CALIFORNIA. DEPT. OF WATER RESOURCES
BULLETIN.

STATE OF CALIFORNIA
The Resources Agency

Department of Water Resources

BULLETIN No. 104-3

MEETING WATER DEMANDS IN THE CHINO-RIVERSIDE AREA

MAY 1971

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The Resources Agency

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STATE OF CALIFORNIA

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MAY 1971

FOREWORD

At present, about half the water supply of Southern California's South Coastal Area comes from its ground water basins. In general, extractions from this source have exceeded replenishment, resulting in a decline of ground water level elevations.

The Department of Water Resources, recognizing the need for information to be used to cope with the potentially detrimental effects of such a water level decline, has undertaken a comprehensive study of various plans by which Southern California's major ground water basins could be safely used in conjunction with possible surface water supplies. The Coastal Plain of Los Angeles County was selected as the first area to be investigated. The San Gabriel Valley was the second. The Chino-Riverside Area is the third.

This investigation in the Chino-Riverside Area was a cooperative venture by the Chino Basin Municipal Water District, the Western Municipal Water District of Riverside County, and the Department. Statutory authority for the Department to conduct investigations of surface and subsurface water is contained in Section 226 of the California Water Code. Statutory authority for investigation of ground water conditions is also conferred under the Porter-Dolwig Ground Water Basin Protection Law, Water Code Section 12920 and those that follow, and Section 231.

In this investigation, comprehensive studies were made of the geology, hydrology, and operation-economics of the Chino-Riverside Ground Water Basin. Detailed information on the geohydrology was presented in Appendix A to this bulletin. The detailed operation-economics information is given in Appendix B, which is being published as a memorandum report. This bulletin is a summary of all the studies.

William R. Gianelli, Director
Department of Water Resources
The Resources Agency
State of California
April 27, 1971

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ACKNOWLEDGMENTS

The Department of Water Resources acknowledges with thanks the information and advice provided by the Technical Advisory Committee and various Federal, State, and local agencies during the preparation of this bulletin and its appendixes.

Technical Advisory Committee

The Technical Advisory Committee, which was consulted on significant items in the investigation at a series of meetings held from January 1967 to April 1969, was established within the study area to give guidance to the investigators. Its members are:

Chino Basin Municipal Water District

Mr. William Carroll
Mr. Ed LaBahn
Mr. Donald Stark

Western Municipal Water District of Riverside County

Mr. Howard Hicks
Mr. Albert A. Webb
Mr. Ralph Stone

California Regional Water Quality Control Board, Santa Ana Region

Mr. Richard Bueermann

Federal, State, and Local Agencies

In the compilation of data, which was essential to this investigation, the Department received assistance from a number of Federal, State, and local agencies. In particular, these are:

Federal Agency

Geological Survey (Water Resources Division)

State Agencies

Department of Conservation, Division of Mines and Geology; Division of Oil and Gas
Department of Public Works, Division of Highways
Public Utilities Commission
Water Resources Control Board

County Agencies

Assessor (Los Angeles, Riverside, and San Bernardino)
Planning Commission (Los Angeles, Riverside, and San Bernardino)
Sanitation District (Los Angeles)
Office of County Engineer (Los Angeles, Riverside, and San Bernardino)
Flood Control District (Los Angeles, Riverside, and San Bernardino)

Special Districts

The Metropolitan Water District of Southern California
Pomona Valley Municipal Water District
San Bernardino Valley Municipal Water District
Chino Basin Municipal Water District
Western Municipal Water District of Riverside County

Universities and Colleges

The Associated Colleges of Claremont
California Institute of Technology
University of California at Los Angeles
University of California at Riverside
University of California at Davis
University of Southern California

Oil Companies

Humble Oil and Refining Company
Signal Oil and Gas Company
Standard Oil Company of California
Texaco, Incorporated

ABSTRACT

The water demand of the Chino-Riverside Area was approximately 450,000 acre-feet in 1965 and by 2015 is expected to be almost 850,000 acre-feet. / One of the most significant sources of supply is the ground water basin, in which approximately 12 million acre-feet of water was in storage in 1960. Estimates are that the net replenishment to this from all sources (including effluent waste water percolation) will average annually about 394,000 acre-feet under mean hydrologic conditions. / This bulletin summarizes the geologic and hydrologic data developed in this investigation and, in addition, presents physical and economic information for four alternative plans of conjunctive use of ground and surface water resources to meet future water demand.

CONCEPT UNDERLYING WATER PLANNING

Water is a commodity that meets basic human needs; without it, life cannot continue. This fact has made us somewhat emotional about water and we have come to treat water differently from other commodities.

However, water is an ever present commodity. It cannot be destroyed; it is used and then it returns to be used again. Water is around us in many forms. By means of treatment and timely delivery, which may be either expensive or inexpensive, this water can be put to all uses to meet our needs any place on earth. It is, then, not difficult to conclude that all the water needs of any area, now and in the future, can be met with proper planning.

ELEMENTS OF PLANNING. An analogy between financial planning and water resources planning will help to identify the elements to be considered.

Figure 1 represents the components that are considered in family financial planning. To ensure sound financial planning, a complete inventory must be taken of the supply of money in terms of annual income, assets, and borrowing capabilities, as well as an inventory of financial obligations. For financially advantageous decision-making, various alternative ways of meeting financial obligations and of increasing income must be considered very carefully. Only after a full evaluation of the advantages and limitations of various alternatives should a plan be selected and implemented.

Figure 2 represents the analogous components of water resources planning. This process involves;

1. Inventory of needs, supplies and associated facilities.
2. Formulation of alternative schemes of meeting needs.
3. Evaluation of advantages and limitations of alternatives.
4. Selection of a plan.
5. Implementation of the selected plan.

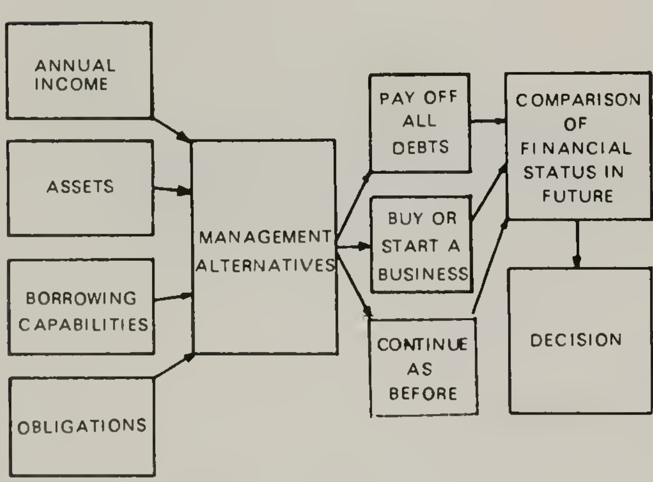


Fig. 1
FINANCIAL MANAGEMENT PLANNING

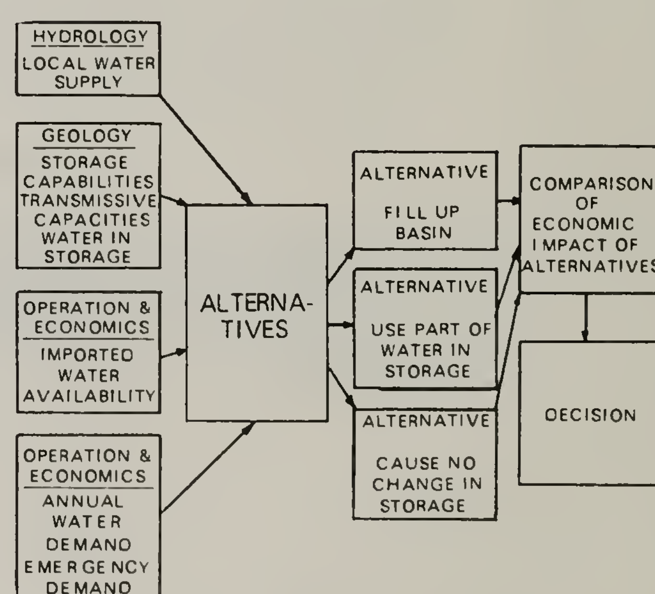


Fig. 2
WATER MANAGEMENT PLANNING

CHAPTER I. INTRODUCTION*

The Chino-Riverside Area, because of its heavy reliance on local water supplies, has been concerned with the problem of managing its water resources from the time it was first settled.

The increasing demand for water and the cost of obtaining it have made clear to local water managers that they must have all necessary information on comprehensive alternative water supply plans so that they can make an informed selection of the most suitable one. A prerequisite to the formulation of such plans is the collection and analysis of data pertinent to the problems of water demand and supply, especially concerning the ground water resources, which are among the most readily available supplies.

The Department of Water Resources, together with the two major municipal water districts in the Chino-Riverside Area, has completed an investigation to furnish such information. The findings are summarized in this bulletin.

Objective of Investigation

The objective of the investigation was to provide information on a wide range of alternative plans to be used as a guide by local agencies for selecting a plan for managing their ground water supplies in coordination with surface water supplies and facilities.

Area of Investigation

The study area (Figure 3) occupies about 641 square miles in portions of Riverside, San Bernardino, and Los Angeles Counties. Of this, 433 square miles are water-bearing floor lands; the remainder are tributary mountains and hills.

Elevations range from 475 feet at Prado Dam to 10,064 feet above sea level at the peak of Mount San Antonio.

The precipitation variation from year to year at one station is shown in Figure 4. For the mean base period, 1934-35 through 1959-60, the average annual depth of precipitation at specific points on the valley floor ranged from 10 inches near Arlington to 25 inches at the base of the San Gabriel Mountains. At Mount San Antonio, the average was about 45 inches. For the same period, the average annual depth of precipitation on the entire valley floor was 15.7 inches, ranging from 32.2 inches in 1940-41 to 5.9 inches in 1958-59.

The Santa Ana River begins in the San Bernardino Mountains and traverses the entire study area on its way to the Coastal Plain and then the Pacific Ocean.

Historically, the land in the Chino-Riverside Area has been primarily in agriculture, but recently agricultural land has been giving way to urban development. Figure 5 shows how irrigated agricultural acreage increased steadily from 9,400 acres in 1879 to 113,900 acres in 1932. It remained essentially the same until 1957, but then began decreasing so that, by 1963, it amounted to 87,100 acres. Urbanization, on the other hand, increased steadily from 1,700 acres in 1888 to 75,500 acres in 1963. Another measure of the urbaniza-

* For definition of terms used in this bulletin and for a bibliography of references used, see Appendix A: "Water Supply", bound separately.

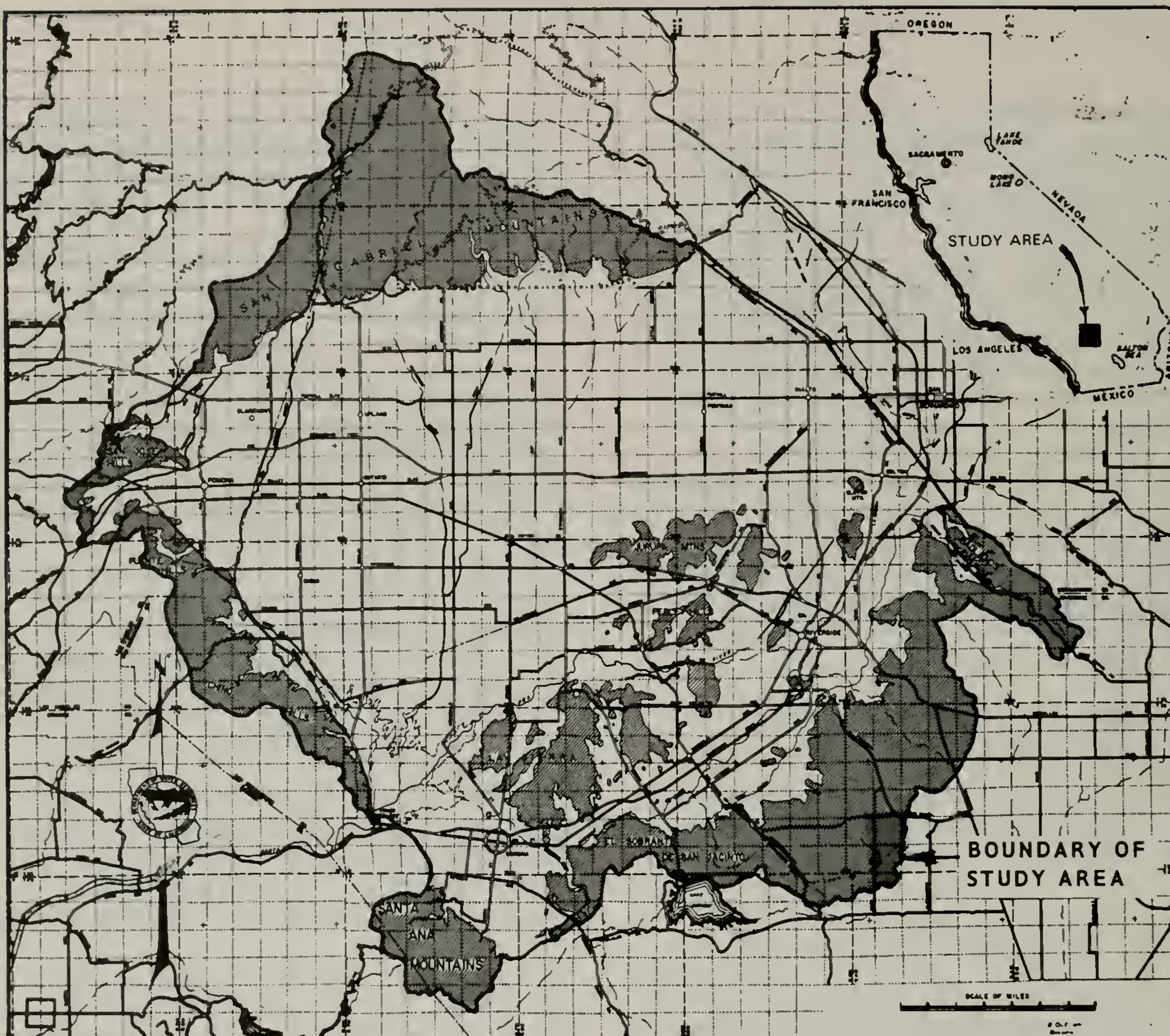


Figure 3 - **STUDY AREA**

tion of the Chino-Riverside Area is the threefold increase in population, from 146,000 to 460,000 between 1940 and 1960.

In the late 19th century and the early 20th century, numerous diversion works, including ditches, weirs, and canals, were used by the settlers to irrigate the fertile farmland from the numerous streams and washes within the Area.

Because of a decrease in the streamflow around the turn of the century, resulting from increased upstream use of diverted surface water, wells were dug and ground water was used to supplement streamflow for irrigation during dry seasons. The use of electric and gas power to drive well pumps and the development of the deep-well turbine pump greatly accelerated this transition.

From about 1883 to 1910, cities like Riverside, Ontario, Pomona, Upland, and Chino were incorporated and developed their own water systems, using ground and local surface waters to supply the

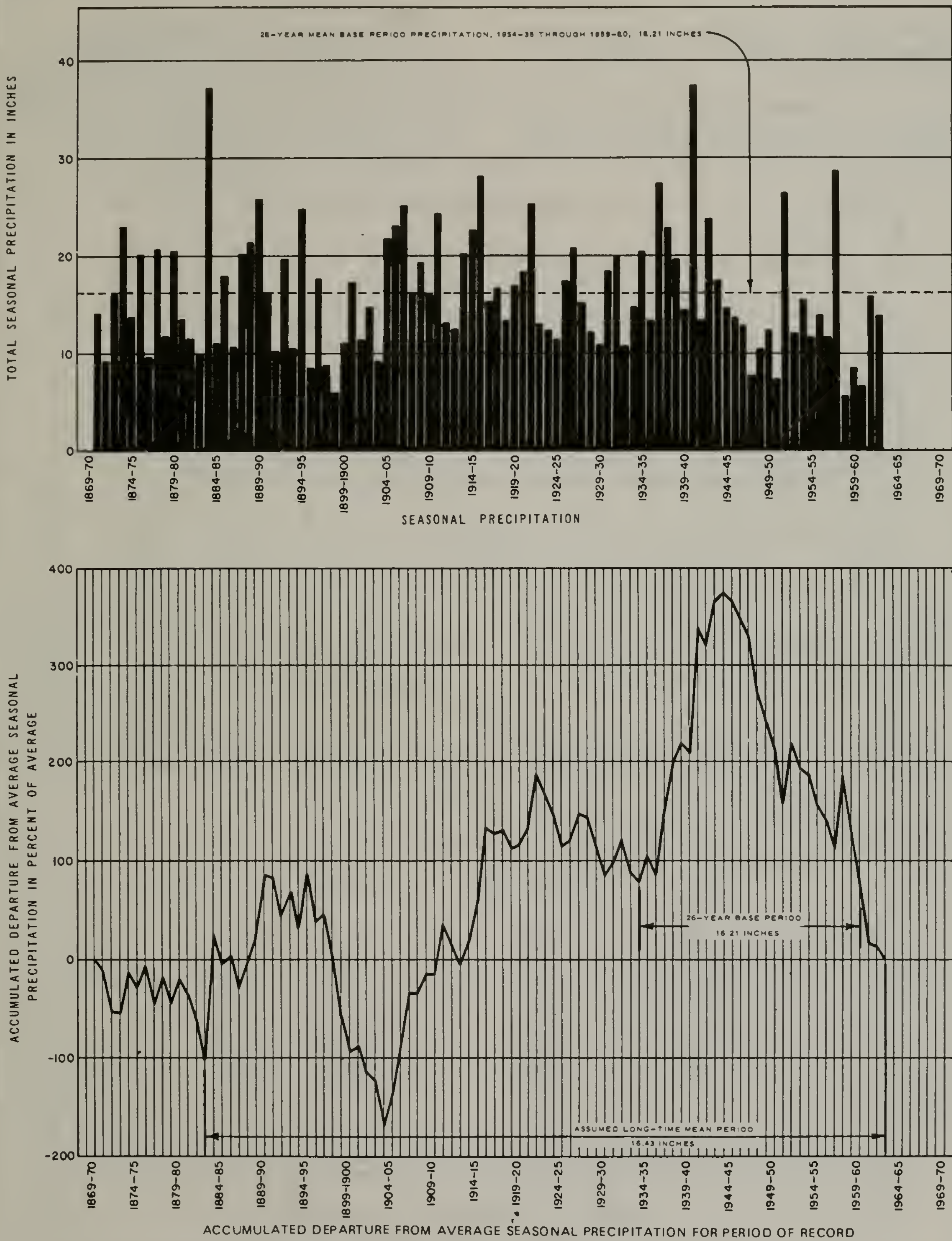


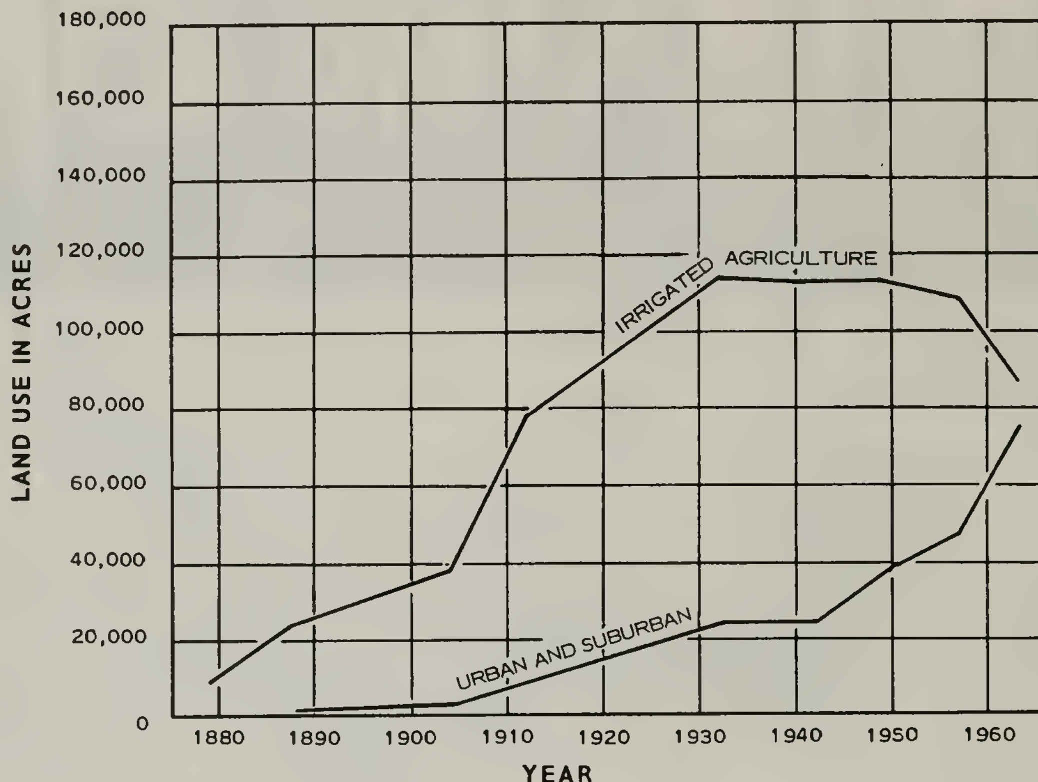
Figure 4-PRECIPITATION CHARACTERISTICS AT ONTARIO

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1971 needs of their residents. Later, water districts were formed to purchase imported water.

Figure 6 summarizes the data on the supply, use, and disposal during the mean base period.

Conduct of Investitation

The work program for this investigation was divided into three phases: geology, hydrology, and operation-economics. The first two phases were conducted to develop: (1) information on locally



SURVEY YEAR	IRRIGATED AGRICULTURE	URBAN AND SUBURBAN	TOTAL
1879	9,400	- - -	- - -
1888	24,400	1,700	26,100
1904	38,100*	4,000*	42,100
1912	77,900*	9,500*	87,400
1932	113,900	24,500	138,400
1942	112,500	24,600	137,100
1948	113,800	35,100	148,900
1957	108,200	48,800	157,000
1963	87,100	75,500	162,600

*ESTIMATED

NOTE: TOTAL WATER-BEARING AREA IN CHINO-RIVERSIDE AREA IS 277,000 ACRES

FIGURE 5 – HISTORICAL LAND USE

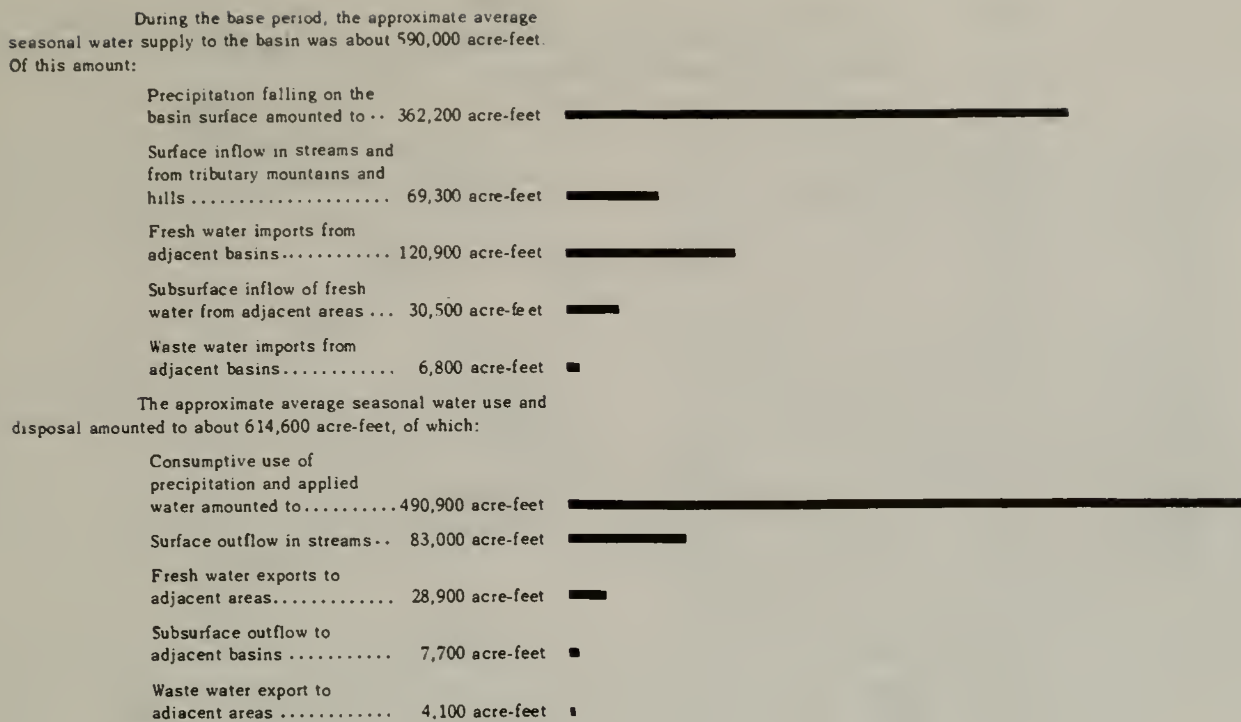


FIGURE 6 – WATER SUPPLY, USE, AND DISPOSALS – 1934-35 THROUGH 1959-60

available water supplies and (2) the data required to construct a mathematical model of a ground water basin that will simulate water level responses of the Area under various postulated plans. The model was then used in the operational-economic phase of the investigation in which the cost of water service under those alternatives was determined.

In this study, except as otherwise noted, the "future" period for which plans were designed was 1965-2015.

Because this investigation dealt with future water service in the study area, a number of factors affecting the supply and cost could not be predicted conclusively. Some of these factors were the future pricing policy of The Metropolitan Water District of Southern California (MWD), quality of imported water, water demand, mean water supply, and land use. Therefore, conditions that might develop in the future had to be assumed. During the investigation, some of these assumed conditions changed and they are expected to continue to change.

To determine the effects of changing conditions on the economic findings of the study, an evaluation was made of the impact of these changes. The impact was not found to be large enough to change the conclusions that could be arrived at by evaluating the results presented.

A wide range of alternative plans for operation of the ground water basin, in coordination with surface water supplies, were considered. However, this report presents only the economic impact of operational variables. Legal, political, social, organizational, and water quality factors must also be considered by local agencies in the selection of a plan of operation.

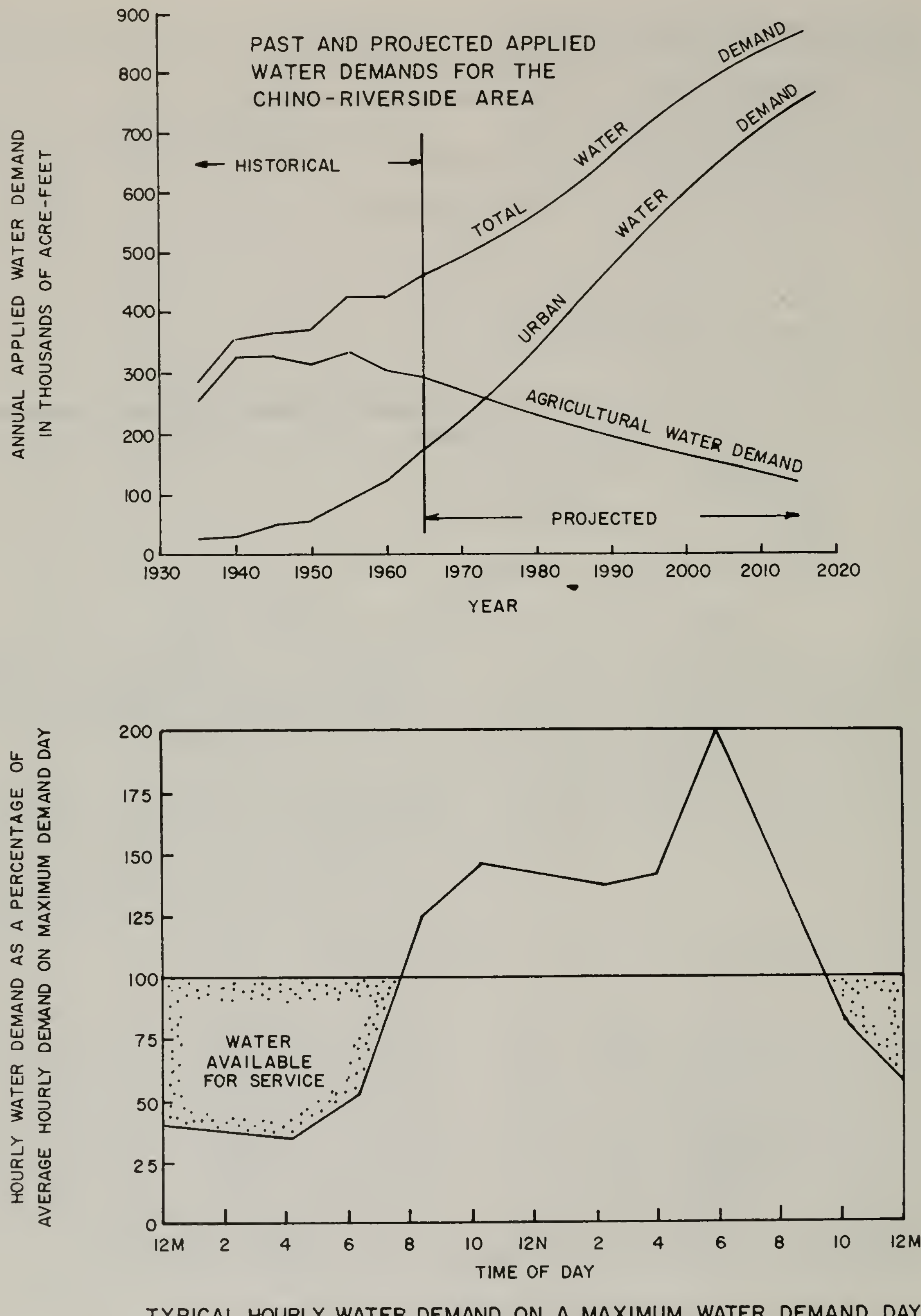


Figure 7 - WATER DEMAND

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1971

To develop effective plans for the management of water resources, both the future demand and the extent of available supplies must be determined.

Water Demand

The demand of the study area for applied water* has increased from approximately 280,000 acre-feet in 1935 to 450,000 acre-feet in 1965. The demand for 2015, based on future population and land use forecasts, is projected to be approximately 850,000 acre-feet.

The high agricultural water demand in the early years and its decline in the subsequent years is illustrated in Figure 7. This decline is based on the projected urban encroachment, not on any anticipated increase in price of water for agricultural use. Under all the alternative plans developed in this study, the price of water for agricultural use is about the same.

To ensure that adequate facilities are provided to meet fluctuating urban demands for delivered water, information on monthly and hourly demand on a day of maximum water use must be considered. For the area, the peak monthly demand is about 130 percent of that for the average month. The average demand on a day of maximum use is about 200 percent of that for the average day. The peak hourly water demand is about 200 percent of the average hourly demand on a day of maximum use, or 400 percent of that for the average hour. (See Figure 7.)

In addition, to the urban and agricultural demands for applied water, two other requirements are to be considered. One is for supplemental water for artificial recharge of the basin which would be required under some of the operational plans that were studied.

The second requirement is an outflow obligation to satisfy the rights of downstream claimants on the Coastal Plain of Orange County (Orange County Water District v. City of Chino, et al., Orange County Superior Court No. 117628 (1967)). This obligation is for a specified average annual base flow at Prado Dam. However, the quantity required to supply this outflow obligation was found to be available in all the selected plans of operation (Appendix B). Therefore, no additional water was required.

Water Supply

At the beginning of the study period (1965), water supplies to meet the various demands in the area consist primarily of locally pumped ground water, imported ground water, local surface water, and imported Colorado River water. (See Figure 8.)

Imported and Surface Water

Most of the imported water is delivered in pipelines and canals from the Bunker Hill-San Timoteo Area Ground Water Basin. The remainder (27,500 acre-feet in 1965) is Colorado River water supplied by MWD.

The four major water districts with legal and financial capacity to import supplemental water supplies are the San Bernardino Valley Municipal Water Dis-

* "Applied water" is defined as water delivered to a farmer's headgate or to an urban water user's meter. The terms "applied water" and "delivered water" are used interchangeably.

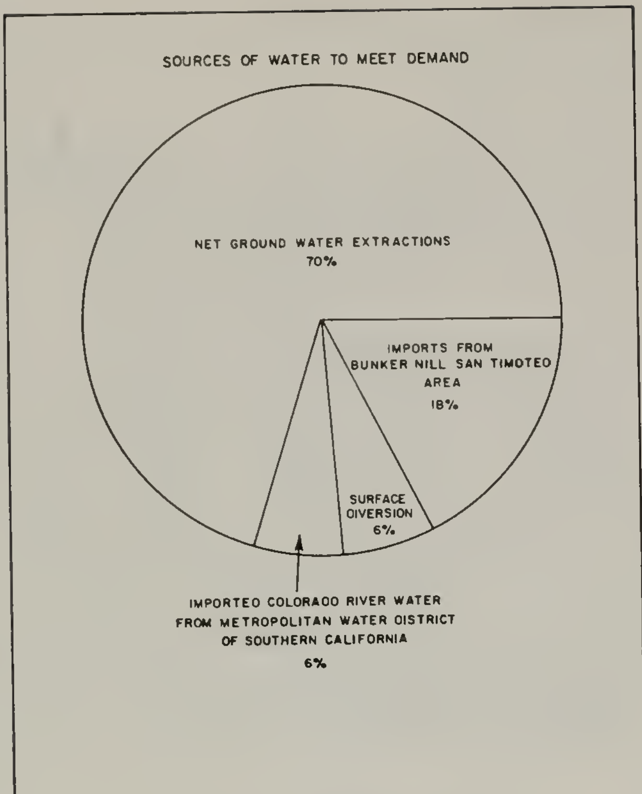


Figure 8 - COMPARATIVE MAGNITUDE OF 1965 SUPPLY

trict (SBVMWD), the Pomona Valley Municipal Water District (PVMWD), the Western Municipal Water District of Riverside County (WMWD), and the Chino Basin Municipal Water District (CBMWD). (See Figure 9.) All except SBVMWD are members of MWD.

SBVMWD has a contract with the State of California for delivery of Northern California water from the California Aqueduct beginning in 1972.

In the foreseeable future, any needed quantity of imported water could be delivered by MWD, provided that: (1) no water shortage exists throughout the MWD system and (2) adequate pipelines connecting the local agency's distribution system with the MWD system are constructed.

Average surface flow in most streams is relatively small and intermittent; its importance as a source of water has declined. With the change of economic activity of the Area from agricultural to urban, the future supply of surface water was estimated to be approximately 30,000 acre-feet per year.

Ground Water

To estimate the supply potential of ground water to meet the Area's needs, the amount of ground water in storage at the start of the study period and of the future replenishment rate must be determined.

Water in Storage. Only a portion of the water contained in aquifers can be extracted. Even when an aquifer is supposedly pumped "dry", a small amount of water remains as a thin film coating the particles of sand and gravel. The percentage that is still retained by the sediments is called specific retention.

Specific yield is the ratio of the volume of water that can be removed by gravity drainage to the total volume of the saturated sediments. Hence, as used by hydrologists, storage refers only to the actual amount of water that can be extracted from sediments.

In the study area, the principal water-bearing deposits are unconsolidated sediments and alluvium; they underlie most of the Area. Ground water is stored in the interstices of these deposits and, to a limited amount, in fractures of nonwater-bearing rocks that surround the Area.

The water-bearing deposits are bounded by the San Gabriel Mountains on the north, the San Jacinto fault on the east, and the Chino Hills on the west. The ground water basin thus formed divides into four subbasins: the Pomona, the Chino, the Colton-Rialto, and the Riverside.

The base of the basin is formed by granitic rocks, consolidated sedimentary rocks, and such impermeable sediments as clay and silty clay. A contour map of the base is shown in Figure 10.

In the Pomona, Chino, and Colton-Rialto subbasins, the depth of the water-bearing deposits ranges from a few feet near the mountains to about 1,300 feet in the center of the basin. Average depth is about 700 feet.

In the Riverside subbasin, the water-bearing deposits are shallow; their depth ranges from a few feet to 250 feet, with an average of 150 feet. Consequently, this subbasin has little storage capacity.

In the basin as a whole, the specific yield of the water-bearing materials was estimated at 3 percent for the finer materials to 35 percent for the coarser ones.

To calculate the total storage capacity, the basin was divided into smaller parts

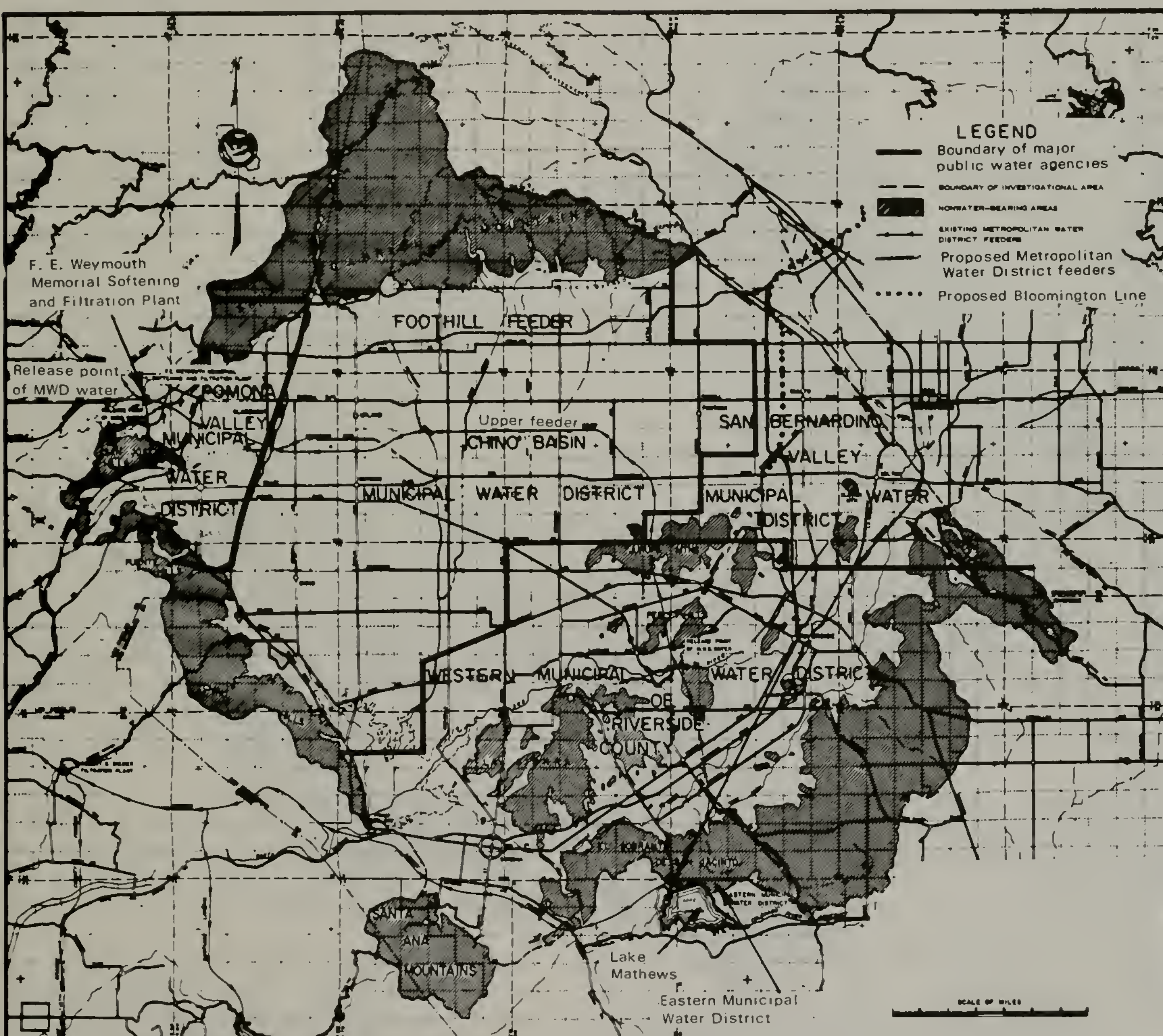


Figure 9 — MAJOR PUBLIC WATER AGENCIES AND EXISTING AND PROPOSED MAJOR WATER DISTRIBUTION FACILITIES

and the specific yield of each part was multiplied by the thickness of the aquifer and the areal size of the part.

This showed that, when full, the Chino-Riverside Ground Water Basin would hold 18.3 million acre-feet of water. In 1960, it was found to contain 12 million acre-feet.*

Replenishment. The ground water basin can be replenished by subsurface inflow and by deep percolation of water from various sources. These sources are precipitation and resulting runoff, delivered water, and imported water spread in streambeds and spreading grounds. Deep percolation due to precipitation occurs both inside and outside of streambeds.

*This total was assumed to have remained virtually unchanged in 1965.

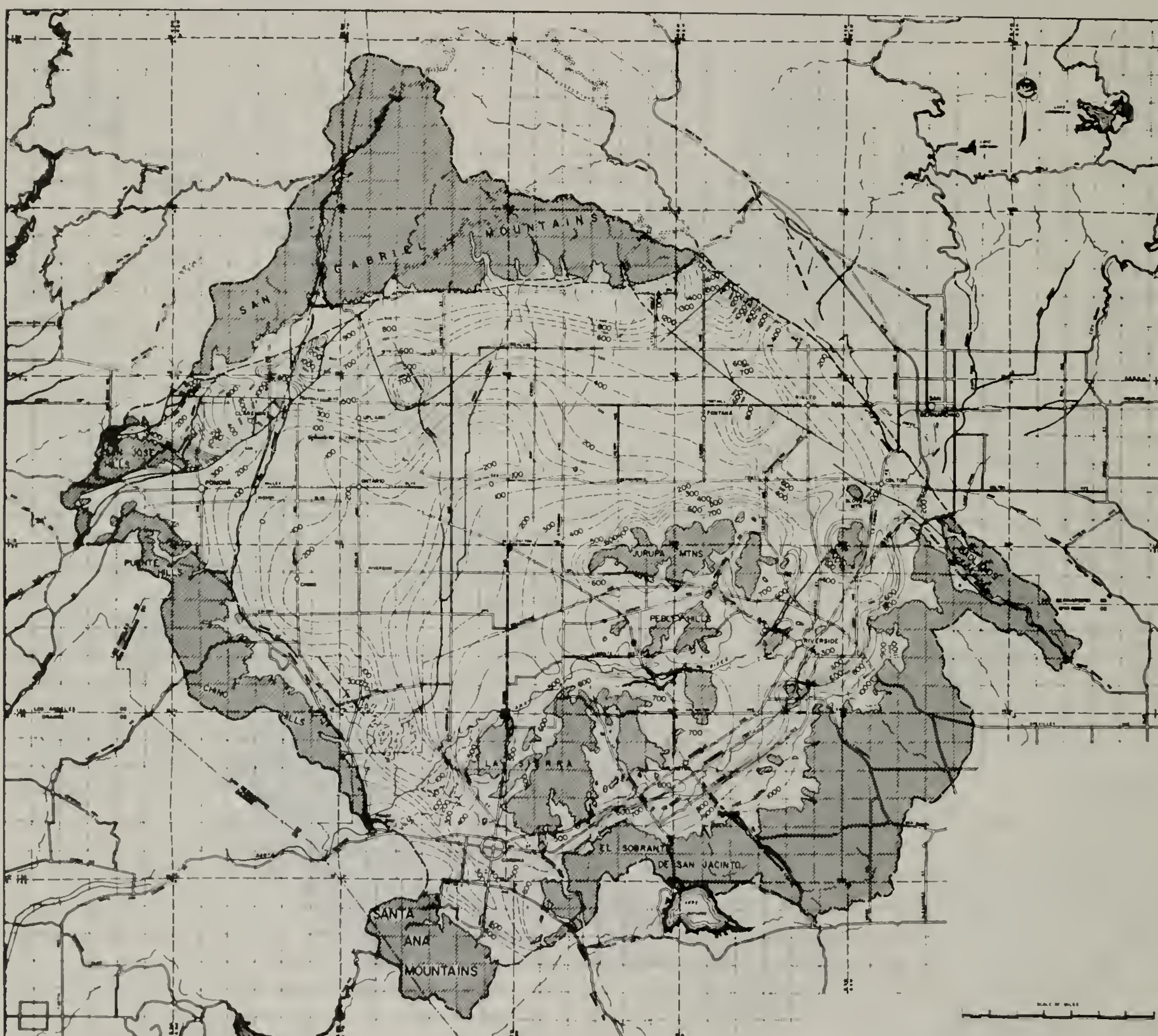


Figure 10 – LINES OF EQUAL ELEVATION ON THE EFFECTIVE BASE OF THE GROUND WATER RESERVOIR

Outside the streambed the deep percolation of precipitation is estimated to be about 57,000 acre-feet per year. Within the streambed of the Santa Ana River (only stream with significant percolation that will remain unlined in the future) and spreading grounds, under mean precipitation conditions, about 36,000 acre-feet is estimated to percolate annually.

Deep percolation from delivered water results from: (1) irrigation of lawns, gardens, and agricultural crops; (2) water discharged into cesspools and septic tanks; and (3) waste water effluent from treatment plants.

Under conditions of mean rainfall, the estimated deep percolation of delivered water from the first two sources is about 105,000 acre-feet per year (1965). However, because both irrigated acreage and the number of cesspools and septic tanks are decreasing, deep percolation from these two sources is expected to decrease to 72,000 acre-feet in 2015. It was assumed to average 86,000 acre-feet per year.

At the same time, deep percolation of the treated waste water effluent discharged into either the Santa Ana River or the percolation basins is expected to average 217,000 acre-feet per year. This represents an increase to more than 370,000 acre-feet in 2015 from 60,000 acre-feet in 1965. This increase will result from increasing water demands and from an increasing number of sewage treatment and disposal facilities.

With the exception of small evaporation losses, discharges of treated waste water percolate to the ground water and are effectively used as a source of water supply in the Chino-Riverside Area.

The City of San Bernardino has two waste water treatment facilities that are expected to continue to discharge into the Santa Ana River just above the San Jacinto fault (boundary with Bunker Hill-San Timoteo study area). In addition, future plans of waste water disposal agencies in both the CBMWD and WMWD service areas are to discharge a large amount of waste water in either the Santa Ana River or in off-stream percolation sites.

However, with the expected increasing discharge of quantities of future waste water effluent to the streams, more of the effluent will flow out of the ground water basin as rising water, which can be used to meet the base flow obligation. For this study, only minor amounts of waste water are expected to be used as a direct source to meet future water demand.

Negligible quantities of imported water have deep percolated in the past in the reach of the Santa Ana River streambed that is between the MWD turnout on the Upper Feeder (Riverside Narrows) and the Coastal Plain of Orange County. The amount has depended upon the amount of imported water released at the MWD turnout. This was an interim practice that has been replaced by deliveries from the Lower Feeder. Only small amounts of MWD water have been used for artificial recharge in the Chino-Riverside Area.

In the past, subsurface inflow has occurred along the Bunker Hill-San Timoteo Basin boundaries and from the San Gabriel Mountains. The amount of subsurface flow varies with the water level elevations inside and outside the study area. Thus, the amount will fluctuate according to the method of operating the ground water basins.

The base period average from the Bunker Hill-San Timoteo Area amounted to 17,000 acre-feet per year. This included an average inflow of 10,300 acre-feet per year through the Colton Narrows (ranging from 19,700 acre-feet in 1935-36 to 3,900 acre-feet in 1959-60).

Because, by 1965, the estimated inflow at Colton Narrows was zero, the total subsurface inflow from the Bunker Hill-San Timoteo Area was assumed to average only 7,000 acre-feet per year throughout the study period.

In addition to these inflows, a subsurface inflow of 13,000 acre-feet per year was assumed to continue to come from the San Gabriel Mountains in the north. This comes from stored water moving out of the fractures in the basement complex into the alluvial fill.

Removal. Ground water is removed by subsurface outflow and by pumping.

Historically, the only subsurface outflow from the Area occurred along the boundary with the San Gabriel Valley. Because this outflow has diminished, significant outflow is not expected to occur in the future.

In 1965, about 70 percent (315,000 acre-feet) of the demand for delivered water in the study area was met with pumped ground water. In the future, the amount of water to be taken out of the basin by pumping will depend upon the plan of operation to be implemented.

In addition to this variable amount of water to be pumped, smaller amounts were assumed to be fixed for all plans of operation. These include the water that is transferred within the basin across the boundaries of the different water districts. The average is 22,000 acre-feet per year.

Thus, the net replenishment to the basin for 1965-2015 is estimated to be approximately 394,000 acre-feet each year.

CHAPTER III. INVENTORY OF FACILITIES

Water supply facilities are those required for transmission and storage of surface and ground water to meet the fluctuating demand.

Many of the water delivery facilities would be required no matter whether surface or ground water is used. This group includes small pipelines beyond the connection to the MWD's pipeline and the distribution systems owned and operated by both private and municipal agencies. These facilities were excluded from consideration because they are common to all plans of operation and do not affect the comparison of alternative plans.

Underground Facilities

The ground water basin can be considered as a part of the network of storage and delivery facilities. To illustrate, the deep percolation and subsurface inflow into the ground water reservoir are equivalent to the inflow into a surface reservoir. The storage capacity of the ground water basin is comparable to the storage capacity of a surface reservoir. The transmissive characteristics of the aquifers of the basin may be compared to the delivery characteristics of a surface distribution system. Finally, the piezometric pressure and ground water table in the basin are analogous to the hydraulic grade line elevations in a surface distribution system.

Mathematical Model

Equations that numerically describe the transmissive and storage characteristics of the ground water basin can be used to calculate the capabilities of the basin as a storage and delivery medium.

Thus, by developing the series of equations that describe the physical characteristics of a particular basin, a mathematical model of it can be constructed and can be used to simulate the physical reaction of the basin.

Accordingly, a detailed geologic study was conducted to get the information to define the transmissive, storage, and boundary conditions of the ground water basin in the study area.

Before the model can be used for predictions, however, it must demonstrate that it does in fact truly represent the ground water system. The model is considered verified, or validated, if ground water levels computed by it match, reasonably well, field-measured water levels.

One of the objectives of the hydrologic study was to develop historic hydrologic information, such as percolation of streamflow, precipitation, and pumpage, so that the model could be validated.

Once verified, the ground water basin model can be used to predict future water conditions under alternative plans of basin operation. Although the model has been used only for the plans considered in this investigation, it is also available for use for other alternative plans that may be considered by local agencies in the future.

Recharge and Extraction Points

When the ground water basin is regarded as a delivery facility, streambeds and manmade spreading grounds may be considered as the initial point of the delivery facility and wells as the terminal point.

In addition to the Santa Ana River bed, which is a natural spreading ground, many manmade spreading grounds have been

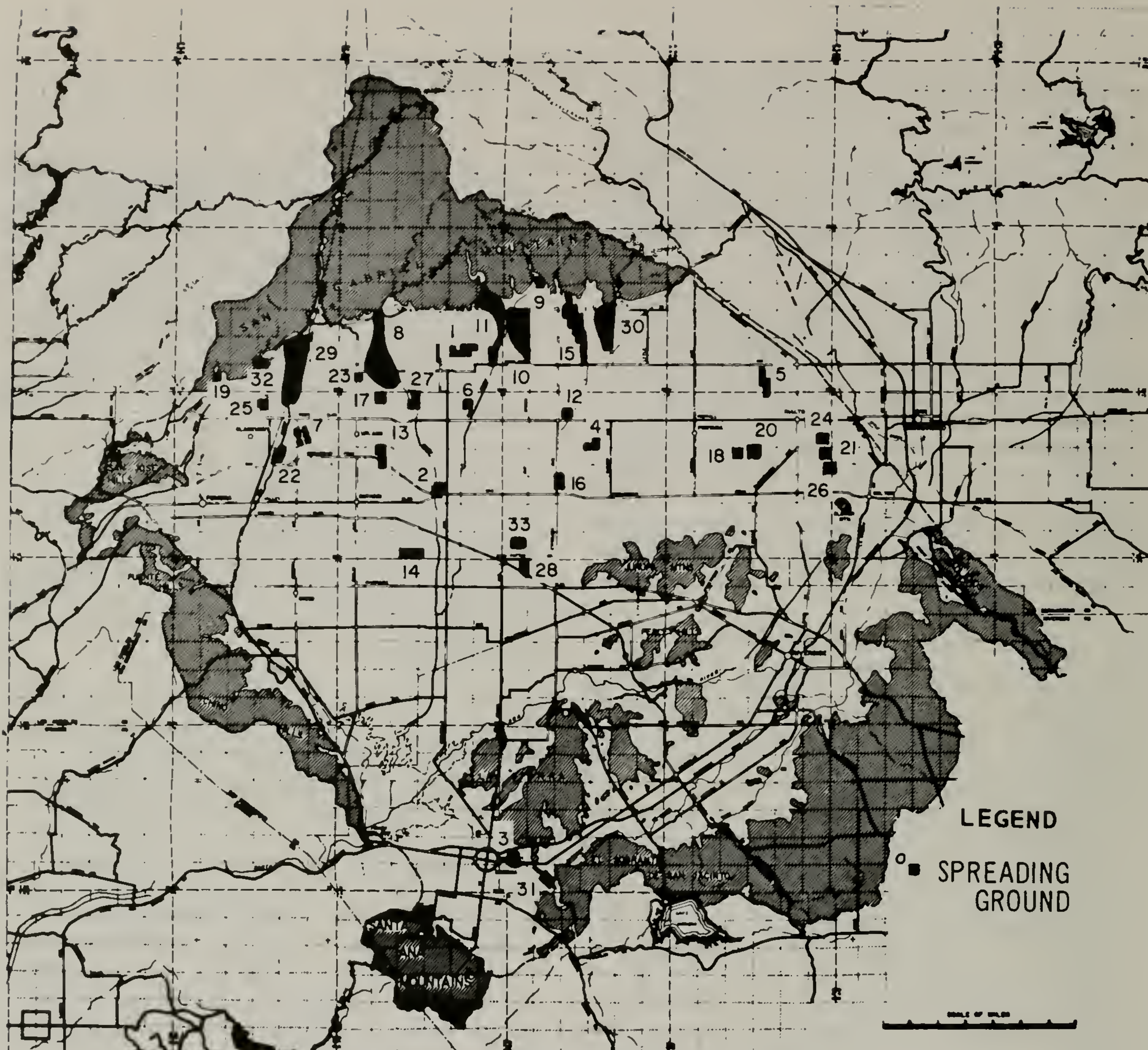


Figure 11 – **LOCATION OF SPREADING GROUNDS**

Name	Owner or operator
1. ALTA LOMA	SBCFCD
2. ARCHIBALD AVENUE	SBCFCD
3. ARLINGTON	RCFC & WCD
4. BANANA AVENUE	SBCFCD
5 CACTUS	SBCFCD
6 CHURCH	SBCFCD
7. COLLEGE HEIGHTS	SBCFCD
8. CUCAMONGA	San Antonio Water Co.
9. DAY CANYON	Etiwanda Water Co.
10. DAY CREEK	SBCFCD
11. DEER CREEK	SBCFCD
12. EAST AVENUE	Etiwanda Water Co.
13. EIGHTH STREET	SBCFCD
14. ELY STREET	SBCFCD
15 ETIWANDA	SBCFCD
16. ETIWANDA CONSERVATION BASIN	SBCFCD
17. FIFTEENTH STREET	SBCFCD
18. LINDEN	SBCFCD
19. LIVE OAK	LACFCD
20. MERRILL	SBCFCD
21. MILL	SBCFCD
22. MONTCLAIR	SBCFCD
23. 19 TH STREET	SBCFCD
24. PEPPER	SBCFCD
25. POMONA	City of Pomona
26. RANDALL	SBCFCD
27. RED HILL	SBCFCD
28. RIVERSIDE	SBCFCD
29. SAN ANTONIO	PVPA
30. SAN SEVAINE	SBCFCD
31. TEMESCAL	RCFC & WCD
32. THOMPSON	PVPA
33. WINEVILLE	SBCFCD

ABBREVIATIONS: San Bernardino County Flood Control District — SBCFCD; Riverside County Flood Control and Water Conservation District – RCFC & WCD; Pomona Valley Protective Association — PVPA; and Los Angeles County Flood Control District–LACFCD.

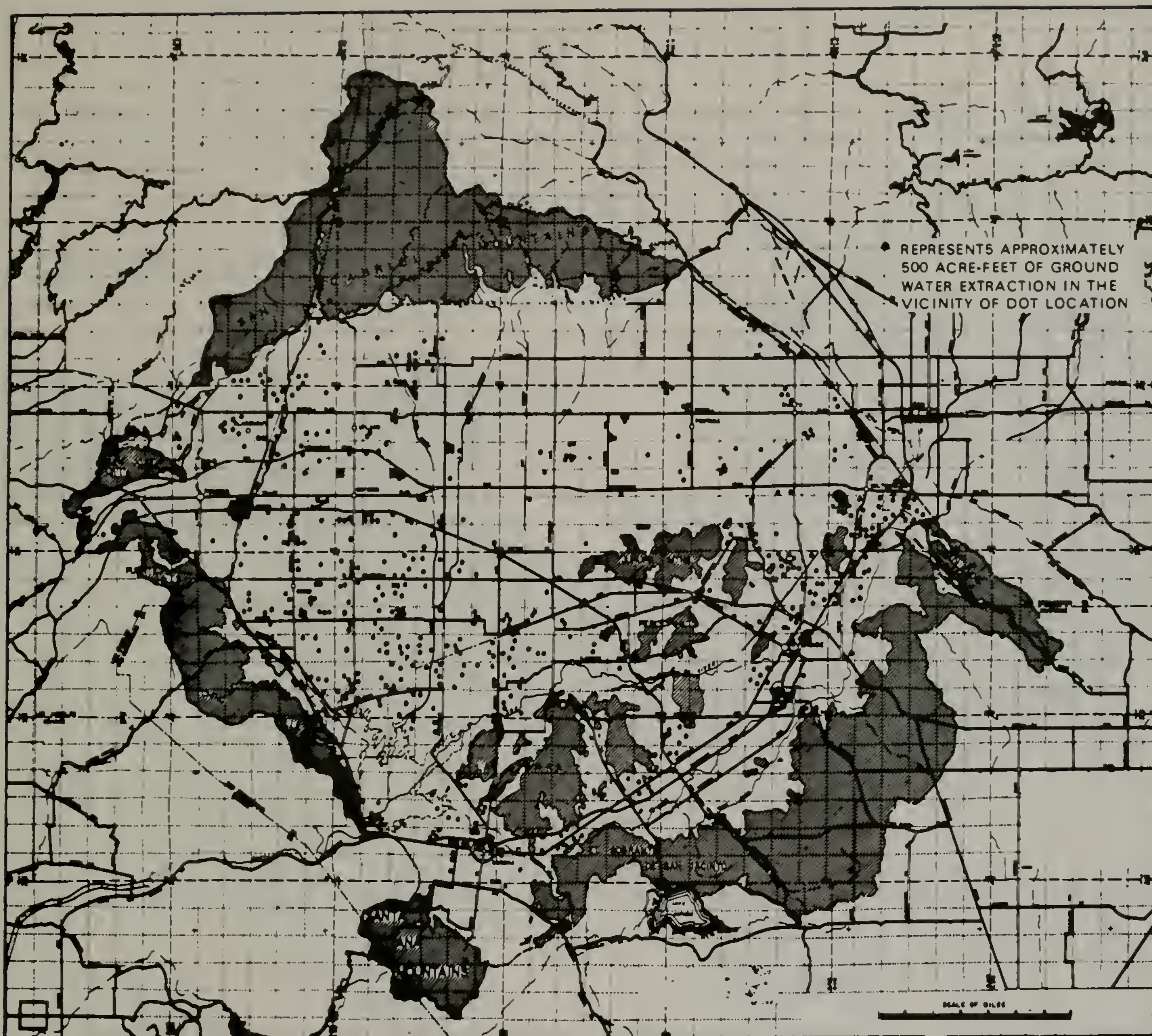


FIGURE 12 – PATTERN OF GROUND WATER PUMPAGE IN 1960

constructed in the area. The total infiltration capacity of all existing spreading grounds (see Figure 11) exceeds 1 million acre-feet per year.

A large number of wells are scattered throughout the Area. The distribution of these is shown in Figure 12.

Surface Facilities

In the Chino-Riverside Area, capacities of existing and proposed facilities of MWD and the State Water Project (SWP) are adequate to meet the annual demand for imported water at least until 2015 under any plan of basin operation.

The primary pipeline network of the MWD in the Chino-Riverside Area and its proposed expansion are shown in Figure 9. Not shown is a major pipeline that the SBVMWD would construct should it wish to convey SWP water from Devil Canyon to its service area in the Chino-Riverside Area (Rialto-Colton portion).

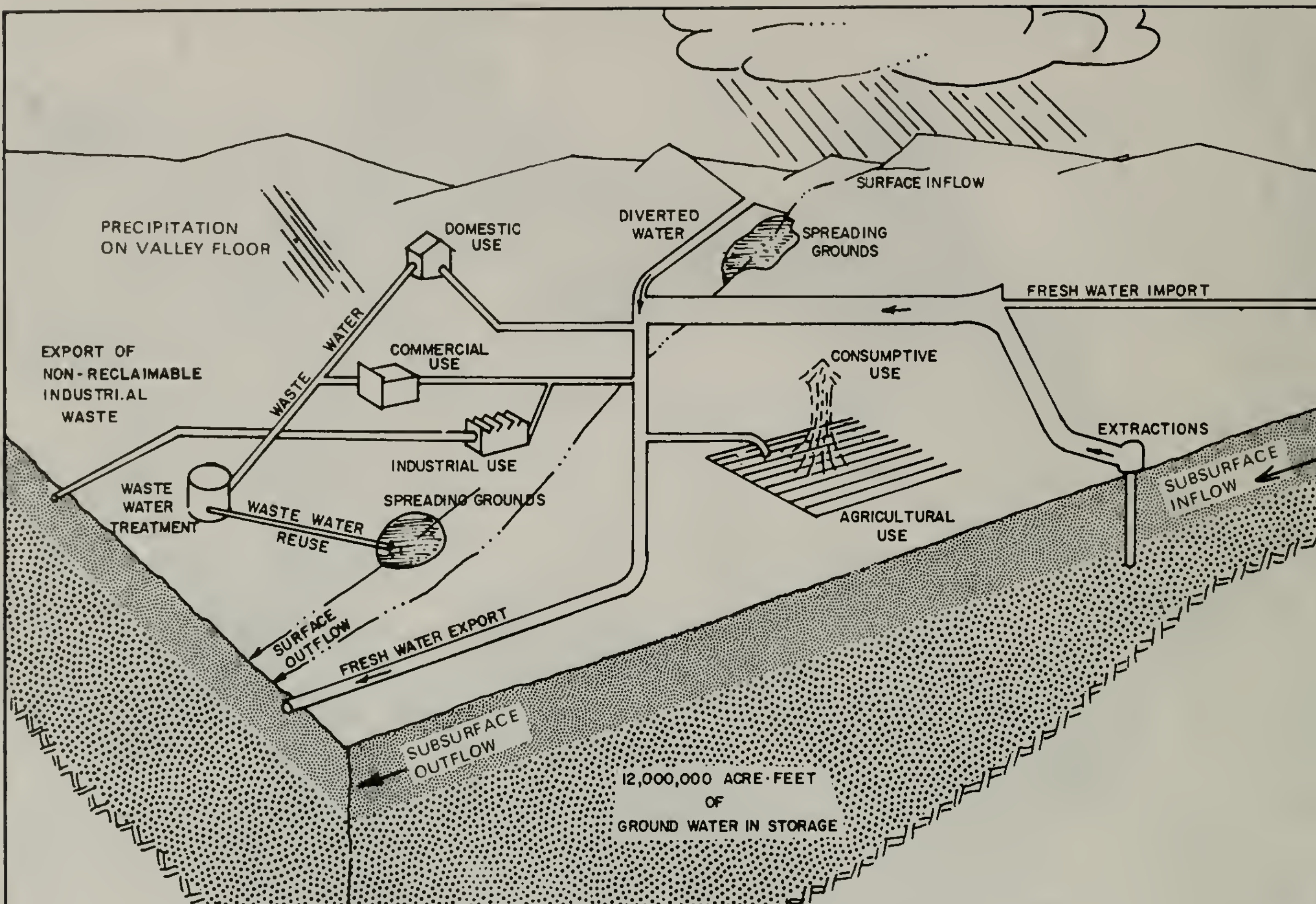
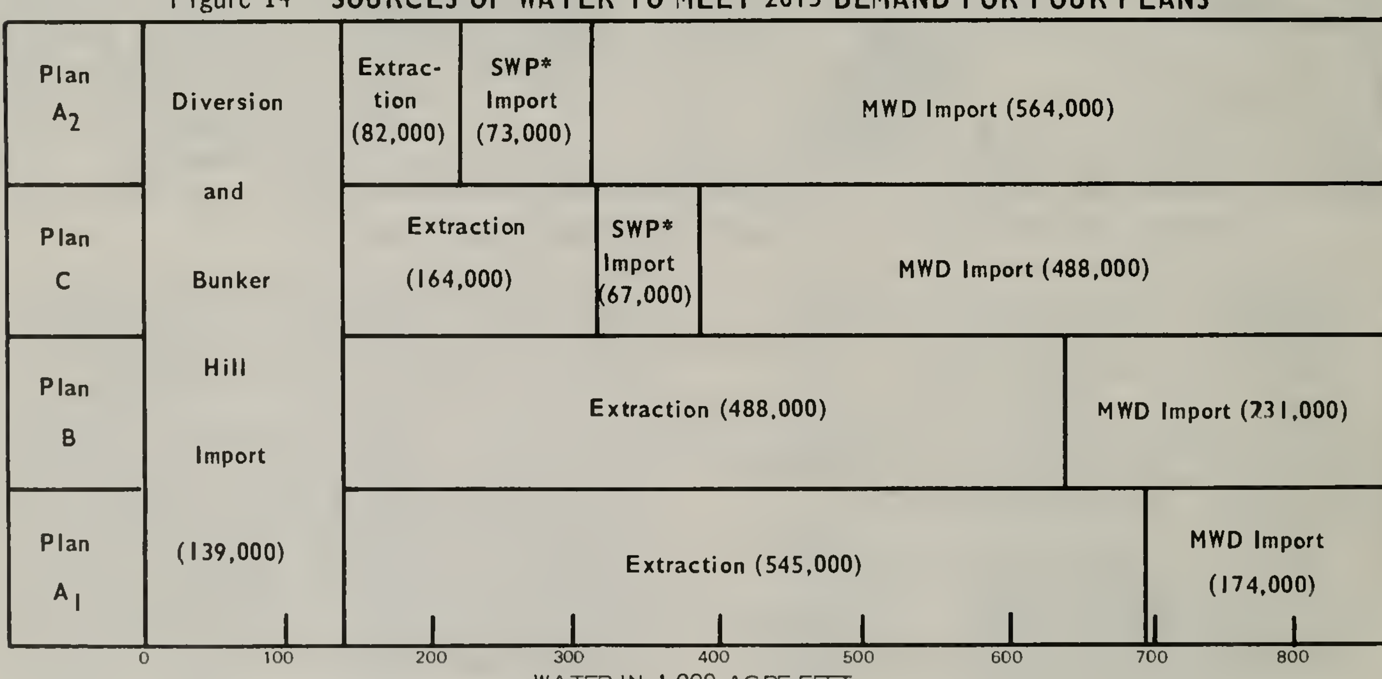


Figure 13 – **WATER DEMANDS AND SUPPLY**

Figure 14 – **SOURCES OF WATER TO MEET 2015 DEMAND FOR FOUR PLANS**



*Imported by SBVMWD for portion located in study area

In selecting a basin management plan, as in making any management decision, the decision makers must be able to compare the benefit-cost ratios of all alternative plans. Because all the plans will meet the same demand for delivered water, their benefits are the same.* Therefore, the question is, how can the water demand be satisfied with the least cost?

From an economic standpoint, the answer lies in considering the full range of alternative operational plans, making a cost estimate for each alternative, and comparing them. However, one must understand that political, legal, social and organizational forces may play a dominant role in the selection of a management plan and may override cost and benefit considerations.

Two extremes for providing water service are possible. One is to rely exclusively on the ground water basin as a source of water and the other is to use imported water exclusively. As shown in Figure 13, a wide range of possible alternatives lie between these two extremes.

Operational possibilities for using the ground water in storage are also numerous. The amount of ground water in storage could be: (1) increased, (2) left unchanged, or (3) decreased from the present level.

Four Selected Plans

Although 10 plans in all were formulated, comprehensive operational-economic information was developed for four plans that were selected to reflect the four widely divergent methods of meeting the Area's future water demand. Brief descriptions of each plan follow:

<u>Plan A_1</u> - provides the maximum amount of imported water for artifical recharge commensurate with assumptions made on pumping pattern, recharge facilities, and water levels, while using ground water to the fullest extent possible to meet water demands. Ground water in storage is increased by 2015.

<u>Plan A_2</u> - uses maximum amount of imported water for direct delivery and reduces pumping of ground water. Result is increase in ground water in storage by 2015.

<u>Plan B</u> - uses the maximum amount of ground water (draws down the basin to the <u>lowest possible</u> level without dewatering the last 50 feet of the aquifers). Result is decrease in ground water in storage by 2015.

<u>Plan C</u> - stabilizes water levels (no change in storage) by direct delivery of sufficient imported water and by recharging no imported water.

Figure 14 shows the sources of water used by the four plans to meet the 2015 demand. Figures 15-18 illustrate the amount of change in ground water levels that will take place under each plan between 1965 and 2015. Table 1 summarizes other information regarding each plan.

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* This is true even for users of ground water for agriculture although the levels of the ground water decline more under some plans than under others. The study showed that the cost of ground water for agriculture will be about the same under all plans.

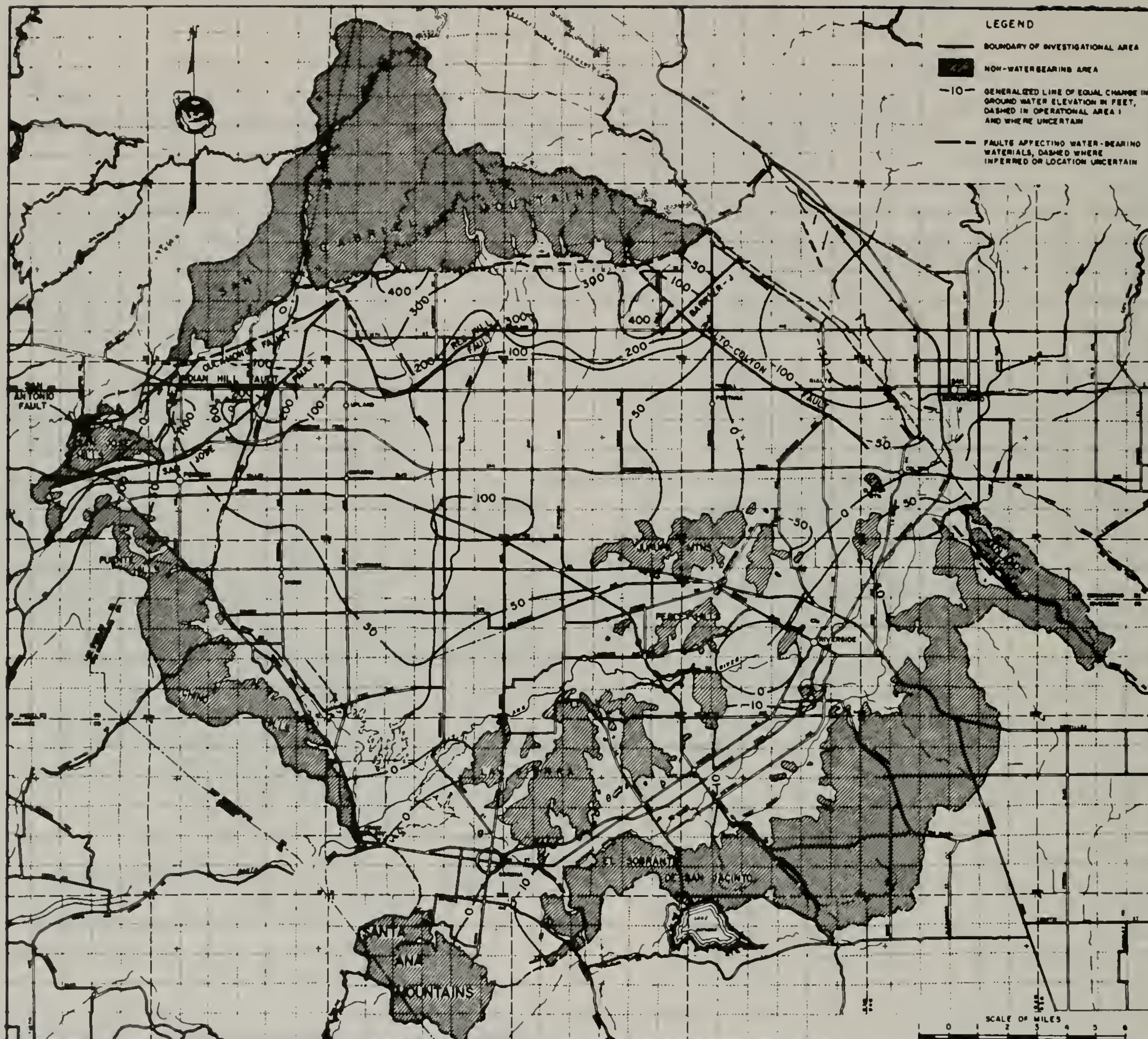

Figure 15. LINES OF EQUAL CHANGE IN GROUND WATER ELEVATIONS BETWEEN 1965 AND 2015 FOR PLAN A_1

For these four plans, more detailed information is published in the memorandum report Appendix B: "Operation-Economics".

Cost of Each Plan

In computing the total cost of each plan, only those costs that vary with the different plans were considered. For this study, these were the costs for additional facilities (both for ground water and for surface water) and the costs for imported water. No cost was assigned to a possible change in water quality or to possible subsidence of the land.

Change in Water Quality

In 1965, the general quality of the extracted ground water in the central portion of the Chino-Riverside Area (Chino subbasin) is good (Figure 19). The Riverside and Corona subbasins, how-

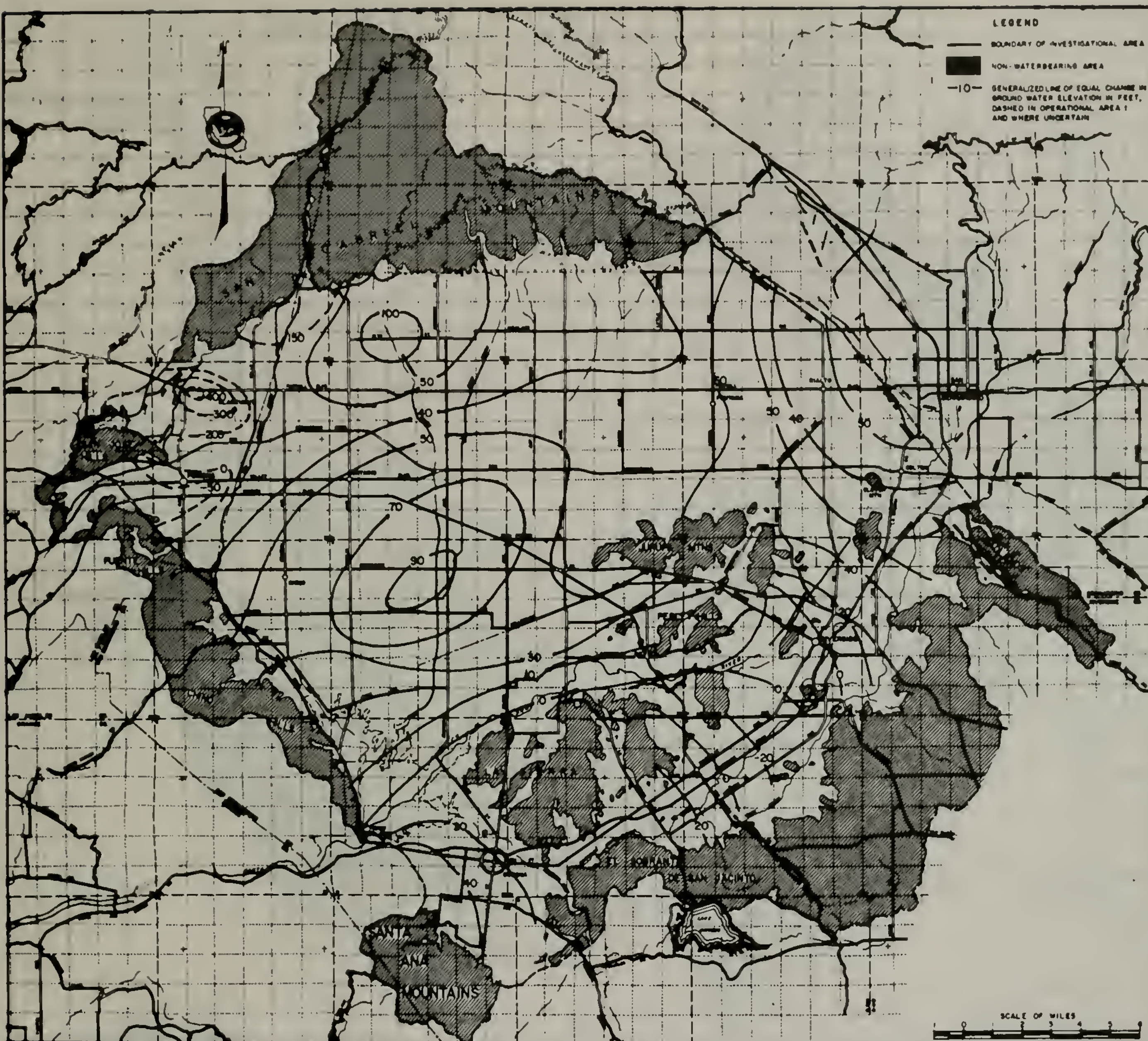

Figure 16. LINES OF EQUAL CHANGE IN GROUND WATER ELEVATIONS BETWEEN 1965 AND 2015 FOR PLAN A_2

ever, have only fair to poor quality (600-1,000 ppm of TDS).

A general quantitative discussion of the past, present, and expected future quality of the components of the water supply in the study area is presented in Appendix B.

A more detailed study of the future water quality is now being made by Santa Ana Watershed Planning Agency (SAWPA).* The purpose of SAWPA's study, which is being made in cooperation with the Department and other agencies, is to develop a comprehensive plan for water quality management.

* SAWPA was created under the State Joint Exercise of Powers Act (Sections 6500-6580 in Government Code) and consists of the four major water agencies covering most of the Santa Ana River watershed.

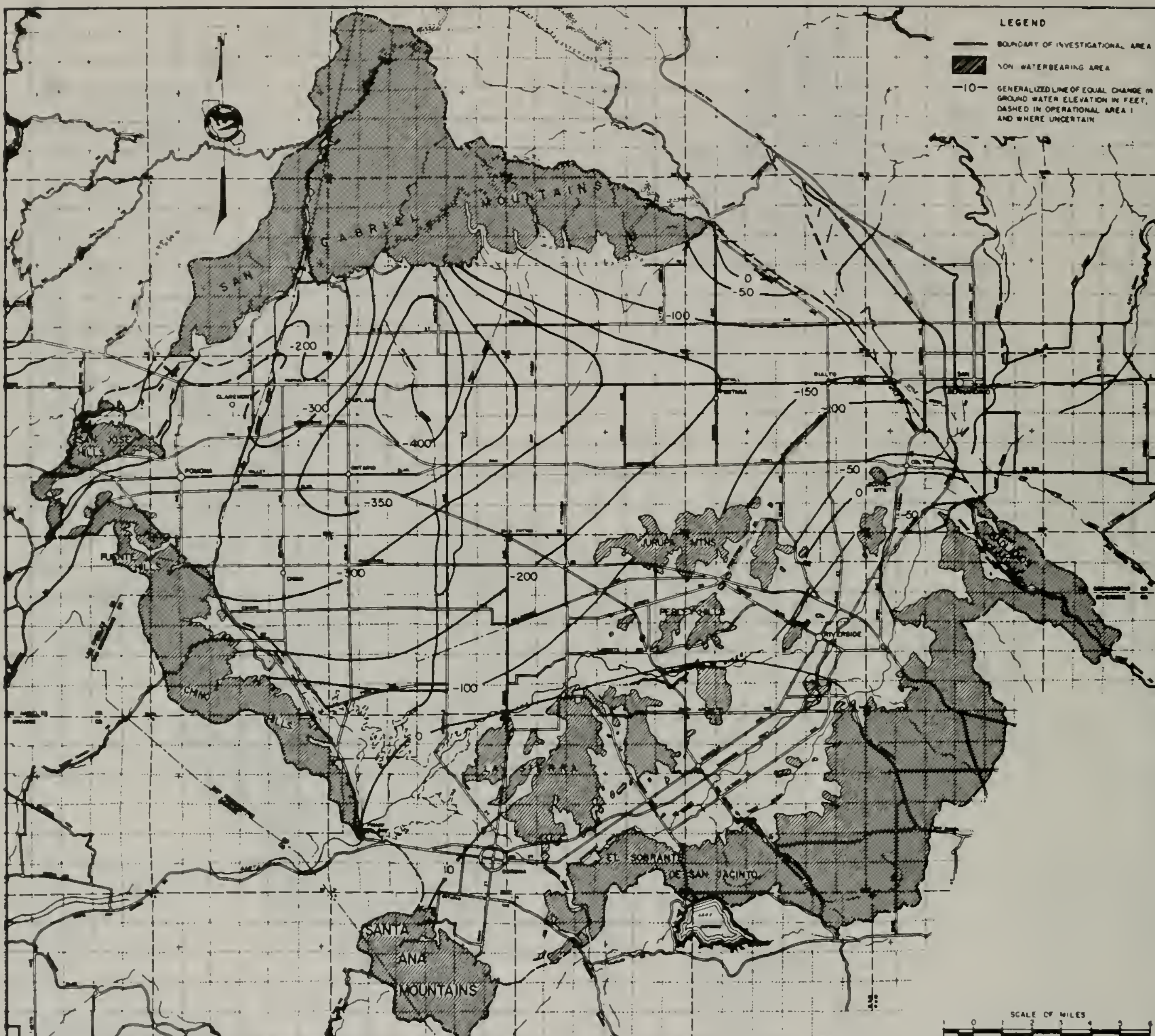

Figure 17. **LINES OF EQUAL CHANGE IN GROUND WATER ELEVATIONS BETWEEN 1965 AND 2015 FOR PLAN B**

During the investigation reported here, Water Resources Engineers, Inc., (WRE) was retained by the California Regional Water Quality Control Board, Santa Ana Region, to develop, in cooperation with the Department, a technique for estimating future water quality under alternative plans of basin management. The Department recognizes the value of the work being done by WRE; however, the results were not available in time for use in this investigation.* Therefore, no value could be assigned to water quality change for each plan of operation.

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* A summary of all tasks performed in the joint program to develop a water quality model is being published by the Department of Water Resources, Southern District, as a memorandum report.

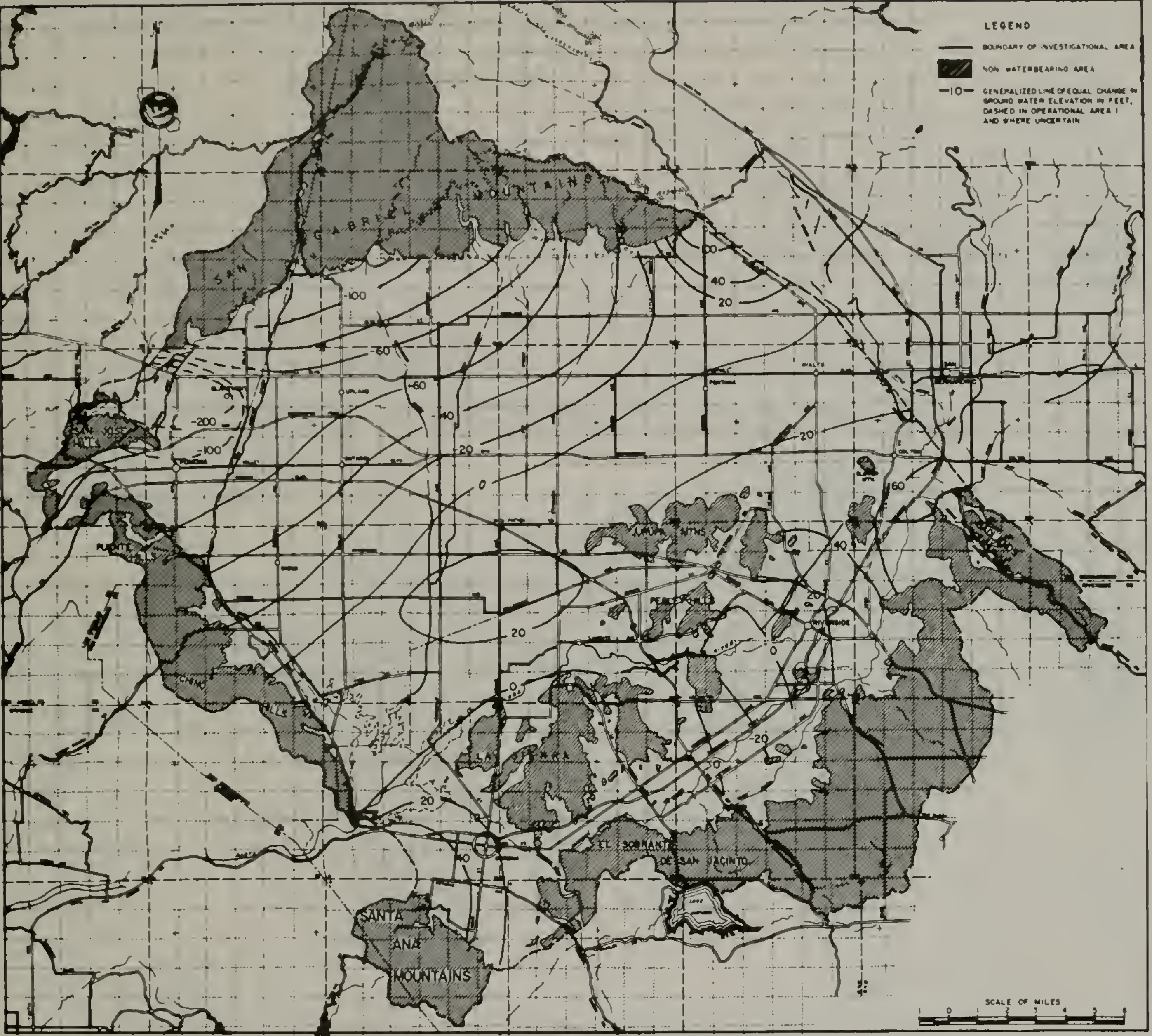

Figure 18. LINES OF EQUAL CHANGE IN GROUND WATER ELEVATIONS BETWEEN 1965 AND 2015 FOR PLAN C

Land Subsidence

The United States Geological Survey (USGS) has conducted a land subsidence study in the Chino-Riverside Area on a cooperative basis with the Department.*

Under Plan B, which is the plan using the greatest amount of ground water in storage, ground water levels would decline about 400 feet by 2015 in the Chino subbasin. The USGS report noted that the estimated subsidence would be small -- about 1.5 feet near Ontario and 0.2 foot near Colton. The subsidence would be essentially uniform and, therefore, should not cause significant damage.

*"Estimated Subsidence in the Chino-Riverside and Bunker Hill-Yucaipa Areas in Southern California for a Postulated Water-Level Lowering, 1965-2015", USGS.

The degree of subsidence would be reduced proportionately for the other plans with less decline in water level.

Experience in California to date has shown that major damage has resulted from subsidence under two specific conditions: (1) areas immediately adjacent to the ocean where levees and local facilities may become inundated and (2) areas where long, low-gradient open channels cross the subsidence area.

Because neither of the conditions mentioned above occurs within the areas of possible subsidence, the cost of damage from subsidence will be negligible.

Additional Facilities

For convenience, the costs of storage facilities were included in those of surface water facilities, and both the energy cost and the connected load charge for well pumps and boosters were included in the costs of electrical energy.

The unit costs of these facilities were based on interest rates of 4 percent*

* As of spring 1971, bond interest rates were greater than 4 percent.

TABLE 1

SUMMARY INFORMATION FOR FOUR SELECTED PLANS OF OPERATION IN CHINO-RIVERSIDE AREA, 1965-2015

All values in 1,000 acre-feet

Plan of operation	1965 Ground water in storage	Comment	Average annual amounts, 1965-2015			Accumulated change in ground water storage 1965 to 2015	2015 Ground water in storage	Average annual rising water	Present worth of future variable costs of water service[a]
			Ground water extraction	Imported water					
				Spread	Direct use				
A_1	12,000	Maximum imported water (spread) maximum extraction	413[b]	196[c]	86	+1,300	13,300	117	$346,000,000
A_2	12,000	Maximum imported water (direct use) minimum extraction	195	0	304	+1,100	13,100	175	390,000,000
B	12,000	Maximum extraction	394	0	105	-4,200	7,800	83	348,000,000
C	12,000	No change in storage	235	0	264	+ 9	12,000	159	379,000,000

[a] Based on costs for MWD system as reported in MWD Report No. 821 and interest rates of 4% for MWD and 4-1/2% for all other agencies.

[b] Because of recharging large quantities of imported water near Operational Areas 4 and 6, the extraction in Operational Area 6 is 12,000 acre-feet greater than that in Plan B and the extraction in Operational Area 4 is 7,000 acre-feet greater. (See Appendix B for location of operational areas.)

[c] Average annual imported water spread after 1975.

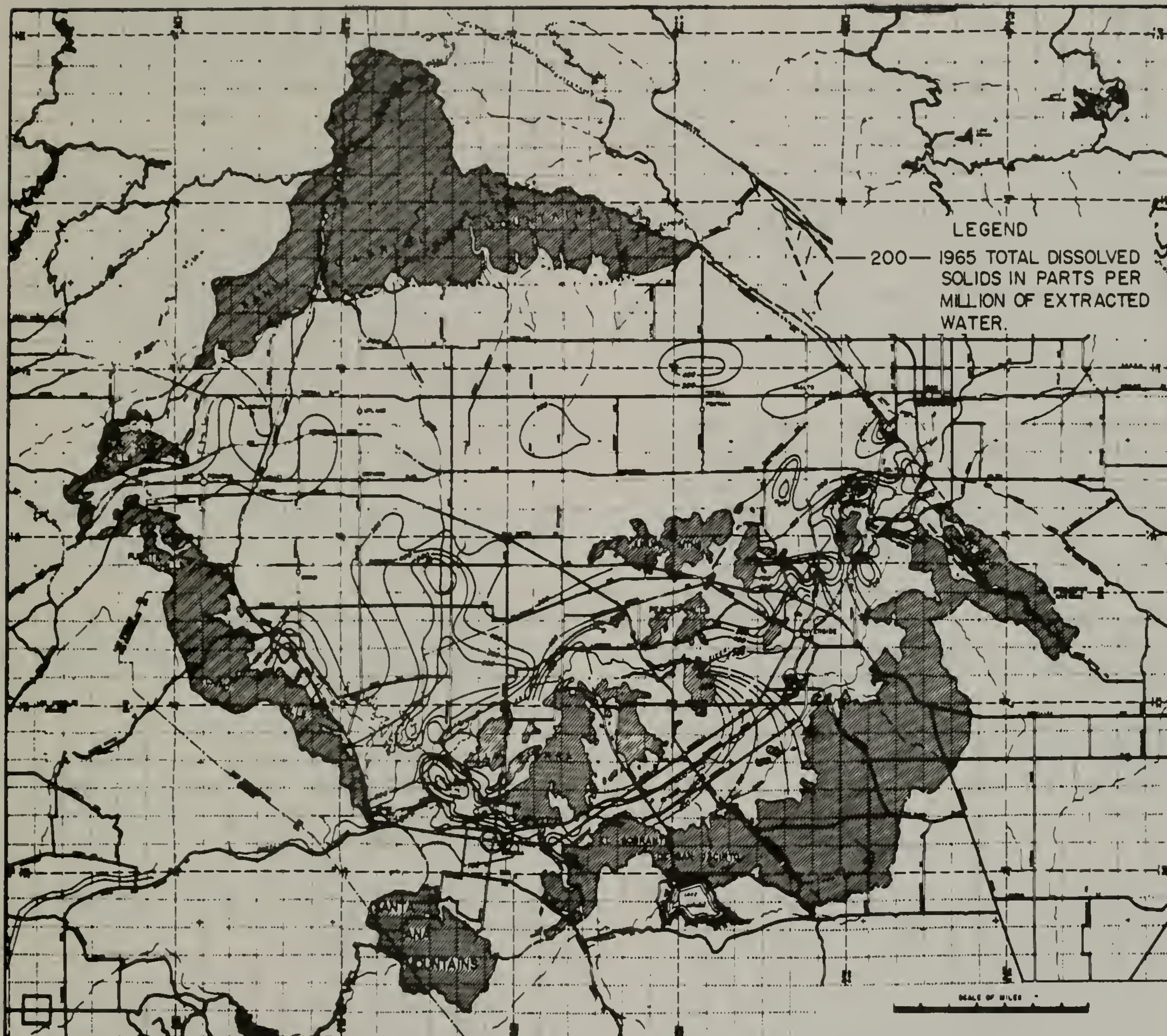

FIGURE 19 – ISOSALINITY MAP OF EXTRACTED GROUND WATER IN 1965

for MWD and 4.5 percent for smaller water agencies and on representative lifespans of facilities in the Area. They were also adjusted to the 1965 cost level by using the Engineering News-Record construction cost index.

Imported Water

For SBVMWD, the actual variable cost of water from the State Water Project was computed for each alternative plan.

For the three agencies that belong to MWD, the cost of imported water was based on the price that may be charged by MWD for the various types of raw and treated water it sells.

MWD has not announced its long-term future pricing policy; therefore, to obtain the long-range economic evaluation of alternative plans, the assumption was made that the ad valorem taxes (paid by property owners), pricing differentials, and energy cost that were in effect in 1968 will continue.*

Conceptually, various means can be used to pay for water service: users of imported water can pay the complete cost of carrying it from source to point of delivery, property owners can pay the complete cost through taxes, and users and taxpayers can divide the cost.

MWD has used this last method to date -- 40 to 50 percent of its capital cost of constructing new facilities is now borne by an ad valorem tax.

In addition, the 1968 pricing policy provides a different price for water used for agriculture and ground water replenishment from that for water used for domestic and industrial purposes.

Another significant factor affecting the unit price of MWD water is the energy cost of pumping State Water Project water over the Tehachapi Mountains. The estimates of this cost have varied from approximately $24 per acre-foot (estimated in 1964) to approximately $10 per acre-foot (estimated in 1969).

Evaluation of Costs

Before the total costs for each plan can be compared, adjustment must be made for the fact that costs would be incurred at different times under the different plans. In other words, the economic effect of incurring the same total amount of expenditure varies with the plan.

To establish a realistic economic comparison of the alternative, all costs--regardless of the difference in time of expenditure--must be converted to the common denominator of present worth.

Present worth of the total costs of water service under each plan may be considered as the amount of money that is needed today to meet future financial obligations associated with the water service. Thus, a comparison of present worth of the four plans would provide a measure of the extent of financial obligation. This comparison is given in Table 2.

Water Service After 2015

The total present worth of all plans was originally determined for the period 1965 to 2015 as shown on last line of Table 2.

In discussions with the local agencies, it was agreed that value of ground water in storage after 2015 should also be included.

This was done by extending the period of analysis to 2055. The value of ground water as mentioned here is not the value of water rights.

A method was used to determine the value of ground water after 2015 for four selected plans, Plans A_1, A_2, B, and C.

This analysis was based on the assumption that, after 2015, Plan B will consist of a no-change-in-storage operation and Plans A_1, A_2, and C will use ground

* MWD in June 1969 released the report "Preliminary Water Pricing Policy Study", prepared for it by Robert A. Skinner and Brown and Caldwell Consulting Engineers. This report proposes a definite pricing policy for imported water for 1971-72 through 1989-90. A cursory analysis of the effects of the proposed pricing policy on the study area indicates that the cost differences between the plans using imported water (Plans A_1 and A_2) and the plan that continues to use ground water (Plan B) would increase if this policy is carried out. This is because it gives a decline in the ad valorem taxes, which will mean that more of the financial obligation of MWD will be put on the user of imported water. A more detailed analysis of the effect of this proposed pricing policy on the Chino-Riverside Area is being made by the local agencies and their consulting engineers.

TABLE 2

SUMMARY OF PRESENT WORTH OF VARIABLE COST OF WATER SERVICE* IN CHINO–RIVERSIDE AREA FOR 1965 – 2015

In millions of dollars

Item	Plan			
	A_1	A_2	B	C
1. Ground water facilities	90	71	141	84
2. Surface storage**	48	48	48	48
3. MWD imported water costs				
Water sales	136	193	86	169
Tax payments	55	55	55	55
Item 3 total	191	248	141	224
Subtotal Items 1 – 3	329	367	330	356
4. Operational Area 5	17	23	18	23
GRAND TOTAL	346	390	348	379

*These assumptions were made:

Energy = $10/A.F.
Tax = 40 % (MWD tax revenues would be used to defray 40 percent of the taxable capital costs related to MWD's share of SWP costs and other capital improvement.)
Differential between M & I and spreading water = $20/A.F.
Unit price of MWD domestic-treated water (after 1972) = $50/A.F.
Unit price of untreated spreading water (after 1972) = $21/A.F.

**Includes $30 million worth of existing storage facilities water in storage until ground water levels reach those of Plan B in 2055, as shown in Figure 20. If Plan B is to be on a no-change-in-storage operation, supplemental water will have to be supplied. For this study, this additional supplemental supply was assumed to come through a second state water facility at the same price as was used for the 1972-2015 period -- i.e., $50 per acre-foot.

Although this price may be higher in the future, it was used here for comparison. It is the price of MWD treated water for other than replenishment or agricultural uses under a pricing policy of: revenue from taxation is 40 percent, price differential is $20 per acre-foot, and energy charge is $10 per acre-foot.

Plans A_1, A_2, and C will use their ground water in storage until the ground water

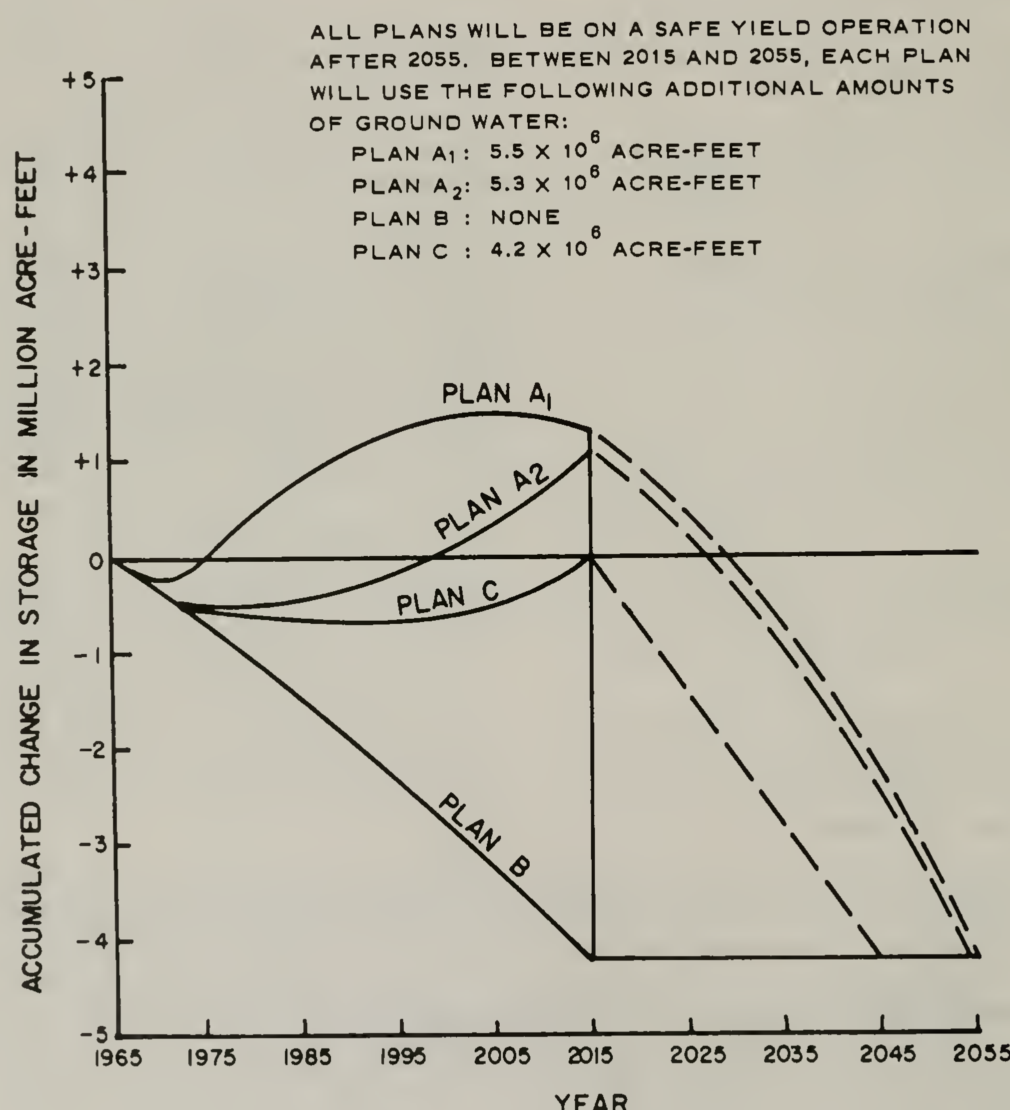

Figure 20 – ACCUMULATED CHANGE IN STORAGE OF GROUND WATER TO 2055

TABLE 3

COMPARISON OF PRESENT WORTH OF VARIABLE COST OF PLANS TO 2055 IN THE CHINO-RIVERSIDE AREA

In millions of dollars

Item	A_1	A_2	B	C
1. Total present worth (1965 – 2015, Table 2)	346	390	348	379
2. Present worth (2015 – 2055)	55*	65*	77	64*
3. Total present worth (1965 – 2055, Items 1 and 2)	401	455	425	443
4. Change in amount of ground water in storage, 1965–2015, in millions of acre-feet	+1.3	+1.1	–4.2	0

*Based on assumption that Plan B will use no-change-in-storage operation from 2015 to 2055. Plans A_1, A_2, and C will use ground water in storage until the level of Plan B is reached. Value of ground water ranges from $2.30 to $4.00 per acre-foot.

levels reach those of Plan B. For Plans A_1 and A_2, this would be reached in 2055; for Plan C, it would be reached in 2045. All costs after 2055 are common to all plans.

The present worth cost from 2015 to 2055 is that shown on line 2 of Table 3 and the total present worth cost from 1965 to 2055 is that shown on line 3 of Table 3. The unit value for an incremental amount of ground water in storage* that Plans A_1, A_2, and C have over Plan B ranges from $2.30 to $4.00 per acre-foot.

By selected Plans A_1, A_2, and C, the decision makers would delay future importation projects and reduce pumping lifts from 2015 to 2055. They would thereby derive substantial savings in the cost of operation for Plans A_1, A_2, and C as compared to Plan B from 2015 to 2055. Plan A_1 is still the most economical (line 3, Table 3).

*Derived by dividing the difference in present worth of cost between Plans B and A_1, B and A_2, and B and C for the period 2015 to 2055 (line 2, Table 3) by the difference in the quantity of ground water in storage (line 4, Table 3) as of 2015. The value of ground water in storage, derived in this manner, is included in the costs for the extended period of analysis, but not for those for the period 1965 to 2015.