State of California
THE RESOURCES AGENCY
Department of Water Resources

BULLETIN No. 104-2

PLANNED UTILIZATION OF GROUND WATER BASINS

SAN GABRIEL VALLEY

Appendix A: Geohydrology

MARCH 1966

HUGO FISHER
Administrator
The Resources Agency

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Director
Department of Water Resources

Courtesy of Spence Air Photos

SAN GABRIEL VALLEY, LOOKING EAST ON LAS TUNAS DRIVE

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Administrator	*Governor*	*Director*
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NTO

December 21, 1965

Honorable Edmund G. Brown, Governor, and
Members of the Legislature of the
State of California

Gentlemen:

Appendix A, "Geohydrology", a portion of Bulletin No. 104-2, "Planned Utilization of Ground Water Basin: San Gabriel Valley", reports on a study authorized in Section 226 of the California Water Code and Item 262 of the Budget Act of 1959.

Appendix A presents the results of comprehensive geologic and hydrologic studies of the San Gabriel Valley in Los Angeles County. The geologic information contained in this appendix includes data and findings on the extent, thickness, and lithology of the aquifer comprising the San Gabriel Valley Ground Water Basin, the structural features within the basin that influence ground water movement, and the areas of subsurface inflow and outflow. The hydrologic information includes a summary of the historical amounts of each of the items of water supply, use, and disposal, and seasonal changes in the amounts of ground water in storage. Based on this geologic and hydrologic information, a mathematical model of the ground water basin was developed, seasonal overdraft and safe yield were estimated, and criteria for the deep percolation of future water supplies were established.

The information in this appendix will be utilized during the operational-economic phase of the overall investigation. The results of the investigation will provide local agencies with the operational and economic information needed for optimum management of the San Gabriel Valley Ground Water Basin.

Sincerely yours,

William E. Warne

Director

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

EDMUND G. BROWN, Governor
HUGO FISHER, Administrator, The Resources Agency
WILLIAM E. WARNE, Director, Department of Water Resources
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AUTHORIZATION

Statutory authorization for the Department of Water Resources to conduct investigations of surface and underground water conditions is contained in Section 226 of the California Water Code. In Item 262 of the Budget Act of 1959, a broad authority was delegated to the Department and funds were appropriated "for conducting water resources investigations, surveys and studies, preparing plans and estimates, making reports thereon, and otherwise performing all work and doing all things required relative thereto ...." Subsequently, annual appropriations have been made by the Legislature to carry on these investigations under the program title, "Planned Utilization of Ground Water Basins".

ACKNOWLEDGMENT

Valuable assistance and data for this investigation were contributed by numerous federal, state, and local agencies. This cooperation is gratefully acknowledged.

Special mention is made of the helpful cooperation of the following:

California Department of Public Works, Division of Highways

California Department of Conservation,

Division of Mines and Geology

Division of Oil and Gas

Los Angeles County, Department of County Engineer

Los Angeles County Flood Control District

Humble Oil Company

Signal Oil and Gas Company

Standard Oil Company of California

Texas Company, Inc.

The Associated Colleges of Claremont

The California Institute of Technology

The University of California, Los Angeles

The University of California, Riverside

The University of Southern California

United States Geological Survey, Ground Water Branch

CHAPTER I. INTRODUCTION*

The native water supplies of the San Gabriel Valley in Los Angeles County have been reduced due to the continuing drought, exportation of relatively large amounts of waste water, and ever-increasing ground water extractions. These conditions have caused ground water levels to fall lower and lower over the past decade. Because of this water shortage and the probable future increasing water demands, concern has arisen over the magnitude and management of the future water supply of the San Gabriel Valley.

To effectively utilize the ground water resources of the valley in concert with imported supplies, and to meet the increasing and fluctuating demands for water with the most economical distribution and storage facilities, implementation of a program for planned utilization of the ground waters of the San Gabriel Valley is highly desirable. The summary of the investigation leading to such a program is being presented in Bulletin No. 104-2, "Planned Utilization of Ground Water Basins: San Gabriel Valley". Engineering details on this program are being published in two appendixes. In this, Appendix A, emphasis is on geology and hydrology; Appendix B will present operational and economic details. Appendix A is the first part of the report to be published.

Objectives of Investigation

The major objective of this investigation of the San Gabriel Valley is to provide local agencies with information and techniques which will enable them to evaluate alternative plans of ground water management and to select the optimum plan for future implementation. The overall

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*For definitions of terms as used in this report, see Attachment 1.

objective of the geologic and hydrologic phase was to provide a firm basis from which the operational-economic phase of the investigation may proceed. The following must be accomplished to attain this objective:

1. Determine the hydrologic and geologic parameters and boundary conditions of the ground water basin, delineate basin boundaries, establish the location of structures affecting ground water movement, and establish quantitative values of transmissive and storage characteristics from which subsurface flow and change in storage for a base period can be calculated.

2. Determine the historical amounts of annual water supply, use, and disposal for the ground water basin for a selected base period. From this information, evaluate the character and amount of deep percolation, determine the water supply surplus or deficiency, and estimate overdraft and safe yield.

3. Develop a mathematical model of the ground water basin which will reliably provide a quantitative mathematical relationship of ground water movement and storage.

4. Determine relationships, based on historical data, between water supply and deep percolation to provide a basis for the estimation of future deep percolation to the ground water reservoir.

Scope and Conduct of Investigation

The investigation consisted of a comprehensive and detailed geologic and hydrologic study of the San Gabriel Valley, shown on Plate 1, "Location and General Geology of Area of Investigation". The geologic investigation consisted of detailed field mapping, field transmissibility tests, and the review of all available geologic data on the area. From these data, basin boundaries and the physical properties of the area were determined. This information was supplemented with data obtained by contacting numerous individuals and agencies.

In the hydrologic investigation, the available reports on the study area were reviewed and data were compiled from reports published by the United States Geological Survey, Los Angeles County Flood Control District, United States Weather Bureau, State Water Rights Board, and Department of Water Resources. Numerous contacts were made with individual agencies to gather the necessary data regarding the various items of water supply, use, and disposal. A limited amount of field work was necessary to supplement the basic data which were developed on a seasonal basis. The hydrologic information was used together with geologic information to develop and verify a mathematical model of the basin and to derive criteria for the deep percolation of future water supplies. The verification of the mathematical model was made possible by the use of large general-purpose analog and digital computers.

During the geologic and hydrologic phases of the study, a set of definitions, concepts, and assumptions were adopted. Definitions of terms used in this appendix are presented in Attachment 1.

The flow chart of the general steps taken in this investigation is shown on Plate 2, "Flow Chart of Geologic and Hydrologic Phases of the Investigation of Planned Utilization of the San Gabriel Valley Ground Water Basin". These steps are summarized below:

1. An investigation of geologic properties of the study area was made to determine ground water basin boundaries, transmissibility of sediments, storage factors, and ground water levels.

2. After the base period was determined, seasonal changes in the amount of ground water in storage were estimated by the specific yield method.

3. The seasonal amounts of water supply, use, and disposal were estimated. Water use and disposal were subtracted from water supply to obtain seasonal water supply surplus or deficiency. This quantity was compared with change in storage calculated by the specific yield method.* This comparison was used as a tool to minimize errors in assumptions and data.

4. A preliminary mathematical model of the ground water basin was developed from geologic data, and the reliability of the model was tested by use of preliminary inflow and outflow estimates. From the knowledge gained by working with the model, the components of water supply, use, and disposal, and change in storage were adjusted within reasonable limits and finalized.

5. The validity of the mathematical model was ascertained by applying the finalized hydrologic data to it and comparing computed water level elevations with historical water level elevations.

6. A set of assumptions relative to overdraft and safe yield were adopted and water supply, use, and disposal under 1960 cultural conditions were estimated. From these estimates, overdraft and safe yield under 1960 conditions were computed.

7. Criteria for deep percolation of future water supplies were developed, verified, and finalized.

An important consideration, water quality, is not discussed in this report because the quality of the waters of the San Gabriel Valley and the basin salt balance have been excellent in the past, and it is anticipated that they will not be a problem in the immediate future. Water quality considerations in future operational plans will be discussed in the forthcoming Appendix B of Bulletin No. 104-2.

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*Ideally, these two quantities are equal. However, in practice, this rarely occurs, for the following reasons: (1) The cumulative errors of all items are included in the figure for seasonal water supply surplus or deficiency; and (2) the amount of water in transit in the zone of aeration is not considered, it would have to be the same at the beginning and the end of the water year for the two quantities in question to be equal.

Related Investigations and Reports

Previous hydrologic investigations of the San Gabriel Valley area have been made and reported on by the Department of Water Resources and its predecessor agencies, by the Los Angeles County Flood Control District, and by the United States Geological Survey. The reports utilized in the preparation of this report are listed in the bibliography, Attachment 2.

Base Hydrologic Period

In any watershed, the original source of local water is precipitation. Therefore, the amount of precipitation to a ground water basin and to its tributary areas serves as an index to the water supply available to that basin. Consequently, by analysis of long-term precipitation records, it is possible to select as a "base period" a relatively short and recent period which represents the long-time average water supply. Such a period is needed for study purposes because long-term hydrologic data are generally unavailable.

The base period should be reasonably representative of long-time hydrologic conditions and should include both normal and extreme wet and dry years. Both the beginning and end of the base period should be preceded by a series of dry years or a series of wet years, so that the difference between the amount of water in transit within the zone of aeration at the beginning and end of the base period would be a minimum. The base period should also be within the period of available records and should include recent cultural conditions as an aid to future basin operational studies.

The long-time period was determined from an accumulated deviation from mean graph of precipitation at Glendora, Plate 3, entitled

"Precipitation Characteristics at Glendora". This graph shows three pairs of wet and dry trends covering, progressively, the periods 1883-84 through 1903-04, 1904-05 through 1932-33, and 1933-34 through 1960-61. The long-time period was taken as the water years 1904-05 through 1960-61 on the assumption that this 57-year period, covering the most recent two pairs of wet and dry trends, was the best available representation of long-time hydrologic conditions in the San Gabriel Valley.

The water years 1933-34 through 1959-60, selected as the base period for this study, meet all the criteria. This 27-year period includes the most recent pair of wet and dry trends, begins and ends after a series of dry years, is within the period of available data, and includes recent cultural conditions. The base period mean precipitation at Glendora, which amounted to 21.22 inches, corresponds very closely to the long-time period mean of 21.39 inches. Because of the similarity of hydrologic conditions preceding the years 1933-34 and 1959-60, the assumption could be made that there was no significant change in the amount of water in transit at the beginning and end of the base period. In effect, it was assumed that the difference in the amount of water percolating downward to the zone of saturation was nil for both periods. This assumption facilitated change in storage computations for the base period.

CHAPTER II. DESCRIPTION OF AREA

The San Gabriel Valley Ground Water Basin and its tributary hill and mountain areas are located in the eastern portion of Los Angeles County, approximately 25 miles from the Pacific Ocean. The area is shown on Plate 1. More detailed features are shown on Plate 4, "Lines of Equal Average Seasonal Precipitation for Base Period, 1933-34 through 1959-60".

The detailed description of the area under investigation is presented in this chapter. This chapter, along with the geologic information presented in Chapter III, describes the varied and complex relationships of nature and man's activities in the area, which is one of the more heavily developed ground water basins in California.

Physiographic Characteristics

The San Gabriel Valley is bounded on the north by the San Gabriel Mountains, which consist of steep, rocky ridges broken by numerous irregular canyons. The elevations of these mountains vary from about 900 feet along their base to a maximum of more than 10,000 feet above sea level.

The San Gabriel Valley is a broad piedmont plain that slopes downward from the base of the San Gabriel Mountains to Whittier Narrows, the lowest point of the area. The average slope of the valley floor is about 65 feet per mile.

South of the San Gabriel Valley, a system of low rolling hills rise about 500 feet from the valley floor to separate the valley from the coastal plain. These hills, from west to east, are: the Repetto, Merced, Puente, and San Jose Hills. The hills, broken only at Whittier Narrows by a floodplain 1-1/2 miles wide, form a crescent shape around the valley.

Study Area and Boundaries

The study area is bounded on the north by the watershed divide of the San Gabriel Mountains. From the foot of the San Gabriel Mountains north of La Verne, the eastern boundary follows a subsurface bedrock high between San Dimas and La Verne; this bedrock high separates the study area from the Upper Santa Ana Valley. The areas immediately east of the San Dimas-La Verne boundary are not tributary to the Santa Ana River, but instead, they are tributary to Live Oak Wash and Thompson Wash from which streamflow eventually reaches the San Gabriel River. The watershed divide of the San Jose, Puente, Merced, and Repetto Hills forms the southeast, southern, and western boundary of the study area. From north of the Repetto Hills, the Raymond fault (sometimes referred to as the "Raymond Hill dike") angles northeasterly and intersects the San Gabriel Mountains north of Monrovia to form the northwestern boundary of the area under investigation.

That portion of the study area containing the principal ground water-bearing deposits underlying the valley floor is called, in this report, the "San Gabriel Valley Ground Water Basin". It is on this area that the major emphasis of this investigation is placed. The boundaries of this area are the Raymond fault on the northwest, the line of contact between alluvium and the bedrock of the San Gabriel Mountains on the north, the bedrock high between San Dimas and La Verne on the east, and the line of contact between alluvium and the bedrock of the low hills on the southern periphery of the basin. Bedrock areas that occur within the valley area are excluded from the San Gabriel Valley Ground Water Basin. The San Gabriel Valley Ground Water Basin is also referred to in this appendix as the "San Gabriel Valley". This area is to be distinguished from the entire study area which includes portions of the surrounding mountains and hills.

For hydrologic analysis, it was convenient to segregate that portion of the San Gabriel Mountains directly tributary to the ground water basin and below San Gabriel Dam from the rest of the San Gabriel Mountains. In this appendix, the area is termed "the frontal area" and is shown on Plate 4. This division could be made easily because the inflow from the area above the San Gabriel Dam could be accounted for accurately by using records of measured releases through the dam.

The total study area is made up of about 167 square miles of ground water-bearing valley land, 46 square miles of nonwater-bearing hill land, and 275 square miles of nonwater-bearing mountain land of which the frontal area encompasses about 72 square miles.

Surface Stream Systems

The stream systems in the San Gabriel Valley consist of the two major streams, the Rio Hondo and San Gabriel River, and their tributaries. These streams have their headwaters in the San Gabriel Mountains from which the major portion of their runoff is derived. As shown on Plate 4, the rivers and their tributaries which traverse the valley floor have a common exit from the valley at Whittier Narrows, a narrow gap in the low hills flanking the southern portion of the basin. Almost all natural surface outflow from the San Gabriel Valley passes through Whittier Narrows, the only exceptions being small amounts which pass through two low gaps in the Repetto Hills, south of Monterey Park, and minor amounts which pass over the eastern portion of the basin boundary near La Verne.

Most natural surface inflow to the valley land comes from the tributary San Gabriel Mountains, although significant amounts come from the Raymond Basin, Walnut Creek (near San Dimas), and San Jose Creek (southwest of Pomona). The San Gabriel River drains about 77 percent of the San Gabriel Mountains that are tributary to the San Gabriel Valley. From its mouth near Azusa, the San Gabriel River traverses the San Gabriel Valley in a southwesterly direction, passes through Whittier Narrows and extends southerly across the coastal plain to the Pacific Ocean near Seal Beach. Within the San Gabriel Valley, the San Gabriel River has as tributaries: Fish Canyon, Rogers Canyon, Big Dalton, Little Dalton, San Dimas, Walnut, and San Jose Creeks, all of which have their headwaters in the San Gabriel Mountains.

Prior to 1943, the San Gabriel River bifurcated near El Monte and formed the Rio Hondo, which is tributary to the Los Angeles River. However, upon completion of the Santa Fe Dam in 1943, the natural division of flow at the bifurcation was stopped.

The Rio Hondo drains the northwestern portion of the San Gabriel Valley and has as its tributaries: Santa Anita, Arcadia, Eaton, Rubio, and Alhambra Washes, all entering the valley from the Raymond Basin. Sawpit Wash is also tributary to the Rio Hondo; its drainage area is entirely within the study area.

The stream channels in the San Gabriel Valley are relatively well defined, although historically they have braided and meandered. In the past, most streams had some sort of improvement that sometimes amounted to no more than a trash dike. Farmers had numerous diversions on the streams for irrigation and water conservation. Phreatophytes were abundant in the stream channels and along their banks. During the summer months, most streams were dry, although the Rio Hondo and San Gabriel Rivers have perennial flow at Whittier Narrows due to rising water.

During the base period of this investigation, 1933-34 to 1959-60, the Los Angeles County Flood Control District and the United States Army Corps of Engineers were active in improving stream channels and controlling the destructive floodwaters that occasionally pass through the area. At present (1965), floodflows in most major stream channels are controlled by flood control reservoirs. All stream channels are improved, with the exception of the San Gabriel River above Santa Fe Dam and San Jose Wash for most of its reach in San Gabriel Valley. Most stream channel improvements consist of concrete-lined bottoms and sides which prevent percolation from these channels. The improved portion of the San Gabriel River between Santa Fe Dam and Whittier Narrows Dam, however, has a pervious bottom, which allows valuable waters to continue percolating and replenishing the underground water supply.

Climatological Characteristics

The area under investigation is in a region of both semiarid and Mediterranean climate. Like most of Southern California, this climate consists of intermittent rain during the winter months and rainless summer months. The major portion of the annual precipitation, about 77 percent, occurs during December through March. Table 1 shows the average monthly precipitation at Glendora for the 27-year base period, 1933-34 through 1959-60. Seasonal precipitation varies from periods of above-normal rainfall to periods of long persistent droughts. Plate 3 shows historical seasonal rainfall characteristics for the United States Weather Bureau station at Glendora.

TABLE 1

MONTHLY VARIATION IN PRECIPITATION
AT THE CITY OF GLENDORA[a]

Month	Average monthly precipitation[b]		Accumulative average monthly precipitation	
	In inches	In percent	In inches	In percent
October	0.92	4	0.92	4
November	1.48	7	2.40	11
December	4.28	20	6.68	31
January	4.07	19	10.75	50
February	4.36	21	15.11	71
March	3.54	17	18.65	88
April	1.81	9	20.46	97
May	0.31	2	20.77	99
June	0.09	0	20.86	99
July	0.01	0	20.87	99
August	0.08	0	20.95	99
September	0.27	1	21.22	100

a. Los Angeles County Flood Control District Station No. 185.
b. Average for 27-year base period, 1933-34 through 1959-60.

Precipitation in the area under investigation usually occurs in the form of rainfall, although snow is common in higher elevations in the San Gabriel Mountains. Precipitation, affected mainly by ground surface elevation, varies within the area under investigation. During the base period, the average seasonal precipitation on the frontal area of the

San Gabriel Mountains was about 27 inches; during the same period, the average seasonal precipitation on the valley was about 18 inches. The precipitation pattern for the area under investigation is shown on Plate 4, "Lines of Equal Average Seasonal Precipitation for Base Period 1933-34 through 1959-60".

Temperatures are usually moderate in the valley areas, with little fluctuation in the extremes. The average annual temperature of the San Gabriel Valley is about 62 degrees Fahrenheit. Temperatures in the valley rarely drop below freezing, although plant killing frosts occur in the late fall and winter in the high mountains. Recorded temperatures in the City of San Gabriel have varied from 22 to 111 degrees Fahrenheit.

History of Land and Water Use

The preeighteenth century Indians that inhabited the Los Angeles area were the first men to beneficially use the waters of the San Gabriel Valley. The perennial flow at Whittier Narrows, as well as the marshes north of the Raymond Hill dike, must have been the major attraction to the Indians who cultivated and hunted in the area. The earliest recorded use of water by man was at the San Gabriel Mission founded in 1771 by Fr. Junipero Serra. The padres of the mission diverted waters from the perennial streams flowing from the cienegas north of the Raymond Hill dike. During one period of time, as much as 6,000 acres were irrigated by the mission from surface diversions and shallow artesian wells. The marshes, as well as the flowing water in the Rio Hondo, San Gabriel River, and smaller streams debouching from Rubio, Eaton, and San Dimas Canyons, were the main sources of water supply to the settlers in San Gabriel Valley for many years.

In the nineteenth century, with a rapid influx of settlers, surface water supplies started to become inadequate. As farms began to blossom over the valley floor, wells were drilled to pump ground water to augment the water supply. However, the quantities of pumped ground water must have been small due to the lack of efficient pumps and cheap power: electricity was not yet available nor was the deep well turbine pump.

The early twentieth century saw the development of numerous wells equipped with the deep well turbine pump and with gas and electric motors for power. Large quantities of ground water were pumped to supplement surface supplies to irrigate the many flourishing farms that nearly covered the San Gabriel Valley. Today, there are hundreds of wells extracting ground water from the reservoir underlying the valley floor.

During the base period of this investigation, the San Gabriel Valley area has undergone a cultural change, progressing from a predominantly rural and agricultural community to a residential and commercial urban complex. Agricultural land increased from 6,300 acres in 1880 to 60,300 acres in 1924, then decreased steadily to 15,300 in 1960; urbanization, on the other hand, increased constantly -- from 1,700 acres in 1904 to 74,500 in 1960. This historical growth and decline in irrigated agriculture in the San Gabriel Valley were recorded by land use surveys which are summarized in Table 2.

The magnitude of population increases, the cause of the change in land use in the San Gabriel Valley, is indicated by the valley's 1960 population which is more than three times the population of 1940. The number of people living in the San Gabriel Valley increased from 192,100 in 1940 to 690,200 in 1960. Table 3 presents historical population data

TABLE 2

HISTORICAL LAND USE IN
SAN GABRIEL VALLEY

Year	Gross area, in acres		
	Irrigated agriculture	Urban and suburban	Total
1880	6,300	--[a]	--
1888	8,900	--[a]	--
1904	28,300	1,700	30,000
1912	--[a]	--[a]	49,300
1924	60,300	15,200	75,500
1932	55,800	21,900	77,700
1941	50,400	29,500	79,900
1950	38,300	45,000	83,300
1955	23,900	59,100	83,000
1960	15,300	74,500	89,800

a. Data unavailable.

Note: Total acreage in San Gabriel Valley Ground Water Basin is 107,000 acres.

of the incorporated cities in the San Gabriel Valley. Because nearly all vacant land in the western portion of the study area has been urbanized, the rate of population increase in that portion of the area has slowed down, as exhibited by the experience of Alhambra, South Pasadena and San Gabriel. The remainder of the study area, however, is continuing its rapid expansion in population. West Covina, for instance, showed a tenfold growth in population between 1950 and 1960.

TABLE 3

HISTORICAL POPULATION OF INCORPORATED CITIES IN SAN GABRIEL VALLEY

Incorporated city	Date incorporated	Population							
		1890	1900	1910	1920	1930	1940	1950	1960
Alhambra	7-11-03			5,021	9,096	29,472	38,935	51,359	54,807
Arcadia[a]	8- 5-03			696	2,239	5,216	9,122	23,066	41,005
Azusa	12-29-98		863	1,477	2,460	4,808	5,209	11,042	20,497
Baldwin Park	1-25-56								33,951
Bradbury	7-26-57								618
Covina	8-14-01			b	b	2,774	3,049	3,956	20,124
Duarte	8-22-57								13,964
El Monte	11-18-12				b	3,479	4,746	8,101	13,163
Glendora	11-13-11				b	2,761	2,822	3,988	20,752
Industry	6-18-57								778
Irwindale	8- 6-57								1,518
La Puente	8- 1-56								24,723
La Verne[a]	8-20-06			b	b	2,860	3,092	4,198	6,516
Monrovia	12-15-87	907	1,205	3,576	5,480	10,890	12,807	20,186	27,079
Monterey Park[a]	5-29-16				4,108	6,406	8,531	20,395	37,821
Rosemead	8- 5-59								15,476
San Dimas	8- 4-60							1,840[c]	7,743
San Gabriel	4-24-13				2,640	7,224	11,867	20,343	22,561
San Marino[a]	4-25-13				584	3,730	8,175	11,230	13,658
South El Monte	7-30-58								4,850
South Pasadena[a]	3- 2-88	623	1,001	4,649	7,652	13,730	14,356	16,935	19,706
Temple City	5-25-60								24,273
Walnut	1-19-59								934
West Covina	2-17-23					769	1,072	4,499	50,945

a. Includes areas outside the San Gabriel Valley.

b. Incorporated but figures not available.

Man's activities in the San Gabriel Valley have greatly affected the supply and disposal of water. The shift of land use from rural to urban use has changed the areas of recharge to, and withdrawal from, the ground water reservoir. The construction of flood control and conservation works has changed entirely the regimen of surface streams. The recharge of waste water has been reduced by construction of sewers which convey waste water through and out of the basin to the ocean.

Water Agencies and Facilities

Along with the large growth in population and development of the San Gabriel Valley, numerous water agencies were formed to plan, construct, and maintain water supply facilities. In addition, agencies were organized to contain, control and conserve flood waters, and to dispose and reclaim waste water.

Water Supply Agencies

The present water supply to the San Gabriel Valley is from ground water, from surface diversions of streams in the San Gabriel Mountains, and from imported Colorado River water.

Ground water is extracted by 63 major agencies comprising municipalities, commercial and mutual water companies, and public water districts, and by private individuals. The major water service agencies are shown on Plate 5, "Areas Served by Water Service Agencies Extracting Ground Water in 1964". Many of these same agencies, principally those adjacent to the San Gabriel Mountains, import water from surface diversions in the San Gabriel Mountains. In 1960, water service agencies pumped 193,400 acre-feet from the ground water reservoir underlying the valley and imported 18,700 acre-feet of water from stream diversions in the San Gabriel Mountains. The pattern of pumped ground water extractions in 1960 in the San Gabriel Valley is shown on Plate 6, "Pattern of Ground Water Pumpage in 1960".

The major portion of the diversions of surface water from streams in the San Gabriel Mountains is made by the San Gabriel River Water Committee. This agency, formed in 1889, is commonly known as the "Committee of Nine", and is presently composed of the Duarte Mutual Water Company, Covina Irrigating Company, Azusa Agricultural Water Company, Azusa Irrigating Company, Contract Water Company, and Vosburg and MacNeil. The Committee of Nine has diverted substantial quantities of water from the San Gabriel River above Morris Dam. These diversions, divided among the members, were used for domestic and agricultural purposes and the excess water was spread in the spreading grounds at the mouth of San Gabriel Canyon.

The Metropolitan Water District of Southern California first made Colorado River water available to the San Gabriel Valley in 1941. The City of San Marino joined the Metropolitan Water District in 1928 but did not take water from the District until 1961. In 1950, the Pomona Valley Municipal Water District joined the Metropolitan Water District and has purchased Colorado River water for use in the eastern portion of the San Gabriel Valley since that date. In 1963, the Upper San Gabriel Valley Municipal Water District, which will furnish Colorado River water to most of the central portion of the San Gabriel Valley, joined the Metropolitan Water District.

Since 1954, large quantities of untreated Colorado River water have been transported by the Los Angeles County Flood Control District through the San Gabriel Valley to the Coastal Plain of Los Angeles County for spreading purposes in the Central Basin. Colorado River water is released into Alhambra Wash above its confluence with the Rio Hondo, into the San Gabriel River near El Monte, and, until 1957, from Puddingstone Reservoir near San Dimas. From these points of release, Colorado River water flows through and out of the San Gabriel Valley to the Central Basin. While passing through the basin, some of the water percolates and increases the amounts of subsurface outflow and rising water. The points of release of Colorado River water to stream channels and the major water service areas are shown on Plate 7, "Major Public Water Agencies and Main Water Distribution Lines in 1964".

The San Gabriel Valley Municipal Water District, shown on Plate 7, was formed in 1959 for the purpose of obtaining water for the Cities of Sierra Madre, Alhambra, Azusa, and Monterey Park, which are within the District. At the present time, this District has no supplemental water supply; ground water, pumped by its individual members, is this District's only source of water supply.

Flood Control and Water Conservation Agencies

The Los Angeles County Flood Control District and the United States Army Corps of Engineers have been active for many years in planning, constructing, and operating flood control and water conservation projects in the San Gabriel Valley. While the Corps of Engineers is empowered to build only flood control works, some of these projects are used to conserve flood waters. This federal agency has planned and constructed projects, such as dams and concrete-lined channels. In general, dams increase the replenishment of ground water and concrete-lined channels decrease it.

The Los Angeles County Flood Control District has constructed numerous storm drains, debris basins, dams, and levees to control flood water which historically inundated and capriciously ravaged much of the valley areas adjacent to watercourses. This construction of flood control dams and debris basins has helped to conserve flood waters by retarding the rapid rate of runoff so that more time is allowed for percolation. On the other hand, the construction of concrete-lined channels has materially decreased the opportunity of deep percolation. To offset the effects of concrete-lined channels, the Los Angeles County Flood Control District has constructed, operated and maintained artificial recharge projects for spreading local water in stream channels and spreading grounds. As previously noted, the Committee of Nine has also spread San Gabriel River water in its spreading grounds at the mouth of San Gabriel Canyon for many years. The spreading grounds operated in the San Gabriel Valley have played, and will continue to play, an important part in the replenishment of ground water.

Waste Water Disposal Agencies

Historically, much of the domestic waste water of San Gabriel Valley was discharged to cesspools where it percolated to the ground water. In recent years, the systems of sewers in the San Gabriel Valley have been expanded to remove the major portion of the waste water from the area. During the base period a small amount of waste water was reclaimed for spreading. The maximum seasonal amount of reclaimed waste water used for spreading during the base period amounted to 1,200 acre-feet.

Six Los Angeles County Sanitation Districts serve the San Gabriel Valley area, except for a small portion which is served by the City of

Los Angeles. Waste water originating from these Districts flows through the Whittier Narrows on its way to the Joint Disposal Plant at Whites Point near Wilmington. The Sanitation Districts of Los Angeles County have been active by pursuing a plan to implement a major waste water reuse program in the County, including the San Gabriel Valley. This conservation program is based on the successful operation of the District's Whittier Narrows Water Reclamation Plant which was placed in operation in July 1962 with a rated capacity of 11,200 acre-feet a year and an actual production of well over 16,000 acre-feet per year. Plate 8, "Areas Served by County Sanitation Districts of Los Angeles County and City of Los Angeles", depicts the areas served by the Los Angeles County Sanitation Districts and the City of Los Angeles; it also shows the location of facilities where waste water was treated prior to reuse or disposal.

CHAPTER III. GEOLOGY

An intensive geologic study of the San Gabriel Valley and adjacent highlands was conducted as the first phase of this investigation. The primary objective of the study was to determine the hydraulic characteristics of the water-bearing material, such as storage and transmission factors. The investigation included a complete inventory of the physical properties of the study area. The physiographic features, or land forms, of the area, which include the mountains, hills, and valleys, were delineated and the manner and degree in which they contributed to the basin hydrology were evaluated quantitatively. The physical properties of the rocks and soils, their areal extent, thickness, nature, juxtaposition and water-bearing characteristics were studied. The surface areas open to deep percolation in the ground water basin, the subsurface areas where inflow and outflow to or from the basin could occur, and the location of any structures affecting ground water movement were determined. The data secured during this phase of the study were then utilized to develop a mathematical model of the valley area. This model was developed for use in formulating plans for the optimum utilization of the ground water basins in San Gabriel Valley during the operational-economic phase of the investigation.

Physiographic Features

Physiographic features that affect any hydrologic study are the land forms, the topographic highlands, lowlands, and drainage systems that separate specific subareas from the surrounding areas. The major physiographic features in this discussion are the San Gabriel Valley;

the San Gabriel Mountains, which form the northern boundary of the valley; the Repetto, Merced, Puente, and San Jose Hills, which bound the valley on the southwest to the southeast; and the Rio Hondo and San Gabriel River system which carries runoff from the mountains and drains the valley. Another important feature is Whittier Narrows, located between the Merced and the Puente Hills, through which the Rio Hondo and San Gabriel River system drains after crossing the valley from north to south. Physiographic features of the area are shown on Plate 1 and detailed regional geology is shown on Plates 9A and 9B, "Areal Geology".

The high San Gabriel Mountains are essentially nonwater-bearing igneous and metamorphic rock. They provide runoff from precipitation and the bulk of alluvial debris to the valley below.

The low hills surrounding the valley area were formed primarily by the folding of sedimentary and volcanic rocks ranging in age from Tertiary to Quaternary. Like the mountains to the north, these hills also contribute runoff and some alluvial debris to the valley areas.

The valley portion of the study area includes all of the San Gabriel Valley that lies southeast of the Raymond fault as shown on Plate 9A. In this report, Puente Valley, situated between the Puente and San Jose Hills, is considered to be part of San Gabriel Valley because the two are in direct hydraulic continuity.

The San Gabriel Valley is the subsurface reservoir which provides water to wells drilled in the area. It is a structural basin filled with permeable alluvial deposits, which is underlain and surrounded by relatively impermeable rock. These features are shown on Plate 10, "Geologic Sections" and Plate 11, "Lines of Equal Elevation of the

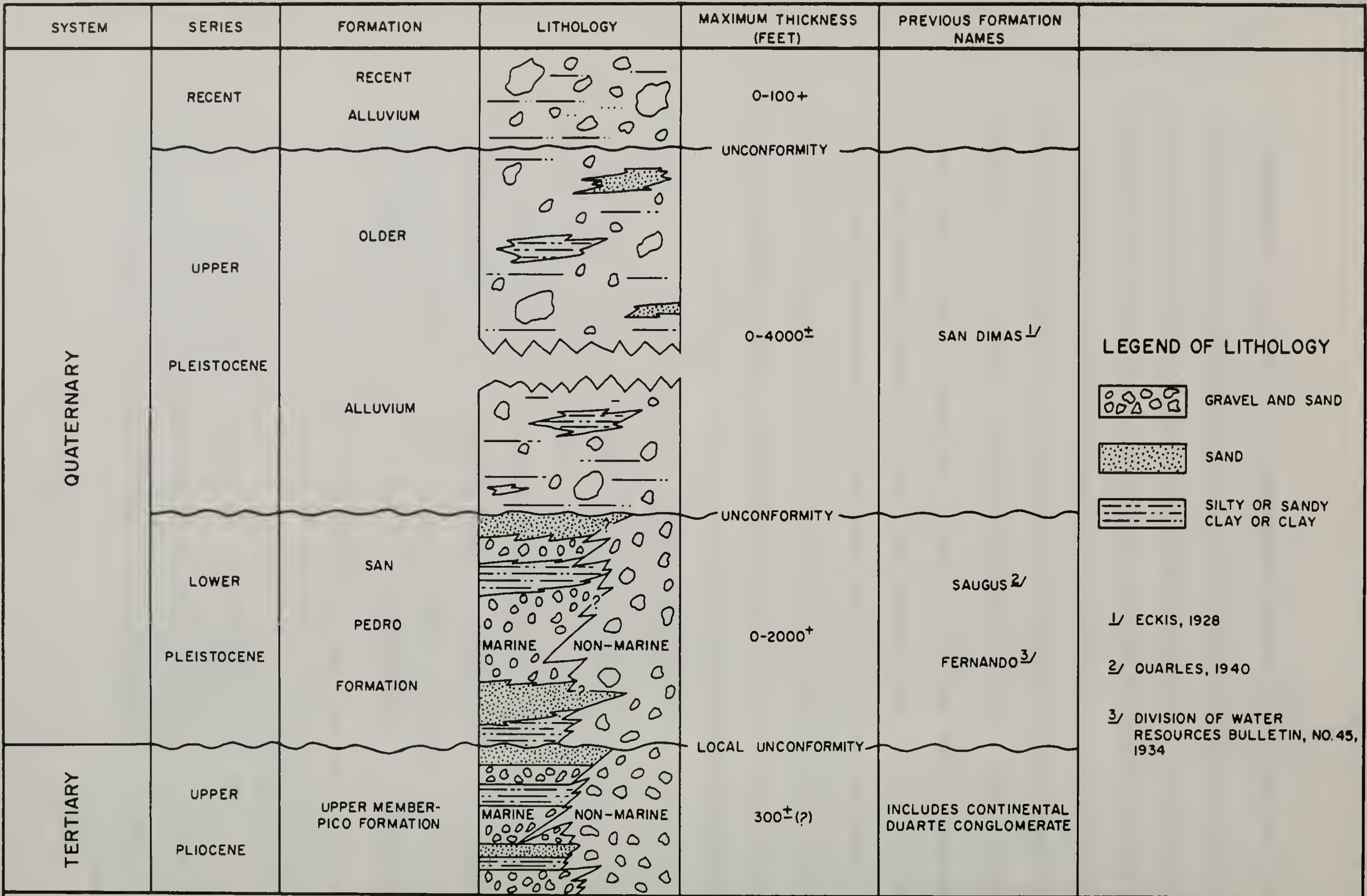
Effective Base of the Ground Water Reservoir". The type of material forming the ground water basin was determined mainly from water well data; Plate 12, "Lines of Geologic Sections Constructed from Well Log Data, and Location of Wells", shows some of the wells used. Plates 13A through C, "Well Log Sections" show the type of material encountered. The alluvial deposits which fill the valley are mainly Quaternary in age. The thickness of the water-bearing deposits averages 900 to 1,000 feet over most of the center of the basin, and about 800 feet in Whittier Narrows. At the east and west ends of the basin the average thickness is about 400 feet, and is less than 200 feet in average thickness in Puente Valley. Figure 1 shows the stratigraphic sequence of the water-bearing formations or units, their lithology, and the approximate thickness of each formation or unit.

Nonwater-Bearing Formations

In this report, the basement complex rocks, the Glendora Volcanics, and most of the sedimentary Tertiary formations, all shown on Plates 9A and 9B, are considered nonwater-bearing. This should not be construed to imply that these rocks contain no water, but that wells drilled into these formations produce relatively limited quantities of water (5-15 gallons per minute) compared to wells obtaining water from the water-bearing series (100-4,600 gallons per minute).

Basement Complex

Basement complex is a term applied to the pre-Cretaceous crystalline and metamorphic rocks comprising the main mass of the San Gabriel Mountains and outcropping in the northeast portions of the San Jose and Puente Hills.



GENERALIZED STRATIGRAPHIC COLUMN OF

The basement complex contains numerous faults and fractures, many of which contain water. Tunnels driven into the rock along the southern face of the San Gabriel Mountains, outside the study area, have yielded permanent flows in excess of 180 gallons per minute (City of Sierra Madre). Horizontal wells drilled into bedrock in the San Gabriel Mountains yield from 5 to 50 gallons per minute during the wet season. However, 5 gallons per minute during the dry season is considered a high yield. Estimates based on a rudimentary study indicate that a maximum of approximately 5,000 acre-feet per year of water may enter the San Gabriel Valley from the basement complex. However, the total amount of water obtained from wells and tunnels in the mountains is a relatively small fraction of the water pumped from the ground water basins in the adjacent valley.

Glendora Volcanics

The name Glendora Volcanics was proposed by Shelton (1946), for the volcanic rocks of Miocene age, exposed in the foothills of the San Gabriel Mountains near Glendora. Similar volcanic rocks have also been found in the South Hills and in the northeast end of San Jose Hills.

Tertiary Formations

The Tertiary sedimentary units identified in the San Gabriel Valley are the Punchbowl, Topanga, Puente, Repetto, and Pico Formations, which range in age from Miocene to Pliocene. With one exception, these formations are found underlying and flanking the unconsolidated alluvial sediments that constitute the ground water basin. The one exception is the Punchbowl Formation.

Punchbowl Formation. The Punchbowl Formation is a continental deposit of Miocene age, occupying a structural trough within the San Jacinto fault system. It is composed of interbedded shale, sandstone, and conglomerate members, some of which are permeable; however, this formation is not considered to be part of the water-bearing series because of its isolated position.

Topanga and Puente Formations. The Topanga and Puente Formations are marine deposits of middle and upper Miocene age, respectively. They consist of interbedded siltstones, sandstones, conglomerate, and shale. The Topanga Formation also has some volcanics interbedded with the shale. These formations outcrop in places along the base of the San Gabriel Mountains and in the South Hills, and constitute a major part of the low hills which form the basin boundary on the east, south, and west. No effort has been made to delineate the Topanga and Puente Formations separately in this report because they are considered essentially nonwater-bearing. The Puente Formation does, however, yield some water locally which is used for domestic purposes and for limited irrigation. No wells in the area of investigation are known to produce fresh water from the Topanga Formation.

Repetto Formation. The Repetto Formation overlies the Topanga and Puente Formations in parts of the Repetto, Merced, Puente, and San Jose Hills. The sedimentary beds that form the Repetto Formation were laid down during early Pliocene time in the last and most extensive of the seas that invaded the San Gabriel Valley toward the end of the Tertiary period.

A typical section of the Repetto Formation, over 2,000 feet thick, is exposed in the Repetto Hills, and consists of micaceous siltstone with subordinate layers of sandstone and conglomerate. Other outcrops of the Repetto Formation can be observed in the western extensions of the Puente and San Jose Hills.

Sediments believed to be part of the Repetto Formation were encountered in several oil wells drilled in the southern part of San Gabriel Valley just north of Whittier Narrows. No Repetto sediments were encountered in several oil wells drilled in the southern part of San Gabriel Valley just north of Whittier Narrows. No Repetto sediments were identified elsewhere in the water well logs of San Gabriel Valley and if such deposits are present, underlying the younger formations, they are either not recognizable from the description on the well logs or the water wells in the area are not deep enough to penetrate them.

The Repetto Formation is generally nonwater-bearing, but some sandstone and conglomerate members are permeable and, if located in the zone of saturation, could yield water. The quantity of water derived from the Repetto Formation, however, is usually small, 5 to 60 gallons per minute.

Pico Formation. The Pico Formation was deposited in shallow water during the late Pliocene Epoch as the sea receded from the area which now constitutes the San Gabriel Valley. It crops out in the Repetto, Merced, Puente, and San Jose Hills, unconformably overlying the lower Pliocene Repetto Formation. Small isolated outcrops of the Pico Formation are also exposed low on the south flank of the San Gabriel Mountains, north of the Sante Fe Dam.

Based on differences in lithology and paleontology, the Pico Formation can be divided into lower and upper members. The lower member is nonwater-bearing and consists of greenish-gray micaceous siltstone and fine to coarse light gray feldspathic sandstone interbedded with claystone and shale. The upper member, which yields water to wells in some areas, will be discussed with the water-bearing series.

The Pico Formation has been encountered in several oil wells drilled in the Whittier Narrows area north of the Merced Hills, but like the underlying Repetto Formation, it has not been definitely identified in any of the water wells drilled throughout the area.

Water-Bearing Formations

The principal water-bearing formations of the San Gabriel Valley are unconsolidated and semiconsolidated nonmarine sediments of Recent and Pleistocene age. Of lesser importance are marine sediments of probable Pleistocene age, and marine sediments of late Pliocene age. The water-bearing sediments forming this free ground water basin vary in size depending on locality, but generally grade from coarse gravel and boulders, close to the mountain front, to fine- and medium-grained sand containing a larger amount of silt and clay, as the distance away from the mountains increases. These formations have relatively large and interconnected interstices between the particles in which water can be stored and through which the stored water is readily transmitted to water wells. In contrast, the nonwater-bearing sedimentary formations surrounding the basin have smaller interstices between the grains which are often unconnected, or poorly connected, and which generally transmit no water or very small quantities of water.

The Tertiary water-bearing deposits consist of semiconsolidated alluvial sediments of the upper member of the Pico Formation.

The Quaternary deposits which constitute the valley fill material in the basin are divided into three categories (Plate 9A); (1) the lower Pleistocene San Pedro Formation which is exposed in the Repetto and Merced Hills, and overlies the water-bearing Pico Formation in the area north of Whittier Narrows, (2) the older alluvium, including terrace deposits, which constitutes the main valley fill material and is exposed around the margins of the entire San Gabriel Valley, (3) the Recent alluvium which blankets the center of the valley floor, and the transition zone deposits that lie along Dalton Wash, San Dimas Wash, and Walnut Creek in the eastern part of the basin. The transition zone deposits were derived from reworked older and Recent alluvium, and they could not be positively classified as either Recent or older.

The material forming the water-bearing formations in San Gabriel Valley was derived chiefly from the San Gabriel Mountains and extends to a maximum depth of over 4,000 feet. This thickness of alluvial deposits is the result of sedimentation combined with uplift in the mountains and subsidence in the valley. Between late Pliocene time and the present, the mountains were uplifted several times, increasing the amount of debris, especially the coarse fraction, deposited in the valley below. The rate of subsidence of the valley, however, apparently approximately equaled the rate of deposition, resulting in little change in the elevation of the valley floor during the period of deposition.

The subsequent discussion of water-bearing formations is in order of deposition.

Upper Member of Pico Formation

The upper member of the Pico is water-bearing in the vicinity of Whittier Narrows. It contains little or no water, however, in the Repetto, Merced and Puente Hills where it crops out. The lower member of the Pico Formation is considered nonwater-bearing.

The upper member of the Pico Formation is composed of semiconsolidated marine deposits of sand, silt, and clay, interbedded with marine gravels. Beds of sand and gravel or sand which vary from 20 to 100 feet in thickness are separated by beds of micaceous clay and silt. The Pico Formation may extend a considerable distance northward from Whittier Narrows. However, this is largely speculative, since no water well extends to a sufficient depth to encounter the formation in the central or northern part of the basin. An oil well drilled just north of the Workman Hill fault extension penetrated upper Pico deposits at an elevation of 3,936 feet below sea level, or about 4,100 feet below the ground surface.

Quaternary Formations

The Quaternary formations in the San Gabriel Valley consist of alluvial deposits laid down during the Pleistocene and Recent Epochs. The Quaternary formations include the San Pedro Formation of lower Pleistocene age; the older alluvium (including terrace deposits) which are considered late Pleistocene in age; the Transition Zone deposits; and the Recent alluvium.

San Pedro Formation. The San Pedro Formation comprises all of the known lower Pleistocene sediments in the San Gabriel Valley. It crops out in the Repetto and Merced Hills and has been encountered in wells drilled just north of Whittier Narrows.

In the Repetto and Merced Hills, the San Pedro Formation consists of predominantly coarse sand and gravel members with interbedded medium- and fine-grained sands and dark gray massive silts, some of which contain faunal remains. These beds occupy a synclinal depression that trends southwest and slopes gently downward in that direction. The maximum thickness of the San Pedro Formation exposed in the Repetto and Merced Hills is approximately 2,000 feet and includes members previously called the Saugus Formation (Quarles 1940) and the Fernando Formation (Division of Water Resources Bulletin 45, 1934). The San Pedro Formation is marine in origin; however, it may grade into a continental facies in the central and northern parts of the basin, in which case it would be extremely difficult to distinguish from the overlying older alluvium (Plate 10, Section W-W').

Older Alluvium. The term older alluvium encompasses all of the late Pleistocene, and possibly some early Pleistocene sedimentary deposits in the San Gabriel Valley. These deposits are shown on Plates 9A and 9B.

The older alluvium crops out at the surface and occurs as dissected alluvial fans and locally as isolated low hills or ridges that stand above the general level of Recent deposits around them. Older alluvium occurs around the northern margins of the San Gabriel Valley as erosional remnants or terraces along the foothills of the San Gabriel Mountains, and as locally merging alluvial fans which overlie Tertiary sediments on the San Jose, Puente, Repetto, and Merced Hills. A large dissected alluvial fan of older alluvium occupies nearly all of the surface area west of the Rio Hondo and San Gabriel River drainage channels to Arroyo Seco, and extends southward from the San Gabriel Mountains to the Repetto and Merced Hills. The older alluvium extends to the San Jose and Puente Hills, and is exposed on the surface over much of Puente Valley. In the central and north-central part of the San Gabriel Valley, the older alluvium is covered by Recent alluvium carried down from the mountains by the Rio Hondo and San Gabriel River system. Deposition of these older sediments has been essentially continuous probably since early Pleistocene time. The heterogeneous nature of the older alluvium and the presence of weathered soil horizons, which have been encountered at varying depths throughout the basin, are indicative of periods of restricted sedimentation, during which weathering of the surface deposits occurred.

The older alluvial deposits consist of unsorted yellowish to reddish-brown, angular to subrounded continental debris, derived from the surrounding highlands. The material in these deposits ranges in size from silt to boulders over 2 feet in diameter. The degree to which the sediments have been weathered is reflected in the preservation or decomposition of the included constituent particles, the development of clay at various horizons, and the intensity of color. The darker red and reddish-brown alluvium, containing much residual clay and decomposed gravel, has been subjected to a much longer period of oxidation and hydration than other deposits of similar age that were quickly buried. The residual clay present in the older alluvium is probably due to the weathering process after the sediments were deposited.

The percentage of clay in the older alluvium varies throughout the valley. Generally, however, the sediments underlying the Rio Hondo and San Gabriel River system and the alluvial fan built up by this system contain less clay than the older alluvium in other parts of the valley. In the Puente Valley where the older alluvium was derived largely from older sedimentary beds, the water-bearing series contain more clay than in San Gabriel Valley proper.

Older alluvium cropping out in the northeastern area of San Gabriel Valley, in the vicinity of San Dimas, Glendora, La Verne and Covina, was originally named the San Dimas Formation by Eckis (1928). Later in Division of Water Resources Bulletin No. 45 (1934), Eckis dropped the formation name in favor of the term older alluvium, because the latter term was already well established in ground water usage. In this report, the San Dimas Formation and terrace deposits in the valley are grouped with the older alluvium.

In the northern part of the area, near the mouth of the San Gabriel River, the older alluvium extends to a depth of 300 feet. Here basement complex rock was found at depths ranging from 34 to 308 feet. However, very few wells penetrate to bedrock in the central and southern parts of the valley. Pliocene sediments were encountered underlying the older alluvium at a depth of about 4,100 feet just north of the Workman Hill fault extension, indicating the depth of older alluvium in this area. The San Pedro Formation may overlie the Pliocene sediments in the southern part of the basin; however, except locally in the

Whittier Narrows area, San Pedro sediments cannot be differentiated from the older alluvium.

The approximate configuration of the interface between the essentially nonwater-bearing materials and the overlying water-bearing deposits is shown on Plate 11.

Transition Zone Deposits. In the northeastern portion of San Gabriel Valley, in a zone approximately 2 miles wide extending from San Dimas to Baldwin Park, are alluvial deposits which possess characteristics common to both the older and Recent alluvium. These deposits contain gravels of the types found in both the older and Recent alluvium, and occurring at random throughout the zone are small outcrops of older alluvium completely surrounded by younger deposits. These outcrops of older alluvium, however, were too small to map. Because of the difficulty in delineating the age of the alluvium in this area, it is referred to as the transition zone and is shown on Plate 9A by the symbol "Qat".

Shallow test hole and deep core hole data indicate that these transition zone deposits are limited in thickness. These deposits thin and merge laterally into the older alluvium flanking San Jose Hills to the southeast and into the Recent deposits along Little Dalton and Big Dalton Washes to the southwest. The maximum known thickness of these deposits occurs at Azusa Avenue and Big Dalton Wash and is 26 feet.

The transition zone alluvial deposits, because of their limited areal extent and thinness, comprise a very small percentage of the water-bearing series. They lie above the water table and are significant because their vertical permeability allows rapid percolation of applied water to the underlying ground water basin.

Recent Alluvium. The Recent alluvium, Plates 9A and 9B, overlies the older alluvium in the central part of San Gabriel Valley, is also found in the streambeds, and as alluvial fans overlying older sediments along the front of the San Gabriel Mountains. These deposits were derived primarily from the basement complex which forms the mountains to the north, with minor contributions from Tertiary marine sediments and volcanic rocks which crop out in the marginal hill areas surrounding the basin. The geologic map of the area of investigation depicts the outcrop pattern of the Recent alluvium and its relationship to the older sediments. The Recent deposits are restricted to narrow, ribbon-like bands blanketing the active stream channels in many parts of the southeastern, eastern, and western areas of the San Gabriel Valley. To the north, the Recent debris is much more widespread and mantles the entire central and north-central portions of the valley floor, narrowing to the south where the alluvial fan, formed by the Rio Hondo and San Gabriel River system, passes through Whittier Narrows.

The Recent alluvium consists of predominantly coarse boulders, gravels, and sands, light-gray to buff in color, ranging in thickness from a few inches to roughly 100 feet, the latter recorded in Whittier Narrows. Throughout the rest of the basin, the thickest portions are found along the San Gabriel River Channel and its adjacent floodplains. Laterally, away from the river, the Recent deposits thin gradually and feather out at the contact with older exposed sediments.

The deposits of this alluvium are, because of their coarseness, the most favorable for absorbing, transmitting, and yielding water. However, most of these deposits lie above the historic high water table.

Soil Types

The study of soils is important to geologic and hydrologic studies because soils control the rate at which surface water infiltrates into the zone of aeration (vadose water) on its way downward to the ground water table below.

The soil types found in San Gabriel Valley are listed in reports on the Soil Surveys of the San Gabriel area (1901) and the Pasadena area (1907) by the United States Department of Agriculture. Soil is the name commonly given to the surface material covering the area of valley fill and overlying the bedrock in some areas; more specifically, soil is that residual formed *in situ* by chemical, mechanical, and plant weathering processes. In the soil studies made by the Department of Agriculture, soil profiles extending down to a depth of 6 feet were studied.

The infiltration rate of a soil is indicative of the rate at which surface water can infiltrate into the soil belt, and begin moving downward into the intermediate belt through which water must pass to reach the zone of saturation.

Infiltration rate data were obtained from the United States Department of Agriculture, Agricultural Research Service, which performed infiltration tests on soil types in the Chino Basin, and which utilized these data to assign representative infiltration rates to similar soil types found in San Gabriel Valley. The values applied to the individual soil types in San Gabriel Valley are assumed to reflect the permeability of the entire soil profile to a depth of 6 feet. Plate 14, "Soil Infiltration Characteristics", shows the distribution of the soils grouped according to infiltration rates in San Gabriel Valley.

Soils of high infiltration rate, greater than 2 inches per hour, were all derived from Recent alluvium and are usually found in the channels and adjacent floodplains of the rivers and streams in the San Gabriel Valley. As noted earlier, the Recent alluvium is generally coarse-grained with relatively few fines. As reported in Bulletin 45, samples of Recent material taken from the San Gabriel River varied from 11 percent fines near the mountains to 27 percent fines near Whittier Narrows.

The soils of intermediate infiltration rate, ranging from 0.6 to 2.0 inches per hour, are derived largely from Recent alluvium. Some of these soils are on the alluvial cone formed by the Rio Hondo and San Gabriel River system and on the floodplain immediately adjacent to it. However, these soils generally lie at some distance from the mouth of the river system or along the water course of smaller stream systems. The soils of intermediate infiltration rate contain more fine-grained material than the high infiltration rate soils. The boundary between the intermediate and low infiltration groups is based on interpretations of the infiltration rate, texture, and thickness of the soils involved.

Soils of low infiltration rate, 0.01 to 1.0 inches per hour, are around the perimeter of the San Gabriel Valley, generally along the upper limits of the alluvial slopes. These are usually residual soils developed on older alluvium, Tertiary sediments and volcanics in the foothills of the San Gabriel Mountains, and on the low hills surrounding the valley. The residual soils are generally characteristic of the underlying bedrock and often contain grains and pebbles of the more resistant minerals. The soils derived from the older valley fill material can be differentiated from those derived from Recent alluvium by the weathering of the constituent pebbles, by the development of compact subsoil, and in some instances, by the development of hardpans.

Structures Affecting Ground Water Movement

The structural features affecting ground water movement are anticlines, synclines, and faults which may or may not have surface expression, and valleys or topographic highs formed by folding or faulting. The structural features comprised of nonwater-bearing material may divert or restrict the movement of ground water. In some instances, a fault may impede ground water movement even though the presence of the fault is not apparent on the surface.

The major topographic features in the San Gabriel Valley are also major structural features and are comprised of the San Gabriel Mountains in the northern portion of the area; the San Gabriel Valley, which occupies the central portion of the area; the Repetto, Merced, Puente, and San Jose Hills; and the Whittier Narrows.

In addition to the major structures named above, three other low structural features formed by folding or faulting are also present in San Gabriel Valley. South Hill is a northeast trending anticline. Way Hill and Lone Hill, which also trend northeast, are upthrown fault blocks. All these features are in the northeastern part of the basin.

San Gabriel Mountains

The San Gabriel Mountains were formed by the uplift of several fault blocks along essentially parallel lines during late Pleistocene and Recent times. The mountains, which trend generally east-west, are bounded on the north by the San Andreas fault system, and on the south by the

Sierra Madre fault system. They are also cut longitudinally by the San Gabriel fault zone which extends nearly the entire length of the range, generally following the east and west forks of the San Gabriel River. The San Gabriel fault zone effectively divides the mountains in the study area into what may be conveniently termed a front and a back range. The front range lies between the San Gabriel Valley on the south, and the east and west forks of the San Gabriel River on the north. The back range extends northward from the east and west forks of the San Gabriel River to the San Andreas fault, which marks the northern boundary of the mountains. The watershed boundary connecting the highest points in the back range constitutes the drainage divide forming the northern boundary of the study areas. The southern slope of the front range is called the Frontal area in this report and provides direct runoff to the ground water basins of the San Gabriel Valley; the back range contributes runoff to the valley via the San Gabriel River which cuts through the front range on its way to the valley.

San Gabriel Valley

San Gabriel Valley is a sediment-filled downdropped block which constitutes the ground water reservoir of the study area. The Sierra Madre fault system, which extends along the north side of the valley, affects the ground water in the valley. It impedes the subsurface flow of water into the valley from the alluvial fill of the canyons along the mountain front, causing a ground water cascade in the vicinity of San Gabriel and San Dimas Canyons. The fault system is also responsible for the extensive alluvial deposits found on the south side of the bedrock-alluvium contact, where alluvial deposits are from about 200 to about 800 feet in depth.

The San Gabriel Valley also contains several smaller structural features and faults that influence ground water movement into or through the basin. Three smaller structural features within the valley are South Hill, shown on Plate 1, and two low bedrock outcrops lying north of the Lone Hill-Way Hill fault. These features divert the flow of ground water around them.

The faults, the Raymond fault and the Lone Hill-Way Hill fault, also affect ground water movement within the valley itself. They are described later in the discussion of faulting.

Repetto, Merced, Puente, and San Jose Hills

Bordering the San Gabriel Valley in a broad arc is a series of hills (Plate 9A). West to east, these are the Repetto, Merced, Puente, and San Jose Hills. These hills are structurally and geographically positioned in such a way that the major surface outflow and all subsurface outflow from the valley must pass through Whittier Narrows.

Whittier Narrows

Whittier Narrows is a gap about 1.5 miles wide in the line of hills forming the southern boundary of the San Gabriel Valley. It is through this gap that the subsurface outflow from the study area occurs through a maximum thickness of about 800 feet of water-bearing materials. The major surface outflow from the San Gabriel Valley, via the Rio Hondo and San Gabriel River system, also passes through Whittier Narrows. It is believed that structurally the narrows was originally formed as a northeast-trending syncline, lying between the Puente Hills on the east and the Repetto and Merced Hills on the west. This structure has subsequently been cut by erosion during Pleistocene and probably Pliocene time (Slosson 1958). Three northeast-trending faults have also been delineated in the narrows area (Plate 9A). These faults do not restrict the flow of ground water from the San Gabriel Valley.

Faults Affecting Ground Water Movement

All of the major structural features surrounding the valley have been subjected to faulting at one time or another, and several subsurface faults have been delineated in the valley. Plates 9A and 9B show the location of most of the faults in the study area. However, only a few of these faults influence ground water movement in the basin, and it is these faults that will be discussed.

Faults can affect ground water movement in a number of ways:

1. Impervious rock brought into contact with water-bearing material may create a barrier, thereby restricting ground water flow across the fault. In a similar manner, an aquifer may be offset and made discontinuous.

2. Impervious gouge formed in bedrock or alluvium as a result of movement along a fault plane may create a barrier to ground water movement.

3. Fractures in bedrock may be sealed by minerals deposited by percolating water and made impervious.

4. Breccia and fractured rock that result from faulting may also create a permeable or open area generally along the line of faulting, especially in crystalline rock. In some instances the openings produced act as a conduit that carries water laterally along the fault line.

San Gabriel Fault Zone. The San Gabriel fault zone cuts the San Gabriel Mountains in a generally east-west direction and separates it into two fault blocks. This fault zone varies from about 1/4 mile to 2 miles in width and within the study area extends from San Antonio Canyon on the east to the western boundary of the area in the mountains near Cogswell Reservoir on the west fork of the San Gabriel River.

The San Gabriel fault zone appears to be an effective barrier to subsurface movement of water between the back and front ranges because of the gouge formed by faulting of basement rock, and the clays developed from weathering of fractured rock found in the fault zone itself. For these reasons, it is believed that the only flow from the back range which reaches the valley is surface flow carried by the San Gabriel River.

Sierra Madre Fault System. The Sierra Madre fault system trends generally east-west along the southern base of the San Gabriel Mountains, extending from the eastern boundary of the study area northeast of San Dimas to the western boundary at Sawpit Canyon in the vicinity of Monrovia (Plates 9A and 9B). This system is not one single displacement, but consists of several distinct faults traceable along the mountain front. The generally east-west trending faults that comprise this system are in turn cut by numerous transverse faults which generally coincide with, or are usually named from, the major north and northeast trending canyons that are cut into the front range.

Faults belonging to the Sierra Madre fault system which directly influence ground water movement are the Duarte and Cucamonga faults, and an unnamed fault which extends across the mouth of San Gabriel Canyon paralleling and passing about 0.75 miles north of the Duarte fault (Plate 9A). The Duarte fault crosses the upper portion of the alluvial fan at the mouth of San Gabriel Canyon, passes under the City of Azusa, and continues to the east possibly as far as South Hills. The Cucamonga fault cuts across the mouth of Big Dalton Canyon, and extends eastward along the mountain front north of San Dimas where it bifurcates and continues eastward as two subsurface faults which cross the fan at the mouth of San Dimas Canyon. East of San Dimas Canyon, the Cucamonga fault appears to continue east as a single fault. The three faults mentioned above are traceable in the basement complex or sedimentary bedrock along the foothills of the San Gabriel Mountains. Where they cross the alluvial fans, at the mouths of canyons, they have been identified by subsurface differences in bedrock or by differences in water level elevations on opposite sides of the fault. Faults at the mouths of San Dimas and San Gabriel Canyons do not form complete barriers to ground water movement in the alluvium. At these locations ground water moves through the upper 50 feet of alluvium not cut by faulting. The faults do, however, impede subsurface flow below a depth of 50 feet which results in ground water cascading across the faults into the valley. Plate 11 shows the apparent displacement of bedrock on some of these faults.

The contours at the mouth of the San Gabriel River shown on Plate 11 reflect the estimated elevation of the base of fresh water as determined using data from the deepest wells in the area. Many of these wells, however, do not penetrate to bedrock. Consequently, displacements across the Duarte fault and the unnamed fault to the north could be greater than displacements shown by the contours, which average 200 feet and 100 feet, respectively.

Estimates of the vertical displacement of bedrock along the Cucamonga fault where it crosses the mouth of San Dimas Canyon range from 100 to 200 feet (Plate 11). The barrier condition imposed by the Cucamonga fault in this area is similar to the barrier condition that exists along the same faults in San Gabriel Canyon, where the lower portion of the faults are effective barriers, while water moves freely through the upper part of the alluvium.

Raymond Fault. The Raymond fault (Plate 9A) forms the northwestern basin boundary from a point northwest of South Pasadena eastward to Sawpit Canyon in the San Gabriel Mountains. The fault, also known as the Raymond Hill dike, impedes ground water movement southward from the Raymond Ground Water Basin into San Gabriel Valley Ground Water Basin. The barrier effect is shown by a difference in water level elevation across the fault, by the presence of artesian conditions during periods of high water level, and by the creation of ponds and swampy areas north of the fault line.

The Raymond fault is marked by an escarpment in the western end of the basin where bedrock, labeled "Ms" on Plate 9A, protrudes above the surface as a series of low hills north of the fault. In this area the fault forms a complete barrier to ground water movement. Eastward from this point to Eaton Wash the fault becomes more permeable, and some movement southward does occur. Eastward from Eaton Wash the fault becomes still more permeable. In the vicinity of Santa Anita Wash the effectiveness of the fault as a ground water barrier diminishes and subsurface flow from the Raymond Ground Water Basin is practically unrestricted.

The Raymond Basin was not included in the geologic study of the San Gabriel Valley area because it has been discussed in detail in "Report of Referee, City of Pasadena vs. City of Alhambra, et al., No. Pasadena C-1323", prepared by the Division of Water Resources in 1943.

Lone Hill-Way Hill Fault. The Lone Hill-Way Hill fault extends in a northeast direction along the south side of Lone and Way Hills. North of these hills another small fault is present. Water level data indicate that the Lone Hill-Way Hill fault displaces the water-bearing series. Differences in water levels on either side of this fault vary as much as 150 feet. However, subsurface flow is mainly to the southwest parallel to these faults. The small unnamed fault lying north of Lone and Way Hills apparently has no effect on ground water movement.

Workman Hill Fault Extension. The Workman Hill fault extension (Plate 9A) which trends northwest into San Gabriel Valley from the Puente Hills northeast of Whittier Narrows, does not appear to affect the movement of ground water. This fault was so named because it appeared to be a possible westward extension of the Workman Hill fault system which offsets Tertiary sediments in the western Puente Hills. Data from deep oil wells indicate that the fault offsets by 3,000 feet the Tertiary deposits underlying the ground water basin. The area north of the fault moved down relative to the south side.

Walnut Creek Fault. The Walnut Creek fault trends northeast in the alluvium northwest of the San Jose Hills. The existence of the fault is suggested by a few water level differences across the fault, and petroleum exploration data substantiate the fault at depth.

CHAPTER IV. WATER SUPPLY, USE, AND DISPOSAL

Water supply, use, and disposal data are essential for the determination of safe yield and overdraft, the verification of a mathematical model, and the development of criteria for deep percolation of future water supplies. In this chapter, studies of components of water supply, use, and disposal for the water-bearing portion of the study area (Plate 4) are discussed and summarized. These studies include the determination of the historical seasonal quantities of precipitation, surface inflow, fresh water import, subsurface inflow, consumptive use, surface outflow, fresh water export, net waste water export, and subsurface outflow. The seasonal amounts of water supply, use, and disposal were estimated for the 27-year base period, and the seasonal amounts of water supply surplus or deficiency that occurred during the base period were determined. The 27-year base period, 1933-34 through 1959-60, and the reasons for selecting it are discussed in Chapter I.

Inflow and outflow amounts across the common boundary between the San Gabriel Valley and the Coastal Plain of Los Angeles County were based mainly on data presented in Department of Water Resources Bulletin No. 104, "Planned Utilization of the Ground Water Basins of the Coastal Plain of Los Angeles County, Appendix B, Safe Yield Determinations". It was, however, necessary to modify some of the data presented in that publication. The modifications were due to data made available or discovered after the completion of that publication. The net result of the modifications was an increase in the estimated water supply of the coastal plain averaging about 3,000 acre-feet a year.

Water Supply

Water supply is considered, in this report, to be accretions to the water-bearing portion of the study area (Plate 4) from outside the ground water basin. The components of water supply include precipitation, surface inflow, fresh water import, and subsurface inflow. The average seasonal water supply to the basin during the 27-year base period, 1933-34 through 1959-60, was about 345,700 acre-feet. The seasonal amounts of historical water supplies during the base period are summarized in Table 4.

Although pumped ground water could be considered here as an item of inflow for the surface water supply, since it is part of that supply which is used or otherwise disposed, it is discussed in the next chapter as an item of outflow from the zone of saturation. However, it should be noted that when the surface and ground water supplies are simultaneously considered for the area, pumped ground water cancels out as a factor in the overall hydrologic equation.

Precipitation

The average seasonal precipitation on the San Gabriel Valley varied with location, ranging from 16 inches at Whittier Narrows to 22 inches along the base of the San Gabriel Mountains. Plate 4, which shows the average seasonal isohyetals for the 27-year base period, depicts the areal variation of precipitation over the San Gabriel Valley. The average seasonal precipitation over the valley for the 27-year base period was 18.2 inches, or 162,200 acre-feet, and provided about 47 percent of the average seasonal total water supply. As can be seen from Table 4,

TABLE 4

ESTIMATED HISTORICAL SEASONAL WATER SUPPLY
TO THE SAN GABRIEL VALLEY GROUND WATER BASIN

In thousands of acre-feet

Season[a]	Precipitation	Surface inflow[b]	Fresh water import[e]: Used in basin	Fresh water import[e]: MWD water for conservation in Montebello Forebay[f]	Subsurface inflow	Total supply
1933-34	167.5	48.9	37.6		15.9	269.9
34-35	215.3	110.7	61.9		16.4	404.3
1935-36	134.2	41.4	47.8		15.7	239.1
36-37	246.3	208.1	56.2		21.2	531.8
37-38	247.9	404.8	53.9		20.6	727.2
38-39	177.7	68.2	40.9		19.6	306.4
39-40	137.9	53.3	39.1		20.3	250.6
1940-41	340.9	348.4	69.6		19.6	778.5
41-42	123.9	23.6	61.7		21.4	230.6
42-43	229.4	344.2	65.3		19.6	658.5
43-44	195.1	180.5	76.5		21.7	473.8
44-45	147.3	70.9	60.1		20.4	298.7
1945-46	133.2	79.5	59.5		17.7	289.9
46-47	149.2	77.3	60.7		18.2	305.4
47-48	91.9	17.4	41.5		17.7	168.5
48-49	100.8	11.2[c]	28.5		16.5	157.0
49-50	121.0	11.0[c]	35.7		16.5	184.2
1950-51	86.0	11.3[c]	21.9		14.4	133.6
51-52	269.3	137.1[c]	61.0		15.2	482.6
52-53	105.9	61.5[c]	43.8		16.7	227.9
53-54	139.2	48.7[c,d]	44.0	30.6	16.9	279.4
54-55	118.4	10.7[c,d]	50.1	23.2	16.0	218.4
1955-56	152.0	19.1[c,d]	50.1	50.7	18.0	289.9
56-57	115.6	21.8[c,d]	42.4	53.7	18.2	251.7
57-58	263.3	254.7[c]	68.2	105.1	19.5	710.8
58-59	77.9	22.5[c]	53.5	54.4	21.4	229.7
59-60	93.0	11.2[c]	33.5	80.6	17.7	236.0
27-Year Average	162.2	99.9	50.6	14.7	18.3	345.7

a. 12-month period from October 1 through September 30.
b. Excludes surface diversions imported from the San Gabriel Mountains.
c. Includes effluent from Pomona Sewage Treatment Plant released into San Jose Wash.
d. Excludes Colorado River water released from Puddingstone Reservoir.
e. Includes surface water diversions imported from the San Gabriel Mountains. These amounts are shown in Attachment 5.
f. Colorado River water released at Alhambra Wash, at San Gabriel River and from Puddingstone Reservoir.

the highest seasonal precipitation occurred in 1940-41 with a volume of 340,900 acre-feet, while the lowest volume, 77,900 acre-feet occurred in 1958-59. In general, precipitation was above average during the period 1933-34 to 1943-44 and below average during the period 1944-45 to 1959-60.

Estimates of the seasonal volume of precipitation on the valley were based on records obtained from the United States Weather Bureau and the Los Angeles County Flood Control District. After these records were evaluated for length and location, 44 rain gage stations were selected and the records from these stations were used to estimate the seasonal volume of precipitation. To estimate missing records and adjust data errors, stations were correlated with the average of ten stations with complete and reliable records. The location of the rainfall stations used in this study is shown on Plate 4 and seasonal depth of rainfall at each station is shown in Attachment 3.

The Thiessen Method was used to compute volume of seasonal precipitation. This was done by constructing a polygon of influence around each rain gage station and by multiplying the seasonal depth of rainfall with the area of the polygon. The total volume of precipitation in the study area was obtained by summing up the volume of rainfall at each polygon.

To verify the reliability of the values obtained by the Thiessen Method, precipitation volumes were determined independently for the years 1934-35, 1940-41, and 1959-60. Isohyetal maps were constructed for these years; the precipitation volumes were computed by measuring the areas between isohyets and multiplying by the average precipitation between isohyets. A comparison of the values from this method and the Thiessen Method showed volume differences of 1.1, 0.6, and 0.1 percent for the years 1934-35, 1940-41 and 1959-60, respectively. These differences are well within the range of error of rainfall measurement; hence, the values obtained by the Thiessen Method were adopted.

Surface Inflow

Surface inflow consists of flow originating from precipitation on the tributary areas and entering the basin through stream channels or as overland flow. Small amounts of treated waste water, discharge from the Pomona Sewage Treatment Plant into San Jose Wash, were included in surface inflow. Surface inflow to the San Gabriel Valley is contributed by the San Gabriel Mountains, the Raymond Basin, the Upper Santa Ana Valley, and the hills within and on the southern periphery of the ground water-bearing area. Inflow from the San Gabriel Mountains, the Raymond Basin, and the La Verne area is mostly gaged; ungaged amounts from these areas were estimated from a rainfall-runoff relationship derived from gaged areas of similar morphologic character. Inflow from the impervious hills within and on the southern periphery of the basin was estimated by rainfall-runoff relationships. Inflow from southwest of Pomona through San Jose Wash consists of storm flow, estimated from rainfall-runoff relationships, and of estimated releases of effluent from the Pomona Sewage Treatment Plant. Over 90 percent of the flow into the San Gabriel Valley was gaged; consequently, estimates of inflow are considered to be accurate. Records of stream-gaging stations used in this report are presented in Attachment 4; station locations are shown on Plate 4.

The average seasonal surface inflow to the basin during the base period was about 99,900 acre-feet, of which about 65,200 acre-feet were contributed by the San Gabriel River. Water diverted from the San Gabriel River and other streams in the San Gabriel Mountains, which entered the basin through ditches and pipes for domestic and agricultural uses, and for spreading at artificial recharge projects, was not considered in surface inflow in this report but was included in fresh-water imports.

The average seasonal surface inflow amounted to about 29 percent of the average seasonal total supply to the basin. The seasonal surface inflow varied from a low of 10,700 acre-feet in 1954-55 to a high of 404,800 acre-feet in 1937-38. The seasonal amounts of surface inflow for the period 1933-34 through 1959-60 are presented in Table 4.

Fresh Water Import

Fresh water import to the basin is considered to be any transportation of water effected by man into the area, such as water conveyed in a ditch or pipeline. Water conveyed through the area, without contributing to the water supply of the basin, such as the water conveyed through the area in Metropolitan Water District feeders, is not included in imports. Colorado River water released into the area for transportation to spreading grounds in the Montebello Forebay is included because, in the process of passing through the basin, some of the water percolates and flows out of the basin as rising water or subsurface flow.

The average seasonal fresh water import to the area during the base period was about 65,300 acre-feet, which amounted to about 19 percent of the average seasonal total supply to the basin. The import of fresh wat to the area has increased from 37,600 acre-feet in 1933-34 to 114,100 acre-feet in 1959-60. Estimates of seasonal fresh water imports to the basin, that occurred during the base period, are presented in Table 4.

About 37,000 acre-feet of average seasonal surface water diverted from streams in the San Gabriel Mountains were considered as water imports; of this amount, 35,400 acre-feet were diverted from the San Gabriel Reservoir, Morris Reservoir, and San Gabriel River and of this amount, 20,300 acre-feet were spread in artificial recharge projects and 15,100 acre-feet were used for domestic and irrigation purposes. Although diversions were considered as imports, it should be noted that they were merely transported from the frontal area of the mountains into the water-bearing area. The seasonal amounts of water diverted from the San Gabriel Mountains are shown in Attachment 5.

Colorado River water was first made available to the study area by the Metropolitan Water District in 1941 but was used only in minor amounts at that time. In recent years the importation of Colorado River water to the area has been greatly increased because the water was released in the San Gabriel Valley to be conveyed and spread in the Central Basin area. Part of the Colorado River water percolated in the river channels and the remainder flowed out of the San Gabriel Valley to spreading grounds in the Montebello Forebay. In 1954, large quantities of Colorado River water were released from Puddingstone Reservoir and conveyed through Walnut Creek and San Gabriel River to the spreading grounds. In 1957, releases for this purpose from Puddingstone Reservoir ceased and Colorado River water was discharged from a newly constructed lateral into San Gabriel River, about 6 miles upstream from Whittier Narrows, and into Alhambra Wash, about 1 mile from its confluence with Rio Hondo.

Diversions from the San Gabriel Mountains and imports of Colorado River water constituted the major portion of fresh water imports.

Small amounts of ground water and reclaimed waste water were imported across the basin boundaries near La Verne and Pomona. Minor quantities of fresh water were imported into the Merced Hills area by the City of Los Angeles. Insignificant amounts were imported from the Montebello Forebay to the Whittier Narrows area. Attachment 5 lists the water service agencies and the amounts of water imported by each agency to the basin

For the most part, estimates of water imports were based on information received from the individual importer. In several cases, estimates were based on gaging station data published by the Los Angeles County Flood Control District and the United States Geological Survey. Where water agency service areas partially overlapped the ground water basin boundaries, estimates of fresh water imports were based on actual metered deliveries or water company estimates.

Subsurface Inflow

Ground water moves into the San Gabriel Valley from the Raymond Ground Water Basin across the Raymond fault on the northwest, and from the Chino Ground Water Basin on the east. The subsurface flow into the valley from Chino Basin occurs in the vicinity of San Dimas, north of the San Jose Hills, and through the gap separating the San Jose and Puente Hills at the northeast end of Puente Valley. Some subsurface inflow also takes place from the San Gabriel Mountains on the north, as a result of stored water moving out of fractures in the Basement Complex into the alluvial fill, and a negligible quantity of water may enter the valley from the hills on the south.

During the base period, the average seasonal subsurface inflow to San Gabriel Valley amounted to 5 percent of the average seasonal total supply. The seasonal subsurface inflow varied from a minimum of 14,400 acre-feet in 1950-51 to a maximum of 21,700 acre-feet in 1943-44. The seasonal amounts of subsurface inflow are presented in Tables 4 and 5.

Amounts of subsurface flow into the San Gabriel Valley were computed for the gaps mentioned above by applying Darcy's equation. The thickness of the alluvium, which was used to compute the cross sectional area, and the lithology which was used to determine the transmissibility of the cross section were secured from well logs and other available subsurface information. The hydraulic gradient across each gap, in the direction of flow, was determined from water level records.

At San Dimas, the underflow from Chino Basin into the San Gabriel Valley varied from about 4,000 to 8,000 acre-feet per year during the base period. In the San Dimas area the primary separation between Chino and San Gabriel Basins is a bedrock high, trending generally northeast, that lies between San Jose Hills and the San Gabriel Mountains. During the base period, this structural high caused ground water moving westward from Chino Basin into San Gabriel Valley to be shunted toward the south. The Lone Hill-Way Hill fault which trends generally east-west in this area complicated the estimation of subsurface flow; however, the values determined for this area are believed to be reliable because the fault is parallel to the general direction of ground water movement and does not restrict flow to the west. It does, however, offset the water-bearing series and causes local cascading conditions across the fault from north to south.

Subsurface flow from Chino Basin into Puente Valley, at the northeast end of Puente Valley in a narrow gap between the San Jose and Puente Hills, averaged about 200 acre-feet a year for the study period.

TABLE 5

SUBSURFACE INFLOW INTO THE SAN GABRIEL VALLEY GROUND WATER BASIN[a]

In thousands of acre-feet per year

Year[b]	Inflow					
	From Chino Basin in the San Dimas-La Verne area	From Chino Basin at east end of Puente Valley	From Raymond Basin past Raymond fault	Total from Adjacent Basins	From Frontal Mountains in North (Estimated)	Total inflow
1933-34	4.3	0.1	6.5	10.9	5.0	15.9
34-35	4.3	0.2	6.9	11.4	5.0	16.4
1935-36	4.3	0.1	6.3	10.7	5.0	15.7
36-37	4.0	0.2	12.0	16.2	5.0	21.2
37-38	5.6	0.1	9.9	15.6	5.0	20.6
38-39	6.9	0.1	7.6	14.6	5.0	19.6
39-40	5.6	0.2	9.5	15.3	5.0	20.3
1940-41	6.2	0.1	8.3	14.6	5.0	19.6
41-42	7.7	0.2	8.5	16.4	5.0	21.4
42-43	7.7	0.2	6.7	14.6	5.0	19.6
43-44	8.2	0.3	8.2	16.7	5.0	21.7
44-45	8.2	0.3	6.9	15.4	5.0	20.4
1945-46	8.2	0.3	4.2	12.7	5.0	17.7
46-47	8.2	0.3	4.7	13.2	5.0	18.2
47-48	8.2	0.2	4.3	12.7	5.0	17.7
48-49	7.7	0.2	3.6	11.5	5.0	16.5
49-50	7.7	0.2	3.6	11.5	5.0	16.5
1950-51	7.5	0.2	1.7	9.4	5.0	14.4
51-52	6.2	0.1	3.9	10.2	5.0	15.2
52-53	6.9	0.2	4.6	11.7	5.0	16.7
53-54	7.5	0.2	4.2	11.9	5.0	16.9
54-55	6.9	0.2	3.9	11.0	5.0	16.0
1955-56	7.5	0.2	5.3	13.0	5.0	18.0
56-57	6.9	0.2	6.1	13.2	5.0	18.2
57-58	7.5	0.2	6.8	14.5	5.0	19.5
58-59	7.7	0.3	8.4	16.4	5.0	21.4
59-60	7.6	0.3	4.8	12.7	5.0	17.7
27-Year Average	6.9	0.2	6.2	13.3	5.0	18.3

a. Computed by slope area method.
b. 12-month period from October 1 through September 30.

Although there were sparse water well data available for use in determining cross sectional area and ground water gradients in this area, the values computed for underflow in this area were verified through the use of the mathematical model. Computed amounts of underflow were used in the model and were verified when computed ground water levels obtained from the mathematical model matched historic ground water levels.

Underflow into San Gabriel Valley across the Raymond fault varied from 2,000 to 12,000 acre-feet per year during the base period. This subsurface flow did not occur at the same rate along the length of the fault, but varied from west to east. The lowest rates occurred near the western edge of the basin where the Raymond fault constitutes a nearly impervious barrier to ground water movement, and the highest rates occurred near Santa Anita Wash where the barrier effect is negligible. Estimates of underflow across the Raymond fault were based on values of ground water gradients between water levels north of the fault. Computed underflow amounts were also verified on the mathematical model.

The rate of subsurface inflow to San Gabriel Valley from the surrounding highland was approximated. It was estimated that possibly a maximum of 5,000 acre-feet per year of ground water could be entering the basin from the basement complex of the San Gabriel Mountains through cracks and fractures below ground surface. This estimate was based on the volume of surface water flowing from cracks in bedrock in a few known areas; these cracks or fractures narrow or close completely with increasing depth. Subsurface flow into San Gabriel Valley from the Repetto, Merced, Puente, and San Jose Hills was considered to be negligible.

Water Use and Disposal

Water use and disposal are considered in this report to be negative items in the hydrologic equation and reduce the amount of ground water in storage. The components of water use and disposal include consumptive use, surface outflow, net waste water export, fresh water export, and subsurface outflow. The average seasonal water use and disposal for the water-bearing portion of the study area (Plate 4) during the 27-year base period 1933-34 to 1959-60, was about 353,200 acre-feet. Table 6 summarizes all the components of historical water use and disposal for the 27-year base period. Each of the components is discussed below.

Consumptive Use

Consumptive use is water consumed by vegetative growth in transpiration and building plant tissue, and water evaporated from adjacent soil, from water surfaces, and from foliage. It also includes water similarly consumed and evaporated by urban and nonvegetative types of land use

In general, consumptive use decreased during the base period reflecting the change from agricultural to urban land use. The average seasonal consumptive use of applied water and precipitation during the base period was about 174,800 acre-feet, which represented about 50 percent of the average seasonal total water use and disposal. As shown in Table 6, consumptive use varied from a low of 134,500 acre-feet in 1958-59 to a high of 209,800 acre-feet in 1934-35.

The basis for the amounts of seasonal consumptive use was land use surveys made in 1932, 1941, 1950, 1955 and 1960. Other data considered were number of dwelling units, population, and ground water contours obtained fr planning commissions, census reports, and flood control and water districts.

TABLE 6

ESTIMATED HISTORICAL SEASONAL WATER USE AND DISPOSAL
FOR THE SAN GABRIEL VALLEY GROUND WATER BASIN

In thousands of acre-feet

Season[a]	Consumptive use[b]	Surface outflow[c]	Fresh water export: Local water	Fresh water export: MWD water for conservation in Montebello Forebay[f]	Net waste water export[g]	Subsurface outflow	Total use and disposal
1933-34	184.6	69.3[d]	24.2		- 4.6	32.7	306.2
34-35	209.8	64.2[d]	21.8		- 4.7	33.5	324.6
1935-36	183.4	48.9[d]	27.1		- 4.9	33.5	288.0
36-37	205.4	115.6[d]	28.2		- 5.1	31.1	375.2
37-38	199.9	346.0[d]	30.3		- 5.2	25.6	596.6
38-39	193.2	87.9[d]	31.7		- 5.2	25.0	332.6
39-40	180.7	74.6[d]	28.8		- 5.0	23.9	303.0
1940-41	207.9	274.3[d]	28.1		- 5.1	23.3	528.5
41-42	173.4	92.5[d]	33.3		- 4.6	21.8	316.4
42-43	188.4	310.9[d]	35.4		- 4.6	21.9	552.0
43-44	184.5	196.5[d]	35.5		- 5.2	23.7	435.0
44-45	180.3	109.4[d]	32.5		- 4.9	23.5	340.8
1945-46	171.4	113.1[d]	33.9		- 4.9	23.1	336.6
46-47	174.8	122.4[d]	36.1		- 4.6	22.4	351.1
47-48	157.5	60.2[d]	37.3		4.4	25.7	285.1
48-49	171.2	36.6[d]	33.2		10.0	30.3	281.3
49-50	170.3	34.9	28.5		10.9	34.0	278.6
1950-51	155.7	24.4	34.6		12.5	32.8	260.0
51-52	179.7	105.9	28.7		16.9	32.1	363.3
52-53	162.4	47.0	30.8		19.9	32.8	292.9
53-54	159.2	40.1[e]	30.8	15.0	20.7	33.2	299.0
54-55	157.6	26.4[e]	32.3	14.5	25.8	33.6	290.2
1955-56	150.3	34.4[e]	32.4	31.9	28.6	31.4	309.0
56-57	151.9	25.8[e]	30.0	38.5	30.9	30.0	307.1
57-58	182.8	140.8[e]	34.1	91.6	34.6	30.9	514.8
58-59	134.5	38.6[e]	34.3	48.4	38.2	28.2	322.2
59-60	148.8	25.8[e]	36.1	69.7	41.1	25.5	347.0
27-Year Average	174.8	98.7	31.5	11.4	8.4	28.4	353.2

a. 12-month period from October 1 through September 30.
b. Includes extraction by phreatophytes.
c. Includes rising water at Whittier Narrows.
d. Includes waste water discharged from the Tri-City Sewage Treatment Plant at Alhambra and from the El Monte Sewage Treatment Plant.
e. Excludes Colorado River water flowing through Whittier Narrows in the natural stream channel.
f. Colorado River water flowing through Whittier Narrows in the natural stream channel.
g. Excludes waste water discharged from the Tri-City Sewage Treatment Plant at Alhambra, from the El Monte Sewage Treatment Plant, and from the Pomona Sewage Treatment Plant.

Land use was estimated for each year of the base period by straight-line extrapolation between years of land use surveys. Studies of population trends and other factors indicated that the accuracy of this method was within the limits of accuracy of the land use data. Land use for each of the survey years is shown in Table 7. As shown in this table, urban and suburban areas in the San Gabriel Valley increased from 21,900 acres in 1932 to 74,500 acres in 1960. On the other hand, irrigated agriculture areas decreased from 55,800 acres in 1932 to 15,300 acres in 1960. The nonwater service service areas decreased from 29,300 acres in 1932 to 17,200 acres in 1960. Definitions of the nature and class of land use are presented in Attachment 6.

TABLE 7

ESTIMATES OF LAND USE IN THE SAN GABRIEL VALLEY GROUND WATER BASIN
FOR 1932, 1941, 1950, 1955, AND 1960

In acres

Nature and class of land use[a]	1932	1941	1950	1955	1960[b]
WATER SERVICE AREAS					
Urban and Suburban					
Residential, single	3,300	6,200	13,500	25,300	34,800
Residential, multiple	600	800	1,300	1,700	2,200
Residential, rural	8,900	10,000	10,800	5,800	200
Commercial	800	1,100	1,600	2,000	2,200
Industrial	200	400	600	900	2,800
Unclassified	900	1,200	1,800	2,400	3,600
Street	4,100	5,700	9,300	13,200	18,300
Included nonwater service areas	3,100	4,100	6,100	7,800	10,400
Gross urban and suburban areas	21,900	29,500	45,000	59,100	74,500
Irrigated Agriculture					
Alfalfa	1,700	2,400	1,700	1,000	200
Pasture	500	800	1,700	2,200	2,800
Deciduous orchard, walnuts	16,300	10,100	3,400	1,200	700
Citrus	26,200	26,300	24,000	13,600	7,600
Truck crops	8,300	8,200	5,600	4,700	3,200
Street	2,800	2,500	1,900	1,200	800
Gross irrigated agricultural areas	55,800	50,300	38,300	23,900	15,300
NONWATER SERVICE AREA					
Gross nonwater service areas	29,300	27,200	23,700	24,000	17,200
GRAND TOTALS	107,000	107,000	107,000	107,000	107,000

a. Definition is presented in Attachment No. 6.
b. 1960 acreages are preliminary and subject to revision.

The seasonal amounts of consumptive use of precipitation and applied water were estimated by using the "Blaney-Criddle Method". The monthly consumptive use of irrigated crops and native vegetation is the product of an empirical consumptive use crop coefficient, average monthly temperature, and monthly percent of daylight hours divided by one hundred. To account for that portion of rainfall not used by plants, runoff due to rainfall was first established; then, runoff was subtracted from total rainfall to yield the rainfall supply available to plants.

Consumptive use of applied water during the growing and nongrowing season was calculated as the amount of water needed over and above the available precipitation. The average unit values of consumptive use of applied water and of precipitation developed in the above manner are tabulated in Table 8. The monthly consumptive use of irrigated crops, during the four to five months of nongrowing season, was considered to equal the potential consumptive use or to equal the available precipitation, whichever was smaller. To account for the moisture holding capacity of the soil, it was assumed that soil moisture would be depleted at the beginning of the water year and would be replenished, depending on the monthly precipitation available in excess of runoff and consumptive use by the plants; by the end of the water year soil moisture would be depleted again. When the root zone or the belt of soil water became saturated, it was assumed that the excess would percolate through the intermediate belt and finally reach the zone of saturation.

Surface Outflow

The average seasonal surface outflow from the basin for the 27-year base period was about 98,700 acre-feet or about 28 percent of the

TABLE 8

ESTIMATES OF AVERAGE SEASONAL UNIT VALUES OF CONSUMPTIVE USE IN THE SAN GABRIEL VALLEY GROUND WATER BASIN FOR THE BASE PERIOD, 1933-34 THROUGH 1959-60

In feet

Nature and class of land use*	Applied water	Precipi-tation	Total
WATER SERVICE AREAS			
Urban and Suburban			
Residential, single	1.4	0.7	2.1
Residential, multiple	0.2	0.5	0.7
Residential, rural	0.9	0.7	1.6
Commercial	0.4	0.5	0.9
Industrial	1.4	0.5	1.9
Unclassified	0.5	0.6	1.1
Street	-	0.5	0.5
Included nonwater service area	-	0.6	0.6
Irrigated Agriculture			
Alfalfa	2.4	1.0	3.4
Pasture	2.5	0.9	3.4
Deciduous orchard, walnuts	1.9	1.0	2.9
Citrus	1.5	0.9	2.4
Truck crops	1.2	0.9	2.1
Street	-	0.5	0.5
NONWATER SERVICE AREAS			
Native vegetation, light	-	0.6	0.6
Native vegetation, medium	-	1.1	1.1
Native vegetation, heavy	-	1.2	1.2
Street	-	0.5	0.5

*Definition is presented in Attachment No. 6.

average seasonal total use and disposal. About 96 percent of surface outflow passed through Whittier Narrows; the remaining amount flowed out through the Atlantic Boulevard gap and across the investigational area boundary between San Dimas and La Verne. As can be seen in Table 6, the seasonal outflow varied from a low of 24,400 acre-feet in 1950-51 to a high of 346,000 acre-feet in 1937-38. In general, the variation of seasonal surface outflow followed the variation of seasonal rainfall.

The seasonal surface outflow passing over the San Dimas-La Verne boundary consisted of surface runoff from the San Dimas area and of flows diverted from the San Gabriel Mountains and transported through the basin to Puddingstone Reservoir. The amount of outflow from the San Dimas area was estimated in part and gaged in part. The seasonal surface outflow through the Atlantic Boulevard gap consisted of surface runoff originating in the Alhambra area. The estimates for the Atlantic Boulevard gap flows were obtained from Bulletin No. 104, "Planned Utilization of the Ground Water Basins of the Coastal Plain of Los Angeles County, Appendix B, Safe Yield Determinations".

Surface outflow at Whittier Narrows consisted of storm or native water, rising water, and waste water. The seasonal amounts of surface outflow, shown in Table 9, are based on gaged quantities for the Rio Hondo, Mission Creek, and Rio Hondo Bypass Channel and estimated values for the San Gabriel River. Surface outflow in the San Gabriel River was estimated by using runoff records at Beverly Boulevard and at Standifer Ditch. The seasonal amounts of Colorado River water passing through the Whittier Narrows to be conveyed to spreading grounds in the Montebello Forebay were not included in the estimates of surface outflow. In this report, these amounts were included with fresh water exports.

TABLE 9

ESTIMATED HISTORICAL SEASONAL SURFACE OUTFLOW THROUGH WHITTIER NARROWS

In thousands of acre-feet

Season[a]	Storm water	Rising water[b]	Waste water[c]	Total[d]
1933-34	36.8	21.2	6.3	64.3
34-35	32.7	25.7	2.8	61.2
1935-36	18.9	25.9	1.9	46.7
36-37	74.1	31.2	4.5	109.8
37-38	284.6	42.3	6.1	333.0
38-39	25.6	49.4	10.6	85.6
39-40	13.9	48.7	10.9	73.5
1940-41	184.7	66.0	11.6	262.3
41-42	3.5	76.4	11.5	91.4
42-43	218.5	69.3	11.9	299.7
43-44	94.0	85.1	12.8	191.9
44-45	9.2	84.8	13.5	107.5
1945-46	29.0	67.4	14.1	110.5
46-47	45.0	59.6	14.9	119.5
47-48	9.9	42.0	7.1	59.0
48-49	6.1	28.9	0.4	35.4
49-50	8.4	24.7	--	33.1
1950-51	5.6	17.4	--	23.0
51-52	78.5	19.5	--	98.0
52-53	24.4	20.4	--	44.8
53-54	25.5	11.9	--	37.4
54-55	10.5	13.9	--	24.4
1955-56	19.5	11.2	--	30.7
56-57	14.2	9.1	--	23.3
57-58	114.0	17.1	--	131.1
58-59	19.9	17.5	--	37.4
59-60	13.0	10.1	--	23.1
27-Year Average	52.6	36.9	5.2	94.7

a. 12-month period from October 1 through September 30.

b. Equals total rising water reported in the Annual and Biennial Reports of the Los Angeles County Flood Control District minus diversions of rising water above Whittier Narrows.

c. Waste water discharged from Tri-City Sewage Treatment Plant at Alhambra and from El Monte Sewage Treatment Plant.

d. Excludes Colorado River water flowing through Whittier Narrows in the natural stream channel.

Net Waste Water Export

The net seasonal waste water export is considered as waste water outflow minus waste water inflow to the water-bearing portion of the study area. Only waste water transported in pipes is considered in this computation; small amounts of waste water inflow and outflow that occurred in streams are included in surface flow. The Metropolitan Water District Water Treatment Plant at La Verne, Plate 8, produces brine which is conveyed out of the basin in pipeline. The amount of Colorado River water used in the production of brine was not included in fresh water imports because it did not contribute to the water supply of the basin; consequently, the amount of brine produced by the treatment plant was excluded in the computation of net waste water export.

Total waste water production in the San Gabriel Valley equals the sum of the following: (1) net waste water export, (2) waste water discharged to spreading grounds, (3) waste water discharged into cesspools, and (4) treated waste water percolated in streambeds or discharged out of the valley in streams. The average seasonal waste water production during the base period was about 22,400 acre-feet.

Waste water was conveyed to the San Gabriel Valley from the Raymond Basin, Upper Santa Ana Valley, nonwater-bearing areas within the San Gabriel Valley, and the Coastal Plain of Los Angeles County. From 1934 until 1948, the waste water from Raymond Basin was treated at Alhambra, released into Alhambra Wash, and flowed out of the San Gabriel Valley through Whittier Narrows. During the period 1934 through 1938, Alhambra Wash was unlined, allowing some of this waste water to percolate. After 1948, all waste water imports from the Raymond Basin passed through the valley. Small amounts of waste water were transported into the San Gabriel Valley from the Coastal Plain of Los Angeles County (the City of Pasadena) and from the Upper Santa Ana Valley (Pomona Sewage Treatment Plant). Generally, waste water import was estimated from metered amounts.

Waste water export from the San Gabriel Valley originated from five Los Angeles County Sanitation Districts, 2, 15, 16, 21, and 22, which are shown on Plate 8. Almost all waste water outflow passed through Whittier Narrows in various trunk lines, was treated at the joint disposal plant at Wilmington, and was finally disposed into the ocean at Whites Poin Seasonal amounts of waste water imported, exported, and discharged from treatment plants in and adjacent to the San Gabriel Valley are shown in Attachment 7.

The average net seasonal waste water export from the valley during the base period was estimated to be about 8,400 acre-feet, which represents about 2 percent of the average seasonal total water use and disposal. As can be seen from Table 6, net waste water export increased from minus 5,200 acre-feet in 1937-38 and 1938-39 to 41,100 acre-feet in 1959-60. The rapid increase in the rate of waste water export that started in 1947-48 was the result of increased urbanization and expanded sewerage facilities which lessened the opportunity of water to percolate.

Fresh Water Export

The average seasonal fresh water export from the San Gabriel Valley for the base period was about 42,900 acre-feet or 12 percent of the total water use and disposal. Most of the exportation of fresh water through Whittier Narrows originated from surface water diverted above Whittier Narrows (assumed to be substantially rising water), pumped ground water, and Colorado River water conveyed through the San Gabriel Valley for spreading in the Montebello Forebay. Fresh water was also exported, in minor quantities, to the Raymond Basin and Upper Santa Ana Valley. These quantities amounted to a 27-year average of about 900 and 100 acre-feet, respectively, and consisted of pumped ground water for the most part. An average seasonal amount of about 6,000 acre-feet of water was exported to nonwater-bearing areas, predominantly in the southern part of the investigational area.

Fresh water exports were estimated for the most part from metered records supplied by the various water agencies in the San Gabriel Valley. Surface water that was diverted and exported was estimated from staff gage data published by the Los Angeles County Flood Control District. Colorado River water passing through the Whittier Narrows area in the Rio Hondo and San Gabriel River was estimated by the Los Angeles County Flood Control District. Most of the export data to the coastal plain was obtained from Department of Water Resources Bulletin 104; however, it was necessary to modify some values presented in that publication. Amounts of exports by the Cate Ditch Company were modified because amounts of surface water diversions were inadvertently not added to estimates of pumped ground water for the Cate Ditch Company. Also, new data on the export of Colorado River water to the Montebello Forebay were made available by the Los Angeles County Flood Control District. Attachment 5 of this report shows the seasonal amounts of water exported from the San Gabriel Valley by principal water service agencies.

Subsurface Outflow

The only area where subsurface outflow from the San Gabriel Valley is known to take place is through Whittier Narrows. Underflow at this point, computed by applying Darcy's equation, averaged 28,400 acre-feet per year for the 27-year period of study. No barriers to the southward movement of ground water exist in the narrows. However, the Whittier Narrows forms a constriction to ground water movement due to the presence of hills on either side. The older sedimentary formations, which constitute bedrock in this area, slope upward abruptly from the center of the valley floor toward the narrows, causing water moving southward to be funnelled through this narrow gap. Whittier Narrows is shown on Plate 9A and the bedrock profile is indicated on well log sections D-D' and G-G' Plates 13B and 13C, respectively.

During the base period, the average seasonal subsurface outflow amounted to 8 percent of the average seasonal total water use and disposal. Subsurface outflow varied from a low of 21,800 acre-feet in 1941-42 to a high of 34,000 acre-feet in 1949-50. The seasonal amounts of subsurface outflow are presented in Table 6.

Water Supply Surplus or Deficiency

A balance must exist between water entering or leaving the water-bearing portion of the study area (Plate 4) and water stored within this area. A quantitative statement of this balance, for any increment of time, is provided by a general equation of hydrologic equilibrium which, expressed in its general form, is:

Inflow - Outflow = Change in Storage

When the water-bearing area, from the base of alluvium to and including the ground surface, is considered as a free or separate body, as shown in Figure 2, the equation of hydrologic equilibrium can be expressed as:

Water Supply - Water Use and Disposal =
Water Supply Surplus or Deficiency.

By using this equation, seasonal water supply surplus or deficiency during the base period for the water-bearing portion of the study area was determined.

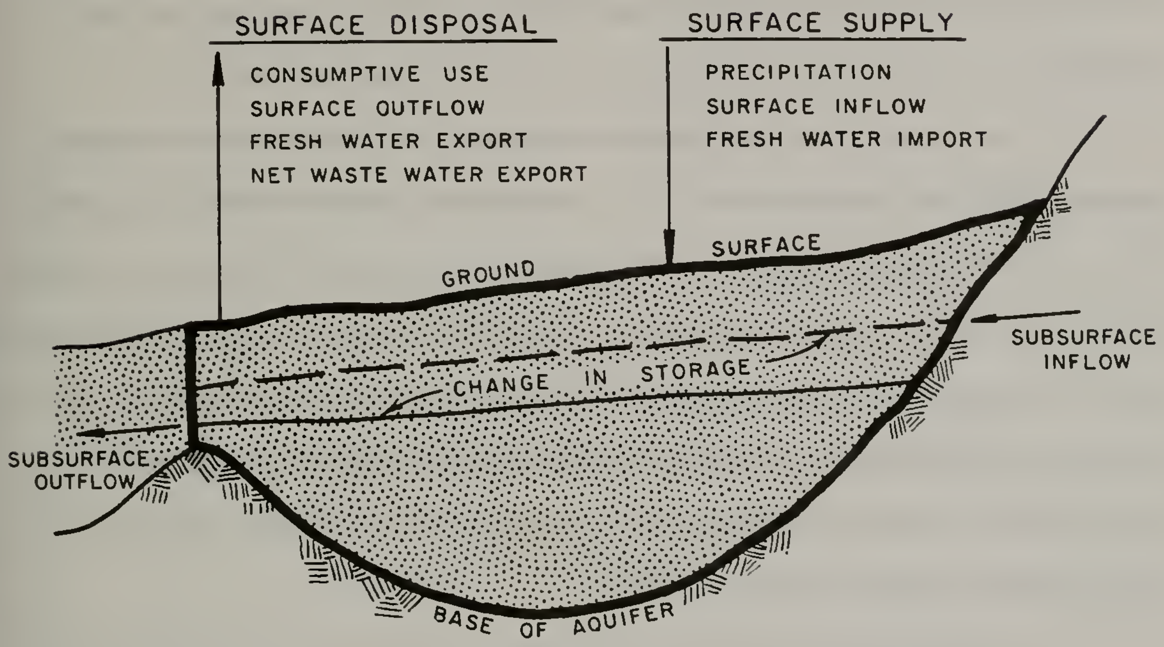


Fig. 2 THE GROUND WATER BASIN AS A FREE BODY

Because of the similarity in hydrologic conditions which existed immediately prior to the beginning and the end of the base period, the assumption could be made that there was no significant difference between the amount of water in transit within the zone of aeration at the beginning and at the end of the base period. It is recognized that, because the water table was lower at the end of the base period than at the beginning of the period, some additional water would be in transit at the end of the base period in the zone that was dewatered. However, because of the dry periods preceding the beginning and end of the base period, this amount of water would be small.

When this difference in the amount of water in transit is negligible, as was assumed in this investigation, the total amount of water supply surplus or deficiency during the base period may be considered to be equal to the total change in ground water storage during the same period.

As a means of checking the validity of the amounts of water supply, use, and disposal used for computation of water surplus or deficiency, independent estimates were made by two different methods. These methods are described in Chapter V. When the results of the two approaches were at variance, the individual items were tested for reliability and the necessary adjustments were made to balance the equation of hydrologic equilibrium. These adjustments are reflected in the water supply, use, and disposal amounts presented here.

During the base period, the total seasonal fresh water supply, that is, the sum of all the amounts of surface and subsurface inflow to the water-bearing portion of the San Gabriel Valley, was less than the sum of all the amounts of surface and subsurface outflow (including consumptive use) from the area. This resulted in a water supply deficiency of about 202,700 acre-feet during the base period. This deficiency was met by pumpage of ground water in storage.

As shown on Table 10, the total surface water supply during the base period amounted to 8,841,400 acre-feet, the total surface water disposal amounted to about 8,771,600 acre-feet and the net subsurface outflow amounted to 272,500 acre-feet for the base period. Water supply surplus occurred from 1934 to 1944, accumulating a surplus of about 512,600 acre-feet. Water supply deficiency that occurred during the remaining portion of the base period amounted to 715,300 acre-feet. Table 10 presents the seasonal amounts of all the components of water supply, use, and disposal, along with amounts of seasonal water supply surplus or deficiency that existed during the base period under existing cultural conditions.

The seasonal amount of water deficiency must be met by pumpage of ground water and must be equal to the change in storage of water in the zones of aeration and saturation. The occurrence of subsurface water in both of these zones will be described in the next chapter.

TABLE 10

ESTIMATES OF SEASONAL WATER SUPPLY, USE, AND DISPOSAL, AND WATER SUPPLY SURPLUS OR DEFICIENCY IN THE SAN GABRIEL VALLEY GROUND WATER BASIN[a]

In thousands of acre-feet

1	2	3	4	5	6	7	8	9	10	11	12	
Season[b]	Precipitation	Surface inflow[c]	Fresh water import	(2+3+4) Surface supply	Consumptive use[g]	Surface outflow[h]	Fresh water export	Net waste water export[l]	(6+7+8+9) Surface disposal	Net subsurface outflow	Water supply surplus or deficiency (5-10-11)	
											Seasonal	Accumulated
1933-34	167.5	48.9	37.6	254.0	184.6	69.3[i]	24.2	- 4.6	273.5	16.8	- 36.3	- 36.3
34-35	215.3	110.7	61.9	387.9	209.8	64.2[i]	21.8	- 4.7	291.1	17.1	+ 79.7	+ 43.4
1935-36	134.2	41.4	47.8	223.4	183.4	48.9[i]	27.1	- 4.9	254.5	17.8	- 48.9	- 5.5
36-37	246.3	208.1	56.2	510.6	205.4	115.6[i]	28.2	- 5.1	344.1	9.9	+156.6	+151.1
37-38	247.9	404.8	53.9	706.6	199.9	346.0[i]	30.3	- 5.2	571.0	5.0	+130.6	+281.7
38-39	177.7	68.2	40.9	286.8	193.2	87.9[i]	31.7	- 5.2	307.6	5.4	- 26.2	+255.5
39-40	137.9	53.3	39.1	230.3	180.7	74.6[i]	28.8	- 5.0	279.1	3.6	- 52.4	+203.1
1940-41	340.9	348.4	69.6	758.9	207.9	274.3[i]	28.1	- 5.1	505.2	3.7	+250.0	+453.1
41-42	123.9	23.6	61.7	209.2	173.4	92.5[i]	33.3	- 4.6	294.6	0.4	- 85.8	+367.3
42-43	229.4	344.2	65.3	638.9	188.4	310.9[i]	35.4	- 4.6	530.1	2.3	+106.5	+473.8
43-44	195.1	180.5	76.5	452.1	184.5	196.5[i]	35.5	- 5.2	411.3	2.0	+ 38.8	+512.6
44-45	147.3	70.9	60.1	278.3	180.3	109.4[i]	32.5	- 4.9	317.3	3.1	- 42.1	+470.5
1945-56	133.2	79.5	59.5	272.2	171.4	113.1[i]	33.9	- 4.9	313.5	5.4	- 46.7	+423.8
46-47	149.2	77.3	60.7	287.2	174.8	122.4[i]	36.1	- 4.6	328.7	4.2	- 45.7	+378.1
47-48	91.9	17.4	41.5	150.8	157.5	60.2[i]	37.3	4.4	259.4	8.0	-116.6	+261.5
48-49	100.8	11.2[d]	28.5	140.5	171.2	36.6[i]	33.2	10.0	251.0	13.8	-124.3	+137.2
49-50	121.0	11.0[d]	35.7	167.7	170.3	34.9	28.5	10.9	244.6	17.5	- 94.4	+ 42.8
1950-51	86.0	11.3[d]	21.9	119.2	155.7	24.4	34.6	12.5	227.2	18.4	-126.4	- 83.6
51-52	269.3	137.1[d]	61.0	467.4	179.7	105.9	28.7	16.9	331.2	16.9	+119.3	+ 35.7
52-53	105.9	61.5[d]	43.8	211.2	162.4	47.0	30.8	19.9	260.1	16.1	- 65.0	- 29.3
53-54	139.2	48.7[d,e]	74.6[f]	262.5	159.2	40.1[j]	45.8[k]	20.7	265.8	16.3	- 19.6	- 48.9
54-55	118.4	10.7[d,e]	73.3[f]	202.4	157.6	26.4[j]	46.8[k]	25.8	256.6	17.6	- 71.8	-120.7
1955-56	152.0	19.1[d,e]	100.8[f]	271.9	150.3	34.4[j]	64.3[k]	28.6	277.6	13.4	- 19.1	-139.8
56-57	115.6	21.8[d,e]	96.1[f]	233.5	151.9	25.8[j]	68.5[k]	30.9	277.1	11.8	- 55.4	-195.2
57-58	263.3	254.7[d]	173.3[f]	691.3	182.8	140.8[j]	125.7[k]	34.6	483.9	11.4	+196.0	+ 0.8
58-59	77.9	22.5[d]	107.9[f]	208.3	134.5	38.6[j]	82.7[k]	38.2	294.0	6.8	- 92.5	- 91.7
59-60	93.0	11.2[d]	114.1[f]	218.3	148.8	25.8[j]	105.8[k]	41.1	321.5	7.8	-111.0	-202.7
TOTALS	4,380.1	2,698.0	1,763.3	8,841.4	4,719.6	2,666.5	1,159.6	225.9	8,771.6	272.5	-202.7	
27-Year Average	162.2	99.9	65.3	327.4	174.8	98.7	42.9	8.4	324.8	10.1	- 7.5	

a. Results are based on ground water basin as free body as shown in Figure 2.
b. 12-month period from October 1 through September 30.
c. Excludes surface diversions imported from the San Gabriel Mountains. Amounts are included under fresh water imports.
d. Includes effluent from Pomona Sewage Treatment Plant released into San Jose Wash.
e. Excludes Colorado River water released from Puddingstone Reservoir.
f. Includes Colorado River water released at Alhambra Wash, at San Gabriel River, and from Puddingstone Reservoir.
g. Includes extraction by phreatophytes.
h. Includes rising water at Whittier Narrows.
i. Includes waste water discharged from the Tri-City Sewage Treatment Plant at Alhambra and from the El Monte Sewage Treatment Plant.
j. Excludes Colorado River water flowing through Whittier Narrows for conservation in Montebello Forebay.
k. Includes Colorado River water flowing through Whittier Narrows in the natural stream channels.
l. Excludes waste water discharged from the Tri-City Sewage Treatment Plant at Alhambra, from the El Monte Sewage Treatment Plant, and from the Pomona Sewage Treatment Plant.

CHAPTER V. GROUND WATER MOVEMENT, STORAGE, OVERDRAFT, AND SAFE YIELD

Subsurface water and surface water are considered together in this hydrologic study, since together they constitute the sum total of water available to any given area and since they affect each other's occurrence and movement. The components of water supply, use, and disposal, including subsurface flow at the boundary of the study area, were discussed in the previous chapter. Subsurface water storage and movement within the water-bearing area are discussed in this chapter.

Figure 3 depicts schematically the zones in which the subsurface waters of a ground water basin occur. Subsurface waters can be broadly classified into two groups according to the zone in which they are found: vadose water in the zone of aeration, and ground water in the zone of saturation. The zone of aeration includes a belt of soil water extending downward from the ground surface, from which plants obtain the water needed for their survival and growth. It also includes a capillary fringe zone, immediately overlying the zone of saturation, so named because ground water in the capillary fringe is held above the water table by capillary forces. Between the soil belt and capillary fringe an intermediate belt is usually found. This intermediate belt, which is present in the San Gabriel Valley, exists in basins where the zone of saturation lies some distance below the ground surface.

The older sedimentary formations flanking and underlying the basin do contain some permeable members that yield ground water. However, due to folding and faulting of the strata, readily observed in the Repetto, Merced and Puente Hills, in most instances the permeable members of the

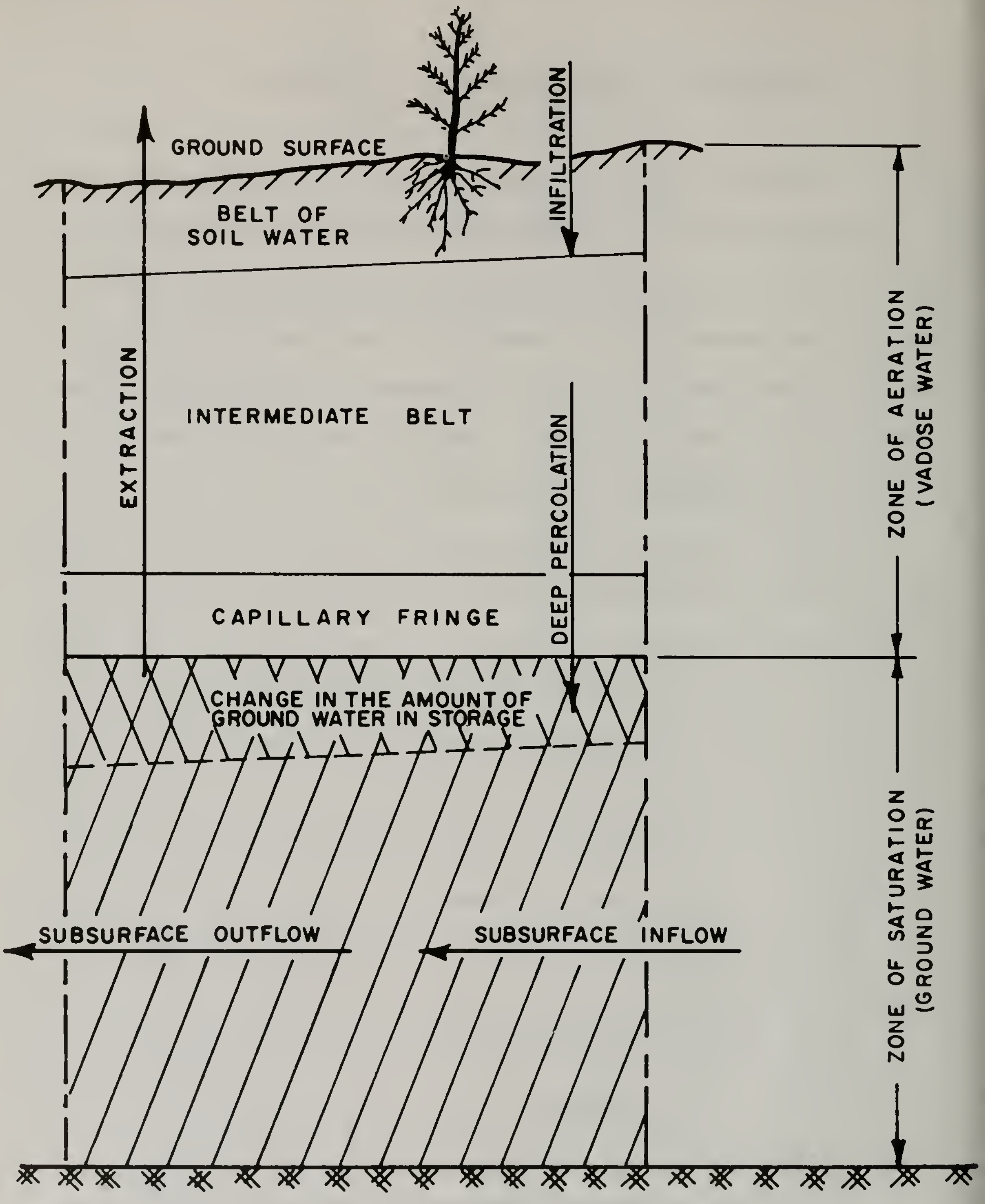


DIAGRAM SHOWING
GENERALIZED HYDROLOGIC ELEMENTS OF SUBSURFACE WATER

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1965

older formations are not always interconnected with the water-bearing formations in the ground water basin, and movement of ground water between these formations is restricted. Thus, further discussion of subsurface water will be centered on the water-bearing portion of the study area. Although subsurface water in both the zones of aeration and saturation are described hereinafter, emphasis will be placed on the occurrence of ground water in the zone of saturation because of its importance to operation of the basin.

Vadose Water in the Zone of Aeration

Precipitation and applied water enter the zone of aeration from the surface and are drawn down by the force of gravity toward the zone of saturation. The rate at which this water reaches the zone of saturation depends on factors which include: the amount of precipitation or applied water available, the infiltration rate and moisture content of the soil belt, and the vertical permeability of the intermediate zone. If only a small amount of water is applied or is available through precipitation, it may be used up by evaporation and transpiration in the soil belt, even though the infiltration rate of the soil belt is high. Water that passes the soil belt moves downward through the intermediate zone in which water is usually not affected by evaporation and transpiration. Water that reaches the zone of saturation is considered as deep percolation and is treated as an increment to the ground water supply. To determine the general order of magnitude of the time required for water applied at the ground surface to reach the zone of saturation, varying amounts of water in transit were imposed upon the mathematical model. The model indicated that water remaining in the zone of aeration for increments of time greater than a year caused time delays in the computed water level elevations as compared to historic water levels, thus indicating that the effects of water in transit are felt at the zone of saturation within one year where the zone of saturation is 100 feet or more below the ground surface (Chapter VI, "Mathematical Model") as is the case in much of San Gabriel Valley.

Studies on the rate of flow of vadose water through the zone of aeration are currently being carried on by several agencies, including the Department of Water Resources. No such studies have been made in San Gabriel Valley in this investigation because data and facilities needed for directly measuring unsaturated flow are beyond the scope of this investigation. As mentioned in the first chapter, it was partially for this reason that the base period was chosen to contain a dry period of precipitation directly preceding the beginning and end of the study period. It was then assumed that the amount of water in transit in the zone of aeration was essentially the same at the beginning and end of the base period.

Inflow and Outflow at the Zone of Saturation

Inflow to the zone of saturation is comprised of percolation to the zone of saturation and subsurface inflow. Outflow from the zone of saturation is comprised of extractions from the zone of saturation and subsurface outflow. Since subsurface inflow and outflow at the boundaries of the study area were discussed in the previous chapter, the following sections are limited to the discussion of percolation to and extractions from the zone of saturation.

Percolation to the Zone of Saturation

Water which passes the belt of soil water eventually reaches the zone of saturation. Water which reaches the zone of saturation is termed "deep percolation". Since in the San Gabriel Valley the effects of water in transit are felt at the zone of saturation within one year, deep percolation was assumed to be equal to percolation to the intermediate belt. The components of deep percolation as considered in this study were artificial recharge, streambed percolation, percolation of delivered water, and percolation of precipitation. The amounts of deep percolation of each component, except artificial recharge, were not directly measured, but were determined as the residual of the amounts of surface water supply, use, and disposal described in the previous chapter.

It is recognized that, when estimating deep percolation in this way, relatively small errors in the amounts of water supply, use, and disposal may cause relatively large errors in the estimated amounts of deep percolation. This is because these amounts, when compared with the amounts of water supply, use, and disposal, are relatively small. However, because the amounts of water supply, use, and disposal were checked and adjusted when balancing the equation of hydrologic equilibrium, and because the estimated amounts of deep percolation were checked for reasonableness and adjusted within limits of physical probability, it is believed that errors in the estimated amounts of deep percolation were minimized.

The average seasonal total deep percolation during the base period was estimated to be about 205,100 acre-feet. During the base period, deep percolation varied from a minimum of 92,700 acre-feet in 1950-51 to a maximum of 459,500 acre-feet in 1940-41. Table 11 shows the seasonal amounts of total deep percolation as well as the seasonal amounts for each of the four components of deep percolation.

TABLE 11

ESTIMATED HISTORICAL SEASONAL DEEP PERCOLATION
IN THE SAN GABRIEL VALLEY GROUND WATER BASIN

In thousands of acre-feet

Season[a]	Artificial recharge[b]	Streambed percolation	Percolation of delivered water[f]	Percolation of precipitation	Total
1933-34	17.0	26.6[c]	66.0[g]	61.8	171.4
34-35	52.1	74.2[c]	55.6[g]	69.0	250.9
1935-36	25.0	29.0[c]	71.1[g]	33.5	158.6
36-37	55.3	123.6[c]	65.7[g]	111.0	355.6
37-38	45.4	114.5[c]	69.6[g]	116.4	345.9
38-39	24.1	28.4	58.5	62.7	173.7
39-40	27.8	24.8	58.5	35.9	147.0
1940-41	61.6	156.4	53.9	187.6	459.5
41-42	29.6	30.6	57.7	25.2	143.1
42-43	34.5	130.4	63.0	108.2	336.1
43-44	42.0	97.5	62.1	75.6	277.2
44-45	49.5	49.9	63.3	43.3	206.0
1945-46	36.2	50.8	65.0	38.4	190.4
46-47	33.0	47.9	62.8	36.5	180.2
47-48	7.0	25.6	64.5[h]	11.3	108.4
48-49	4.3	20.3[d]	70.5[h,i]	9.4	104.5
49-50	11.8	19.1[d]	67.7[h,i]	25.3	123.9
1950-51	2.0	13.8[d]	67.8[h,i]	9.1	92.7
51-52	38.1	84.3[d]	58.0[h,i]	129.2	309.6
52-53	21.5	47.5[d]	61.6[h,i]	12.2	142.8
53-54	27.0	48.1[d,e]	64.3[h,i]	46.1	185.5
54-55	26.4	21.4[d,e]	55.9[h,i]	26.3	130.0
1955-56	28.2	36.5[d,e]	55.0[h,i]	53.4	173.1
56-57	23.6	32.8[d,e]	49.2[h,i]	25.6	131.2
57-58	75.8	147.6[d,e]	65.6[h,i]	117.7	406.7
58-59	34.5	22.8[d,e]	64.9[h,i]	9.7	131.9
59-60	10.9	20.2[d,e]	60.7[h,i]	9.6	101.4
27-Year Average	31.3	56.5	62.1	55.2	205.1

a. 12-month period from October 1 through September 30.
b. From Annual and Biennial Reports of the Los Angeles County Flood Control District; for detailed information, see Attachment No. 8.
c. Excludes percolation of waste water in Alhambra Wash.
d. Excludes percolation of waste water in San Jose Wash.
e. Includes percolation of Colorado River water.
f. Includes cesspool percolation.
g. Includes percolation of waste water in Alhambra Wash
h. Includes waste water spread by Lucky Lager Brewing Company and City of Azusa.
i. Includes percolation of waste water in San Jose Wash.

Artificial Recharge. Average seasonal artificial recharge to the San Gabriel Valley Ground Water Basin during the base period was about 31,300 acre-feet or about 15 percent of the average seasonal total deep percolation. Seasonal amounts of water used for artificial recharge varied during the base period from a low of 2,000 acre-feet in 1950-51 to a high of 75,800 acre-feet in 1957-58. The seasonal amounts of water spread in the San Gabriel Valley are shown in Table 11. The various spreading grounds in the San Gabriel Valley are shown on Plate 4, and the historical amounts spread in each are shown in Attachment 8.

Artificial recharge in the San Gabriel Valley Ground Water Basin consists of diverted storm flows within the valley and surface water diverted and imported from the tributary San Gabriel Mountains. Artificial recharge is considered as only the water conserved by use of spreading grounds. Percolation in stream channels, whether it be native or imported water, is considered in streambed percolation. Waste water disposed by spreading is considered percolation of delivered water.

During the base period, the Committee of Nine, a group of water users mentioned in Chapter II, has spread diverted surface waters from the San Gabriel River in spreading grounds at the mouth of San Gabriel Canyon. This agency has also artificially recharged water in canals near Azusa. The Los Angeles County Flood Control District has spread water in ten spreading grounds in the San Gabriel Valley, using mostly storm water imported from the San Gabriel Mountains.

Streambed Percolation. Average seasonal streambed percolation in the San Gabriel Valley Ground Water Basin during the base period was about 56,500 acre-feet, or 28 percent of the total deep percolation.

Because of stream channel lining, the length of pervious stream channel available for percolation has decreased from about 110 miles to 60 miles during the base period. During this period, the seasonal amounts of streambed percolation varied from a minimum of 13,800 acre-feet in 1950-51 to a maximum of 156,400 acre-feet in 1940-41. The seasonal amounts of streambed percolation are presented in Table 11.

Streambed percolation is comprised of percolation of natural storm flows and, starting in 1954, Colorado River water. Natural storm flows consist of surface inflow from the San Gabriel Mountains and Raymond Basin as well as surface runoff from within the San Gabriel Valley. Streambed percolation was estimated by dividing streams in the San Gabriel Valley into reaches between which gaging stations were located. Percolatio in each reach would then equal the gaged inflow to the reach plus estimated or measured accretions to the reach minus the gaged outflow from the reach.

<u>Percolation of Delivered Water</u>. Average seasonal percolation of delivered water in the San Gabriel Valley during the base period was about 62,100 acre-feet or 30 percent of the average seasonal total deep percolation and 38 percent of the delivered water. Seasonal amounts of percolation of delivered water varied from a maximum of 71,100 acre-feet in 1935-36 to a minimum of 49,200 acre-feet in 1956-57. The seasonal amounts of percolation of delivered water are shown in Table 11.

Delivered water is defined as applied water plus conveyance losse Applied water is defined as the total amount of water, including ground wat actually delivered to a consumer for any domestic, agricultural, commercial, or industrial use, except water used for spreading purposes.

Percolation of delivered water has been separated into two components: (1) percolation of irrigation water, and (2) percolation of waste water. Irrigation water, which consists of water used for agricultural purposes and for the irrigation of lawns and shrubs in urban and suburban areas, was computed by subtracting total waste water production and commercial and industrial consumptive use from delivered water; percolation of irrigation water was computed by subtracting consumptive use of irrigation water from irrigation water. Percolation of waste water was estimated by adding waste water discharged to spreading grounds, waste water percolated in streams, and waste water disposed to cesspools. For the water-bearing portion of the San Gabriel Valley, it was found that percolation of irrigation water was 37.5 percent (62.5 percent irrigation efficiency) of irrigation water. Percolation of waste water was estimated to be about 6 percent of the delivered water.

Percolation of Precipitation. Average seasonal percolation of precipitation in the San Gabriel Valley during the base period was about 55,200 acre-feet or about 27 percent of the average seasonal total deep percolation. Percolation of precipitation averaged about 34 percent of the total precipitation and varied from a maximum of 187,600 acre-feet in 1940-41 to a minimum of 9,100 acre-feet in 1950-51. The seasonal estimates of percolation of precipitation are shown in Table 11.

Percolation of precipitation in the San Gabriel Valley is equal to precipitation minus the disposal of precipitation. The disposal of precipitation is equal to consumptive use of precipitation plus surface runoff.

Extractions from the Zone of Saturation

Extractions from the zone of saturation are direct withdrawals from the ground water reservoir by man or by nature. The components of these withdrawals in the San Gabriel Valley are: ground water pumpage, extractions by phreatophytes, and rising water. The average seasonal extractions from the zone of saturation during the base period were about 202,500 acre-feet. During the base period, seasonal extractions from the zone of saturation varied from a maximum of 245,000 acre-feet in 1944-45 to a minimum of 154,100 acre-feet in 1934-35. Table 12 presents the seasonal extractions from the zone of saturation.

Pumpage. The estimated average seasonal ground water pumpage for the base period was about 156,300 acre-feet or about 77 percent of the total extractions from the zone of saturation. In 1960, ground water pumpage supplied about 90 percent of the total delivered water in the San Gabriel Valley. The seasonal ground water pumpage has increased from 160,600 acre-feet in 1933-34 to 193,400 acre-feet in 1959-60. This increase was due primarily to the continuing drought and to the increased demand for water resulting from an expansion of the population.

The estimates of seasonal ground water pumpage shown in Table 12 are based on estimated amounts for the years 1933-34 through 1954-55 and recorded amounts for the years 1955-56 through 1959-60. Unfortunately, ground water pumpage data prior to 1955 were either unavailable or incomplete for most of the ground water extracting agencies in the San Gabriel Valley. Reliable extraction data became available in 1955 as a result of the Recordation of Water Extractions and Diversions Act (Sections 4999

TABLE 12

ESTIMATED HISTORICAL SEASONAL EXTRACTIONS
FROM THE ZONE OF SATURATION IN THE
SAN GABRIEL VALLEY GROUND WATER BASIN

In thousands of acre-feet

Season[a]	Ground water pumpage	Extractions by phreatophytes	Rising water[c]	Total
1933-34	160.6	2.9	27.4	190.9
34-35	119.8	2.9	31.4	154.1
1935-36	153.3	2.9	33.5	189.7
36-37	146.3	2.9	39.9	189.1
37-38	153.5	2.9	53.9	210.3
38-39	129.3	2.7	62.5	194.5
39-40	135.7	2.5	57.6	195.8
1940-41	125.6	2.3	77.9	205.8
41-42	134.9	2.1	91.5	228.5
42-43	138.8	2.0	86.5	227.3
43-44	132.1	1.8	102.5	236.4
44-45	145.1	1.7	98.2	245.0
1945-46	148.3	1.6	81.8	231.7
46-47	146.3	1.4	74.0	221.7
47-48	160.0	1.3	55.7	217.0
48-49	175.3	1.1	38.6	215.0
49-50	170.9	1.0	28.9	200.8
1950-51	177.8	0.8	22.1	200.7
51-52	151.0	0.8	21.6	173.4
52-53	168.6	0.8	22.3	191.7
53-54	173.3	0.8	14.7	188.8
54-55	168.2	0.8	15.2	184.2
1955-56	166.5[b]	0.8	11.5	178.8
56-57	164.7[b]	0.8	9.3	174.8
57-58	181.2[b]	0.8	17.3	199.3
58-59	199.0[b]	0.8	17.8	217.6
59-60	193.4[b]	0.8	10.4	204.6
27-Year Average	156.3	1.6	44.6	202.5

a. 12-month period from October 1 through September 30.
b. Recorded amounts per calendar year from State Water Rights Board data.
c. From Annual and Biennial Reports of the Los Angeles County Flood Control District. Includes diversions of rising water in the vicinity of Whittier Narrows.

through 5008 of the California Water Code). Estimates of ground water pumpage for the years 1933-34 through 1954-55 were based on population and land use information and on the assumption that the average irrigation efficiency, estimated for the years of known extractions, would be the same for the remainder of the base period.

Extractions by Phreatophytes. Average seasonal extractions by phreatophytes in the San Gabriel Valley Ground Water Basin for the base period were about 1,600 acre-feet or about 1 percent of the total extractions from the zone of saturation. Extractions by phreatophytes have decreased from about 2,900 acre-feet in 1933-34 to about 800 acre-feet in 1959-60 because of the destruction of these plants by flood control works and by development of lands adjacent to stream channels.

Phreatophytes are abundant throughout the San Gabriel Valley; however, these plants extract ground water only in the vicinity of Whittier Narrows where the distance to the water table is small. Phreatophyte extractions are considered as the excess water requirement of these plants over and above what is supplied by rainfall. By using the Blaney-Criddle method, a unit use value of about 3.20 feet per year was estimated for the consumptive use of phreatophytes, and of this amount, an average of about 1.10 feet per year was supplied from rainfall during the base period. The gross area where phreatophytes could extract ground water, based on land use studies and water level contours, decreased during the base period from about 3,500 acres in 1933-34 to about 1,000 acres in 1959-60. In estimating extractions by phreatophytes, actual plant cover was assumed to be about 40 percent of the gross acreage.

Rising Water. Rising water, a natural direct outflow from the zone of saturation was caused by a constriction of the bedrock in the Whittier Narrows area which caused the ground water table to intersect the ground surface. Currently, this intersection takes place only within the streambeds. The geologic aspects of this constriction were discussed in detail in Chapter III, Geology.

The average seasonal rising water for the base period was about 44,600 acre-feet or about 22 percent of the average seasonal total extractions from the zone of saturation. In general, rising water fluctuated with the ground water levels and water supply of the basin. Rising water reached a high of 102,500 acre-feet in 1943-44 and a low of 9,300 acre-feet in 1956-57. Starting in 1954, large amounts of Colorado River water percolated in the San Gabriel Valley and contributed to the rising water flowing out of the basin.

The seasonal amounts of rising water shown in Table 12 were estimated by the Los Angeles County Flood Control District on the basis of gaging station data and current meter measurements of the flow passing Whittier Narrows.

Change in Storage of Ground Water

In Chapter IV, the change in the amount of ground water in storage was expressed as an item of the general equation of hydrologic equilibrium,which is repeated here for convenience:

Inflow - Outflow = Change in storage

This equation was used as one of the tools to evaluate most accurately the seasonal occurrences of both surface water and subsurface water in the study area during the base period. In this evaluation, seasonal changes in the amount of ground water in storage were determined by two methods: (1) Water Supply Inventory Method, (2) Specific Yield Method.

The seasonal amounts of changes in storage obtained by these two methods differed. Such deviations are usual because small errors in the seasonal quantity of some of the components of water supply, use, and disposal may cause significant variations in the amounts of change in ground water storage, when the Water Supply Inventory Method is used. The differences were minimized by requiring that the accumulated amounts of bot methods reasonably follow each other and by making the summation of both methods during the base period exactly equal each other. Balancing of the equation of hydrologic equilibrium during the base period was accomplished by adjusting values of water supply, use, and disposal within reasonable limits, based on the accuracy of the data. In some cases, the values of th parameters involved in the computation of change in storage by the Specific Yield Method were also adjusted.

The determination of change in storage by the Water Supply Invent Method and by the Specific Yield Method will be described in the following sections.

Change in Storage by Water Supply Inventory Method

The equation of hydrologic equilibrium can be applied to the stud area with the zone of saturation as a free body. As shown in Figure 4, the equation of hydrologic equilibrium for this free, or separate, body can be expressed as:

Deep Percolation + Subsurface Inflow - Extraction from the Zone of Saturation - Subsurface Outflow = Change in Storage

By using this equation, the seasonal amount of change in storage can be indirectly determined.

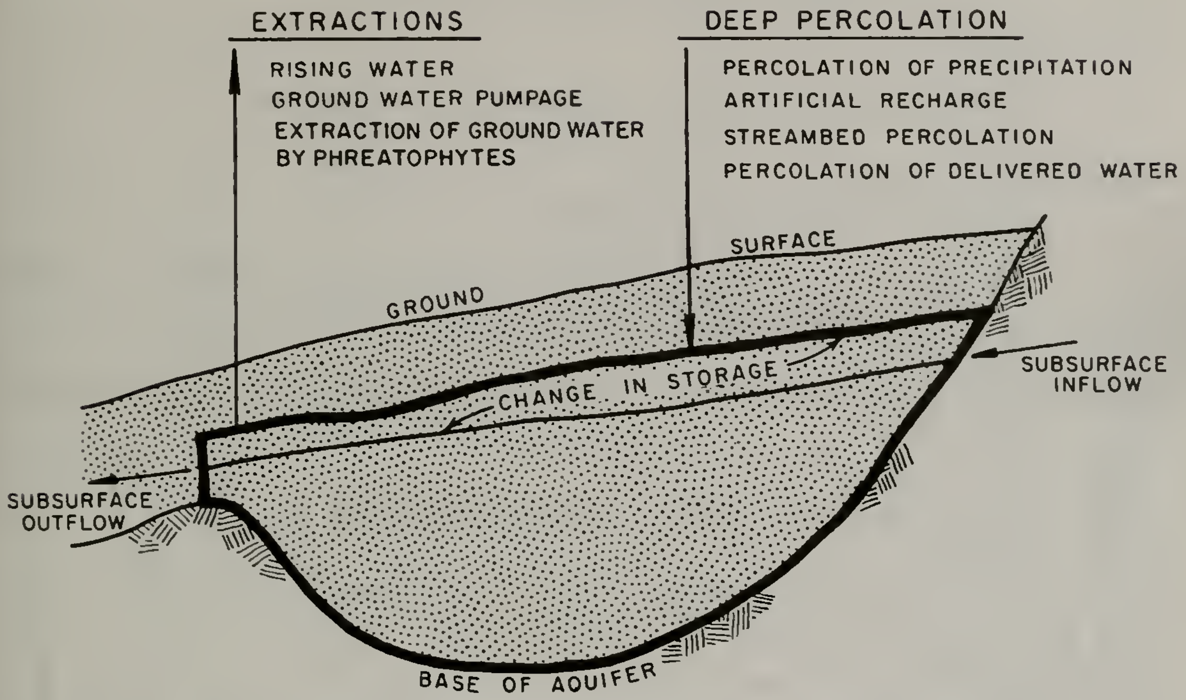


Fig. 4 THE ZONE OF SATURATION AS A FREE BODY

In the previous section, it was mentioned that the components in the above equation are related to the residual amounts of water supply that infiltrates into the zone of aeration after the area's water supply has been used and disposed. When the amount of water in the zone of aeration is about the same at the end of each water year, as was apparent in this investigation, the annual water supply surplus or deficiency presented in the previous chapter can be assumed to be equal to the seasonal amount of change in storage of ground water.

Table 13 presents the seasonal amounts of each component of deep percolation and of extractions, net subsurface outflow, and change in storage as computed by use of the above equation. Because the components of the above equation are directly related to the components of water supply,

TABLE 13

ESTIMATES OF SEASONAL DEEP PERCOLATION, EXTRACTIONS, NET SUBSURFACE OUTFLOW, AND CHANGE IN STORAGE IN THE SAN GABRIEL VALLEY GROUND WATER BASIN[a]

In thousands of acre-feet

1	2	3	4	5	6	7	8	9	10	11	12		13	
Season[b]	Artificial recharge[c]	Streambed percolation	Percolation of delivered water[g]	Percolation of precipitation	(2+3+4+5) Total deep percolation	Ground water pumpage	Extractions by phreatophytes	Rising water[l]	(7+8+9) Total extractions	Net subsurface outflow	Water supply surplus or deficiency (6-10-11)		Change in storage by specific yield method[m]	
											Seasonal	Accumulated	Seasonal	Accumulated
1933-34	17.0	26.6[d]	66.0[h]	61.8	171.4	160.6	2.9	27.4	190.9	16.8	- 36.3	- 36.3	- 18.0	- 18.0
34-35	52.1	74.2[d]	55.6[h]	69.0	250.9	119.8	2.9	31.4	154.1	17.1	+ 79.7	+ 43.4	+118.1	+100.1
1935-36	25.0	29.0[d]	71.1[h]	33.5	158.6	153.3	2.9	33.5	189.7	17.8	- 48.9	- 5.5	- 79.0	+ 21.1
36-37	55.3	123.6[d]	65.7[h]	111.0	355.6	146.3	2.9	39.9	189.1	9.9	+156.6	+151.1	+181.1	+202.2
37-38	45.4	114.5[d]	69.6[h]	116.4	345.9	153.5	2.9	53.9	210.3	5.0	+130.6	+281.7	+ 94.5	+296.7
38-39	24.1	28.4	58.5	62.7	173.7	129.3	2.7	62.5	194.5	5.4	- 26.2	+255.5	- 2.9	+293.8
39-40	27.8	24.8	58.5	35.9	147.0	135.7	2.5	57.6	195.8	3.6	- 52.4	+203.1	- 39.4	+254.4
1940-41	61.6	156.4	53.9	187.6	459.5	125.6	2.3	77.9	205.8	3.7	+250.0	+453.1	+228.1	+482.5
41-42	29.6	30.6	57.7	25.2	143.1	134.9	2.1	91.5	228.5	0.4	- 85.8	+367.3	-139.4	+343.1
42-43	34.5	130.4	63.0	108.2	336.1	138.8	2.0	86.5	227.3	2.3	+106.5	+473.8	+114.6	+457.7
43-44	42.0	97.5	62.1	75.6	277.2	132.1	1.8	102.5	236.4	2.0	+ 38.8	+512.6	+ 26.3	+484.0
44-45	49.5	49.9	63.3	43.3	206.0	145.1	1.7	98.2	245.0	3.1	- 42.1	+470.5	- 60.5	+423.5
1945-46	36.2	50.8	65.0	38.4	190.4	148.3	1.6	81.8	231.7	5.4	- 46.7	+423.8	- 55.5	+368.0
46-47	33.0	47.9	62.8	36.5	180.2	146.3	1.4	74.0	221.7	4.2	- 45.7	+378.1	- 98.8	+269.2
47-48	7.0	25.6	64.5[i]	11.3	108.4	160.0	1.3	55.7	217.0	8.0	-116.6	+261.5	- 89.9	+179.3
48-49	4.3	20.3[e]	70.5[i,j]	9.4	104.5	175.3	1.1	38.6	215.0	13.8	-124.3	+137.2	-108.7	+ 70.6
49-50	11.8	19.1[e]	67.7[i,j]	25.3	123.9	170.9	1.0	28.9	200.8	17.5	- 94.4	+ 42.8	-102.2	- 31.6
1950-51	2.0	13.8[e]	67.8[i,j]	9.1	92.7	177.8	0.8	22.1	200.7	18.4	-126.4	- 83.6	-103.8	-135.4
51-52	38.1	84.3[e]	58.0[i,j]	129.2	309.6	151.0	0.8	21.6	173.4	16.9	+119.3	+ 35.7	+176.1	+ 40.7
52-53	21.5	47.5[e]	61.6[i,j]	12.2	142.8	168.6	0.8	22.3	191.7	16.1	- 65.0	- 29.3	-110.4	- 69.7
53-54	27.0	48.1[e,f]	64.3[i,j]	46.1	185.5	173.3	0.8	14.7	188.8	16.3	- 19.6	- 48.9	- 13.9	- 83.6
54-55	26.4	21.4[e,f]	55.9[i,j]	26.3	130.0	168.2	0.8	15.2	184.2	17.6	- 71.8	-120.7	- 22.5	-106.1
1955-56	28.2	36.5[e,f]	55.0[i,j]	53.4	173.1	166.5[k]	0.8	11.5	178.8	13.4	- 19.1	-139.8	- 57.2	-163.3
56-57	23.6	32.8[e,f]	49.2[i,j]	25.6	131.2	164.7[k]	0.8	9.3	174.8	11.8	- 55.4	-195.2	- 40.5	-203.8
57-58	75.8	147.6[e,f]	65.6[i,j]	117.7	406.7	181.2[k]	0.8	17.3	199.3	11.4	+196.0	+ 0.8	+248.5	+ 44.7
58-59	34.5	22.8[e,f]	64.9[i,j]	9.7	131.9	199.0[k]	0.8	17.8	217.6	6.8	- 92.5	- 91.7	-142.3	- 97.6
59-60	10.9	20.2[e,f]	60.7[i,j]	9.6	101.4	193.4[k]	0.8	10.4	204.6	7.8	-111.0	-202.7	-105.1	-202.7
TOTALS	844.2	1,524.6	1,678.5	1,490.0	5,537.3	4,219.5	44.0	1,204.0	5,467.5	272.5	-202.7		-202.7	
27-Year Average	31.3	56.5	62.1	55.2	205.1	156.3	1.6	44.6	202.5	10.1	- 7.5		- 7.5	

a. Results are based on zone of saturation as free body as shown in Figure 2.
b. 12-month period from October 1 through September 30.
c. Includes all fresh water recharge in the San Gabriel Valley· for detailed information see Attachment No. 7.
d. Excludes percolation of waste water in Alhambra Wash.
e. Excludes percolation of waste water in San Jose Wash.
f. Includes percolation of Colorado River water.
g. Includes cesspool percolation.
h. Includes percolation of waste water in Alhambra Wash.
i. Includes waste water spread by Lucky Lager Brewing Company and City of Azusa Sewage Treatment Plant.
j. Includes percolation of waste water in San Jose Wash.
k. Recorded amounts from State Water Rights Board data.
l. Includes diversions of rising water in the vicinity of Whittier Narrows.
m. Computed by using specific yield, area, and change in water level.

use, and disposal, the seasonal amounts of changes in storage are exactly equal to the seasonal amounts of water supply or deficiency for the corresponding year presented in the previous chapter. Change in the amount of ground water in storage by the Specific Yield Method, which will be described in the next section, is also shown in this table for comparison.

Change in Storage by the Specific Yield Method

Seasonal amounts of change in ground water storage were directly determined by the Specific Yield Method. The general procedure used was as follows:

1. Ground water in storage was computed at the fall of each year by the following equation:

   Specific Yield x Thickness of Saturated Water-bearing Material x Area = Ground Water in Storage

2. Change in storage for each year of the base period was computed by subtracting the ground water in storage at the fall of each year from the ground water in storage at the fall of the following year.

Specific Yield. Specific yield is defined as the ratio of the volume of water a saturated sediment will yield by gravity drainage over a period of time to the total volume of the saturated sediment prior to draining; it is customarily expressed in percent. Specific yield values vary according to the type of sediment or rock. These values are high for gravel and sand and low for consolidated bedrock and clay; for hard unfractured crystalline or other igneous bedrock the specific yield is zero. Specific yield values for the materials present in the San Gabriel Valley are shown in Attachment 9, Table 9-1.

The determination of specific yield was based on analyses of about 1,000 well logs; all San Gabriel Valley well logs of known locations, available in the files of the Department of Water Resources, were used. Specific yield values, ranging from 3 to 28 percent, were assigned to each lithologic interval shown on the logs, and the average specific yield values for each 20-foot increment of each well log were then computed. The selection of a 20-foot interval was based on the nature of the data and the extent and thickness of the water-bearing materials. All individual well logs located in a given section of land were then combined into a single composite log, representing the entire section, with an average specific yield for each 20-foot interval. Any composite log which did not extend to the base of fresh water was extended using data from surrounding sections and by extrapolating the logs of the overlying interval. For those sections containing no well log data, "idealized" logs were developed with data from surrounding sections having similar geologic conditions. These specific yield values were then used to compute seasonal amounts of ground water in storage.

The specific yield from ground surface to base of fresh water varied by section across the basin from a minimum of 3 percent in the peripheral areas to a maximum of 24 percent in the center of the valley. The lowest average specific yields were found in the east end of the basin, east of Covina, where yields averaged about 8 percent. The center, and more permeable portion of the basin, averaged 14 percent while the west end of the basin averaged between 9 and 10 percent. The average specific yield throughout the valley is shown on Plate 15, entitled "Average Specific Yield Contours".

<u>Change in Ground Water Level</u>. The thickness of the saturated water-bearing material is dependent on the elevation of the ground water in storage. Maps were prepared showing lines of equal elevation of the ground water table in three years during the base period: Fall 1933, the beginning of the base period; Fall 1944, the year of highest water level in the valley; and Fall 1960, the end of the base period and the year of lowest water levels. These maps are shown on Plates 16, 17, and 18, entitled "Lines of Equal Elevation of Ground Water in Wells,Fall 1933"; "Lines of Equal Elevation of Ground Water in Wells,Fall 1944"; and "Lines of Equal Elevation of Ground Water in Wells,Fall 1960", respectively.

The difference in elevation of the fall ground water levels was used to obtain the change in the amount of ground water in storage. Maps were also prepared showing lines of equal changes in the ground water table between the periods 1933-1944, 1944-1960, and 1933-1960; these maps are shown on Plates 19, 20, and 21 entitled "Change in Elevation of Ground Water Levels in Wells,Fall 1933-Fall 1944"; "Change in Elevation of Ground Water Levels in Wells,Fall 1944-Fall 1960"; and "Change in Elevation of Ground Water Levels in Wells,Fall 1933-Fall 1960", respectively.

The beginning of the study period, 1933, was the end of the dry period. Water levels throughout the valley had been dropping for several years, and no large pumping troughs existed at that time. By 1944, the end of the wet period, water levels had risen over the entire basin; the gain in water levels throughout the valley during the first 11 years of the base period is shown on Plate 19. The maximum water level gain of over 200 feet occurred in the area east of San Dimas. Water level contours in 1944 (Plate 17) show that a ground water low, presumably due to heavy pumping and probably aggravated by low transmissibility, was starting to develop west of Rosemead and east of Alhambra, just below the Raymond fault. Plate 20, "Change in Elevation of Ground Water Levels in Wells, Fall 1944-Fall 1960", indicates that by 1960, with the exception of a small area east of San Dimas, water levels had dropped, about 60 feet over most of the basin and 90 feet along the Raymond fault. Indeed, in most areas of the valley the water levels for 1960 were lower than those of 1933. The ground water low in the vicinity of Rosemead that appears on the 1944 water level contour map had, by 1960, increased in size and shifted to the north and northwest.

The fluctuation of ground water levels at selected wells during the study period is shown on Plates 22A and B, entitled, "San Gabriel Valley Well Hydrographs"; locations of these wells are shown on Plate 12. The water level elevation fluctuation in the main portion of the San Gabriel Valley is shown by the hydrographs of three selected wells, numbered 1S/10W-23F1, 7R2, 31A2. These hydrographs show that water level elevations rose sharply between 1934 and 1944, reaching a maximum in 1944 or 1945; the water levels declined sharply between 1945 and 1951 and continued to decline slowly until 1960, except in 1952 and 1958.

The hydrographs of the remaining selected wells show the water level fluctuation in the perimeter areas, adjacent to the main portion of the basin. One of the selected wells, Well 1S/12W-13H1, is about 1 mile northwest of Rosemead between Rubio Wash and Rosemead Boulevard (Plate 22A). This well is situated in the trough mentioned above, and the hydrograph clearly demonstrates the steady decline of water levels in the trough during the base period. The hydrographs for two other wells, 1N/10W-22P2 and 29K1 (Plate 22B), reflect the influence of the two faults crossing the mouth of San Gabriel Canyon. Well 29K1 is between the two faults and Well 22P2 is north of both faults. The hydrographs for these wells show that peak water levels reach approximately the same elevation for most years of the study. As water levels in 1N/10W-22P2 and 29K1 fall about 50 feet below the land surface, water no longer crosses over the faults. As water levels rise into the upper 50 feet of alluvium not affected by faulting, water is free to cascade over the faults.

Well 1N/9W-25K1 (Plate 22B) is on the northwest side of the San Dimas Wash. The hydrograph for this well reflects a rapid response to applied water. The sharp peaks indicate that applied water passes quickly, and that only minor amounts remain in storage. The water level fluctuation in the Puente Valley is shown on the hydrograph for Well No. 2S/10W-11M1 which is located near the intersection of Valley Boulevard and Fifth Avenue. This hydrograph shows the usual water level rise and decline similar to that of the adjacent main basin between the years 1934 and 1951; however, between the years 1951 and 1960 there was a slight rise in the water level elevation. This rise was probably due to percolation of treated waste water discharged into San Jose Creek from Pomona Sewage Treatment Plant, commencing in 1948-49.

Change in Storage. Ground water in storage at the beginning of each year was computed for each section of land within the San Gabriel Valley. Change in storage for each section was then computed by subtracting ground water in storage in the fall of each year from the ground water in storage in the fall of the following year. Summation of the change in storage for each section provided the change in storage for the San Gabriel Valley.

The seasonal amounts of change in ground water storage are presented in Table 14. This table shows that during the 27-year base period, 19 years had decreases in the amount of ground water in storage and only 8 years had increases in storage. With the exception of the water years 1951-52 and 1957-58, decreases in storage have occurred without interruption since 1944-45. The greatest seasonal increase in storage, amounting to 248,500 acre-feet occurred in 1957-58; the greatest seasonal decrease in storage, amounting to 142,300 acre-feet, occurred in 1958-59. During the base period water in storage in the San Gabriel Valley decreased by 202,700 acre-feet; the average seasonal decrease amounted to 7,500 acre-feet.

Storage Capacity. The total storage capacity of the San Gabriel Valley, from ground surface to base of fresh water, was estimated to be about 9,500,000 acre-feet. In 1960, the amount of ground water remaining in storage was about 7,900,000 acre-feet.

Ground Water Movement Within the San Gabriel Valley Ground Water Basin

Ground water in the San Gabriel Valley generally moves from the perimeter of the valley toward Whittier Narrows. The direction of ground water flow is perpendicular to the water level contours; lines of equal elevation of the ground water table, for 1933, 1944, and 1960 are shown on Plates 16, 17, and 18, respectively.

Plate 16 indicates that in 1933 the general direction of ground water movement across all of the San Gabriel Valley was from the perimeter of the valley towards Whittier Narrows, the only area where subsurface outflow from the San Gabriel Valley is known to take place. Water level

TABLE 14

SEASONAL CHANGE IN STORAGE IN THE
SAN GABRIEL VALLEY GROUND WATER BASIN

In thousand acre-feet

Year	Change in Storage
1933-34	- 18.0
34-35	118.1
1935-36	- 79.0
36-37	181.1
37-38	94.5
38-39	- 2.9
39-40	- 39.4
1940-41	228.1
41-42	-139.4
42-43	114.6
43-44	26.3
44-45	- 60.5
1945-46	- 55.5
46-47	- 98.8
47-48	- 89.9
48-49	-108.7
49-50	-102.2
1950-51	-103.8
51-52	176.1
52-53	-110.4
53-54	- 13.9
54-55	- 22.5
1955-56	- 57.2
56-57	- 40.5
57-58	248.5
58-59	-142.3
59-60	-105.1
TOTAL	-202.7
27-year average	- 7.5

contours in 1944, Plate 17, show that the general pattern of ground water movement in 1944 was similar to that in 1933. Water level contours in 1960, Plate 18, show that a ground water low had formed between the cities of South Pasadena and Rosemead and that ground water in the northwestern portion of the valley no longer moved towards Whittier Narrows but towards this ground water low; the direction of ground water movement throughout the remainder of the valley, however, remained generally the same as that during earlier periods.

The amount of ground water movement through the San Gabriel Valle is dependent on not only the slope of the water table, but also the transmissive characteristic of the alluvial deposits through which it must pass. The rate at which water can move through the permeable sediments in the zone of saturation must be determined if ground water movement in the groun water basin is to be determined. The capacity of a material for transmitting a fluid is usually referred to as its permeability or transmissibility The coefficient of transmissibility is defined as the rate of flow of water in gallons per day, at the prevailing water temperature, through each vertical strip of the aquifer 1 foot wide having a height equal to the saturated thickness of the aquifer and under a unit hydraulic gradient.

To determine transmissibility for the basin, 22 aquifer tests, 16 of which produced valid results, were made on wells distributed throughout San Gabriel Valley. The results of these tests are presented in Attachment 9. While the mathematical model of the San Gabriel Valley was being developed, the transmissibility values obtained by aquifer tests were used as a guide to determine representative permeability values for the alluvial deposits in the vicinity of each test. These permeability values were then extrapolated to water-bearing sediments in other areas of the valley and one transmissibility value was computed for each 640-acre section.

Computed transmissibility values ranged from a maximum of about 3,360 acre-feet per year per foot of width in the vicinity of Baldwin Park to a minimum of about 40 acre-feet per year per foot of width near San Dimas. Computed transmissibilities were highest in the central portion of the basin where they averaged about 2,240 acre-feet per year per foot of width. At Whittier Narrows the average computed transmissibility was about 670 acre-feet per year per foot of width. In the western and eastern portions of the basin average transmissibilities amounted to about 170 and 110 acre-feet per year per foot of width, respectively. Computed transmissibilities over most of Puente Valley were relatively low and averaged about 60 acre-feet per year per foot of width.

During the verification of the mathematical model, it was noted that directional transmissibility exists in the valley. The greatest transmissibility is from north to south with the maximum toward the center of the valley. The transmissibility in any one section, in an east to west direction, is about half of the value from north to south. Further discussion of directional transmissibility appears in Chapter VI.

Ground Water Overdraft and Safe Yield

As used in this report, ground water overdraft is equal to the average seasonal decrease in ground water in storage during a long-time period under a particular set of physical conditions that affect the supply, use, and disposal of water in the ground water basin. The water supply and climatic conditions during the 27-year base period are considered as equivalent to conditions during the long-time period. The physical conditions affecting the supply, use, and disposal of water are considered as the cultural and physical conditions that existed in 1960 in the San Gabrie Valley. These assumptions fix the mean seasonal amounts of supply, use, and disposal at one level for the 27-year base period. These assumptions also fix the place and manner in which the water supply is applied, used, and disposed.

After the determination of overdraft, safe yield can be estimated As used in this report, safe yield is the average seasonal amount of ground water that can be extracted or pumped from the ground water basin over a long-time period under a particular set of physical conditions without effecting a long-time net change in ground water storage. These physical conditions are the same conditions that were used to determine overdraft. Consequently, safe yield is equal to the total pumpage for the 1960 season minus the average seasonal overdraft that would have occurred under 1960 conditions. The safe yield figure, then, represents the amount of water that could be pumped from the ground water basin over a long-time period without effecting a long-time change in ground water storage, if the total water supply to the ground water basin under 1960 conditions were applied, used, and disposed in the same place and in the same manner as occurred in 1960.

A detailed explanation of the average seasonal amounts of water supply, use, and disposal under historical conditions is given in Chapter I The assumptions and methods used to estimate the mean seasonal supply and disposal that would have occurred under 1960 conditions are given below.

<u>Supply and Disposal Under 1960 Conditions</u>

Precipitation is not affected by cultural conditions; therefore, the mean seasonal precipitation under 1960 cultural conditions would have amounted to 162,200 acre-feet, which is equal to the average seasonal historical precipitation. Since most of the areas contributing surface inflow to the valley, such as the San Gabriel Mountains, have not changed significantly during the base period, it was assumed that the average seasonal surface inflow that would have occurred under 1960 cultural conditions would be 99,900 acre-feet which is the same as the historical inflow that occurred during the base period. Some surface inflow enters the San Gabriel Valley from the Raymond Basin, but an analysis indicated that there was little change between average historical amounts and mean amounts under 1960 conditions.

Mean seasonal fresh water imports that would have occurred under 1960 cultural conditions were estimated to be 47,700 acre-feet. This value is equal to: (1) the average seasonal amount of water diverted into the San Gabriel Valley from streams in the San Gabriel Mountains and used for spreading at artificial recharge projects, 20,300 acre-feet, plus (2) the 1959-60 amount of imports used to meet urban, suburban and agricultural water demands, 27,400 acre-feet. Colorado River water released into the area and transported through Whittier Narrows for spreading in Montebello Forebay was excluded. This was done because it was assumed that the increase in subsurface outflow and rising water resulting from percolating Colorado River water would be equal to that which percolates.

Mean seasonal consumptive use of precipitation and of applied water that would have occurred under 1960 cultural conditions is 154,400 acre-feet; this amount was estimated by applying the average historical unit use values of consumptive use to 1960 land use. The mean seasonal net waste water export, subsurface inflow, and subsurface outflow that would have occurred under 1960 cultural conditions were assumed to be equal to those that occurred during the 1959-60 season, or 41,100 acre-feet, 17,700 acre-feet, and 25,500 acre-feet, respectively. The mean seasonal fresh water export that would have occurred under 1960 conditions was assumed to be 35,800 acre-feet; this amount equals the 1959-60 seasonal value of fresh water exports less: (1) the reported amount of Colorado River water transported through the valley for spreading in the Montebello Forebay area during 1959-60 and, (2) the 1959-60 amount of rising water exported to the Coastal Plain of Los Angeles County by the Rincon Ditch Company, which was the only agency that exported rising water in 1959-60.

The mean seasonal amount of surface outflow that would have occurred under 1960 cultural conditions was estimated to be 98,000 acre-feet. An analysis of historical outflow of storm water indicated that the net effect of cultural changes on this component of surface outflow has bee negligible. As stated previously, most stream channels in the San Gabriel Valley have been lined with concrete. Although lining of stream channels tends to increase outflow of storm waters by decreasing streambed percolation, other activities, such as the construction of flood control dams and artificial recharge projects have offset the effects of channel lining. Consequently, mean seasonal outflow of storm waters that would have occurre under 1960 cultural conditions was assumed to be equal to that which occurr during the base period. Outflow of rising water that would have occurred under 1960 cultural conditions was assumed to be the average seasonal historical outflow of rising water that occurred during the base period less the amount of Colorado River water that percolated in the streams of the San Gabriel Valley Ground Water Basin while being transported through the area for conservation in the Montebello Forebay. The amount of Colorado River water that percolated in streams was not included in rising water because, as stated above, Colorado River water released into the area for transportation to the Montebello Forebay was excluded from the estimated amount of fresh water imports that would have occurred under 1960 conditions. It is not possible to determine the amount of percolating Colorado River water that leaves the basin as subsurface outflow and the amount that leaves it as rising water; thus, for convenience, it was assumed that all percolating Colorado River water would eventually leave the basin as rising water. The estimated average seasonal amount of surface outflow that would have occurred under 1960 cultural conditions includes the average seasonal amounts of rising water exported by the Cate, Rincon, and Standifer Ditch Companies and excludes the average seasonal amounts of waste water from the Tri-Cities Sewage Treatment Plant near Alhambra and the El Monte Sewage Treatment Plant. Historically, effluent from these plants was discharged into streams. Part of this effluent percolated and part flowed out of the San Gabriel Valley through Whittier Narrows. Operation of these plants, however, was discontinued in 1948 and 1949.

Overdraft and Safe Yield Under 1960 Conditions

The seasonal overdraft from the San Gabriel Valley that would have occurred under fixed 1960 cultural conditions is 27,300 acre-feet.

Average seasonal amounts of the items of supply and disposal under actual conditions, the mean seasonal amounts of the items of supply and disposal that would have occurred under 1960 conditions, and the steps used to estimate seasonal overdraft are shown in Table 15. This table shows that

TABLE 15

ESTIMATE OF MEAN SEASONAL OVERDRAFT IN THE SAN GABRIEL VALLEY GROUND WATER BASIN UNDER 1960 CONDITIONS[a]

In acre-feet

Items of total water supply and disposal	Mean seasonal amount under 1960 conditions	Average seasonal amount under historical conditions	Difference	Decrease in ground water storage
Average Seasonal Decrease in Ground Water Storage During Base Period Under Historical Conditions				7,500
Surface and Subsurface Supply				
Precipitation	162,200	162,200	0	
Surface inflow	99,900	99,900	0	
Fresh water import	47,700	65,300	-17,600	
Subsurface inflow	17,700	18,300	- 600	
TOTAL SUPPLY	327,500	345,700	-18,200	18,200
Surface and Subsurface Disposal				
Consumptive use[b]	154,400	174,800	-20,400	
Surface outflow	98,000	98,700	- 700	
Net waste water export	41,100	8,400	32,700	
Fresh water export	35,800	42,900	- 7,100	
Subsurface outflow	25,500	28,400	- 2,900	
TOTAL DISPOSAL	354,800	353,200	1,600	1,600
Seasonal Overdraft (Mean Seasonal Change in Storage During Base Period Under 1960 Conditions)				27,300

a. Estimate based on the assumption that the 27-year base period, 1933-34 through 1959-60, is equal to a period of long-time water supply and disposal.
b. Includes extractions by phreatophytes.

the mean seasonal surface and subsurface supply that would have occurred under 1960 conditions is 18,200 acre-feet less than the average seasonal supply under historical conditions and that the mean seasonal surface and subsurface disposal that would have occurred under 1960 conditions is 1,600 acre-feet greater than that under historical conditions. Therefore, the water supply deficiency, and consequently the decrease in ground water storage that would have occurred under 1960 conditions is 19,800 acre-feet greater than historical. Because the historical average seasonal decrease in ground water in storage was 7,500 acre-feet, the mean seasonal overdraft during the base period under fixed 1960 conditions would have been 27,300 acre-feet.

Safe yield is obtained by subtracting overdraft from pumpage. Pumpage during the 1960 water year amounted to 193,400 acre-feet. Assuming this extracting had occurred during each year of the base period, the seasonal ground water safe yield during the base period, under fixed 1960 cultural conditions, would have been 166,100 acre-feet.

It is pointed out that the assumptions on which the determination of overdraft and safe yield were based and, consequently, the values of overdraft and safe yield presented in this report, are hypothetical. In this study, a particular set of physical conditions affecting the supply and disposal of water in the San Gabriel Valley was assumed. It was also assumed that these conditions remained fixed throughout the 27-year base period. These assumptions fixed the amounts of supply, use, and disposal of water, and also fixed the place and manner in which the water supply was applied, used, and disposed. This situation did not occur in the past, nor is it expected to occur in the future.

Despite the hypothetical nature of the conditions under which it was derived, the estimated safe yield can be used as a guide or tool in the interim management of the ground waters of the San Gabriel Valley. It should be emphasized, however, that any estimate of safe yield is subject to change if any of the fixed conditions of water supply, use, and disposal under which it is derived are varied. The use of the estimated safe yield in the management of the San Gabriel Valley Ground Water Basin requires an understanding of this relationship. For instance, should it be desired to reduce pumpage in order to decrease overdraft, the amount of such reduction would have to be made up by an equal amount of supplemental water, such as imported water, or reclaimed waste water, and this supplemental water would have to be used in the same place and in the same manner as the pumped water for which it is substituted, if the estimated safe yield is to remain unchanged.

Because overdraft and safe yield are subject to change whenever any of the fixed conditions of water supply or disposal are varied, and because the San Gabriel Valley is an area of dynamic growth, subject to constantly changing cultural conditions, the estimates of overdraft and safe yield presented in this report should be periodically redetermined.

In 1965, the Upper San Gabriel Valley Municipal Water District and the Los Angeles County Flood Control District initiated a program for spreading Colorado River water in the San Gabriel Valley Ground Water Basin. Because the amounts of water that will be used for this purpose do not constitute a firm supply but are dependent on the availability, after direct surface delivery, of Colorado River water, the effects of this spreading program on safe yield and overdraft were not considered.

In February 1965, the stipulation for judgment in the lawsuit "City of Long Beach et al., vs. San Gabriel Valley Water Company et al., Case No. 722647, Superior Court, Los Angeles County", was signed and filed by plaintiffs and defendants. In this suit the plaintiffs are the cities of Long Beach and Compton, and the Central Basin Municipal Water District, and the defendants are a number of cities and water agencies in the San Gabriel Valley. The judgment guarantees the plaintiffs an average annual usable supply of 98,415 acre-feet through Whittier Narrows. The effect of this on the overdraft and safe yield will be to fix the average seasonal outflow from the San Gabriel Valley in terms of the amount of water or equivalent amount of water in terms of dollars. This will tend to more or less make the amount of overdraft and safe yield dependent on the amount of fresh water imported into the area and the waste water exported from the area. Pursuant to one of the clauses in the stipulation for judgment, execution of the stipulation is in the process of validation. This judicial action is expected to be completed by the end of 1965.

CHAPTER VI. DEEP PERCOLATION OF FUTURE WATER SUPPLIES AND THE GROUND WATER BASIN MODEL

The operational-economic studies of the San Gabriel Valley Ground Water Basin that will follow this appendix can be undertaken with confidence only when the quantities of future inflow to the ground water reservoir from local and imported supplies are reasonable estimates. Although the estimates of the safe yield and overdraft of the valley provide a guide in management of the ground water basins, they do not provide a flexible tool for accurately estimating the future development in the basin under changing physical and cultural conditions. Consequently, criteria were developed to estimate deep percolation of future water supplies.

The ability to estimate the time-dependent fluctuation of ground water levels at various locations in the basin under a wide range of operating conditions is also a necessary requirement for reliable operational and economic analyses of alternative plans. To meet this requirement, a mathematical model of the ground water basin of the San Gabriel Valley was developed that could reliably simulate the hydraulic properties of the basin and, thus, enabled the engineers to estimate future ground water levels. In this chapter, a detailed discussion of the criteria of deep percolation and the mathematical model is presented.

Criteria for Deep Percolation of Future Water Supplies

The criteria for deep percolation of future water supplies were based mainly on the historical information and data developed in Chapters IV and V, and the knowledge gained from the mathematical model, which will be discussed in the next section. Deep percolation is the movement of water from the zone of aeration to the zone of saturation. In the San Gabriel Valley, the effects of water entering the intermediate belt are felt at the zone of saturation within a year. Because this time lag is not considered to be significant, deep percolation was assumed to be equal to percolation to the intermediate belt.

Total deep percolation was divided into four components: artificial recharge, streambed percolation, percolation of delivered water, and percolation of precipitation. Because artificial recharge depends only on the amount of water delivered to spreading grounds, a criterion for this component of deep percolation is not required, and criteria for only the remaining components of deep percolation were developed.

To account for different percolation rates in various parts of the area, the valley was divided into three areas, as shown on Figure 5. These areas, referred to as the "west", "center", and "east", have relative percolation rates of medium, high, and low, respectively. The boundaries of the areas, shown on Figure 5, were drawn along nodal polygon boundaries to permit the direct use of data from the mathematical model study. Criteria for percolation of delivered water and for percolation of precipitation were developed for each of these three areas.

Streambed Percolation

Flood control projects in the San Gabriel Valley have caused a reduction in stream channel area available for percolation of flood flows. Almost all of the stream channels tributary to the Rio Hondo and San Gabriel River have been improved with concrete sides and bottoms. The Rio Hondo

AREAS OF RELATIVE PERCOLATION RATES IN THE SAN GABRIEL VALLEY GROUND WATER BASIN

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1965

Channel has been lined for most of its reach; because of rising water, only a negligible amount of water percolates in the unlined reach, which is just above Whittier Narrows Dam. The only stream channel in which percolation will occur in the future is the San Gabriel River.

The San Gabriel River was the only stream for which a deep percolation criterion was developed. This criterion, which applies to the entire reach of the San Gabriel River in the San Gabriel Valley, is based on a relationship between seasonal net accretions to the river reach, the most significant parameter of percolation, and seasonal percolation in this reach. This relationship, shown on Figure 6, is applicable only to native waters. Native waters are considered as runoff from the tributary mountains and valley land of the river.

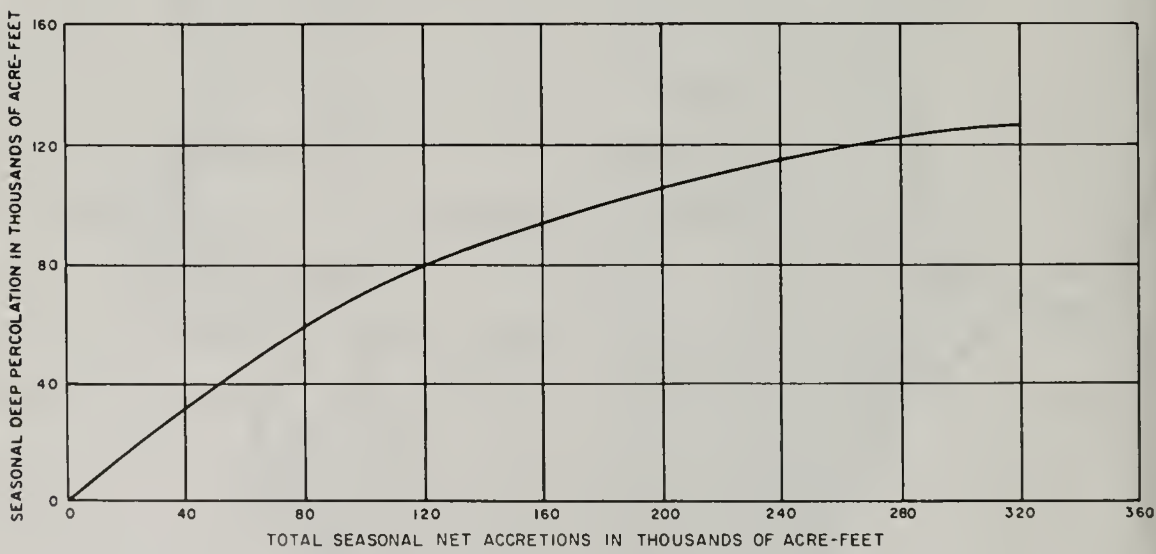


Fig. 6 CRITERION FOR DEEP PERCOLATION IN THE SAN GABRIEL RIVER IN THE SAN GABRIEL VALLEY GROUND WATER BASIN

Net accretions to the San Gabriel River were estimated from historical runoff data; overland flow to the river was considered negligible because of the small drainage area that is ungaged. Net accretions are composed of gaged inflow to the river reach near Azusa and gaged values of tributary stream inflow. Diversions were subtracted from total inflow to the river to obtain net accretions. Thus, percolation in the San Gabriel River is considered to equal net accretions less outflow of local waters, excluding rising water, in the San Gabriel River at Whittier Narrows. It is anticipated that the San Gabriel River will not be modified and will remain substantially as it is today; therefore, the percolation curve shown on Figure 6 will provide a basis for estimating quantities of future streambed percolation.

Percolation of Delivered Water

Historically, delivered water has been disposed of by waste water outflow from the basin, consumptive use of applied water, percolation in cesspools, percolation of irrigation water, and distribution line losses. Percolation in cesspools is largely dependent on the amount of water discharged to cesspools; consequently, no development of a percolation criterion for cesspools is necessary because it can be estimated directly from per capita sewage figures and population data.

Therefore, this section is concerned only with percolation of irrigation water which includes line losses for the total basin. The irrigated acreage, percolation rates, and irrigation practices determine the percolation of irrigation water. For this study, it was assumed that future irrigation practices will be the same as historic irrigation practices. Irrigated acreage is made up of irrigated agriculture, lawns, and ornamental shrubs.

As discussed in Chapter V, the irrigation efficiency for the entire valley was computed for the last five years of the base period because adequate pumped extraction data were available only for these years. Based on the irrigation efficiency computations in Chapter V, the deep percolation criterion for the total basin was assumed to be an average 37.5 percent of seasonal irrigation water. To determine the percentage of irrigation water percolating in each of the three regions of different relative percolation rates, data from the mathematical model study were analyzed in conjunction with the data for the total basin. These estimates yielded 40 percent, 48 percent, and 32 percent of seasonal irrigation water percolating in the west, center, and east regions, respectively. Hence, the percolation of irrigation water for future studies will be obtained by multiplying these percentages by the amount of irrigation water.

Percolation of Precipitation

Percolation of precipitation is defined as the percolation from rainfall on the land surface of the basin, excluding surface inflow and runoff that percolate in stream channels which are considered in streambed percolation. The parameters used in developing the seasonal percolation of precipitation criterion were seasonal amount of precipitation, pervious area available for rainfall penetration, and relative percolation rate.

Pervious area, the area where rainfall penetration can take place, was estimated from land use studies. During the base period, pervious area decreased from 87 percent of the total basin area in 1934 to 63 percent of the total basin area in 1960. The historic and future anticipated decrease in pervious area causes a decrease in the area available to percolation of precipitation. On the other hand, precipitation falling on impervious areas, such as roofs and driveways, often drains to pervious areas where it commingles with the precipitation falling directly on these areas and becomes available for percolation. Another factor which will increase the seasonal amount of percolation of rainfall is land use practices of leveling off the land and planting more shrubbery which impedes runoff, allowing more percolation to occur. The combination of these factors is somewhat compensating, making it difficult to evaluate the actual effects of cultural changes on the amount of seasonal percolation of precipitation. Historically, the net effect from land use change has been a slight decrease in the amount of seasonal percolation from precipitation. In future years, however, the decrease in the amount of percolation from precipitation because of land use change will probably be more pronounced.

The amount of water resulting from direct precipitation on pervious areas plus runoff from impervious to pervious areas is referred to in this appendix as "equivalent precipitation". In estimating equivalent precipitation, it was assumed that only impervious surfaces within residential single and residential rural land use classifications contribute runoff to the pervious areas of the valley. Runoff from impervious areas within all other land use classifications, such as commercial, industrial, residential multiple, streets, etc., was assumed to go into storm drains which then discharge the water directly into stream channels.

Seasonal percolation of precipitation, in feet, and seasonal equivalent precipitation, in feet, were estimated for pervious areas in each of the three areas, shown in Figure 5. The results of the estimates were plotted and curves of best fit were drawn through the data. Data

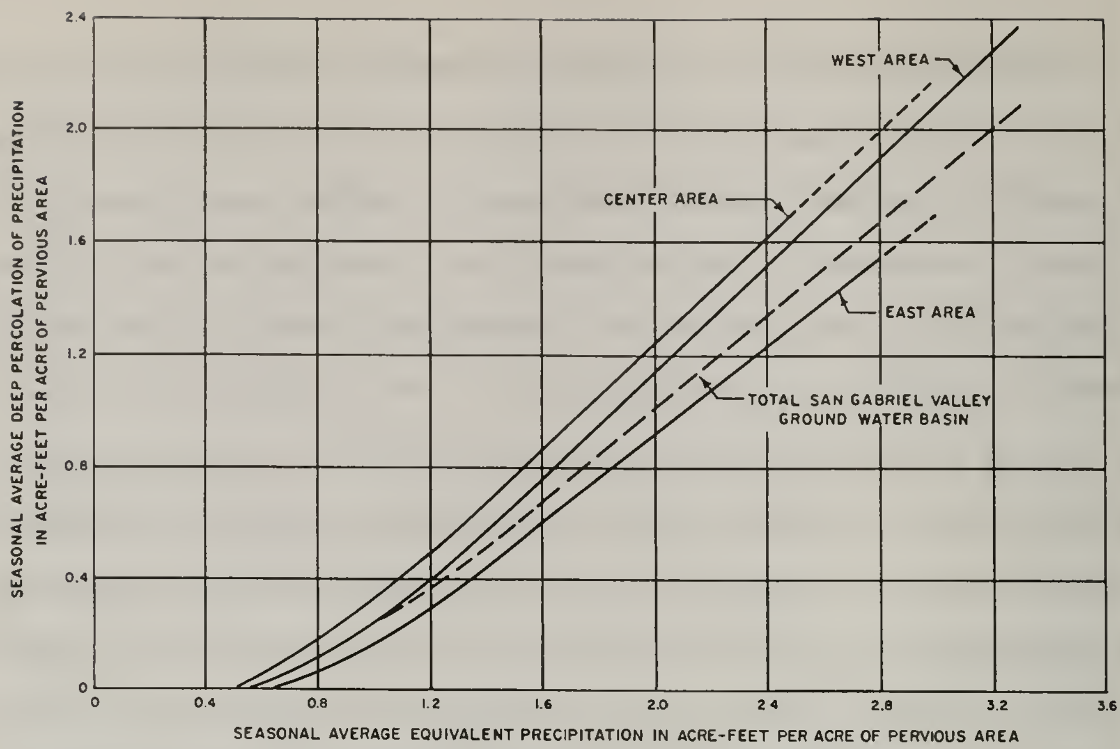


Fig. 7 CRITERIA FOR DEEP PERCOLATION OF PRECIPITATION IN THE SAN GABRIEL VALLEY GROUND WATER BASIN

deviated from the curves of best fit by only a small amount, which indicates that confidence can be placed in the data. These curves are shown on Figure 7. Examination of this figure will show that the curves are somewhat concave upward. Percolation curves should describe an "S" shape; however, in this case, the range of data was not great enough to define the upper portions of the curves.

It was concluded that the relationships developed are of sufficient accuracy to arrive at reasonable estimates of future percolation of precipitation.

Mathematical Model

The successful attainment of an optimum plan for operating a ground water basin in coordination with the overlying surface distribution and storage facilities requires a model that can reliably simulate the hydraulic properties of that basin. For use in the operational-economic phase of this investigation, a model of the ground water basin of the San Gabriel Valley was developed that integrated the storage and transmissive capabilities of the basin. A linear model was developed at the beginning of the investigation, utilizing available equipment and techniques; the more complex nonlinear model was developed at a later stage of the investigation, when more sophisticated equipment was available and more advanced techniques had been developed. The general procedures, followed in developing the model of the San Gabriel Valley, are given here.

Generalized Ground Water Equation

A generalized ground water equation that could define the storage, transmissive, and water inflow-outflow characteristics was first developed for the Los Angeles Coastal Plain study and was subsequently used for the San Gabriel Valley study. A discussion of the details of the computer application and the derivation of the generalized ground water equation is presented in Attachment 5 to Appendix C, Bulletin 104, "Planned Utilization of Ground Water Basins: Coastal Plain of Los Angeles County". The equation shown on Figure 8 defines the storage and transmissive characteristics of any unit area of the ground water basin. Figure 8 also shows the relation of the items in the equation. The symbol definitions are as follows:

h_i = water level elevation associated with node i, in feet

h_B = water level elevation associated with node B, in feet

$T_{i,B}$ = transmissibility at midpoint between nodes i and B, in $\frac{\text{acre-feet}}{\text{year foot}}$

$W_{i,B}$ = length of perpendicular bisector associated with nodes i and B, in feet

$L_{i,B}$ = distance between nodes i and B, in feet

A_B = area associated with node B, in acres

Q_B = flow rate net deep percolation per unit area at node B, in $\frac{\text{acre-feet}}{\text{year acre}}$

S_B = storage coefficient of polygonal zone associated with node B, (dimensionless)

t = time, in years

EQUATIONS

INFLOW − OUTFLOW = ± CHANGE IN STORAGE

$$\sum \left[\left(\frac{h_i - h_B}{L_{iB}} \right) T_{iB} W_{iB} \right] + A_B Q_B = A_B S_B \frac{dh_B}{dt}$$

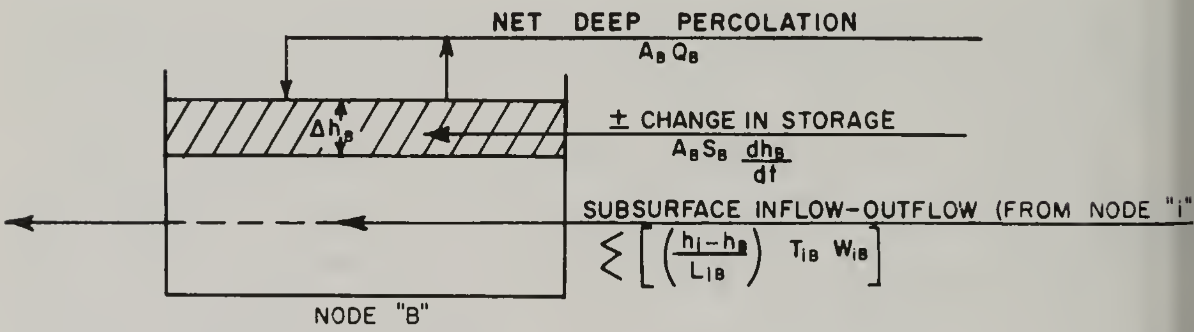


FIG.8 SCHEMATIC SKETCH OF GENERALIZED GROUND WATER FLOW EQUATION

The first term on the left-hand side of the equation is the summation of the subsurface flows between a given unit area and its surrounding areas. The second term describes the surface flow rate from the ground surface into or out of the zone of saturation of the given unit area. The rate of change in storage is given by the right-hand expression. A set of these differential equations, one for each unit within the basin, with proper coefficients, forms the mathematical model of the ground water basin.

Development and Verification of Mathematical Model

The general steps taken in developing the mathematical model and verifying its reliability were as follows:

1. The San Gabriel Valley Ground Water Basin was subdivided into subareas, called polygons, by using the Thiessen Method of polygon construction.

2. Geologic data were analyzed and the transmissive factors between polygons and the storage factors within each polygon were determined.

3. Historical surface hydrologic data were analyzed and the seasonal net deep percolation at each polygon was determined for the period 1949-50 through 1959-60. Also, hydrographs of representative ground water level fluctuations, during the same period, were prepared for each polygon based on measurements of historical ground water level elevations.

4. With the general purpose computer properly programmed and the problem parameters placed in the computer, the model was tested. The testing process consisted of matching the water level elevations generated by the computer, using historic hydrologic input data, with historic water level elevations.

5. Based on the information developed during the testing period, final verification was achieved when machine-computed water level elevations and historic water level elevations matched.

Determination of Number and Location of Control Nodes and Their Polygons. As stated above, the entire San Gabriel Valley Ground Water Basin was divided into subareas called polygons. In the computer analysis, each polygon was represented by a node. A 49-control-node network was used to simulate the ground water basin of the San Gabriel Valley. Although the number of control nodes could have been increased, the resulting increase in the accuracy of the results would not justify the increased expenditure for additional computer capacity. It is believed that the number of nodes used provided satisfactory basin coverage.

The determination of the sizes and locations of the 49 nodes was based upon variations in replenishment, extraction, transmission, storage, and water level factors. Nodes were concentrated in areas of large spatial rates of change in water level elevations to provide better overall control and results. The final nodal network used for the San Gabriel Valley is shown on Plate 23, entitled "Nodal Network and Vector Representation of Transmissibility Values Developed in the Mathematical Model".

In the areas north of the Duarte fault which are represented by nodes 38, 39, 40, an attempt was made to make the nodal boundaries coincide with the two faults that cross the basin in this area. The area to the north of the upper fault (node 39) is referred to as the Upper Canyon area. The area between the upper fault (node 39) and the Duarte fault (nodes 38 and 40) is called the Lower Canyon area.

The nodes in the Whittier Narrows area were located so that historic rising water could be simulated.

Prior to development of the 49-node model, a 14-node model of the study area was developed and tested. This smaller model was constructed to gain some insight into the dynamic behavior of the ground water system, with a minimum expenditure. After the results of the 14-node model had been fully analyzed, the development, testing, and verification of the 49-node model followed.

Determination of Transmissibility and Storage Factors. Results from the geologic investigation of the San Gabriel Valley were used to estimate the transmissive and storage factor values. Some 1,000 drillers' logs of water and oil wells located throughout the area were analyzed to delineate the water-producing zones and to obtain estimates of the hydraulic properties of these zones. Transmissibility and specific yield information from which transmissive and storage factors were developed are discussed in Chapter V.

Specific yield and transmissibility values were assigned to all water-bearing sediments. These values were the first estimates of the coefficients of storage and transmissibility used in the set of differential equations that make up the mathematical model of the San Gabriel Valley.

The transmissive factor (TW/L), which affects the subsurface flow between two nodes, was obtained by the following procedure:

1. Maps showing lines of equal transmissibility (T) were prepared for the saturated water-bearing section in the linear model and for the entire water-bearing section in the nonlinear model.

2. The average transmissibility value at the northeast corner of each section was obtained by interpolating between contour lines of equal transmissibility values.

3. From these maps, the appropriate value of transmissibility (T) of the water-bearing material at the midpoint of the line connecting any two nodes was obtained.

4. To obtain the transmissive factor (TW/L), the transmissibility value (T) was multiplied by the width (W) of the nodal boundary and divided by the length (L) of the flow path between nodes.

The transmissibility factors, associated with nodes 1, 2, 3, 5, 7, 8 and 20 representing Whittier Narrows, were made to change from some finite value to infinity at ground surface elevation to simulate the dynamics of rising water. This was achieved by fixing a limit on the water level elevation in those areas in which rising water occurred historically.

The storage factor (AS) is considered a measure of the storage characteristics at each nodal polygon. This factor is the product of the area (A) of the nodal polygon times the average specific yield (S) of the water-bearing sediments within that area. For this study, a specific yield value, representative of the zone in which anticipated water changes would take place, was determined for each node, and multiplied by the area of the nodal polygon. These representative specific yield values were obtained from data developed for the change in storage determinations made during the geologic phase of the investigation. The storage factor for each node is presented in Table 16. For this study, the storage factor was considered to be a constant.

The effect of a constant storage factor, set within reasonable limits on the water level responses, was negligible. In a test of the models, the difference in water level responses between uniform versus nonuniform storage factors was in the order of a few tenths of a foot. Therefore, handling of the storage factor as a constant was considered reasonable for the verification of the model.

TABLE 16

STORAGE FACTORS (AS) FOR THE
49-NODE MATHEMATICAL MODELS

Node number	Storage factor, in acre-feet per foot	Node number	Storage factor, in acre-feet per foot
1	56	26	382
2	103	27	434
3	127	28	412
4	100	29	391
5	112	30	345
6	122	31	158
7	225	32	157
8	348	33	259
9	475	34	119
10	258	35	204
11	159	36	205
12	435	37	200
13	258	38	70
14	211	39	99
15	264	40	159
16	424	41	261
17	533	42	400
18	561	43	313
19	449	44	130
20	297	45	111
21	233	46	45
22	385	47	103
23	228	48	107
24	338	49	67
25	316		

Preparation of Historical Net Deep Percolation and Water Level Elevation Data. Testing and verification of both mathematical models were achieved by the use of historical water supply, use, and disposal data described in Chapter IV. The seasonal amounts of net deep percolation for each nodal polygon were determined for the 11-year period from 1949-50 through 1959-60, using the following procedure:

1. A basin wide inventory was first made of the seasonal amounts of each of the components of water supply, use, and disposal. Then the seasonal surplus or deficiency in water supply was determined for the entire basin by summing the contributions of all the components. A preliminary balance was made between these items and the change in storage, which was calculated by the specific yield method. Details of these studies are discussed in Chapters IV and V.

2. The seasonal amounts of the items of water supply, use, and disposal, were distributed to nodal polygons, and deep percolation and pumped extractions estimated for each nodal polygon in the following manner

a. A factor expressing the amount of deep percolation of precipitation, as a percent of the amount of precipitation, was computed for the basin. The seasonal amounts of precipitation on each nodal polygon were then estimated by the Thiessen Method and multiplied by this factor to obtain deep percolation of precipitation for each node.

b. A factor expressing the amount of deep percolation of delivered water, as a percent of the amount of delivered water, was derived for the basin. The seasonal amount of delivered water for each nodal area was then determined by apportioning total basin-delivered water on the basis of land use. This figure was multiplied by the factor to obtain percolation of delivered water for each node.

c. Seasonal amounts of water spread in each nodal area were obtained from records of water spread at artificial recharge projects.

d. The seasonal amounts of stream percolation were determined for each reach between existing gaging stations, and apportioned to each node in direct proportion to the length of river channel traversing each nodal polygon.

e. Seasonal quantities from steps a, b, c, and d were added to obtain total deep percolation to the zone of saturation for the 11-year period, 1949-50 through 1959-60.

f. Pumped extractions for each square mile section were determined and were apportioned to each node.

3. The seasonal net surface inflow and outflow at each node was determined by subtracting step "f" from step "e", above. Graphs of net surface inflow were prepared for each node. For nodes on the periphery of the San Gabriel Valley Ground Water Basin, where subsurface inflow or outflow occurs, seasonal subsurface inflow was added to the net deep percolation and seasonal subsurface outflow was subtracted from the net deep percolation values. Thus, the seasonal net deep percolation (AQ) to each node is equal to total deep percolation to each node, minus extractions from each node.

Historical water well hydrographs and maps of lines of equal ground water level elevations for the 11-year period, 1949-50 through 1959-60, were used to develop representative seasonal ground water level elevations for each node in the system. These representative seasonal nodal water level elevations were used for comparison in the testing and verification of the mathematical model.

The techniques developed for the Los Angeles Coastal Plain study served as a starting point for the development of both a linear and a nonlinear system for the San Gabriel Valley. In order to check both programming techniques and data, the logical sequence for this study was to develop and conduct a few preliminary tests on the linear system, then proceed to the nonlinear system for final model testing and verification.

The linear system is represented by the generalized equation, shown on Figure 8. In converting to the nonlinear system, the transmissive factor $(\frac{TW}{L})$ becomes a function of water level change. Further, the nonlinear system requires three additional kinds of data:

1. The representative ground surface elevation at each node.

2. The representative base of the fresh water reservoir at each node.

3. The base of the fresh water reservoir at the branch connecting between two nodes.

In the linear system, the determination of the transmissive factor was based upon the thickness of alluvium between a mean value of the historic water level elevation and the base of the fresh water reservoir.

In the nonlinear system, a nominal transmissive factor was determined for the entire alluvial section, from the ground surface to the base of the fresh water reservoir. During the solution of the equations, the transmissive factor was continually recomputed, based on the mean water level elevation at the midpoint of the flow path between nodes. This was done by setting up a ratio between the total thickness of alluvium and the saturated thickness of alluvium at selected time intervals and then multiplying the nominal transmissive factor by that ratio to give the representative transmissive factor for that water level elevation.

In order to simplify the testing procedure, a digital plotting technique was developed. A plot tape was generated on the large computer simultaneously with the water level tabulations. The actual plotting was done on a high speed printer of a smaller computer. The plot consists of two curves plotting water levels, in feet, against time, in years.

Figures 9, 10, 11, and 12 show some representative water level plots and total rising water. The curve plotted with asterisks represents the computed water level elevations, the curve plotted with X's represents the historic water elevations. Having both curves on the same sheet allows rapid visual comparison. When one point falls upon another, the asterisk takes precedence.

Details of the program techniques developed for the model, using both the general purpose analog and general purpose digital computer, are presented in Attachments 5 and 6 to Appendix C, "Operation and Economics" to Bulletin 104, "Planned Utilization of Ground Water Basins: Coastal Plain of Los Angeles County".

Testing the Reliability of the Mathematical Model. Testing of the model consisted of matching the water level elevations generated by the computer for each node with hydrographs of historical water level elevations for the corresponding node. Although the initial water level responses from the computer matched historical water level elevations reasonably well in most areas, there were deviations in some areas. To obtain a closer match of the water levels in all areas, some of the values of storage factors, transmissive factors, and net deep percolation, were adjusted, based on the known sensitivity of the prototype. These changes were made within limits of the reliability of the data used in the development of the parameters.

A number of adjustments in the various factors were rapidly incorporated in the computer and the effects of these changes were graphically plotted. When the best overall match commensurate with the available data and equipment was achieved, the mathematical model was accepted

COMPT.	HIST.
251.0	251.0
248.0	248.0
246.8	245.0
245.4	244.0
243.6	243.0
242.2	242.0
241.7	241.0
242.1	242.0
243.4	244.0
244.7	246.0
245.4	248.0
245.4	247.0
244.7	247.0
244.0	247.0
243.3	247.0
242.9	246.0
242.6	246.0
242.4	245.0
242.0	245.0
241.4	244.0
240.6	243.0
239.8	242.0
239.1	242.0
238.4	241.0
237.9	240.0
237.5	239.0
236.9	238.0
236.3	237.0
235.6	236.0
235.5	234.0
236.6	233.0
238.8	239.0
242.4	245.0
245.5	252.0
247.2	258.0
247.4	256.0
246.2	253.0
244.4	251.0
242.6	247.0
240.7	245.0
238.7	242.0

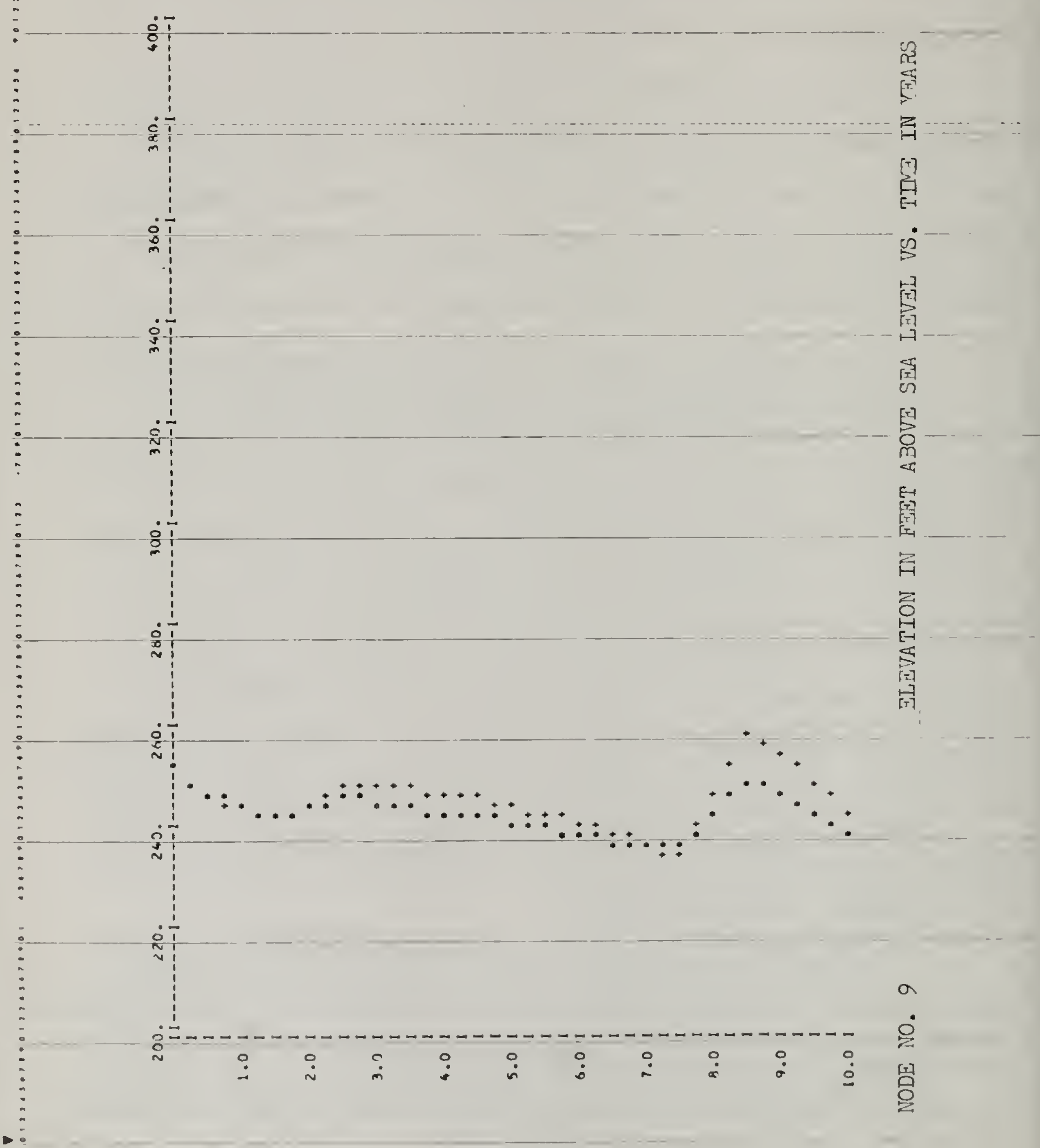
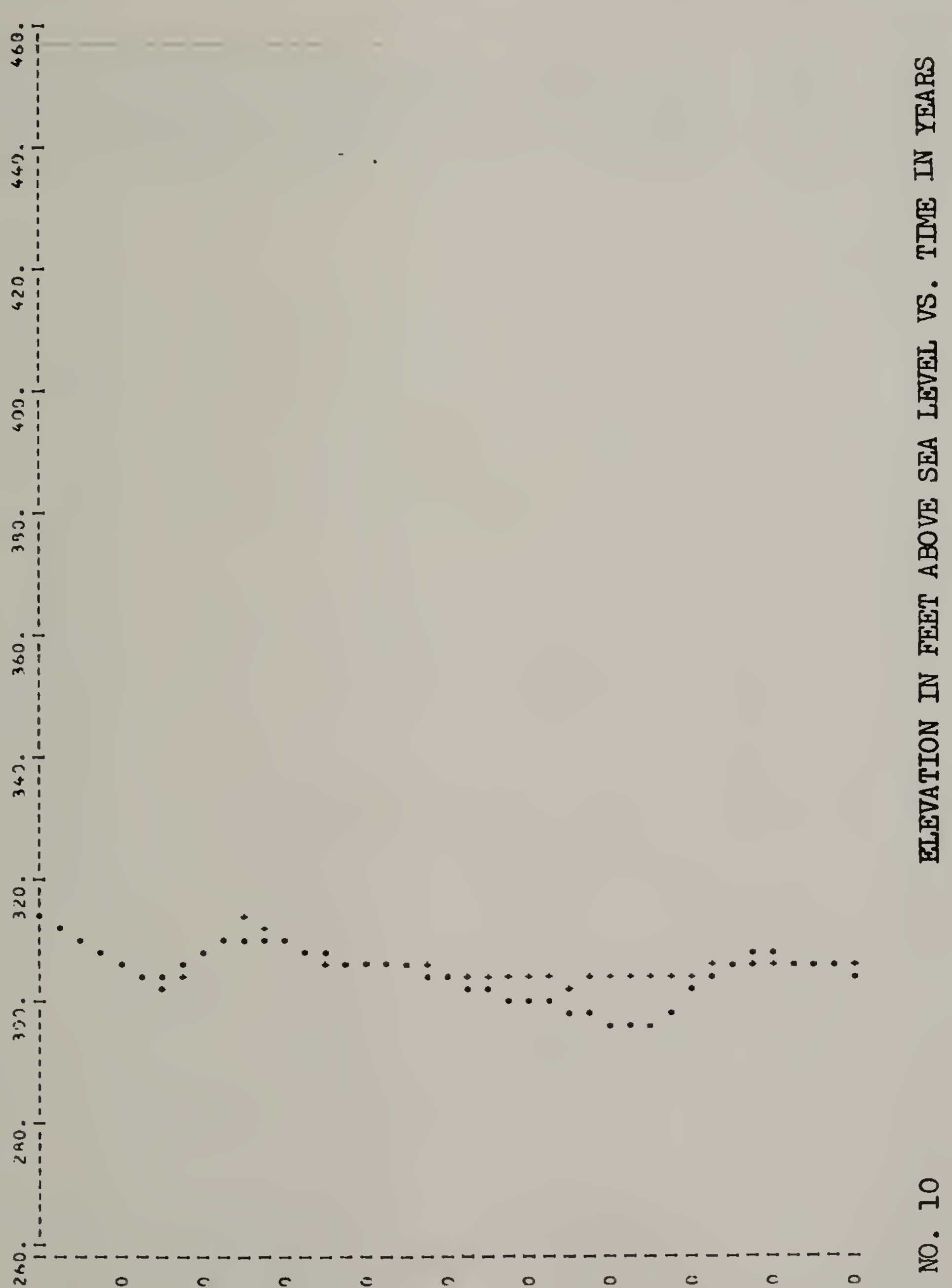
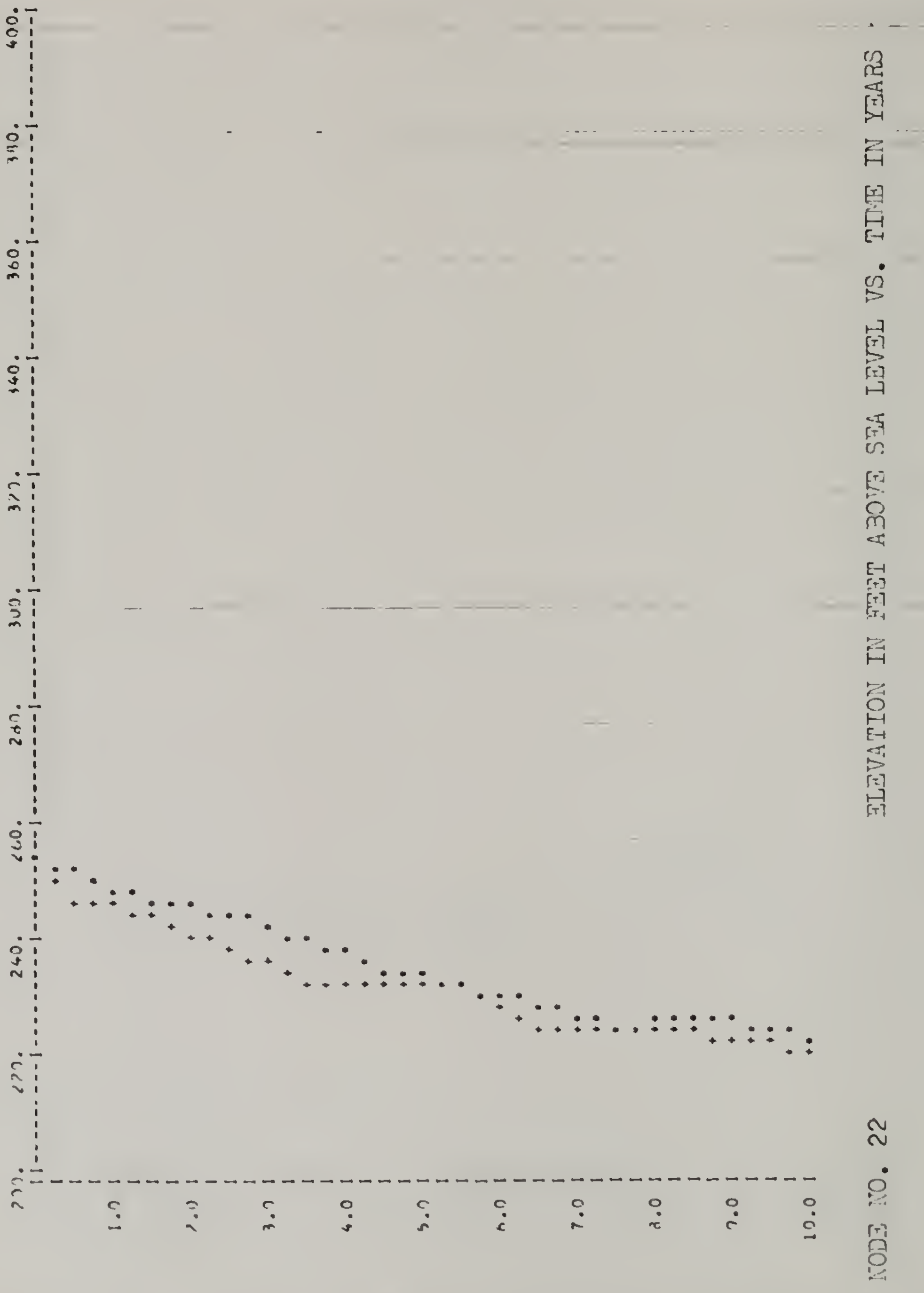


FIGURE 9 - COMPARISON OF CHANGE IN GROUND WATER LEVEL ELEVATIONS AT NODE 9 - DIGITAL COMPUTOR OUTPUT



COMPT.	HIST.
313.0	313.0
311.3	311.0
309.5	309.0
307.6	307.0
305.6	305.0
304.3	304.0
304.3	302.0
305.4	304.0
307.8	307.0
309.9	310.0
310.8	313.0
310.7	311.0
309.5	309.0
308.1	307.0
307.1	305.0
306.4	305.0
306.0	305.0
305.6	305.0
305.1	305.0
304.3	305.0
303.4	304.0
302.5	304.0
301.6	303.0
300.7	303.0
300.0	303.0
299.2	303.0
298.3	302.0
297.4	303.0
296.3	303.0
295.9	303.0
295.7	303.0
298.5	304.0
301.6	304.0
304.5	305.0
306.4	306.0
307.4	306.0
307.3	306.0
306.8	306.0
306.1	305.0
305.4	305.0
304.6	305.0

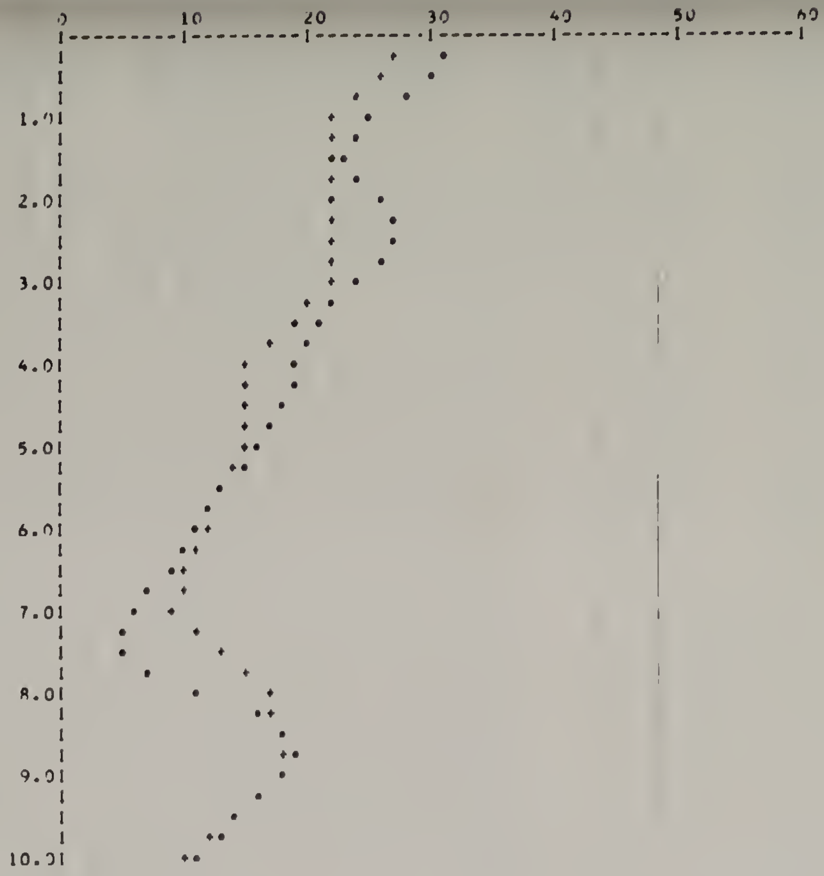
FIGURE 10 – COMPARISON OF CHANGE IN GROUND WATER LEVEL ELEVATIONS AT NODE 10-DIGITAL COMPUTOR OUTPUT



COMPT.	HIST.
253.0	253.0
252.1	250.0
251.1	246.0
250.0	245.0
248.7	245.0
247.5	244.0
246.5	243.0
245.8	242.0
245.2	240.0
244.6	239.0
243.9	238.0
243.0	236.0
241.9	235.0
240.8	234.0
239.6	232.0
238.4	232.0
237.1	232.0
236.0	231.0
234.9	231.0
234.0	231.0
233.1	231.0
232.4	231.0
231.6	231.0
230.9	229.0
230.2	228.0
229.5	226.0
228.5	224.0
227.5	224.0
226.2	224.0
225.3	223.0
224.8	223.0
224.7	223.0
225.2	223.0
225.6	223.0
225.7	223.0
225.6	222.0
225.2	222.0
224.6	222.0
224.0	221.0
223.3	220.0
222.6	220.0

FIGURE 11 — COMPARISON OF CHANGE IN GROUND WATER LEVEL ELEVATIONS AT NODE 22 — DIGITAL COMPUTOR OUTPUT

SURFACE FLOWS, IN THOUSANDS OF ACRE FEET



TOTAL RISING WATER CURVE

31049.4	27200.0
29666.2	25500.0
27715.0	23800.0
25361.1	22100.0
23523.1	21900.0
22973.9	21800.0
23614.9	21700.0
25574.0	21600.0
26711.8	21800.0
26725.9	21900.0
25823.6	22100.0
23921.3	22300.0
22170.7	20400.0
20869.5	18500.0
19861.2	16600.0
19135.1	14700.0
18614.3	14700.0
17953.0	15000.0
17151.7	15100.0
16136.4	15200.0
14831.7	14300.0
13441.0	13300.0
12112.8	12400.0
10896.2	11500.0
9933.2	10900.0
8767.9	10400.0
7350.8	9800.0
5777.7	9300.0
4607.5	11300.0
5169.2	13300.0
7441.8	15300.0
11358.2	17300.0
15666.8	17400.0
18143.0	17500.0
18870.8	17600.0
17739.9	17800.0
16089.6	15900.0
14463.0	14100.0
12759.7	12200.0
10982.2	10400.0

COMPUTED - HISTORIC

FIGURE 12 → COMPARISON OF HISTORIC AND COMPUTED RISING WATER AT WHITTIER NARROWS— DIGITAL COMPUTOR OUTPUT as fully representative of the San Gabriel Valley. The operational data obtained from this model is considered to be completely reliable for use in the operational-economic analyses of plans for ground water basin operation.

Hydraulic Characteristics of the Model

The information generated by the computer, during the testing period, provided valuable information regarding the hydraulic characteristics of the ground water basin. The principal observed conditions are discussed below.

The changes in storage factors within the limits of specific yield data did not cause significant changes in water level elevations. This was mainly due to the small differences in the water level elevations between beginning and end of the study period. Thus, the initial values of storage factors were not changed.

Computed transmissibilities compared fairly well with the initial input data. A vector representation of the transmissibility around each node is shown on Plate 23. As shown, the transmissibility is generally 1,500 to 2,500 acre-feet per year in the center of the basin and between 200 to 500 acre-feet per year in the peripheral areas. Much lower transmissibilities were found at the extreme east and west periphery of the basin. As shown on Plate 23, vectors were excluded from these areas of lower transmissibility because they could not be shown at the scale used for the plate. These values are representative of the saturated alluvial materials that existed during the test period.

Quite early in the testing period, a directional transmissibilit was found to be prevalent in the central portion of the basin; that is, higher transmissibilities exist in a north-south direction than in an east-west direction. This directional effect can be explained by the geologic condition of a rising mountain front contributing sediments to the south for an extended period. Deposition of the coarser material generally takes place in the central portion of the stream channel with the finer grained material being deposited in the peripheral areas. The result is considerably greater transmissive characteristics in the direction of deposition, from the north to south.

The eastern part of the basin did not show marked water level changes over short periods, as a result of large hydrologic changes made in the central portion of the basin. Therefore, for periods of five years or less, this portion of the model could have been simulated separately. This is mainly due to the generally lower permeability and also to the shallowness of the basin in this eastern area. For longer periods, hydrologic changes in any portion of the basin affect the remaining portions; this indicates that the San Gabriel Valley is one large interconnected hydraulic system.

Minor changes in representative ground surface elevation were made in the nodes in which rising water had occurred. The amount of rising water produced by the model was sensitive to changes in ground surface elevations. The rising water for the San Gabriel model is shown in Figure 12. The historic cumulative rising water for this period is about 191,000 acre-feet and the model's cumulative amount is 204,000 acre-feet.

The water levels and the rising water produced by the model compared favorably with the historic levels to which they were matched. Changes of historic input data to arrive at the model parameters were made well within limits of the data.

In summary, using the nodal network described and the parameters developed during the course of the detailed geologic and hydrologic studies, a reliable mathematical model of the ground water basin of the San Gabriel Valley was developed, tested and verified.

CHAPTER VII. SUMMARY OF FINDINGS AND CONCLUDING REMARKS

Summary of Findings

The San Gabriel Valley Ground Water Basin is an irregularly shaped structural trough bounded on the north by the San Gabriel Mountains and the Raymond fault, and surrounded on the other three sides by low hills. The entire study area covers about 488 square miles and contains about 167 square miles of water-bearing area.

The alluvial water-bearing deposits that constitute the ground water basin were derived chiefly from the granitic mountains to the north which were uplifted beginning with the late Pleistocene time and continuing to the present. The alluvial deposits are heterogeneous, averaging about 1,000 feet in thickness over the center of the basin, and varying from 200 to 400 feet in thickness in the peripheral areas.

The specific yield and transmissibility of the alluvial deposits vary throughout the basin. The average specific yield, from ground surface to base of fresh water, in the eastern end of the basin is approximately 8 percent. In the center and more permeable portion of the basin, the average specific yield is about 14 percent. In the western end of the basin, the average specific yield is approximately 9 percent. An average transmissibility of about 2,240 acre-feet per year per foot of width applies to most of the center of the basin. At Whittier Narrows--at the southwestern edge of the basin--the average transmissibility is about 670 acre-feet per year per foot of width. The average transmissibilities in the western and eastern portions of the basin are about 170 and 110 acre-feet per year per foot of width, respectively. Transmissibility is directional in the basin, being greater in the north-south direction than in the east-west direction.

Subsurface inflow to the San Gabriel Valley occurs from the Chino Ground Water Basin on the east, from the Raymond Ground Water Basin on the northwest, and from fractures in the San Gabriel Mountains on the north. During the 27-year base period, 1933-34 through 1959-60, the average subsurface inflow from the Chino Ground Water Basin was about 7,100 acre-feet a year; the average subsurface inflow from the Raymond Ground Water Basin was about 6,200 acre-feet a year; and the average subsurface inflow from the San Gabriel Mountains was about 5,000 acre-feet a year. The only location where subsurface outflow from the San Gabriel Valley is known to occur is at Whittier Narrows. During the base period, subsurface outflow through Whittier Narrows averaged about 28,400 acre-feet a year.

Total storage capacity in the San Gabriel Valley Ground Water Basin between ground surface and base of fresh water is about 9,500,000 acre feet. In 1960, about 7,900,000 acre-feet of water remained in storage. During the 27-year base period, there was a net decrease of 202,700 acre-feet in the amount of ground water in storage.

The seasonal amounts of water supply, use, and disposal were estimated for the 27-year base period from gaging station records, precipitation records, surface water delivery records, water well data, etc. Water supply to the basin was separated into four components: precipitation, surface inflow, fresh water import, and subsurface inflow which were 47 percent, 29 percent, 19 percent, and 5 percent, respectively, of the total average seasonal water supply of 345,700 acre-feet. Water use and disposal from the basin were separated into five components: consumptive use, surface outflow, net waste water export, fresh water export, and subsurface outflow which were 50 percent, 28 percent, 2 percent, 12 percent, and 8 percent, respectively, of the total average seasonal disposal of 353,200 acre-feet. Subtracting water use and disposal from water supply yielded an average seasonal water supply deficiency of 7,500 acre-feet. This water supply deficiency is the result of increased urbanization in the area and drought conditions that have prevailed in the southwestern United States for the past two decades. If 1960 conditions had prevailed throughout the base period, the average annual overdraft would have been 27,300 acre-feet and the corresponding average annual safe yield would have been 166,100 acre-feet.

In addition to the derivation of water supply, use, and disposal, quantities of ground water extractions and deep percolation were estimated. These estimates provided the basis for the determination of criteria for the deep percolation of future water supplies. Deep percolation criteria were developed for streambed percolation, percolation of delivered water, and percolation of precipitation.

To derive a working tool for the operational-economic studies, a mathematical model of the San Gabriel Valley Ground Water Basin was developed. This model was developed from geologic data and verified by the use of historical water supply and disposal and water level data. The mathematical model consists of the simultaneous solution of 49 differential equations which represent the transmissive and storage characteristics of the ground water basin. The model was developed by using large general-purpose analog and digital computers.

Concluding Remarks

This study was undertaken to provide the geologic and hydrologic information necessary to develop plans for the operation of the San Gabriel Valley Ground Water Basin. During the first, or geologic phase, the physical characteristics of the area were examined; the boundary conditions of the study area and the areal extent and thickness of the water-bearing series were determined; quantitative values were assigned to the transmissive and storage characteristics of the water-bearing alluvial deposits; and the volume of the subsurface flow into and through the ground water basin was computed. A mathematical model of the basin was also constructed during this phase and was ready for verification when the necessary hydrologic data were available.

In the hydrologic phase, a quantitative hydrologic inventory of the ground water basin was made. The historical amounts of seasonal water supply and disposal for the 27-year base period, 1933-34 through 1959-60, were determined; from this information, deep percolation, water supply surplus or deficiency, ground water overdraft, and safe yield were estimated. For the determination of future water supply to the basin, percolation criteria were developed from historical data.

It is concluded that the geologic and hydrologic phases accomplished their objectives, providing a firm base from which the operational-economic phase of the investigation may proceed toward the goal of optimum management of the San Gabriel Valley Ground Water Basin.

ATTACHMENT NO. 1

DEFINITION OF TERMS

DEFINITION OF TERMS

Acre-foot - The volume of water required to cover 1 acre 1 foot in depth (43,560 cubic feet or 325,851 gallons).

Anticline - A fold, or arch, of rock strata, dipping in opposite directions from a common axis.

Applied Water - The water delivered to a farmer's headgate or to an urban individual's meter, or its equivalent. Excludes precipitation.

Aquiclude - A geologic formation, or zone, which, although porous and capable of absorbing water slowly, will not transmit it rapidly enough to furnish an appreciable supply for a well or spring.

Aquifer - A geologic formation, or zone, sufficiently permeable to yield an appreciable supply of water to wells or springs.

Artesian Well - Any artificial hole made in the ground through which water naturally flows from subterranean sources to the surface of the ground for any length of time.

Artificial Recharge - For this study, the water that is added to the ground water basin through facilities primarily designed for that purpose, such as through spreading basins and injection wells.

Cienaga - A spring caused by an obstruction across an underground watercourse.

Confined Ground Water - A body of ground water that is immediately overlain by material sufficiently impervious to sever free hydraulic connection with overlying water, and that moves under gradient or pressure caused by the differences in head between the intake, or forebay, area and the discharge area of the confined water body.

Connate Water - Water entrapped in the interstices of a sedimentary rock at the time it was deposited. This water may be fresh, brackish, or saline in character. Because of the dynamic geologic and hydrologic conditions in California, this definition has been altered in practice to apply to water in older formations even though the water may have been altered in quality since the rock was originally deposited.

Consumptive Use of Water - Water consumed by vegetative growth in transpiration and building plant tissue, and water evaporated from adjacent soil, from water surfaces, and from foliage. It also includes water similarly consumed and evaporated by urban and nonvegetative types of land use.

Cultural Development - For this study, the state of man's activities, particularly the level of agricultural and urban growth, and the resulting physical structures affecting the supply, use, and disposal of water.

Deep Percolation - See Percolation, Deep.

Delivered Water - The sum of the applied water and any conveyance losses within a study area in delivering this water.

Drawdown - The change in water surface elevation in a well as the result of pumping ground water.

Free Ground Water - Water in interconnected interstices in the zone of saturation down to the first impervious barrier, moving under the control of the water table slope.

Ground Water - Subsurface water occurring in the zone of saturation and moving under control of the water table slope or piezometric gradient.

Ground Water Overdraft - For this study, the average annual decrease in the amount of ground water in storage that occurs during a long period of time, under a particular set of physical conditions affecting the suppl, use, and disposal (including extractions) of water in the ground basin. It is expressed as amount of ground water.

Ground Water Safe Yield - For this study, the average annual amount of ground water that could be extracted from a ground water basin over a long period of time without causing a net change in storage of ground water; the extractions must occur under a particular set of physical conditions affecting the supply, use, and disposal of water in the ground water basin.

Ground Water Storage - That stage of the hydrologic cycle during which water occurs as ground water in the zone of saturation, including that part of such stage when water is passing through the zone of aeration and entering or leaving storage.

Ground Water Table - See Water Table.

Hydraulic Gradient - Under unconfined ground water conditions, the slope of the profile of the water table. Under confined ground water conditions, the line joining the elevations to which the water would rise in wells if they were perforated in the aquifer.

Hydrology - The applied science concerned with the waters of the earth, their occurrences, distribution, use, and circulation through the unending cycle of precipitation; consequent runoff, infiltration, storage, use, and disposal; eventual evaporation; and reprecipitation. It is concerned with the physical and chemical reaction of water with the rest of the earth and with its relation to the life of the earth.

Hydrology, Ground Water - The branch of hydrology that treats of subsurface water--its occurrence, movement, and storage, and its replenishment and depletion--also, of the properties of unconsolidated materials and rocks that control the occurrence, movement, and storage of subsurface water, and of the method of investigation and utilization of subsurface water.

Impermeable - Impervious. Having a texture that does not permit water to move through it perceptibly under the head differences ordinarily found in subsurface water.

Infiltration - The flow or movement of water through the soil surface into the ground.

Percolation - The movement, or flow, of water through the interstices, or the pores, of a soil or other porous media.

Percolation, Deep - The movement of water into the zone of saturation from the intermediate belt.

Period - A specified division or portion of time.

a. Average. An arithmetical average relating to a period other than a mean period.

b. Base. A period chosen for detailed hydrologic analysis because prevailing conditions of water supply and climate are approximately equivalent to mean conditions, and because adequate data for such hydrologic analysis are available.

c. Mean. A period chosen to represent conditions of water supply and climate over a long series of years.

d. Seasonal. Any 12-month period other than the calendar year. In this study, seasonal period is synonymous to the runoff period, October 1 through September 30.

Permeability - The permeability (or perviousness) of rock is its capacity for transmitting a fluid. Degree of permeability depends upon the size and shape of the pores, the size and shape of their interconnections, and the extent of the interconnections.

Permeability, Field Coefficient of - The amount of water moving through a unit area of aquifer per unit time under unit hydraulic gradient at the natural temperature. Ordinarily, in gallons per day per square foot.

Permeability, Coefficient of - Same as above, except that reference temperature of 60 degrees Fahrenheit is defined. Other units are also used, such as: cubic feet per second per square foot, acre-feet per year per square foot, etc.

Permeable - Pervious. Having a texture that permits water to move through it perceptibly under the head differences ordinarily found in subsurface water.

Piedmont Slope - The series of coalescing fans produced when two or more streams flow out from a highland and, closely adjacent to one another, deposit sediment. This sloping plain is relatively high near the highland and lower further out and is composed of a series of fans in whose growth there has been mutual interference.

Rising Water - Ground water from the zone of saturation which rises to the ground surface, usually to a streambed, when the ground surface is at a lower elevation than the ground water table or the piezometric surface of a confined aquifer.

Safe Yield - See Ground Water Safe Yield.

Soil - For this study, the mixture of decomposed, divided rock material and small amounts of organic matter occurring at the surface of the land; its thickness is variable, ranging from a few inches to more than 6 feet.

Specific Yield - The ratio of the volume of water a saturated sediment will yield by gravity drainage to the total volume of the sediment and water prior to draining, customarily expressed in percent.

Storage Coefficient - Volume of water released from storage in each vertica column of aquifer having a base 1 foot square when the water level declines 1 foot. In an unconfined aquifer it approximates specific yield. In a confined aquifer it is related to elasticity of the aqui and is usually very small.

Subsurface Water - All water that occurs beneath the earth's surface, including that which occurs in the zone of aeration and in the zone o saturation.

Syncline - A fold in rocks in which the strata dip inward from both sides toward the axis.

Thiessen Method - A method used to determine the amount of precipitation o an area by constructing polygons or areas of influence about each gaging station. The polygon is formed by the perpendicular bisectors of the straight lines joining adjacent gaging stations. When using this method, it is assumed the depth of precipitation within the polyg is equal to the depth of precipitation at the corresponding gaging station.

Transmissibility, Coefficient of - The rate of flow of water, expressed in gallons per day, at the prevailing water temperature through each ver cal strip, 1 foot wide, having a height equal to the thickness of the aquifer, and under a unit hydraulic gradient.

Transpiration - The exhalation of water vapor from the stomata of plant leaves and other surfaces.

Unconfined Ground Water - Ground water that is not immediately overlain by impervious materials and that moves under control of the water table slope.

Unconformity - A surface of erosion or nondeposition, usually the former, that separates younger strata from older rocks.

Vadose Water - Subsurface water occurring in the zone of aeration.

Water Table - The surface of ground water at atmospheric pressure in an unconfined aquifer. This is revealed by the levels at which water stands in wells penetrating the unconfined aquifer.

Water Supply Surplus or Deficiency - For this study, the difference between the inflow to, and the outflow from, a ground water basin during any given period. The outflow of water includes the consumptive use of water. A water supply surplus results when the inflow is greater than the outflow and a water supply deficiency results when the inflow is less than the outflow.

ATTACHMENT NO. 2

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BIBLIOGRAPHY

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*Indicates sources used in compiling areal geology map, Plates 9A and 9B.

ATTACHMENT NO. 3

PRECIPITATION STATIONS
AND
SEASONAL DEPTH OF PRECIPITATION

TABLE 3-1

LOCATION OF SELECTED PRECIPITATION STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY

Station number[a]	Station name	Location[b]
63 B-E	Big Santa Anita Dam	Santa Anita Dam at caretaker's house
66	Sierra Madre - Peglar Ranch	415 Orange Grove Avenue, Sierra Madre
67 D	Monrovia - New Post	119 West Palm Avenue, Monrovia
68 B	Sawpit Dam	Sawpit Dam near right abutment
69 B	Sawpit Canyon	Sawpit Canyon, one mile north-east of Sawpit Dam
70 C	San Gabriel Canyon - Wade	San Gabriel Canyon near mouth, 0.15 miles east of Robert's Canyon
73	Glendora - Englewild Ranch	Mouth of Englewilde Canyon, Glendora
76 B	San Gabriel Dam Camp	San Gabriel Canyon above San Gabriel Dam
87	San Dimas Guard Station	9292 N. Mainfork, San Dimas Canyon Road
89 B-E	San Dimas Dam	San Dimas Canyon below dam at caretaker's house
90	Elder Ranch	6025 Brydon Road, La Verne
94 B	Charter Oaks - Mayo	Bonnie Cove Drive and Arrow Highway, Covina
95	San Dimas Fire Warden	114 East First Street, San Dimas
96 B-E	Puddingstone Dam	Puddingstone Dam at caretaker's house
98	Azusa - Hibsch	325 East Foothill Boulevard, Azusa

LOCATION OF SELECTED PRECIPITATION STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

Station number[a]	Station name	Location[b]
101 B	West Covina - Hurst Ranch	Southwest corner Merced Avenue and Orange Avenue, West Covina
102 B	Walnut Patrol Station	19711 East Valley Boulevard, Walnut
104	No. Whittier - Cole Ranch	14570 East Orange Grove Avenue, La Puente
108 C	El Monte Fire Station	119 South Hoyt Avenue, El Monte
109 D	West Arcadia	7225 North Rosemead Boulevard, Arcadia
110	Alhambra - City Hall	7 North Second Street, Alhambra
111	South Pasadena - City Hall	1414 Mission Street, South Pasadena
134	San Dimas - Stevens	North of Foothill, west of San Dimas Canyon Road, San Dimas
144	Sierra Madre Dam	Below Sierra Madre Dam
158	Tanbark Flats	West Fork San Dimas Canyon, Tanbark Flats
170 C	Potrero Heights	1140 North Walnut Grove Avenue, San Gabriel
171 B	Chapman Wells	South of Colorado Street at Michillinda Avenue, Pasadena
174	Glendora - Warren	310 Amelia Avenue, Glendora
181 B	Bassett - Clifford	13010 East Valley Boulevard, La Puente
185	Glendora - West	460 East Bennett Street, Glendora

LOCATION OF SELECTED PRECIPITATION STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

Station number[a]	Station name	Location[b]
188 C	San Dimas - Morrison	961 San Dimas Canyon Road, San Dimas
193	Covina No. 2 - Temple	19248 Puente Street, Covina
201	Puente Hills - Alta Mira Ranch	3075 Turnbull Canyon Road, La Puente
206	Valencia Heights	1126 South Azusa Avenue, Valencia Heights, West Covina
223 B-E	Big Dalton Dam	Below Big Dalton Dam at caretaker's house
227 D	San Gabriel - Bruington	636 West Hermosa Drive, San Gabriel
254 B	Puente - Rowland Ranch	16838 Valley Boulevard, La Puente
255 C	Mount San Antonio College - Spadra	San Jose Hills near Spadra, Mt. San Antonio College
263 F	Pomona - Rivera	West of Park Avenue, 2 miles south of Fifth Street, Pomona
265 D	Puente Hills - Weisel Ranch	1500 Fullerton Avenue, Puente Hills
269 B	Diamond Bar Ranch - Horse Camp	Diamond Bar Ranch No. 2, Horse Camp, Brea Canyon Road
275	San Marino Huntington Library	1151 Oxford Road, San Marino
290 B	Monterey Park - Fire Station	2001 South Garfield Avenue, Monterey Park
294 B	Sierra Madre - Mira Monte Pumping Plant	Mira Monte Avenue and Mt. Wilson Road, Sierra Madre
304	Sawpit Canyon - Deer Park	Deer Park, 1.5 miles above Sawpit Dam

LOCATION OF SELECTED PRECIPITATION STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

Station number[a]	Station name	Location[b]
312	Azusa Plant - Glendora Irrigation Company	One mile northwest of Azusa, 17015 Sierra Madre, Azusa
339	Walnut Fruit Growers Association	0.5 mile southeast of Walnut, 20651 East Lycoming Road, Walnut
347 E	Baldwin Park Experimental Station	Scott Place, one block west of Main Street, Baldwin Park
380	El Sereno - Morgan	4566 Bedillion Street, El Sereno
387 B	Covina Sewage Plant	227 South Hollenbeck Avenue, Covina
389 B	Glendora - Brown	229 West Sierra Madre Avenue, Glendora
390 B-E	Morris Dam	Morris Dam, San Gabriel Canyon
406 C	West Azusa - Azusa Irrigation Company, Plant No. 6	17018 East Gladstone Street, West Azusa
432	Santa Anita - Fern Lodge	Santa Anita Canyon, Fern Lodge
445 B	Live Oak Dam	Live Oak Dam, north of La Verne
477 C	Santa Anita - Spring Camp	Spring Camp at head of East Fork - Santa Anita Canyon
480 B	Temple City Fire Station	5946 Kauffman Avenue, Temple City
627	San Gabriel Canyon Power House	Mouth of San Gabriel Canyon at powerhouse
679	Puente - North Whittier Heights Citrus Association	749 Ninth Avenue, City of Industry
719	Duarte - Maddocks	Maddocks Ranch, north end of Los Lomas Avenue, Duarte

LOCATION OF SELECTED PRECIPITATION STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

Station number[a]	Station name	Location[b]
724	Big Dalton - Monroe Canyon Flume	Near Mouth of Monroe Canyon, above Big Dalton Dam
732 B	Robert's Canyon - San Gabriel West Fork Divide	Between Robert's Canyon and San Gabriel-West Fork, near Pine Mountain[c]
740 B	San Dimas Canyon - Fern No. 2	San Dimas Canyon, Fern Canyon
741	San Dimas Canyon - Upper East Fork	San Dimas Canyon, Upper East Fork
742 C	San Gabriel - Fire Department	Del Mar near Mission Street, San Gabriel
1041 B	Santa Fe Dam	Santa Fe Dam east of spillway, south of Monrovia

a. Los Angeles County Flood Control District designation.
b. Station locations delineated on Plate 4.
c. Located outside the area covered by Plate 4.

TABLE 3-2

SEASONAL DEPTH OF PRECIPITATION AT SELECTED STATIONS IN AND ADJACENT TO THE SAN GABRIEL VALLEY

In inches

Season[a]	Station number[b]							
	63B-E	66	67D	68B	69B	70C	73	76B
1933-34	22.40	21.98	21.97[c]	24.23	27.48	22.24	25.11	24.71
34-35	28.70	28.28	23.02[d]	25.41	32.77	28.60	28.14	32.82
1935-36	20.29	19.20	18.89[d]	19.91	27.49	20.06	20.77	24.61
36-37	36.26	35.69	31.53[d]	34.00	44.24	34.52	35.63	43.97
37-38	36.97	35.06	32.43[d]	42.93	47.24	37.30	36.37	47.98
38-39	26.59	23.01	22.80[d]	26.00	31.90	23.85	21.55	28.19
39-40	21.22	18.37	16.85[d]	20.46	24.64	18.60	18.84	19.11
1940-41	47.29	43.46	42.75[d]	46.83	54.14	43.90	42.38	52.50
41-42	18.24	15.76	15.80[d]	18.32	21.64	16.09	14.96	17.74
42-43	48.63	36.05	32.49[d]	29.76	53.02	33.36	32.87	47.57
43-44	28.60	24.60	23.62[d]	28.76	34.62	25.10	26.50	31.97
44-45	22.75	18.74	18.67[d]	24.31	28.14	21.35	24.49	26.90
1945-46	20.21	16.53	17.17[d]	21.58	25.01	20.90	22.91	29.13
46-47	24.17	21.65	19.82[d]	25.84	31.07	21.18	19.74	28.52
47-48	12.24	11.59	10.70[d]	13.33	14.69	10.90	12.27	13.51
48-49	15.35	12.26	12.20[d]	16.73	19.17	14.59	15.38	14.53
49-50	19.07	16.38	15.12	20.25	21.59	17.28	17.50	20.14
1950-51	13.95	12.21	11.25	14.85	15.38	12.88	13.16	11.34
51-52	40.00	36.75	34.47	41.74	45.52	37.62	34.00	46.10
52-53	16.07	13.81	12.39	16.12	17.18	14.34	13.81	15.52
53-54	20.52	17.33	17.03	19.75	21.63	20.75	21.16	25.23
54-55	17.57	15.39	15.44[c]	19.78	21.00	16.63	17.72	20.06
1955-56	21.26	20.76	20.42	22.61	24.00	22.49	21.63	22.04
56-57	19.08	16.71	13.28	20.01	21.81	18.31	18.00	21.78
57-58	34.66	31.76	33.69	36.28	41.39	35.73	37.22	45.90
58-59	12.23	12.55	10.93	13.08	13.85	12.59	11.85	15.27
59-60	13.28	11.91	12.11	14.02	15.85	13.50	12.64	14.56
27-Year Average	24.37	21.77	20.62	24.33	28.76	22.77	22.84	27.47

SEASONAL DEPTH OF PRECIPITATION AT SELECTED STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In inches

Season[a]	Station number[b]							
	87	89B-E	90	94B	95	96B-E	98	101B
1933-34	23.37	24.59	21.55	18.99	19.74[d]	19.20	24.77	18.80
34-35	30.62	27.50	26.08	27.30	24.08[d]	22.68	25.82	23.14
1935-36	21.42	21.05	20.02	15.98	15.00[d]	14.55	17.17	14.16
36-37	31.76	36.27	35.65	28.72	30.21[d]	27.71	29.76	26.69
37-38	35.67	36.76	34.51	27.70	27.02[d]	27.34	29.95	25.88
38-39	26.15	20.44	24.16	20.43	17.44[d]	18.39	20.57	19.96
39-40	20.87	18.65	18.11	16.69	16.11	14.58	15.71	15.71
1940-41	41.46	37.71	39.40	36.66	37.92	36.96	38.37	37.80
41-42	15.15	14.62	14.89	11.97	12.61	12.31	13.82	15.34
42-43	37.12	37.03	34.47	27.96	28.49	23.87	28.49	23.02
43-44	26.83	25.00	25.04	22.45	21.42	18.78	24.19	20.94
44-45	27.83	24.96	25.60	19.11	19.40	17.01	19.33	15.77
1945-46	22.18	19.37	16.54	16.18	16.05	14.98	17.93	14.01
46-47	22.57	20.69	19.61	16.40	15.07	14.30	16.33	16.04
47-48	12.86	11.63	11.58	11.67	10.53	10.31	10.29	9.26
48-49	16.08	16.08	14.86	13.72	11.93	12.80	12.18	10.92
49-50	19.22	17.93	17.37	13.95	14.00	14.08	14.72	12.19
1950-51	11.04	11.71	11.39	11.69	9.63	9.53	10.80	9.37
51-52	37.23	34.41	34.14	32.15	29.01	27.45	32.10	29.23
52-53	15.52	15.07	15.43	12.37	12.54	11.87	12.31	11.43
53-54	22.17	21.30	19.82	16.98	17.50	16.45	17.32	15.80
54-55	16.35	15.08	15.39	14.09	13.29	12.17	14.19	12.03
1955-56	20.07	19.43	18.98	18.21	16.44	15.84	19.57	15.45
56-57	17.81	17.35	17.99	14.83	14.60	12.62	15.64	12.53
57-58	43.33	40.38	40.73	34.84	34.25	31.92	31.71	28.13
58-59	11.85	10.91	10.12	9.63	9.58	8.04	11.41	8.09
59-60	11.22	12.40	12.44	10.59	10.35	10.17	10.79	9.81
27-Year Average	23.62	22.53	22.07	19.31	18.67	17.63	19.82	17.46

SEASONAL DEPTH OF PRECIPITATION AT SELECTED STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In inches

Season[a]	Station number[b]							
	102B	104	108C	109D	110	111	134	144
1933-34	13.34[d]	18.22	13.65[d]	21.69[d]	18.23	21.82	23.13	23.76
34-35	20.26[d]	24.20	24.88[d]	25.28[d]	26.33	23.98	25.02	30.02
1935-36	11.77[d]	14.59	14.68[d]	16.31[d]	16.92	15.42	17.17	20.79
36-37	23.87[d]	28.45	27.34[d]	27.85[d]	27.10	25.93	32.71	36.98
37-38	23.71[d]	27.69	27.87[d]	30.94[d]	30.16	28.15	31.41	39.22
38-39	19.84[d]	20.21	18.82[d]	20.24[d]	22.55	20.27	18.99	25.04
39-40	13.63[d]	15.30	15.29[d]	15.72[d]	15.87	16.13	16.82	19.49
1940-41	33.43[d]	36.80	40.83[d]	41.43[d]	41.01	42.01	40.42	48.85
41-42	12.64[d]	15.62	14.58[d]	14.12[d]	16.92	15.93	12.52	16.63
42-43	22.77	25.72	24.23[d]	26.72[d]	29.21	28.94	31.67	45.65
43-44	17.11	21.69[d]	22.50[d]	23.87[d]	23.77	21.33	22.71	27.30
44-45	16.15	17.64[d]	15.40[d]	16.67[d]	15.58	14.46	22.55	21.37
1945-46	13.11	16.52[d]	14.58[d]	15.68[d]	15.42	15.11	17.05	20.13
46-47	13.88	17.51[d]	16.68[d]	19.52[d]	20.32	20.37	16.53	25.28
47-48	9.55	9.94[d]	10.86[d]	11.10	10.92	9.69	10.99	12.60
48-49	9.24	12.08[d]	11.41[d]	10.64	9.97	10.84	14.59	14.79
49-50	11.97	12.88[d]	14.79[d]	14.13	15.11	13.47	15.62	19.75
1950-51	9.24	9.18[d]	9.59[d]	10.22	9.56	9.56	10.79	13.05
51-52	28.16	30.37[d]	30.44[d]	36.37	32.98	32.83	31.29	38.29
52-53	11.31	13.11	12.18[d]	12.72	13.27	11.70	13.85	14.83
53-54	15.44	17.43	13.97	16.25	15.45	14.90	18.40	19.62
54-55	12.27	13.47	13.92	13.07	14.24	13.82	15.41	17.95
1955-56	13.46	17.81	17.63	17.64	19.24	17.95	18.34	21.50
56-57	10.12	12.12	14.54	12.87	13.53	13.89	16.47	18.00
57-58	27.77	29.99	27.73	28.10	29.53	29.27	36.20	35.05
58-59	7.52	9.29	7.56	9.94	8.43	8.00	9.57	12.99
59-60	9.98	11.37	11.50	10.29	11.66	10.14	12.19	12.73
27-Year Average	15.98	18.49	18.05	19.24	19.38	18.74	20.46	24.14

SEASONAL DEPTH OF PRECIPITATION AT SELECTED STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In inches

Season[a]	Station number[b]							
	158	170C	171B	174	181B	185	188C	193
1933-34	24.61	17.42	23.43	24.14	13.79	26.80	21.78[d]	18.63
34-35	34.80	24.44	26.41	27.68	21.00	27.97	24.18[d]	22.90
1935-36	25.21	12.48	17.49	18.27	12.55	18.52	16.97[d]	13.95
36-37	43.28	23.25	31.99	32.90	24.81	34.23	32.41[d]	25.64
37-38	47.83	26.84	32.14	32.14	24.65[c]	31.69	30.24[d]	25.65
38-39	27.45	19.32	22.32	20.69	17.68[c]	20.81	18.43[d]	19.64
39-40	21.99	15.40	16.59	17.28	13.98	17.03	15.07[d]	13.97
1940-41	48.23	36.93	41.36	41.19	36.49	40.54	39.44[d]	36.15
41-42	16.65	13.71	15.30	13.02	13.16	13.51	12.67[d]	12.57
42-43	45.23	21.84	33.53	26.76	21.01	29.95	30.34	24.01
43-44	34.46	23.21	23.85	23.27	19.85	24.44	21.63	21.77
44-45	29.89	13.20	17.87	22.47	14.20	21.22	20.05	15.96
1945-46	26.85	12.72	15.71	17.34	12.79	20.14	16.38	13.72
46-47	27.68	15.55	21.16	16.92	15.59	18.28	15.90	14.60
47-48	15.83	10.06	11.24	12.52	9.54	12.30	10.54	11.60
48-49	16.94	10.59	11.75	15.24	10.60	14.14	13.76	11.87
49-50	20.78	13.71	15.83	15.77	11.68	16.19	14.39	13.21
1950-51	11.47	8.24	11.24	11.30	8.22	10.95	9.51	9.85
51-52	41.11	27.28	34.25	33.06	24.91	33.42	29.36	29.18
52-53	15.47	11.30	13.45	13.18	11.03	13.21	12.78	11.66
53-54	24.92	14.46	17.03	17.88	14.32	19.46	17.95	15.47
54-55	19.94	12.89	14.53	14.72	12.72	15.28	13.57	12.97
1955-56	20.16	17.15	18.75	16.51	14.28	20.04	16.97	15.41
56-57	19.81	10.87	15.30	15.90	10.76	16.23	14.65	13.40
57-58	48.14	27.41	30.53	37.95	26.02	34.99	35.03	32.59
58-59	14.31	7.03	11.34	9.63	7.95	10.22	9.01	8.51
59-60	13.93	9.60	11.21	11.61	9.42	11.46	10.36	10.42
27-Year Average	27.30	16.92	20.58	20.72	16.04	21.22	19.38	17.60

SEASONAL DEPTH OF PRECIPITATION AT SELECTED STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In inches

Season[a]	Station number[b]							
	201	206	223B-E	227D	254B	255C	263F	265D
1933-34	17.76[d]	13.53	25.10	22.30	15.09	19.07[d]	13.97	14.16
34-35	24.65[d]	23.35	30.91	23.16	24.39	23.69[d]	21.19	24.67
1935-36	15.12[d]	12.27	21.57	15.78	13.07	14.04[d]	13.09	12.40
36-37	30.38[d]	24.93	39.80	25.24	26.16	27.29[d]	29.27	26.76
37-38	28.93[d]	26.16	40.44	29.17	24.44	26.86[d]	24.77	24.35
38-39	18.40[d]	17.72	24.87	20.80	19.13	19.50[d]	19.62	19.38
39-40	15.24[d]	14.35	21.45	15.29	15.03	15.69[d]	13.64	14.96
1940-41	38.92[d]	35.93	46.24	39.58	36.82	38.72[d]	37.13	34.49
41-42	14.83[d]	12.57	16.16	15.36	13.64	12.89[d]	12.87	13.70
42-43	25.00[d]	21.83	39.19	28.82	21.82	24.43[d]	24.69	22.41
43-44	21.76[d]	18.95	29.78	23.95	21.74	20.79[d]	18.60	18.26
44-45	16.35[d]	15.28	29.30	14.11	15.92	16.57[d]	15.00	18.01
1945-46	16.45[d]	13.02	23.70	14.29	13.21	14.58[d]	13.51	12.53
46-47	15.71	14.06	25.73	18.44	16.99	14.41[d]	13.34	12.85
47-48	10.30	9.46	14.60	11.24	10.31	10.16	8.59	8.68
48-49	10.47	10.87	18.44	9.95	9.36	10.88	10.25	9.35
49-50	13.14	11.52	20.81	14.23	12.15	13.36	11.12	12.73
1950-51	9.74	9.62	13.53	9.84[c]	8.62	9.65	9.51	10.68
51-52	32.26	28.89	41.87	33.58	26.44	27.93	27.36	29.94
52-53	11.87	11.21	16.09	12.60	10.55	12.28	12.05	11.71
53-54	16.94	14.72	23.39	14.96	13.83	15.70	14.69	15.25
54-55	12.81	12.22	18.21	13.35	13.11	12.70	12.15	11.28
1955-56	17.82	14.77	22.40	18.32	14.80	14.75	14.07	16.24
56-57	12.02	11.81	20.28	13.50	10.88	11.45	10.68	10.89
57-58	28.52	28.58	44.62	28.14	29.88	32.40	33.09	27.28
58-59	8.38	7.79	13.54	8.95	7.96	8.15	7.55	6.59
59-60	10.62	9.90	14.51	10.03	10.61	10.98	9.45	9.51
27-Year Average	18.31	16.49	25.80	18.70	16.89	17.74	16.71	16.63

SEASONAL DEPTH OF PRECIPITATION AT SELECTED STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In inches

Season[a]	Station number[b]						
	269B	275	290B	294B	304	312	339
1933-34	14.71	21.25	16.15[d]	24.37	29.82	26.33	14.93
34-35	22.82	26.08	22.96[d]	29.14	40.88	25.82	25.20
1935-36	14.16	17.10	13.11[d]	20.64	32.00	18.27	13.95
36-37	28.59	28.69	24.32[d]	36.67	50.89	31.47	28.03
37-38	26.58	30.48	25.79[d]	39.07	51.19	31.73	27.08
38-39	20.86	23.73	19.72[d]	24.14	37.00	21.65	21.61
39-40	15.01	17.06	14.26[d]	18.61	27.34	16.94	14.99
1940-41	37.20	42.75	33.94[d]	48.45	59.62	39.88	35.77
41-42	13.93	16.46	13.39[d]	16.65	21.51	14.21	13.79
42-43	24.52	30.81	21.35[d]	43.50	57.25	30.43	22.99
43-44	17.92	23.56	20.09[d]	25.82	37.80	23.55	19.39
44-45	17.44	13.75	13.40[d]	20.27	31.76	18.71	15.86
1945-46	13.82	17.09	11.45[d]	18.42	30.55	19.18	13.69
46-47	14.16	22.22	16.44[d]	23.40	37.32	18.84	13.71
47-48	8.97	11.41	9.22[d]	11.74	17.39	11.24	9.33
48-49	10.65	10.33	10.09[d]	13.99	22.59	12.68	9.47
49-50	12.76	16.15	12.06[d]	19.33	26.68	15.95	11.99
1950-51	10.50	11.12	8.14	13.06	17.44	11.52	9.92
51-52	31.23	35.64	27.52	38.52	56.20	32.90	28.73
52-53	11.17	14.11	11.31	15.12	21.02	12.19	11.43
53-54	16.25	15.93	13.70	19.38	26.80	17.66	15.58
54-55	12.44	14.91	13.06	17.75	23.93	13.86	12.62
1955-56	16.08	18.85	17.12	21.67	28.02	19.70	14.18
56-57	10.06	15.01[c]	9.64	17.99	26.88	16.09	10.73
57-58	30.50	30.75	25.21	35.08	51.39	30.75	28.15
58-59	7.45	10.11	7.00	13.84	17.28	11.23	8.00
59-60	10.40	10.37	9.69	12.62	18.12	11.80	10.16
27-Year Average	17.41	20.21	16.30	23.68	33.28	20.54	17.08

SEASONAL DEPTH OF PRECIPITATION AT SELECTED STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In inches

Season	Station number[b]						
	347E	380	387B	389B	390B-E	406C	432
1933-34	21.54	22.35[c]	17.69	23.93[c]	27.33[c]	19.05	38.00[c]
34-35	24.29	21.80	20.28	26.82[c]	31.64	23.53	46.00[c]
1935-36	13.96	14.05	14.03	19.69	23.29	15.14	30.00[c]
36-37	26.31	25.02	24.31	33.95	39.73	26.88	48.50[c]
37-38	26.26	25.98	24.95	34.06	40.62	25.83	50.79[c]
38-39	19.50	18.53	18.30	21.95	26.96	18.95	30.77
39-40	14.49	14.55	14.43	17.55	21.19	15.91	25.00
1940-41	36.73	37.15	33.39	41.67	50.20	36.66	61.72
41-42	13.57	13.89	11.50	14.42	17.50	13.48	19.52
42-43	23.40	25.90	22.96	31.69	42.10	24.83	55.72
43-44	20.21	20.47	20.47	25.20	29.49	21.92	36.59
44-45	15.72	13.92	16.95	23.07	26.13	17.29	28.05
1945-46	14.55	13.79	14.61	21.68	26.81	16.10	23.79
46-47	15.03	16.64	14.56	18.21	26.19	15.31	32.60
47-48	9.50	9.63	10.16	11.20	12.91	10.07	15.04
48-49	11.54	9.29	11.47	13.94	17.22	11.61	20.66
49-50	11.75	12.23	12.14	16.91	19.58	13.45	27.71
1950-51	9.69	8.83	9.15	12.70	13.15	9.47	15.77
51-52	28.07	32.04	28.15	33.85	42.66	29.23	55.09
52-53	11.47	11.49	10.36	13.80	15.89	11.73	20.39
53-54	15.60	14.51	15.69	19.44	22.62	16.93	31.66
54-55	13.30	13.14	12.27	16.14	18.18	13.69	22.75
1955-56	17.05	18.08	15.49	21.24	24.43	17.53	28.82
56-57	14.15	11.57	12.34	17.38	20.57	13.80	22.95
57-58	26.60	25.91	26.71	34.51	39.92	30.08	47.27
58-59	8.28	6.98	8.56	11.04	14.48	9.11	14.84
59-60	9.72	9.29	10.39	11.67	14.20	10.16	16.60
27-Year Average	17.49	17.30	16.72	21.77	26.11	18.06	32.10

SEASONAL DEPTH OF PRECIPITATION AT SELECTED STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In inches

Season[a]	Station number[b]					
	445B	477C	480B	627	679	719
1933-34	21.86[c]	40.00[c]	20.38[c]	23.31[c]	18.14[c]	23.66[c]
34-35	27.16[c]	48.00[c]	25.31[c]	28.96[c]	22.53[c]	29.40[c]
1935-36	17.47[c]	34.00[c]	16.28[c]	18.62[c]	14.18	18.91[c]
36-37	31.21[c]	53.00[c]	29.08[c]	33.28[c]	27.59	33.78[c]
37-38	31.78[c]	59.00[c]	29.62[c]	33.88[c]	25.75	34.40[c]
38-39	22.79[c]	36.00[c]	21.24[c]	24.30[c]	18.78	24.67[c]
39-40	16.94	21.00[c]	16.18[c]	18.51[c]	14.91	18.79[c]
1940-41	40.52	59.00[c]	40.82[c]	46.71[c]	34.03	47.41[c]
41-42	14.94	22.00	14.50[c]	16.58[c]	12.96	16.83[c]
42-43	32.43	66.09	26.99[d]	34.04	23.91	32.53[d]
43-44	21.24	42.63	23.09[d]	25.61	20.52	24.82[d]
44-45	22.59	29.76	15.87[d]	20.92	15.57	19.46[d]
1945-46	17.27	30.78	15.13[c]	20.36	13.87	17.57
46-47	18.43	38.82	17.73[c]	20.26	16.11	20.47
47-48	12.72	20.15	9.85[c]	10.59	9.92	10.53
48-49	14.98	23.04	10.77	14.25	10.63	13.64
49-50	16.37	29.37	13.24	16.39	13.31	15.73
1950-51	11.08	14.28	9.72	12.71	8.82	12.33
51-52	32.35	60.66	32.19	36.05	30.54	35.38
52-53	13.76	19.72	12.40	13.14	11.96	13.21
53-54	19.53	30.15	14.43	19.69	16.25	17.29
54-55	14.38	25.61	13.27	15.47	12.24	13.59
1955-56	17.90	27.06	17.87	20.77	16.74	19.31
56-57	15.75	25.17	12.29	16.85	11.59	15.31
57-58	38.75	58.50	27.17	33.44	27.76	32.74
58-59	8.99	19.12	9.17	11.97	8.40	12.30
59-60	11.87	18.20	10.00	13.36	10.23	11.48
27-Year Average	20.93	35.23	18.69	22.22	17.31	21.69

SEASONAL DEPTH OF PRECIPITATION AT SELECTED STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In inches

Season[a]	Station number[b]					
	724	732B	740B	741	742C	1041B
1933-34	25.00[c]	32.61[c]	27.00[c]	24.00[c]	18.82[c]	18.93[c]
34-35	30.00[c]	48.10	39.00[c]	34.00[c]	23.38[c]	23.51[c]
1935-36	21.00[c]	33.70	26.00[c]	25.00[c]	15.04[c]	15.12[c]
36-37	40.00[c]	58.00	46.00[c]	42.00[c]	26.90[c]	27.01[c]
37-38	40.00[c]	62.70	55.00[c]	46.00[c]	27.39[c]	27.51[c]
38-39	24.00[c]	40.00	28.94	28.24	19.65[c]	19.73[c]
39-40	20.96	31.30	22.26	20.25	14.38	15.03[c]
1940-41	45.87	73.80	54.49	45.97	37.89	37.92[c]
41-42	16.55	27.00	18.08	14.68	14.51	13.46[c]
42-43	39.81	56.00	49.71	40.96	25.97	27.22[c]
43-44	30.48	42.20	39.32	32.15	22.05	21.90[c]
44-45	29.30	35.80	31.48	31.48	13.99	16.30[c]
1945-46	24.13	33.70	29.20	20.98	13.91	15.02[c]
46-47	26.89	38.99	33.56[c]	27.69[c]	18.77	17.60[c]
47-48	15.19	20.04	19.96	14.92	9.90	9.78[c]
48-49	18.08	19.69	20.52	17.00	10.39	10.75[c]
49-50	20.97	37.49	24.09	20.61	13.88	13.60
1950-51	12.94	12.61	13.84	11.96	8.60	8.92
51-52	41.57	63.58	49.78	42.93	32.63	28.35
52-53	16.46	20.23	19.29	16.52	12.55	10.02
53-54	23.54	23.05	31.10	24.70	14.35	12.95
54-55	18.26	23.23	23.18	19.11	12.68	11.83
1955-56	22.29	29.14	23.04	20.12	17.74	16.30
56-57	20.26	25.80	23.74	18.85	12.30	12.51
57-58	43.72	57.07	59.96	48.39	27.65	26.69
58-59	13.46	16.51	17.71	13.61	8.71	8.86
59-60	14.26	16.55	16.66	14.26	10.56	8.74
27-Year Average	25.74	36.26	31.22	26.53	17.95	17.61

a. 12-month period from October 1 through September 30.
b. Los Angeles County Flood Control District designations. Locations of these stations are described in Table 3-1 and delineated on Plate 4.
c. Estimated by the Department of Water Resources.
d. Adjusted by the Department of Water Resources principally for changes in gage location.

ATTACHMENT NO. 4

STREAM GAGING STATIONS
AND
SEASONAL RUNOFF

TABLE 4-1

LOCATION OF SELECTED STREAM GAGING STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY

Station number	Station name	Period of record[a]
	Department of Water Resources Gaging Stations[b]	
C 331-R	Arcadia Wash at Huntington Drive	12-56 to present
4057-F-11	Broadway Drain at Raymond Fault	1933 to 10-45
4068-G-11	Broadway Drain at Mission Street	10-45 to present
4108-G-12	Rubio Drain at Rose Avenue	10-23 to present
4117-F-13	Eaton Wash at San Pasqual Street Bridge	10-44 to 9-51
4117-F-13	Eaton Wash at San Pasqual Street Bridge	10-52 to 5-57
4116-F-12	Eaton Wash at Lombardy Road	4-58 to present
	Los Angeles County Flood Control District Gaging Stations[c]	
F 31-R	Live Oak Creek near Mouth of Canyon	1-28 to present
F 40-R	Puddingstone Creek below Puddingstone Dam	12-27 to present
F 47-R	Walnut Creek at Baldwin Park Avenue (formerly Covina Boulevard)	12-28 to 10-52
F 48-R	San Jose Creek at Workman Mill Road	1-29 to present
F 64-R	Rio Hondo above Mission Bridge	7-28 to present
F 65-R	Little Dalton Creek at Mouth of Canyon	1-29 to 11-38
F 65 B-R	Little Dalton Creek above Mouth of Canyon	11-38 to present
F 81-R	Alhambra Wash at Garvey Avenue Bridge	1-30 to 9-34
F 81 B-R	Alhambra Wash at Emerson Place	10-34 to 2-35

LOCATION OF SELECTED STREAM GAGING STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

Station number	Station name	Period of record[a]
	Los Angeles County Flood Control District Gaging Stations[c] (continued)	
F 81 C-R	Alhambra Wash at Gladys Avenue	2-35 to 4-36
F 81 B-R	Alhambra Wash at Emerson Place	4-36 to 5-36
F 81 D-R	Alhambra Wash at Klingerman Street	9-36 to present
F 82 B-R	Rubio Wash at Broadway	1-32 to 9-36
F 82 C-R	Rubio Wash at Glendon Way	11-36 to present
F 83-R	Mission Creek at San Gabriel Boulevard	6-30 to present
F 104-R	Eaton Wash at Temple City Boulevard	10-30 to 5-55
F 120 B-R	Big Dalton Creek below Big Dalton Dam	6-40 to present
F 190-R	San Gabriel River at Foothill Boulevard	4-32 to present
F 191 B-R	San Gabriel River below Garvey Avenue	10-51 to 9-57
F 192-R	Rio Hondo at Lower Azusa Road	3-32 to 5-58
F 192 B-R	Rio Hondo at Lower Azusa Road	12-58 to present
F 193-R	Santa Anita Wash below Arrow Highway	4-32 to 3-38
F 195-R	Monrovia Storm Drain at Peck Road	4-32 to 12-54
F 195 B-R	Monrovia Storm Drain above Peck Road	12-55 to present
F 202-R	Big Dalton Wash at Sierra Madre Avenue	12-51 to present
F 218-R	San Dimas Wash below Puddingstone Diversion Dam	11-45 to present

LOCATION OF SELECTED STREAM GAGING STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

Station number	Station name	Period of record[a]
	Los Angeles County Flood Control District Gaging Stations[c] (continued)	
F 220-R	San Gabriel-Azusa Conduit at Garcia Canyon	2-33 to present
F 250-R	San Gabriel-Azusa Conduit at Weir below San Gabriel Dam	2-35 to present
F 260-R	Santa Anita Creek above Junction with Little Santa Anita Creek	8-36 to 3-38
F 260 B-R	Santa Anita Creek at Foothill Boulevard	4-38 to 9-59
F 260 C-R	Santa Anita Wash below Foothill Boulevard	12-59 to present
F 261-R	San Gabriel River at Elliot Avenue	3-37 to 9-41
F 261 B-R	San Gabriel River at Valley Boulevard	10-41 to 9-51
F 261 C-R	San Gabriel River below Valley Boulevard	11-60 to present
F 263-R	San Gabriel River at Whittier Boulevard	7-27 to 1-37
F 263 B-R	San Gabriel River at Beverly Boulevard	2-37 to present
F 274-R	Dalton Wash at Merced Avenue	11-40 to 9-58
F 274 B-R	Dalton Wash to Merced Avenue	10-58 to present
F 278-R	Sawpit Creek below Sawpit Dam	2-42 to present
F 280-R	Santa Fe Channel below Santa Fe Dam	10-42 to present
F 303-R	San Dimas Creek below San Dimas Dam	12-51 to present
F 304-R	Walnut Creek at Puente Avenue	10-52 to present

LOCATION OF SELECTED STREAM GAGING STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

Station number	Station name	Period of record[a]
	Los Angeles County Flood Control District Gaging Stations[c] (continued)	
F 307-R	Puddingstone Diversion Channel - San Dimas Water Company Outlet at Juanita Avenue	6-53 to present
F 311-R	Live Oak Wash below Seventh Street, La Verne	7-54 to present
F 312-R	San Jose Channel above Workman Mill Road	9-55 to present
F 313-R	Rio Hondo Bypass Channel above Whittier Narrows Dam	8-54 to present
F 317-R	Arcadia Wash below Grand Avenue	12-55 to present
F 318-R	Eaton Wash at Loftus Drive	2-56 to present
	United States Geological Survey Gaging Stations[d]	
11-0835.00	San Gabriel River near Azusa	9-1895 to present
11-0840.00	Rogers Creek near Azusa	10-17 to present
11-0845.00	Fish Canyon near Duarte	7-17 to present
11-0860.00	Dalton Creek near Glendora	12-19 to present
11-0995.00	Sawpit Creek near Monrovia	10-16 to present
	United States Army Corps of Engineers Gaging Station[c]	
E 281-R	San Gabriel River below Santa Fe Dam	2-43 to present
	Metropolitan Water District Gaging Stations[c]	
M 335-R	San Gabriel-MWD Outlet below San Bernardino Road	11-57 to present

LOCATION OF SELECTED STREAM GAGING STATIONS
IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

Station number	Station name	Period of record[a]
	Metropolitan Water District Gaging Stations[c] (continued)	
M 340-R	Alhambra Wash-MWD Outlet near Rush Street	3-58 to present
	San Gabriel River Water Committee Gaging Station[c]	
S 100 A-R	San Gabriel Azusa-Duarte Tunnel Diversion at Mouth of Canyon	1918 to present

a. "Present" denotes that station was in operation on September 30, 1961.
b. Detailed information on gaging stations is presented in Watermaster Reports of the Department of Water Resources. Gaging stations are delineated on Plate 4 of this report.
c. Detailed information on gaging stations is presented in Annual and Biennial Hydrologic Reports of the Los Angeles County Flood Control District. Gaging stations are delineated on Plate 4.
d. Detailed information on gaging stations is presented in the Water Supply Papers of the United States Geological Survey. Gaging stations are delineated on Plate 4.

TABLE 4-2

SEASONAL RUNOFF AT SELECTED GAGING STATIONS IN AND ADJACENT TO THE SAN GABRIEL VALLEY

In acre-feet

Season[a]	Station name and number[b]				
	Arcadia Wash at Huntington Drive C331-R	Broadway Drain at Raymond Fault 4068-G-11 4057-F-11	Rubio Drain at Rose Avenue 4108-G-12	Eaton Wash at Lombardy Road 4117-F-13 4116-F-12	Live Oak Creek near Mouth of Canyon F31-R[c]
1933-34		1,700	--[d]	1,950	228
34-35		1,420	--[d]	827	0
1935-36		742	--[d]	820	0
36-37		1,570	2,560	--[d]	429
37-38		1,740	3,320	--[d]	794
38-39		1,364	1,790	340	0
39-40		876	1,300	188	10
1940-41		2,630	4,440	8,416	763
41-42		694	1,150	2	0
42-43		1,899	3,410	5,272	822
43-44		1,450	2,410	1,890	215
44-45		746	967	211	150
1945-46		568	1,168	724	76
46-47		812	1,700	480	38
47-48		398	943	36	0
48-49		708	887	66	0
49-50		890	1,236	181	0
1950-51		634	1,156	71	0
51-52		2,093	3,997	--[d]	397
52-53		926	1,320	652	0
53-54		953	1,338	679	57
54-55		1,076	1,691	252	0
1955-56		1,231	2,296	447	67
56-57	482	1,442	2,035	192	0
57-58	1,474	2,325	3,988	3,500	594
58-59	724	787	2,038	1,281	2
59-60	699	1,144	1,590	1,670	0

SEASONAL RUNOFF AT SELECTED GAGING STATIONS IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In acre-feet

Season[a]	Station name and number[c]				
	Puddingstone Creek below Puddingstone Dam F40-R	Walnut Creek at Baldwin Park Avenue F47-R	San Jose Creek at Workman Mill Road F48-R	Rio Hondo above Mission Bridge F64-R	Little Dalton above Mouth of Canyon F65-R F65B-R
1933-34	--[d]	6,310	7,610	28,970	482
34-35	44	1,920	3,860	29,230	495
1935-36	36	1,670	1,390	20,700	465
36-37	198	4,300	9,600	50,900	1,430
37-38	4,810	12,610	15,450	209,300	2,660
38-39	1,330	1,010	3,440	30,650	207
39-40	145	923	3,020	27,660	231
1940-41	1,790	7,300	22,730	130,600	1,950
41-42	1,640	216	3,930	28,810	198
42-43	3,060	10,140	20,470	59,470	1,910
43-44	1,120	2,930	11,910	51,390	900
44-45	394	1,510	7,010	32,300	748
1945-46	2,840	2,750	5,750	43,160	519
46-47	131	910	5,100	48,420	400
47-48	49	164	2,000	25,370	41
48-49	45	48	1,220	11,100	58
49-50	28	340	1,920	12,280	94
1950-51	11	44	851	7,880	4
51-52	108	6,370	17,870	34,570	935
52-53	135		1,530	16,120	60
53-54	30,650		3,970	23,390	308
54-55	23,300		1,160	11,350	45
1955-56	50,800		926	16,180	211
56-57	53,780		988	16,840	67
57-58	314		3,240	116,500	1,400
58-59	60		1,090	39,800	81
59-60	42		1,300	50,100	8

SEASONAL RUNOFF AT SELECTED GAGING STATIONS IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In acre-feet

Season[a]	Station name and number[c]				
	Alhambra Wash near Klingerman Street F81-R F81B-R F81C-R F81D-R	Rubio Wash at Glendon Way F82B-R F82C-R	Mission Creek at San Gabriel Boulevard F83-R	Eaton Wash at Temple City Boulevard F104-R	Big Dalton Creek below Big Dalton Dam F120B-R
1933-34	5,820	2,580	9,030	1,990	
34-35	2,380	1,770	9,140	543	
1935-36	1,420	1,280	9,810	866	
36-37	3,880	2,800	10,840	1,300	
37-38	5,520	4,180	14,220	4,170	
38-39	2,990	2,370	16,320	718	
39-40	1,730	1,720	16,210	402	
1940-41	5,650	5,890	18,120	5,860	2,890
41-42	1,810	1,530	18,740	293	235
42-43	6,070	4,520	17,410	7,100	3,180
43-44	4,100	3,190	18,850	1,650	1,160
44-45	2,250	1,540	18,010	273	842
1945-46	3,000	1,840	15,630	509	549
46-47	3,800	2,300	14,230	840	545
47-48	2,040	1,080	12,670	191	15
48-49	2,020	1,080	10,640	86	103
49-50	3,090	1,690	8,780	392	122
1950-51	2,360	1,010	6,700	133	14
51-52	9,040	5,300	6,090	2,820	1,600
52-53	3,240	1,460	6,170	539	107
53-54	3,770	2,490	3,580	1,120	363
54-55	3,020	1,870	3,100	472	7
1955-56	5,520	2,880	2,310		222
56-57	4,440	2,290	1,840		23
57-58	9,270	5,610	2,660		2,140
58-59	3,020	2,030	3,920		140
59-60	2,720	1,820	2,160		10

SEASONAL RUNOFF AT SELECTED GAGING STATIONS IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In acre-feet

Season[a]	Station name and number[c]			
	San Gabriel River at Foothill Boulevard F190-R	San Gabriel River below Garvey Avenue F191B-R	Rio Hondo at Lower Azusa Road F192-R F192B-R	Santa Anita Wash below Arrow Highway F193-R
1933-34	14,690		8,110	870
34-35	59,220		8,160	193
1935-36	15,300		3,400	156
36-37	117,400		27,960	2,090
37-38	280,300		174,300	
38-39	10,850		1,570	
39-40	9,980		3,640	
1940-41	220,100		81,450	
41-42	3,990		1,980	
42-43	230,200		10,680	
43-44	118,300		11,600	
44-45	16,620		1,380	
1945-46	42,060		13,030	
46-47	47,520		8,560	
47-48	10,370		5,250	
48-49	0		71	
49-50	67		203	
1950-51	0		234	
51-52	71,210	21,270	6,340	
52-53	41,180	8,700	6,550	
53-54	21,920	0	10,800	
54-55	38	0	1,460	
1955-56	1,430	0	2,940	
56-57	5,320	0	4,280	
57-58	165,600		23,610	
58-59	13,590		1,290	
59-60	499		303	

SEASONAL RUNOFF AT SELECTED GAGING STATIONS IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In acre-feet

Season[a]	Station name and number[c]			
	Monrovia Storm Drain above Peck Road F195-R F195B-R	Big Dalton Wash at Sierra Madre Avenue F202-R	San Dimas Wash below Puddingstone Diversion Dam F218-R	San Gabriel-Azusa Conduit at Garcia Canyon F220-R
1933-34	433			19,770
34-35	392			46,570
1935-36	307			29,500
36-37	539			21,030
37-38	1,130			11,910
38-39	579			0
39-40	494			23,760
1940-41	1,600			16,820
41-42	228			38,360
42-43	855			26,510
43-44	508			41,310
44-45	249			42,910
1945-46	324		247	39,820
46-47	322		483	46,900
47-48	169		0	24,960
48-49	150		0	17,380
49-50	272		0	27,140
1950-51	184	--[d]	0	8,310
51-52	1,410	--[d]	780	47,300
52-53	359	51	0	31,680
53-54	441	28	244	28,090
54-55	--[d]	--[d]	0	36,600
1955-56	552	56	92	35,580
56-57	474	0	0	26,670
57-58	1,360	936	1,110	20,140
58-59	417	9	49	35,730
59-60	384	0	0	17,850

SEASONAL RUNOFF AT SELECTED GAGING STATIONS IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In acre-feet

Season[a]	Station name and number[c]			
	San Gabriel-Azusa Conduit at Weir below San Gabriel Dam F250-R	Santa Anita Creek at Foothill Boulevard F260-R F260B-R	San Gabriel River at Valley Boulevard F261-R F261B-R	San Gabriel River at Beverly Boulevard F263B-R
1933-34				16,950
34-35	36,610			12,190
1935-36	30,540			4,590
36-37	19,740	6,450	--[d]	34,240
37-38	11,160	--[d]	--[d]	94,810
38-39	4,280	1,680	5,790	24,620
39-40	34,440	1,060	1,320	20,180
1940-41	17,220	12,920	53,500	100,900
41-42	39,940	694	1,560	28,630
42-43	32,250	21,670	160,300	209,580
43-44	43,050	6,140	60,290	104,200
44-45	59,050	1,540	7,570	42,520
1945-46	47,930	1,480	8,640	34,370
46-47	52,990	2,490	21,940	45,420
47-48	26,830	0	0	8,590
48-49	18,120	0	0	6,470
49-50	27,060	68	0	4,130
1950-51	8,610	23	0	558
51-52	47,400	4,530		50,900
52-53	31,660	116		13,880
53-54	28,070	2,500		10,990
54-55	36,610	419		9,250
1955-56	35,580	949		24,050
56-57	26,670	297		18,000
57-58	21,500	6,320		82,190
58-59	35,620	550		33,660
59-60	17,840	161		36,100

SEASONAL RUNOFF AT SELECTED GAGING STATIONS IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In acre-feet

Season[a]	Station name and number[c]			
	Dalton Wash at: Merced Avenue F274-R F274B-R	Sawpit Creek below Sawpit Dam F278-R	Santa Fe Channel below Santa Fe Dam F280-R	San Dimas Creek below San Dimas Dam F303-R
1933-34				
34-35				
1935-36				
36-37				
37-38				
38-39				
39-40				
1940-41	3,840			
41-42	727	30		
42-43	3,500	2,860		
43-44	1,620	666	15,180	
44-45	894	290	0	
1945-46	1,610	169	22,610	
46-47	984	329	12,200	
47-48	96	0	7,880	
48-49	97	16	0	
49-50	306	25	0	
1950-51	64	32	0	
51-52	2,090	1,080	2,280	4,660
52-53	287	67	7,720	1,110
53-54	1,060	251	8,350	1,540
54-55	706	107	0	563
1955-56	2,260	168	0	816
56-57	980	15	3,400	436
57-58	4,690	1,260	19,530	6,530
58-59	2,130	776	0	1,260
59-60	2,260	151	0	484

SEASONAL RUNOFF AT SELECTED GAGING STATIONS IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In acre-feet

Season[a]	Station name and number[c]			
	Walnut Creek at Puente Avenue F304-R	Puddingstone Diversion Channel-San Dimas Water Company Outlet at Juanita Avenue F307-R	Live Oak Wash below Seventh Street, La Verne F311-R	San Jose Channel above Workman Mill Road F312-R
1933-34				
34-35				
1935-36				
36-37				
37-38				
38-39				
39-40				
1940-41				
41-42				
42-43				
43-44				
44-45				
1945-46				
46-47				
47-48				
48-49				
49-50				
1950-51				
51-52				
52-53	292	331		
53-54	25,290	432	29,604	
54-55	21,640	1,368	24,080	
1955-56	49,730	74	56,039	4,070
56-57	51,530	27	50,010	796
57-58	8,490	0	0	14,060
58-59	1,610	--[d]	0	3,210
59-60		0	464	3,430

SEASONAL RUNOFF AT SELECTED GAGING STATIONS IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In acre-feet

Season[a]	Station name and number[c]			
	Rio Hondo Bypass Channel above Whittier Narrows Dam F313-R	Arcadia Wash below Grand Avenue F317-R	Eaton Wash at Loftus Drive F318-R	San Gabriel River near Azusa 11-0835
1933-34				22,080
34-35				74,080
1935-36				22,980
36-37				141,100
37-38				300,200
38-39				38,680
39-40				36,640
1940-41				229,300
41-42				9,480
42-43				242,000
43-44				133,700
44-45				45,490
1945-46				54,930
46-47				54,220
47-48				13,170
48-49				4,140
49-50				51
1950-51				6,220
51-52				66,120
52-53				50,240
53-54	7,230			25,030
54-55	9,730			86
1955-56	14,990	--[d]		176
56-57	20,400	1,340	2,400	9,010
57-58	15,300	3,330	7,460	174,100
58-59	0	1,360	2,850	8,200
59-60	0	1,220	2,420	0

SEASONAL RUNOFF AT SELECTED GAGING STATIONS IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In acre-feet

Season[a]	Station name and number[c]			
	Rogers Creek near Azusa 11-0840	Fish Canyon near Duarte 11-0845	Dalton Creek near Glendora 11-0860	Sawpit Creek near Monrovia 11-0995
1933-34	1,890	2,440	485	474
34-35	1,870	3,080	282	543
1935-36	1,420	3,280	213	645
36-37	5,180	6,770	1,780	1,750
37-38	7,560	9,520	3,680	4,740
38-39	1,020	1,750	149	287
39-40	809	1,570	104	397
1940-41	7,610	9,340	2,590	2,840
41-42	477	1,030	136	80
42-43	9,290	10,720	3,170	3,780
43-44	3,100	4,200	982	1,050
44-45	1,840	2,580	365	437
1945-46	1,670	2,310	256	366
46-47	2,230	2,910	336	422
47-48	190	536	31	3
48-49	314	610	119	16
49-50	623	888	131	26
1950-51	92	237	4	34
51-52	5,100	6,060	2,080	1,180
52-53	458	813	109	88
53-54	1,140	1,510	460	946
54-55	311	567	20	304
1955-56	772	1,100	288	300
56-57	440	674	16	73
57-58	5,280	5,680	3,110	1,488
58-59	776	1,590	156	971
59-60	138	794	1	135

SEASONAL RUNOFF AT SELECTED GAGING STATIONS IN AND ADJACENT TO THE SAN GABRIEL VALLEY
(continued)

In acre-feet

Season[a]	Station name and number[c]			
	San Gabriel River below Santa Fe Dam E281-R	San Gabriel River-MWD Outlet below San Bernardino Road M335-R	Alhambra Wash-MWD Outlet near Rush Street M340-R	Azusa-Duarte Tunnel Diversion S100A-R
1933-34				6,540
34-35				17,520
1935-36				12,830
36-37				30,640
37-38				27,780
38-39				24,150
39-40				25,380
1940-41				22,810
41-42				4,430
42-43	175,100			10,720
43-44	96,890			10,100
44-45	10,140			27,370
1945-46	32,560			15,230
46-47	38,600			10,660
47-48	8,120			151
48-49	0			2,920
49-50	0			0
1950-51	0			5,610
51-52	32,800			1,140
52-53	16,990			2,520
53-54	0			2,180
54-55	0			0
1955-56	0			0
56-57	0			3,116
57-58	91,530	41,427	63,700	3,300
58-59	9,000	30,320	24,070	0
59-60	15	43,190	39,520	0

a. 12-month period from October 1 through September 30.
b. Station locations and period of record are described in Table 4-1, and station locations are delineated on Plate 4. Data are from watermaster reports of the Department of Water Resources.
c. Station locations and period of record are described in Table 4-1, and station locations are delineated on Plate 4. Data are from Annual and Biennial Hydrologic Reports of the Los Angeles County Flood Control District.
d. Incomplete record, not shown.

ATTACHMENT NO. 5

SEASONAL AMOUNTS OF WATER IMPORTED
AND
SEASONAL AMOUNTS OF WATER EXPORTED
BY
WATER SERVICE AGENCIES

TABLE 5-1

SEASONAL AMOUNTS OF WATER IMPORTED BY PRINCIPAL WATER SERVICE AGENCIES TO THE SAN GABRIEL VALLEY GROUND WATER BASIN FOR 1933-34 THROUGH 1959-60

In acre-feet

Season[a]	Surface diversions from San Gabriel Valley frontal area				Imported by The Metropolitan Water District of Southern California	
	Duarte Water Company[b]	Glendora Irrigating Company[c]	Monrovia, City of[d]	San Gabriel Azusa Conduit[e]	Used in Basin	Used for conservation in Montebello Forebay[f]
1933-34	0	281	686	20,295		
34-35	131	530	757	47,569		
1935-36	150	332	825	30,804		
36-37	304	1,164	1,310	39,452		
37-38	406	1,068	1,470	37,159		
38-39	247	247	1,593	24,831		
39-40	234	191	1,043	23,148		
1940-41	315	1,186	1,550	52,085	0	
41-42	200	138	1,340	44,026	53	
42-43	300	887	1,880	43,945	150	
43-44	250	501	2,000	56,476	354	
44-45	225	707	1,683	43,979	362	
1945-46	225	469	1,274	45,440	505	
46-47	225	762	1,278	45,558	241	
47-48	245	8	815	28,177	279	
48-49	398	113	774	17,076	241	
49-50	355	130	756	27,045	253	
1950-51	398	14	499	8,323	3,552	
51-52	337	1,612	1,220	49,032	1,289	
52-53	216	68	728	31,661	3,419	0
53-54	66	359	354	31,974	3,225	30,598
54-55	229	5	382	36,479	4,577	23,247
1955-56	148	213	535	35,581	4,655	50,728
56-57	430	38	577	26,752	5,296	53,732
57-58	360	1,027	1,190	54,717	2,339	105,112
58-59	210	123	579	35,755	6,127	54,422
59-60	70	49	625	17,924	5,606	80,604
27-Year Average	247	453	1,027	35,380	1,575	14,757

SEASONAL AMOUNTS OF WATER IMPORTED BY PRINCIPAL WATER SERVICE AGENCIES TO THE SAN GABRIEL VALLEY GROUND WATER BASIN FOR 1933-34 THROUGH 1959-60
(continued)

In acre-feet

Season[a]	Imported from Raymond Basin[g]			
	Alhambra, City of	Arcadia, City of	California Water and Telephone Company	Monrovia, City of
1933-34	1,042	2,265	1,123	903
34-35	991	1,283	586	842
1935-36	931	1,781	676	933
36-37	551	2,408	840	773
37-38	746	2,641	964	524
38-39	790	2,087	1,754	610
39-40	1,461	2,273	1,665	668
1940-41	1,534	2,552	1,688	407
41-42	1,528	3,169	1,770	437
42-43	1,434	3,520	1,753	401
43-44	1,448	3,988	1,596	425
44-45	636	2,475	800	686
1945-46	755	1,624	1,202	767
46-47	816	1,891	490	515
47-48	682	1,410	0	572
48-49	690	1,085	0	678
49-50	640	108	0	419
1950-51	693	0	0	682
51-52	772	0	166	606
52-53	713	0	0	760
53-54	731	0	0	460
54-55	887	0	0	890
1955-56	909	0	0	1,145
56-57	1,020	0	0	890
57-58	1,064	0	0	991
58-59	836	0	608	753
59-60	977	0	0	554
27-Year Average	936	1,354	655	677

SEASONAL AMOUNTS OF WATER IMPORTED BY PRINCIPAL WATER SERVICE AGENCIES TO THE SAN GABRIEL VALLEY GROUND WATER BASIN FOR 1933-34 THROUGH 1959-60
(continued)

In acre-feet

Season[a]	Imported from Raymond Basin[g] (continued)			
	Pasadena, City of	San Gabriel County Water District	Sunny Slope Water Company	Other companies[h]
1933-34	955	1,143	1,559	2,521
34-35	991	1,022	1,530	1,547
1935-36	1,179	1,194	1,683	2,019
36-37	886	1,258	1,425	1,378
37-38	576	1,374	1,485	932
38-39	160	1,421	1,763	1,020
39-40	146	1,523	1,806	937
1940-41	137	1,429	1,726	884
41-42	143	1,346	2,003	797
42-43	156	1,779	2,232	854
43-44	161	1,320	1,587	852
44-45	150	685	1,560	626
1945-46	177	173	801	694
46-47	201	431	946	751
47-48	217	373	758	911
48-49	259	111	918	539
49-50	219	101	748	21
1950-51	278	336	1,003	21
51-52	253	182	1,188	22
52-53	240	105	1,051	0
53-54	240	40	1,477	0
54-55	240	584	1,079	0
1955-56	240	647	1,356	0
56-57	240	888	1,616	0
57-58	270	368	1,416	0
58-59	334	1,252	1,362	0
59-60	327	1,176	1,431	7
27-Year Average	347	824	1,389	642

SEASONAL AMOUNTS OF WATER IMPORTED BY PRINCIPAL WATER SERVICE AGENCIES TO THE SAN GABRIEL VALLEY GROUND WATER BASIN FOR 1933-34 THROUGH 1959-60
(continued)

In acre-feet

Season[a]	Imported from Upper Santa Ana Valley				
	La Verne, City of[i,j]	Old Baldy Water Company	La Verne Water Association[j]	Fruit Street Water Company[j]	Base Line Water Company
1933-34	--	255	740	169	281
34-35	--	201	751	152	205
1935-36	--	243	767	138	283
36-37	--	255	799	162	135
37-38	--	267	769	153	133
38-39	--	350	760	120	55
39-40	--	270	750	144	8
1940-41	--	264	742	116	16
41-42	--	298	976	147	70
42-43	--	388	990	182	70
43-44	--	406	899	152	70
44-45	--	361	1,173	168	70
1945-46	--	310	820	109	80[j]
46-47	--	310	820	211	80[j]
47-48	--	310	820	188	80[j]
48-49	--	310	820	161	80[j]
49-50	30	310	896	121	92[j]
1950-51	35	310	917	96	98[j]
51-52	35	310	799	76	60[j]
52-53	40	310	780	101	66[j]
53-54	40	310	668	126	81[j]
54-55	45	310	643	97	80[j]
1955-56	46	310	690	104	77[j]
56-57	51	310	484	77	56[j]
57-58	52	310	817	86	72[j]
58-59	58	310	1,179	178	121[j]
59-60	59	310	846	157	58[j]
27-Year Average	18	304	819	137	95

SEASONAL AMOUNTS OF WATER IMPORTED BY PRINCIPAL WATER SERVICE AGENCIES TO THE SAN GABRIEL VALLEY GROUND WATER BASIN FOR 1933-34 THROUGH 1959-60
(continued)

In acre-feet

Season[a]	Imported from Upper Santa Ana Valley (continued)			
	Bonita Water Company	La Verne Heights Domestic Water Company[j,k]	Peyton Corporation	Puddingstone Water System
1933-34	174	--	83	210
34-35	8	--	61	171
1935-36	58	--	70	203
36-37	126	--	65	196
37-38	14	--	79	215
38-39	0	--	68	241
39-40	0	--	60	192
1940-41	0	--	65	143
41-42	0	--	67	143
42-43	0	--	69	165
43-44	0	--	67	309
44-45	0	--	45	192
1945-46	0	--	65[j]	169
46-47	0	--	59[j]	218
47-48	0	--	63[j]	180
48-49	0	--	58[j]	164
49-50	0	--	85[j]	111
1950-51	0	--	65	108[j]
51-52	0	--	65	91[j]
52-53	0	--	65	88[j]
53-54	0	98	65	95[j]
54-55	0	119	65	81[j]
1955-56	0	151	65	49[j]
56-57	0	129	65	39[j]
57-58	0	164	65	61[j]
58-59	0	165	65	82[j]
59-60	0	153	65	32[j]
27-Year Average	14	36	66	146

SEASONAL AMOUNTS OF WATER IMPORTED BY PRINCIPAL WATER SERVICE AGENCIES TO THE SAN GABRIEL VALLEY GROUND WATER BASIN FOR 1933-34 THROUGH 1959-60
(continued)

In acre-feet

Season[a]	Imported from Upper Santa Ana Valley (continued): San Dimas Water Company	Covina Irrigating Company	Diamond Bar Ranch and Northside Water Company[l]	Imported from Coastal Plain, Los Angeles County: Citrus Grove Heights Mutual Water Company[m]	Los Angeles, City of
1933-34	840	272	1,128	36	800
34-35	647	12	1,304	40	800
1935-36	1,418	0	1,312	44	900
36-37	468	0	1,501	48	900
37-38	634	20	1,476	52	1,000
38-39	428	0	1,480	56	1,000
39-40	126	0	1,533	60	1,000
1940-41	111	82	1,635	64	1,000
41-42	196	30	1,872	64	1,000
42-43	611	52	2,235	64	1,100
43-44	197	0	2,364	64	1,200
44-45	203	18[j]	2,362	64	1,200
1945-46	91	5[j]	2,466	76	1,200
46-47	1,283	64[j]	2,691	88	1,300
47-48	912	147[j]	2,787	96	1,400
48-49	738	392[j]	1,370	108	1,400
49-50	611	0[j]	1,370	100	1,400
1950-51	529[j]	3[j]	1,495	100	1,600
51-52	213[j]	0	1,413	100	1,600
52-53	447[j]	0	1,646	100	1,600
53-54	342[j]	0	1,514	100	1,600
54-55	319[j]	0	1,351	100	1,500
1955-56	235[j]	0	1,312	100	1,600
56-57	77[j]	0	1,544	100	1,700
57-58	6[j]	0	948	100	1,900
58-59	446[j]	0	649	100	2,000
59-60	434[j]	0	450	100	2,000
27-Year Average	465	41	1,600	79	1,322

SEASONAL AMOUNTS OF WATER IMPORTED BY PRINCIPAL WATER SERVICE AGENCIES TO THE SAN GABRIEL VALLEY GROUND WATER BASIN FOR 1933-34 THROUGH 1959-60
(continued)

a. 12-month period from October 1 through September 30.
b. Water diverted from Fish Creek.
c. Water diverted from Big Dalton Creek and Little Dalton Creek.
d. Water diverted from Sawpit Creek.
e. Water diverted from Morris and San Gabriel Reservoirs through the San Gabriel-Azusa Conduit by the San Gabriel River Water Committee, San Gabriel Spreading Corporation, and San Gabriel Valley Protective Association.
f. Water released to Alhambra Wash, to the San Gabriel River, and from Puddingstone Reservoir.
g. From Raymond Basin watermaster reports of the Department of Water Resources.
h. The companies included are: California-Michigan Land and Water Company, Bradbury Estates Company, Alice Graves, Graves and Bean, Rancho Santa Anita Incorporated, City of South Pasadena.
i. No portion of the City of La Verne existed in the San Gabriel Valley prior to 1950.
j. 12-month period from January 1 through December 31.
k. La Verne Heights Domestic Water Company was organized in 1953.
l. Effluent from the Pomona Sewage Treatment Plant, used for irrigation in the San Gabriel Valley. Excludes effluent released to San Jose Wash which is included under surface inflow.
m. Water used by the Rose Hill Mortuary.

TABLE 5-2

SEASONAL AMOUNTS OF WATER EXPORTED BY PRINCIPAL WATER SERVICE AGENCIES FROM THE SAN GABRIEL VALLEY GROUND WATER BASIN FOR 1933-34 THROUGH 1959-60

In acre-feet

Season[a]	Exported to Coastal Plain of Los Angeles County through Whittier Narrows			
	California Domestic Water Company[b]	Cate Ditch Company[c]	Metropolitan Water District of Southern California[d]	Rincon Ditch Company[c]
1933-34	7,221	3,051		1,573
34-35	7,158	2,478		1,573
1935-36	7,975	3,244		1,573
36-37	7,585	3,483		1,573
37-38	7,583	4,062		1,573
38-39	7,329	5,016		1,487
39-40	7,418	3,669		1,404
1940-41	6,393	4,331		1,320
41-42	7,187	5,747		1,234
42-43	7,303	6,609		1,151
43-44	6,633	7,495		1,067
44-45	6,999	5,527		788
1945-46	6,604	6,269		851
46-47	7,784	5,991		855
47-48	8,746	6,133		639
48-49	8,237	4,816		464
49-50	7,365	2,347		385
1950-51	7,959	1,519		390
51-52	6,796	957		490
52-53	7,337	703		600
53-54	7,164	684	14,990	550
54-55	7,216	609	14,500	520
1955-56	8,033	696	31,910	370
56-57	8,152	326	38,520	290
57-58	8,757	312	91,552	370
58-59	9,639	348	48,440	420
59-60	9,300	433	69,652	360
27-Year Average	7,625	3,217	11,465	884

SEASONAL AMOUNTS OF WATER EXPORTED BY PRINCIPAL WATER SERVICE AGENCIES FROM THE SAN GABRIEL VALLEY GROUND WATER BASIN FOR 1933-34 THROUGH 1959-60 (continued)

In acre-feet

Season[a]	Exported to Coastal Plain of Los Angeles County through Whittier Narrows (continued)		
	Standefer Ditch Company[e]	Suburban Water Systems	Whittier, City of
1933-34	4,459	4,069	0
34-35	3,658	2,934	0
1935-36	5,542	3,915	734
36-37	5,303	3,419	2,685
37-38	6,856	3,349	2,747
38-39	7,095	3,656	2,752
39-40	5,235	3,674	2,688
1940-41	6,596	3,223	1,859
41-42	8,232	3,378	2,394
42-43	9,477	3,367	2,497
43-44	8,898	3,676	2,659
44-45	7,260	3,408	2,780
1945-46	7,580	4,040	3,053
46-47	7,850	4,120	3,109
47-48	7,535	4,220	3,054
48-49	5,539	4,320	3,519
49-50	3,010	4,420	3,881
1950-51	3,900	4,520	6,580
51-52	1,820	4,600	4,500
52-53	1,570	4,690	5,760
53-54	2,450	4,864	4,330
54-55	930	4,734	5,500
1955-56	30	5,406	5,250
56-57		4,783	5,420
57-58		5,200	7,180
58-59		5,520	7,946
59-60		6,051	7,300
27-Year Average	4,475	4,206	3,711

SEASONAL AMOUNTS OF WATER EXPORTED BY PRINCIPAL WATER SERVICE AGENCIES FROM THE SAN GABRIEL VALLEY GROUND WATER BASIN FOR 1933-34 THROUGH 1959-60
(continued)

In acre-feet

Season[a]	Exported to Coastal Plain of Los Angeles County[f]		Exported to Upper Santa Ana Valley
	Monterey Park, City of	South Pasadena, City of	San Dimas Water Company[g]
1933-34		382	
34-35		334	
1935-36		381	
36-37		364	
37-38		0	
38-39		130	
39-40		295	
1940-41	100	225	
41-42	100	155	
42-43	100	274	
43-44	100	335	
44-45	100	368	
1945-46	200	335	
46-47	200	458	
47-48	200	542	
48-49	200	361	
49-50	700	332	
1950-51	700	656	
51-52	800	630	
52-53	1,000	712	330
53-54	1,800	648	432
54-55	1,700	711	1,368
1955-56	2,200	741	74
56-57	2,500	659	27
57-58	2,600	607	
58-59	3,100	517	
59-60	3,300	837	
27-Year Average	804	444	83

SEASONAL AMOUNTS OF WATER EXPORTED BY PRINCIPAL WATER SERVICE AGENCIES FROM THE SAN GABRIEL VALLEY GROUND WATER BASIN FOR 1933-34 THROUGH 1959-60
(continued)

In acre-feet

Season[a]	Exported to Raymond Basin[h]			
	Arcadia, City of	California Water and Telephone Company	California-Michigan Land and Water Company	South Pasadena, City of
1933-34				
34-35				
1935-36				
36-37				147
37-38				155
38-39				155
39-40				155
1940-41				155
41-42				155
42-43				155
43-44				155
44-45				155
1945-46				155
46-47				155
47-48		747		
48-49		531		155
49-50		479	32	155
1950-51	1,626	383	187	155
51-52	2,331	0	165	155
52-53	966	197	115	155
53-54	1,291	0	130	155
54-55	1,476	374	217	155
1955-56	1,900	500	200	155
56-57	900	100	200	155
57-58	2,300	100	100	155
58-59	0	0	200	155
59-60	1,500	400	200	155
27-Year Average	529	141	64	132

SEASONAL AMOUNTS OF WATER EXPORTED BY PRINCIPAL WATER SERVICE AGENCIES FROM THE SAN GABRIEL VALLEY GROUND WATER BASIN FOR 1933-34 THROUGH 1959-60
(continued)

a. 12-month period from October 1 through September 30.
b. Includes water exported to Orange County.
c. Includes both ground water pumpage and rising water.
d. Amounts spread in the Montebello Forebay of the Coastal Plain of Los Angeles County. Values from Los Angeles County Flood Control District.
e. Rising water only.
f. Water exported other than through Whittier Narrows.
g. Water released to Puddingstone Reservoir on request by Los Angeles County Parks and Recreation Department.
h. From Raymond Basin watermaster reports of the Department of Water Resources.

ATTACHMENT NO. 6

DEFINITION OF NATURE AND
CLASS OF LAND USE

TABLE 6-1

DEFINITION OF NATURE AND CLASS OF LAND USE
IN THE SAN GABRIEL VALLEY

<u>WATER SERVICE AREAS</u>	
<u>Urban and Suburban</u>	
Residential, single	One- and two-family urban units and recreational residences.
Residential, multiple	Three-family and larger units, hospitals and institutions, one-and-two story hotels, and subdivided land.
Residential, rural	Small rural units and farmsteads.
Commercial	Three-and more-story hotels, commercial office and retail buildings, theaters, arenas, and churches.
Industrial	Manufacturing, assembling and processing establishments, and oil refineries.
Unclassified	Schools, dairies, and livestock and poultry feed lots.
Street	Streets, all paved and oiled surfaces, and lined stream channels.
Included nonwater service area	Vacant unpaved or graveled areas, quarries, dumps, oil fields, and tank farms.
<u>Irrigated Agriculture</u>	
Alfalfa	Alfalfa.
Pasture	Clover, pasture, lawns, parks, and cemeteries.
Deciduous, walnuts	Deciduous fruits and nuts.
Citrus	Citrus fruit, avocados, subtropical fruit, and vineyards.

DEFINITION OF NATURE AND CLASS OF LAND USE
IN THE SAN GABRIEL VALLEY
(continued)

WATER SERVICE AREAS

Irrigated Agriculture (continued)

Truck crops	Fresh vegetables, melons, flower seed, hay and grain, rice, and field crops.
Street	Streets in agricultural areas.

NONWATER SERVICE AREAS

Native vegetation, light	Bare ground, river washes, and beaches.
Native vegetation, medium	Nonirrigated agriculture, grassland, and light and medium brush.
Native vegetation, heavy	Heavy brush, brush and timber, forest, and swamps and marshes.
Street	Streets in native vegetation areas.

ATTACHMENT NO. 7

SEASONAL AMOUNTS OF WASTE WATER IMPORTED,
SEASONAL AMOUNTS OF WASTE WATER EXPORTED,
AND
SEASONAL AMOUNTS OF WASTE WATER
DISCHARGED FROM TREATMENT PLANTS

TABLE 7-1

SEASONAL AMOUNTS OF WASTE WATER IMPORTED TO THE SAN GABRIEL VALLEY GROUND WATER BASIN FOR 1933-34 THROUGH 1959-60

In acre-feet

Season[a]	From County Sanitation Districts of Los Angeles County[a]		From Raymond Basin	From nonwater-bearing area[b]	Total
	16	21[b]			
1933-34	0		5,100	200	5,300
34-35	0		5,300	200	5,500
1935-36	0		5,500	200	5,700
36-37	0		5,700	300	6,000
37-38	0		5,900	300	6,200
38-39	0		5,900	300	6,200
39-40	0		6,000	300	6,300
1940-41	0		6,400	400	6,800
41-42	0		6,300	400	6,700
42-43	0		6,500	400	6,900
43-44	0		7,100	500	7,600
44-45	0		7,000	500	7,500
1945-46	0		7,300	500	7,800
46-47	0		7,600	500	8,100
47-48	900		7,900	800	9,600
48-49	900		8,500	900	10,300
49-50	900		9,200	1,000	11,100
1950-51	1,000		9,400	1,000	11,400
51-52	1,000		9,500	1,000	11,500
52-53	1,000		9,800	1,100	11,900
53-54	1,100	1,000	9,900	1,100	13,100
54-55	1,100	3,100	10,200	1,200	15,600
1955-56	1,100	3,100	10,500	1,300	16,000
56-57	1,100	3,200	11,000	1,300	16,600
57-58	1,200	3,500	11,400	1,400	17,500
58-59	1,200	4,400	12,400	1,400	19,400
59-60	1,200	5,000	12,500	1,400	20,100
27-Year Average	507	863	8,141	737	10,248

a. 12-month period from October 1 through September 30.
b. Estimated by Department of Water Resources; although a Sanitation District of Los Angeles County, these amounts disposed through Hyperion Outfall.

TABLE 7-2

SEASONAL AMOUNTS OF WASTE WATER EXPORTED
FROM THE SAN GABRIEL VALLEY GROUND WATER BASIN
FOR 1933-34 THROUGH 1959-60

In acre-feet

Season[a]	To Whites Point Outfall[b]							To Hyperion Outfall[c]			Grand Total
	Through Whittier Narrows										
	J.O.B.-1D Trunk Line	J.O.H.-5A[d] Trunk Line	Santa Anita Trunk Line	Metropolitan Water District Line[e]	Total	Atlantic Boulevard Trunk Line[d]	Total	Los Angeles, City of[d]	District 16[d,f]	Total	
1933-34								645	21	666	666
34-35								743	22	765	765
1935-36								764	12	776	776
36-37						34[g]	34	843	12	855	889
37-38						102[g]	102	854	13	867	969
38-39						192[g]	192	836	13	849	1,041
39-40						402[g]	402	853	13	866	1,268
1940-41						732[g]	732	933	14	947	1,679
41-42						1,180[g]	1,180	879	13	892	2,072
42-43			317		317	1,123[g]	1,440	879	14	893	2,333
43-44			572		572	749[g]	1,321	1,051	15	1,066	2,387
44-45			1,021		1,021	576[g]	1,597	978	15	993	2,590
1945-46			1,196		1,196	700	1,896	972	15	987	2,883
46-47			1,957		1,957	400	2,357	1,135	14	1,149	3,506
47-48	8,400[d]		3,883		12,283	500	12,783	1,215	15	1,230	14,013
48-49	18,253			109	18,362	700	19,062	1,232	19	1,251	20,313
49-50	19,651			459	20,110	700	20,810	1,161	20	1,181	21,991
1950-51	21,426			527	21,953	800	22,753	1,100[d]	21	1,121	23,874
51-52	25,851			600[d]	26,451	800	27,251	1,100[d]	22	1,122	28,373
52-53	29,161			600[d]	29,761	900	30,661	1,100[d]	24	1,124	31,785
53-54	31,120			600[d]	31,720	1,000	32,720	1,100[d]	25	1,125	33,845
54-55	38,712			600[d]	39,312	1,000	40,312	1,100[d]	26	1,126	41,438
1955-56	41,800			560[d]	42,360	1,100	43,460	1,100[d]	26	1,126	44,586
56-57	44,742			520[d]	45,262	1,100	46,362	1,100[d]	25	1,125	47,487
57-58	49,228			480[d]	49,708	1,200	50,908	1,200[d]	26	1,226	52,134
58-59	54,587			450[d]	55,037	1,300	56,337	1,200[d]	30	1,230	57,567
59-60	52,694	5,400		448	58,542	1,400	59,942	1,200[d]	23	1,223	61,165
27-Year Average	16,134	200	331	221	16,886	692	17,578	1,010	19	1,029	18,607

a. 12-month period from October 1 through September 30.
b. Disposal of waste water from County Sanitation Districts of Los Angeles County.
c. Disposal of waste water from service area of City of Los Angeles.
d. Estimated by Department of Water Resources.
e. Amounts are domestic waste water; brine water is excluded.
f. Although a sanitation district of Los Angeles County, these amounts disposed through Hyperion Outfall.
g. Effluent from Graves Pumping Plant.

TABLE 7-3

SEASONAL AMOUNTS OF WASTE WATER DISCHARGED FROM TREATMENT PLANTS
IN AND ADJACENT TO SAN GABRIEL VALLEY
FOR 1933-34 THROUGH 1959-60

In acre-feet

Season[a]	Tri-Cities Sewage Treatment Plant[b]	El Monte Sewage Treatment Plant[b]	Total	Pomona Sewage Treatment Plant[c]		
				Diamond Bar Ranch and Northside Water Company[d]	Discharge to San Jose Wash[e]	Total
1933-34	8,118	500[f]	8,618	1,100		1,100
34-35	8,210	500[f]	8,710	1,300		1,300
1935-36	8,711	500[f]	9,211	1,300		1,300
36-37	9,184	600[f]	9,784	1,500		1,500
37-38	9,665	600[f]	10,265	1,500		1,500
38-39	10,039	600[f]	10,639	1,500		1,500
39-40	10,320	600[f]	10,920	1,500		1,500
1940-41	11,003	600[f]	11,603	1,600		1,600
41-42	10,825	700[f]	11,525	1,900		1,900
42-43	11,208	700[f]	11,908	2,200		2,200
43-44	12,002	800	12,802	2,400		2,400
44-45	12,504	1,000	13,504	2,400		2,400
1945-46	13,346	800	14,146	2,500		2,500
46-47	14,062	800	14,862	2,700		2,700
47-48	6,160	900	7,060	2,800		2,800
48-49		400	400	1,400	1,600	3,000
49-50			0	1,400	1,600	3,000
1950-51			0	1,500	1,600	17,500
51-52			0	1,400	2,000	3,400
52-53			0	1,600	2,100	3,700
53-54			0	1,500	2,600	4,100
54-55			0	1,400	1,300	2,700
1955-56			0	1,300	2,000	3,300
56-57			0	1,500	3,100	4,600
57-58			0	900	3,800	4,700
58-59			0	600	4,300	4,900
59-60			0	400	4,800	5,200
27-year Average	5,754	393	6,147	1,596	1,674	3,270

a. 12-month period from October 1 through September 30.
b. Included in surface outflow.
c. Does not include waste water from remainder of Sanitation District No. 21; this amount discharged at Whites Point.
d. Used for irrigation; included in freshwater imports; estimated by the Department of Water Resources.
e. Estimated by Department of Water Resources; included in surface inflow.
f. Estimated by Department of Water Resources.

ATTACHMENT NO. 8

SPREADING GROUNDS
AND
SEASONAL AMOUNTS SPREAD

TABLE 8-1

SPREADING GROUNDS IN THE SAN GABRIEL VALLEY GROUND WATER BASIN[a]

Project No.[b]	Name of spreading ground[c]	Location	Period of operation[d]
1	Buena Vista	One mile east of Sawpit Wash and one-half mile north of Arrow Highway	1954-55 to present
2	Big Dalton Canyon	West side of Big Dalton Wash intake, one-half mile above Sierra Madre Avenue	1930-31 to present
3	Citrus	South side of Big Dalton Wash between Citrus and Cerritos Avenues	1960-61 to present
4	Little Dalton	West of Glendora Mt. Road between Little Dalton Debris Dam and East Palm Drive	1931-32 to present
5	Eaton Spreading Basin	North of Duarte Road on the east side of Eaton Channel	1956-57 to present
6	Irwindale	Northeast of intersection of Big Dalton Channel and Irwindale Avenue	1958-59 to present
7	Peck Road	Confluence of Sawpit and Santa Anita Washes	1959-60 to present
8	Ben Lomond	Both north and south sides of San Dimas Wash Channel at southwest corner of intersection of Arrow Highway and Ben Lomond Avenue	1958-59 to present
9	Canyon Basin[e]	Both east and west sides of San Gabriel River below mouth of San Gabriel Canyon	About 1917 to present
10	Santa Fe Reservoir	Within Santa Fe Dam Reservoir area, north of spillway	1953-54 to present

SPREADING GROUNDS IN THE SAN GABRIEL VALLEY GROUND WATER BASIN[a]
(continued)

Project No.[b]	Name of spreading ground[c]	Location	Period of operation[d]
11	Sawpit	West side of Sawpit Wash below mouth of canyon at head of Norumbega Street, Monrovia	1946-47 to present
12	Main Basin[f]	Water spread in the San Dimas and Little and Big Dalton Washes	1926-27 to 1959-60

a. Except for the Main Basin spreading grounds which were discontinued in 1959-60, spreading grounds are delineated on Plate 4.
b. Project number assigned by the Department of Water Resources for this investigation.
c. Spreading grounds owned and operated by Los Angeles County Flood Control District.
d. "Present" denotes that spreading ground was in operation on September 3[illegible] 1961.
e. Spreading grounds owned and operated by the San Gabriel Spreading Corporation, sometimes referred to as the East Side and West Side spreading grounds.
f. Spreading grounds owned and operated by the San Gabriel Spreading Corporation. Water is conveyed to the spreading grounds through the Azusa and Covina Canals.

TABLE 8-2

SEASONAL AMOUNTS OF WATER SPREAD
IN THE SAN GABRIEL VALLEY GROUND WATER BASIN[a]

In acre-feet

Season[b]	Project number and name of spreading grounds					
	1 Buena Vista	2 Big Dalton Canyon	3 Citrus	4 Little Dalton	5 Eaton Spreading Basin	6 Irwindale
1933-34		100		0		
34-35		131		0		
1935-36		0		0		
36-37		866		275		
37-38		397		287		
38-39		49		12		
39-40		0		0		
1940-41		1,528		1,166		
41-42		0		0		
42-43		1,191		1,084		
43-44		543		469		
44-45		64		290		
1945-46		47		73		
46-47		174		89		
47-48		0		0		
48-49		88		0		
49-50		66		28		
1950-51		0		0		
51-52		856		563		
52-53		3		9		
53-54		370		161		
54-55	10	0		0		
1955-56	227	180		30	0	
56-57	817	16		11	260	
57-58	2,730	2,380	began op-	658	1,236	
58-59	1,087	145	eration in	22	441	242
59-60	1,230	0	1960-61	0	501	934
27-Year Average	226	341	0	194	90	44

SEASONAL AMOUNTS OF WATER SPREAD
IN THE SAN GABRIEL VALLEY GROUND WATER BASIN[a]
(continued)

In acre-feet

Season[b]	Project number and name of spreading grounds					
	7	8	9	10	11	12
	Peck Road	Ben Lomond	Canyon Basin	Santa Fe Reservoir	Sawpit	Main Basin
1933-34			12,401			4,506
34-35			34,315			17,692
1935-36			17,997			6,975
36-37			33,814			20,297
37-38			31,627			13,134
38-39			17,815			6,194
39-40			19,304			8,544
1940-41			45,618			13,298
41-42			21,392			8,241
42-43			24,502			7,702
43-44			31,130			9,820
44-45			34,681			14,467
1945-46			23,351			12,745
46-47			23,716		89	8,936
47-48			4,796		0	2,218
48-49			2,874		8	1,343
49-50			9,125		0	2,590
1950-51			1,378		19	622
51-52			27,847		517	8,361
52-53			15,765		56	5,705
53-54			18,021	3,500	0	4,960
54-55			20,328	0	0	6,096
1955-56			19,135	0	180	8,406
56-57			16,225	0	38	6,199
57-58			47,419	12,752	978	7,616
58-59		1,431	24,558	181	199	6,176
59-60	970	1,055	6,111	59	38	
27-Year Average	36	92	21,676	611	79	7,883

a. Amounts spread obtained from Annual and Biennial Hydrologic Reports of the Los Angeles County Flood Control District. Project number assigned by the Department of Water Resources for this investigation. Except for the Main Basin spreading grounds which were discontinued in 1959-60, spreading grounds are delineated on Plate 4.

b. 12-month period from October 1 through September 30.

ATTACHMENT NO. 9

SPECIFIC YIELD AND
TRANSMISSIBILITY TEST DATA

TRANSMISSIBILITY TEST PROCEDURES

The transmissibility rates of aquifers penetrated by wells in the San Gabriel Valley of Los Angeles County were determined by the use of drawdown and recovery tests, in conjunction with specific capacity data. In the drawdown test, measurements of the ground water level are taken at frequent intervals from the moment the pump is turned on until the water level stabilizes or the rate of change in the water level becomes negligible. The quantity of ground water pumped is also measured. A recovery test is essentially the reverse: that is, the well is pumped for a specified period of time and the discharge is measured. Measurements of the ground water level are taken at frequent intervals from the moment the pump is shut off until the water level has recovered to the static prepumping level.

Ideally, measurements are made in an observation well perforated in the same aquifer as the pumping well; however, the measurements can be made in the pumping well. In both the drawdown and the recovery test, the change in water level can be plotted against the time required for the change.

Using mathematical formulas developed by the United States Geological Survey and other investigators in the field of ground water movement, the transmissibility, permeability, and storage coefficients can be computed when a pumping well and an observation well are used together. When testing is conducted using just the pumping well, generally only transmissibility and permeability can be determined.

The transmissibility rate, or the coefficient of transmissibility, is the rate of flow of water in gallons per day at the prevailing water temperature through a vertical strip of the aquifer one-foot wide having a height equal to the saturated thickness of the aquifer and under a unit hydraulic gradient.

The permeability of a material is its capacity for transmitting a fluid. The coefficient of permeability is the rate of flow of water in gallons per day through a cross section of one square foot under a unit hydraulic gradient. The standard coefficient is defined for water at a temperature of 60° F. The field coefficient requires no temperature adjustment and the units are stated in terms of the prevailing water temperature.

Storage coefficient, or the coefficient of storage, is the volume of water released from storage in each vertical column of water having a base one foot square when the water table or piezometric surface declines one foot. It is expressed as a decimal and is dimensionless.

Transmissibility values and storage coefficients determined from the pumping tests conducted in the San Gabriel Valley are shown in Table 9-2

TABLE 9-1

SPECIFIC YIELD VALUES USED
IN SAN GABRIEL VALLEY

(After State Water Rights Board Revised Values of Specific Yield as used for San Fernando Valley Reference, 7/9/59, which is based on values used in Bulletin 45, "Geology and Ground Water Storage Capacity of Valley Fill" and Bulletin 104, Appendix A, "Ground Water Geology")

03 Percent

Adobe	Decomposed shale	Hard sandy shale	Sandy shale
Boulders in clay	Dirt	Hard shell	Shaley clay
Cemented clay	Granite clay	Muck	Shell rock
Clay	Hard clay	Sandy clay loam	Silty clay loam
Clayey loam	Hard pan	Shale	Soapstone

05 Percent

Cemented sand	Decomposed granite	Sand rock	Silt
Cemented gravel	Gravelly clay	Sandstone	Silty clay
Chalk rock	Loam	Sandy clay	Silty loam
Clay and gravel	Rotten conglomerate	Sandy silt	Silty sand
Clayey sand	Rotten granite	Sediment	Soil
Clayey silt	Sand and clay	Shaley gravel	Slum
Conglomerate	Sand and silt	Shale and boulders	Peat

10 Percent

Caliche	Sandy Loam	Dirty sand	Packed gravel
Cemented boulders	Sand and boulders	Hard gravel	Sandy soil
Cemented sand and gravel	Dead gravel	Hard sand	Soft sandstone
	Dead sand	Heavy rocks	Tight boulders

14 Percent

Cobbles and gravel	Broken rocks	Heavy gravel	Sand and gravel, silty
Coarse gravel	Gravel and boulders	Large gravel	Tight fine gravel
Boulders	Heaving gravel	Rocks	Tight medium gravel

16 Percent

Fine sand	Quicksand	Sand, gravel and boulders	Tight sand
Heaving sand	Sand and boulders		

21 Percent

Sand and gravel			

23 Percent

Dry gravel	Gravel	Medium gravel	Water gravel
Loose gravel	Gravelly sand	Sand	

28 Percent

Coarse sand	Fine gravel	Medium sand	

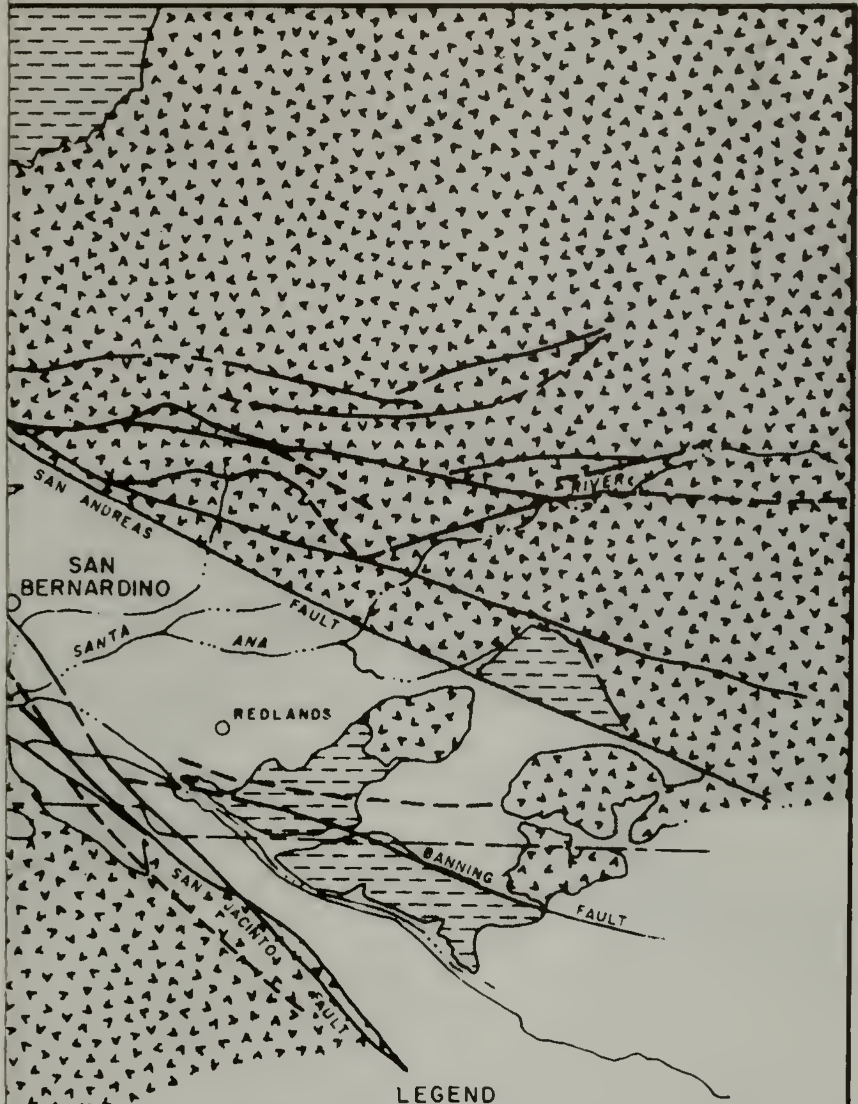
Notes: The specific yield value is increased by 1 percent where streaks of sand or gravel occur in clay or clayey material.

Likewise, the specific yield value is decreased by 1 percent where streaks of clay occur in sand, gravel, and mixtures of sand and gravel.

TABLE 9-2

TRANSMISSIBILITY TESTS CONDUCTED
IN THE SAN GABRIEL VALLEY

Pumping well	Observation well	Type of test	Date	Transmissibility gal/day/ft	Permeability gal/day/ft^2	Storage coefficient
1N/10W-22P1	1N/10W-22P2	Drawdown	12-22-60	124,000	--	$6.0x10^{-5}$
1N/10W-27K2	1N/10W-27K1	Drawdown	12-19-60	595,000	4,900	$1.8x10^{-2}$
1N/11W-34N3	1N/11W-34N5	Drawdown	12- 7-60	377,000	696	$3.6x10^{-3}$
1S/ 9W- 8D1	--	Recovery	12-16-61	49,000	--	--
1S/10W- 3A1	1S/10W- 3H1	Drawdown	12-16-60	875,000	2,182	$2.8x10^{-4}$
1S/10W-10C1	1S/10W-10C2	Drawdown	12-21-60	263,000	954	$1.1x10^{-2}$
1S/10W-12R1	--	Recovery	11- 6-61	203,000	--	--
1S/10W-14B1	--	Recovery	11- 7-61	42,000	--	--
1S/10W-28K3	1S/10W-28K4	Drawdown	11-16-60	83,000	512	$2.2x10^{-4}$
1S/10W-30G1	1S/10W-30G3	Drawdown	11-30-60	559,000	--	$2.5x10^{-3}$
1S/11W- 2F1	1S/11W- 2F2	Drawdown	12- 8-60	750,000	1,769	$2.9x10^{-4}$
1S/11W-10N6	--	Recovery	11-14-61	260,000	--	--
1S/11W-26K1	1S/11W-26G1	Drawdown	11-14-61	477,000	--	$6.0x10^{-4}$
1S/11W-30B1	--	Recovery	11-15-61	110,000	--	--
1S/12W-11D1	--	Recovery	11-17-61	134,000	--	--
1S/12W-13B1	1S/12W-13B2	Drawdown	11-16-61	33,000	--	--



LEGEND

- ALLUVIUM AND ASSOCIATED DEPOSITS OF RECENT OR PLEISTOCENE AGE
- SEDIMENTARY ROCKS OF MARINE ORIGIN, MAINLY TERTIARY WITH SOME CRETACEOUS
- CRYSTALLINE AND METAMORPHIC ROCKS, JURASSIC OR OLDER; SOME TERTIARY ROCKS
- INVESTIGATIONAL AREA
- KNOWN FAULTS
- INFERRED FAULTS
- CONCEALED FAULTS

STATE OF CALIFORNIA

THE RESOURCES AGENCY

DEPARTMENT OF WATER RESOURCES

SOUTHERN DISTRICT

GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

LOCATION AND GENERAL GEOLOGY OF AREA OF INVESTIGATION

SCALE OF MILES

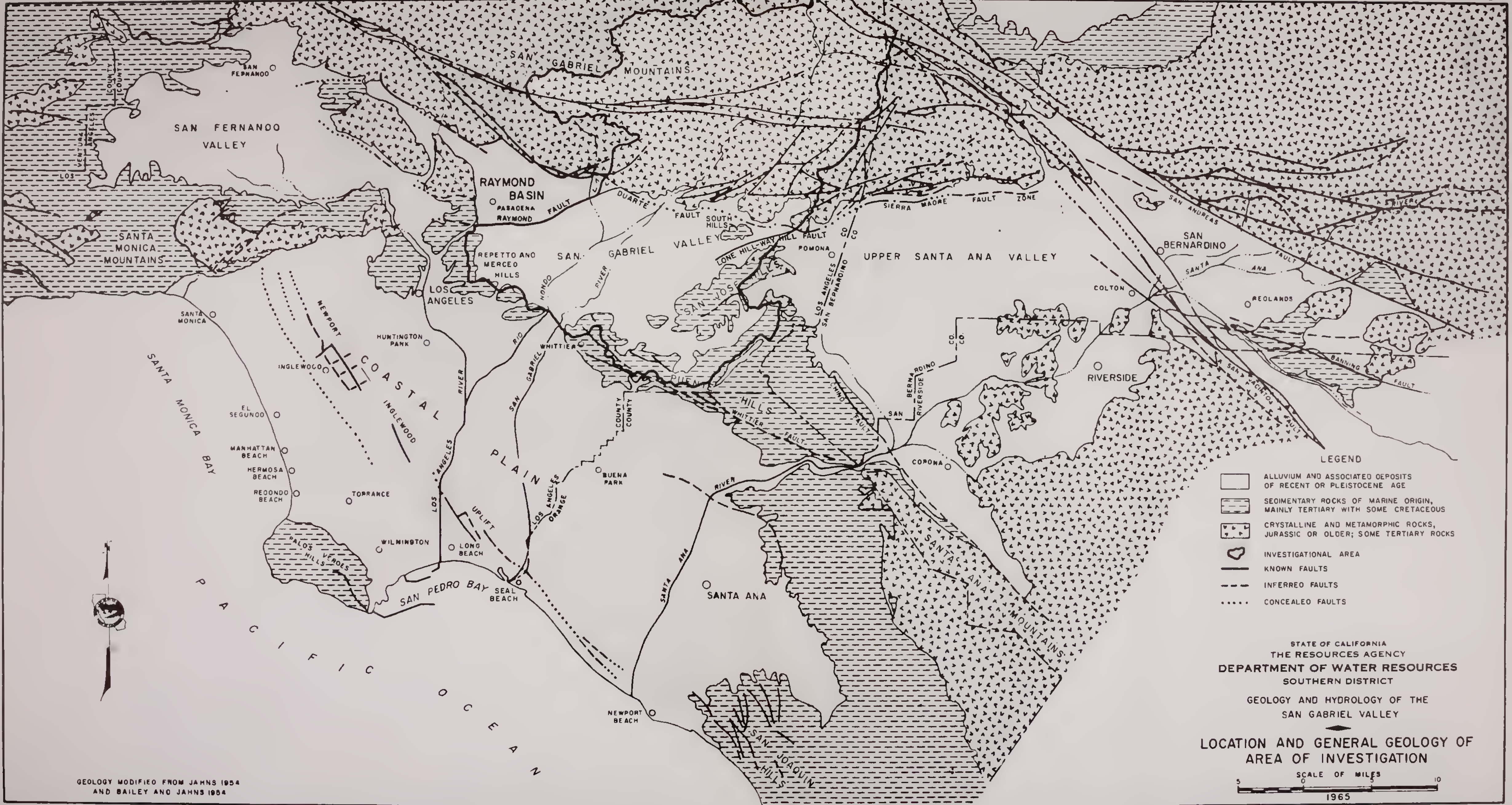
5 0 5 10

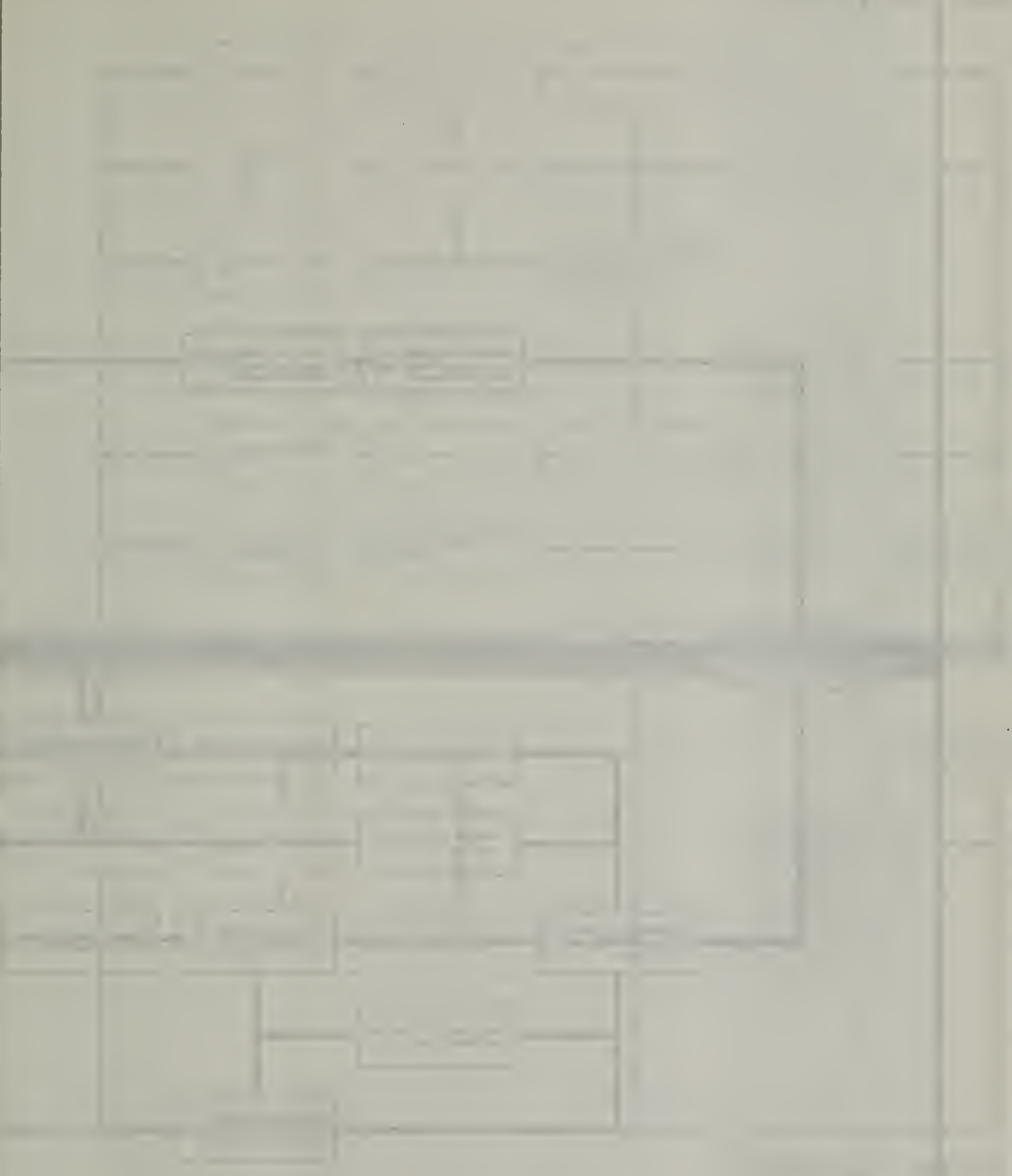
1965

TABLE 9-2

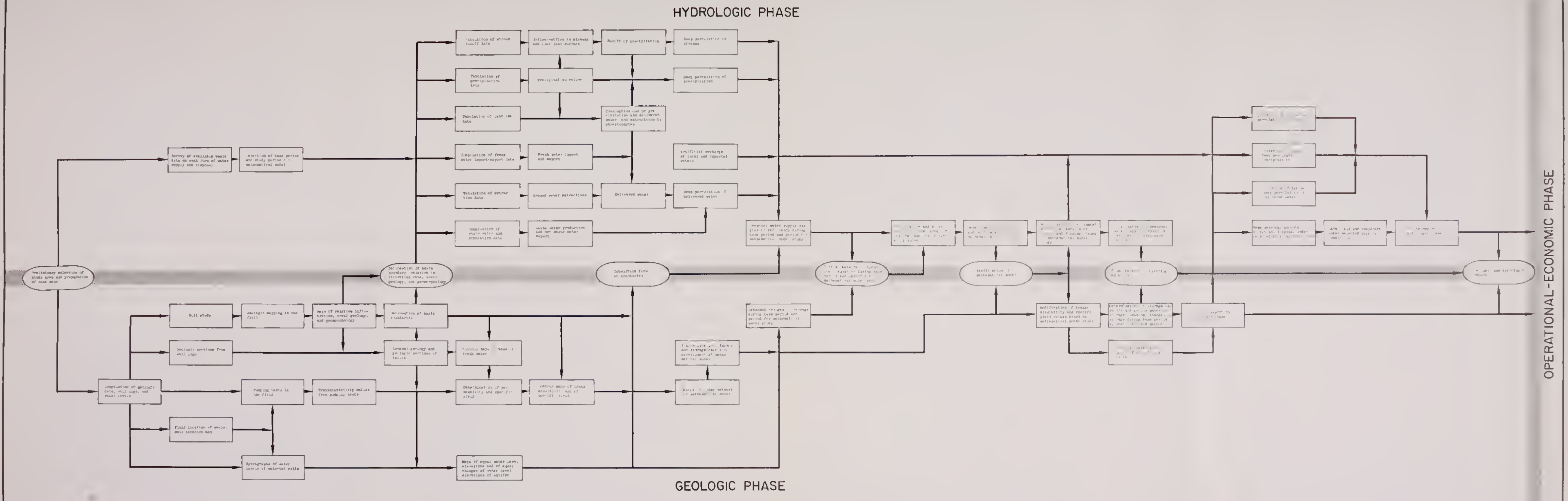
TRANSMISSIBILITY TESTS CONDUCTED
IN THE SAN GABRIEL VALLEY

Pumping well	Observation well	Type of test	Date	Transmissibility gal/day/ft	Permeability gal/day/ft^2	Storage coefficient
1N/10W-22P1	1N/10W-22P2	Drawdown	12-22-60	124,000	--	6.0×10^{-5}
1N/10W-27K2	1N/10W-27K1	Drawdown	12-19-60	595,000	4,900	1.8×10^{-2}
1N/11W-34N3	1N/11W-34N5	Drawdown	12- 7-60	377,000	696	3.6×10^{-3}
1S/ 9W- 8D1	--	Recovery	12-16-61	49,000	--	--
1S/10W- 3A1	1S/10W- 3H1	Drawdown	12-16-60	875,000	2,182	2.8×10^{-4}
1S/10W-10C1	1S/10W-10C2	Drawdown	12-21-60	263,000	954	1.1×10^{-2}
1S/10W-12R1	--	Recovery	11- 6-61	203,000	--	--
1S/10W-14B1	--	Recovery	11- 7-61	42,000	--	--
1S/10W-28K3	1S/10W-28K4	Drawdown	11-16-60	83,000	512	2.2×10^{-4}
1S/10W-30G1	1S/10W-30G3	Drawdown	11-30-60	559,000	--	2.5×10^{-3}
1S/11W- 2F1	1S/11W- 2F2	Drawdown	12- 8-60	750,000	1,769	2.9×10^{-4}
1S/11W-10N6	--	Recovery	11-14-61	260,000	--	--
1S/11W-26K1	1S/11W-26G1	Drawdown	11-14-61	477,000	--	6.0×10^{-4}
1S/11W-30B1	--	Recovery	11-15-61	110,000	--	--
1S/12W-11D1	--	Recovery	11-17-61	134,000	--	--
1S/12W-13B1	1S/12W-13B2	Drawdown	11-16-61	33,000	--	--

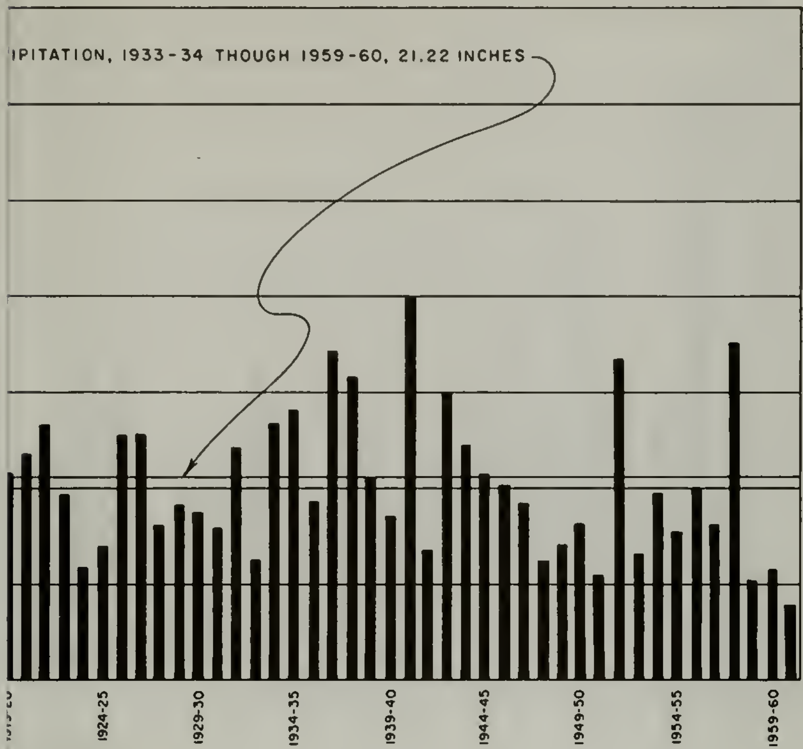

SAN GABRIEL MOUNTAINS
SAN FERNANDO
SAN FERNANDO VALLEY
VENTURA COUNTY
LOS ANGELES COUNTY
RAYMOND BASIN
PASADENA
RAYMOND FAULT
DUARTE FAULT
SOUTH HILLS
SIERRA MADRE FAULT ZONE
SAN ANDREAS FAULT
SANTA MONICA MOUNTAINS
REPETTO AND MERCED HILLS
SAN GABRIEL VALLEY
LONE HILL-WAY HILL FAULT
POMONA
LOS ANGELES CO
SAN BERNARDINO CO
UPPER SANTA ANA VALLEY
SAN BERNARDINO
SANTA ANA RIVER
COLTON
REDLANDS
BANNING FAULT
SAN JACINTO FAULT
SAN JOSE HILLS
LOS ANGELES
SANTA MONICA
NEWPORT
HUNTINGTON PARK
INGLEWOOD
COASTAL PLAIN
INGLEWOOD
RIO HONDO
SAN GABRIEL RIVER
WHITTIER
PUENTE HILLS
WHITTIER FAULT
CHINO FAULT
SAN BERNARDINO CO
RIVERSIDE CO
RIVERSIDE
CORONA
SANTA MONICA BAY
EL SEGUNDO
MANHATTAN BEACH
HERMOSA BEACH
REDONDO BEACH
TORRANCE
LOS ANGELES RIVER
LOS ANGELES COUNTY
ORANGE COUNTY
BUENA PARK
UPLIFT
WILMINGTON
LONG BEACH
PALOS VERDES HILLS
SAN PEDRO BAY
SEAL BEACH
SANTA ANA
SANTA ANA RIVER
SANTA ANA MOUNTAINS
NEWPORT BEACH
SAN JOAQUIN HILLS
PACIFIC OCEAN
LEGEND
ALLUVIUM AND ASSOCIATED DEPOSITS OF RECENT OR PLEISTOCENE AGE
SEDIMENTARY ROCKS OF MARINE ORIGIN, MAINLY TERTIARY WITH SOME CRETACEOUS
CRYSTALLINE AND METAMORPHIC ROCKS, JURASSIC OR OLDER; SOME TERTIARY ROCKS
INVESTIGATIONAL AREA
KNOWN FAULTS
INFERRED FAULTS
CONCEALED FAULTS
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY
LOCATION AND GENERAL GEOLOGY OF AREA OF INVESTIGATION
SCALE OF MILES
5 0 5 10
1965
GEOLOGY MODIFIED FROM JAHNS 1954 AND BAILEY AND JAHNS 1954



FLOW CHART OF



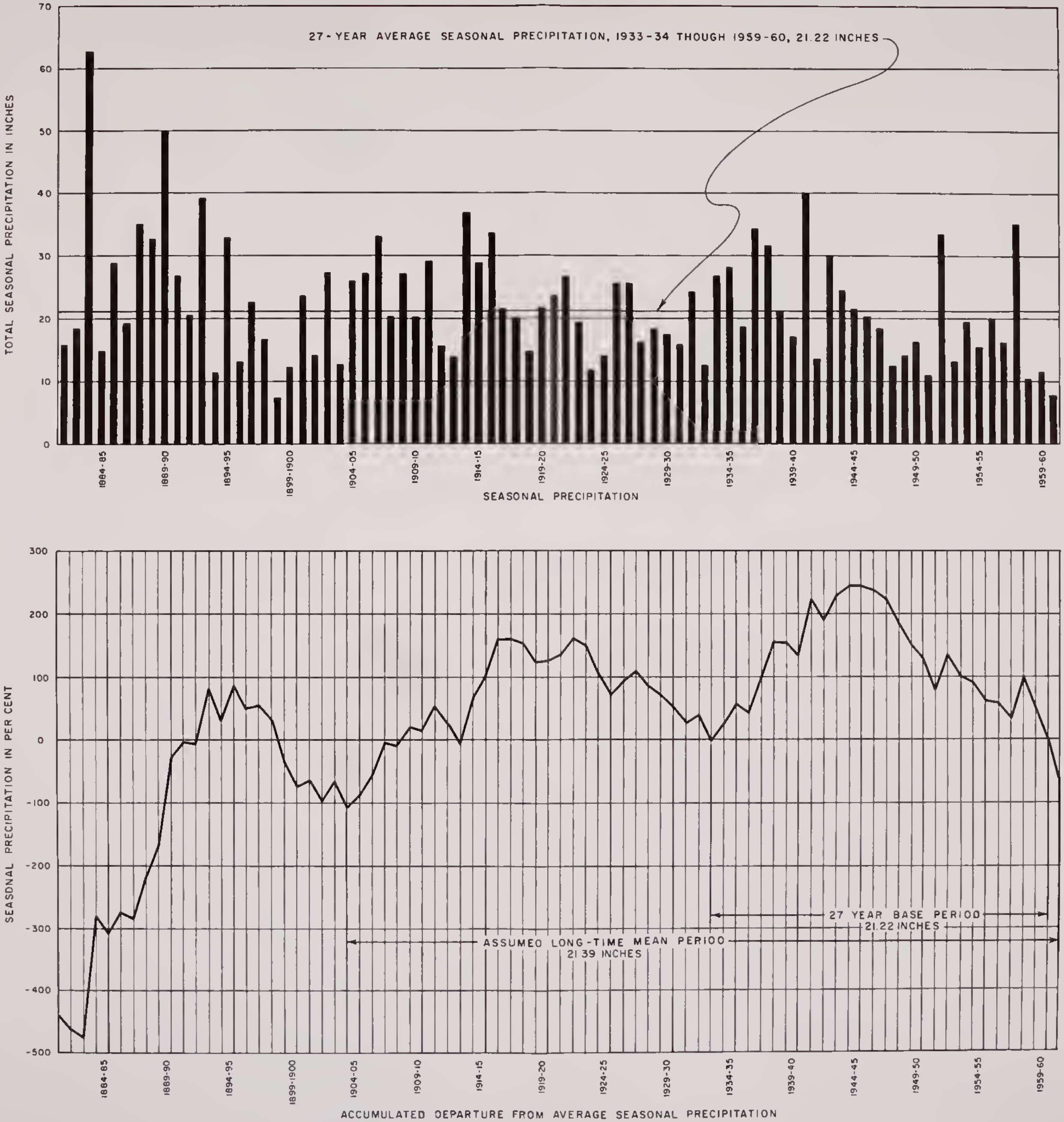
FLOW CHART OF GEOLOGIC AND HYDROLOGIC PHASES OF THE INVESTIGATION OF PLANNED UTILIZATION OF THE SAN GABRIEL VALLEY GROUND WATER BASIN



PRECIPITATION

AVERAGE SEASONAL PRECIPITATION

CTERISTICS AT GLENDORA



PRECIPITATION CHARACTERISTICS AT GLENDORA

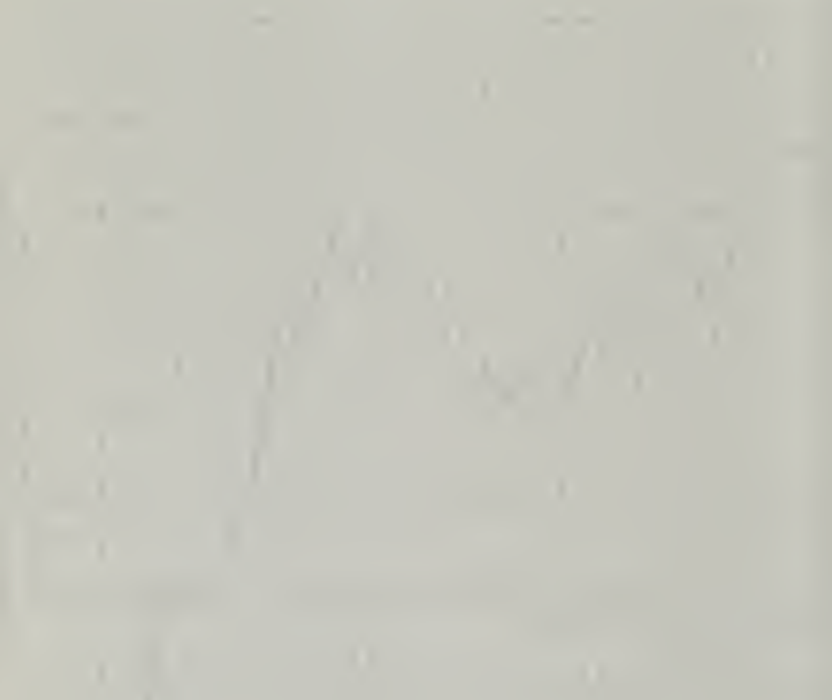
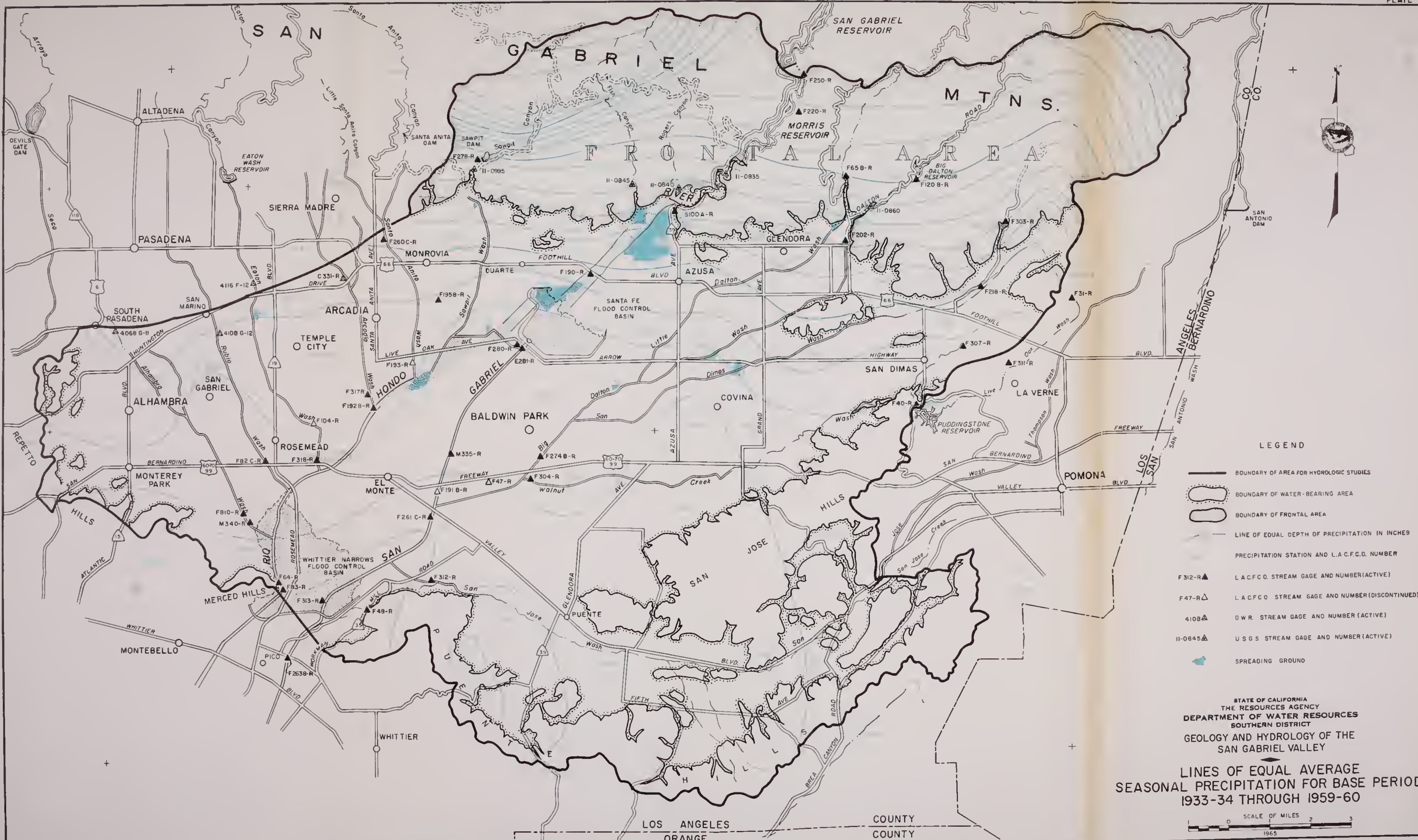
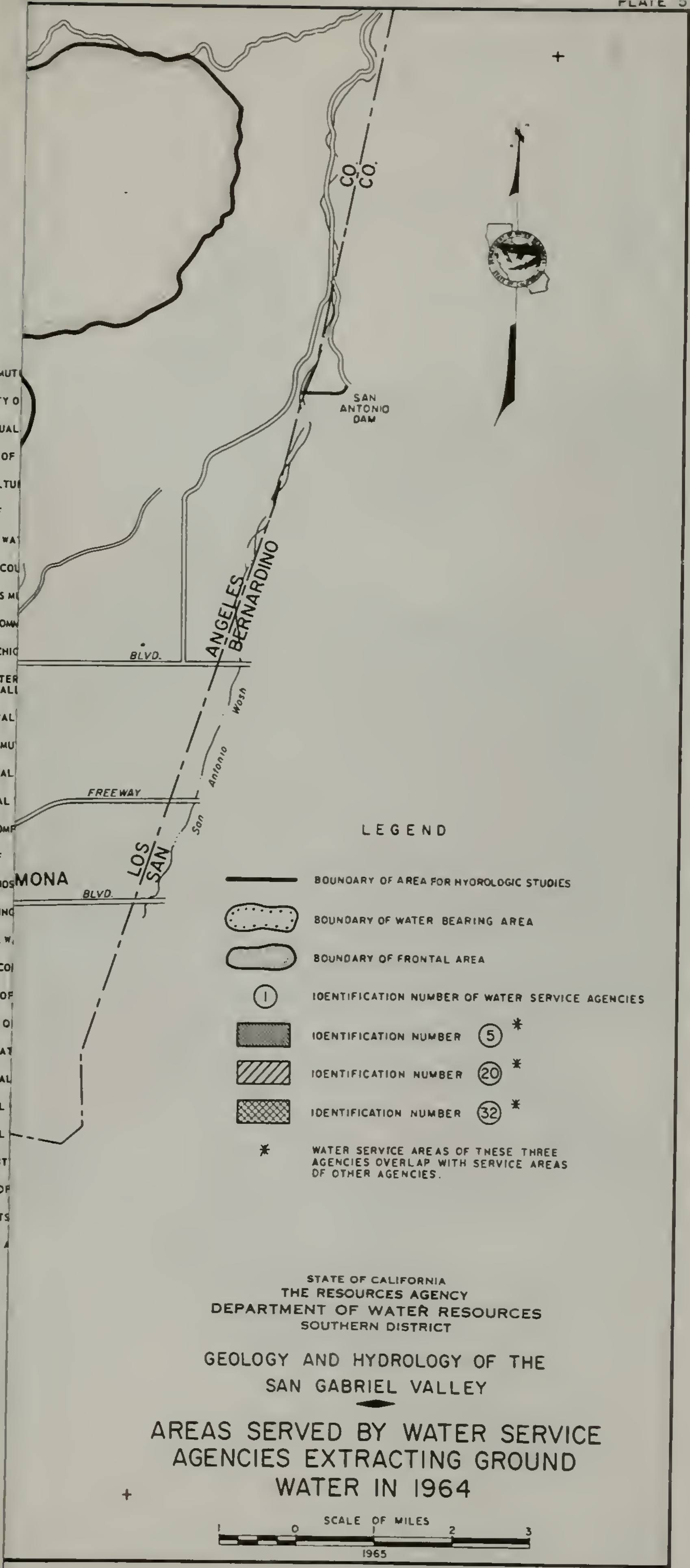


PLATE 4


SAN GABRIEL MTNS.
FRONTAL AREA
SAN GABRIEL RESERVOIR
MORRIS RESERVOIR
SANTA ANITA DAM
SAWPIT DAM
EATON WASH RESERVOIR
DEVILS GATE DAM
SAN ANTONIO DAM
PUDDINGSTONE RESERVOIR
SANTA FE FLOOD CONTROL BASIN
WHITTIER NARROWS FLOOD CONTROL BASIN
ALTADENA
PASADENA
SIERRA MADRE
MONROVIA
DUARTE
ARCADIA
SAN MARINO
SOUTH PASADENA
TEMPLE CITY
SAN GABRIEL
ALHAMBRA
ROSEMEAD
MONTEREY PARK
EL MONTE
BALDWIN PARK
AZUSA
GLENDORA
COVINA
SAN DIMAS
LA VERNE
POMONA
PUENTE
MONTEBELLO
PICO
WHITTIER
MERCED HILLS
REPETTO HILLS
SAN JOSE HILLS
PUENTE HILLS
LOS ANGELES COUNTY
ORANGE COUNTY
LOS ANGELES
SAN BERNARDINO
CO.
LEGEND
BOUNDARY OF AREA FOR HYDROLOGIC STUDIES
BOUNDARY OF WATER-BEARING AREA
BOUNDARY OF FRONTAL AREA
LINE OF EQUAL DEPTH OF PRECIPITATION IN INCHES
PRECIPITATION STATION AND L.A.C.F.C.D. NUMBER
F312-R L.A.C.F.C.D. STREAM GAGE AND NUMBER (ACTIVE)
F47-R L.A.C.F.C.D. STREAM GAGE AND NUMBER (DISCONTINUED)
4108 D.W.R. STREAM GAGE AND NUMBER (ACTIVE)
11-0845 U.S.G.S. STREAM GAGE AND NUMBER (ACTIVE)
SPREADING GROUND
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY
LINES OF EQUAL AVERAGE SEASONAL PRECIPITATION FOR BASE PERIOD 1933-34 THROUGH 1959-60
SCALE OF MILES
1965

Identification Number	
1	ADAMS RANCH MUT
2	ALHAMBRA, CITY O
3	AMARILLO MUTUAL
4	ARCADIA, CITY OF
5	AZUSA AGRICULTU
6	AZUSA, CITY OF
7	AZUSA VALLEY WA
8	BALDWIN PARK COU
9	BEVERLY ACRES M
10	BLUE RIBBON COM
11	CALIFORNIA-MICHIC
12	CALIFORNIA WATER (SAN GABRIEL VALL
13	CANTRILL MUTUAL
14	CEDAR AVENUE MU
15	CHAMPION MUTUAL
16	CLAYTON MUTUAL
17	CROSS WATER COMP
18	COVINA, CITY OF
19	COVINA HIGHLANDS
20	COVINA IRRIGATING
21	DEL RIO MUTUAL W
22	DUARTE WATER CO
23	EL MONTE, CITY OF
24	GLENDORA, CITY O
25	GLENDORA IRRIGAT
26	HALLWOOD MUTUAL
27	HEMLOCK MUTUAL
28	HERBERT MUTUAL
29	LA PUENTE COUNT
30	LA VERNE, CITY OF
31	LA VERNE HEIGHTS
32	LA VERNE WATER



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

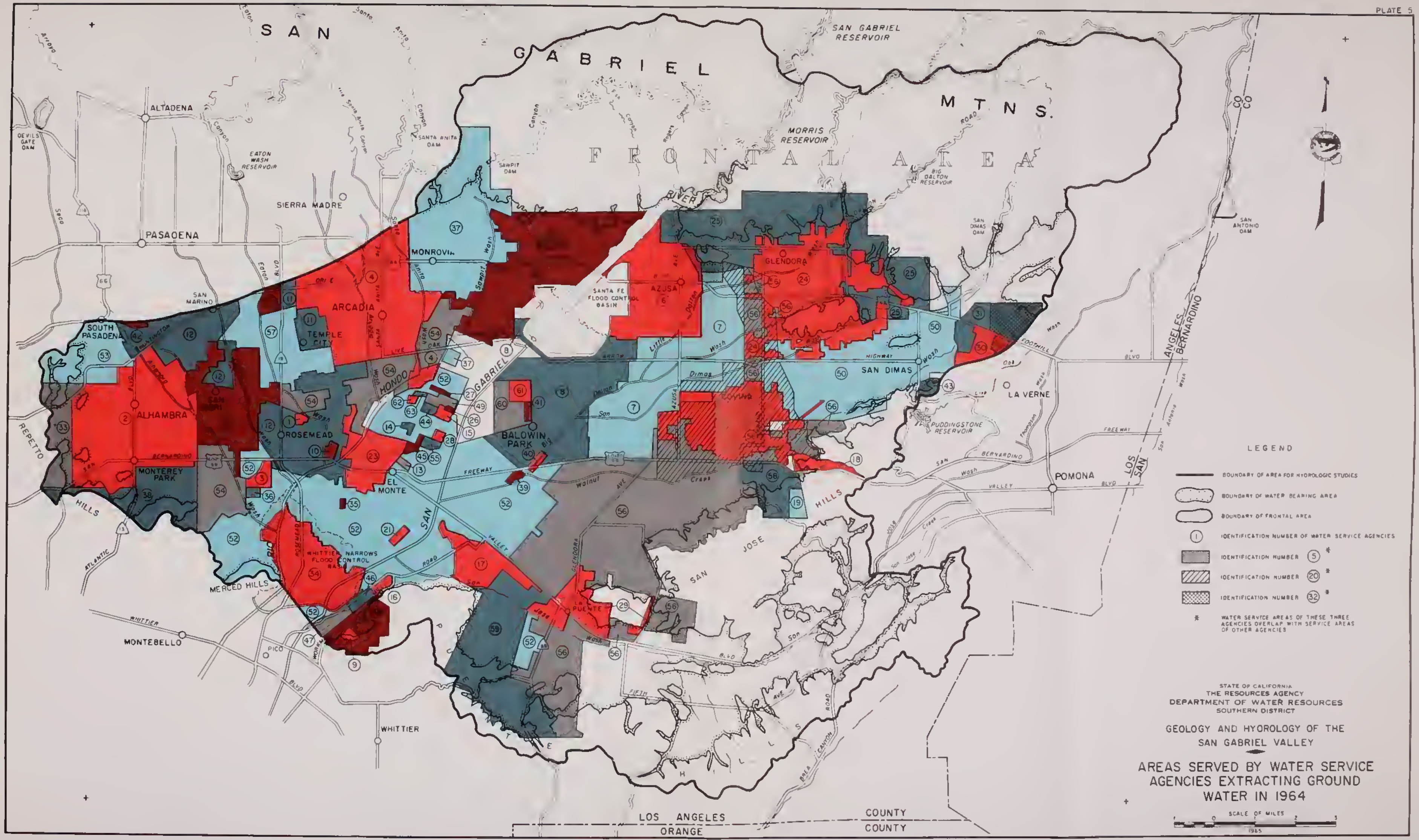
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

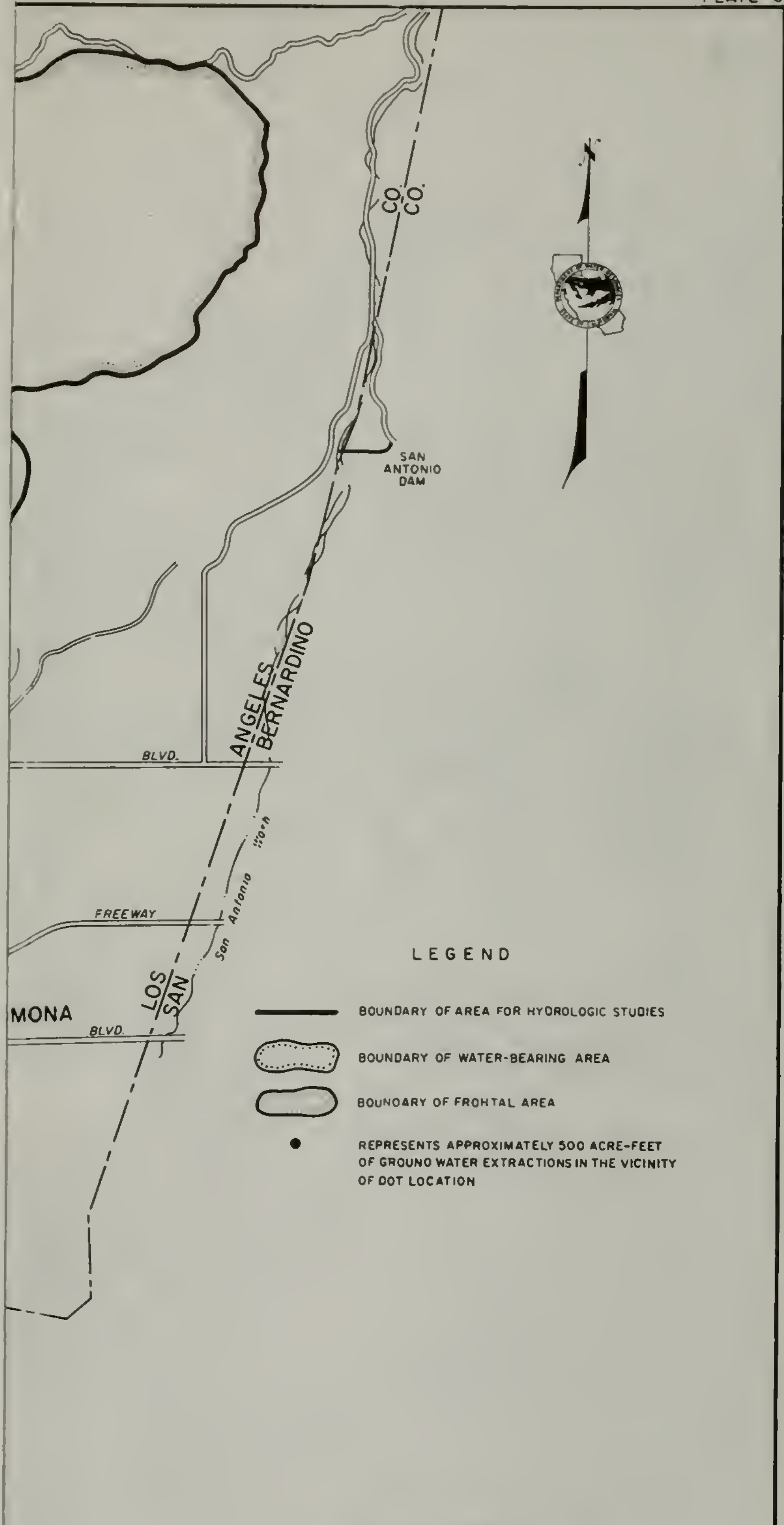
AREAS SERVED BY WATER SERVICE AGENCIES EXTRACTING GROUND WATER IN 1964

INDEX

LIST OF WATER SERVICE AGENCIES EXTRACTING GROUND WATER IN THE SAN GABRIEL VALLEY IN 1964

Identification Number	Entry	Identification Number	Entry
1	ADAMS RANCH MUTUAL WATER COMPANY	33	LOS ANGELES, CITY OF
2	ALHAMBRA, CITY OF	34	LOS ANGELES COUNTY OF (DEPT. OF PARKS AND RECREATION)
3	AMARILLO MUTUAL WATER COMPANY	35	LOS FLORES MUTUAL WATER COMPANY
4	ARCADIA, CITY OF	36	MISSION GARDENS MUTUAL WATER COMPANY
5	AZUSA AGRICULTURAL WATER COMPANY	37	MONROVIA, CITY OF
6	AZUSA, CITY OF	38	MONTEREY PARK, CITY OF
7	AZUSA VALLEY WATER COMPANY	39	NO. 17 WALNUT PLACE MUTUAL WATER COMPANY
8	BALDWIN PARK COUNTY WATER DISTRICT	40	NOS. 36 AND 47 WALNUT PLACE MUTUAL WATER COMPANY
9	BEVERLY ACRES MUTUAL WATER USERS ASSOCIATION	41	PARK WATER COMPANY
10	BLUE RIBBON COMMUNITY WATER COMPANY	42	PASADENA, CITY OF
11	CALIFORNIA-MICHIGAN LAND AND WATER COMPANY	43	PUDDINGSTONE WATER SYSTEM
12	CALIFORNIA WATER AND TELEPHONE COMPANY (SAN GABRIEL VALLEY DIVISION)	44	PURITY MUTUAL WATER COMPANY
13	CANTRILL MUTUAL WATER COMPANY	45	RICHWOOD MUTUAL WATER COMPANY
14	CEDAR AVENUE MUTUAL WATER COMPANY	46	RINCON DITCH COMPANY
15	CHAMPION MUTUAL WATER COMPANY	47	RINCON IRRIGATION COMPANY
16	CLAYTON MUTUAL WATER COMPANY	48	ROSE HILL MEMORIAL PARK
17	CROSS WATER COMPANY	49	RURBAN HOMES MUTUAL WATER COMPANY
18	COVINA, CITY OF	50	SAN DIMAS-CHARTER OAK DOMESTIC WATER COMPANY AND SAN DIMAS WATER COMPANY
19	COVINA HIGHLANDS WATER COMPANY	51	SAN GABRIEL COUNTY WATER DISTRICT
20	COVINA IRRIGATING COMPANY	52	SAN GABRIEL VALLEY WATER COMPANY (EL MONTE DIVISION AND KWIS AREA)
21	DEL RIO MUTUAL WATER COMPANY	53	SOUTH PASADENA, CITY OF
22	DUARTE WATER COMPANY	54	SOUTHERN CALIFORNIA WATER COMPANY (SOUTH ARCADIA AND SOUTH SAN GABRIEL TARIFF AREAS)
23	EL MONTE, CITY OF	55	STERLING MUTUAL WATER COMPANY
24	GLENDORA, CITY OF	56	SUBURBAN WATER SYSTEMS (SAN JOSE HILLS DISTRICT TARIFFS)
25	GLENDORA IRRIGATING COMPANY	57	SUNNY SLOPE WATER COMPANY
26	HALLWOOD MUTUAL WATER COMPANY	58	VALENCIA HEIGHTS MUTUAL WATER COMPANY
27	HEMLOCK MUTUAL WATER COMPANY	59	VALLECITO WATER COMPANY
28	HERBERT MUTUAL WATER COMPANY	60	VALLEY VIEW MUTUAL WATER COMPANY
29	LA PUENTE COUNTY WATER DISTRICT	61	WERNER TRACT MUTUAL WATER COMPANY
30	LA VERNE, CITY OF	62	WOOD MUTUAL WATER COMPANY
31	LA VERNE HEIGHTS DOMESTIC WATER CO	63	WOODLAND MUTUAL WATER COMPANY
32	LA VERNE WATER ASSOCIATION		





STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

PATTERN OF GROUND WATER PUMPAGE IN 1960

SCALE OF MILES
1 0 1 2 3

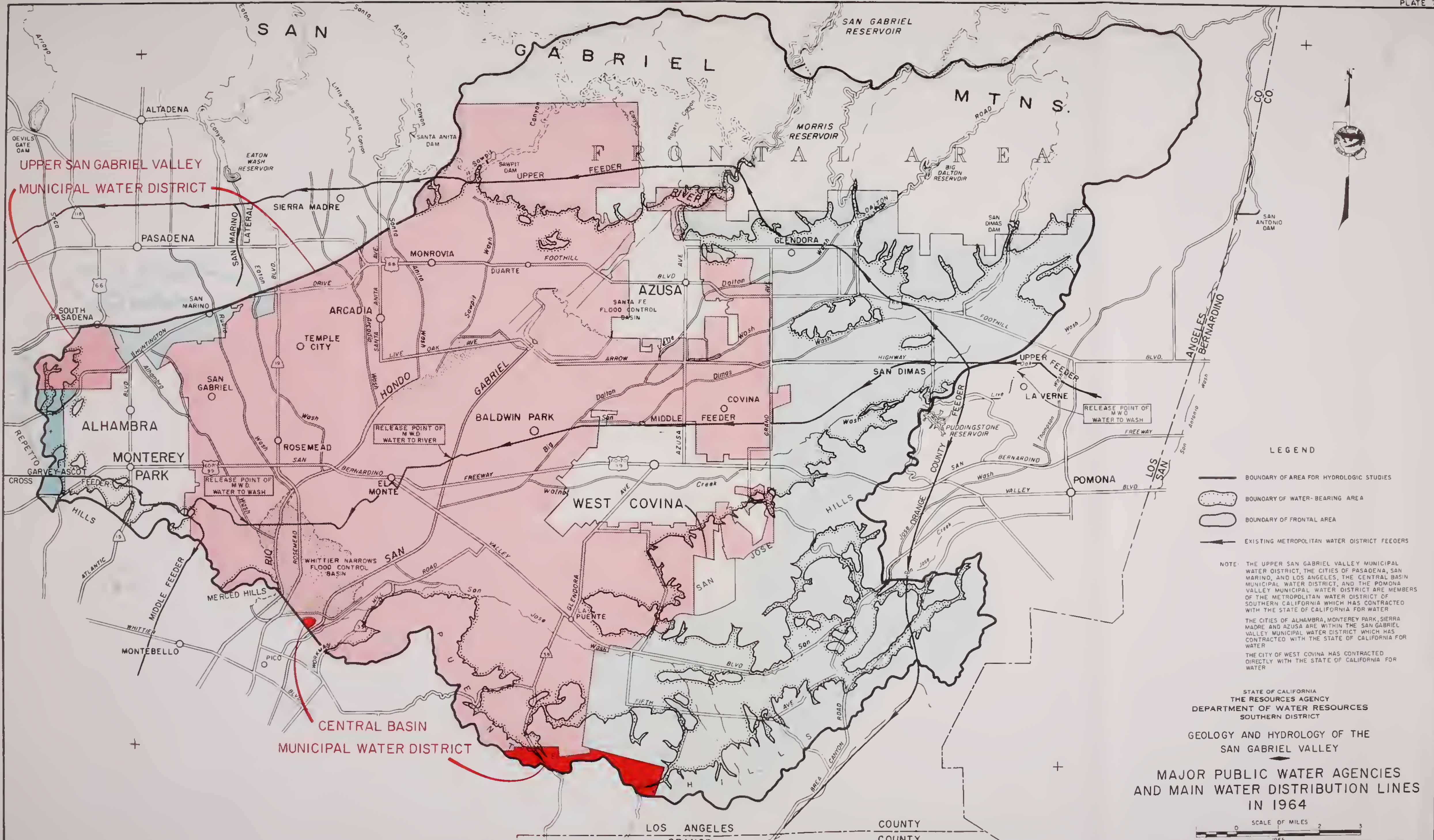
1965

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

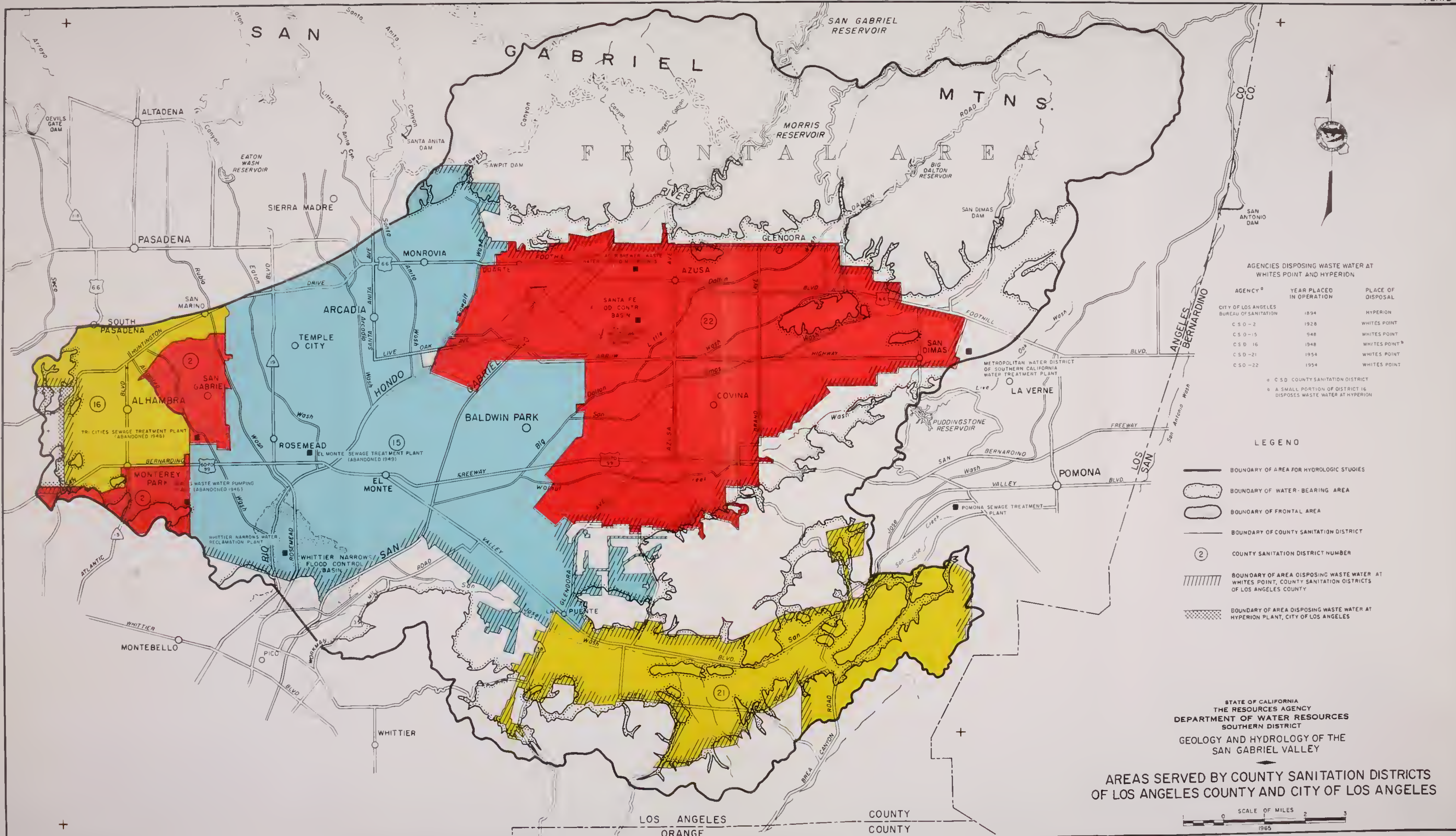
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

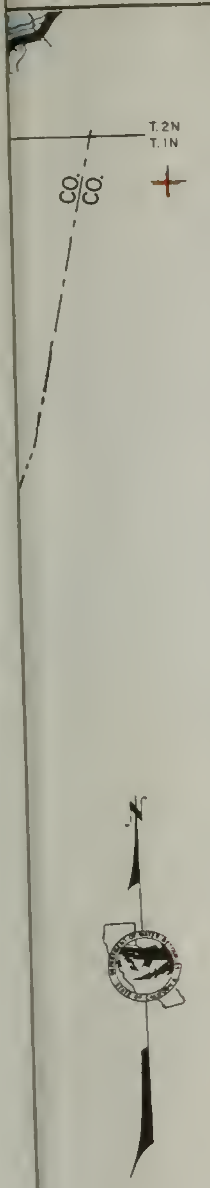
PATTERN OF GROUND WATER PUMPAGE IN 1960

PLATE 7


SAN GABRIEL MTNS.
FRONTAL AREA
SAN GABRIEL RESERVOIR
MORRIS RESERVOIR
UPPER SAN GABRIEL VALLEY MUNICIPAL WATER DISTRICT
CENTRAL BASIN MUNICIPAL WATER DISTRICT
ALTADENA
PASADENA
SIERRA MADRE
SOUTH PASADENA
SAN MARINO
ARCADIA
MONROVIA
DUARTE
AZUSA
GLENDORA
TEMPLE CITY
SAN GABRIEL
ALHAMBRA
MONTEREY PARK
ROSEMEAD
EL MONTE
BALDWIN PARK
COVINA
WEST COVINA
SAN DIMAS
LA VERNE
POMONA
LA PUENTE
MONTEBELLO
UPPER FEEDER
MIDDLE FEEDER
RELEASE POINT OF M.W.D. WATER TO RIVER
RELEASE POINT OF M.W.D. WATER TO WASH
WHITTIER NARROWS FLOOD CONTROL BASIN
SANTA FE FLOOD CONTROL BASIN
PUDDINGSTONE RESERVOIR
PUENTE HILLS
SAN JOSE HILLS
MERCED HILLS
LOS ANGELES COUNTY
ORANGE COUNTY
LEGEND
BOUNDARY OF AREA FOR HYDROLOGIC STUDIES
BOUNDARY OF WATER-BEARING AREA
BOUNDARY OF FRONTAL AREA
EXISTING METROPOLITAN WATER DISTRICT FEEDERS
NOTE: THE UPPER SAN GABRIEL VALLEY MUNICIPAL WATER DISTRICT, THE CITIES OF PASADENA, SAN MARINO, AND LOS ANGELES, THE CENTRAL BASIN MUNICIPAL WATER DISTRICT, AND THE POMONA VALLEY MUNICIPAL WATER DISTRICT ARE MEMBERS OF THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA WHICH HAS CONTRACTED WITH THE STATE OF CALIFORNIA FOR WATER
THE CITIES OF ALHAMBRA, MONTEREY PARK, SIERRA MADRE AND AZUSA ARE WITHIN THE SAN GABRIEL VALLEY MUNICIPAL WATER DISTRICT WHICH HAS CONTRACTED WITH THE STATE OF CALIFORNIA FOR WATER
THE CITY OF WEST COVINA HAS CONTRACTED DIRECTLY WITH THE STATE OF CALIFORNIA FOR WATER
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY
MAJOR PUBLIC WATER AGENCIES AND MAIN WATER DISTRIBUTION LINES IN 1964
SCALE OF MILES
1965

FREEWAY
BLVD.
AREA
LOS


SAN GABRIEL MTNS.
FRONTAL AREA
SAN GABRIEL RESERVOIR
MORRIS RESERVOIR
BIG DALTON RESERVOIR
SAN DIMAS DAM
SAN ANTONIO DAM
SANTA ANITA DAM
SAWPIT DAM
EATON WASH RESERVOIR
DEVILS GATE DAM
ALTADENA
SIERRA MADRE
PASADENA
SAN MARINO
SOUTH PASADENA
ALHAMBRA
SAN GABRIEL
MONTEREY PARK
ARCADIA
TEMPLE CITY
MONROVIA
ROSEMEAD
EL MONTE
BALDWIN PARK
AZUSA
GLENDORA
COVINA
SAN DIMAS
LA VERNE
POMONA
PUENTE
MONTEBELLO
PICO
WHITTIER
TRI CITIES SEWAGE TREATMENT PLANT (ABANDONED 1946)
EL MONTE SEWAGE TREATMENT PLANT (ABANDONED 1949)
WHITTIER NARROWS WATER RECLAMATION PLANT
WHITTIER NARROWS FLOOD CONTROL BASIN
SANTA FE FLOOD CONTR BASIN
METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA WATER TREATMENT PLANT
POMONA SEWAGE TREATMENT PLANT
PUDDINGSTONE RESERVOIR
2
15
16
21
22
LOS ANGELES COUNTY
ORANGE COUNTY
LOS ANGELES
SAN BERNARDINO
AGENCIES DISPOSING WASTE WATER AT WHITES POINT AND HYPERION
AGENCY[a] | YEAR PLACED IN OPERATION | PLACE OF DISPOSAL
CITY OF LOS ANGELES BUREAU OF SANITATION | 1894 | HYPERION
CSD-2 | 1928 | WHITES POINT
CSD-15 | 1948 | WHITES POINT
CSD 16 | 1948 | WHITES POINT[b]
CSD-21 | 1954 | WHITES POINT
CSD-22 | 1954 | WHITES POINT
a CSD COUNTY SANITATION DISTRICT
b A SMALL PORTION OF DISTRICT 16 DISPOSES WASTE WATER AT HYPERION
LEGEND
BOUNDARY OF AREA FOR HYDROLOGIC STUDIES
BOUNDARY OF WATER-BEARING AREA
BOUNDARY OF FRONTAL AREA
BOUNDARY OF COUNTY SANITATION DISTRICT
COUNTY SANITATION DISTRICT NUMBER
BOUNDARY OF AREA DISPOSING WASTE WATER AT WHITES POINT, COUNTY SANITATION DISTRICTS OF LOS ANGELES COUNTY
BOUNDARY OF AREA DISPOSING WASTE WATER AT HYPERION PLANT, CITY OF LOS ANGELES
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY
AREAS SERVED BY COUNTY SANITATION DISTRICTS OF LOS ANGELES COUNTY AND CITY OF LOS ANGELES
SCALE OF MILES
1965



LEGEND

SEDIMENTARY ROCKS

WATER-BEARING SERIES — QUATERNARY

RECENT

Qal — RECENT ALLUVIUM
GRAVEL, SAND, SILT, AND CLAY DEPOSITS, PRESENTLY BEING FORMED IN STREAM BEDS AND ON ALLUVIAL FANS.

Qat — TRANSITION ZONE
ZONE OF REWORKED OLDER ALLUVIAL DEBRIS

PLEISTOCENE

Qoal — OLDER ALLUVIUM
PALE TO DARK REDDISH-BROWN, DEEPLY AND STRONGLY WEATHERED GRAVEL, SAND, SILT, AND CLAY INCLUDES BRECCIAS AND COARSE DEBRIS AT HIGH ELEVATIONS IN SAN GABRIEL MOUNTAINS, LATE PLEISTOCENE TERRACE DEPOSITS, AND SAN DIMAS FORMATION

Qsp — SAN PEDRO FORMATION
MARINE AND CONTINENTAL, FINE TO COARSE SAND AND CONGLOMERATE AND GRAY TO GREENISH SILTSTONE AND MUDSTONE, PARTIALLY CONSOLIDATED. (INCLUDES "SAUGUS" FORMATION OF MERCED-REPETTO HILLS AREA).

NONWATER-BEARING SERIES — TERTIARY

PLIOCENE

Pp — PICO FORMATION
MARINE SAND, SILT, AND CLAY INTERBEDDED WITH MEDIUM TO COARSE GRAVEL. UPPERMOST PART OF FORMATION IS WATER BEARING. THE CONTINENTAL DUARTE CONGLOMERATE IS INCLUDED WITHIN THIS DIVISION

Pr — REPETTO FORMATION
LIGHT GRAY, BUFF, WHITE AND GRAYISH-GREEN MARINE SILTSTONE, THIN-BEDDED SOFT SHALE WITH LAYERS OF MEDIUM TO COARSE GRAVEL AND A BASAL CONGLOMERATE.

MIOCENE

Ms — PUENTE FORMATION
PALE BUFF, CREAMY, WHITE TO BROWN AND GRAYISH-GREEN MARINE SILTSTONE, SANDSTONE AND SILICEOUS SHALE. LOCAL CONGLOMERATE LENSES UPPERMOST SEVERAL HUNDRED FEET COMPRISED OF SANDY, FINE TO MEDIUM CONGLOMERATE.

TOPANGA FORMATION
BUFF TO PALE BROWN AND LOCALLY PALE LAVENDER, FINE TO COARSE GRAINED, MODERATELY TO WELL CONSOLIDATED MARINE SANDSTONE, BOULDERY SANDSTONE AND CONGLOMERATE, LOCALLY INTERBEDDED AND CUT BY GLENDORA VOLCANICS.

PUNCHBOWL FORMATION
NONMARINE LIGHT GRAY TO BROWN GYPSIFEROUS SHALE, LIGHT TAN TO BUFF ARKOSIC SANDSTONE AND CONGLOMORATE, AND BUFF SILTSTONE.

PALEOCENE

Tpm — MARTINEZ FORMATION
MARINE, DARK GRAY CARBONACEOUS SHALE AND TAN ARKOSIC SANDSTONE AND CONGLOMERATE.

IGNEOUS AND METAMORPHIC ROCKS

MIOCENE

Mv — GLENDORA VOLCANICS
VARIOUS SHADES OF LIGHT TO DARK BROWN YELLOWISH, REDDISH, GRAY AND GRAYISH-GREEN ANDESITE, BASALT, DACITE, RHYOLITE, ANDESITE TUFF-BRECCIA, DOLERITIC DIKES AND VOLCANIC AGGLOMERATE.

LATE PRECAMBRIAN (?) — PRECAMBRIAN (?) PLIOCENE

Bc — BASEMENT COMPLEX ROCK
QUARTZ DIORITIC GNEISS, GRANITE APLITE DIKES, PEGMATITES, QUARTZ DIORITE, MYLONITE, MIGMATITE, HORNFELS, MICA SCHIST, QUARTZITE, MARBLE, GNEISSIC GRANITE, GRANODIORITE, AND ASSOCIATED DIKES AND BASIC INCLUSIONS

U (UPTHROWN SIDE) / D (DOWNTHROWN SIDE) — FAULT
DASHED WHERE APPROXIMATELY LOCATED, DOTTED WHERE CONCEALED OR INFERRED.

THRUST FAULT
DASHED WHERE APPROXIMATELY LOCATED, TEETH INDICATE THRUST PLATE.

ANTICLINE / SYNCLINE — DASHED WHERE APPROXIMATELY LOCATED, ARROW INDICATES DIRECTION OF PLUNGE.

CONTACT
DASHED WHERE INFERRED AND QUESTIONABLE

W———W' LINE OF GEOLOGIC SECTION

LANDSLIDE AREAS
ARROWS INDICATE DIRECTION OF MOVEMENT

BOUNDARY OF STUDY AREA

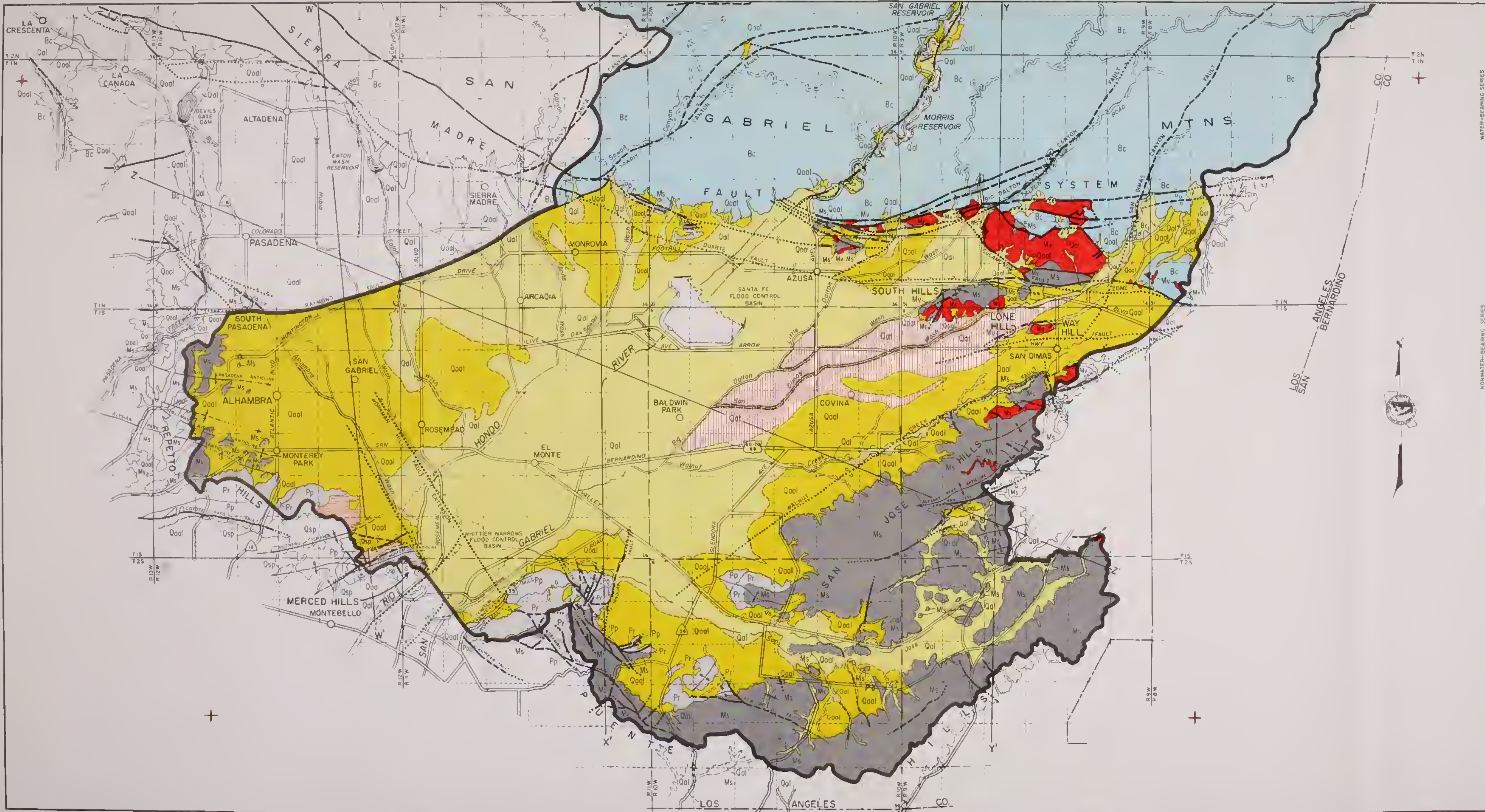
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

AREAL GEOLOGY

SCALE OF MILES
1 0 1 2 3

1965



LEGEND

SEDIMENTARY ROCKS

WATER-BEARING SERIES

QUATERNARY — RECENT

Qal RECENT ALLUVIUM
GRAVEL, SAND, SILT, AND CLAY DEPOSITS, PRESENTLY BEING FORMED IN STREAM BEDS AND ON ALLUVIAL FANS

Qal TRANSITION ZONE
ZONE OF REWORKED OLDER ALLUVIAL DEBRIS

QUATERNARY — PLEISTOCENE

Qoal OLDER ALLUVIUM
PALE TO DARK REDDISH-BROWN, DEEPLY AND STRONGLY WEATHERED GRAVEL, SAND, SILT, AND CLAY INCLUDES BRECCIAS AND COARSE DEBRIS AT HIGH ELEVATIONS IN SAN GABRIEL MOUNTAINS, LATE PLEISTOCENE TERRACE DEPOSITS, AND SAN DIMAS FORMATION

Qsp SAN PEDRO FORMATION
MARINE AND CONTINENTAL, FINE TO COARSE SAND AND CONGLOMERATE AND GRAY TO GREENISH SILTSTONE AND MUDSTONE, PARTIALLY CONSOLIDATED (INCLUDES "SAUGUS" FORMATION OF MERCED-REPETTO HILLS AREA)

PLIOCENE

Pp PICO FORMATION
MARINE SAND, SILT, AND CLAY INTERBEDDED WITH MEDIUM TO COARSE GRAVEL. UPPERMOST PART OF FORMATION IS WATER BEARING. THE CONTINENTAL DUARTE CONGLOMERATE IS INCLUDED WITHIN THIS DIVISION

NONWATER-BEARING SERIES

Pr REPETTO FORMATION
LIGHT GRAY, BUFF, WHITE AND GRAYISH-GREEN MARINE SILTSTONE, THIN-BEDDED SOFT SHALE WITH LAYERS OF MEDIUM TO COARSE GRAVEL AND A BASAL CONGLOMERATE

TERTIARY — MIOCENE

Ms PUENTE FORMATION
PALE BUFF, CREAMY, WHITE TO BROWN AND GRAYISH GREEN MARINE SILTSTONE, SANDSTONE AND SILICEOUS SHALE. LOCAL CONGLOMERATE LENSES. UPPERMOST SEVERAL HUNDRED FEET COMPRISED OF SANDY, FINE TO MEDIUM CONGLOMERATE

TOPANGA FORMATION
BUFF TO PALE BROWN AND LOCALLY PALE LAVENDER, FINE TO COARSE GRAINED, MODERATELY TO WELL CONSOLIDATED MARINE SANDSTONE, BOULDERY SANDSTONE AND CONGLOMERATE, LOCALLY INTERBEDDED AND CUT BY GLENDORA VOLCANICS

PUNCHBOWL FORMATION
NONMARINE LIGHT GRAY TO BROWN GYPSIFEROUS SHALE, LIGHT TAN TO BUFF ARKOSIC SANDSTONE AND CONGLOMORATE, AND BUFF SILTSTONE

PALEOCENE

Tpm MARTINEZ FORMATION
MARINE, DARK GRAY CARBONACEOUS SHALE AND TAN ARKOSIC SANDSTONE AND CONGLOMERATE

IGNEOUS AND METAMORPHIC ROCKS

MIOCENE

Mv GLENDORA VOLCANICS
VARIOUS SHADES OF LIGHT TO DARK BROWN YELLOWISH, REDDISH, GRAY AND GRAYISH-GREEN ANDESITE, BASALT, DACITE, RHYOLITE, ANDESITE TUFF-BRECCIA, DOLERITIC DIKES AND VOLCANIC AGGLOMERATE

LATE PRECAMBRIAN(?) — PRECAMBRIAN(?) PLIOCENE

Bc BASEMENT COMPLEX ROCK
QUARTZ DIORITIC GNEISS, GRANITE APLITE DIKES, PEGMATITES, QUARTZ DIORITE, MYLONITE, MIGMATITE, HORNFELS, MICA SCHIST, QUARTZITE, MARBLE, GNEISSIC GRANITE, GRANODIORITE, AND ASSOCIATED DIKES AND BASIC INCLUSIONS

FAULT (UPTHROWN SIDE / DOWNTHROWN SIDE)
DASHED WHERE APPROXIMATELY LOCATED, DOTTED WHERE CONCEALED OR INFERRED

THRUST FAULT
DASHED WHERE APPROXIMATELY LOCATED, TEETH INDICATE THRUST PLATE

ANTICLINE / SYNCLINE
DASHED WHERE APPROXIMATELY LOCATED, ARROW INDICATES DIRECTION OF PLUNGE

CONTACT
DASHED WHERE INFERRED AND QUESTIONABLE

W——W' LINE OF GEOLOGIC SECTION

LANDSLIDE AREAS
ARROWS INDICATE DIRECTION OF MOVEMENT

BOUNDARY OF STUDY AREA

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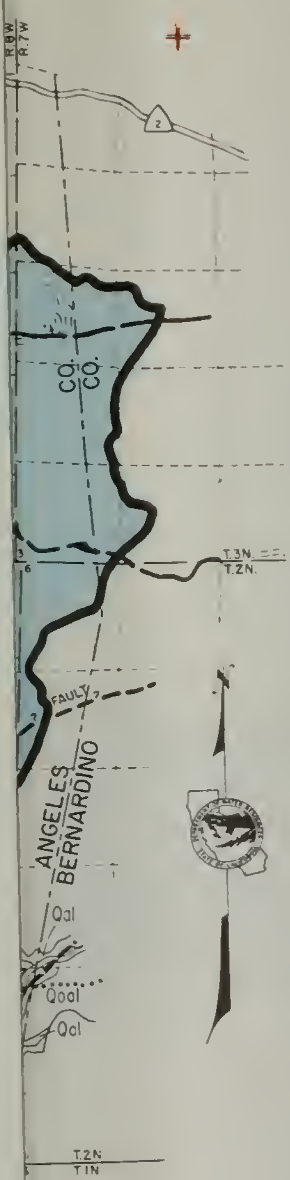
SOUTHERN DISTRICT

GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

AREAL GEOLOGY

SCALE OF MILES
1 0 1 2 3

1965



LEGEND

SEDIMENTARY ROCKS

WATER-BEARING SERIES — QUATERNARY

- RECENT
  - **Qal** RECENT ALLUVIUM
    GRAVEL, SAND, SILT, AND CLAY DEPOSITS, PRESENTLY BEING FORMED IN STREAM BEDS AND ON ALLUVIAL FANS
  - **Qat** TRANSITION ZONE
    ZONE OF REWORKED OLDER ALLUVIAL DEBRIS
- PLEISTOCENE
  - **Qoal** OLDER ALLUVIUM
    PALE TO DARK REDDISH-BROWN, DEEPLY AND STRONGLY WEATHERED GRAVEL, SAND, SILT, AND CLAY. INCLUDES BRECCIAS AND COARSE DEBRIS AT HIGH ELEVATIONS IN SAN GABRIEL MOUNTAINS, LATE PLEISTOCENE TERRACE DEPOSITS, AND SAN DIMAS FORMATION
  - **Qsp** SAN PEDRO FORMATION
    MARINE AND CONTINENTAL, FINE TO COARSE SAND AND CONGLOMERATE AND GRAY TO GREENISH SILTSTONE AND MUDSTONE, PARTIALLY CONSOLIDATED. (INCLUDES "SAUGUS" FORMATION OF MERCED-REPETTO HILLS AREA).

NONWATER-BEARING SERIES — TERTIARY

- PLIOCENE
  - **Pp** PICO FORMATION
    MARINE SAND, SILT, AND CLAY INTERBEDDED WITH MEDIUM TO COARSE GRAVEL. UPPERMOST PART OF FORMATION IS WATER BEARING. THE CONTINENTAL DUARTE CONGLOMERATE IS INCLUDED WITHIN THIS DIVISION
  - **Pr** REPETTO FORMATION
    LIGHT GRAY, BUFF, WHITE AND GRAYISH-GREEN MARINE SILTSTONE, THIN-BEDDED SOFT SHALE WITH LAYERS OF MEDIUM TO COARSE GRAVEL AND A BASAL CONGLOMERATE.
- MIOCENE
  - **Ms**
    PUENTE FORMATION
    PALE BUFF, CREAMY, WHITE TO BROWN AND GRAYISH-GREEN MARINE SILTSTONE, SANDSTONE AND SILICEOUS SHALE. LOCAL CONGLOMERATE LENSES. UPPERMOST SEVERAL HUNDRED FEET COMPRISED OF SANDY, FINE TO MEDIUM CONGLOMERATE.
    TOPANGA FORMATION
    BUFF TO PALE BROWN AND LOCALLY PALE LAVENDER, FINE TO COARSE GRAINED, MODERATELY TO WELL CONSOLIDATED MARINE SANDSTONE, BOULDERY SANDSTONE AND CONGLOMERATE, LOCALLY INTERBEDDED AND CUT BY GLENDORA VOLCANICS
    PUNCHBOWL FORMATION
    NONMARINE LIGHT GRAY TO BROWN GYPSIFEROUS SHALE, LIGHT TAN TO BUFF ARKOSIC SANDSTONE AND CONGLOMERATE, AND BUFF SILTSTONE.
- PALEOCENE
  - **Tpm** MARTINEZ FORMATION
    MARINE, DARK GRAY CARBONACEOUS SHALE AND TAN ARKOSIC SANDSTONE AND CONGLOMERATE

IGNEOUS AND METAMORPHIC ROCKS

LATE PRECAMBRIAN (?)

- MIOCENE
  - **Mv** GLENDORA VOLCANICS
    VARIOUS SHADES OF LIGHT TO DARK BROWN, YELLOWISH, REDDISH, GRAY AND GRAYISH-GREEN ANDESITE, BASALT, DACITE, RHYOLITE, ANDESITE TUFF-BRECCIA, DOLERITIC DIKES AND VOLCANIC AGGLOMERATE.
- PRECAMBRIAN (?) – PLIOCENE
  - **Bc** BASEMENT COMPLEX ROCK
    QUARTZ DIORITIC GNEISS, GRANITE APLITE DIKES, PEGMATITES, QUARTZ DIORITE, MYLONITE, MIGMATITE, HORNFELS, MICA SCHIST, QUARTZITE, MARBLE, GNEISSIC GRANITE, GRANODIORITE AND ASSOCIATED DIKES AND BASIC INCLUSIONS.

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ANTICLINE / SYNCLINE — DASHED WHERE APPROXIMATELY LOCATED, ARROW INDICATES DIRECTION OF PLUNGE.

CONTACT
DASHED WHERE INFERRED AND QUESTIONABLE

W———W' LINE OF GEOLOGIC SECTION

LANDSLIDE AREAS
ARROWS INDICATE DIRECTION OF MOVEMENT.

BOUNDARY OF STUDY AREA

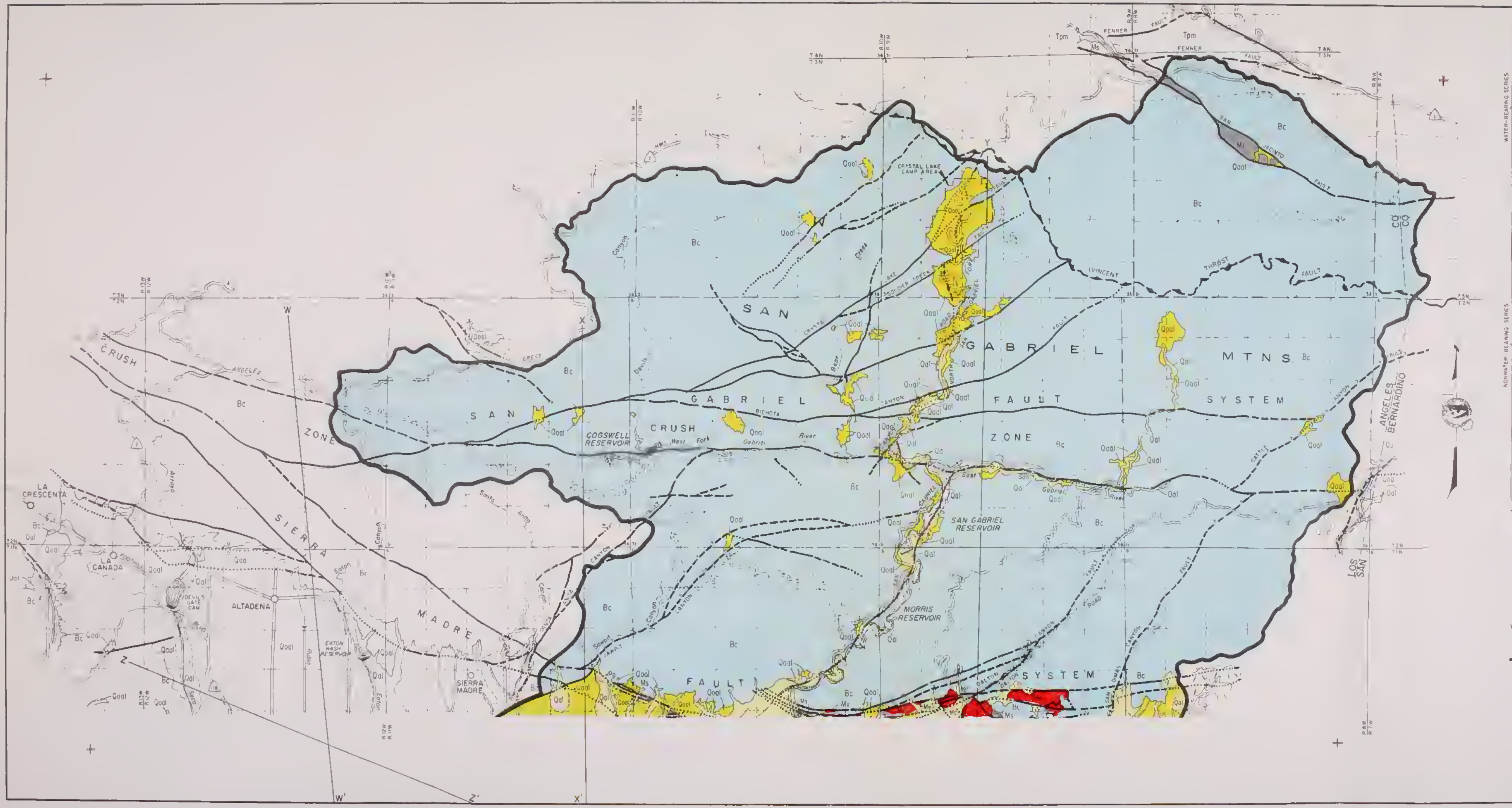
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

AREAL GEOLOGY

SCALE OF MILES
0 1 2 3

1965



LEGEND

SEDIMENTARY ROCKS

WATER-BEARING SERIES — QUATERNARY

RECENT

- **Qal** — RECENT ALLUVIUM: GRAVEL, SAND, SILT, AND CLAY DEPOSITS, PRESENTLY BEING FORMED IN STREAM BEDS AND ON ALLUVIAL FANS
- **Qal** — TRANSITION ZONE: ZONE OF REWORKED OLDER ALLUVIAL DEBRIS

PLEISTOCENE

- **Qoal** — OLDER ALLUVIUM: PALE TO DARK REDDISH-BROWN, DEEPLY AND STRONGLY WEATHERED GRAVEL, SAND, SILT, AND CLAY. INCLUDES BRECCIAS AND COARSE DEBRIS AT HIGH ELEVATIONS IN SAN GABRIEL MOUNTAINS, LATE PLEISTOCENE TERRACE DEPOSITS, AND SAN DIMAS FORMATION
- **Qsp** — SAN PEDRO FORMATION: MARINE AND CONTINENTAL, FINE TO COARSE SAND AND CONGLOMERATE AND GRAY TO GREENISH SILTSTONE AND MUDSTONE, PARTIALLY CONSOLIDATED (INCLUDES "SAUGUS" FORMATION OF MERCED-REPETTO HILLS AREA)

NONWATER-BEARING SERIES — TERTIARY

PLIOCENE

- **Pp** — PICO FORMATION: MARINE SAND, SILT, AND CLAY INTERBEDDED WITH MEDIUM TO COARSE GRAVEL. UPPERMOST PART OF FORMATION IS WATER BEARING. THE CONTINENTAL DUARTE CONGLOMERATE IS INCLUDED WITHIN THIS DIVISION
- **Pr** — REPETTO FORMATION: LIGHT GRAY, BUFF WHITE AND GRAYISH-GREEN MARINE SILTSTONE, THIN-BEDDED SOFT SHALE WITH LAYERS OF MEDIUM TO COARSE GRAVEL AND A BASAL CONGLOMERATE

MIOCENE

- PUENTE FORMATION: PALE BUFF CREAMY, WHITE TO BROWN AND GRAYISH-GREEN MARINE SILTSTONE, SANDSTONE AND SILICEOUS SHALE. LOCAL CONGLOMERATE LENSES. UPPERMOST SEVERAL HUNDRED FEET COMPRISED OF SANDY, FINE TO MEDIUM CONGLOMERATE
- **Ms** — TOPANGA FORMATION: BUFF TO PALE BROWN AND LOCALLY PALE LAVENDER, FINE TO COARSE GRAINED, MODERATELY TO WELL CONSOLIDATED MARINE SANDSTONE, BOULDERY SANDSTONE AND CONGLOMERATE, LOCALLY INTERBEDDED AND CUT BY GLENDORA VOLCANICS
- PUNCHBOWL FORMATION: NONMARINE LIGHT GRAY TO BROWN GYPSIFEROUS SHALE, LIGHT TAN TO BUFF ARKOSIC SANDSTONE AND CONGLOMERATE, AND BUFF SILTSTONE

PALEOCENE

- **Tpm** — MARTINEZ FORMATION: MARINE, DARK GRAY CARBONACEOUS SHALE AND TAN ARKOSIC SANDSTONE AND CONGLOMERATE

IGNEOUS AND METAMORPHIC ROCKS

MIOCENE

- **Mv** — GLENDORA VOLCANICS: VARIOUS SHADES OF LIGHT TO DARK BROWN, YELLOWISH REDDISH, GRAY AND GRAYISH-GREEN ANDESITE, BASALT, DACITE, RHYOLITE, ANDESITE TUFF-BRECCIA, DOLERITIC DIKES AND VOLCANIC AGGLOMERATE

LATE PRECAMBRIAN (?) — PRECAMBRIAN (?) — PLIOCENE

- **Bc** — BASEMENT COMPLEX ROCK: QUARTZ DIORITIC GNEISS, GRANITE APLITE DIKES, PEGMATITES, QUARTZ DIORITE, MYLONITE, MIGMATITE, HORNFELS, MICA SCHIST, QUARTZITE, MARBLE, GNEISSIC GRANITE, GRANODIORITE AND ASSOCIATED DIKES AND BASIC INCLUSIONS

- FAULT: DASHED WHERE APPROXIMATELY LOCATED, DOTTED WHERE CONCEALED OR INFERRED
- THRUST FAULT: DASHED WHERE APPROXIMATELY LOCATED, TEETH INDICATE THRUST PLATE
- ANTICLINE / SYNCLINE: DASHED WHERE APPROXIMATELY LOCATED, ARROW INDICATES DIRECTION OF PLUNGE
- CONTACT: DASHED WHERE INFERRED AND QUESTIONABLE
- W — W' LINE OF GEOLOGIC SECTION
- LANDSLIDE AREAS: ARROWS INDICATE DIRECTION OF MOVEMENT
- BOUNDARY OF STUDY AREA

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

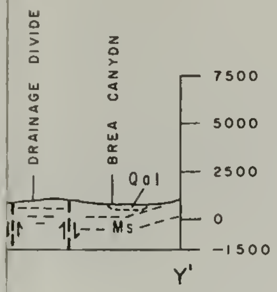
AREAL GEOLOGY

SCALE OF MILES

0 1 2 3

1965

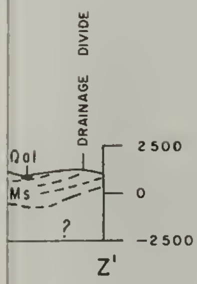
SEE PLATE 9A



LEGEND

Qal	RECENT ALLUVIUM
Qat	TRANSITION ZONE
Qoal	OLDER ALLUVIUM
Qsp	SAN PEDRO FORMATION
Pp	PICO FORMATION
Pr	REPETTO FORMATION
Ms	PUENTE FORMATION TOPANGA FORMATION
Mv	GLENDORA VOLCANICS
Bc	BASEMENT COMPLEX ROCK

NOTE: GEOLOGIC SECTIONS SHOWN ON PLATE 9A AND 9B
SEE PLATE 13 FOR MORE DETAILED CROSS SECTIONS



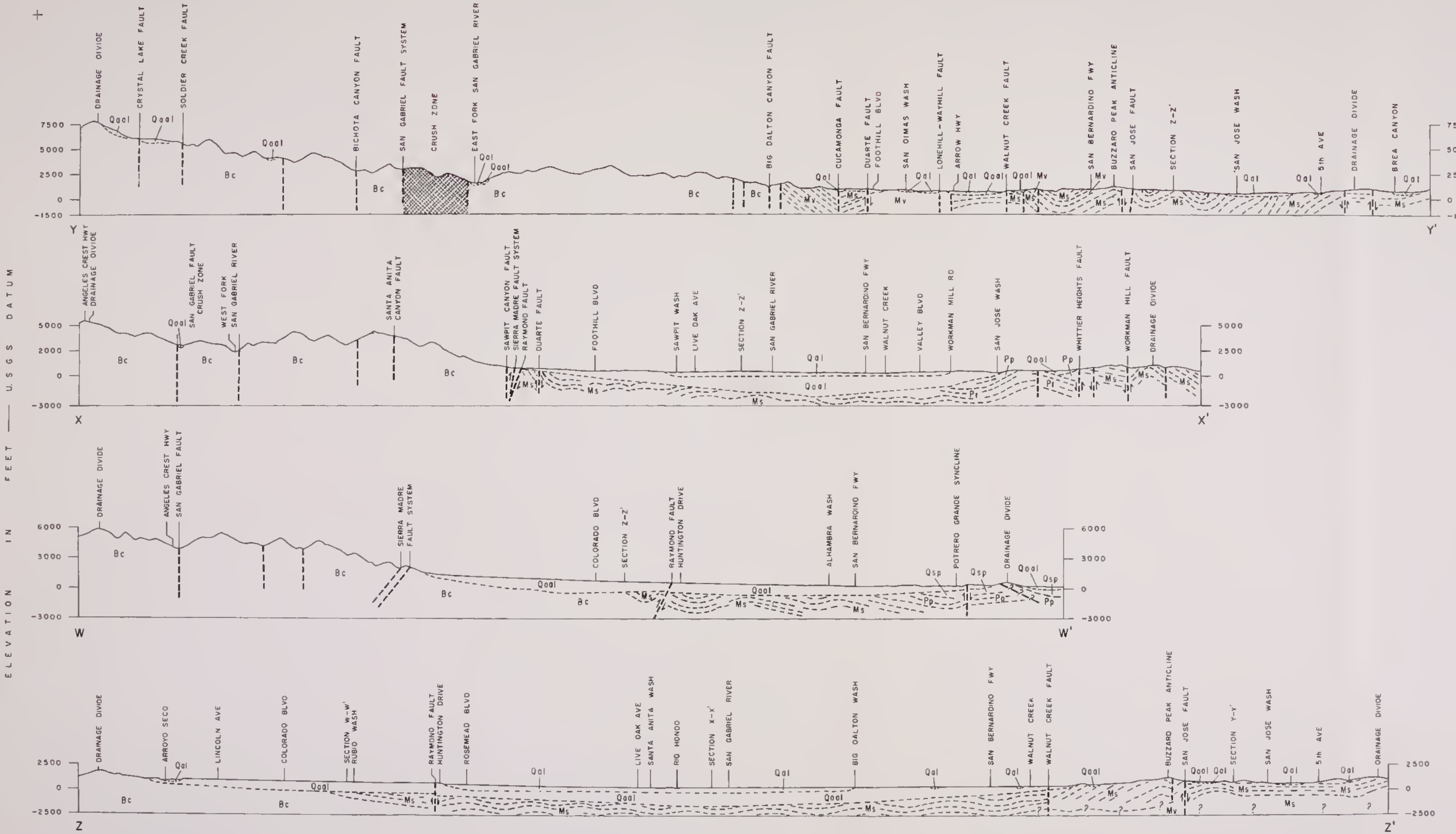
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

GEOLOGIC SECTIONS

SCALE OF MILES
1 0 1 2 3

1965



LEGEND

Qal	RECENT ALLUVIUM
Qal	TRANSITION ZONE
Qoal	OLDER ALLUVIUM
Qsp	SAN PEDRO FORMATION
Pp	PICO FORMATION
Pr	REPETTO FORMATION
Ms	PUENTE FORMATION / TOPANGA FORMATION
Mv	GLENDORA VOLCANICS
Bc	BASEMENT COMPLEX ROCK

NOTE GEOLOGIC SECTIONS SHOWN ON PLATE 9A AND 9B. SEE PLATE 13 FOR MORE DETAILED CROSS SECTIONS

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
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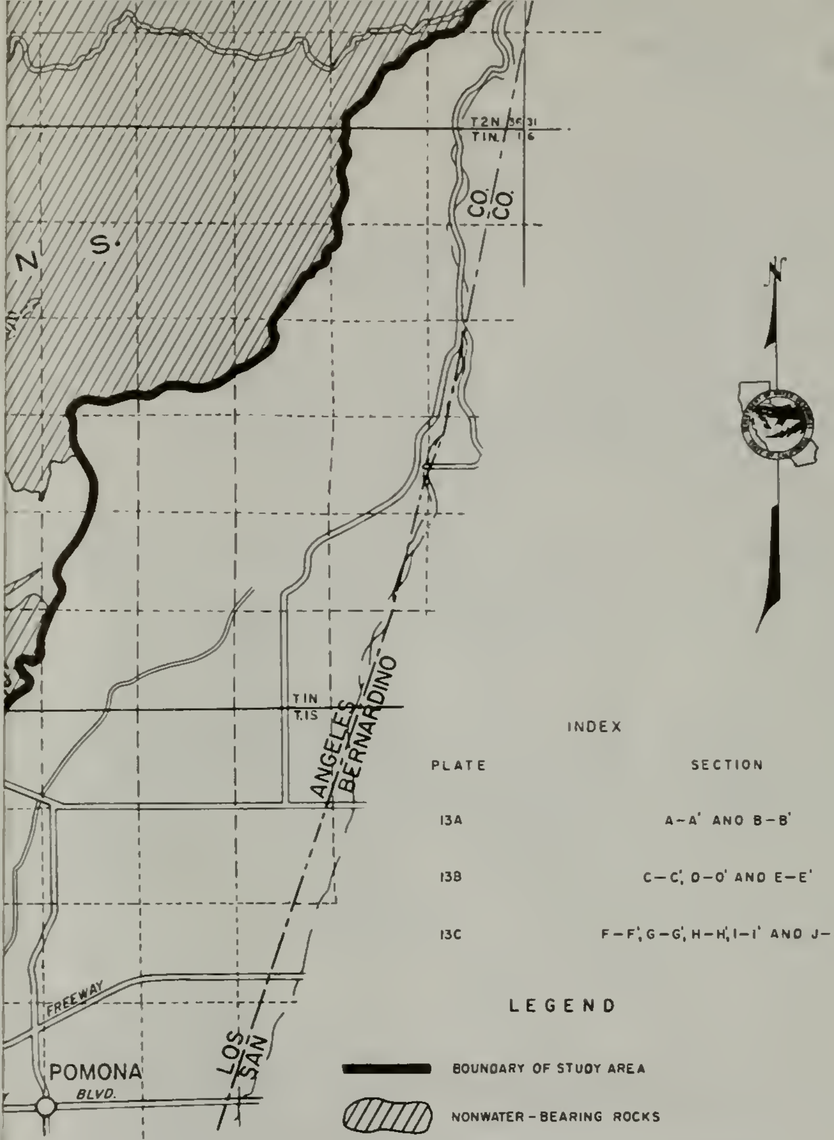
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

GEOLOGIC SECTIONS

SCALE OF MILES

1965



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13A	A–A' AND B–B'
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LEGEND

- BOUNDARY OF STUDY AREA
- NONWATER-BEARING ROCKS
- FAULTS AFFECTING WATER-BEARING MATERIALS, DASHED WHERE INFERRED OR LOCATION UNCERTAIN
- A——A' LINE OF GEOLOGIC SECTION
- 7H1● LOCATION OF WATER WELL
- #3● LOCATION OF OIL WELL
- CH11◆ LOCATION OF TEXAS COMPANY CORE HOLE
- 22P2◉ LOCATION OF WATER WELLS USED FOR HYDROGRAPHS SHOWN ON PLATES 21A AND 21B

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GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

LINES OF GEOLOGIC SECTIONS CONSTRUCTED FROM WELL LOG DATA, AND LOCATION OF WELLS

SCALE OF MILES

1 0 1 2 3

1965

STATE OF CALIFORNIA
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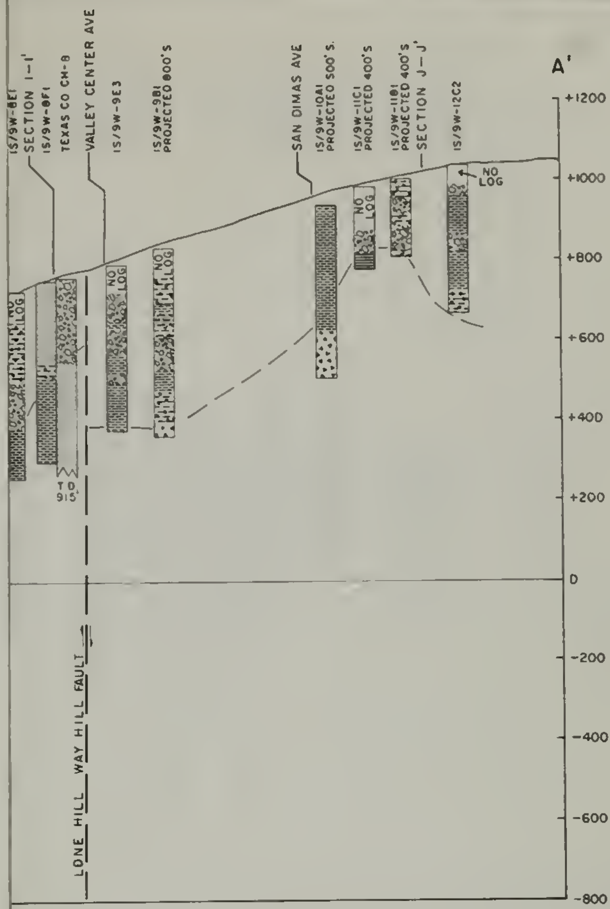
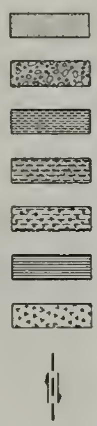
SOUTHERN DISTRICT

GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

LINES OF EQUAL ELEVATION OF THE EFFECTIVE BASE OF THE GROUND WATER RESERVOIR



LEGEND



	SAND
	GRAVEL OR GRAVEL AND SAND
	CLAY
	SANDY CLAY
	GRAVELY CLAY
	SEDIMENTARY BEDROCK
	CRYSTALLINE BEDROCK
	FAULTS

NOTE LOCATIONS OF WELL LOG SECTIONS ARE SHOWN ON PLATE 13

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THE RESOURCES AGENCY
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GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

WELL LOG SECTIONS A-A', AND B-B'

1965


LA CRESCENTA
LA CANADA
DEVILS GATE DAM
ALTADENA
EATON WASH RESERVOIR
SIERRA MADRE
PASADENA
MONROVIA
ARCADIA
SOUTH PASADENA
ALHAMBRA
ROSEMEAD
MONTERY PARK
EL MONTE
BALDWIN PARK
AZUSA
GLENDORA
COVINA
SAN DIMAS
SOUTH HILLS
WAY HILL
POMONA
MONTEBELLO
MERCED HILLS
REPETTO HILLS
WHITTIER NARROWS FLOOD CONTROL BASIN
SANTA FE FLOOD CONTROL BASIN
SAN GABRIEL RESERVOIR
MORRIS RESERVOIR
S A N G A B R I E L M T N S.
SAN JOSE HILLS
PUENTE HILLS
RIO HONDO
SAN GABRIEL RIVER
LOS ANGELES CO.
LOS ANGELES CO.
SAN BERNARDINO CO.
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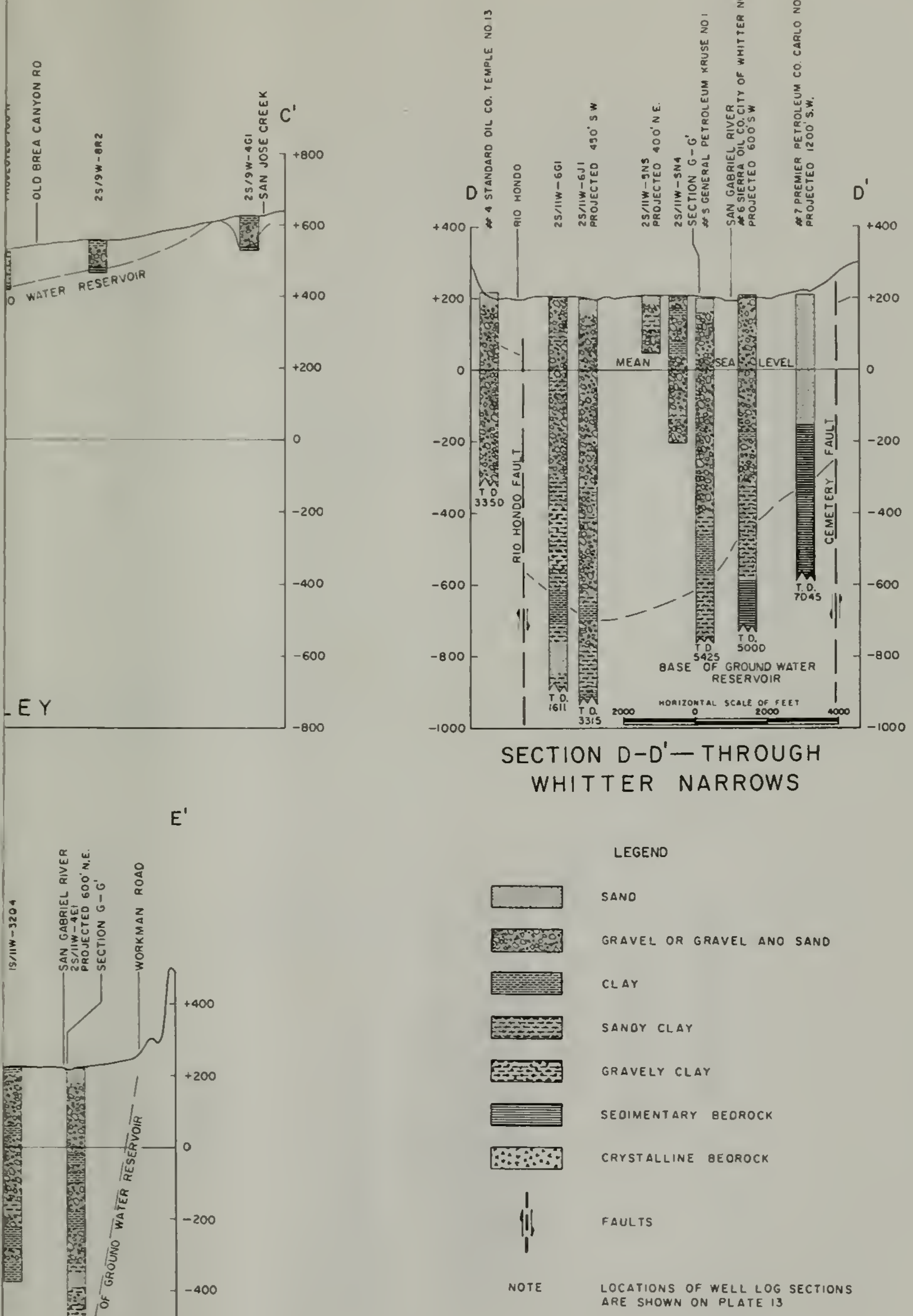
SCALE OF MILES
1965



STATE OF CALIFORNIA
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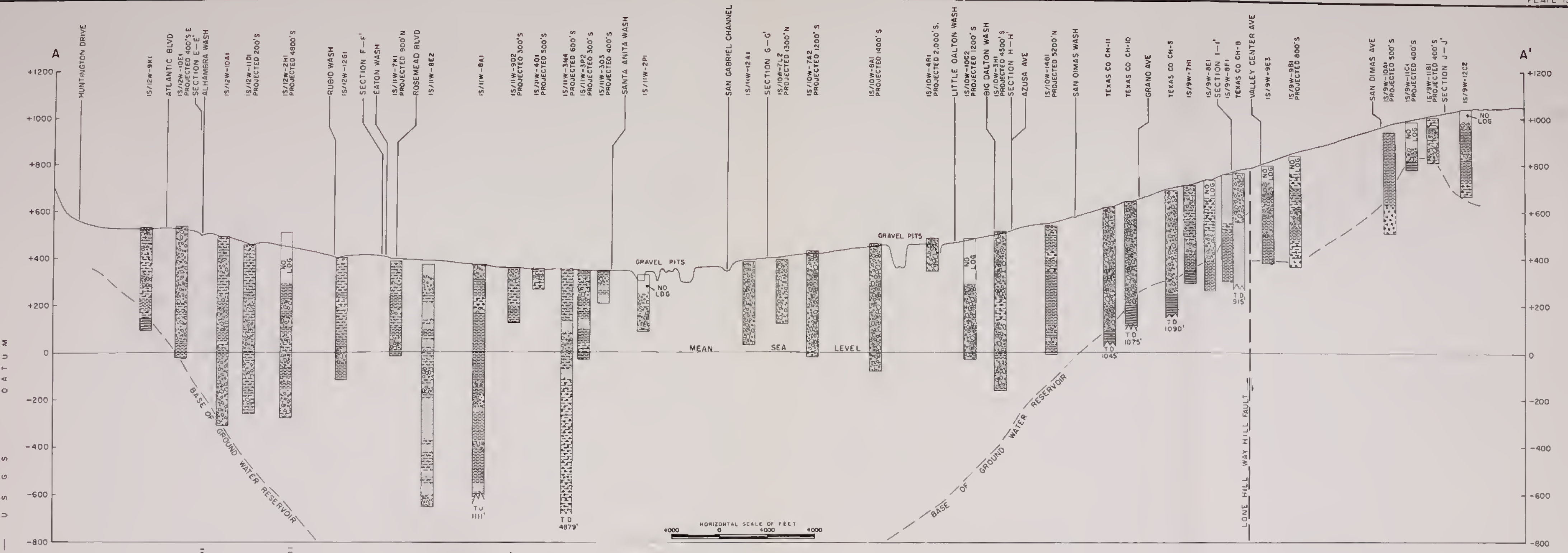
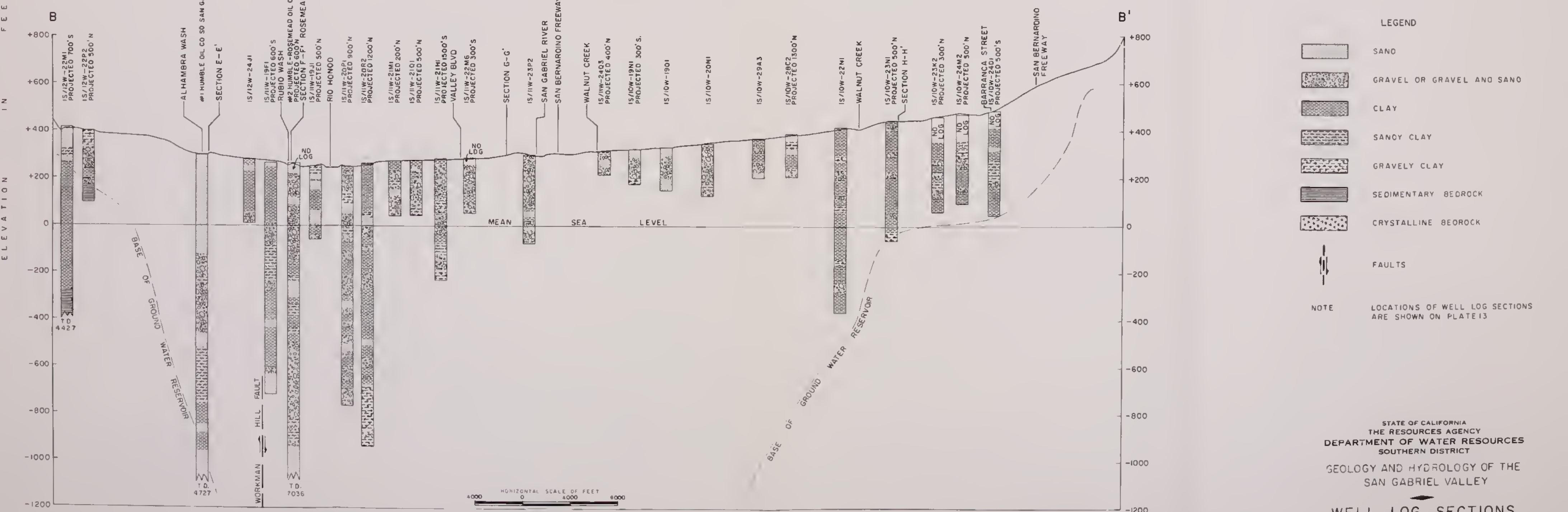
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

WELL LOG SECTIONS
C-C', D-D', E-E'

1965



SECTION A–A' — ALHAMBRA EASTERLY TO SAN DIMAS ALONG LIVE OAK AVE. AND ARROW HIGHWAY.



SECTION B–B' — MONTEREY PARK EASTERLY TO SAN JOSE HILLS ALONG SAN BERNARDINO FREEWAY.

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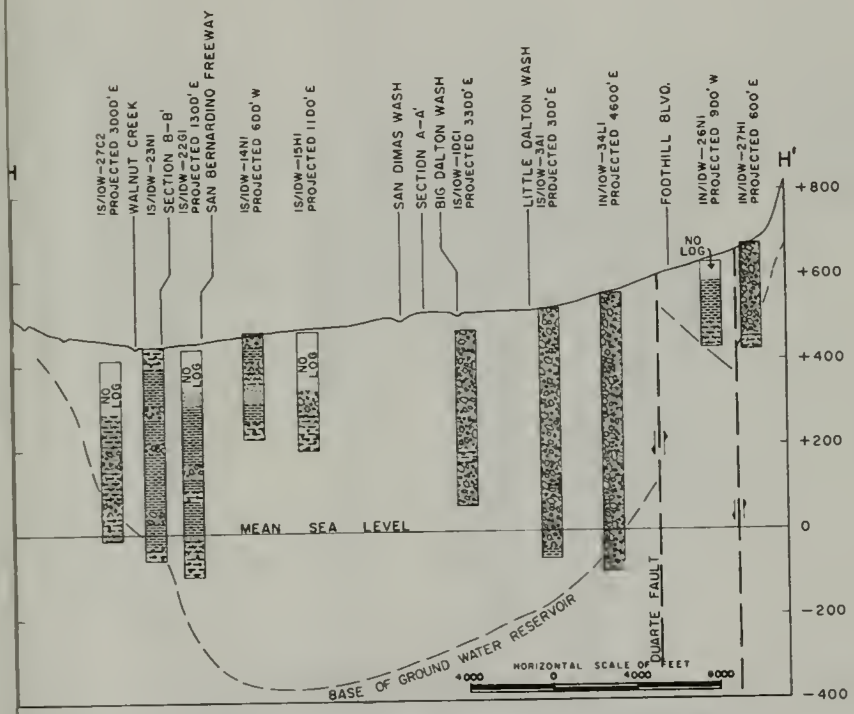
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

WELL LOG SECTIONS A–A' AND B–B'

1965



SECTION H—H'— NORTH ALONG AZUSA AVE

NO

TIONS

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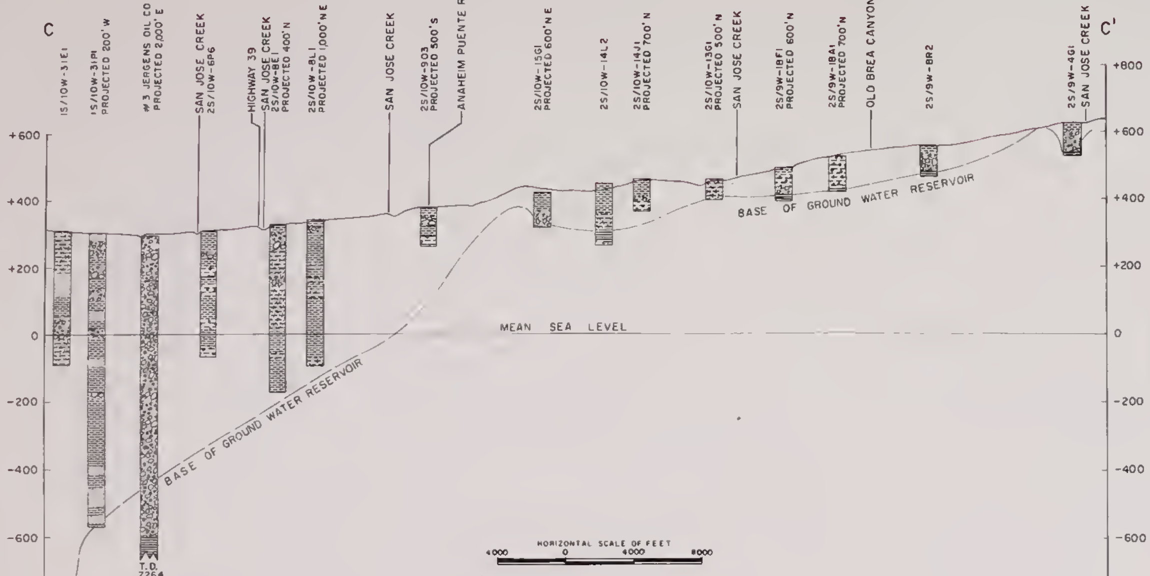
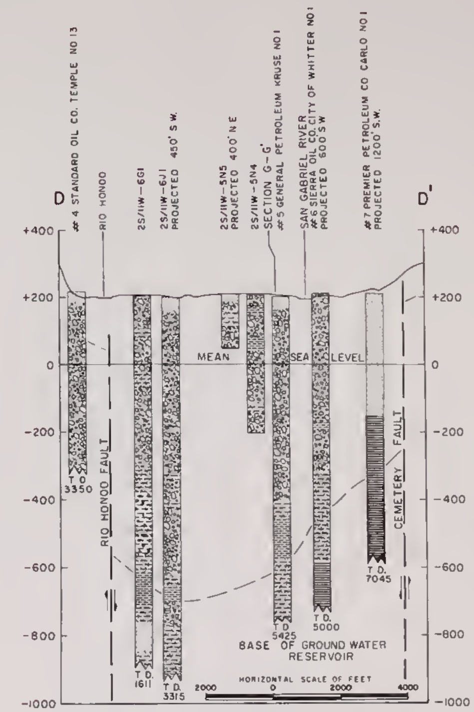
GEOLOGY AND HYDROLOGY OF THE
SAN GABRIEL VALLEY

WELL LOG SECTIONS
F—F', G—G', H—H', I—I', J—J'

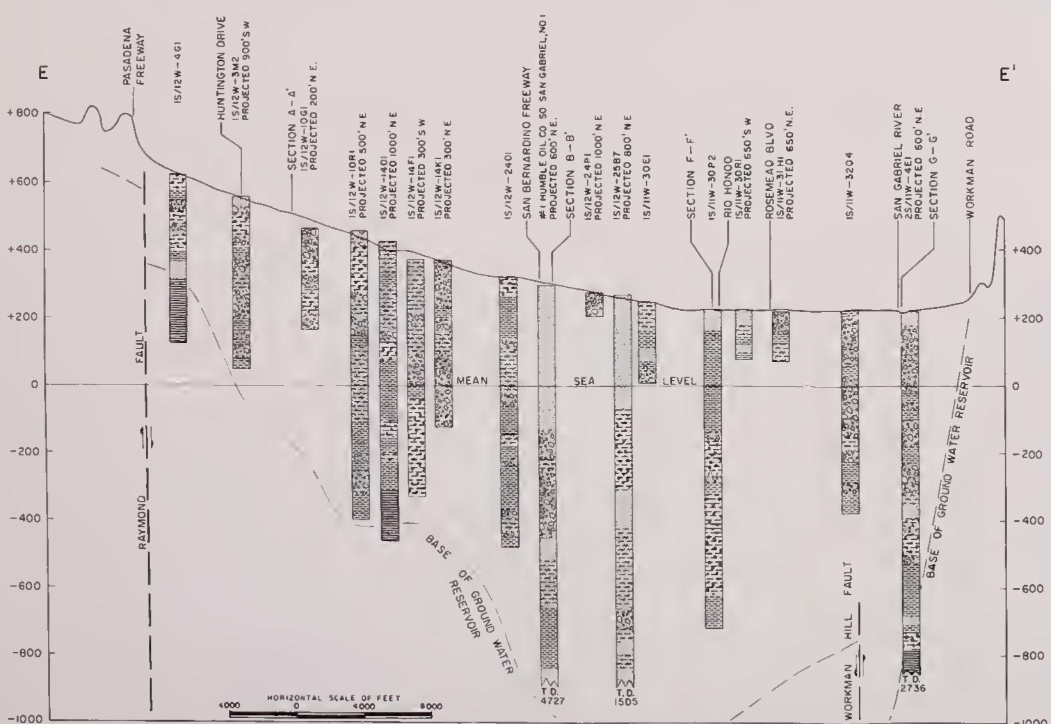
1965



SECTION C–C'— THROUGH PUENTE VALLEY



SECTION D–D'— THROUGH WHITTER NARROWS



SECTION E–E'— SOUTH PASADENA SOUTHEASTERLY TO PUENTE HILLS ALONG ALHAMBRA WASH

LEGEND

- SAND
- GRAVEL OR GRAVEL AND SAND
- CLAY
- SANDY CLAY
- GRAVELY CLAY
- SEDIMENTARY BEDROCK
- CRYSTALLINE BEDROCK
- FAULTS

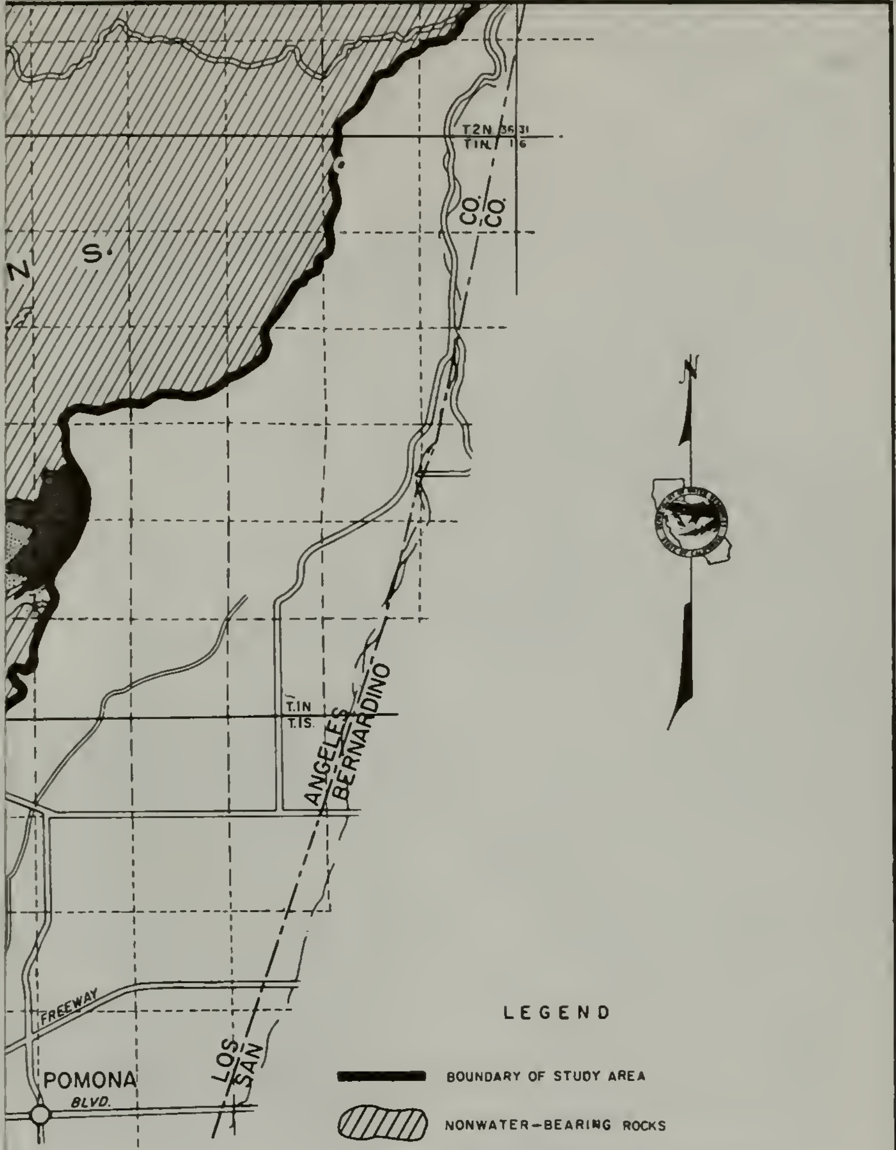
NOTE: LOCATIONS OF WELL LOG SECTIONS ARE SHOWN ON PLATE 13

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

WELL LOG SECTIONS
C–C', D–D', E–E'

1965



LEGEND

BOUNDARY OF STUDY AREA

NONWATER-BEARING ROCKS

FAULTS AFFECTING WATER-BEARING MATERIALS, DASHED WHERE INFERRED OR LOCATION UNCERTAIN

SOILS HAVING HIGH INFILTRATION CHARACTERISTICS GREATER THAN 2 INCHES PER HOUR

SOILS HAVING MEDIUM INFILTRATION CHARACTERISTICS 0.6 TO 2.0 INCHES PER HOUR

SOILS HAVING LOW INFILTRATION CHARACTERISTICS 0.01 TO 1.0 INCHES PER HOUR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

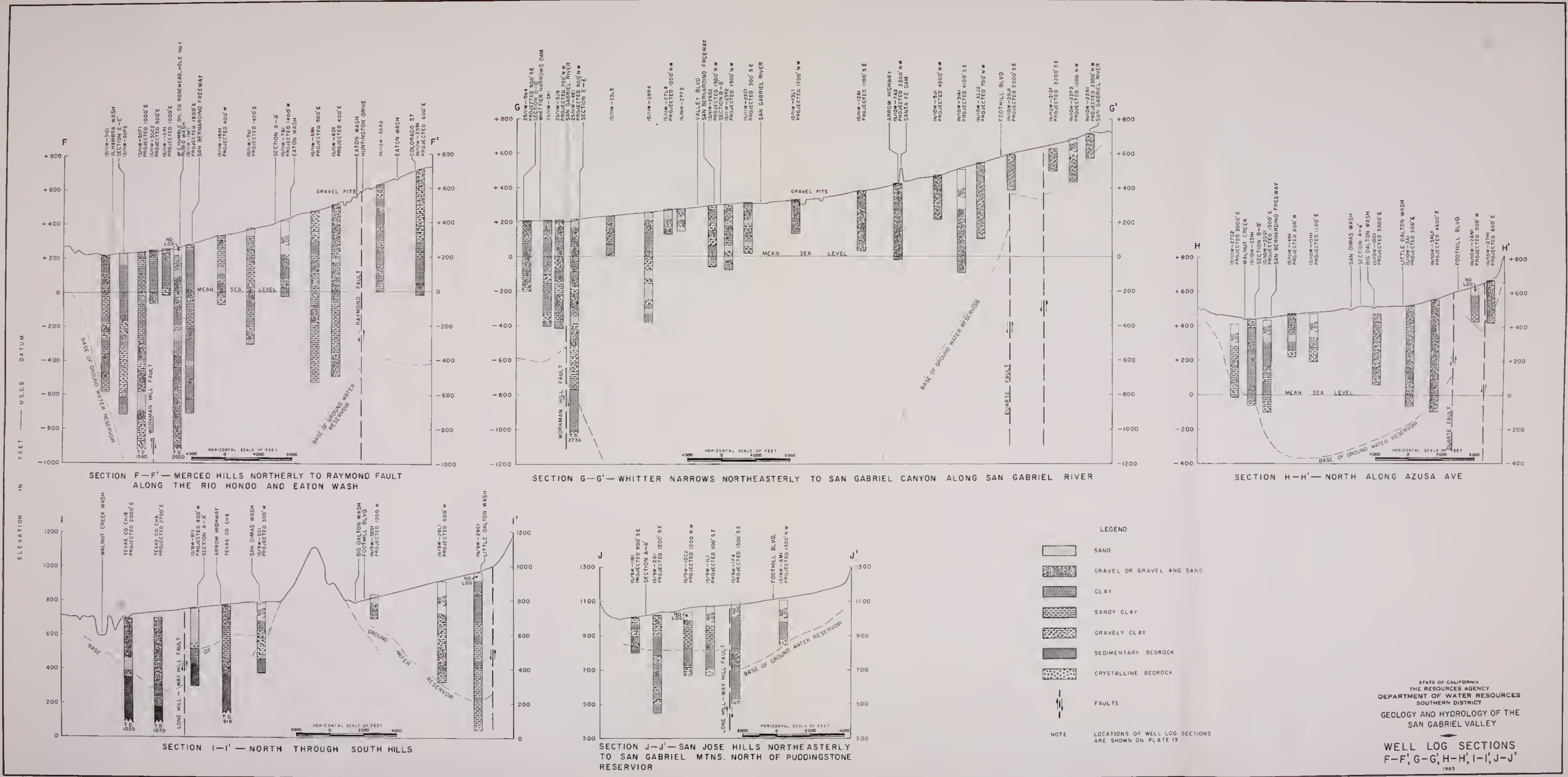
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

SOIL INFILTRATION CHARACTERISTICS

SCALE OF MILES
1 0 1 2 3

1965

PLATE 13C


SECTION F—F' — MERCED HILLS NORTHERLY TO RAYMOND FAULT ALONG THE RIO HONDO AND EATON WASH
SECTION G—G' — WHITTER NARROWS NORTHEASTERLY TO SAN GABRIEL CANYON ALONG SAN GABRIEL RIVER
SECTION H—H' — NORTH ALONG AZUSA AVE
SECTION I—I' — NORTH THROUGH SOUTH HILLS
SECTION J—J' — SAN JOSE HILLS NORTHEASTERLY TO SAN GABRIEL MTNS. NORTH OF PUDDINGSTONE RESERVIOR
ELEVATION IN FEET — U.S.G.S. DATUM
MEAN SEA LEVEL
BASE OF GROUND WATER RESERVOIR
GRAVEL PITS
RAYMOND FAULT
WORKMAN HILL FAULT
QUARTE FAULT
LONE HILL—WAY HILL FAULT
HORIZONTAL SCALE OF FEET
LEGEND
SAND
GRAVEL OR GRAVEL AND SAND
CLAY
SANDY CLAY
GRAVELY CLAY
SEDIMENTARY BEDROCK
CRYSTALLINE BEDROCK
FAULTS
NOTE LOCATIONS OF WELL LOG SECTIONS ARE SHOWN ON PLATE 13
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY
WELL LOG SECTIONS
F—F', G—G', H—H', I—I', J—J'
1965

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

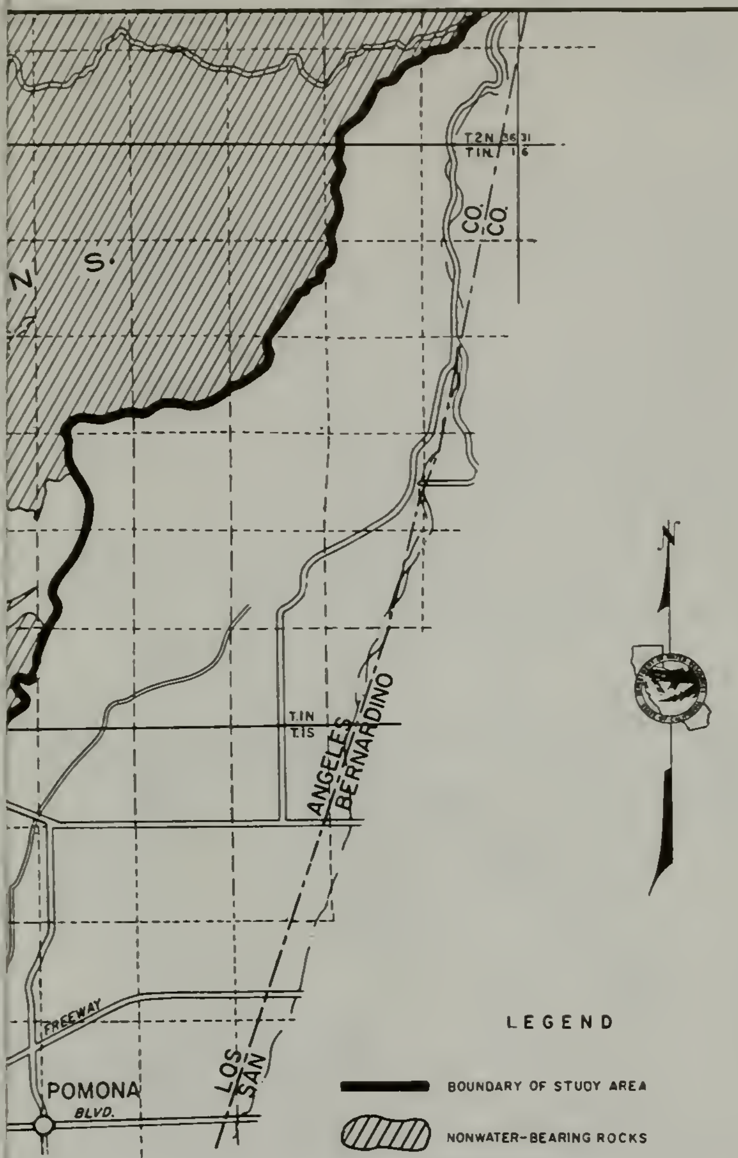
GEOLOGY AND HYDROLOGY OF THE
SAN GABRIEL VALLEY

AVERAGE SPECIFIC YIELD CONTOURS

SCALE OF MILES
1 0 1 2 3

1965


LA CRESCENTA
LA CANADA
DEVILS GATE DAM
ALTADENA
EATON WASH RESERVOIR
SAN GABRIEL MTNS.
SAN GABRIEL RESERVOIR
MORRIS RESERVOIR
SIERRA MADRE
PASADENA
MONROVIA
AZUSA
GLENDORA
SANTA FE FLOOD CONTROL BASIN
ARCADIA
SOUTH HILLS
WAY HILL
SOUTH PASADENA
SAN DIMAS
COVINA
BALDWIN PARK
ALHAMBRA
ROSEMEAD
EL MONTE
MONTEREY PARK
POMONA
REPETTO HILLS
WHITTIER NARROWS FLOOD CONTROL BASIN
MERCED HILLS
MONTEBELLO
SAN JOSE HILLS
PUENTE HILLS
LOS ANGELES CO.
SAN BERNARDINO CO.
LEGEND
BOUNDARY OF STUDY AREA
NONWATER-BEARING ROCKS
FAULTS AFFECTING WATER-BEARING MATERIALS, DASHED WHERE INFERRED OR LOCATION UNCERTAIN
SOILS HAVING HIGH INFILTRATION CHARACTERISTICS GREATER THAN 2 INCHES PER HOUR
SOILS HAVING MEDIUM INFILTRATION CHARACTERISTICS 0.6 TO 2.0 INCHES PER HOUR
SOILS HAVING LOW INFILTRATION CHARACTERISTICS 0.01 TO 1.0 INCHES PER HOUR
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY
SOIL INFILTRATION CHARACTERISTICS
SCALE OF MILES
1965



LEGEND

BOUNDARY OF STUDY AREA

NONWATER-BEARING ROCKS

FAULTS AFFECTING WATER-BEARING MATERIALS, DASHED WHERE INFERRED OR LOCATION UNCERTAIN

—650— LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS U.S.G.S. DATUM

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

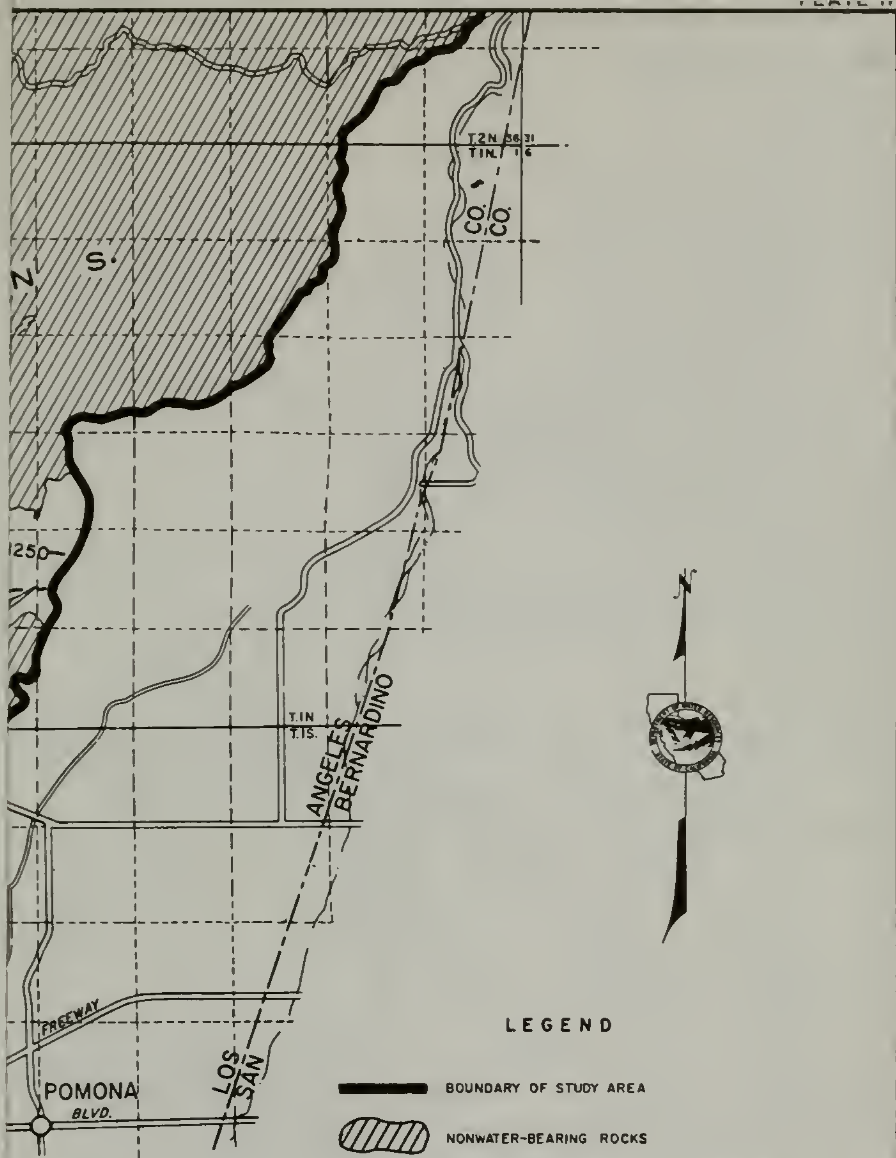
LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS FALL 1933

SCALE OF MILES

1 0 1 2 3

1965


LA CRESCENTA
LA CANADA
ALTADENA
DEVIL'S GATE DAM
EATON WASH RESERVOIR
SIERRA MADRE
PASADENA
MONROVIA
ARCADIA
SOUTH PASADENA
ALHAMBRA
ROSEMEAD
MONTEREY PARK
EL MONTE
BALDWIN PARK
AZUSA
GLENDORA
COVINA
SAN DIMAS
POMONA
SOUTH HILLS
WAY HILL
SANTA FE FLOOD CONTROL BASIN
WHITTIER NARROWS FLOOD CONTROL BASIN
MERCED HILLS
MONTEBELLO
REPETTO HILLS
SAN GABRIEL RESERVOIR
MORRIS RESERVOIR
S A N G A B R I E L M T N S.
SAN JOSE HILLS
LOS ANGELES CO.
LEGEND
BOUNDARY OF STUDY AREA
NONWATER—BEARING ROCKS
FAULTS AFFECTING WATER-BEARING MATERIALS, DASHED WHERE INFERRED OR LOCATION UNCERTAIN
—10— LINES OF EQUAL SPECIFIC YIELD FOR THE STRATIGRAPHIC INTERVAL EXTENDING FROM 30 FEET ABOVE HIGH WATER LEVEL TO 30 FEET BELOW LOW WATER LEVEL FOR THE PERIOD 1950 TO 1960. VALUES OF SPECIFIC YIELD IN PERCENT
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY
AVERAGE SPECIFIC YIELD CONTOURS
SCALE OF MILES
1965



LEGEND

BOUNDARY OF STUDY AREA

NONWATER-BEARING ROCKS

FAULTS AFFECTING WATER-BEARING MATERIALS, DASHED WHERE INFERRED OR LOCATION UNCERTAIN

—300— LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS U.S.G.S. DATUM

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS FALL 1944

SCALE OF MILES

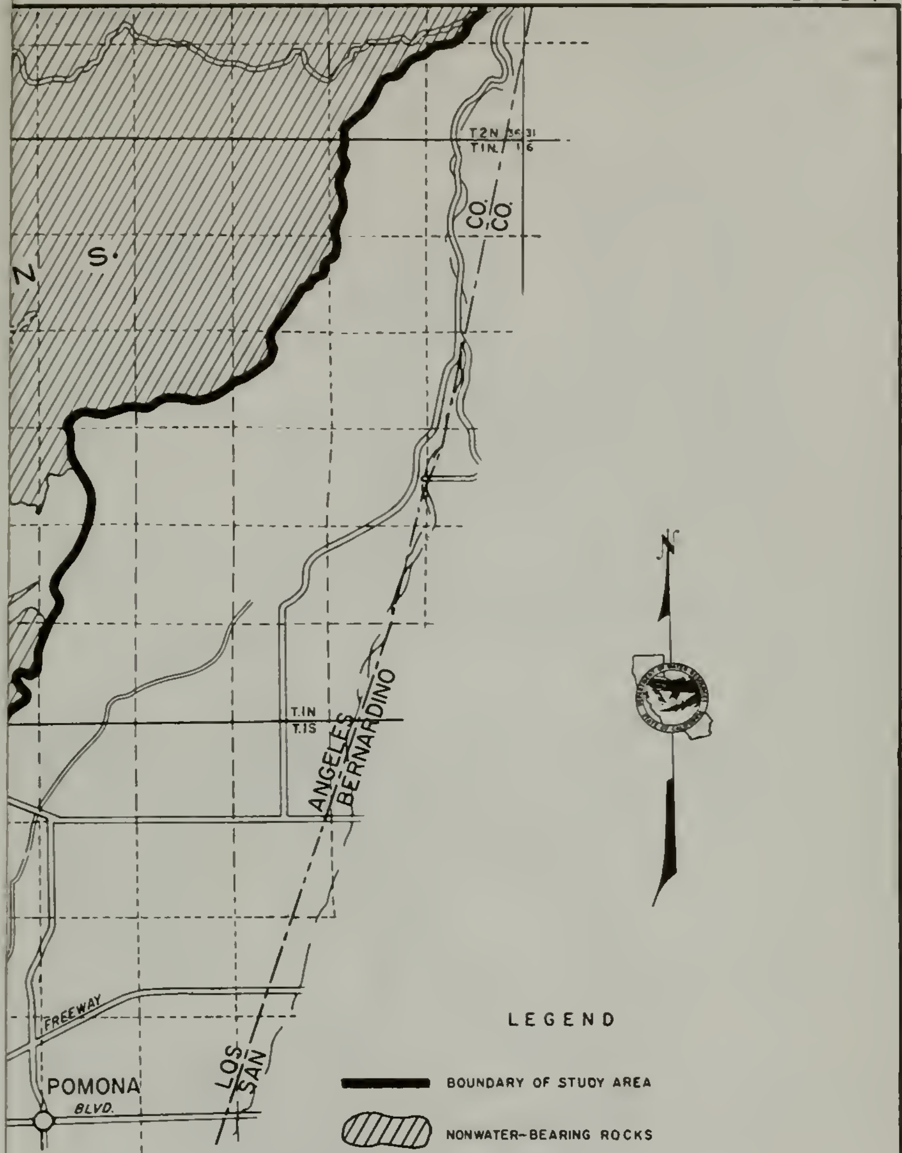
1 0 1 2 3

1965

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS FALL 1933



LEGEND

BOUNDARY OF STUDY AREA

NONWATER-BEARING ROCKS

FAULTS AFFECTING WATER-BEARING MATERIALS, DASHED WHERE INFERRED OR LOCATION UNCERTAIN

—650— LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS U.S.G.S. DATUM

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

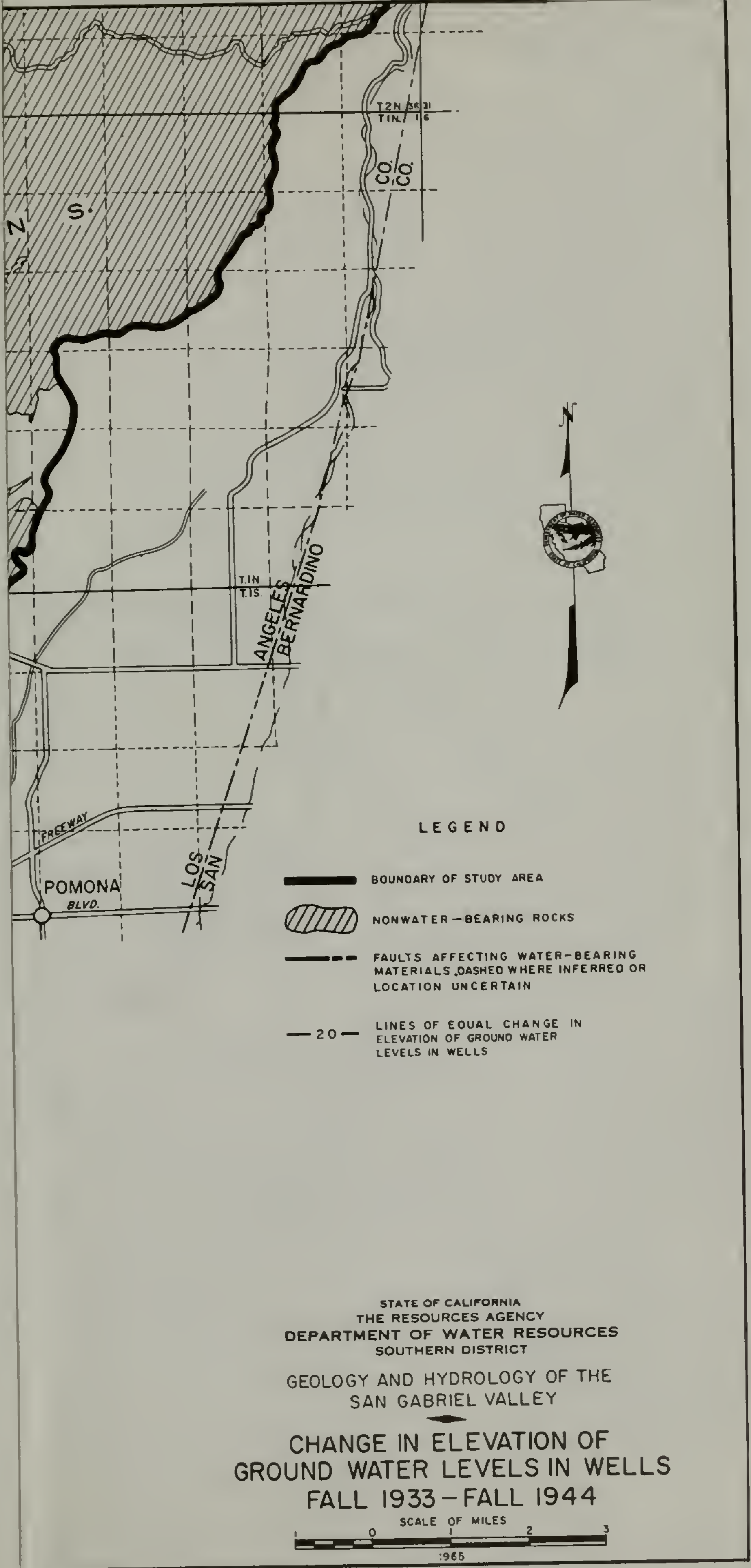
LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS FALL 1960

SCALE OF MILES

1 0 1 2 3

1965


LA CRESCENTA
LA CANADA
ALTADENA
DEVILS GATE DAM
EATON WASH RESERVOIR
SAN GABRIEL MTNS.
SAN GABRIEL RESERVOIR
MORRIS RESERVOIR
SIERRA MADRE
PASADENA
MONROVIA
ARCADIA
AZUSA
GLENDORA
SANTA FE FLOOD CONTROL BASIN
SOUTH HILLS
WAY HILL
SAN DIMAS
SOUTH PASADENA
ALHAMBRA
BALDWIN PARK
COVINA
ROSEMEAD
EL MONTE
MONTEREY PARK
REPETTO HILLS
WHITTIER NARROWS FLOOD CONTROL BASIN
MERCED HILLS
MONTEBELLO
PUENTE
SAN JOSE HILLS
POMONA
LOS ANGELES CO.
SAN BERNARDINO CO.
LEGEND
BOUNDARY OF STUDY AREA
NONWATER-BEARING ROCKS
FAULTS AFFECTING WATER-BEARING MATERIALS, DASHED WHERE INFERRED OR LOCATION UNCERTAIN
LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS USGS DATUM
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY
LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS
FALL 1944
SCALE OF MILES
1965

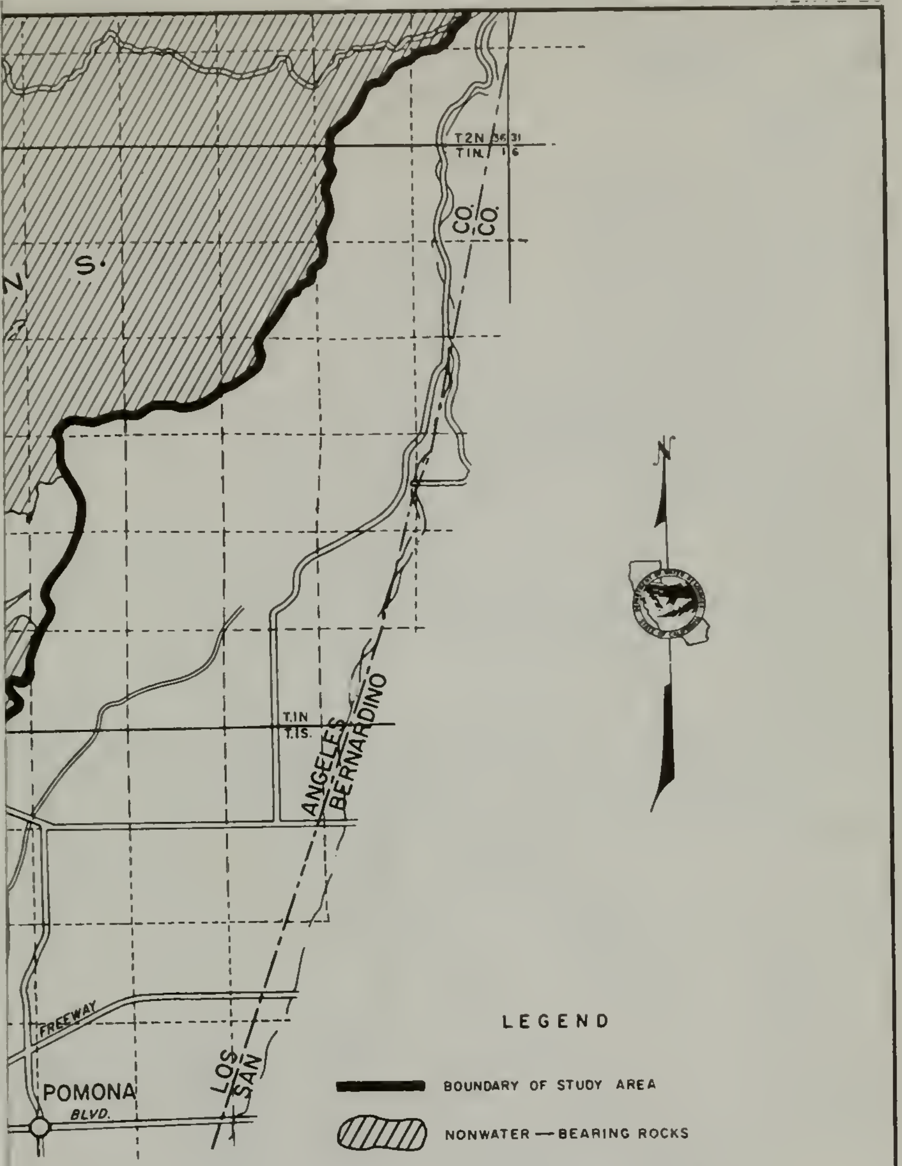


T2N
T1N
CO.
CO.
N
S.
T.1N
T.1S.
ANGELES
BERNARDINO
LOS
SAN
FREEWAY
POMONA
BLVD.
LEGEND
BOUNDARY OF STUDY AREA
NONWATER-BEARING ROCKS
FAULTS AFFECTING WATER-BEARING MATERIALS, DASHED WHERE INFERRED OR LOCATION UNCERTAIN
—20— LINES OF EQUAL CHANGE IN ELEVATION OF GROUND WATER LEVELS IN WELLS
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY
CHANGE IN ELEVATION OF GROUND WATER LEVELS IN WELLS
FALL 1933 – FALL 1944
SCALE OF MILES
1 0 1 2 3
1965

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

LINES OF EQUAL ELEVATION OF GROUND WATER IN WELLS FALL 1960



LEGEND

BOUNDARY OF STUDY AREA

NONWATER — BEARING ROCKS

FAULTS AFFECTING WATER-BEARING MATERIALS, DASHED WHERE INFERRED OR LOCATION UNCERTAIN

—20— LINES OF EQUAL CHANGE IN ELEVATION OF GROUND WATER LEVEL IN WELLS

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

CHANGE IN ELEVATION OF GROUND WATER LEVELS IN WELLS FALL 1944–FALL 1960

SCALE OF MILES

1 0 1 2 3

1965


LEGEND
BOUNDARY OF STUDY AREA
NONWATER-BEARING ROCKS
FAULTS AFFECTING WATER-BEARING MATERIALS, DASHED WHERE INFERRED OR LOCATION UNCERTAIN
—20— LINES OF EQUAL CHANGE IN ELEVATION OF GROUND WATER LEVELS IN WELLS
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY
CHANGE IN ELEVATION OF GROUND WATER LEVELS IN WELLS
FALL 1933 - FALL 1944
SCALE OF MILES
0 1 2 3
LA CRESCENTA
LA CANADA
DEVILS GATE DAM
ALTADENA
EATON WASH RESERVOIR
SAN GABRIEL MTNS.
SIERRA MADRE
PASADENA
MONROVIA
SAN GABRIEL RESERVOIR
MORRIS RESERVOIR
AZUSA
GLENDORA
SANTA FE FLOOD CONTROL BASIN
ARCADIA
SOUTH PASADENA
SOUTH HILLS
WAY HILL
SAN DIMAS
ALHAMBRA
BALDWIN PARK
COVINA
ROSEMEAD
EL MONTE
MONTEREY PARK
REPETTO HILLS
WHITTIER NARROWS FLOOD CONTROL BASIN
MERCED HILLS
MONTEBELLO
SAN JOSE HILLS
PUENTE HILLS
POMONA
LOS ANGELES CO.
SAN BERNARDINO CO.

LEGEND

BOUNDARY OF STUOY AREA

NONWATER — BEARING ROCKS

FAULTS AFFECTING WATER-BEARING MATERIALS, OASHEO WHERE INFERREO OR LOCATION UNCERTAIN

—-20— LINES OF EOUAL CHANGE IN ELEVATION OF GROUNO WATER LEVELS IN WELLS

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

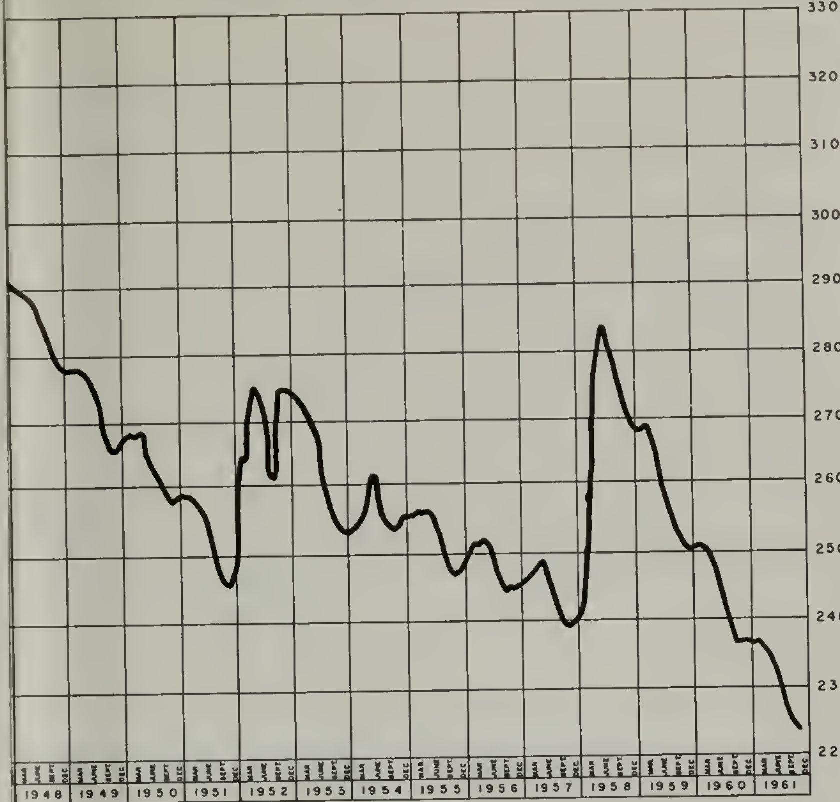
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY

CHANGE IN ELEVATION OF GROUND WATER LEVELS IN WELLS FALL 1933 – FALL 1960

SCALE OF MILES
1 0 1 2 3

1965


LEGEND
BOUNDARY OF STUDY AREA
NONWATER — BEARING ROCKS
FAULTS AFFECTING WATER-BEARING MATERIALS, DASHED WHERE INFERRED OR LOCATION UNCERTAIN
LINES OF EQUAL CHANGE IN ELEVATION OF GROUND WATER LEVEL IN WELLS
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY
CHANGE IN ELEVATION OF GROUND WATER LEVELS IN WELLS FALL 1944–FALL 1960
SCALE OF MILES
1965


330
320
310
300
290
280
270
260
250
240
230
220
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961

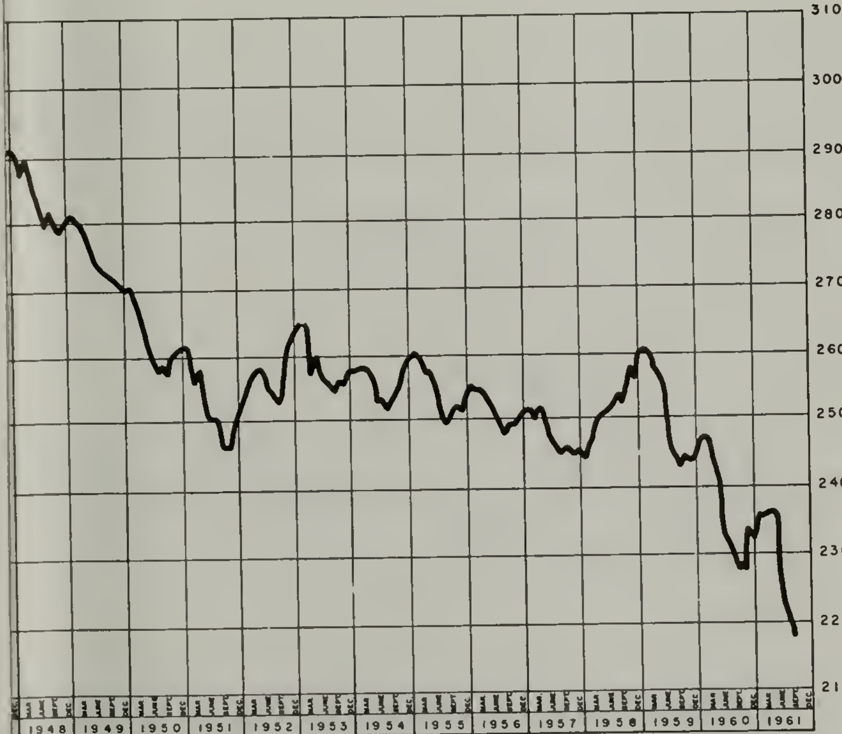

310
300
290
280
270
260
250
240
230
220
210
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961

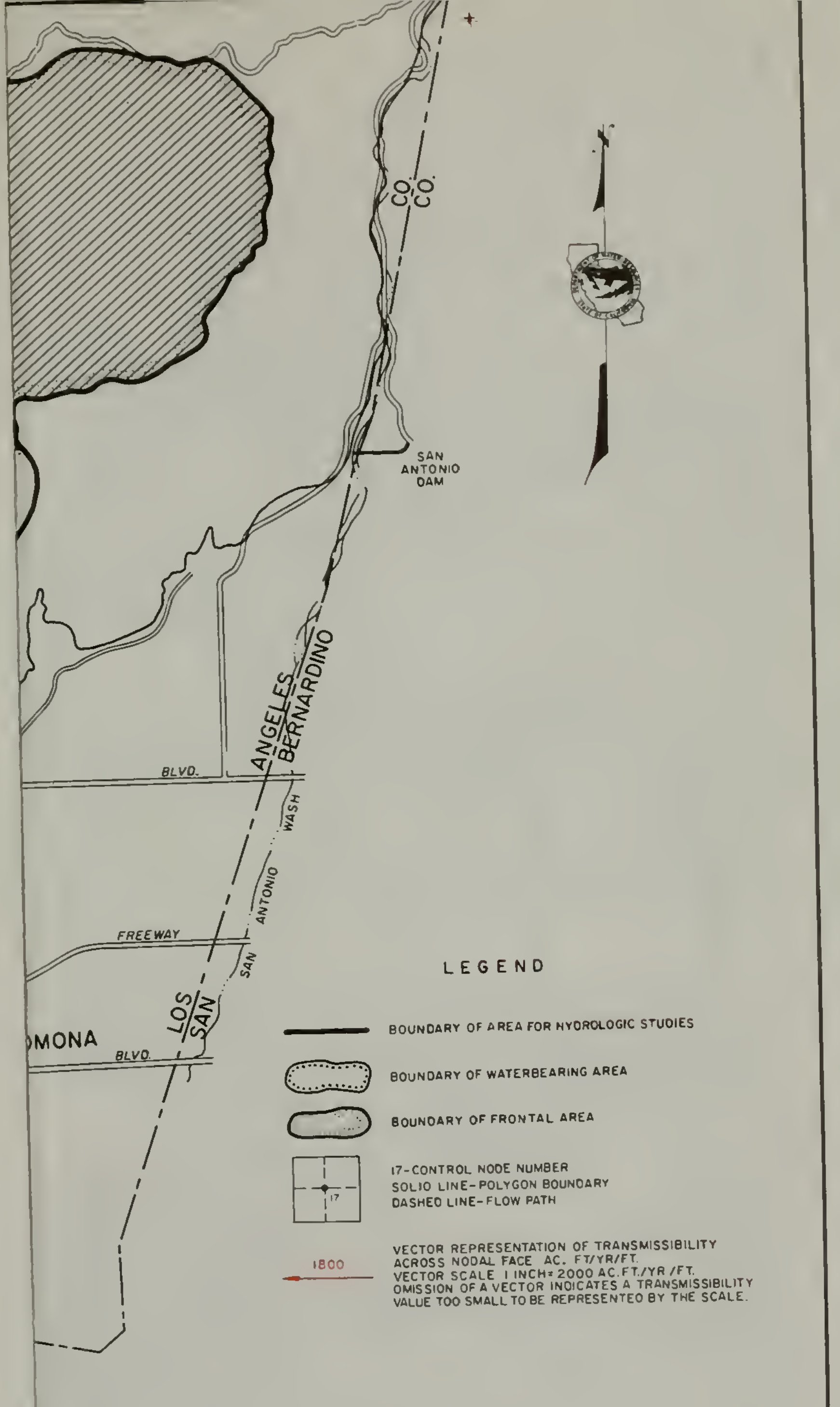
PLATE 21

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

GEOLOGY AND HYDROLOGY OF THE
SAN GABRIEL VALLEY

CHANGE IN ELEVATION OF GROUND WATER LEVELS IN WELLS FALL 1933 – FALL 1960

SCALE OF MILES
1 0 1 2 3
1965



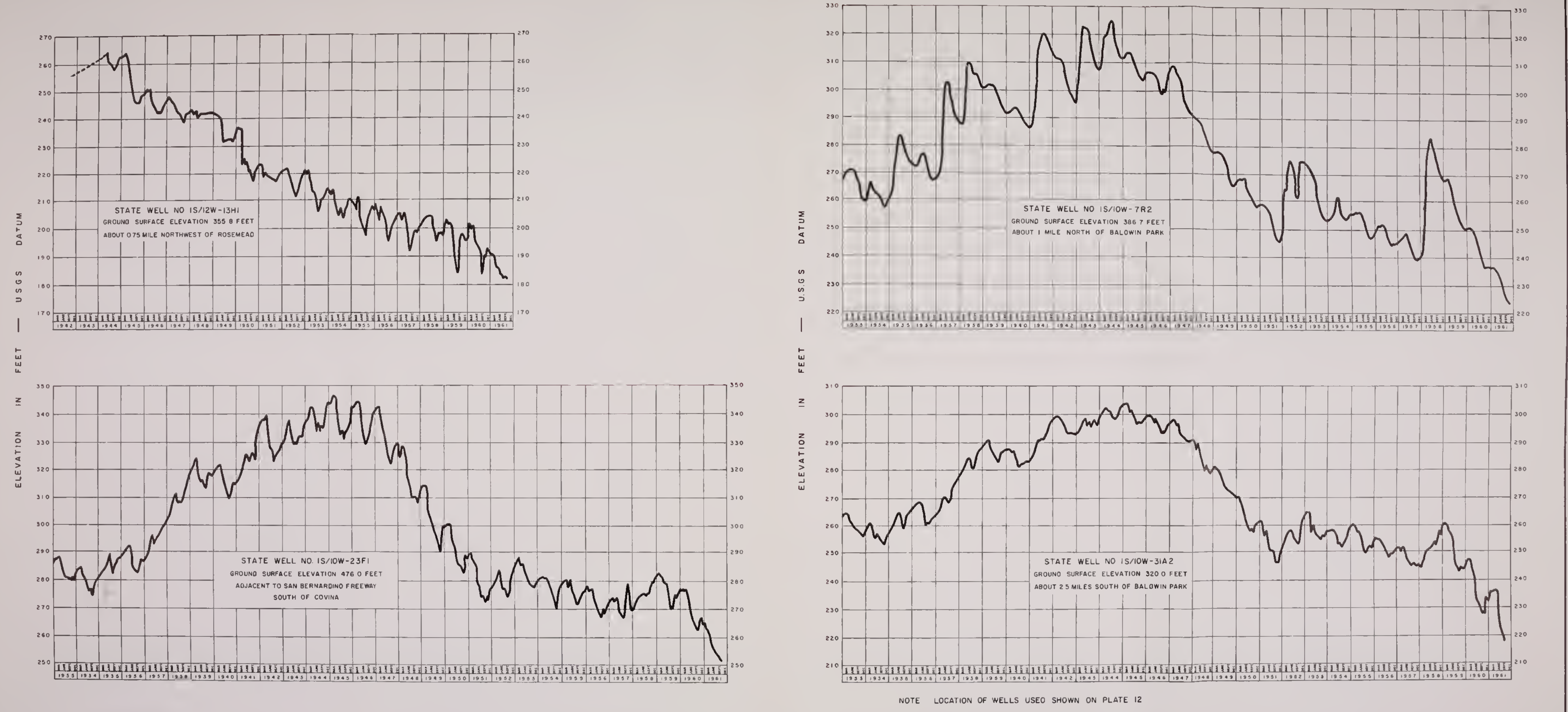
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

GEOLOGY AND HYDROLOGY OF THE
SAN GABRIEL VALLEY

NODAL NETWORK AND VECTOR REPRESENTATION OF TRANSMISSIBILITY VALUES DEVELOPED IN THE MATHEMATICAL MODEL

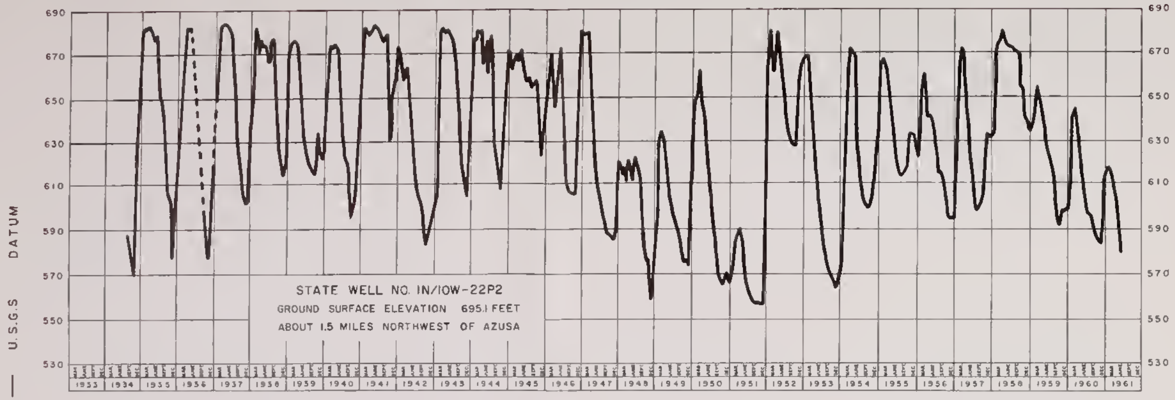
SCALE OF MILES
1 0 1 2 3

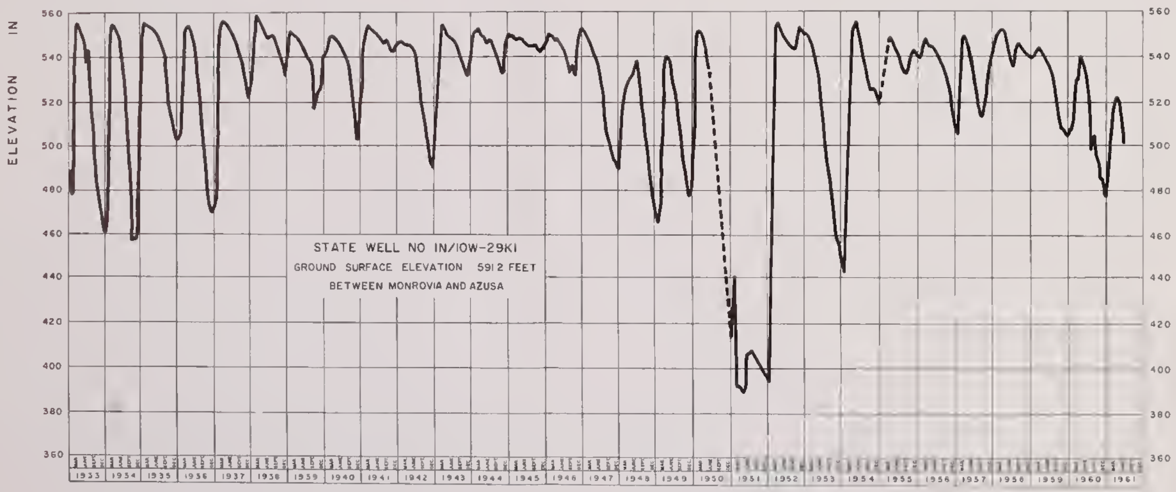
1965

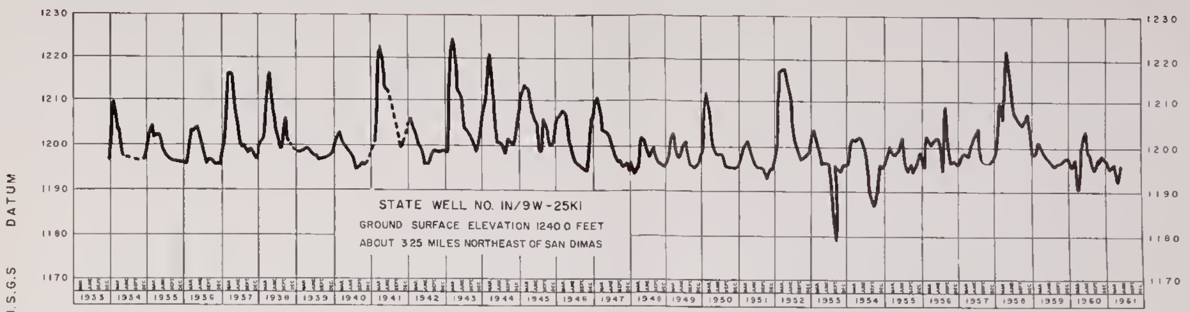


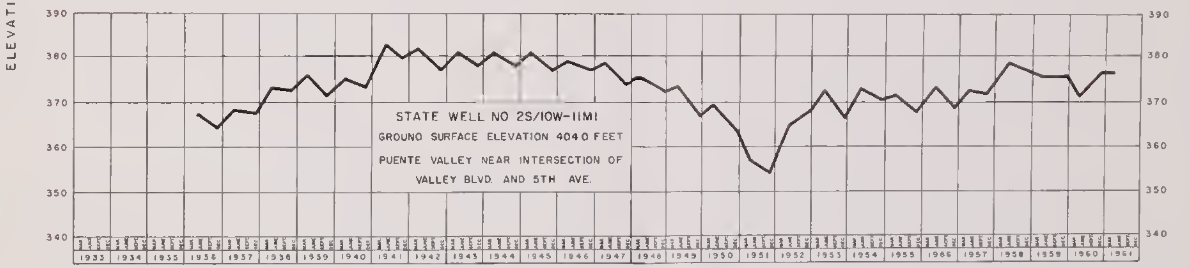
NOTE LOCATION OF WELLS USED SHOWN ON PLATE 12

SAN GABRIEL VALLEY WELL HYDROGRAPHS









NOTE LOCATION OF WELLS USED SHOWN ON PLATE 12

SAN GABRIEL VALLEY WELL HYDROGRAPHS

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1965


SAN GABRIEL MTNS.
FRONTAL AREA
SAN GABRIEL RESERVOIR
MORRIS RESERVOIR
BIG DALTON RESERVOIR
SAN ANTONIO DAM
DEVILS GATE DAM
EATON WASH RESERVOIR
ALTADENA
PASADENA
SIERRA MADRE
MONROVIA
ARCADIA
SAN MARINO
SOUTH PASADENA
TEMPLE CITY
SAN GABRIEL
ALHAMBRA
ROSEMEAD
MONTEREY PARK
EL MONTE
BALDWIN PARK
AZUSA
GLENDORA
SANTA FE FLOOD CONTROL BASIN
SOUTH HILLS
WAY HILL
SAN DIMAS
COVINA
LA VERNE
PUDDINGSTONE RESERVOIR
POMONA
REPETTO HILLS
MERCED HILLS
WHITTIER NARROWS FLOOD CONTROL BASIN
MONTEBELLO
PICO
WHITTIER
PUENTE
SAN JOSE HILLS
PUENTE HILLS
LOS ANGELES COUNTY
ORANGE COUNTY
LOS ANGELES
SAN BERNARDINO
LEGEND
BOUNDARY OF AREA FOR HYDROLOGIC STUDIES
BOUNDARY OF WATERBEARING AREA
BOUNDARY OF FRONTAL AREA
17 - CONTROL NODE NUMBER
SOLID LINE - POLYGON BOUNDARY
DASHED LINE - FLOW PATH
1800
VECTOR REPRESENTATION OF TRANSMISSIBILITY ACROSS NODAL FACE AC. FT/YR/FT
VECTOR SCALE 1 INCH = 2000 AC FT/YR/FT
OMISSION OF A VECTOR INDICATES A TRANSMISSIBILITY VALUE TOO SMALL TO BE REPRESENTED BY THE SCALE
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
GEOLOGY AND HYDROLOGY OF THE SAN GABRIEL VALLEY
NODAL NETWORK AND VECTOR REPRESENTATION OF TRANSMISSIBILITY VALUES DEVELOPED IN THE MATHEMATICAL MODEL
SCALE OF MILES
1 0 1 2 3
1965