STATE OF CALIFORNIA

The Resources Agency

Department of Water Resources

BULLETIN No. 104

PLANNED UTILIZATION OF GROUND WATER BASINS: COASTAL PLAIN OF LOS ANGELES COUNTY

SEPTEMBER 1968

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FIGURES

TABLES

FOREWORD

At present, more than half the water supply of Southern California's south coastal area comes from its ground water basins. In general, extractions from this source exceed replenishments, resulting in a decline of ground water level elevations. The Central and West Basin Water Replenishment District and other water entities have contributed significantly in managing the basins effectively.

However, there is a need for information related to the optimum conjunctive use of ground water resources with other local and imported water supplies.

The Department of Water Resources, recognizing this need, has undertaken a comprehensive study of the planned use of Southern California's major ground water basins. The Coastal Plain of Los Angeles County was selected as the first area to be investigated.

Statutory authority for the Department to conduct investigations of surface and subsurface water conditions is contained in Section 226 of the California Water Code. Statutory authority for investigation of ground water conditions is conferred under the Porter-Dolwig Ground Water Basin Protection Law, Water Code Section 12920 and those that follow, and Water Code Section 231.

In this investigation, comprehensive studies were made of the geology, hydrology, and operations-economics of the ground water basins in the Coastal Plain of Los Angeles County. Detailed information issuing from these studies was presented earlier in Appendixes A, B, and C to Bulletin No. 104. This bulletin is intended to serve as a brief, but comprehensive summary of the findings of these studies.

William R. Gianelli
William R. Gianelli, Director
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August 26, 1968

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State Agencies

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

Los Angeles County Agencies

Assessor
Regional Planning Commission
Sanitation Districts of Los Angeles County
Waterworks Districts 10, 13, and 16
Museum of Natural History.

Special Districts

Central Basin Municipal Water District
Central and West Basin Water Replenishment District
Downey County Water District
Los Angeles County Flood Control District
The Metropolitan Water District of Southern California
Orange County Water District
Orchard Dale County Water District
South Montebello Irrigation District

City Water Departments

Bellflower
Beverly Hills
Compton
El Segundo
Hawthorne
Huntington Park
Inglewood
Lakewood
Long Beach
Los Angeles
Lynwood
Manhattan Beach
Santa Monica
Signal Hill
South Gate
Torrance
Vernon
Whittier

Private Water Companies

California Water Service Company
Conservative Water Company
Dominguez Water Corporation
Laguna-Maywood Mutual Water Company
La Habra Heights Mutual Water Company No. 3
La Mirada Water Company
Maywood Mutual Water Company No. 3
Montebello Land and Water Company
Pacific Water Company
Park Water Company
Peerless Land and Water Company
San Gabriel Valley Water Company
Somerset Mutual Water Company
Southern California Water Company
Southwest Water Company
Suburban Water Systems
Tract 180 Mutual Water Company
Walnut Park Mutual Water Company No. 3

Other Companies

Continental Can Company, Inc.
McDonnell-Douglas Corporation
Electronic Associates
Fibreboard Paper Products Corporation
The Flintkote Company
International Business Machines Corporation
Mobil Oil Company
Oil Operators, Inc.
Atlantic Richfield Corporation
Shell Oil Company
Signal Oil and Gas Company
Standard Oil Company of California
Texaco, Inc.
Union Oil Company of California
Western Gulf Oil Company

Universities and Colleges

The Associated Colleges of Claremont
The California Institute of Technology
California State College at Long Beach
The University of California at Los Angeles
The University of California at Riverside
The University of Southern California

Other

Southwest Museum
San Gabriel Valley Protective Association

State of California
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Abstract

The water demand of the Coastal Plain of Los Angeles County is approximately 860,000 acre-feet a year at present and is expected to grow to 1,200,000 acre-feet by 1990. Water supply from various sources which include the Los Angeles Aqueduct, the Colorado River Aqueduct and soon the State Water Project will be adequate at least until 1990. One of these sources of supply is the ground water basin in the Coastal Plain. Approximately 35 million acre-feet of fresh water is believed to be in storage at present. In the report, four alternative plans of conjunctive use of ground and surface water resources to meet future water requirements in the service area were analyzed. From this analysis understanding evolved regarding the economic impact of pumping schedule and pattern, spreading schedule of imported water, and methods of preventing sea-water intrusion. It was found that the most significant economic factors are the price of imported water and the proportionate use of imported water and ground water in storage.

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 a most abundant 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 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.

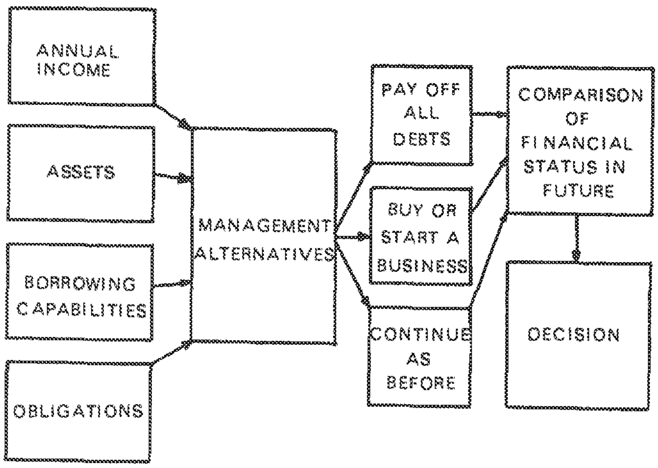


Fig. 1
FINANCIAL MANAGEMENT PLANNING

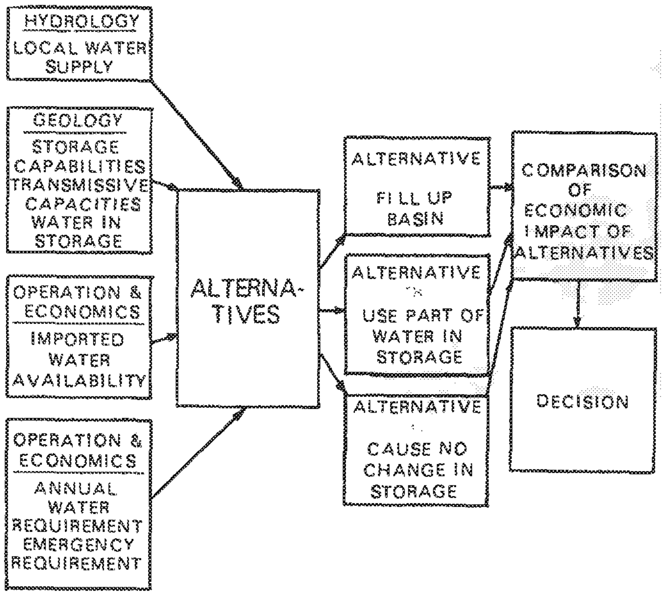


Fig. 2
WATER MANAGEMENT PLANNING

I INTRODUCTION

The management of its water resources has been of vital concern to Southern California from the time it was first settled. This has been especially true in the Coastal Plain of Los Angeles County. The increasing demand for water in this area and the economic realities of obtaining that water have made it clear that local water managers must have available to them information related to comprehensive alternative water supply plans in order to make an informed selection of the most suitable plan. A necessary prerequisite to the formulation of such plans is the collection and analysis of data pertinent to the problems of water need and supply, especially concerning the ground water resources.

A study has been completed to furnish information on alternative plans. Its findings, in detail and in depth, were published previously in Appendixes A, B, and C, to Bulletin No. 104, covering the areas of geology, hydrology, and operations and economics. These findings are summarized in this bulletin.

OBJECTIVE OF THE INVESTIGATION

The objective of the investigation is 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 the ground water supplies in the Coastal Plain in coordination with surface water supplies and facilities.

AREA OF INVESTIGATION

The region selected for this study lies in the heart of the Los Angeles urban complex. It covers approximately 600 square miles and contains all or part of 42 incorporated cities, including a large part of the metropolitan section of the City of Los Angeles.

Physically, the Coastal Plain of Los Angeles County is an almost featureless, semiarid flatland that slopes gently toward the sea (Figure 3). On the north, it is bounded by the Santa Monica Mountains, extending inland from Malibu. On the northeast, the plain is hemmed in by another mountainous ridge, though not as steep, formed by the Elysian, Repetto, Merced, and Puente Hills. Through them slice the channels of the Los Angeles and the San Gabriel Rivers and the Rio Hondo on their journey to the ocean. To the south, the massive hump of the Palos Verdes Hills forms a solid barrier between Santa Monica Bay and San Pedro Bay. The Coastal Plain is bounded on the west by the Pacific, while its eastern boundary is not a physical, but rather a political, one--the line that separates Los Angeles County from Orange County.

Annual precipitation for the study area averages about 15 inches and varies widely from year to year as shown on Figure 4.

At present, more than 4,000,000 persons live within the Los Angeles County

Coastal Plain and current population projections indicate that by 1990 there may be considerably more than 5,000,000--an increase of more than 25 percent. Today, the area needs and uses some 860,000 acre-feet of water a year.

The use of water in the Coastal Plain has shifted from agricultural to urban-suburban. In 1880, some 27,000 acres of the Coastal Plain were being irrigated for farming. About 9,000 acres were either urban or suburban, most of it confined to Los Angeles, Santa Monica, and Wilmington.

Fifty years later, this condition was completely reversed. By 1930, the agricultural area had increased to 80,000 acres, while the urban-suburban area had grown to 160,000 acres. During the next three decades, urban expansion con-

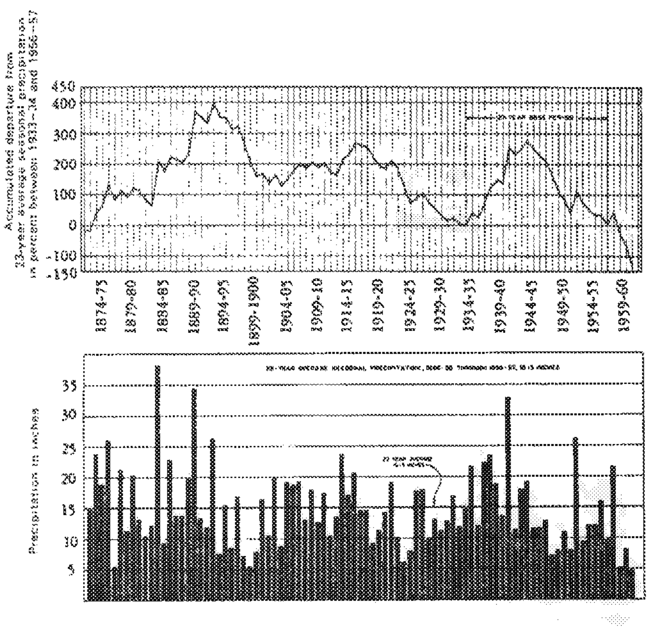


Figure 4 – SEASONAL PRECIPITATION

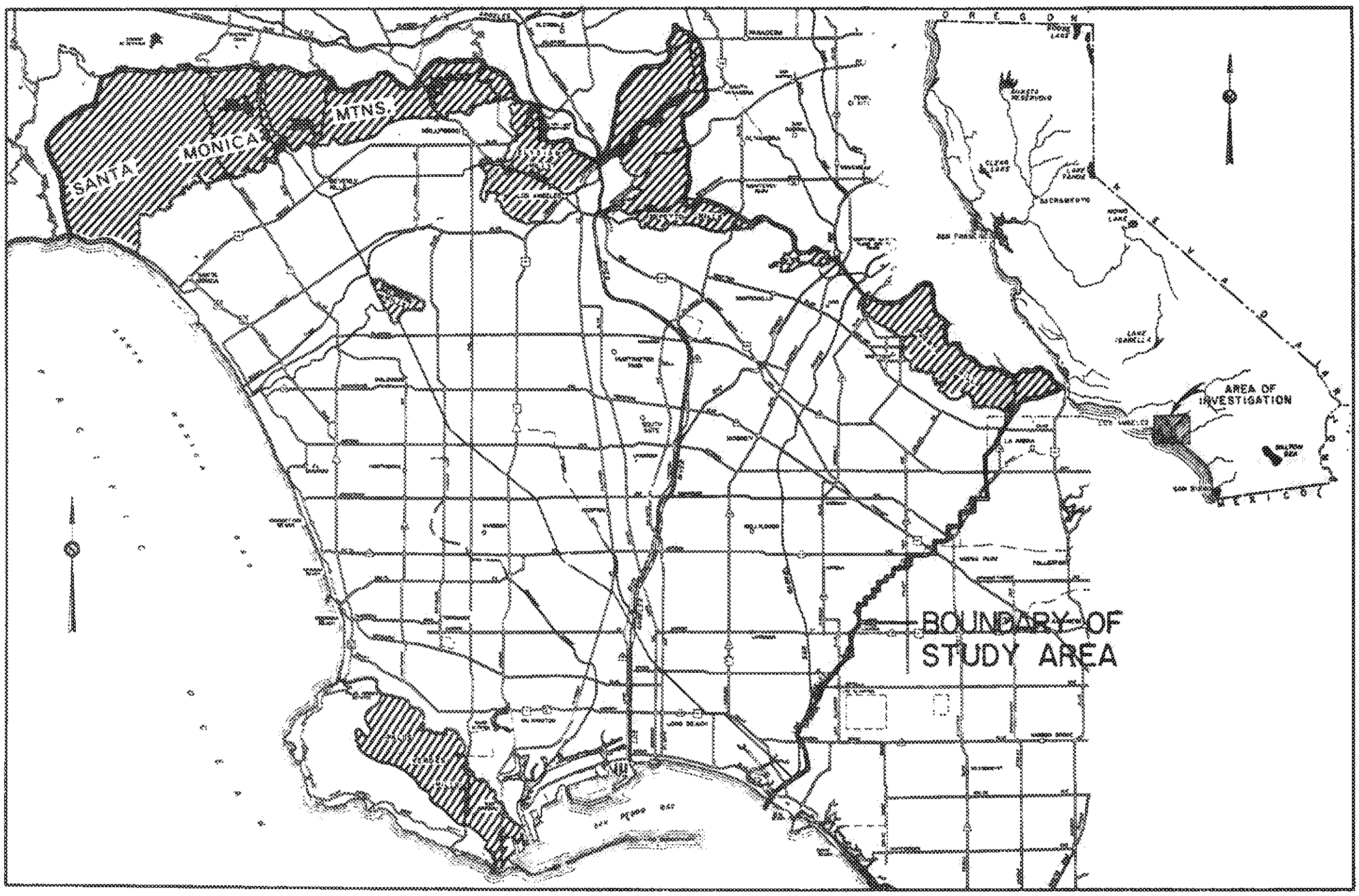
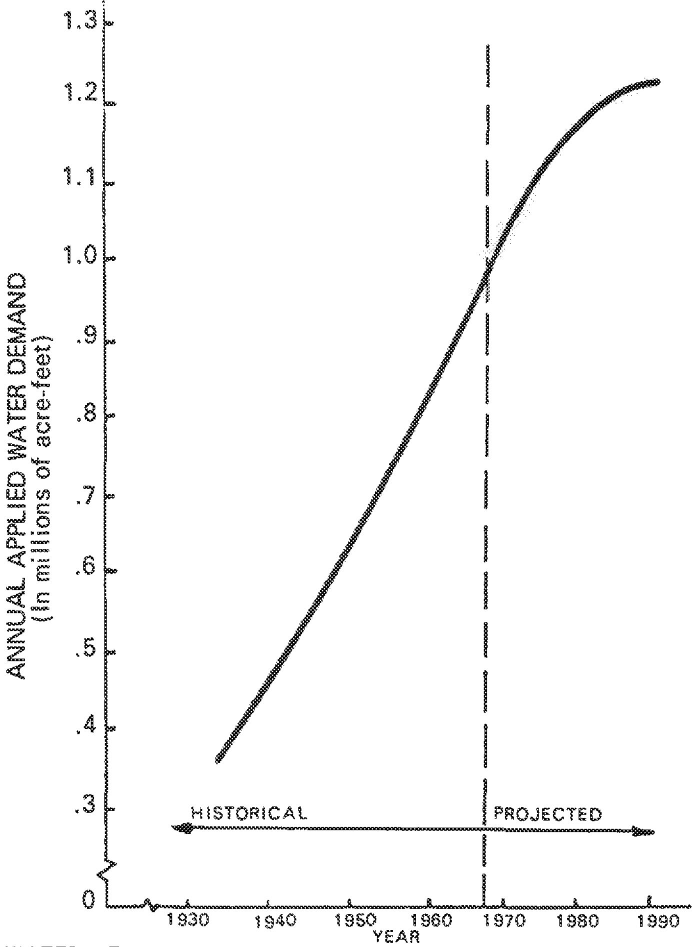


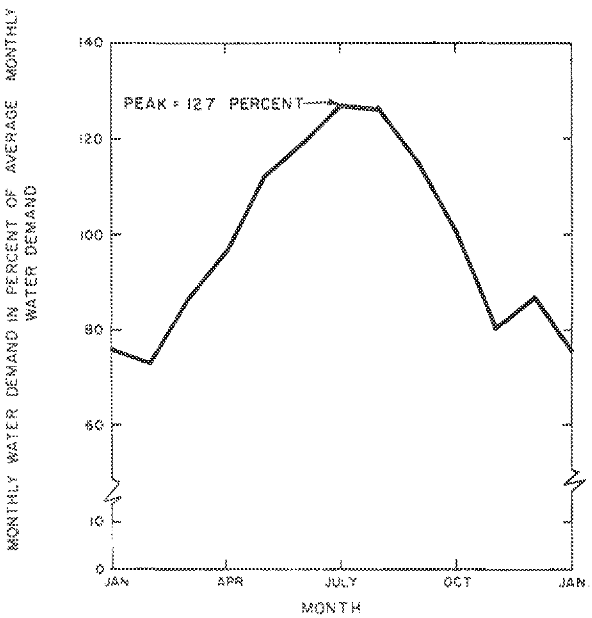
Figure 3 – LOCATION MAP OF THE COASTAL PLAIN OF LOS ANGELES COUNTY

HISTORICAL AND PROJECTED WATER DEMAND

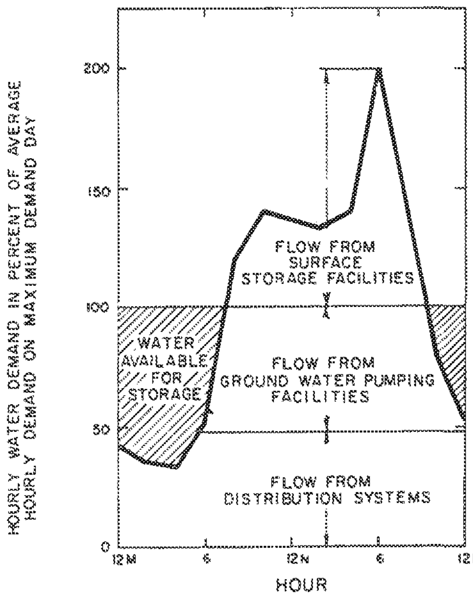
YEAR	WATER DEMAND (ACRE-FEET)
1935	370,000
1940	450,000
1950	610,000
1960	800,000
1970	1,001,000
1980	1,163,000
1990	1,218,000



PAST AND PROJECTED APPLIED WATER DEMANDS FOR THE COASTAL PLAIN OF LOS ANGELES COUNTY



AVERAGE MONTHLY WATER DEMAND



TYPICAL HOURLY WATER DEMAND ON A MAXIMUM WATER DEMAND DAY

Figure 7 – WATER DEMAND

conversion plant on Bolsa Island in Orange County has been considered for many years by The Metropolitan Water District of Southern California (MWD). However, present indication is that the plant will not be built.

Imported Water Supply

Present supplies of imported water include Colorado River water, Owens River-Mono Basin water, ground water from the San Fernando Valley, and ground water and reclaimed waste water from the San Gabriel Valley. In the future, these supplies will be augmented by water from the State Water Project.

Colorado River water, which is distributed by MWD, is a major source of imported water to the Coastal Plain. Softened, filtered, and untreated waters are now available for use from MWD. Softened and filtered waters are used for applied water, filtered water for applied water and injection, and untreated waters for spreading.

Before 1972, the delivery of imported water to the Coastal Plain by MWD would be limited either by the capacity of the delivery system to provide water at specified pressures or by the available supply from the Colorado River. In the event of a water shortage, which cannot be anticipated before 1990, this water would be allocated among member agencies of MWD by each agency's preferential rights and would be limited to the combined supply from the Colorado River and the State Water Project after 1972. The preferential rights of the member agencies are based on all payments made by each agency to MWD, exclusive of payments for purchased water.

The State Water Project will begin delivering water to Southern California in 1971. At that time, MWD will begin importing a portion of this supply to the Coastal Plain through a planned increase in the delivery capacity of its distribution system.

Water imported by MWD is a supplemental source of supply to the Los Angeles Department of Water and Power, which utilizes two primary sources to supply the City's needs in the Coastal Plain: imported water from the Owens River-Mono Basin and ground water from San Fernando Valley.

In view of the anticipated rate of development in the San Fernando Valley, more water imported from Owens River-Mono Basin will be used in the valley by the City of Los Angeles. However, exports of ground water from the valley to the Coastal Plain will continue. Because additional water from the Owens River-Mono Basin will be required, the City of Los Angeles, in 1964, initiated construction of the Second Los Angeles Aqueduct. The estimated importation schedules of ground water from San Fernando Valley and the Owens River-Mono Basin by the Los Angeles Department of Water and Power to the Coastal Plain are:

Year	Quantity in Acre-Feet
1969	309,000
1970	300,000
1975	260,000
1980	221,000
1985	181,000
1990	141,000

The Los Angeles Department of Water and Power has reported that the foregoing values should be reduced by 30,000 acre-feet per year if the 1968 trial court decision is upheld in the case of City of Los Angeles vs. City of San Fernando, et al.

In addition to the water imported into the Coastal Plain by MWD and the Los Angeles Department of Water and Power, approximately 23,000 acre-feet annually has been pumped from the ground water basin or diverted from streams in the San Gabriel Valley and delivered to the Coastal Plain during the hydrologic study period of this investigation. It was assumed for the purpose of this investigation that approximately the same amount would be delivered from the San Gabriel Valley to the Coastal Plain in the future.

Approximately 16,000 acre-feet of reclaimed waste water is imported from the San Gabriel Valley and is spread in the Montebello Forebay below Whittier Narrows.

Los Angeles County Sanitation Districts now plan to double the capacity of this plant to increase the amount of water available for spreading.

Local Water Supply

Among the local supplies--surface water, ground water, and reclaimed water--ground water is the most important resource. Because of the intermittent nature of runoff in streams, the direct use of surface water is negligible. The Los Angeles County Sanitation Districts are contemplating the construction of reclamation plants in the Coastal Plain. These plants may in time play a vital role in meeting the Coastal Plain's spreading and injection water demands.

DETAILED DISCUSSION OF GROUND WATER SUPPLY

To estimate the supply potential of ground water to meet the area's needs, it is essential to determine the amount of fresh water currently in storage and the long-term average replenishment by deep percolation and subsurface inflow in the ground water basins.

Currently Available Water in Storage

The Coastal Plain of Los Angeles County consists mainly of unconsolidated sediments or alluvium underlain by and bounded on the north and east by bedrock. On the west and south, it is bounded by the Pacific Ocean. Ground water is stored within the interstices of these unconsolidated sediments and, to a limited amount, in fractures of nonwater-bearing rocks that bound the area.

The Coastal Plain has been divided into four ground water basins by geological and surface features, as shown on Figure 8. Two of these four ground water basins are southwest and two are northeast of the series of low hills formed by the uplifts along the Newport-Inglewood fault.

The Santa Monica Basin extends south from the Santa Monica Mountains to the Ballona escarpment between the fault and the Pacific Ocean. The West Coast Basin extends southeast to the Palos Verdes Hills, San Pedro Bay, and Orange County. The Hollywood Basin extends eastward to the Elysian Hills and south to the La Brea high, formed by the Newport-Inglewood fault. The Central Basin borders the Hollywood Basin on the south and occupies the rest of the Coastal Plain of Los Angeles County east of the Newport-Inglewood fault.

Both granitic and consolidated sedimentary rocks are considered nonwater bearing because their specific yield is negligible. They form a base of the Coastal Plain's ground water basins when impermeable sediments, such as clay and silty clay, are not found above them. Where thick layers of these impermeable sediments are found above the bedrock without significant quantities of water-bearing materials between them and the bedrock, their surface is considered a base of the subsurface reservoir.

A contour map (Figure 9) was drawn connecting the points of equal elevation of the base of the water-bearing material. The elevation of the base ranges from sea level at the Santa Monica Hills and Palos Verdes Hills to more than 3,000 feet below sea level in the south-central part of the Coastal Plain.

Not all the water in the Coastal Plain 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 of water that is still retained by the sediment is technically termed "specific retention". On the other hand, the ratio of the volume of water in saturated soil that can be removed by gravity drainage to the total volume of saturated sedi-

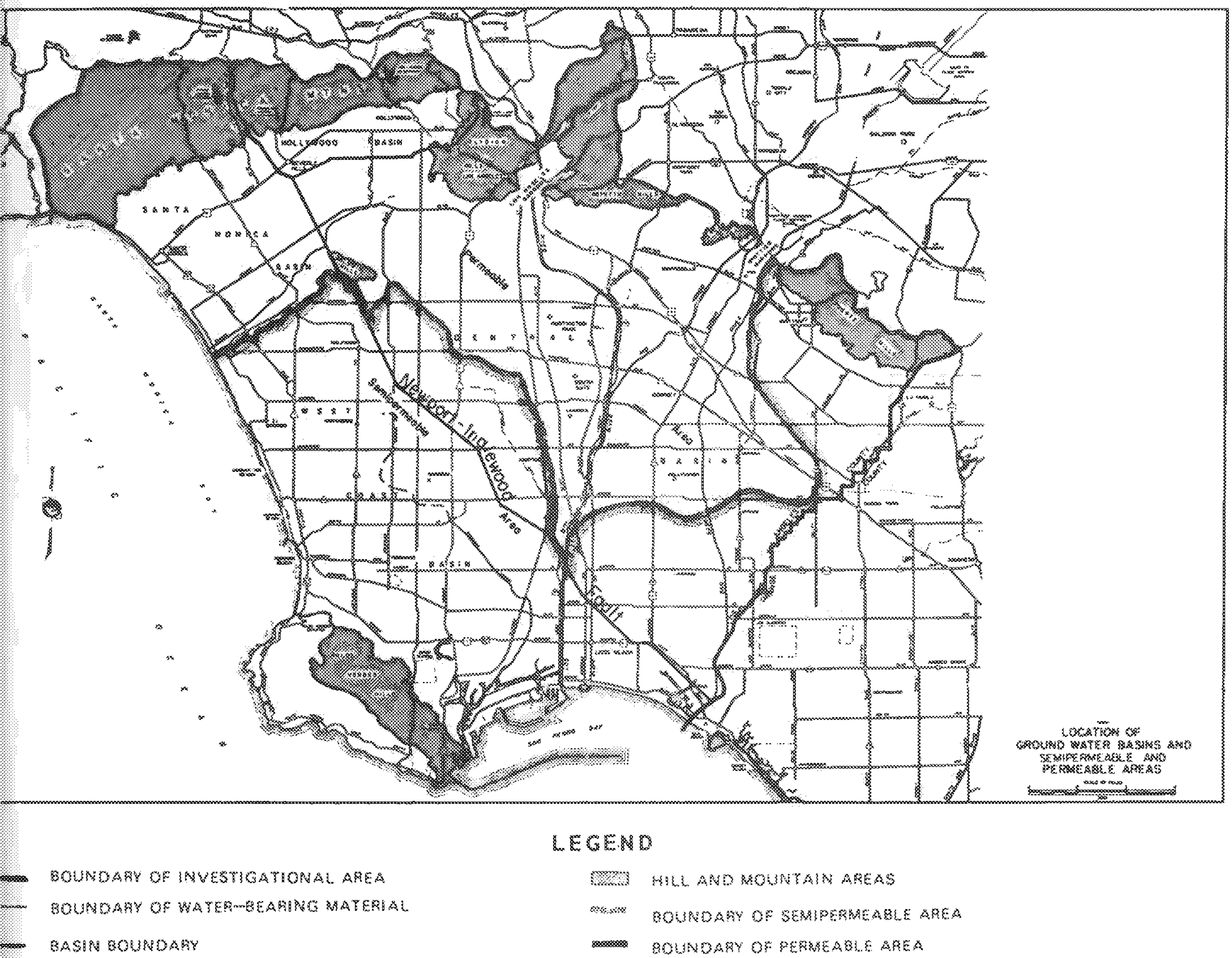


Figure 8

ment is technically termed "specific yield". Hence, as employed by hydrologists, the word "storage" refers only to the actual net amount of water that can be removed from sediments.

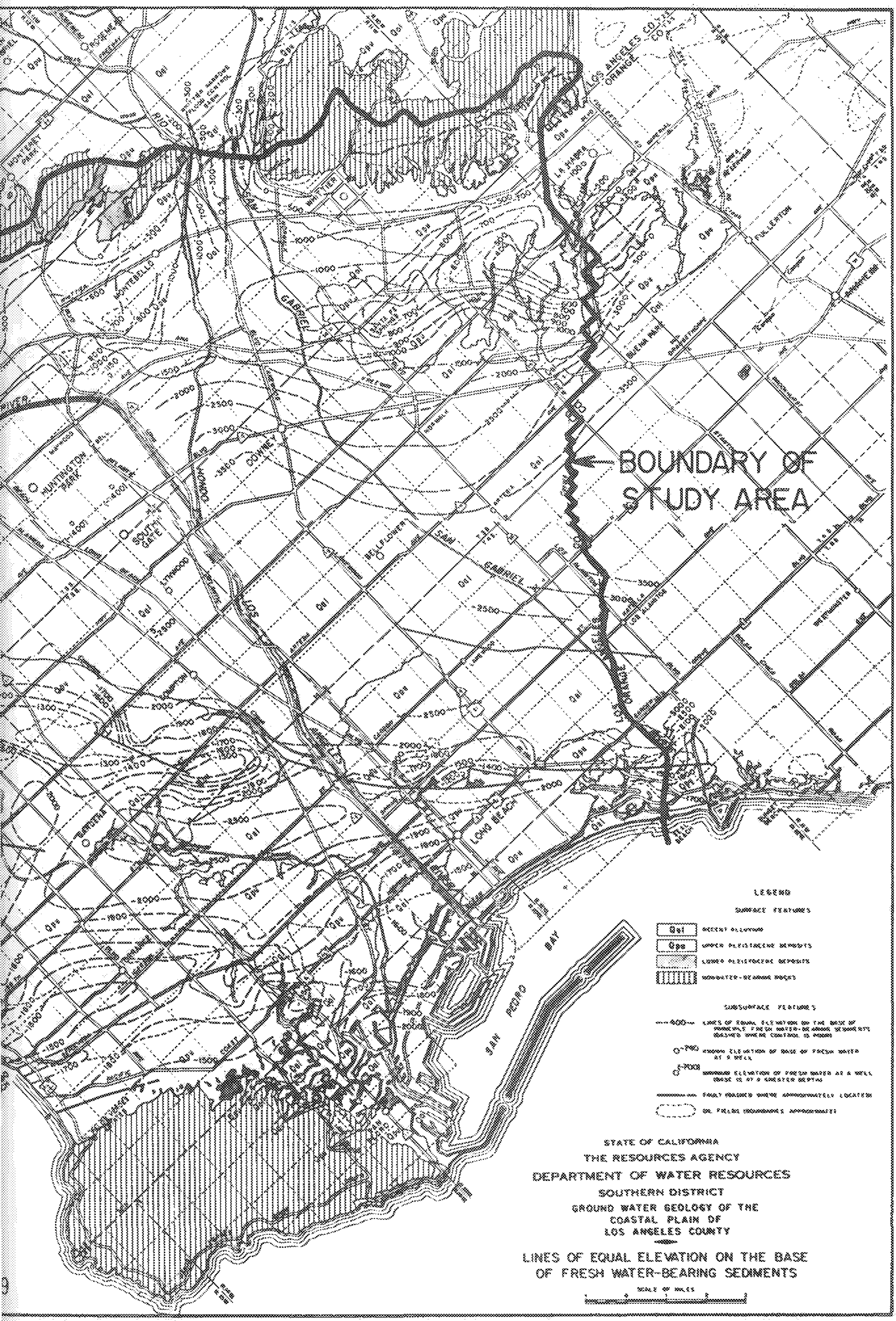
In the Coastal Plain, the specific yield of the water-bearing materials was estimated at from 3 percent for the finer materials to 26 percent for the coarser. To calculate the total storage capacity, the specific yield of the area was multiplied by the thickness of the aquifers and the area.

Although the volume of fresh water stored in the ground water basins in the Coastal Plain was estimated to be 20 million acre-feet in an earlier study, a recent evaluation indicated that about 35 million acre-feet is stored at present. Of this amount, about 29 million acre-feet is stored in the top 1,200 feet of sediments. However, the amount of ground water that can be extracted is limited by physical and economic considerations.

Replenishment of Ground Water

The ground water basins are replenished by subsurface inflow, injection of water for sea-water intrusion barriers, and deep percolation of water from various sources. These sources are precipita-

LA CRESCENTA
GLENDALE
BURBANK
NORTH HOLLYWOOD
VAN NUYS
HOLLYWOOD
BEVERLY HILLS
LOS ANGELES
SANTA MONICA
MANHATTAN BEACH
SANTA MONICA
PACIFIC
OCEAN


BOUNDARY OF STUDY AREA
LOS ANGELES CO.
ORANGE CO.
WHITTIER
MONTEBELLO
FULLERTON
DOWNEY
HUNTINGTON PARK
SOUTH GATE
LYNWOOD
BELLFLOWER
LONG BEACH
SAN PEDRO BAY
LEGEND
Qal
Qpu
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GROUND WATER GEOLOGY OF THE
COASTAL PLAIN OF
LOS ANGELES COUNTY
LINES OF EQUAL ELEVATION ON THE BASE
OF FRESH WATER-BEARING SEDIMENTS

tion and resulting runoff, applied water, and imported and reclaimed water in streambeds and spreading grounds.

Deep percolation due to precipitation occurs both inside and outside of streambeds. Within the streambed and spreading grounds, under mean precipitation conditions, about 48,000 acre-feet is estimated to percolate annually. Of this amount, 10,000 acre-feet is derived from storm runoff, originating within the study area and as flow from the San Gabriel Valley, and 38,000 acre-feet from water seeping into the streambed in the San Gabriel Valley because of high water tables. The 48,000 acre-feet of percolation occurs in a portion of the San Gabriel River streambed located in the forebay portion of the Central Basin, in the existing spreading grounds adjacent to the Rio Hondo and the San Gabriel River in the Montebello Forebay and in the existing spreading grounds adjacent to the Los Angeles River in the Dominguez Gap. Outside the streambed, the deep percolation from precipitation averages approximately 29,000 acre-feet per year.

Deep percolation from applied water results from irrigation of gardens and other areas and also from water discharged into cesspools. Because of the diminishing size of irrigated areas and the decreasing number of cesspools, the deep percolation from applied water is expected to decline in the future.

Significant amounts of imported water have deep percolated in the past in a portion of the San Gabriel River streambed in the Central Basin and in spreading grounds. The amount of deep percolation from this source depends upon the delivery capacity of the pipeline and the availability of replenishment water from MWD.

Also, ground water basins will be incidentally replenished by the injection of fresh water to maintain barrier projects to prevent sea-water intrusion along the coast. The amount injected depends upon the water level elevations that develop along the coast as a result of ground water basin operation.

In addition to the runoff from storms and water seeping out from streambeds in San Gabriel Valley because of high water tables, water reclaimed from waste water originating in the San Gabriel Valley is available for conservation by spreading in the Coastal Plain. The annual amount currently available for spreading is 16,200 acre-feet, which is about equal to the existing capacity of the Whittier Narrows Reclamation Plant.

Subsurface inflow also adds to the ground water supply of the area. Subsurface inflow of fresh water has occurred in the past and may be assumed to occur in the future at the Los Angeles Narrows and Whittier Narrows. The average annual subsurface inflow was estimated to be 200 acre-feet for the Los Angeles Narrows and 28,000 acre-feet for Whittier Narrows. With respect to flow across the Los Angeles-Orange County boundary line, both subsurface inflow and outflow have occurred, depending upon levels in adjoining basins. The amounts of inflow in the future at each location would vary with each plan of basin operation both within and outside the Coastal Plain.

Reduction of Water from Ground Water Basins

The amount of ground water in storage is reduced by subsurface outflow and pumping of ground water. Prior to initiation of the investigation, the average subsurface outflow was small.

In 1963, about 40 percent, or about 300,000 acre-feet, of the demand of the Coastal Plain for applied water was met by water pumped from ground water basins. In the future, the amount to be taken out of the basins by pumping will depend upon the plan of basin operation to be implemented.

III INVENTORY OF FACILITIES

Supply facilities within the Coastal Plain are those required for transmission and storage of surface and ground water to meet the fluctuating demand for applied water, spreading water, and fresh water barrier projects.

A highly developed network of both surface and ground water facilities for storage, transmission, and extraction exists within the Coastal Plain to meet the applied water demand of residential, industrial, and commercial entities, and the very small water requirement of agriculture.

GROUND WATER BASINS AS DELIVERY FACILITIES

The ground water basins can be considered as a part of this network of facilities as is illustrated by the analogy between the physical characteristics of the ground water basins and surface distribution systems.

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

Using equations that numerically describe the flow characteristics of ground water basins and surface distribution networks, it is possible to calculate the capabilities of these water delivery media and to determine the additional facilities required. This determination makes it possible to estimate the cost of water service under various plans of basin operation.

To integrate the ground water basins into the delivery facility, a mathematical model of a basin was developed. First, however, surveys were made of the areal extent, boundaries, thickness, structures, storage capacities, and transmissibilities of aquifers. This information was then consolidated to represent an "equivalent aquifer", a composite combining the essential physical features of 11 major Coastal Plain aquifers. Those features furnished the coefficients for a set of equations simulating storage and flow in the equivalent aquifer. This set of equations, with proper values for the coefficients, is the ground water basin mathematical model. The 82 equations required for this study were solved by a general purpose analog computer because the manual simultaneous solution of these equations would have been impossible.

The ground water basin mathematical model was used to estimate future ground water level elevations at various parts of the Coastal Plain under various alternative plans of basin operation.

When the ground water basins are regarded as a transmission facility, streambeds and man-made spreading grounds may be considered as the initial point of the delivery facility and wells may be considered as the terminal point. In addition to the San Gabriel River bed, which is a natural spreading facility with an approximate capacity of 120 cubic feet per second, four man-made spreading facilities exist in the area adjacent to the Rio Hondo and San Gabriel River in the Montebello Forebay, and adjacent to the Los Angeles River in the Dominguez area.

The total infiltration capacity of the spreading grounds in the forebay is about 570 cubic feet per second, which is equivalent to about 400,000 acre-feet per year, provided the infiltration rate is not reduced by a ground water mound that could develop beneath the spreading site. Usable capacity, however, is limited because of the need to rotate the use of percolation basins within the spreading grounds.

A large number of wells, the terminal points of a ground water delivery facility, are scattered throughout the Coastal Plain. The distribution of these wells and the approximate magnitude of ground water pumpage in various areas are shown on Figure 10.

LEGEND

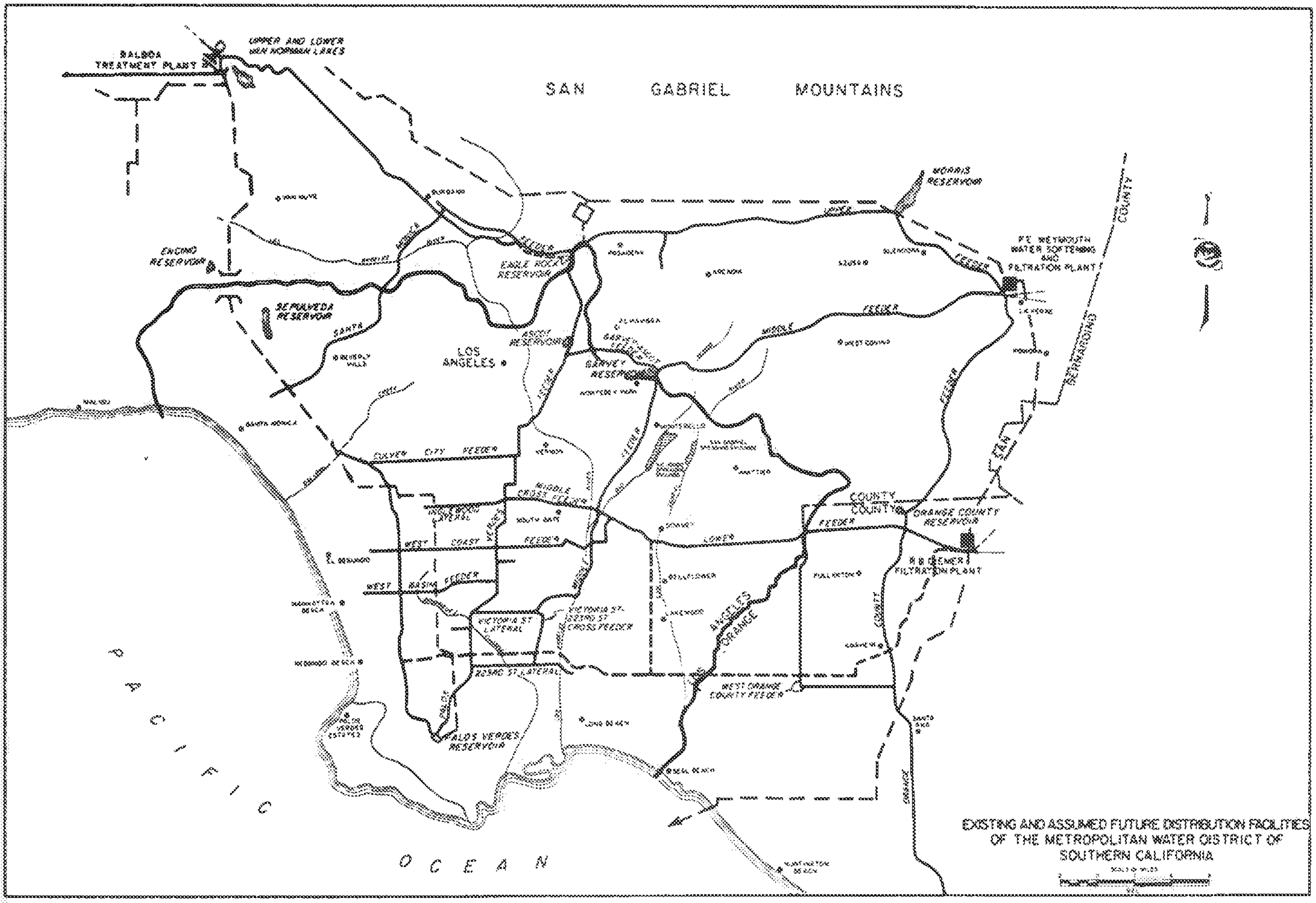
- BOUNDARY OF INVESTIGATIONAL AREA
- BOUNDARY OF WATER—BEARING MATERIAL
- BASIN BOUNDARY
- HILL AND MOUNTAIN AREAS
- EXISTING SPREADING GROUNDS
- EXISTING BARRIER FACILITIES OPERATED BY LOS ANGELES COUNTY FLOOD CONTROL DISTRICT
- PROPOSED BARRIER FACILITIES BY LOS ANGELES COUNTY FLOOD CONTROL DISTRICT
- EACH DOT REPRESENTS ANNUAL GROUND WATER EXTRACTIONS OF 500 ACRE—FEET

Figure 10

Because the water injected in fresh water barriers to prevent sea-water intrusion along the coast contributes to the supply of water in ground water basins, these barriers can be also considered as initiating points of water delivery facilities. At present, there are two barrier projects located in West Coast Basin along Santa Monica Bay and at Alamitos Gap. A barrier project will be constructed at Dominguez Gap soon. The lengths of these existing and planned projects are about 9 miles, 2 miles, and 4 miles, respectively.

IMPORTED WATER DELIVERY FACILITIES

The distribution systems owned and operated by the City of Los Angeles to bring water from outside the Coastal Plain are adequate for the delivery of the scheduled amounts of water to the area. The existing and proposed facilities of MWD and the State Water Project are also adequate to meet the demand for imported water in the Coastal Plain at least to 1990 under any economical plan of basin operation. The primary pipeline



LEGEND

BOUNDARY OF INVESTIGATIONAL AREA

EXISTING FACILITIES

PROPOSED FACILITIES

Figure 11

network of MWD in the Coastal Plain is shown on Figure 11.

COMMON DELIVERY FACILITIES

Many of the water delivery facilities would be required no matter what plan is adopted for meeting the water requirement in the Coastal Plain. This group of facilities would include small pipelines beyond the connection to the MWD's pipelines. The distribution systems owned and operated by both private and municipal agencies, such as the pipeline networks of the City of Los Angeles and the City of Long Beach, would also be in this category.

IV ECONOMIC EVALUATION

The Coastal Plain ground water managers can best understand the changes in their water service requirements and the political, legal, social, and organizational forces that influence management decisions. These forces may play a dominant role in the selection of a management plan and often override cost and benefit considerations. For these reasons, basin management must remain in local hands.

This investigation was restricted to the physical and economic aspects of basin operation. In considering the costs and benefits of alternative plans of operation, the measure of the benefits is satisfying the applied water demands for the study area. As these water demands (benefits) are common to all plans, one merely needs to estimate the costs of the plans to determine their economic advantages.

There are two extremes in providing water service. One is to rely exclusively on ground water basins as a source of water and the other is to use imported water facilities exclusively. Between these two extremes lie a great range of possible alternatives, as may be surmised by referring to Figure 12.

Operational possibilities for utilizing the ground water in storage are also numerous. The amount of ground water in storage could be increased to halt saline intrusion, or it could be left unchanged or even decreased from the present level by maintaining freshwater barrier projects along the coast.

VARIABLES

The variables in the operation of the ground water basins are the timing, amounts, and locations of both extraction and artificial replenishment. In addition, the method of preventing saline water intrusion also could be considered as an operational variable. These factors can be expressed in terms of:

1. Spreading schedule of imported water at the Montebello Forebay;
2. Methods of preventing saline intrusion;
3. Pattern of ground water extraction;
4. Schedules of ground water extraction.

EVALUATION OF VARIABLES BY APPLICATION TO ALTERNATIVE PLANS

In all, more than 50 plans of operation were evaluated during this investigation, and comprehensive operational-economic information was developed.

It was found that it is impracticable to form a seaward freshwater gradient by filling the Coastal Plain aquifers as rapidly as required to forestall further sea-water intrusion along the coast. Furthermore, economic evaluation of many plans indicated that it is much more expensive to fill the basins than maintain freshwater barriers to stop sea-water intrusion. Consequently, analysis can be confined to those plans that involve freshwater barriers.

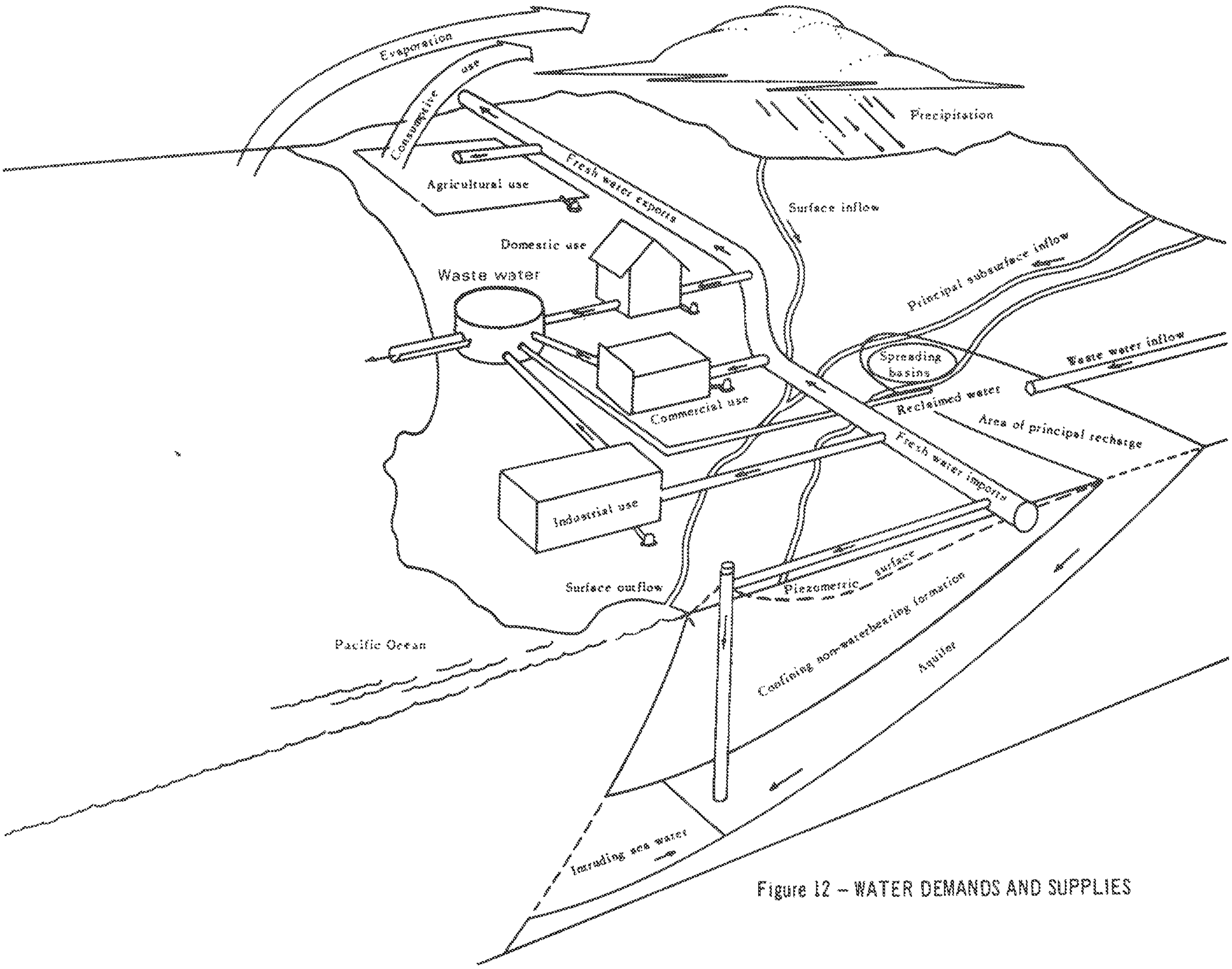


Figure 12 – WATER DEMANDS AND SUPPLIES

It has been generally believed that location of pumping is a significant factor in the management of ground water basins. However, it was found that location of pumping caused a comparatively negligible economic impact in the Central Basin of the Coastal Plain.

Even though the pumping pattern was varied substantially in the Central Basin, cost difference was found to be minor. However, a shift in pumping pattern from the coastal area to the inland portion of the West Coast Basin was found to have a beneficial effect on the cost of maintaining the freshwater barriers.

Five plans that cover the range of significant variables were selected for detailed analyses. An extensive volume of information relating to them was published in Appendix C to this bulletin. Of those five, four were chosen to be offered here for consideration.

Plan A (Plan 117-11 in Appendix C) - provides for the use by 1990 of 4,000,000 of the 35,000,000 acre-feet of ground water in storage. (Ground water levels would be stabilized after 1990, at which time a safe-yield operation would be initiated. The basin would not be filled to its initial--1963--level.)

Plan B (Plan 117-5 in Appendix C) - provides for a median use of stored ground water, 1,000,000 acre-feet.

(Ground water levels would be stabilized after 1990, at which time a safe-yield operation would be initiated. The basin would not be filled to its initial--1963--level.)

Plan C (Plan 117-4 in Appendix C) - provides for the maintenance of ground water storage under average precipitation at present levels (immediate safe-yield operation).

Plan D (Plan 318-5 in Appendix C) - same as Plan C except it includes spreading a large amount of imported water.

Information concerning water demand and supply in the Coastal Plain during the period of detailed economic study is presented in Tables 1, 2, 3, and 4. Table 5 summarizes this information.

In Tables 1-4, columns 5, 6, 7, 8, and 12 (import by Los Angeles Department of Water and Power, import from San Gabriel Valley, filtered import by MWD for domestic use, and ground water extraction) are related to the amount of water directly used for consumption, and columns 9, 10, and 11 (filtered injection water, raw spread water, and reclaimed waste water) indicate the amount of water used for replenishment of ground water basins.

COST OF WATER SERVICE

In the computation of the cost of each plan of operation, facilities that are required for service of water regardless of source, such as existing storage reservoirs, were excluded from economic consideration because the cost associated with those facilities would be the same under each alternative.

TABLE 1
OPERATIONAL PLAN 'A'
ESTIMATED ANNUAL AMOUNTS OF WATER DEMAND AND WATER SUPPLY
IN THE COASTAL PLAIN OF LOS ANGELES COUNTY FROM 1963 THROUGH 1990
IN 1,000 ACRE-FEET PER YEAR

	1	2	3	4	5	6	7	8	9	10	11	12	13
YEAR	Applied water demand	Injection demand	Spreading demand	Total water demand 1, 2, 3	Import* by LADWP	Import from S.G.V.	Import soften domes.	By Metro. filter domes.	Water filter inject.	Dist. raw spread	Reclaimed waste water	Ground water extractn.	Total water supply 5 to 12
1963	852	8	59	919	197	10	277	0	8	46	13	368	919
1964	872	15	36	923	187	10	287	0	15	23	13	388	923
1965	892	22	18	932	178	10	297	0	22	5	13	408	933
1966	912	54	20	986	168	10	318	1	54	7	13	416	987
1967	932	68	19	1,017	158	10	308	33	66	6	13	424	1,018
1968	952	86	18	1,056	148	10	298	65	86	5	13	432	1,057
1969	972	77	17	1,066	138	10	288	97	77	4	13	439	1,066
1970	992	81	16	1,089	128	10	283	124	81	3	13	447	1,089
1971	1,008	85	15	1,108	128	10	270	145	85	2	13	455	1,108
1972	1,024	89	17	1,130	128	10	262	168	89	4	13	457	1,131
1973	1,040	93	18	1,151	127	10	253	191	93	5	13	459	1,151
1974	1,057	95	19	1,171	127	10	244	216	95	6	13	459	1,170
1975	1,073	99	19	1,191	127	10	236	241	99	6	13	459	1,191
1976	1,089	102	20	1,211	127	10	229	264	102	7	13	459	1,211
1977	1,105	104	20	1,229	127	10	222	287	104	7	13	459	1,229
1978	1,121	107	20	1,248	126	10	214	311	107	7	13	459	1,247
1979	1,137	111	20	1,268	126	10	207	335	111	7	13	459	1,268
1980	1,153	113	19	1,285	126	10	201	357	113	6	13	459	1,285
1981	1,158	116	19	1,293	126	10	194	369	116	6	13	459	1,293
1982	1,164	118	19	1,301	126	10	188	381	118	6	13	459	1,301
1983	1,169	121	19	1,309	126	10	182	392	121	6	13	459	1,309
1984	1,174	123	18	1,315	126	10	178	401	123	5	13	459	1,315
1985	1,180	126	18	1,324	127	10	175	410	126	5	13	459	1,325
1986	1,185	128	17	1,330	127	10	168	422	128	4	13	459	1,331
1987	1,191	130	16	1,337	127	10	164	431	130	3	13	459	1,337
1988	1,196	132	16	1,344	127	10	160	440	132	3	13	459	1,344
1989	1,201	135	15	1,351	127	10	157	449	135	2	13	459	1,352
1990	1,207	137	14	1,358	127	10	154	457	137	1	13	459	1,358
TOTAL	30,008	2,673	561	33,242	3,837	280	6,414	6,987	2,673	197	364	12,496	33,248

*From Bulletin No. 104—C. Second Los Angeles Aqueduct not considered as its construction schedule was not definite at time of study.

TABLE 2
OPERATIONAL PLAN 'B'

ESTIMATED ANNUAL AMOUNTS OF WATER DEMAND AND WATER SUPPLY
IN THE COASTAL PLAIN OF LOS ANGELES COUNTY FROM 1963 THROUGH 1990

IN 1,000 ACRE-FEET PER YEAR

	1	2	3	4	5	6	7	8	9	10	11	12	13
YEAR	Applied water demand	Injection demand	Spreading demand	Total water demand 1, 2, 3	Import* by LADWP	Import from S.G.V.	Import soften domes.	By Metro. filter domes.	Water filter inject.	Dist. raw spread	Reclaimed waste water	Ground water extraction	Total water supply 5 to 12
1963	852	7	58	917	197	10	292	36	7	45	13	317	917
1964	872	14	37	923	187	10	308	66	14	24	13	301	923
1965	892	17	18	927	178	10	327	94	17	5	13	284	928
1966	912	42	22	976	168	10	318	131	42	9	13	286	977
1967	932	45	21	998	158	10	308	170	45	8	13	287	999
1968	952	62	20	1,034	148	10	298	208	62	7	13	288	1,034
1969	972	50	19	1,041	138	10	288	247	50	6	13	290	1,042
1970	992	50	18	1,060	128	10	283	280	50	5	13	291	1,060
1971	1,008	50	17	1,075	128	10	270	308	50	4	13	292	1,075
1972	1,024	52	17	1,093	128	10	262	338	52	4	13	287	1,094
1973	1,040	51	17	1,108	127	10	253	368	51	4	13	282	1,108
1974	1,057	50	17	1,124	127	10	244	393	50	4	13	282	1,123
1975	1,073	50	17	1,140	127	10	236	417	50	4	13	282	1,139
1976	1,089	51	17	1,157	127	10	229	440	51	4	13	282	1,156
1977	1,105	51	17	1,173	127	10	222	464	51	4	13	282	1,173
1978	1,121	52	17	1,190	126	10	214	488	52	4	13	282	1,189
1979	1,137	52	16	1,205	126	10	207	511	52	3	13	282	1,204
1980	1,153	53	16	1,222	126	10	201	533	53	3	13	282	1,221
1981	1,158	53	16	1,227	126	10	194	546	53	3	13	282	1,227
1982	1,164	53	16	1,233	126	10	188	557	53	3	13	282	1,232
1983	1,169	54	16	1,239	126	10	182	568	54	3	13	282	1,238
1984	1,174	54	16	1,244	126	10	178	578	54	3	13	282	1,244
1985	1,180	54	15	1,249	127	10	175	586	54	2	13	282	1,249
1986	1,185	54	15	1,254	127	10	168	598	54	2	13	282	1,254
1987	1,191	55	15	1,261	127	10	164	608	55	2	13	282	1,261
1988	1,196	55	15	1,266	127	10	160	617	55	2	13	282	1,266
1989	1,201	55	15	1,271	127	10	157	625	55	2	13	282	1,271
1990	1,207	57	17	1,281	127	10	154	633	57	4	13	282	1,280
TOTAL	30,008	1,343	537	31,888	3,837	280	6,480	11,408	1,343	173	364	7,999	31,884

*From Bulletin No. 104—C. Second Los Angeles Aqueduct not considered as its construction schedule was not definite at time of study.

TABLE 3
OPERATIONAL PLAN 'C'
ESTIMATED ANNUAL AMOUNTS OF WATER DEMAND AND WATER SUPPLY
IN THE COASTAL PLAIN OF LOS ANGELES COUNTY FROM 1963 THROUGH 1990
IN 1,000 ACRE-FEET PER YEAR

	1	2	3	4	5	6	7	8	9	10	11	12	13
YEAR	Applied water demand	Injection demand	Spreading demand	Total water demand 1, 2, 3	Import* by LADWP	Import from S.G.V.	Import soften domes.	By Metro. filter domes.	Water filter inject.	Dist. raw spread	Reclaimed waste water	Ground water extraction	Total water supply 5 to 12
1963	852	7	57	916	197	10	292	60	7	44	13	293	916
1964	872	14	41	927	187	10	308	102	14	28	13	264	926
1965	892	13	25	930	178	10	327	142	13	12	13	236	931
1966	912	38	26	976	168	10	318	179	38	13	13	237	976
1967	932	39	23	994	158	10	308	218	39	10	13	239	995
1968	952	55	24	1,031	148	10	298	251	55	11	13	245	1,031
1969	972	42	24	1,038	138	10	288	285	42	11	13	252	1,039
1970	992	42	23	1,057	128	10	283	317	42	10	13	255	1,058
1971	1,008	42	23	1,073	128	10	270	343	42	10	13	258	1,074
1972	1,024	43	23	1,090	128	10	262	377	43	10	13	247	1,090
1973	1,040	12	23	1,105	127	10	253	413	42	10	13	237	1,105
1974	1,057	11	22	1,120	127	10	244	443	41	9	13	232	1,119
1975	1,073	40	22	1,135	127	10	236	472	40	9	13	228	1,135
1976	1,089	39	21	1,149	127	10	229	495	39	8	13	228	1,149
1977	1,106	39	20	1,164	127	10	222	518	39	7	13	228	1,164
1978	1,121	38	20	1,179	126	10	214	543	38	7	13	228	1,179
1979	1,137	38	19	1,194	126	10	207	566	38	6	13	228	1,194
1980	1,153	38	19	1,210	126	10	201	588	38	6	13	228	1,210
1981	1,158	38	19	1,215	126	10	194	600	38	6	13	228	1,215
1982	1,164	37	18	1,219	126	10	188	612	37	5	13	228	1,219
1983	1,169	37	18	1,224	126	10	182	623	37	5	13	228	1,224
1984	1,174	37	18	1,229	126	10	178	632	37	5	13	228	1,229
1985	1,180	37	17	1,234	127	10	175	641	37	4	13	228	1,235
1986	1,185	37	17	1,239	127	10	168	653	37	4	13	228	1,240
1987	1,191	37	17	1,245	127	10	164	662	37	4	13	228	1,245
1988	1,196	37	17	1,250	127	10	160	672	37	4	13	228	1,251
1989	1,201	37	17	1,255	127	10	157	680	37	4	13	228	1,256
1990	1,207	37	16	1,260	127	10	154	688	37	3	13	228	1,260
TOTAL	30,008	1,021	629	31,658	3,837	280	6,480	12,775	1,021	266	364	6,643	31,665

*From Bulletin No. 104—C. Second Los Angeles Aqueduct not considered as its construction schedule was not definite at time of study.

TABLE 4

OPERATIONAL PLAN 'D'
ESTIMATED ANNUAL AMOUNTS OF WATER DEMAND AND WATER SUPPLY
IN THE COASTAL PLAIN OF LOS ANGELES COUNTY FROM 1963 THROUGH 1990
IN 1,000 ACRE-FEET PER YEAR

	1	2	3	4	5	6	7	8	9	10	11	12	13
YEAR	Applied water demand	Injection demand	Spreading demand	Total water demand 1, 2, 3	Import* by LADWP	Import from S.G.V.	Import By Metropolitan Water District: soften domes.	filter domes.	filter inject.	raw spread	Reclaimed waste water	Ground water extraction	Total water supply 5 to 12
1963	852	7	58	917	197	10	292	49	7	45	13	304	917
1964	872	14	64	950	187	10	308	76	14	51	13	291	950
1965	892	13	66	971	178	10	327	100	13	53	13	278	972
1966	912	39	64	1,015	168	10	318	137	39	51	13	280	1,016
1967	932	40	62	1,034	158	10	308	176	40	49	13	281	1,035
1968	952	56	61	1,069	148	10	298	215	56	48	13	282	1,070
1969	972	43	60	1,075	138	10	288	253	43	47	13	283	1,075
1970	992	43	59	1,094	128	10	283	288	43	46	13	283	1,094
1971	1,008	43	58	1,109	128	10	270	317	43	45	13	284	1,110
1972	1,024	43	57	1,124	128	10	262	344	43	44	13	281	1,125
1973	1,040	42	56	1,138	127	10	253	372	42	43	13	278	1,138
1974	1,057	42	56	1,155	127	10	244	397	42	43	13	278	1,154
1975	1,073	41	55	1,169	127	10	236	421	41	42	13	278	1,168
1976	1,089	41	54	1,184	127	10	229	444	41	41	13	278	1,183
1977	1,105	41	54	1,200	127	10	222	468	41	41	13	278	1,200
1978	1,121	41	53	1,215	126	10	214	492	41	40	13	278	1,214
1979	1,137	41	53	1,231	126	10	207	515	41	40	13	278	1,230
1980	1,153	41	53	1,247	126	10	201	537	41	40	13	278	1,246
1981	1,158	41	52	1,251	126	10	194	550	41	39	13	278	1,251
1982	1,164	41	52	1,257	126	10	188	561	41	39	13	278	1,256
1983	1,169	41	52	1,262	126	10	182	572	41	39	13	278	1,261
1984	1,174	41	52	1,267	126	10	178	582	41	39	13	278	1,267
1985	1,180	41	52	1,273	127	10	175	590	41	39	13	278	1,273
1986	1,185	41	51	1,277	127	10	168	602	41	38	13	278	1,277
1987	1,191	41	51	1,283	127	10	164	612	41	38	13	278	1,283
1988	1,196	41	51	1,288	127	10	160	621	41	38	13	278	1,288
1989	1,201	41	51	1,299	127	10	157	629	41	38	13	278	1,293
1990	1,207	41	51	1,299	127	10	154	637	41	38	13	278	1,298
TOTAL	30,008	1,081	1,558	32,647	3,837	280	6,480	11,557	1,081	1,194	364	7,851	32,644

*From Bulletin No. 104-C. Second Los Angeles Aqueduct not considered as its construction schedule was not definite at time of study.

In addition, other fixed oost items, such as operation cost, profits of water purveyors, and costs related to water rights, were excluded because they would be the same under all plans.

It was also found in Appendix C that water quality degradation and land subsidence from ground water level decline do not require consideration in the cost comparison of alternatives.

Those items that were considered in the computation of cost of each plan are existing and additional facilities, such as pumps and wells, whose associated costs would be different under different alternatives. They were grouped into four categories: surface water facilities, ground water facilities, electrical energy requirements, and imported water supply. 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 for MWD and 4.5 percent for smaller water agencies and on representative life-spans of facilities in the Coastal Plain, and were adjusted to the 1963 cost level by using the Engineering News-Record construction cost index. Costs of imported water supplies to the Coastal Plain were predicated on the cost of delivery, which includes the capital, maintenance, and operation costs for the water imported by the City of Los Angeles (from the Owens River-Mono Basin) and by the City of Whittier from San Gabriel Valley, and also on the <u>prices that may be charged</u> by MWD to water agencies for the various types of raw and treated water sold by it.

TABLE 5

TOTAL AMOUNTS OF COMPONENTS OF WATER DEMAND AND SUPPLY IN THE COASTAL PLAIN OF LOS ANGELES COUNTY FOR THE STUDY PERIOD 1963 THROUGH 1990 FOR SELECTED PLANS OF OPERATION IN THOUSANDS OF ACRE-FEET*

COMPONENT	Plan number			
	Plan 'A'	Plan 'B'	Plan 'C'	Plan 'D'
WATER DEMAND				
Applied water demand	30,010	30,010	30,010	30,010
Injection demand	2,670	1,340	1,020	1,080
Spreading demand	560	540	630	1,560
TOTAL WATER DEMAND	33,240	31,890	31,660	32,650
WATER SUPPLY				
Import by Los Angeles Department of Water & Power	3,840	3,840	3,840	3,840
Import from San Gabriel Valley	280	280	280	280
Import by Metropolitan Water District				
Softened industrial and domestic	6,410	6,480	6,480	6,480
Filtered industrial and domestic	6,990	11,420	12,770	11,560
Filtered injection water	2,670	1,340	1,020	1,090
Raw spread water	200	170	270	1,190
Reclaimed waste water	360	360	360	360
Ground water extraction	12,490	8,000	6,640	7,850
TOTAL WATER SUPPLY	33,240	31,890	31,660	32,650

*From Bulletin No. 104–C. Second Los Angeles Aqueduct not considered as its construction schedule was not definite at time of study.

The cost of each facility was summed to obtain the total cost of water service, which includes the cost of ground water, imported water, replenishment of ground water basins, and prevention of sea-water intrusion. The cost of imported water includes ad valorem taxes paid by property owners in the Coastal Plain.

The total of these costs constitutes the cost of water service for the Coastal Plain. These costs would be incurred at different times under different plans of operation. The economic effect of incurring the same total amount of expenditure at different times would vary with the plan. To establish a viable economic comparison of all alternatives, it is necessary to convert all costs--regardless of the difference in time of expenditure--to the common denominator of present worth.

Present Worth

Present worth of the total cost of water service under each plan of operation 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 comparative measure of the extent of financial obligations that would be imposed on the decision-makers and the water users they serve.

Economic Evaluation

The cost of imported water was shown to be the biggest cost item in each of the four alternative plans. The cost depends chiefly on the future pricing policies of MWD from which the Coastal Plain purchases imported water.

To understand the importance of the MWD pricing policy on the Coastal Plain water economics, an analysis of the policy is necessary.

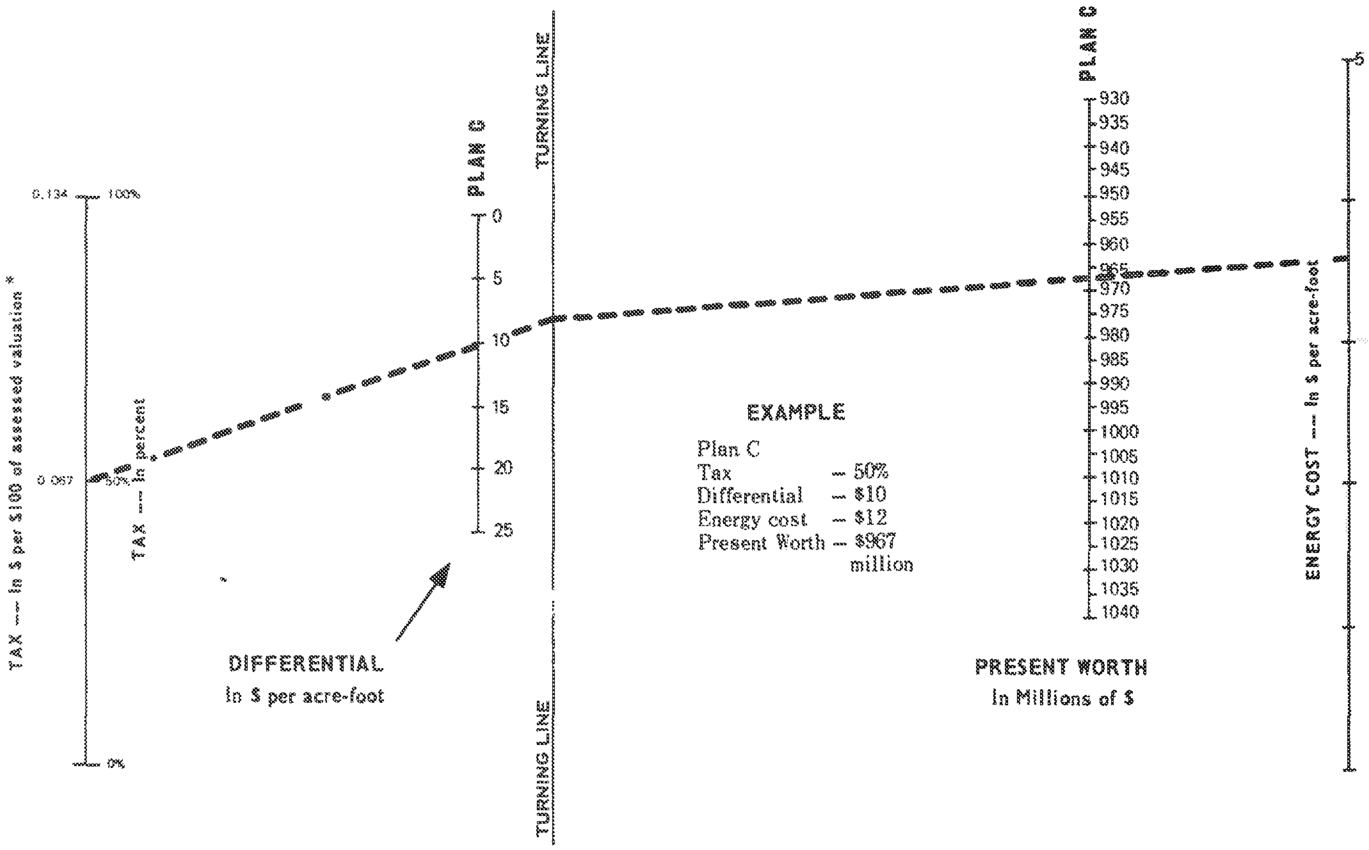
Conceptually, various means can be employed to pay for water service: Users of imported water can pay the complete cost for carrying it from source to point of delivery; property owners can pay the complete cost through taxes (ad valorem taxes); and users and taxpayers can divide the cost. This last means is the one MWD has employed to date--some 50 percent of its capital cost of constructing facilities is now borne by an ad valorem tax.

In addition, the present pricing policy provides different prices for water used for agricultural and ground water replenishment purposes and for water used for domestic and industrial purposes.

TABLE 6

PRESENT WORTH OF FUTURE TOTAL COSTS OF WATER SERVICE IN THE COASTAL PLAIN OF LOS ANGELES COUNTY

Category	Plan A	Plan B	Plan C	Plan D
Present worth of costs from 1963 to 1990	$ 902,000,000	$ 958,000,000	$ 972,000,000	$ 956,000,000
Present worth of costs from 1991 to perpetuity	412,000,000	400,000,000	405,000,000	397,000,000
TOTAL	$1,314,000,000	$1,358,000,000	$1,377,000,000	$1,353,000,000



USE OF THE NOMOGRAPH

1. Select plan of operation.
2. Connect appropriate points on tax scale and differential scale. Mark intersection of this line with turning line.
3. Connect point of turning line with energy cost point. Where this line intersects present worth line, read the present worth of total cost of water service for the selected plan.

DEFINITIONS

Tax. % of financial obligation for Metropolitan Water District facilities borne by property tax.

Differential. Difference in price between domestic–industrial and agricultural–replenishment water imported to the Coastal Plain.

Energy Cost. Energy charge (including operation, maintenance, replacement, and power costs) for State Water Project water delivered to Southern California.

Present Worth. Present worth of total cost of water service, 1963 through 1990.

* Based on the assumption that the indicated ad valorem tax rate will be continued to the year 2039.

Figure 13 – NOMOGRAPH TO DETERMINE PRESENT WORTH OF TOTAL COST OF WATER SERVICE IN THE COASTAL PLAIN UNDER VARIABLE CONDITIONS AFFECTING THE PRICE OF IMPORTED WATER – 1963 THROUGH 1990

owever, MWD has not announced a long-range policy; therefore, to get a long-range economic evaluation of alternatives, ssumptions were made regarding MWD pricing ifferentials and ad valorem taxes.

nother significant factor affecting the nit price of MWD water is the energy ost of pumping water from the State ater Project over the Tehachapi ountains. In recent years, the estimated ost of energy for pumping imported water as decreased. To facilitate the evaluation of the economics of the alternative lans under changing conditions with respect o pricing policies and energy costs, nomographs were developed and presented in ppendix C. One of them is given here as n example. (See Figure 13.)

sing the nomograph, the present worth of ost of water service for Plans A, B, C, nd D was determined under the assumption hat the present MWD pricing policy would e followed in the future. Table 6 shows he result of this determination. The ad alorem tax has been included in this able.

n evaluating this table, it must be remembered that the table is for the entire oastal Plain of Los Angeles County. To btain the economic information for individual water agencies such as Central nd West Basin Water Replenishment istrict, supplemental analyses will be equired.

or Plan D, if surplus water from the State ater Project could be purchased from MWD t a smaller price than indicated in the WD's pricing schedule, proper adjustment hould be made to the present worth of the ost of water service under the plan.

n evaluating these curves, a question may rise as to the differences in the values f ground water remaining in storage in 990 under Plans A, B, C, and D.

nder all plans, the ground water basin will rovide the same quantity of water from 1991 to perpetuity, although from different depths. Therefore, the comparative values of ground water in storage for the alternative plans would be the differences between the present worth of total future costs for these plans from 1991 to perpetuity. These differences have already been included in the costs to perpetuity in Table 6.

In making a long-range water management plan in the Coastal Plain, the timing of the construction of the next water project is also of vital concern to local agencies.

The economically desirable timing would be the time when the total cost of the next imported water project equals the total cost of the least expensive alternative supply -- ground water, converted salt water, and reclaimed waste water. In setting this timing, consideration should be given to ascertaining that an adequate local emergency supply is available. For exact timing, however, a more detailed study should be made by evaluating the present worth of total cost of water service with alternative times of construction.

CONCLUDING REMARKS

An important finding that has evolved from this investigation is that the most economically significant factors in the Coastal Plain's water service cost are the price of imported water and the proportionate use of imported water and ground water in storage. It was also found that changes in assumed conditions substantially affect the comparison of the water service costs under alternative plans.

Because the investigation was based on numerous unavoidable assumptions and these assumed conditions continually change, the water agencies in the Coastal Plain must consider the impact of these changes on the cost of water service before a management decision is made. Appendixes A, B, and C to this bulletin provide data and procedures for such considerations.

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