrigated agriculture, so that they are already adjusted so as to well fit the topography and irrigated surface.

CLIMATE

The climate of the Sacramento Valley is highly favorable to intensive agriculture. The mean monthly temperatures range from about 48° in winter to 72° in summer, with an extreme range from slightly below freezing point occasionally to slightly over 100° at times. The frost free period ordinarily extends from the middle of February to the middle of December and the growing season for fruits and vines from March to October, inclusive. Annual precipitation ranges from less than 8 inches to over 31 inches, with an average of about 17 inches (mean rainfall at Woodland for the fifty years 1886 to 1936). The distribution of this rainfall is typical of the central valleys of California, over 80% of the total occurring in the five months from November to March, leaving less than 20%, or about 3 inches, for the 7 months of the growing season.

As all other conditions are favorable for the development of irrigated agriculture in this region, and as agricultural prices look promising, at least for the near future, the value of these lands would be tremendously enhanced if they had sufficient assurance of a dependable water supply to warrant the development of irrigated agriculture.

GEOLOGICAL HISTORY (PLATES 1 and 2)

The soil in this area has been built up, in the main, by alluvial stream deposits from the Coast Range of mountains, particularly of the two main streams, Cache Creek and Putah Creek. The Coast Range mountains to the west, the erosion of which has formed the soil, are Franciscan formations of the Jurassic Age, composed mostly of sandstone and shale with some volcanic lava and frequent serpentine intrusions. The Franciscan formations are very old and much faulted, in a general direction parallel to the coast line and main mountain ranges of California.

The two large Sacramento Valley west side tributaries, Cache and Putah Creeks, flowing from west to east across the northern and southern edges of the tract, are approximately parallel and about 10 miles apart. Their alluvial ridges come near over-lapping and they have been depositing soil long enough so that most of the tract is composed of alluvial soil of high quality.

Capay Valley, (see Plate 1.) a long, narrow extension of the Sacramento Valley to the northwest, may be of particular interest. Cache Creek enters this valley at Rumsey, near its upper end, from a long steep canyon section, and has apparently deposited enormous quantities of gravel, filling up the floor of Capay Valley and extending onward along Cache Creek and out into the Sacramento Valley. It is believed that these gravel deposits afford unusually favorable conditions for the certain development of economical underground storage which can be drawn upon in emergencies of particularly dry seasons at long intervals.

An engineering investigation as far back as 1900 noted particularly the fact that, even though the creek through Capay Valley in the summer time might be dry, "rising water" appeared beyond the lower end of Capay Valley and this, apparently, was originally responsible for the selection of the admirable location of the old Moore Ditch headgates, water being divertible from the creek at this point later in the season than anywhere else. The underflow from Capay Valley is brought to the surface near this point either because the gravels became merged or submerged in the predominantly tighter deposits of the floor of the more gently sloping Sacramento Valley, or possibly because the ancient gravel aquifers may have been faulted off along the edge of the westerly hills, which is about at this point.

Clear Lake itself has an interesting geological history. For long periods of time the drainage of this area apparently went northwesterly into the Russian River. The lake itself appears to have been formed by an enormous landslide at Blue Lakes. This, of course, occurred ages ago and may likely have synchronized with a wet period when the old Franciscan formations were deeply saturated and possibly badly shaken by a prehistoric earthquake. In recent geological times, Clear Lake has tended both to desilt and regulate the runoff from a large portion of the Cache Creek watershed. The effect of this would be to make the gravels deposited in Capay Valley comparatively free of silt and, hence, open, porous and efficient as underground storage reservoirs or aquifers.

Clear Lake, however, is highly inefficient as a storage reservoir during the dry years when an irrigation enterprise is most in need of water, because it is very shallow, being only 30 feet to 50 feet in depth, and its area so large in proportion to its watershed that in dry years most of its runoff evaporates in the lake. Early investigations of the hydrographs of Clear Lake, however, seem to indicate a strong probability that there were substantial contributions to the inflow into the lake from subterranean, and hence unmeasurable, sources.

AGRICULTURAL DEVELOPMENT, SOILS AND ADAPTABILITY OF LAND TO IRRIGATION

Yolo County is one of the richest agricultural counties in the State, and the area considered here, particularly during the dry farming period of the Sacramento Valley, produced many of the best grain crops; in fact the best quality of barley produced anywhere in the world comes now from the Hungry Hollow District just north of Cache Creek. Irrigation, starting many years ago, has apparently been developed during cycles of abundant rainfall to cover large portions of the entire tract and to demonstrate its exceptional productivity when supplied with sufficient water. There are some of the finest orchards and vineyards in California already in production in this area and, with a certain water supply, it seems particularly adapted also to the dairy and stock business, based upon irrigated alfalfa, and to the production of sugar beets and truck gardening, such as large scale production of lettuce, for example.

The U. S. Department of Agriculture has issued a "Soil Survey of the Woodland Area", 1911. The soil map accompanying this area shows quite an irregular distribution of a large number of soil types produced mostly from the alluvial deposits of Cache and Putah Creeks and consisting largely of the Yolo, Esparto and Capay series of loams, silts and clays. Among comments in the

Government soil bulletin on the Yolo series are the following: "In general, they are of great depth and are free from alkali and are among the most productive soils of the area". "Alfalfa, peaches, apricots, almonds and grapes are grown". "The soil is well adapted to the production of deciduous fruit, alfalfa, sugar beets, truck and a wide variety of general farm crops". Of the Esparto series, "it is recognized as an excellent grape soil". "This crop (alfalfa) produces good yields with irrigation, four crops being cut during the season". "The Esparto clay is adapted to general farm crops suited to the region and especially to alfalfa in connection with dairy farming".

SOURCES OF WATER SUPPLY

The extent of irrigation in this vicinity during the last half century has varied greatly, depending apparently not only on agricultural prices but upon the availability of water in Cache Creek during the irrigation season. The area irrigated and the extension of the irrigation distribution has tended to be excessive during cycles of normal or wet years. Even in such cycles, the flow of Putah Creek, another large stream on the southern edge of the district, is inconsiderable during irrigation seasons. Partially regulated, however, as it has been in the past by Clear Lake, the abundant flow during good rainfall cycles of Cache Creek has led to the extension of the irrigation system from Cache Creek even to and along the northerly bank of Putah Creek and as far east as the flood plane of the Sacramento Valley. The present distribution of water overlaps along the eastern edge a few miles east of Woodland, the large irrigation system of Reclamation District No. 2035, which brings pumped water in from the Sacramento River.

A very considerable amount of irrigation is also coming from wells. If a large body of land, such as proposed in this report, is continuously irrigated from surface water, then the availability within this area of well supplies for irrigation will be enhanced. Underground storage will continue to be replenished during normal or wet years by deep percolation from the irrigated areas, and in particular the very favorable underground storage reservoir underlying Capay Valley will be better replenished as the stream flow in Cache Creek through that valley during the summer time is increased and prolonged. This should result in the retention for emergency use of a large body of underground water which may be drawn upon in the very rare, very dry years.

IRRIGATION DEMAND

The net duty of water at the fields for this project has been assumed at the rather high figure of two acre feet per acre per year, because of the probability that a very considerable portion of this area would go into trees and vines due to the high fertility of the soil. The monthly distribution of this irrigation demand is charted on Plate 6 in Chapter V. The following Table I, the last column of which shows the monthly distribution adopted for this project, indicates that it is very close to the monthly distribution in use in the predominantly horticultural areas of the Nevada Irrigation District and very close to those proposed for the Sacramento Valley areas in Bulletin No. 6 of the State Department of Public Works on the State Wide Water Plan set up. For the purpose of comparison, the actual average monthly distribution of the last seven years of operation by the Clear Lake Water Company also is shown.

TABLE I

IRRIGATION DRAFT IN PERCENT PER MONTH

Month	Average of 7 years of Clear Lake Water Co. Rights	Nevada Irrigation District	State of California Dept. of Public Works Division of Engineering Bulletin No. 6		Adopted
			Foothill Area	Sacramento Valley	
Jan.	0.3	0	0	0	0
Feb.	0.2	0	0	0	0
Mar.	0.3	0	2	1	1
Apr.	4.9	7	2	5	5
May	20.5	18	15	16	18
June	23.0	20	20	20	21
July	24.3	20	22	22	22
Aug.	16.3	20	20	20	19
Sept.	7.6	15	13	12	11
Oct.	2.3	0	5	4	3
Nov.	0.2	0	1	0	0
Dec.	0.1	0	0	0	0

CHAPTER II. CLEAR LAKE WATER COMPANY PROPERTIES AND WATER RIGHTS

EARLY HISTORY OF IRRIGATION IN YOLO COUNTY

Excellent information is available in public and other authentic documents on the development of irrigation from Cache Creek. Information in particular is taken from the followin sources for this report:-

1. Appendix E of the report of the State Engineer of California, 1880, "Report of the Works and Practice of Irrigation in Yolo County."

   (J. D. Schuyler, a very eminent engineer at that time, proposed a navigable canal from Cache Creek to Suisun Bay. The writer judges there must have been more water in sight about that time than now.)

2. Bulletin No. 100 of the U. S. Bureau of Agriculture, "Report on Irrigation Investigations in California," prepared under the direction of Dr. Elwood Mead.

   (In this is an especially comprehensive article with maps and numerous photographs by J. M. Wilson, Civil Engineer and Agricultural expert. A large portion of this report is devoted to criticism of the unsatisfactory conditions of water rights on Cache Creek about 1900.)

3. U. S. Geological Survey Water Supply Paper No. 45, "Water Storage in Cache Creek, California" by A.E.Chandler, 1901.

(This contains by A. E. Chandler, later State Water Commissioner of California, State Engineer of Nevada and now eminent authority on irrigation law, a preliminary report on storage at Indian Valley.)

4. "Report on Little Indian Valley Reservoir Site" by C. E. Grunsky, March, 1914.

5. "Report and Analysis in re Reorganization and Issuance of Securities, Yolo Water and Power Company," October, 1925, by Walter H. Davis, Civil and Hydraulic Engineer of Sacramento and Los Angeles. This contains a very detailed inventory and appraisal of the company's properties.

The first irrigation from Cache Creek was undertaken in 1856 when James Moore began construction of a ditch to serve lands south of Cache Creek. A temporary dam of brush and gravel was constructed at the site of the present Moore Dam and about 3-1/2 miles of ditch completed. Only a small area was irrigated. In 1864 the ditch was enlarged and extended in two branches, one toward Woodland, the other southward, making a total of about 9 miles of main ditch and laterals.

In 1859 a group of farmers in the vicinity of Cacheville (now Yolo) constructed a ditch known as the Cacheville Ditch to irrigate lands on the north side of Cache Creek, diversion being made a short distance below Moore Dam. This ditch began operation in 1860, but functioned only a few years, due to conflict over water rights and ensuing litigation with James Moore, after which the project was abandoned.

In 1871, the Clear Lake Water Company began construction of a dam at the head of Capay Valley, a short distance above Rumsey Station, to divert water southward. This ditch, which was completed in 1874, was 9 miles long, only 6 miles of which were used. Two years later, litigation arose with James Moore over water rights and this project was abandoned. This ditch is now used only to serve a very small area in the vicinity of Rumsey.

During this early period and until about 1903, numerous new ditches diverting from Cache Creek were begun; some were finished, but all invariably were short lived, ending up in litigation with the Moore interests, who successfully defended their water rights against all comers. The Moore Ditch was thus the chief survivor operating, after over thirty years continuous litigation over the waters of Cache Creek. In 1900, the system included about 70 miles of canals and laterals.

In 1903 and subsequent thereto, the property and water rights of Mr. Moore and other interests passed into the hands of various water companies, finally being acquired by the present owners, The Clear Lake Water Company, in 1927. During this period, a large amount of construction work was done and the system materially enlarged and improved.

CLEAR LAKE WATER COMPANY PROPERTIES

GENERAL DESCRIPTION

Properties of the Clear Lake Water Company consist of water rights on Cache Creek and water and flowage rights and storage dam on

Clear Lake, together with two main diversion dams and many miles of canals and laterals and the various physical properties necessary for the operation of its irrigation system in Yolo and Lake Counties, as described hereafter.

EXTENT OF PRESENT SYSTEM (PLATE 2.)

The present system consists of storage facilities at Clear Lake, together with diversion dams, canals and laterals capable of serving approximately 75,000 acres in Yolo County, this area lying north of Putah Creek and, in general, between the Southern Pacific Railroad and the hills to the west.

With minor extensions of the small irrigation laterals, the system is so laid out that it will cover 75,000 acres anywhere in an area of about 100,000 acres, as shown on Plates 1 and 2, covering roughly the territory between Putah and Cache Creeks, including a belt on the northerly slope of the Cache Creek ridge, from the base of the hills to the west down into the floor of the Sacramento Valley as far east as Reclamation District No. 2035, where pumped water is brought in from the Sacramento River.

The waters of Clear Lake are controlled from low water to a point 7.56 feet above this low water by a fine, modern concrete dam at the lake outlet. Water thus released flows down Cache Creek a distance of about 38 miles to the Capay Diversion Dam, (Fig.3) located near the town of Capay about 20 miles west of Woodland. Here a concrete dam diverts the water into the Winters Canal to the south (Figs.9 and 11) and the Adams Canal (Fig.10) to the north. Water released from the Adams Canal through the Alder Canal is picked up at the Moore Dam, (Fig.4) a timber diversion structure across Cache Creek, located about 7 miles west of Woodland, and flows south from Cache Creek through the Moore Canal.

The system includes approximately 190 miles of company-owned canals and a number of private and cooperative canals owned and controlled by various farmers. These comprise three principal systems, the Winters, Adams and Moore.

The Winters Canal serves some 50,000 acres located south of Cache Creek and west of Woodland, including the towns of Esparto, Capay, Madison, Winters and Davis. Its principal laterals are the Yolo Central, Cottonwood, Madison, Willow, Walnut and Pleasant Prairie Canals.

The Adams Canal serves about 10,000 acres north of Cache Creek, the principal laterals being the Acacia (Fig.8) and Alder Canals.

The Moore Canal irrigates approximately 14,000 acres in the vicinity of Woodland. The Magnolia and Maple Canals (Fig.6) are its principal laterals.

The general location of the complete project is shown in Plate 1. The distribution system, with specific location of diversion dams and principal canals is shown in Plate 2.

CLEAR LAKE DAM

In 1914, the Clear Lake Dam was constructed at the outlet of Clear Lake. It is a fine modern concrete, gravity-type structure about 252 feet long and 42 feet high, equipped with 15 hydraulically operated sluice gates 5 feet by 7 feet, log chute, accumulator and appliances. For access to the dam, 5 miles of road were constructed, connecting with the existing county road.

To provide proper control for the release of Clear Lake, the channel at the lower end of the lake was widened and deepened, in 1916.

DIVERSION DAMS IN CAPAY VALLEY

The Capay Diversion Dam, (Fig.3) constructed in 1912-13, is of the concrete, gravity type, about 500 feet long and 15 feet high. Concrete headgates at each end of the dam, equipped with multiple sluice gates and manually operated hoists, divert water into the Winters and Adams Canals.

The Moore Diversion Dam, (Fig.4) built in 1904, is a timber structure about 400 feet long and 30 feet wide. At the south end of the dam a new concrete headgate, (Fig.5) built in 1931 and equipped with multiple sluice gates and manually operated hoists, diverts water into the Moore Canal.

CANALS

Canals range from about 5 to about 600 second foot capacities, with sizes and dimensions varying accordingly. The majority are unlined

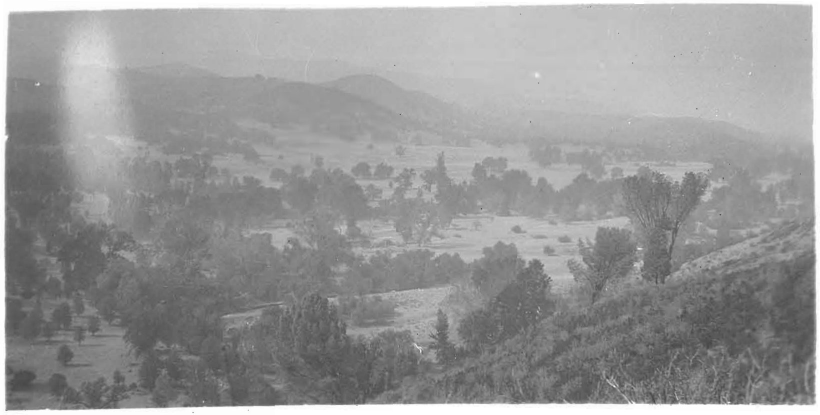

Fig. 1 - Indian Valley Reservoir Site from Left Abutment of Dam - September 26, 1936

Fig. 2 - Indian Valley Dam Site - Looking Upstream September 26, 1936

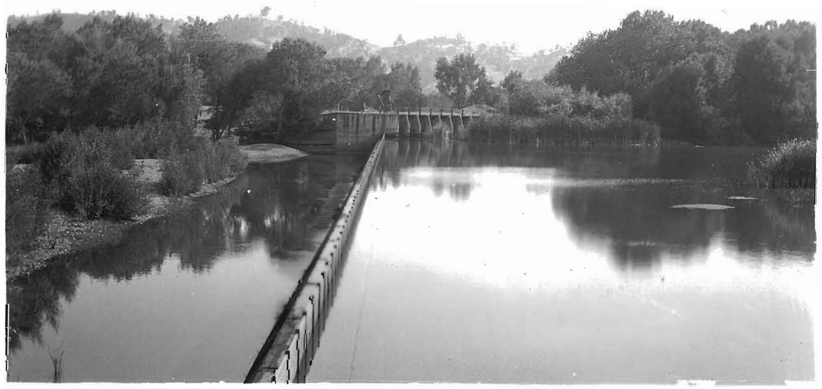

Fig. 3 - Capay Diversion Dam - In Background, Headgate of Winters Canal - September 23, 1936

Fig. 4 - Moore Diversion Dam and Headgate, of Moore Canal, - Garrette, Stevens, Chambers, & Tibbetts - September 22, 1936

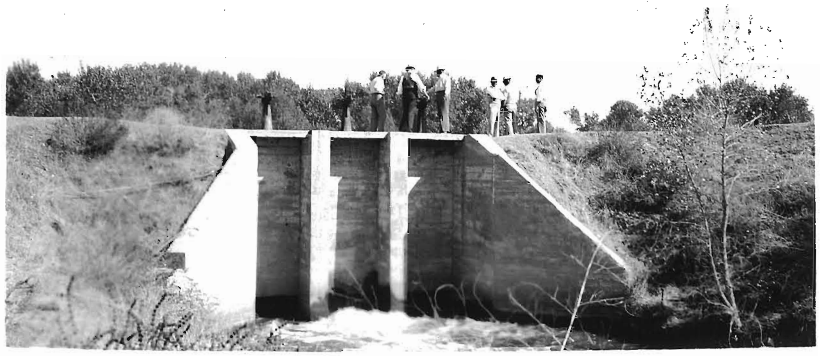

Fig. 5 - Moore Canal and Headgate - Garrette, Stevens, Chambers, Tibbetts - September 22, 1936

Fig. 6 - Concrete County Road Bridge on Maple Canal September 22, 1936

Fig. 7 - Cottonwood Flume on Winters Canal September 23, 1936

Fig. 8 - Acacia Canal - Combined Check and Delivery Gate - September 23, 1936

and have been excavated in earth or clay with stable slopes and sufficient freeboard. With the exception of occasional patches of tules or willows, the canals are in excellent operating condition. (Figs.9 and 12). In general, the water is carried below ground, being checked up by structures where field deliveries are being made.

CANAL LINING

Approximately 7.3 miles of canal are concrete lined and in excellent condition. The lining varies from 1-1/2 inches to 4-1/2 inches thick, depending upon soil conditions, height of water carried above ground, etc., but averages about 2-1/2 inches over the entire length. The concrete lining has been carefully constructed, is in excellent alignment and, altogether, is of very high standard. (Fig.10).

The principal sections of lining are as follows: Winters Canal 17,000 feet long, 17-1/2 foot bottom, height 5-1/2 feet, side slopes 1-1/4 to 1; West Adams Canal 7,300 feet long, 10 foot bottom, height 5-1/2 feet, side slopes 1 to 1; Moore Canal 14,300 feet long, 10 to 12 foot bottom, height 3.0 to 4.2 feet, side slopes 1-1/4 to 1.

STRUCTURES

Canal structures include county and farm bridges, headgates, delivery gates, waste gates, checkgates, drops, siphons, culverts, stock gates, retaining walls, bulkheads, drains, spillways, pipes, flumes, etc. and are of two general types, concrete and timber. There are approximately 260 concrete and 790 timber structures.

Fig. 9 - Unlined Section of Winters Canal from Lower End of Cottonwood Flume - September 23, 1936

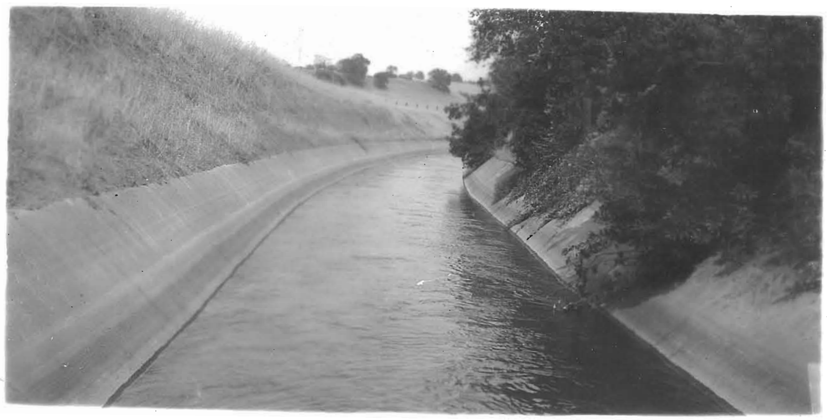

Fig. 10 - Adams Canal, Concrete Lined Section 500 Feet Below Intake - September 23, 1936

Fig. 11 - Winters Canal, Unlined Section, Lamb Valley Flume - September 23, 1936

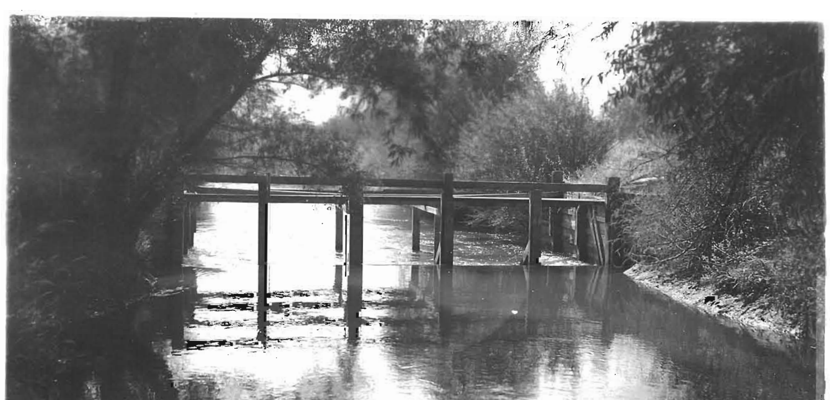

Fig. 12 - Winters Canal, Unlined Section, Timber Check Gate and Drop - September 23, 1936

The concrete structures are, in general, in very good shape and in many cases show practically no deterioration, despite 25 of 30 years service. The concrete appears of high quality, well constructed. Many of the structures are equipped with manually operated hoist gates.

Timber structures are in varying stages of repair - some, despite long age, are in excellent shape - others, in very poor shape. Many structures not used for years show considerable deterioration and decay, while many are worthless. In general, the structures which are being used continually have been kept up in good shape. Where structures have been replaced, the new construction is of high standard and well done. In recent years many concrete structures have been built replacing obsolete timber structures. The majority of timber structures are redwood. Typical structures are shown in Figures 5, 6, 7, 8, 11 and 12.

Where an irrigation distribution system has been in use as long as the one here described, the timber structures, as they have been shifted and replaced, tend to become fixed in the most efficient locations. Replacements for a large system are gradual and many structures are replaced piece by piece, so that after a while at any given time the existing structures, some new, some at the end of their usual life, will average about 50% depreciation. Because of the fact that the use of water in the recent dry cycle has tended to be much less than the capacity of the system, there is, as usual, considerable delayed maintenance work. After study and observation on the ground by the writer and two experienced engineers of his staff, the average depreciation of the timber structures of this system was placed for reproduction valuation purposes at 60%.

APPRAISAL OF PHYSICAL PROPERTIES BASED ON PRESENT REPRODUCTION VALUE LESS DEPRECIATION

Appraisal of physical properties has been based on the field observations and inspection of existing works by the writer and an experienced engineer of his staff during the week ending September 26th, 1936, together with a careful study of data as contained in available reports. Particular attention was paid in the field to deterioration and estimated useful life of structures, for the purpose of fixing depreciation values.

The entire appraisal of the physical properties is based upon the reconstruction cost, at present prices, of the existing system as a whole. Unit prices are used which are typical of construction costs of the past two years. For this portion of the system the bulk of the appraised value is based upon the following principal unit prices:

Canal Excavation	$ .20 per cu. yd.
Concrete in place in canal structures	22.00 per cu. yd.
Timber in place in canal structures	90.00 per M.B.M.
Concrete canal lining in place	.15 per sq. ft.
Land at three dam sites	20.00 per acre
Canal rights of way	150.00 per acre

The appraisal ("reproduction costs") of the physical properties of the Clear Lake Water Company is based upon unit prices as given above for the canals and laterals and their included structures, together with the rights of way, these items totaling about 76% of the total. The principal remaining items are the three dams, the storage dam at Clear Lake and the two diversion dams on Cache Creek. As these items, in the main, are permanent concrete structures not subject to depreciation, they are included in this valuation at the figures made in 1925 by Mr. Walter H. Davis, Civil and Hydraulic Engineer, who made a complete appraisal and valuation of the aforementioned properties in a report to the Yolo Water and Power Company, entitled "Report and Analysis in Re Re-organization and Issuance of Securities." His valuation was based on estimated historical costs, and was used as the basis for negotiations following which the Clear Lake Water Company succeeded to the rights and properties of the Yolo Water and Power Company in 1927. Contained in this report is a complete inventory of physical properties as of October 1, 1925, together with the quantities of excavation, concrete, timber, etc. entering into the construction of the canal system. Detailed quantities for the larger structures such as the Clear Lake Dam, Capay and Moore Dams, jetties and revetment work, Clear Lake Outlet Channel, road, etc. are not given, but lump sum figures are given. Inasmuch as Mr. Davis was Chief Engineer of the Yolo Water and Power Company during the seven year period when a large part of the construction work was done, these lump sum costs are based on much more accurate information than is available to us at this time, and probably represent a fair estimate of the actual present reproduction cost of these items. His figures on the dams are therefore accepted for purposes of this appraisal.

In connection with our field investigation "spot checks" were made on certain typical concrete and timber canal structures. Such structures were selected at random, dimensions measured, and the quantities computed and then compared with the figures in the Davis report, checking very well.

These itemized quantities, given for the various canal systems, were accepted therefore, as correct. The total volume of concrete in small structures, timber in small structures, lengths of pipe and flume, number of gate hoists, etc., were tabulated and summarized, and unit prices applied to each class. The resulting costs for each class were then depreciated in accordance with our estimate of useful life remaining, based on field observations.

To the resulting figures obtained for all physical property were added 16% for overhead costs:- incidentals, contingencies, administration, legal, engineering and interest during construction. This total gives the present valuation.

Percentages of depreciation used over the entire property are as follows:

Clear Lake Dam, road and outlet channel enlargement	-	No	depreciation
Capay Dam	-	"	"
Moore Dam	-	50%	"
Jetties, revetment, etc.,	-	50%	"
Canal excavation		No	depreciation

Concrete structures and lining in canals	-	No depreciation
Timber structures in canals	-	60% "
Corrugated Iron Pipe	-	50% "
Gate Hoists	-	50% "
Lennon Flume	-	33-1/3% "
Fence	-	50% "

The following table gives a summary of reproduction costs, depreciation and present values of the Clear Lake Water Company's physical properties determined by this appraisal.

TABLE II

SUMMARY OF VALUES OF CLEAR LAKE WATER COMPANY PHYSICAL PROPERTIES

Item	Reproduction Cost	Depreciation	Reproduction Cost Less Depreciation
Clear Lake Dam and Outlet Works			
Concrete Dam	$104,435.	$ 0.	$104,435.
Road to Dam	3,719.	0.	3,719.
Outlet Channel enlargement	59,307.	0.	59,307.
	$167,461.	$ 0.	$167,461.
Diversion Dams			
Capay Dam, Concrete	$43,723.	$ 0.	$43,723.
Moore Dam, Timber	10,321.	5,160.	5,161.
Jetties, Revetment, etc.	27,675.	13,837.	13,838.
	$81,719.	$18,997.	$62,722.
Canals			
Excavation	$334,784.	$ 0.	$334,784.
Concrete Lining	163,675.	0.	163,675.
Concrete Structures	75,704.	210.	75,494.
Timber & Misc. Structures	95,806.	56,117.	39,689.
	$669,969.	$56,327.	$613,642.

TABLE II (Continued)
SUMMARY OF VALUES OF CLEAR LAKE WATER COMPANY PHYSICAL PROPERTIES

Item	Reproduction Cost	Depreciation	Reproduction Cost Less Depreciation
Land and Rights of Way			
Land at Clear Lake Dam	$ 279.	$ 0.	$ 279.
Land at Capay Dam	200.	0.	200.
Land at Moore Dam	600.	0.	600.
Deeded Rights of Way	108,628.	0.	108,628.
	$ 109,707.	$ 0.	$109,707.
TOTALS	$1,028,856.	$75,324.	$953,532.
Plus 16% for Overhead Costs			152,565.
GRAND TOTAL			$1,106,097.

No estimate or appraisal has been made of personal property, including such items as a combination clamshell and suction dredger, a pile driver and barge, a gasoline launch and certain miscellaneous office and automotive equipment which was listed in the Davis Report of 1925 at $75,081., as little evidence of this was seen. Similarly no appraisal has been made of 1,120 acres of timber land located on Siegler Mountain upon which the Davis Report places a valuation of $8,400. and about which is written "This tract of land is not used nor useful to the operations of the company and will be disposed of."

WATER RIGHTS

CLEAR LAKE DIVERSION RIGHTS

The Clear Lake Water Company has diversion rights to certain waters of Clear Lake, together with flowage and prescriptive rights on

Clear Lake. These have been acquired over a period of years by the Clear Lake Water Company and its predecessors, through purchase, condemnation and otherwise. The Davis report goes into considerable detail in describing these rights and the manner in which they were obtained. For the purpose of this appraisal, the water right values, as set forth in the Davis report will be accepted, and valuation made accordingly. This valuation is given in Table III herewith.

TABLE III

VALUATION OF CLEAR LAKE WATER RIGHTS

Lakeport Fill	$40,150
Reclamation Surveys and Reports	14,958
10 foot Contour Survey and Maps	9,691
Legal and Condemnation Suits	42,034
Cache Creek Electric Co., 1320 acres	46,000
Flowage rights, 575 acres	38,271
Lands purchased in Fee and Resold Retaining Flowage Rights, 2655 acres	107,315
By right of prescription, 1281 acres	88,507
TOTAL	$386,926

It will be noted that, in the main, this procedure values the company's water rights for diversion from Clear Lake and the fluctuation of storage therein as the amounts which the company has actually paid for their acquisition in purchase of land, flowage rights, condemnation surveys, special legal work, etc. This procedure is believed to be sound. The company is a public service corporation and should, therefore, be entitled to value its water rights for rate fixing purposes at the cost to them of acquiring such rights.

The hydrographic studies of Chapters III and V, as shown graphically on Plate 6 in Chapter V, indicate that even during the last twenty year dry cycle the amounts of water obtainable by the Company from Clear Lake during the irrigation season averaged 72,800 acre feet per year. This would be equivalent to a capitalization of irrigation water rights from Clear Lake of $6.165 per acre foot of water diversion during the irrigation season; that is, when the Clear Lake water rights are used in conjunction with the storage project proposed in this report. This figure is, in a way, comparable with the valuation of $18.58 per acre foot of "safe net yield" obtainable during the irrigation season from the exercise of the water rights of the Kings River Canal, as agreed upon by the writer and Mr. A. Kempkey, Consulting Engineer of the San Joaquin River Water Storage District. (See Transactions of the American Society of Civil Engineers, Volume 94, page 267).

The valuation of $6.165 per acre foot for Clear Lake water rights is, of course, much less than the $18.58 agreed upon for the San Joaquin Valley project, but the latter was for yield in minimum years, and this figure, as deduced above for Clear Lake, is the average of a minimum twenty year dry cycle. These water rights would take on this value in connection with the present storage project because with the construction of the Indian Valley Storage Project and only by such construction could they be fully and economically used.

CACHE CREEK DIVERSION RIGHTS

In 1856 and subsequent years, James Moore acquired by purchase and otherwise, the right to the waters of Cache Creek for irrigation diversion, being made by a brush dam at the present site of the Moore's Dam. From 1860 to 1903, he was engaged in continuous litigation defending his rights from various individuals and companies seeking to appropriate the waters of Cache Creek. In this extended controversy, Moore was said to have spent upward of a quarter of a million dollars and in many cases it was carried to the Supreme Court, with decisions upholding all of his rights.

In 1903, Mr. Moore having died, the Yolo County Consolidated Water Company was organized and succeeded to all of his property and water rights, and also to all property and rights of the Capay Ditch Company, which was the only surviving litigant of the Moore interests.

On December 11, 1912, the Yolo Water and Power Company was organized and succeeded to all of the water and riparian rights together with all assets of the Yolo Consolidated, and also obtained more water rights along the upper portion of Cache Creek and Clear Lake. It also purchased the entire capital stock of the Cache Creek Electric Company, a California corporation who owned valuable riparian and other water rights along upper Cache Creek.

The Clear Lake Water Company was organized on May 5, 1927 and succeeded to all the properties and water rights of the Yolo Water and Power Company and subsidiary companies and at the date of this report, still retain control. There are certain additional water rights in Cache Creek below the Cache Creek Electric holdings which the Clear Lake Water Company claims by right of prescription.

The hydrographic studies of Chapter V indicate that the entire area of the Clear Lake watershed between Clear Lake and Rumsey, including the Indian Valley portion, would have yielded an average during the last twenty years of subnormal streamflow, in the irrigation season, of 14,300 acre feet per year. If this be valued at the same rate per acre foot, as proposed above, for the Clear Lake water rights, then the total value of the rights for direct diversion from Cache Creek would be 14,300 acre feet at $6.165, or a total of $88,160. and this seems quite reasonable in view of the sums that Moore is reported to have spent in successfully defending his water rights through the Supreme Court, which rights are now, admittedly, the first water rights in the natural flow of Cache Creek. ?

SUMMARY OF VALUES OF CLEAR LAKE WATER COMPANY

The following table summarizes the values of the Clear Lake Water Company's properties.

TABLE IV

SUMMARY OF VALUES OF CLEAR LAKE WATER COMPANY

1. Clear Lake Dam and Outlet Works	$167,461.	
2. Diversion Dams	62,722.	
3. Canals and Laterals with Structures	613,642.	
Total Physical Works	$843,825.	
4. Land and Rights of Way	109,707.	
Total Physical Works, Land and Rights of Way	$953,532.	
Plus 16% for Overhead Costs	152,565.	
Total Physical Works, Land and Rights of Way, plus Overhead		$1,106,097.
5. Water Rights from Clear Lake	$386,926.	
6. Water Rights Direct Diversion from Cache Creek and Natural Flow	76,005.	
Total Water Rights	$462,931.	
Plus 16% for Overhead Costs	74,069.	
Total Water Rights plus Overhead		$ 537,000.
Grand Total, Physical Works, Land, Rights of Way, and Water Rights, plus Overhead		$1,643,097.

CHAPTER III. CACHE CREEK REGULATED WATER SUPPLY

CLEAR LAKE WATER SUPPLY

WATERSHED (PLATE 1.)

Lake County, containing all of the Cache Creek and Clear Lake watersheds, has not been as well mapped as other parts of California. The best authority for the figures given herein for watershed areas and elevations comes from:

1. Forest Service Map of the "California National Forest," 1928.

   (This map is an excellent topographical map of the northern portion of the watersheds considered. The southern portion, including Indian Valley, is outside of the National Forest boundary line.)

2. Corps of Engineers, U. S. Army Technical Maps, 1916.

   (These contain in much detail portions of the topography, largely along the creek valleys.)

3. California State Water Commission Irrigation Map of California, 1922. (1 Sq.In. = 8 miles)

4. Map of Cache Creek and Clear Lake (About 6 miles to the inch) from the U.S. Office of Experiment Stations Bulletin No. 100, 1901.

The three principal divisions of the watershed areas above Rumsey at the head of Capay Valley are shown on the general project map of this report, Plate 1.

The significant watersheds for which the water supply was separately analyzed are the following:

Watershed of Clear Lake	435 square miles	52%
Watershed of the proposed Indian Valley Reservoir	123 square miles	15%
Total watersheds subject to close regulation on the proposed project	558 square miles	67%
Unregulated watershed below Clear Lake and the Indian Valley Reservoir Site and above Rumsey	275 square miles	33%
Total Cache Creek Watershed above Rumsey	833 square miles	100%

The Clear Lake watershed varies in elevation from about 1300 feet at the surface of Clear Lake to a maximum of 4800 feet at Bartlett Mountain, northeast of the lake. It is a mountainous watershed, excepting for a narrow rim of level land around Clear Lake and a few isolated mountain valleys. The surface is steep and rugged and generally covered with chaparral and brush, and at higher elevations with some excellent pine and fir timber.

There has been considerable comparatively recent volcanic activity in this region, Mt. Konokti, the most conspicuous feature of the landscape at Clear Lake, being a typical,and in places almost bare, volcanic peak. There is considerable rather porous lava on portions of the surface of the watershed, and there are numerous mineral springs scattered through the mountains, both of which phenomena have a tendency to store, and hence regulate the runoff. The very interesting geology of Clear Lake has been discussed in Chapter I of this report.

There are about six streams of importance draining from this watershed into Clear Lake, among which are Scotts Creek, Middle Creek and Clover Creek on the northern and eastern sides, and Doba Creek, Kelsey Creek and Cole Creek on the south. During the winter and spring these streams have considerable runoff, but after the close of the rainy season the runoff drops rapidly and by summer many of them become dry.

Upper and Lower Blue Lakes are ~~located on~~ tributary to Scotts Creek, but these lakes are very small and have little effect on the water supply from this area.

RUNOFF INTO LAKE

As stated above there are about six main streams tributary to Clear Lake. This water supply has never actually been measured by gaugings and meterings on the streams themselves. The estimates of runoff entering the lake itself have been made in the past by volumetric differences in the level of the lake. This gives a fairly satisfactory idea as to the amount of water entering Clear Lake, but in the time of heavy inflow these results are apt to be erroneous because of the fact that during these periods there has been no attempt to determine the losses due to evaporation. Of course these would be small in comparison with the losses which occur from this source during the summer time and their neglect probably does not cause a very serious error.

As a matter of fact, due to the limitations put upon the operation of Clear Lake, the actual runoff into the lake is not of as great importance as a record of the levels to which the lake rises prior to the opening of the irrigation season and then falls during the irrigation season.

Previous engineering investigations have lead to the conclusion that there may be considerable water entering the lake through subterranean sources.

The amounts of water which may be released from the lower end of Clear Lake into Cache Creek are very closely governed by existing legal decisions, and hence, for the purposes of this report, an historic record of the actual outflow from the lake as operated under these legal decisions has been used as a basis of estimates of water supply available for the proposed project.

AREA OF CLEAR LAKE

The area of the lake is approximately 40,000 acres. In their determination of inflow and average losses, the Clear Lake Water Co. has assumed the constant area of 40,000 acres, which is a fair mean of the legally permissible fluctuation of the water surface. At the higher stages which occur entering summer at the close of the runoff period, the maximum area of the lake may be as great as 50,000 acres, which is about 18% of the total watershed.

This high ratio of open water for the area of the total watershed area results in a large portion of the runoff, perhaps sometimes all of it being evaporated during the summer time of extraordinarily dry seasons and the lake itself therefore becomes in times of greatest need, an inefficient and unreliable source of water supply. This fact alone appears to account for the very small amounts of water developed and sold in comparison to the irrigation requirements of the area covered by existing distributing systems, resulting in the unsatisfactory economic showing during the recent dry cycle of irrigation from Cache Creek. This unfortunate condition could be completely remedied if large volumes of water could be held in storage protected from excessive evaporation losses, such reserves to be drawn upon primarily during excessively dry cycles.

EVAPORATION

Evaporation, like runoff, is somewhat indeterminate because of the meager measurements made at Clear Lake itself. During the irrigation season itself, the records would indicate an average of about 2 1/2 feet, this figure being based entirely on the theory that a rise or fall of one foot on the Rumsey Gauge is equivalent to a change in storage of 40,000 acre feet.

The quantity of water in acre feet released from the lake is converted into its equivalent depth over the 40,000 acre surface of the lake. This depth is then subtracted from the difference in the Rumsey Gauge readings before and after the release and is called the depth of water lost due to evaporation. During periods of inflow this, of course, is in error because the gauge elevations are continuously rising and the effect of evaporation is lost.

In U. S. Geological Water Supply Paper #45: "Water Storage on Cache Creek, California" by Mr. A. E. Chandler, an annual rate of evaporation of 53 1/2 inches was determined. Mr. Chandler reaches the conclusion that this is too high a rate because of the fact that the water lost due to evaporation in a number of instances exceeded the actual measured drop in the lake.

It seems probable from a study of the evaporation occurring during the irrigation season as determined by the Clear Lake Water Co. and a consideration of evaporation experiments performed in the vicinity, that the total seasonal loss is probably between 4 and 4 1/2 feet.

The excessive estimate of evaporation made thirty years ago probably failed to take into account the fact that there is a large marginal area of swamp, producing luxurious aquatic vegetation. The very high rate of water consumption from such areas was not fully realized until a few years ago when it was determined in connection with the engineering investigations of the proposed Salt Water Barrier at Carquinez Straits that the water consumption of this type of swamp may easily reach rates as much as four times the evaporation rates from open water surfaces.

LEGAL LIMITATIONS OF STORAGE FLUCTUATION

The operation of the Clear Lake outlet works is very definitely defined by the courts in the decree of Gopcevic vs. Yolo Water and Power Co., Oct. 7, 1920. This decree limits the bottom of the Clear Lake Outlet to -4.0 feet on the Rumsey Gauge. The outlet channel may neither be widened nor deepened except as is necessary to conform to the provisions of the decree and that may be done only with the approval and supervision of the State Railroad Commission.

In connection with a large project like the present, subject to shortages of surface water supply beyond the limits of ordinary toleration but only once in 20 years or so, the finality of the lake regulation under this decision should be subject to further study. It must have been based, in the first place, upon the riparian rights of lake front property. The riparian doctrine has been much weakened in recent years by legislation and legal decisions, and the economic loss involved in lowering the lake but an additional foot once in 20 years would probably not be considered as anywhere near as great as it was in 1920.

The water supply studies in connection with this project indicate that in the one year, for instance 1933, in which there would have been a very serious shortage of surface supply and for the remedy of which in this report it is proposed to spend large sums of money for an auxiliary supply, this 1933 shortage could have been reduced within tolerable limits by lowering the water level of the lake about an additional foot and a half, and there would have been sufficient supply so that the lake could have been brought up to stipulated levels the following winter. Just how this would operate would require much detailed study. It is suggested here as an alternative possibility for making up shortages which occur only at very rare intervals.

By this decree the lake surface may not be held at over 7.56 feet on the Rumsey Gauge for more than ten successive days and never under any circumstances at over 9.0 feet. Furthermore, during periods of releasing water from the lake, the level may not be dropped more than two feet in any one month, and this two foot measurement includes both irrigation releases and evaporation losses. In addition, the decree provides that the lake level as determined by the gauge reading shall never fall below zero in any year due to reservoir releases in that year.

Furthermore, in the operation of Clear Lake as a source of irrigation water, a reading of the Rumsey Gauge is required by this court order on April 15th of every season and this reading is then the basis of the maximum elevation of the lake during the remainder of the season as follows: On May 1st the lake shall not be higher than 97% of the April 15th reading; on June 1st, 89%; on July 1st, 79%; on August 1st, 69% and on Sept. 1st, 58%. This requires a 42% fall in the surface of the lake in terms of the April 15th Rumsey Gauge reading.

This was a stipulated decree closing a long period of bitter and widespread litigation, and presumably could be modified only with the consent of the litigants or their heirs at an agreed compensation.

CLEAR LAKE DAM

Clear Lake Dam was constructed under the supervision of a very able engineer, Mr. C. E. Grunsky, in 1914. It is several miles below the lower end of the lake but this section of Cache Creek is quite flat and considerable dredging was required to open up the channel. The dam itself is a fine modern concrete gravity structure, 250 feet long and 42 feet high. The control and release of water through this dam is effected by means of fifteen hydraulically operated sluice gates, 5 feet by 7 feet. It is well equipped with log chute, accumulator and appliances, keepers quarters, bank revetment, etc.

RECORDS OF WATER SUPPLY DELIVERED FROM CLEAR LAKE

During the past 20 years the records of the discharge from Clear Lake are available. This discharge is made up of the water released for irrigation, as well as releases caused by complying with the legal requirements for operating the outlet gates of the lake.

Table V shows the releases from Clear Lake for the seasons 1916-17 to 1935-36, inclusive.

TABLE V

CLEAR LAKE RELEASES

(Furnished by Clear Lake Water Company)

1916-17 to 1935-36

Season	Clear Lake Release (Acre Feet)	Season	Clear Lake Release (Acre Feet)
1916-17	125,476	1926-27	474,592
1917-18	102,176	1927-28	194,350
1918-19	129,512	1928-29	35,196
1919-20	4,580	1929-30	93,656
1920-21	219,399	1930-31	2,393
1921-22	140,524	1931-32	44,722
1922-23	113,600	1932-33	0
1923-24	7,392	1933-34	38,798
1924-25	177,101	1934-35	115,778
1925-26	159,874	1935-36	258,000

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Average - 122,000 Acre Feet

During this period it will be noted that there was one season, 1932-33, in which there were no releases from Clear Lake. In three other seasons, 1919-20, 1923-24 and 1930-31, less than 10,000 acre feet were released and that release occurred mostly after the irrigation season, that is during October and November.

INDIAN VALLEY SUPPLY

LOCATION OF INDIAN VALLEY (PLATE 1.)

Indian Valley is located on the North Fork of Cache Creek, on the eastern slopes of the coast range mountains. It is about 20 miles northeast of the town of Lakeport and 50 miles northwest of Woodland.

WATERSHED (PLATE 1.)

The watershed tributary to Indian Valley is about 123 square miles in area. On the west this watershed adjoins that of Clear Lake. It is very similar in character, although slightly higher than the Clear Lake watershed. It ranges in elevation from approximately 1500 feet in the valley itself to just over 6000 feet at Goat Mountain on the northern limits of the watershed.

The North Fork of Cache Creek is the main tributary to Indian Valley, but Bartlett Creek, which joins the North Fork some ten miles or so upstream from Indian Valley is a tributary of considerable importance. The country is steep, brushy and cut by numerous small gullies which carry considerable amounts of water during the rainy periods, but after the rains soon become dry.

PRECIPITATION

The rainfall records in this North Fork watershed are very meager. Records are available at Bartlett Springs from 1911 to 1933. On the adjacent watershed of Stony Creek to the north, there are records at Fouts Springs. These records began in 1885-86, were discontinued in 1888, started again in 1903 and continued until 1913, since which time there are no further records at this point.

At Lakeport, on the western side of Clear Lake, and at East Park Reservoir of the U. S. Reclamation Service, there are records which are being kept at the present time. By study of these records, incomplete though they may be, the average annual rainfall in this North Fork area is estimated at about 35 inches.

The longest record available anywhere in the vicinity is that at Ukiah. These records were started in the season of 1877-78 and have continued without a break to the present season of 1935-36.

The Ukiah rainfall record as given here is used merely as an index of the relative wetness in this general region and is used in preference to the intermittent and shorter records, some of which are on the Cache Creek watershed, merely because it is the longest continuous, reliable, available record. It is nowhere used directly either as an index of the rainfall or of the runoff on which the estimates of water supply for this project are computed. The 59 year average at Ukiah is 34.89, which is very close to the estimated rainfall in the North Fork area. Table VI shows this seasonal precipitation and also the percentage of normal of each of the seasons.

TABLE VI

SEASONAL PRECIPITATION AT UKIAH

AND PERCENTAGE OF NORMAL

1877-78 to 1935-36

Season (July to June)	Rainfall (in Inches	Percent of 59 yr. normal	Season (July to June)	Rainfall (in Inches)	Percent of 59 yr. normal
1877-78	54.88	157	1907-08	29.67	85
1878-79	36.23	104	1908-09	57.39	164
1879-80	42.86	123	1909-10	29.89	86
1880-81	29.49	85	1910-11	32.99	94
1881-82	26.70	77	1911-12	25.73	74
1882-83	23.93	69	1912-13	33.40	96
1883-84	24.41	70	1913-14	54.85	157
1884-85	19.88	57	1914-15	49.28	141
1885-86	45.69	131	1915-16	34.80	100
1886-87	22.33	64	1916-17	30.23	87
1887-88	25.42	73	1917-18	23.43	67
1888-89	30.82	88	1918-19	37.23	107
1889-90	60.48	173	1919-20	19.05	55
1890-91	24.50	70	1920-21	47.94	137
1891-92	29.49	85	1921-22	28.74	82
1892-93	43.53	125	1922-23	30.35	87
1893-94	47.93	137	1923-24	16.19	46
1894-95	52.55	150	1924-25	47.44	136
1895-96	40.85	117	1925-26	26.33	75
1896-97	43.34	124	1926-27	47.32	135
1897-98	19.83	57	1927-28	34.94	100
1898-99	27.60	79	1928-29	24.44	70
1899-1900	33.69	97	1929-30	31.08	89
1900-01	37.09	106	1930-31	20.06	57
1901-02	45.07	129	1931-32	27.67	79
1902-03	34.55	99	1932-33	24.71	71
1903-04	54.73	157	1933-34	25.21	72
1904-05	42.93	123	1934-35	33.05	95
1905-06	44.75	128	1935-36	37.83	108
1906-07	48.64	140	-	-	-
			Normal	34.89	100

The average for the last 20 years, that is from 1916-17 to 1935-36 is 30.66 inches or 88% of the 59 year average, and in the four dry seasons of 1930-31 to 1933-34, the average was 24.41 inches or 70% of the 59 year average. It will be interesting to note that this period was very similar to the seasons of 1881-82 to 1884-85. The precipitation was approximately the same and it followed a period similar to that preceding 1930-31.

The rainfall occurs mostly in the months of November to March, inclusive. On an average of 80% to 85% of the rainfall occurs during these months.

DERIVED RUNOFF

In estimating the runoff of the North Fork of Cache Creek at Indian Valley, the adjacent watershed of Stony Creek to the north (See Plate 1) was used as a basis of comparison. The U. S. Geological Survey maintained a station near Stonyford, where the runoff of Stony Creek was measured, from 1918 to 1935. This watershed has an area of approximately 103 square miles and is quite similar to that of the North Fork of Cache Creek, although the precipitation is a little higher.

Since 1930-31 the U. S. Geological Survey has maintained a station on the North Fork of Cache Creek, some ten miles below Indian Valley and also below the junction of Long Valley Creek (See Plate 1) with the main North Fork of Cache Creek.

There are four seasons, that is from 1930-31 to 1933-34, in which records of stream flow are available both on Stony Creek near Stonyford and on the North Fork of Cache Creek.

The area of the watershed above the station on the North Fork of Cache Creek is approximately 203 square miles. The rates of runoff of these two streams during and just after periods of heavy rainfall were compared, with the result that the North Fork Cache Creek runoff was found to be 60% of the Stony Creek runoff per square mile. Because of the fact that this measurement on Cache Creek is made about ten miles below Indian Valley and the Long Valley tributary is at a lower elevation than the North Fork of Cache Creek above Indian Valley, it was deemed advisable to increase the rate of runoff tributary to Indian Valley over that of Long Valley. Mr. C. E. Grunsky, in his report on the little Indian Valley Reservoir Site, 1914, includes an Isohyetose Map of the area, which indicates that the rainfall above Indian Valley is approximately 15% greater than that in Long Valley. The runoff of the North Fork of Cache Creek at Indian Valley was therefore estimated to be 83% of the runoff of Stony Creek near Stonyford.

Table VII following, shows the estimated runoff of the North Fork of Cache Creek at Indian Valley for the seasons of 1916-17 to 1935-36.

TABLE VII

ESTIMATED RUNOFF OF NORTH FORK
OF
CACHE CREEK AT INDIAN VALLEY DAMSITE

1916-17 to 1935-36

(This cycle, from Ukiah rainfall, is about 88% normal)

Season	Runoff - North Fork Cache Creek at Indian Valley (Acre Feet)
1916-17	81,000
1917-18	41,000
1918-19	102,000
1919-20	35,100
1920-21	239,000
1921-22	80,000
1922-23	71,000
1923-24	22,200
1924-25	129,000
1925-26	76,000
1926-27	163,000
1927-28	105,000
1928-29	39,400
1929-30	85,600
1930-31	10,650
1931-32	52,400
1932-33	27,100
1933-34	34,000
1934-35	75,900
1935-36	90,000

AVERAGE of 20 year subnormal period - 78,000 Acre Feet

After the establishment of the gauging station on the North Fork of Cache Creek, the runoff at Indian Valley was estimated from this actual measured flow, making the correction due to the lower elevation of that portion of the watershed which is below Indian Valley, including Long Valley Creek.

SUMMARY OF CONTROLLED WATER SUPPLY

The summary of the controlled water supply from two sources, Clear Lake as actually operated under the existing legal decisions during the last 20 years and the Indian Valley releases as they would have been available for the last 20 years, had the proposed reservoir been built, are summarized in Table X of Chapter V.

The available water from Clear Lake would have averaged during these periods, 72,800 acre feet per irrigation season and from Indian Valley releases 38,800 acre feet. This latter figure is not in any way the average amount which could be made available from the Indian Valley Reservoir, but is the available amount which would be required to supplement the Clear Lake releases in order to furnish the normal irrigation demand during irrigation seasons for the proposed 75,000 acre project. The Indian Valley Reservoir should be held in reserve, to be used only when the natural runoff and the Clear Lake releases are insufficient to meet the normal irrigation requirements.

The upper diagram of Plate 6 (See Chapter V) shows, month by month for the past 20 years, the amounts of water which would have been held in storage in the Indian Valley Reservoir, if operated as a reserve supply as intended. Even in this 20 year dry cycle, the reservoir would have been full in 1919, 1920, 1921, 1922, 1923, 1924, 1926, 1927, 1928 and 1929, or ten years out of the 20, had it started storing in December, 1916. It would have been emptied in the falls of 1931, 1932, 1933 and 1934, or four years out of the last 20. Only nominal drafts at the beginning or close of the season would have been required in 1922, 1926 and 1927 or three years out of the past 20 year dry cycle.

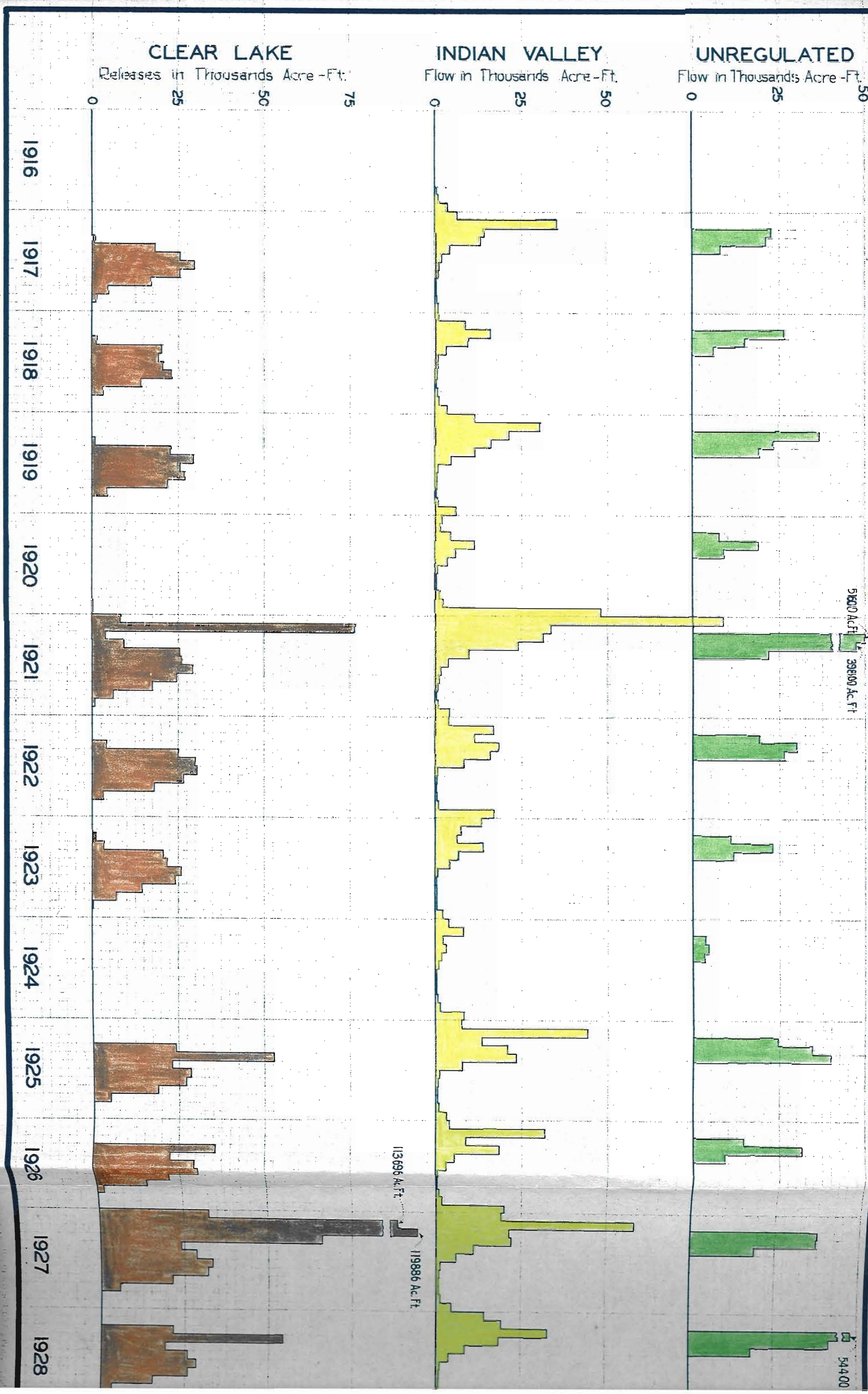
The tremendous economic importance of the proposed Indian Valley Reservoir supply occurs in those frequent seasons in which there is little or sometimes no available draft from Clear Lake and the irrigation seasons are entered with the Indian Valley Reservoir full of water carried over from the previous season. In the lower diagram of Plate 6 the Indian Valley releases are shown in yellow, Clear Lake releases in orange and available uncontrolled runoff in green. In seasons such as 1920, 1924, 1929 and most of all in 1930 and 1931 when the Clear Lake supply completely failed, the Indian Valley Reservoir would have enabled the full irrigation requirements to be met. In the most critical season of the past 60 years, that of 1933, in which there was sold but 6654 acre feet of water by the present Company and no water was available from Clear Lake, there would have been available, even in this season, 24,230 acre feet from Indian Valley. If the proposed dam had been raised, still more water could have been carried into this season in Indian Valley and, as previously suggested, if Clear Lake could be lowered another foot once in 20 years, the deficit could have been reduced to tolerable irrigation limits.

Plate 3 herewith shows in block diagrams the monthly water supply from Clear Lake Releases as they have been in recent years, and the runoff from the area above the Indian Valley Dam Site during the last 20 years.

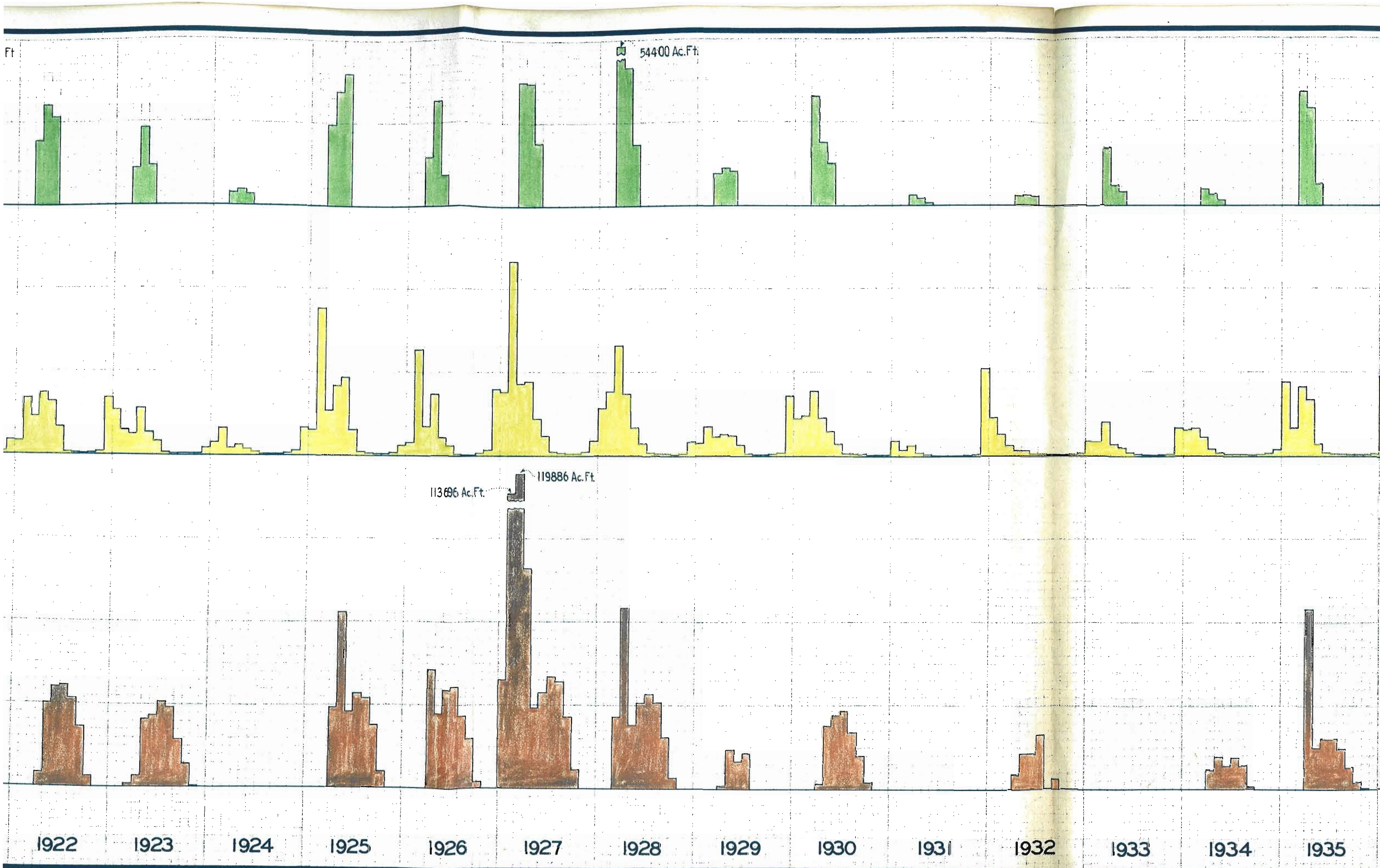
The upper row of green blocks shows natural stream flow originating below the reservoir and available during March, April and May for irrigation use, as subsequently explained in Chapter V. The lower row of orange blocks shows actual releases under present conditions from Clear Lake. It will be noted that this supply fails entirely in 1920, 1924, 1931 and 1933. These were dry years, but even in these dry years, the yellow blocks, representing the runoff from the Indian Valley watershed, show that large amounts of water would have been available during the irrigation months (1 block for each month in the diagram) in these dry years.

In most of these dry years, as shown on the graph of reservoir stages, Plate 6, full supply would have been obtained during the irrigation season, because of the amounts carried over in the reservoir from previous years.

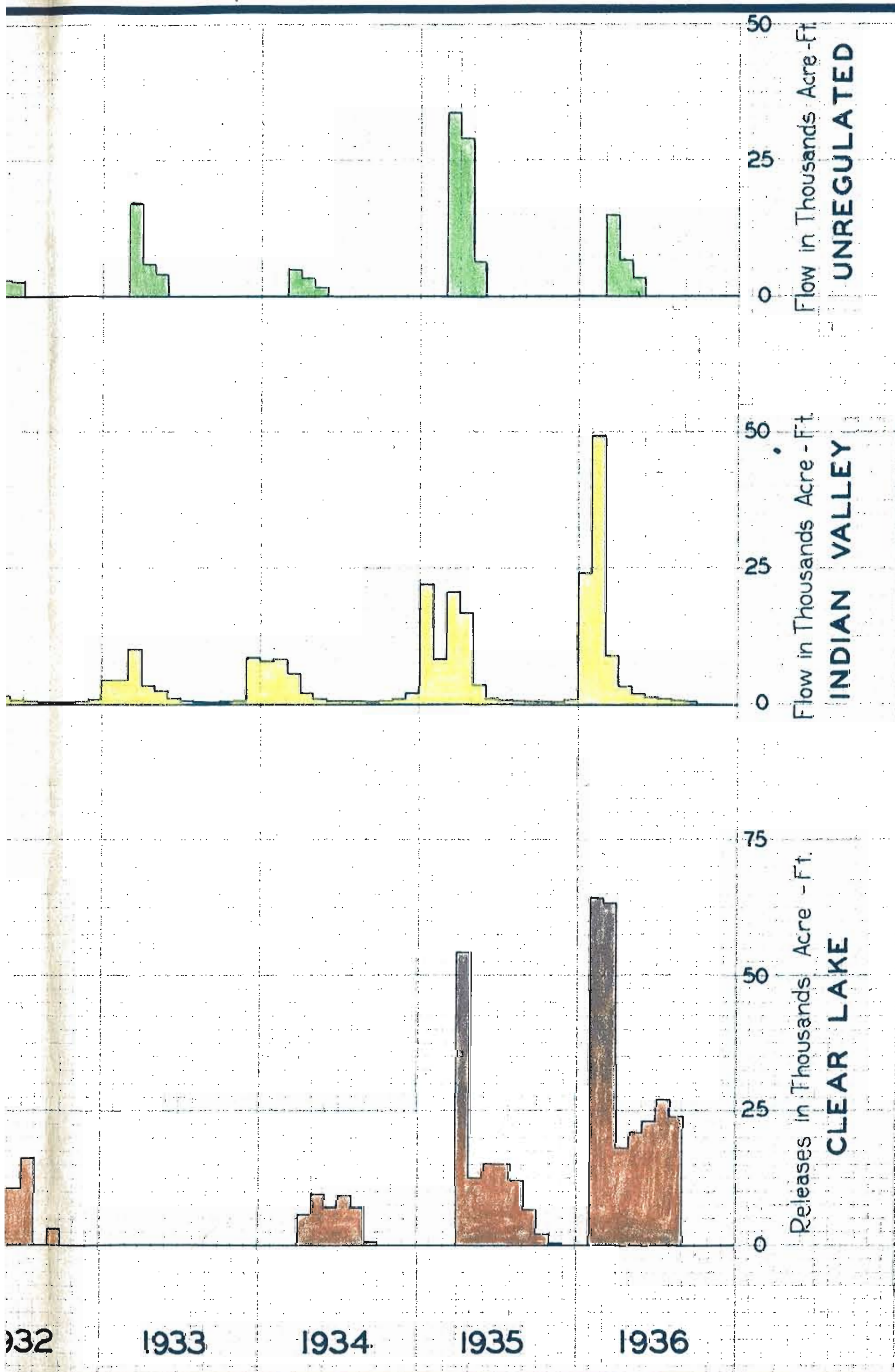
On Plate 6 is shown the method of utilization of the natural supply with Clear Lake regulated according to the legal requirements; this natural supply, occurring as shown on Plate 3, but held over in the Indian Valley Reservoir into the irrigation demand season, and in many cases from previous years, as shown on Plate 6.



CLEAR LAKE
Releases in Thousands Acre-Ft.
0
25
50
75
INDIAN VALLEY
Flow in Thousands Acre-Ft.
0
25
50
UNREGULATED
Flow in Thousands Acre-Ft.
0
25
50
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
51600 Ac.Ft.
39800 Ac.Ft.
113696 Ac.Ft.
119886 Ac.Ft.
54400



Ft
54400 Ac.Ft.
113696 Ac.Ft.
119886 Ac.Ft.
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935



CLEAR LAKE WATER COMPANY PROJECT

WATER SUPPLY CHART

CLEAR LAKE RELEASES
NATURAL FLOW AT INDIAN VALLEY
FLOW FROM UNREGULATED AREA

October 1936
Datum: None
Scale: As shown

Fred. H. Tibbetts
Civil Engineer
San Francisco

Dr. F.G.M.	Ck.
Tr. N.B.	Ap.

File No.
1936 A-2

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PLATE

CHAPTER IV. PROPOSED INDIAN VALLEY STORAGE DEVELOPMENT

RESERVOIR

LOCATION

As shown on Plate 1, the proposed Indian Valley Storage Development is located on the North Fork of Cache Creek, on the western slope of the Coast Range mountains in the eastern part of Lake County. At a point about six miles due north of the junction of the North Fork of Cache Creek and the main stream from Clear Lake, the canyon widens out into a rather large, oblong mountain valley. This valley, known as Indian Valley, is approximately 50 miles northwest of Woodland and about 20 miles due west of Williams. The portion of it proposed to be used as a reservoir ranges in elevation from about 1300 feet above sea level at the dam site to nearly 1500 feet at the high water line. The bottom of the reservoir site is almost identical in elevation with that of the water level in Clear Lake.

ACCESSIBILITY

The reservoir and dam site are accessible from Williams on the east, and Upper Lake and Lakeport on the west, mainly by a county road connecting these points. The first six miles from

Williams is on the paved Tahoe-Ukiah State Highway; the next 7 miles on oiled county road, and the last 19 miles to the reservoir site on a good gravelled county road. In addition to the 32 miles of public road from Williams to the reservoir site, there are approximately 5 miles of fair private road down through Indian Valley to a point within one-quarter of a mile of the dam site. From the upper end of the reservoir to Bartlett Springs is about 20 miles over a good gravelled county road and from there on to the junction of this road with the Tahoe-Ukiah Highway east of Upper Lake is about 15 miles.

AREA

Indian Valley (See Plate 4.) is about 5 to 6 miles in length and varies in width from 1/2 mile to slightly over 1 mile. The area of the proposed reservoir water surface at the level of the spillway lip, some 160 feet above streambed at the dam site, is approximately 2950 acres. This makes an exceptionally good reservoir site, as the area submerged and volume of water stored is very large compared to the height of the required dam.

GEOLOGY OF RESERVOIR SITE (From Report of Chester Marliave)

The geological report on the Indian Valley by Mr. Chester Marliave, a well-known geologist, contains the following:

"The reservoir site lies in a geologic belt which is commonly known as the Franciscan formation. This formation is of Jurassic age and as here found is typical to that found elsewhere in the Coast Ranges. It is composed of thick massive sedimentary beds of sandstone and shale which have a thickness of several thousand feet. During the formation of these beds there was much mountain movement in the Coast Ranges and the sediments have been intruded by masses of deep seated igneous rocks, as well as by a few volcanic lava flows.

"The watershed surrounding the reservoir shows many exposures of sandstones and shales, as well as the associated metamorphic igneous rocks. Igneous material is well exposed along the road that crosses the upper end of the valley leading in and out of the valley and well substantiates the fact that the entire reservoir site is resting on the Franciscan formation. From many view points in the reservoir, the dykes of greenish serpentine can be seen cutting across the hills. These lenticular masses of serpentine seem to predominate the eastern watershed and pass across the valley just below the dam sites. Their relation to the formations at the dam site is worthy of consideration after a definite location of the dam has been decided upon. There seems to be no doubt but that this Franciscan formation not only surrounds the reservoir site, but also underlies it, forming a tight basin. The only outlet for the water that would be impounded would be down the channel and over the bed rock at the dam site."

PRESENT USE OF LAND (Fig. 1.)

At the present time the area required for the proposed reservoir is used only for grazing purposes. In the past, parts of the area were irrigated and various crops raised, including alfalfa, fruit, etc. Remnants of the small irrigation ditches now abandoned are still in evidence. The soil overlying the predominantly gravel fill of the valley is apparently too shallow and the drainage too good for the successful growing of crops on the valley floor. Present vegetation consists of a sparse growth of oak, brush and digger pine, with many open areas of fair size with only native grasses growing thereon.

DAM SITE (Fig. 2.)

GEOLOGY (From Geologist Chester Marliave)

The contraction at the lower end of Indian Valley which forms the dam site consists, for the most part, of hard, massive, indurated Franciscan sandstone. This sandstone has undergone considerable metamorphic action and there exists throughout most of it many seams of secondary quartz. It has a typical blue color where freshly exposed, particularly in the streambed. Associated with the sandstone is the Franciscan shale, which also has been metamorphosed and sometimes has the appearance of slate. The structural conditions in evidence at the dam site indicated no particular complications in regard to foundations. Sandstone and shale cross the creek obliquely and dip at a very high angle. There is no apparent faulting except for that normally expected in material of a schistose structure, and this is of little importance from a structural standpoint.

The creek bed is well exposed in the vicinity of the dam site and rock appears on both sides of the present creek channel for some 25 or 30 feet above the streambed (Fig. 2.). Above this elevation the underlying rock is covered with a thin layer of detritus of varying thickness. It is believed that this layer of over-burden is not very deep and that but little or no trouble should be expected in obtaining a good cutoff trench for the dam. Above the blue sandstone exposed in the creek channel shales are more predominant, as indicated by the outcrops. This shale is a light brown color generally and is not nearly as strong as the sandstone structurally.

GRAVEL AND ROLLED EARTH DESIGN (PLATE 5.)

A decade or two ago a masonry dam would probably have been proposed for this location. With the tremendous development in very recent years of heavy earth moving machinery, it is probable that such a dam would not now be as economical as an earth and gravel fill. A few years ago there were a number of very important and disastrous dam failures in California, which resulted in legislation placing the suprevision of dam construction, as regards safety for the public, under the State Engineer. Extraordinary precautions have subsequently been enforced regarding dam foundations. In formations geologically as old as the Franciscan rocks of the Coast Range, the foundation excavation depths required for masonry dams are very uncertain and very difficult to predetermine. Due to their great age, the Franciscan formations have all been badly shattered by numerous earthquakes and faults and the intrusion of metamorphic rocks from below. Under these conditions, including those which exist at Indian Valley, it is the writer's belief that a combined earth and gravel fill would be a safer structure, one in which the cost could be predetermined much more accurately, one which would be more economical to construct than a masonry structure and one more readily capable of future enlargement.

Where foundation rocks and especially abutment rocks are hard and new and fresh and certain, the more modern designs of light variable radius arch dams when conditions are suitable are favored by the writer. They are quite economical and he has built a number of them. The cost and design of this type, however, is particularly difficult to predetermine where any doubt may exist regarding the abutments, and the designs fail completely if the abutments prove worse than anticipated, something which experience has shown can only be determined when the dam foundation is actually and completely excavated.

The final design, immediately preceding construction, of any dam of this sort can only be made after careful and extensive foundation test borings and test pits. Test pits must also be made to accurately determine the location of materials suitable for whatever type of dam is proposed. The geological reports available, however, together with the personal examinations at the site made by Mr. Tibbetts and Mr. Wood, convinces us that sufficient material is readily available for the dam proposed, and if final tests show the material more favorably situated than first assumed, then the cost of the structure might be considerably reduced. This same comment applies to the assumed depth of foundation stripping and foundation excavation. In the estimates they may exceed those which will finally be required.

In a preliminary report such as this, sufficient funds or time are not available for such borings and tests. The present design is, therefore, submitted as the one which the writer believes would be most economical and safe and readily capable of future enlargement and one in which the costs can be accurately predetermined.

The writer is now completing the last of six rolled earth type dams for the Santa Clara Valley Water Conservation District in a region of the same general geological formation, except that it is much more complicated by faulting, one of these dams actually straddling a major active fault. For all of these dams of the Santa Clara Valley Water Conservation District, it was concluded that the rolled earth type alone fulfilled all the requirements. The design of the proposed Indian Valley Dam definitely indicates the use of the same general type and dimensions as have proven so successful in the Santa Clara Valley. As was the case there, it is necessary to adapt the particular design to the availability of various kinds of material.

The central portion of the dam, as shown on PLATE 5, will be a gravel fill spread in thin layers and compacted only by moistening and hauling over the layers. The water side of this gravel fill will utilize selected clay impervious material, which is available 1/4 to 1/2 mile upstream from the dam site. This selected material will be spread in thin layers, moistened and rolled until thoroughly compacted and impervious. On the downstream side of the gravel fill it is proposed to use material excavated from the spillway channel, which will be largely of rock, varying considerably in structural strength and hardness but all useable in the dam. When the impervious portion of the fill is completed, it will be covered with a blanket of gravel on the water side and finished with a reinforced concrete facing four inches thick. Gravel for all requirements is available in the reservoir site a short distance upstream, estimated at less than 1/2 mile. This gravel, with proper washing and screening, will also be ample and suitable for all necessary concrete work.

Prior to construction of the dam, the site must be stripped of all unsuitable material. The depth of stripping will vary from nothing, where hard rock is exposed, to a maximum probably in excess of 10 or 15 feet. The average depth has been assumed to lie between 8 and 9 feet over the entire base of the dam. Under the impervious clay section of the dam, it will be necessary to excavate a trench into sound, impervious foundation material and carefully backfill the same as a part of the impervious front layer.

The general details of the dam proposed are shown on drawing Plate 4. The dam has a top width of 20 feet and side slopes, both up and down stream, of 1 vertical on 2 1/2 horizontal.

The maximum width of the dam up and down stream at the level of the creek bed will be approximately 900 feet and the length of the dam on its crest about 560 feet.

A very considerable portion of the cost of the proposed dam is the cost of excavating the spillway in rock. This excavation is used in the dam but for that purpose is expensive material; much more expensive than gravel which would be equally suitable. The dam could readily be raised to store more water, and the increased cost of the dam would be partially offset by the decreased cost of the spillway, so that the net cost of the additional storage is relatively small, and in a final study of the project additional storage might be substituted for a considerable portion of the proposed pumping installation. The hydrographs and water supply studies show, however, that additional storage or the proposed pumping installation would probably not be used more than three or four times in a century when very dry years occur in very dry cycles.

OUTLETS

To release water from the reservoir as desired, it will be necessary to construct an outlet conduit under the dam. It is proposed to make this outlet conduit of steel pipe 72 inches in diameter, encased in reinforced concrete and laid in a trench near the base of the dam. At the inlet end to this conduit, it is proposed to install two hydraulically operated sluice gates in a suitable structure, with protection by steel grillages from all trash and debris. At the outlet end, two butterfly valves, manually operated, will be installed in a combination valve house and energy dissipating structure.

This type of outlet structure is identical with those successfully and very economically installed, with the approval of the State Engineer and numerous consulting engineers, in the Santa Clara Valley dams which the writer now has under way under closely similar conditions.

SPILLWAY (PLATE 5.)

The left abutment of the dam rises some 80 feet above the crest of the dam and then drops down into a low, broad depression or saddle approximately 25 feet higher than the dam crest. It is through this saddle that the proposed spillway channel will be constructed. The spillway is designed to pass maximum possible floods which may occur at rare intervals when the reservoir is full. It will be 200 feet wide at the spillway lip and, with a maximum water depth of 12 feet, will pass the maximum estimated "1000 year" flood of about 36,000 cubic feet per second. Below the spillway lip the channel is contracted until, at a distance of about 300 feet, it has a bottom width of 100 feet and then maintains this width to the end of the excavation. The spillway lip will be set 15 feet below the crest of the dam and will consist of a small concrete ogee section weir. Reinforced concrete lining below the weir is proposed, 8 inches in thickness and about 800 feet long. The spillway channel will discharge into a natural draw or ravine by which the wasted waters will be returned to the creek channel below the dam.

COST ESTIMATES

Cost estimates are based, with more than usual confidence, on contract prices for exactly similar work heretofore referred to now under way in the Santa Clara Valley. Reservoir lands are included at $50.00 per acre. It will be necessary to relocate a short section of the county road, probably about two miles or less near the upper end of the reservoir, and the cost thereof has been included. To anticipated contract prices has been added 20% for contingencies, overhead, legal, administration, engineering and organization expenses. Experience has shown the wisdom of the 20% reserve for overhead, legal and unforseen contingencies.

Table VIII herewith shows the writer's best estimate of probable construction costs of the proposed works.

TABLE VIII

PRELIMINARY COST ESTIMATES
OF
INDIAN VALLEY STORAGE DEVELOPMENT

ITEM	UNIT	UNIT PRICE	QUANTITY	AMOUNT
Stripping				
Under Pervious Section Dam (6' Ave)	Cu.Yd.		41,000	
Under Impervious Section Dam (10' Ave)	Cu.Yd.		27,000	
Over Spillway Channel (1' Ave)	Cu.Yd.		10,000	
		$0.30	78,000	$23,400
Trench Excavation				
Cutoff (b=15' Ave,d=10' Ave,s/s 1/2:1)	Cu.Yd.		7,000	
Outlet Conduit	Cu.Yd.		9,000	
		0.75	16,000	12,000
Embankment				
Impervious Clay Blanket	Cu.Yd.	0.30	184,000	55,200
Material from Spillway (with 20% Swell)	Cu.Yd.	0.60	310,000	186,000
Gravel Fill	Cu.Yd.	0.25	132,000	33,000
			626,000	274,200
Mass Concrete				
Outlet Pipe Jacket	Cu.Yd.		1,200	
Outlet Pipe Collars	Cu.Yd.		90	
Inlet Structure	Cu.Yd.		40	
Outlet Structure	Cu.Yd.		160	
Locker & Pump House	Cu.Yd.		15	
Sill for Facing	Cu.Yd.		200	
Spillway Weir	Cu.Yd.		495	
Spillway Cutoffs	Cu.Yd.		350	
		16.00	2,550	$40,800

TABLE VIII (Continued)
PRELIMINARY COST ESTIMATES OF INDIAN VALLEY STORAGE DEVELOPMENT

ITEM	UNIT	UNIT PRICE	QUANTITY	AMOUNT
Dam Facing (4")	Sq.Ft.	$0.175	150,000	$26,250
Spillway Lining (8")	Sq.Ft.	0.375	130,000	48,750
Outlet Pipe - 72" Steel	Lin.Ft.	22.50	900	20,250
Reinforcing Steel				
Outlet Pipe Jacket	Lbs.		90,000	
Outlet Pipe Collars	Lbs.		1,000	
Inlet Structure	Lbs.		9,500	
Outlet Structure	Lbs.		27,000	
Locker & Pump House	Lbs.		1,500	
Sill for Facing	Lbs.		4,000	
Spillway Weir	Lbs.		40,500	
Spillway Cutoffs	Lbs.		20,500	
Dam Facing	Lbs.		161,000	
Spillway Lining	Lbs.		235,000	
		0.05	590,000	29,500
Structural Steel	Lbs.	0.10	12,500	1,250
Caretaker's Cottage	L.S.	-	1	2,000
Bronze Name Plate	L.S.	-	1	100
Valves & Gates in Place Complete	L.S.	-	1	15,000
Premium on Contractors' Surety Bonds	L.S.	-	1	7,500
TOTAL ESTIMATED CONTRACT PRICE OF DAM				$501,000
Lands for Reservoir, Dam, Spillway, Spoil, Storage, Camp, Etc.	Acre	50.00	3,500	175,000
Relocate County Road	Mile	2.0	12,500	25,000
SUB-TOTAL				701,000
20% for Contingencies, Legal, Administration, Engineering, Overhead, etc.				140,000
GRAND TOTAL				$841,000

CHAPTER V. SUPPLEMENTARY WATER SUPPLY FROM UNREGULATED SURFACE RUNOFF AND UNDERGROUND STORAGE

UNREGULATED WATERSHED

AREA

The unregulated watershed (See Plate 1) is that portion of the watershed of Cache Creek between Rumsey on the east and below Clear Lake and the proposed Indian Valley Reservoir. It comprises about 275 square miles, or practically one-third of the total watershed of Cache Creek above Capay Valley. The main tributaries of Cache Creek in this area are Long Valley Creek and Bear Creek.

ELEVATION

The elevation of this area varies from about 4800 feet in the higher part of the Long Valley Creek watershed to 500 feet at Rumsey at the head of Capay Valley. The topography is quite rugged, varying from the deeply eroded foothill to the higher, more precipitous mountains. Most of the area is covered with brush and scattered trees typical of the coast range hills.

PRECIPITATION

Precipitation in this uncontrolled area averages less than that of the Indian Valley and Clear Lake areas, because it lies below these areas and precipitation, unless there are unusual conditions of exposure, varies in the mountains of California, becoming greater at higher altitudes. There are old records at Rumsey, Capay and Esparto, all in Capay Valley near the lower easterly boundary of this uncontrolled watershed area. From these it is deduced that the mean seasonal rainfall over this portion of uncontrolled area is approximately 24 inches. No direct use, however, is made of this factor, as the runoff available for irrigation requirements from the uncontrolled area during the earlier part of the irrigation season is estimated from direct measurements of runoff in adjacent watersheds and not from rainfall.

DEDUCED RUNOFF

The runoff in this large uncontrolled area has not been directly measured at any point. Following the usual practice, we have therefore estimated the runoff of the unmeasured area based directly upon Government measurements of runoff in the adjacent watersheds. The best records from the nearest watershed are the Government measurements for the last six years on the North Fork of Cache Creek. The portion of this area above the North Fork Gauging Station and below the Indian Valley Reservoir Site constitutes the most westerly portion of the uncontrolled area. From these Government measurements of the North Fork of Cache Creek for the last six years and the available records on an adjacent watershed there has been deduced in Chapter III of this report, as shown on Plate 3, the probable runoff month by month for the last 20 years at the Indian Valley Reservoir Site. It was assumed in Chapter III that, because of the highly favorable elevation of the Indian Valley portion of the watershed above the North Fork Gauging Station, the runoff depth would average about 15% more than that gauged at the North Fork Station. From similar considerations, we estimate that the runoff depth in this large uncontrolled area, the elevation of which would average lower than that of the North Fork Gauging Station, would be 15% less in depth than that measured at the station. Arithmetically, this would mean that the runoff depth of the large uncontrolled area would be 85%/115% of the runoff depth of the area tributary to the Indian Valley Reservoir Site; and, inasmuch as the area of the Indian Valley watershed is about 45% of that of the uncontrolled watershed, the total runoff from this uncontrolled area would be approximately 165% of that determined for the area tributary to the Indian Valley Reservoir Site.

The block diagrams in green, on Plate 3, which represent the runoff during the irrigation months of March, April and May from the uncontrolled area are, therefore, about 165% as high as the corresponding yellow blocks representing the runoff from the area above the Indian Valley Reservoir Site directly below them in all cases.

It should be noted that in the extension of the North Fork gauging records to the 20 year period, which the entire investigation

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of this report covers, the North Fork records of runoff have been extended entirely by comparison with the adjacent Stony Creek Drainage Basin on the north, as shown on Plate 1, with four of the twenty years showing overlapping records. The overlapping records were in the years 1930-31 to 1933-34, and the extension is especially valuable because this overlap occurs during dry, and hence critical, seasons.

MONTHLY DISTRIBUTION OF RUNOFF

The monthly distribution of runoff at the gauging station on the North Fork of Cache Creek, calculated as the average of the last five available years, is again of particular significance because most of these were in the critical dry years and are shown Table IX following:

TABLE IX

MONTHLY DISTRIBUTION
OF
RUNOFF OF THE NORTH FORK OF CACHE CREEK

Month	Measured Flow in Acre Feet					Total	%	
	1930-31	1931-32	1932-33	1933-34	1934-35	Ac.Ft.		
Dec.	132	38100	1000	12400	2990	54622	19	)
Jan.	6460	17000	6520	11400	31290	72670	26	)
Feb.	2230	9550	6600	11800	11020	41200	24	)
Mar.	3950	3970	14700	7810	28670	59100	21	) 97%
Apr.	1490	2480	4880	2860	24050	35760	12	)
May	552	2420	3550	1310	4900	12732	4	)
June	196	786	1070	531	1120	3703	1	)
July	46	52	102	144	154	498	0.7	
Aug.	7	0	0	34	31	72	0.5	
Sept.	0	0	0	0	0	0	0.3	
Oct.	5	0	0	0	2	7	0.5	
Nov.	32	6	0	0	3470	3508	1.	
Total	15100	74364	38422	48289	107697	283872	100	

The December to June flow is 97% of the total. The remaining 3% is distributed among the other months so that the minimum occurs in September.

The irrigation demand, as discussed in Chapter I, begins in March, a month of considerable runoff, as shown by the above table. The portion of the irrigation demand which may be obtained from natural runoff is practically limited to the months of March, April and May. An inspection of the table shows that only 3% of the total runoff occurs after May during the irrigation season. The study of available natural runoff from the uncontrolled portion of the watershed is, therefore, limited to the three months, March, April and May at the beginning of the irrigation season, and that is the reason why the green blocks of Plate 3 are projected only for these three months. There is plenty of runoff before the beginning of the irrigation season, but as it has no significance in this project, it is not projected.

It may also be noted at this time that the chart showing the reservoir stages of the proposed Indian Valley storage project, as they would have been had the project been in existance during the last twenty years, shows the beginning of storage accumulation on the assumption that the dam was built in 1916 and began to store water at the beginning of that runoff season, that is, in December, 1916.

UNDERGROUND STORAGE

GEOLOGICAL FORMATION OF CAPAY VALLEY

A brief discussion of the geological formation of this portion of the Sacramento Valley, including Capay Valley, is given in Chapter I.

Capay Valley is a rather long, narrow valley (Plate 1), being about 20 miles long and varying from one to three miles in width. It is a fertile area and there is considerable farming, orchards making up a large part of the agricultural activity in this area.

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In the areas to the north and west of Capay Valley, it has been noticed that in many cases the stream flow practically disappears and then some miles down stream is forced to the surface by underground dikes and lenses of rock. It is practically certain that the same condition occurs in Capay Valley.

The slope of the valley is quite gentle and Cache Creek, which has come down through the canyon above, carrying gravel and other coarse material for ages past, deposited these materials when it reached this valley, gradually building up very substantial aquifers. These aquifers are undoubtedly water-bearing and from them it is possible to obtain an additional source of water to be used during the rare very dry years when there is insufficient water from Clear Lake, the uncontrolled runoff and the proposed Indian Valley Reservoir releases to satisfy full requirements.

PROBABLE VOLUME OF AVAILABLE UNDERGROUND STORAGE

Capay Valley has a surface area of approximately 20,000 acres and below the mouth of Capay Valley over the alluvial fan of Cache Creek there is probably an equal area of excellent water-bearing material. If the "available porosity" or "specific yield" (that is, the amount of water readily withdrawable by pumping and readily replaced by natural stream flow), were assumed not greater than 10%, an "available porosity" about the same as has been assumed in many engineering reports for valleys like the Santa Clara Valley, San Gabriel Valley, etc.; then, if the water table were fluctuated on rare occasions to a maximum depth of not over 30 feet, there could then be obtained as a supplementary water supply from underground storage as much as 120,000 acre feet, and even in the worse seasons of record, occurring perhaps once in thirty years, this additional water would be sufficient to reduce the shortage to tolerable limits.

REPLENISHMENT OF UNDERGROUND STORAGE

The underground storage in Capay Valley, and its alluvial fan below, is replenished by the flow of Cache Creek which transverses the entire 20 miles of valley. Natural percolation from the stream into the underlying sands and gravels is occurring continuously, as is very clearly shown by the fact that during dry periods of little or no flow at the head of Capay Valley near Rumsey, considerable flow is present down near Capay at the Capay Diversion Dam. This flow has come through the underground channel below Capay Valley and has been forced to the surface by some obstruction, probably a geological fault or layer of impervious material.

In the operation of the project here proposed, natural replenishment of underground storage will be greatly augmented because of the increased flow and longer duration of steady flow in Cache Creek and over its alluvial fan. As 75,000 acres of irrigated land are developed in this immediate vicinity, the water plane will also tend to rise, further distributing the outflow of the underflow and increasing this tendency to accumulate, as well as bringing up the water plane and saturating the aquifers, rendering the entire area more resistant to occasional drouth periods, especially in the case of deep-rooted plants, like trees or vines or alfalfa.

AUXILIARY PUMPED SUPPLIES

OCCASIONAL USE

Out of the required water supply of 141,000 acre feet, a shortage in any one season of one-third, or 47,000 acre feet, is considered permissible. In seasons where the shortage exceeds this allowable one-third, it is proposed to supplement the runoff and reservoir releases by pumping from the underground storage in Capay Valley. During the past 20 seasons there were two seasons in which this permissible shortage was exceeded. A pumping capacity of 250 second feet would be ample to augment the stream flow so that at least two-thirds of the required draft could be obtained.

A general scrutiny of rainfall records for the past sixty years in this vicinity would indicate that in the forty years back of the past twenty seasons there would have occurred but one additional period of such excess shortage. The additional cost of pumping once in twenty or thirty years is, therefore, very small and probably will be much more than offset by sales of water for rice during wet or even normal seasons.

LOCATION AND TYPES OF PUMPS

The proposed pumping units, three in number, would be located in the lower end of Capay Valley, a short distance above the existing Capay Diversion Dam. These pumps would be of the horizontal, centrifugal type, placed close to the creek channel. They would draw water from sumps or pits in which the water will be concentrated from radiating, nearly horizontal, tunnels or collecting galleries.

The installation of such auxiliary machinery could readily be deferred until the advent of an extra dry season, as forecast by the exhaustion of the storage in Indian Valley, and also until the rapid extension of irrigation in this vicinity had approached the full irrigation demand, for which this project has been planned.

Water pumped in this manner from underground storage could be discharged directly into the canals from the creek and would naturally be taken from the areas in which the water plane was highest and where the greatest amount of underground storage existed. It is impossible to design such a plant until a good deal further detailed data has been obtained regarding underground water storage, underground water movements, depths to water, etc., but for preliminary estimate purposes it will be assumed that the lifts would be limited to 50 or 60 feet.

COSTS

The capital cost of this auxiliary source of supply is estimated to be $250,000, or $1000 per second foot developed. Each unit will require some 70 feet of pipe on the pump, as well as several hundred feet of collecting galleries. The pumping units will probably cost about $20,000 each and when all the items are added the final cost will be around $250,000.

ALTERNATIVE POSSIBILITIES OF AUXILIARY SUPPLY

The present project is based primarily upon insuring a substantial water supply for irrigation in Yolo County by the construction of a large reservoir at Indian Valley where water deliveries would be very much more dependable in critically dry periods than those which now occasionally fail altogether from Clear Lake. In order to indicate the possibility of absolute insurance of sufficient water for the ultimate irrigation of 75,000 acres, a preliminary scheme is here suggested as only one of a number of possible alternatives which further study might indicate to be preferable.

If the State Wide Water Plan be completed, there will always be an abundance of water during the irrigation season in the Sacramento River. Water is already brought in, in a very economical fashion, from the Sacramento River and right up to the eastern edge of the tract proposed for irrigation. It is easily possible to extend this water supply so as to deliver water from the Sacramento River direct to the headgates of the Moore Canal, or even further, and then hold the available remaining supply in Indian Valley and elsewhere during very dry seasons for the upper diversion points.

The writer has worked out projects for the irrigation from the Sacramento River of a large area from Arbuckle to Dunnigan near the northerly edge of the tract here proposed for irrigation, and this source of supply is also entirely feasible.

The additional auxiliary supply can be obtained by raising the Indian Valley Dam here proposed, or it is possible to store during normal or wet seasons excess runoff from Clear Lake in storage reservoirs on Putah Creek. Such waters could then be diverted at Winters directly into a large portion of the present distribution system. Such an additional supplementary supply, if the Indian Valley Reservoir were built, is not needed until extensive irrigation development has actually taken place and, hence, could readily be postponed until a complete study has been made of all of these alternative possibilities.

SUMMARY OF TOTAL AVAILABLE WATER SUPPLY

The total available water supply for the last twenty years, which is the critical period, apparently about 12% sub-normal, and in which are the dryest years of record, is shown in the following Table X, segregated into the three principal sources: first, the natural streamflow available from the uncontrolled or unregulated area and limited, as previously explained, to the irrigation months of March, April and May; second, from Clear Lake releases as they have actually occurred under drastic legal limitations during the last twenty years; and third, and by far the most important during critical years, the supply which would have been furnished from the proposed storage reservoir at Indian Valley.

TABLE X

SUMMARY OF WATER SUPPLY AVAILABLE

FOR IRRIGATION OF 75,000 Acres

1916-17 to 1935-36

Season (Oct.-Sept.)	Uncontrolled Flow Acre Feet	Clear Lake Releases Acre Feet	Indian Valley Releases Acre Feet	Total Irrigation Supply Acre Feet
1916-17	16,590	117,568	6,842	141,000
1917-18	13,050	99,694	28,256	141,000
1918-19	27,150	105,742	8,108	141,000
1919-20	17,490	4,250	119,260	141,000
1920-21	24,750	104,005	12,245	141,000
1921-22	33,850	106,287	863	141,000
1922-23	19,930	102,744	18,326	141,000
1923-24	9,030	4,250	127,720	141,000
1924-25	33,850	93,887	13,263	141,000
1925-26	17,400	117,652	5,948	141,000
1926-27	26,950	111,263	2,787	141,000
1927-28	22,150	110,190	8,660	141,000
1928-29	18,600	34,112	88,288	141,000
1929-30	20,800	86,391	33,809	141,000
1930-31	3,720	2,317	120,332	126,369
1931-32	5,550	43,254	46,940	95,744
1932-33	9,620	0	24,230	33,850
1933-34	4,740	37,283	31,185	73,208
1934-35	13,720	61,420	61,990	137,130
1935-36	10,250	113,714	17,036	141,000
Average	17,500	72,800	38,800	129,100

This Table X shows that to furnish full irrigation supply for the 75,000 acres would require at the diversion points 141,000 acre feet per year, and that during fifteen of the past 20 years a full supply would have been available. The five years of shortage are found in the five year period 1930 to 1935, and the shortage of the years at the beginning and end of this period is nominal. In the year next to the beginning and the year next to the end of this five year period, the shortage probably could be tolerated without very serious difficulty. Therefore, additional water would have to be furnished from auxiliary sources in one of the 20 years, (1932-33), and probably some of the following year also.

Plate 6, graphically summarizing this irrigation supply, shows month by month for the last 20 years the accumulation of water which would have been stored in the proposed Indian Valley Reservoir. Beginning in 1916, it would not have been emptied until late in 1931 and during many of these years would have been full, or nearly so, for the entire season as only minor releases would have been required. During this last six year subnormal period the reservoir would have been so operated as to enable practically a full supply to have been furnished during three of these six years and would have furnished a most substantial contribution to the water supply in the other three years.

The second diagram on the chart shows the Clear Lake releases as they were actually made in the last 20 years, in four of which there were no releases whatever.

The bottom chart, a graphic summary of this entire report, shows the month by month water demand, the green portions of the demand being confined to the first three months of the irrigation season being the natural streamflow below regulated areas.

The orange portions of the chart, dominating the majority of the years, show the amounts which have been used month by month for irrigation from water releases from Clear Lake. The yellow portions of the diagram, by far the most important of all and dominating the dry or critical years, show the very important additions to the water supply which would come, especially during these dry years, from the Indian Valley Storage. In seasons considered very dry in California and in which most irrigation projects suffered severely, such as the seasons of 1920, 1924 and 1931, the huge yellow blocks of Indian Valley water would have enabled this project to have a full supply, and it would have resulted in extending happy conditions for the Yolo County farmers.

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