EXHIBIT 12

PART 1

IN THE SUPERIOR COURT OF THE STATE OF CALIFORNIA
IN AND FOR THE COUNTY OF LOS ANGELES

THE CITY OF LOS ANGELES,
a Municipal Corporation,
Plaintiff,

vs.

CITY OF SAN FERNANDO,
a Municipal Corporation, et al.,
Defendants.

No. 650079

REPORT OF REFEREE

Volume II

APPENDIXES

By

STATE WATER RIGHTS BOARD

REFEREE

July, 1962

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GEOLOGY

The geology reported herein has been limited primarily to those geologic features and conditions within the watershed of the Los Angeles River above its confluence with the Arroyo Seco, insofar as they affect the occurrence and movement of ground water. The features and formations described herein are shown on Plate 4, Areal Geology, and on Plates 5, and 5A through 5H, Geologic Cross Sections.

Previous Investigation

Several bulletins and papers have been published dividing the area under investigation into numerous basins and subbasins. For the most part these divisions were made at or near locations where there is a change in ground water storage capacity, a drainage divide and/or structures that delay to varying degrees the flow of underground water toward the Los Angeles Narrows.

These bulletins and papers dealing with the geology in the vicinity of the area of investigation pertain mainly to the sedimentary and crystalline rocks in the hills and mountains around the edges of the valley fill.

Division of Water Resources Bulletin No. 45[1/] contains a detailed and broad coverage on the geology of the area of investigation and its effect on ground water. Particular reference is made to the geologic features of the valley fill and to the water-bearing series. This work has been studied in detail and data pertaining to specific yield and storage capacity have been modified and utilized in the present investigation as shown in Appendixes D and Q respectively. The modifications are based on an additional 25 years of records and data.

Regional Geology

The main valley floor is in general an alluvial-filled basin approximately 23 miles long and 12 miles wide. Based on physiography and/or geologic features, the valley fill contained within the hydrologic boundary of the basin has been divided into four hydrologic subareas (see Chapter III). Little is known of the depth of valley fill in the central and eastern part of the San Fernando Hydrologic Subarea where the depth of fill may exceed 1,000 feet in the area to the west of the City of Burbank.

The geologic events which affected the valley floor and the bordering hills and mountains as a whole during the formation of the structural features must be considered as well as features now expressed by surface topography in order to depict their effect on the occurrence and movement of ground water.

Geologic Formations

The geologic formations may be divided into two groups, the nonwater-bearing series and the water-bearing series.

The nonwater-bearing series do not absorb, transmit or yield water readily. They are the Basement Complex rocks and the Cretaceous and

Tertiary sediments of the Chico, Martinez, Domengine, Topanga, Modelo (Puente), Repetto and Pico formations.

The water-bearing series which absorb, transmit and yield water readily, consist of the alluvial deposits of Quaternary age occurring in the area and are classified as the Saugus formation, Older alluvium (terrace deposits), and Recent alluvium. This study deals mainly with the character and extent of the water-bearing series.

The stratigraphy of the area of investigation is shown in Table A-1.

The geological mapping performed by many previous workers has been compiled and supplemented where necessary by work of the staff of the Board and is presented as Plate 4, entitled "Areal Geology". The references utilized in the compilation of the map are listed in the bibliography as Nos. 1 through 18, inclusive.

General Geologic History

The metamorphosed pre-Jurassic sedimentary and igneous rocks found in the Basement Complex in the mountains and hills to the north, east and south of San Fernando Valley indicate that these rocks were intruded, faulted, and metamorphosed prior to the intrusion of the pre-Cretaceous granitics.

The Cretaceous rocks found in the hills and mountains in the southern and western portion of the area and their absence in the eastern portion indicate the presence of a sea in the western portion of the valley

TABLE A-1

STRATIGRAPHY WITHIN LOS ANGELES RIVER WATERSHED ABOVE CONFLUENCE WITH ARROYO SECO

	Age	Geologic formation	Description	Remarks	Thickness, in feet
Quaternary (water-bearing)	Recent	Alluvium	Poorly sorted, unconsolidated, coalescing alluvial fan deposits of sand, gravel and clay. Generally undissected and undeformed.	More gravels in eastern part of valley and fine grained with high clay content in western portion of valley.	0-100±
			Local unconformity		
Quaternary (water-bearing)	Upper Pleistocene	Older alluvium, terrace deposits, and slightly folded Pacoima formation.	Alluvial terrace deposits around basin margin and thick series of poorly consolidated continental gravels, sands and clays. Characteristic red or brown weathered surface. Deformation generally slight at surface but increases with depth. Some layers of fossil soils.	Generally more clayey and compacted than Recent alluvium. More gravelly in east and more clayey in west.	0-2000±
			Local unconformity		
Quaternary (water-bearing)	Lower Pleistocene	Saugus formation (Sunshine Ranch formation included)	Continental and marine poorly consolidated folded conglomerates, sands, silts and clays.	Continental alluvial fan deposits along north central portion of valley; marine finer sediments to west. Not found along southern or eastern portion of valley.	0-6000±
			Local unconformity		
Tertiary (nonwater-bearing)	Upper Pliocene	Pico formation	Blue sandy shale and siltstone with sandstone and conglomerate lenses. Principally marine. Consolidated and cemented.	Found only along northern portion of valley.	1500-3000±
Tertiary (nonwater-bearing)	Lower Pliocene	Repetto formation	Marine blue and brown siltstone and mudstone, arkose, sandstone and conglomerate. Some fossiliferous and petroliferous beds.	Found only along northern portion of valley.	400-3000±
			Local unconformity		
Tertiary (nonwater-bearing)	Upper Miocene	Modelo formation (called Puente formation at Los Angeles River Narrows, Bulletin 45)	Alternating marine shale and sandstone members. Thin-bedded cherty siliceous shale, diatomaceous shale and diatomite varying to clayey and sandy facies. Thick coarse massive arkosic sandstone and conglomerate with interbedded fine sandstone and shales. Sharp local variations. Associated with intrusive and extrusive basalt and other igneous rocks.	Found around the perimeter of the valley and probably underlies whole valley.	4000-7000±
			Local unconformity		
Tertiary (nonwater-bearing)	Middle and/or Lower Miocene	Topanga formation	Northern portion of valley continental arkose, conglomerate, red and yellow beds. Interbedded andesite and basalt flows. Southern and western portion of valley principally marine with some continental beds in lower part.		700-7500±
			Unconformity		
Tertiary (nonwater-bearing)	Middle Eocene	Domengine formation (Meganos formation Bulletin 45)	Marine gray to greenish hard calcareous sandstone and conglomerate.	Small outcrops in hills and mountains in northwestern portion of valley.	650±
			Local unconformity		
Tertiary (nonwater-bearing)	Lower Eocene	Martinez formation	Marine greenish-black sandstone, dark shale, coarse conglomerate.	Found along DeMille fault in San Gabriel Mountains and in Simi Hills at western tip of valley.	250-900±
			Unconformity		
Cretaceous (nonwater-bearing)	Upper Cretaceous	Chico formation	Upper portion marine massive hard coarse conglomerate with some sandstone and shale; lower portion soft red conglomerate and sandstone probably continental deposit.	Found in hills and mountains around western portion of valley.	250-900±
			Unconformity		
Pre-Upper Cretaceous (nonwater-bearing) Basement Complex	Lower Cretaceous or Jurassic	Granodiorite Granite Quartz Diorite, etc.	Granitic intrusion		
Pre-Upper Cretaceous (nonwater-bearing) Basement Complex	Triassic?	Santa Monica Slate	Black slates with schist facies	Santa Monica Mountains southerly of Encino Reservoir	5000-7000±
Pre-Upper Cretaceous (nonwater-bearing) Basement Complex	Pre-Cretaceous	Pelona schist, Placerita series, etc.	Undifferentiated metamorphic and granitic rocks, schists, gneiss and variety of crystalline rocks.	Found in San Gabriel Mountains, Santa Monica Mountains, Verdugo Hills and San Rafael Hills	

during the Cretaceous. It is quite probable that during this period of submergence the eastern portion of the valley was above sea level and undergoing erosion.

For the most part the whole area was undergoing erosion during Eocene time, with the exception of portions of the Santa Monica Mountains, Simi Hills and the Santa Susana Mountains where relatively thin sections of Martinez and Domengine were deposited.

During lower to middle Miocene time, continental deposits of red and yellow arkose, conglomerate, and interbedded volcanic flows were deposited in the northern and eastern portion of the valley. These beds appear to grade westward and southward into shallow water deposits of the Topanga formation. Fragments of Santa Monica slate (Triassic ?) are found in the Topanga formation along the southern portion of the valley, indicating that these sediments were derived from the ancestral Santa Monica Mountains.

In middle Miocene time, seas of the Ventura Basin extended over most of the area and by upper Miocene time had extended to a shoreline on the foothills of the ancestral mountain ranges around the margin of the basin now existing as the San Fernando Valley. In these seas were deposited the sediments of the Modelo formation. The upper Miocene marine deposits (Puente formation) found in the Los Angeles Narrows area are similar to and are the same age as the Modelo but were probably deposited by an arm of the sea extending from the south.

At the close of the Miocene epoch, some movement took place on the San Gabriel and related faults and the Modelo seas receded slightly.

It was in this relatively shallow sea that the nonwater-bearing Repetto and Pico formations were deposited. During middle and upper Pliocene time there was significant uplift of the area, accompanied by some faulting and folding. Middle Pliocene seas extended eastward from the Ventura Basin as far as Sunland. Pliocene deposits are noticeably lacking in the Santa Monica Mountains.

Rise of the San Gabriel Mountains and other ranges and hills was accelerated during lower Pleistocene time. The water-bearing Saugus formation (including Sunshine Ranch formation - Oakeshott, 1958)[2/] is represented by fluviatile and alluvial-fan sediments derived during the lower Pleistocene from the then existing San Gabriel Mountains which merge into marine sediments derived from the Santa Susana Mountains to the west. There is no evidence of a similar deposit along the base of the Santa Monica Mountains, indicating that during Saugus time this portion of the area was undergoing erosion.

The mid-Pleistocene orogeny was the major event in building of the modern mountain ranges and hills around the perimeter of the valley. At that time, the Saugus and all older formations were intensely folded and large movements took place in the San Gabriel and other fault zones at the northern edge of the valley. The Santa Monica Mountains, Simi Hills and Santa Susana Mountains were elevated with the latter two cutting off the San Fernando Valley from the Ventura Basin. The major streams accelerated their erosion and incised deep canyons in the mountains. Some of the first products of post-Saugus erosion are represented in the dark brown and reddish fanglomerate of the Pacoima formation (Oakeshott, 1958).[2] Strata of this formation have been locally folded in and near fault zones, particularly in the fault zone west of the Veterans Hospital north of the City of San Fernando.

Post-Saugus erosion of the higher lands has continued through upper Pleistocene to the present time. Erosion during this time has been modified, accelerated, or interrupted by repeated near-vertical elevation of the mountain masses. A succession of terraces produced by deposition from the various streams have been developed and then incised or eroded as the stream gradient was modified. Most of the terrace deposits parallel present drainage courses and were, therefore, quite evidently left by these streams in earlier cycles of erosion.

Erosion and elevation of the land mass has continued to the present time. The alluvial fill during this time has been derived from two types of material which have a profound effect on the permeability of the aquifers and on the quality of the water. West of the vicinity of San Fernando Reservoir and along the southern portion of the valley, local streams from the hills have deposited debris from predominantly sedimentary rocks of that region forming relatively tight deposits that have low specific yields. Easterly of San Fernando Reservoir, Pacoima, Little and Big Tujunga, Verdugo, and other streams along the northern edge of the valley have deposited alluvial cones consisting almost entirely of coarse crystalline debris of high specific yields from the San Gabriel and Verdugo Mountains.

The coalescing alluvial fans from the major tributaries to the north have pushed the Los Angeles River to the southern edge of the valley and indications are that these conditions existed in the past.

Nonwater-Bearing Series

The nonwater-bearing series, which is made up of relatively impervious formations that underlie and surround the more pervious formations differs from the water-bearing series essentially in three respects: (1) the nonwater-bearing series is for the most part relatively impervious and, therefore, stores comparatively little water which it yields to wells very slowly; (2) where pervious beds or zones occur within the nonwater-bearing series the movement of ground water and recharge from surface outcrops is generally so restricted by faults, structural position, or physical character of the materials that supplies obtained from such beds or zones are too limited and of too uncertain permanence to be comparable to ground water supplies obtainable from the water-bearing series; and (3) the quality of the water found in these formations is usually poor to unusable.

Several types of openings occur in the nonwater-bearing series, the principal ones being: (1) original interstices in porous beds of the sedimentary rocks; (2) interstices in the weathered zone; (3) fractures and joint openings below the surface (including openings along bedding planes and planes of schistosity); and (4) openings caused or enlarged by solution of the country rock.

In most places both the sedimentary and crystalline rocks are so tight that they yield very little water to wells and consequently are of no value except for domestic or stock-watering purposes. The limited amount of water contained in the nonwater-bearing series in the hill and mountain areas is available for transpiration and evaporation and support of effluent stream flow. Since the rate of movement of water through the nonwater-bearing series is generally slow, water derived from one season's precipitation may be held over for use in ensuing years. In a few places pervious strata or fracture zones in the nonwater-bearing series may yield water freely to wells. However, in most cases such production is short lived because of the relatively small storage capacity and inadequate recharge.

Basement Complex

Basement complex is a term applied to the old, pre-Cretaceous series of crystalline and metamorphic rocks that comprise the basal formation within the region. It is chiefly composed of igneous granitic rocks and various intrusive dikes, together with their related metamorphic phases, such as schists, gneisses and slates. It comprises the main mass of the San Gabriel Range and Verdugo Hills to the north, as well as portions of the San Rafael Hills to the east of the area, and the Santa Monica Mountains to the south. These rocks have an average porosity of less than one percent. The permeable openings have developed since the formation of the rocks. Below the soil mantle, the openings are principally joint fractures, cracks along the planes of schistosity and fractured materials near faults. Joint cracks are confined chiefly to the zone of weathering and die out rapidly with depth. Cracks along planes of schistosity diminish in number and become tighter below the weathered zone.

The schistose rock, which includes gneisses, schists and slates, has a relatively poor yield of ground water but is better than the more massive granites. Rocks of these types crop out principally in the Santa Monica and San Gabriel Mountains. Small continuous flows are obtained from a number of tunnels which have been driven into these rocks along the southern base of the San Gabriel Mountains. Water seeps into the tunnels from cracks in crushed zones or along planes of schistosity. Experience in driving tunnels into these banded crystalline rocks has shown that water pockets exist in crushed zones with water stored under rather high heads. As the stored water drains, the flow gradually diminishes. Permanent flows from tunnels up to 700 feet long in this rock unit seldom exceed 20 to 30 gallons per minute.

Upper Cretaceous Sediments

The Chico formation[3/] found in the hills and mountains around the northwestern perimeter of the valley floor consists of compacted and cemented marine deposits of massive, hard, coarse conglomerate with some sandstone and shale in the upper portion and soft, red conglomerate and sandstones of probable continental origin in the lower portion. In most cases the original pores have been closed, making these rocks similar in water-bearing properties to the Basement Complex. Widely spaced jointing, cracks along planes of bedding, and fractures furnish practically the only avenues for percolation of ground water and most of these die out with depth.

Lower and Middle Eocene Sediments

The lower Eocene Martinez formation and middle Eocene Domengine formation found in small outcrops in the mountains around the western and northern portion of the valley floor are for the most part cemented marine shales, sandstones and conglomerates. Their water-bearing properties are similar to the upper Cretaceous Chico formation. These formations are not extensive and for the most part are impervious, therefore are unimportant as possible sources of water.

Miocene Volcanics

Throughout the Topanga formation, volcanic flows and breccias associated with intrusive sills and dikes are common. The flows and sills, like the Basement Complex, are crystalline rocks but the breccias are clastic deposits with high original porosity. Thin beds of impervious bentonitic tuff are relatively common in the Modelo formation.

Jointing due to shrinkage that accompanied cooling and subsequent deformation of the solid lavas has shattered many of them to such an extent that they have become more or less permeable. The breccias and tuffs are not completely cemented and are also permeable. It is possible that where lavas lie beneath the water table but are within reach of shallow wells, good domestic supplies, and in a few instances sufficient water for local irrigation purposes, may be obtained.

Distribution of the volcanics, which generally occur in comparatively thin beds and often in positions unfavorable for storage of water, limits the usefulness of these rocks as ground water reservoirs in the area. Supplies available from this source are relatively small and in terms of total water available are considered negligible.

Upper Miocene, Shales, Sandstone and Conglomerates

The Modelo (Puente) shales which crop out over a large part of the intermediate hills and Santa Monica Mountains are characterized topographically by moderate to low relief with comparatively gentle slopes. The soil mantle is only a few feet thick, is very clayey and overlies a relatively thin weathered zone. The original pore spaces in the shales have in large part been closed by cementation but where they still exist they are too small to permit percolation of water through them. Production of water from the shales is very limited. Some deep wells obtain small quantities of water from the Modelo in the Calabasas area. Water from this source is of poor quality as it exceeds the recommended limits for total dissolved solids (1,000 ppm) sulfates (250 ppm) and magnesium (125 ppm) as set forth by the U. S. Public Health Service.

The Modelo (Puente) sandstones are interbedded with the shale members. Their outcrops are bolder and their slopes are steeper than the shale but otherwise their topography is similar. The sandstones as a rule are rather massive and well cemented. At the surface their weathered outcrops are yellowish brown with prominent partings along contacts between beds and are cut by widely spaced joints. Generally the unweathered sandstone is gray, well cemented and has such a low porosity and permeability as to be considered impervious. There are some sandstone beds that are poorly cemented. These beds permit the storage and movement of small quantities of ground water. Ground water in the sandstones, like that in the shales, originates from rainfall. The conglomerates of the Modelo formation are generally confined to the lower portion of the formation. A basal graywacke is well developed where the Modelo formation overlies the Santa Monica slate. The graywacke is massive and is resistant to weathering. It commonly crops out in a vertical wall 20 to 30 feet high.[10/] The conglomerates are well indurated and have a relatively low permeability.

Although the greater part of the Modelo sandstones and conglomerates are comparable to the shales in their lack of water-bearing properties, outcrops of pervious sandy and gravelly beds indicate that the sandstones are not entirely impervious throughout.

The presence of many faults and enclosed structures, together with the lenticular nature of the permeable beds, prevents deep circulation and replacement of the original (connate) salt waters of the formation by fresh surface water.

<u>Pliocene Deposits</u>

Pliocene deposits of the Repetto and Pico formations consist of clay and silty shales, and soft, fine sandstones which underlie the water-bearing series beneath portions of the valley floor and are exposed at various places in the hills in the northern portion of the area.

Generally, the pore spaces of the Repetto and Pico formations are too small to permit any appreciable movement of ground water through them; however, poorly consolidated marine sandstones and conglomerates with high porosity are present. Although the Saugus beds of this type (Sunshine Ranch formation) are considered to be a part of the water-bearing series, these beds are separated from the water-bearing portion of the Saugus formation by thick shale members, and belong to the nonwater-bearing series.

The ground water contained in the pervious beds near the surface is derived principally from rainfall, and percolation from stream beds. Pervious beds of the Repetto and Pico formations beneath the water-bearing series, but separated from them by shale bodies, generally contain waters too high in dissolved solids to be used for domestic or irrigation purposes. Because these beds outcrop as lenses between finer deposits and have both small recharge of usable water and limited storage capacities, they are unimportant sources of ground water.

Water-Bearing Sediments

Ground water occurs in three principal water-bearing series: the Pleistocene Saugus formation (including upper Pliocene Sunshine Ranch formation), late Quaternary Older alluvium (including Pacoima formation and terrace deposits), and Recent alluvium.

Lower Pleistocene Saugus Formation

The Saugus formation in the San Fernando Valley is generally restricted to marine and terrestrial deposits of probable lower Pleistocene age (Oakeshott, 1958)[2/] usually lying with angular unconformity on formations of all ages from the Basement Complex to the Pico formation.

The Saugus formation crops out in the hills and southern flanks of the mountains along the northern portion of the valley floor and underlies the other water-bearing sediments. The maximum thickness is 6,400 feet as measured on the east side of Lopez Canyon. Two miles east of Little Tujunga Canyon the formation thins rapidly to 2,000 feet. The formation also thins in a southwesterly direction to about 3,000 feet at San Fernando Reservoir. There are no outcrops of the Saugus formation in the Santa Monica Mountains, Simi Hills or Verdugo Mountains, indicating that the formation is restricted to the northern portion of the valley.

The water-bearing portion of the Saugus formation consists of light-colored, poorly sorted, loosely consolidated conglomerate and coarse sandstone, commonly crossbedded, which were deposited as fluviatile and alluvial-fan sediments. Throughout the Saugus formation layers and lenses of clayey gravel were formed by in-place weathering of the original materials.

In general, the water-bearing capacity of the Saugus formation is somewhat lower than the Older alluvium (terrace deposits).

Upper Pleistocene Older Alluvium (Terrace Deposits)

The lower, more folded portions of the Older alluvium have been differentiated by some investigators from the less folded deposits and the name, Pacoima formation, (Oakeshott, 1958),[2/] has been proposed for this early-to-middle Pleistocene deposit. Except for the more pronounced folding and overthrusting of Basement Complex, there is little difference between this unit and the remainder of the Older alluvium.

The Older alluvium was derived from deposits left by modern streams in earlier cycles of erosion with the sources little different from those of the present streams. With the exception of the remnants uplifted and partially eroded around the periphery of the valley floor, deposition has been nearly continuous to the present time.

Lithologically, the materials in all the Older alluvium and terraces are broadly similar, consisting of brownish-to-grayish, dirty, unsorted, angular-to-subangular detritus entirely of local origin. There are numerous breaks in the deposition of the material during which time extensive weathering took place, forming horizons of ancient soils. Consolidation is poor and the deposits are only locally cemented. Deposition of alluvial materials now taking place indicates that topography and drainage were closely similar when the Older alluvial deposits were being laid down. The belts of terrace deposits are broader than present stream deposits in some places and were probably formed by streams flowing at slightly lower gradients and in broader valleys. This would be a logical explanation, in part, for the finer-grained nature of some of the Older alluvium as compared to the Recent deposits. The main explanation for the higher clay content is the formation of residual clays by weathering.

The water-bearing character of these deposits is variable, depending upon the source area. West of the vicinity of San Fernando Reservoir and along the southern boundary of the valley, local streams from the hills have deposited fine debris from the predominantly sedimentary rocks of that region. East of San Fernando Reservoir, Pacoima, Big Tujunga, Little Tujunga, Verdugo, and other streams have deposited alluvial cones which consist almost entirely of coarse crystalline debris from the mountains to the north.

Recent Alluvium

Rejuvenation and increased gradient of the streams tributary to the Los Angeles River at the close of Pleistocene time have accelerated erosion from the mountains and deposition in the valley. Recent deposits east of Pacoima Wash and north of the Los Angeles River consist of predominantly coarse, thick accumulations of boulders, gravels, and sands in coalescing alluvial fans, becoming finer grained as distance increases from the canyon mouths. West of Pacoima Wash and south of the Los Angeles River the sediments are derived from predominantly sedimentary rocks and are finer grained, and deposited in much the same manner as the underlying Older alluvium.

Character of Quaternary Water-Bearing Alluvium

As previously stated, the sediments in the western portion of the valley floor are of a different nature than those found in the eastern portion and, therefore, have different water-bearing characteristics.

From the logs of wells available, it was not possible to distinguish the Saugus formation from the Older alluvium, with the exception of the Sylmar Hydrologic Subarea, so it was assumed that in all other areas the two formations had similar water-bearing characteristics.

Well logs show the western part of the valley floor to have an average of about 75 percent clay, 5 percent sand, and 20 percent gravel. Although the smaller streams of this area probably bring down considerable fine material, the low percentage of sand compared to gravel suggests the finer grained components have been decomposed to clay. These sedimentary materials probably break down more readily under the influence of weathering than do the crystalline rocks in the eastern portion of the valley. An average analysis of material from wells of the coarser crystalline material in the eastern portion of the valley floor shows 20 percent clay, 35 percent sand, and 45 percent gravel. These deposits were originally coarser than those farther west and apparently do not break down as quickly through weathering.

Structural Features

The structure of the Upper Los Angeles River area is rather complicated. The rough surface topography of the Basement Complex and extensive folding and faulting of the rocks in the hills and mountains indicate that the older rocks beneath the alluvium of the valley are folded and possibly faulted; therefore, the overlying alluvium has a variable thickness. With the exception of the faulting and folding along the northern half of the valley, there is no definite evidence that any of the other faults or folds have influenced the Recent alluvium.

Faulting

Structure of the area is dominated by the San Gabriel fault system. The north dipping, reverse or thrust faults of the Sierra Madre fault zone of the San Gabriel Mountains and Santa Susana thrust fault in the Santa Susana Mountains on the north, and the faulted anticlinal structure of the Santa Monica Mountains on the south, are also important features. The locations of the faults described herein are shown on Plate 4 and appear in the cross sections shown on Plates 5, and 5A through 5H.

San Gabriel Fault Zone. The San Gabriel fault zone has strong topographic expression, the faults appearing prominently on aerial photographs because of displaced geologic units, offset drainage, strike valleys, notched ridges, subparallel faulting, fracturing and folding. The major fault plane can be seen in Pacoima Canyon along Little Tujunga Road where the fault zone is marked by slivers of the lower Eocene Martinez formation sliced into crystalline rocks. There is no evidence to indicate activity on the San Gabriel fault in Recent time, and even late Quaternary terrace deposits seem unaffected.

Verdugo Fault Zone. The Verdugo fault zone along the south edge of the Verdugo Mountains, approximately parallel to San Fernando Road, and the Eagle Rock fault to the east appear to be a part or related to the San Gabriel fault system. Good exposures of the Verdugo fault can be seen at the base of the mountains just north of Burbank. It is plainly exposed on either side of a ravine for 50 to 75 feet; it dips 70 degrees south. Older reddish brown consolidated Quaternary gravelly sand is sharply down faulted against Basement Complex. Brecciation, gouge and calcitic vein material all occur in the fault. This fault extends under the alluvium along a line extending along the southern foot of the Verdugo Hills to the south of the Pacoima Hills, an outlier of the Verdugo block.

Subordinate to this major fault, but possibly important to controlling ground water movement, is another fault that strikes along the course of La Tuna Canyon and apparently merges with the Verdugo fault near the intersection of San Fernando Road and Sheldon Street.

Sierra Madre Fault Zone. The Sierra Madre fault zone is a series of discontinuous reverse or thrust faults from the Santa Susana fault on the west to the Rowley fault zone on the east. These comprise, from west to east, the Santa Susana, Grapevine, Sombrero, Hospital, Buck Canyon-Watt, an unnamed fault in upper Kagel Canyon, Lopez, Sunland, and Rowley fault.[2/] "Sierra Madre" comes from an old name for the San Gabriel Mountains, not from the town of Sierra Madre.

The fault zone is a series of curved, convex southward, reverse faults, which separate nonwater-bearing sedimentary and pre-Tertiary crystalline rocks on the north from the Cenozoic sedimentary formations on the south. The faults are discontinuous and of variable dip from 15 degrees to vertical; all dip northward with the older sedimentary and crystalline rocks thrust upward toward the south over sediments as late as the mid-Pleistocene Pacoima formation of the water-bearing series. Displacements have essentially been of the dip-slip type and are as great as 2,000 feet on any one fault. Displacement rapidly dies out as a strike of each of these reverse faults changes from the general east-west trend to a more northerly trend.

Northridge Hills Fault. The Northridge Hills fault is a high-angle fault. Its existence is based primarily on the numerous oil test holes which have been drilled in the Northridge Hills. Logs of these wells indicate that the Modelo formation has been displaced between 500 and 1,000 feet along the dip of the fault. The apparent movement along the fault has been dip-slip with the north block down. Numerous small drag folds in the form of anticlines and synclines have been formed along the fault. The apparent surface trace of the fault can be found in the Cretaceous Chico formation northerly of the town of Chatsworth. Sparse information indicates an effect on the movement of ground water west of Sepulveda Boulevard. There is no apparent effect of the fault east of Sepulveda Boulevard. This could be explained by the removal of materials and subsequent deposition of the coarse-grained deposits by Pacoima and Tujunga Washes. The Northridge Hills fault may be an extension of the Verdugo fault or the La Tuna Canyon fault as the structural pattern suggests; however, there are no data to substantiate this hypothesis.

Mission Hills Fault. A minor fault zone comprising three faults is perfectly exposed in Sepulveda Boulevard road cuts just east of Lower San Fernando Reservoir in the Mission Hills. It is believed that these faults are related to both the San Gabriel and the Sierra Madre fault system. Most southerly of these fault planes is a 60-degree south dipping reverse fault with rocks of the Modelo formation on the north limb of the Pacoima Hill anticline thrust over the lower Pliocene Repetto formation. The next fault north dips 55-degrees south and has thrust Repetto sandstone over fossiliferous sandstone of the middle Pliocene lower member of the

Pico formation. The most northerly of the group is a normal fault dipping 75-degrees north, with upper Pliocene beds down dropped. A north dipping Mission Hills thrust fault south of Lower San Fernando Dam is postulated on the basis of an anomalous geologic section reported for Universal Consolidated Oil Company Panorama 1 (Oakeshott, 1958).[2/] If such a fault exists, it might be expected to have similar features to faults of the Sierra Madre zone. That is, its trace should be convex southward, its trend should turn to the north around the eastern end of Mission Hills, it should dip about 40 to 50 degrees, and it should die out within a mile or two, both east and west.

Pacoima Hills Fault. A well-exposed east trending normal fault dipping 50 degrees north in the Pacoima Hills has brought Basement Complex up on the south side against sedimentary and volcanic rocks of the Topanga formation. Four miles east in the Verdugo Mountains, these formations are in unconformable contact. It is believed that this fault may be of small displacement. Bailey and Jahns (1954)[4/] projected this fault five miles east as a buried extension along the south side of Tujunga Valley. However, the most reasonable structural section shows no necessity for a Tujunga Valley fault (Oakeshott, 1958).[2/]

Raymond Fault. The Raymond fault separates the Topanga formation in the northern upthrown block from the Puente formation in the south block. It is mostly concealed by the Older alluvium along York Boulevard but evidence of its approximate location is given by outcrops near the fault zone. This fault is very likely a high-angle reverse fault, as shown by overturned beds in the Topanga formation along the Arroyo Seco. Overturned beds are also present east of the area of investigation at Raymond Hill. Immediately east of the Arroyo Seco the fault forms an escarpment 50 to 100 feet high in Older alluvium; however, the surface of the alluvium west of the Arroyo Seco apparently has not been displaced. Recent studies in the Eagle Rock Subarea seem to indicate that Older alluvium may have been displaced and deformed by movement on the Raymond fault. The throw on this fault may be in excess of 10,000 feet; however, only a small portion of this has occurred in post alluvial time.

Studies made of the bedrock configuration of the Los Angeles River channel indicate that movement along the Raymond fault has formed a small knob in the center of the channel to the north of the fault and a down-dropped area to the south. This is shown on Plate 6, entitled "Contours on the Base of Valley Fill". This feature may cause a constriction and may be the cause of the rising water which has been noted in the past in the vicinity of Los Feliz Boulevard.

Eagle Rock Fault. The Eagle Rock fault separates the Basement Complex rocks to the north from the Topanga formation to the south. It is a vertical or high-angle reverse fault with the north block up.[5] No alluvium has been displaced by the Eagle Rock fault, indicating that movement on this fault stopped before movement stopped on the Raymond fault. The questionable extension of the Eagle Rock fault westerly to the Verdugo fault is based on a step-like ground water cascade in the mouth of Verdugo Canyon. The general structural pattern also suggests that the Eagle Rock fault may be related to the Verdugo fault system.

<u>Effects of Faulting on Ground Water Movement</u>. There are numerous ways in which faulting may affect the movement of ground water. Some of the more important are listed as follows:

1. Impervious rock may be brought into contact with the water-bearing series thus reducing the underflow cross-sectional area.

2. Continuous pervious strata in the alluvium may be offset and made discontinuous.

3. Impervious gouge may be formed as a result of the grinding action during a recurrent movement along the fault.

4. Repeated uplift and depression of one or both sides of a fault block may allow alternate weathering of the surface deposits with resultant formation of large quantities of impervious residual clay in the vicinity of the fault.

5. Strata may be folded or overturned so that their position is unfavorable for percolation of water through them.

6. Fault fractures may be sealed by chemical deposits.

7. Brittle material may become cracked or brecciated thus creating a more permeable condition along the line of faulting which allows the zone to act as a conduit and carry water. This condition has been observed to exist to a minor extent in the vicinity of the water supply tunnels in the Verdugo Subarea.

A combination of all but the first and last phenomena is believed to have resulted in the formation of an impediment along the

Verdugo and La Tuna Canyon faults. Extensive research and work has been done by the Los Angeles County Flood Control District on the effect of these faults on their spreading operation of water from Hansen Dam.[6]

Folding

In the San Fernando Valley regional dips of the sedimentary formations are away from the pre-Cretaceous crystalline rocks which form the hills around the valley. Unconformities between the successive Cretaceous, Tertiary and Quaternary formations show that orogenic movements took place locally at various times, but the mid-Pleistocene orogeny overshadowed all of the others in intensity. During the faulting and the accompanying folding the crystalline rocks behaved essentially as a competent block undergoing intermittent elevation with adjustments within the block accompanied by faulting, shearing and fracturing. Around the margins of the Basement Complex the sedimentary strata reacted according to their competence and the local intensity of the stresses applied by developing a series of discontinuous folds closely related to the faults. Commonly, local synclines are developed on the down-dropped fault blocks and anticlines on the upthrown blocks.

The dominant fold structures affecting the storage and flow of underground water in the San Fernando Valley are located only along the northern border of the valley. Inasmuch as the other folds have little or no effect on the ground water, no extensive study was made of them.

The Little Tujunga syncline (Plate 5J), located between the Verdugo Mountains and the San Gabriel fault, is one of the principal structural features along the north edge of the valley. The axis of this fold closely parallels the trace of the Sierra Madre fault zone, following it with a west northwest trend in the area from Tujunga to the Veterans Hospital at Pacoima Canyon, where it has been overridden by the crystalline rocks along the Hospital fault. Continuing westward, the axis changes to a southwest trend paralleling the northeastern end of the Santa Susana fault. Formations along the south limb dip northward at angles from 25 degrees to 80 degrees; the north limb is very steep to overturned and has minor folds superimposed on it. Saugus beds are overturned in several places along the Lopez fault, particularly in upper Lopez Canyon. Overturning of the Saugus formation is general along the Sunland fault where the north limb of the syncline has been almost completely cut out by the fault.

The Verdugo Mountains, Pacoima Hills and Mission Hills comprise the remnants of an elevated, faulted anticlinal block trending north 75 degrees west across the northern part of the valley. Structurally, the highest part of this block is in the central part of the Verdugo Mountains, where granitic rocks are exposed. This structure is flanked by the Topanga and Modelo formations, plunges westward to the vicinity of Hansen Flood Control Dam, is faulted up to expose granitic rocks and the Topanga formation in the Pacoima Hills, and plunges west downward to an estimated 8,600 feet in the next four miles (Oakeshott, 1958).[2/]

The most prominent fold of the Mission Hills is the east trending Mission Hills anticline just south of lower San Fernando Reservoir, which exposes diatomaceous shale of the Modelo formation at the southeast end of the reservoir. This fold may be the result of drag on the Mission Hills thrust fault. The strong westward plunge of this structure is indicated by Repetto, lower Pico and upper Pico beds which successively overlie exposures of the Modelo formation on the north, west and south limbs of the anticline. The north and south limbs are faulted and complicated by numerous minor folds in the incompetent Modelo shale. For two miles northwest of the Mission Hills anticline, Saugus beds dip continuously northward on the south limb of the western expression of the Little Tujunga syncline. To the west of San Fernando Reservoir, the sediments of the water-bearing Saugus formation are folded into a series of anticlines and synclines trending about north 70 degrees west.

Geophysical studies of nonwater-bearing formations in the western portion of the San Fernando Hydrologic Subarea made by various oil companies show a series of three synclines with two intervening anticlines in the nonwater-bearing formations that have an easterly plunge. This structure is somewhat simpler than was originally postulated by Eckis in Bulletin 45.[1/]

The Elysian Hills anticline, which is located on the southerly side of the Los Angeles River Narrows, is of interest in that continued movement on this feature after the mid-Pleistocene orogeny may have caused the "reversed gradient" on the base of the water-bearing series in the Narrows area; however, there is no evidence of movement in Recent time. This "reversed gradient" feature shows the profile on the base of water-bearing materials lower in elevation near Colorado Boulevard than at Figueroa Street or Gage F-57. This is shown on Geologic Cross Section M-M' and Plate 6, Contours on the Base of the Valley Fill. Another explanation of this feature could be that the Arroyo Seco flowed northerly into the San Fernando Subarea for a period of time in the mid-Pleistocene.

A small anticline in the Modelo formation in the Hidden Hills area north of Calabasas is worthy of description. This fold is fairly tight and is best traced by a sandstone bed. This fold plunges steeply toward the north. Water wells drilled into the flanks of the anticline yield very little water, while wells drilled along the crest encounter fractured rock and have much better production (80-100 gpm). This water is of poor quality. Continued production of water in this area has resulted in an abnormally high decline in water levels.

Configuration of Base of Valley Fill

The configuration of the base of the valley fill is shown by the contours on Plate 6. The contour locations were developed from logs of approximately 200 wells in which elevations of the base of the water-bearing materials could be determined. The determination was made by subtracting the thickness of the water-bearing materials indicated in the well logs from the surface elevation of the well. The elevation of the well was determined either by survey methods or interpolated from the U.S.G.S. 7-1/2 minute quandrangles that cover the valley area. The nonwater-bearing materials noted in the well logs were shale, sandstone, conglomerate or granite. Since it was not possible to locate the poorly consolidated Saugus formation from the well logs it is assumed that this formation is included in the volume of water-bearing materials in the San Fernando Hydrologic Subarea. The Sylmar Hydrologic Subarea is entirely underlain by the Saugus formation, which extends, in the northern part of the subarea, to a depth in excess of 6,000 feet.

No Saugus formation has been detected at depth in the Verdugo or Eagle Rock Hydrologic Subareas.

San Fernando Hydrologic Subarea

The contours on the base of the valley fill (Plate 6) in the western portion of the subarea in the vicinity of Arroyo Calabasas and Bell Creek seem to indicate the existence of an old drainage system which was located somewhat southerly of the present drainage channels. This ancient drainage appears to have flowed northerly, east of Aliso Canyon Wash into the deep portion of the basin which is traversed by the Southern Pacific Railroad (S.P.R.R.).

The depth of water-bearing material is unknown in the central and eastern portion of the subarea, but probably extends to depths of 1,000 to 1,500 feet. An anomalous dome-like feature is present in the vicinity of Lankershim Boulevard and Vanowen Street. The cause of this feature is unknown; however, its presence is indicated on Figure H-1, Appendix H. Geophysical gravity studies by Corbato,[7] also show this anomaly. The Tujunga Wash area is underlain by nonwater-bearing formations at depths to about 90 feet below ground surface. South of Hansen Dam, well 4904A, which is 226 feet deep, failed to reach nonwater-bearing formations. The exploratory work performed for Hansen Dam[8] indicates the presence of Modelo formation at depths of 90 to 170 feet along the axis of the dam.

The amount of offset in the nonwater-bearing materials along the Verdugo fault south of Hansen Dam is not known due to a lack of deep wells with logs. In the Sunland area, which is adjacent to Big Tujunga Wash, there is an offset in the nonwater-bearing formations amounting to about 30 feet. The location of this offset is in grid coordinates 4983. This feature may be due to faulting which is evident in the hills to the northeast and southwest of this feature.

In the vicinity of the confluence of Verdugo Wash and the Los Angeles River, the depths to nonwater-bearing material rapidly decreases as the Los Angeles River enters the Los Angeles River Narrows. The reason for this rapid change in the bedrock profile is not known; however, it has been postulated that this feature is caused by a westerly extension of the Eagle Rock fault, the scarp of which was modified by erosion prior to burial. This feature is located in grid coordinates 3904, 3914, 3924 and 3934 and shown on Plate 6.

Sylmar Hydrologic Subarea

The subarea is almost entirely underlain by the folded Saugus formation which extends to great depth. Immediately below the Saugus formation are the nonwater-bearing Repetto and Pico formations. The Repetto formation is exposed in both banks of Pacoima Wash at the Pacoima submerged dam, located in the vicinity of well 5989A. These outcrops and their westerly extension constitute the eastern portion of the southern boundary of the subarea. Although the Saugus is underlain by the Pico formation in the Mission Hills, the western portion of the southern boundary is believed to be within the lower Saugus formation where impervious beds prevent lateral movement of ground water. The Repetto, Pico and Saugus formations dip approximately 60 degrees to the north and drop rapidly in elevation under the water-bearing materials.

The Stetson Sombrero No. 1,[19] drilled by Sunray Oil Corporation (1950) in the proximity of well 5937 in the northern part of the subarea, penetrated 12,027 feet of sediments reported to be continental Saugus. Dipmeter records of the hole indicate formation dips of about 45 degrees. These data indicate that the thickest section of Saugus in the area is in the vicinity of this test hole. The Little Tujunga syncline plunges toward this location from both the east and west.

Verdugo Hydrologic Subarea

Contours of the base of the valley fill (Plate 6) in the Verdugo Hydrologic Subarea show several interesting features. The most important of these is the existence of the buried channel eroded into the Basement Complex of an ancestral Pickens Wash draining easterly into the Monk Hill area. Under low water table conditions this buried channel carries all tributary subsurface water. Under high water table conditions the southwesterly bank is overtopped and subsurface flow in a westerly direction is presumed to occur.

A second feature is the depression in the buried bedrock surface in the vicinity of well 5058J. The bedrock elevation at this location is somewhat lower than the bedrock surface in Verdugo Canyon. This depression may be due to displacement on the La Crescenta Valley fault. It is interesting to note that the maximum depth of water-bearing materials is about 54 feet at Verdugo well (3963) adjacent to the Verdugo submerged dam, while upstream approximately 1-1/2 miles the depth of fill material has increased to a maximum of 190 feet. This decrease in the thickness of the water-bearing materials is related to tilting associated with movement on the Verdugo fault and/or the normal thinning of deposits at the toe of an alluvial fan.

Eagle Rock Hydrologic Subarea

The configuration of the base of the valley fill in the Eagle Rock Hydrologic Subarea is not shown in detail on Plate 6 due to the small area involved and to the 100-foot contour interval which was utilized on the plate. A more graphic representation of the subarea is shown on Geologic Cross Section S-S' on Plate 5H. This section shows the deepest portion of the basin to be located in the vicinity of the Raymond fault and in the area of extraction from the confined artesian portion of the basin. The configuration of the base of the valley fill along Colorado Boulevard in the subarea is not known; however, the depth to bedrock for a well located just northwest of the intersection of Colorado Boulevard and Eagle Rock Boulevard was stated as 140 feet (well No. 333, U.S.G.S. Water Supply Paper 219 field notes).[20] The depth of the water-bearing materials near the Raymond fault is about 200 feet.

Geologic Conditions Affecting Occurrence and Movement of Ground Water

Geologic features greatly influence the occurrence and movement of ground water within the Upper Los Angeles River Basin. Features such as faults, folds and lithologic variations have pronounced effects on the water surface elevation and direction of movement.

The source of ground water supply to the hydrologic subareas is percolation of direct rainfall, surface runoff from valley areas and hill and mountain areas, spread waters, imported waters, and a minor amount of underground percolation of water from the mountain masses to the alluvium. Disposal of the supply, other than by export, evaporation, consumptive use and surface runoff, is by relatively small amounts of underflow out of the area at the Los Angeles Narrows and in the Pickens Canyon area.

Both the Basement Complex pre-Quaternary sediments and volcanics, which are known to underlie the area, are deep-seated and relatively impervious and any contribution by ground water movement from them must therefore be small. The investigation has revealed no evidence of subsurface outflow conduits other than through the Los Angeles Narrows to the Los Angeles forebay of the Central Basin, and the subsurface underflow from the Pickens Canyon area to the Monk Hill Basin of the Arroyo Seco drainage system.

San Fernando Hydrologic Subarea

For purposes of discussion the San Fernando Hydrologic Subarea is best divided into two general units on the basis of the type of alluvial-fill material present in each part. The valley fill of the western portion of the area is essentially fine-grained material derived from the surrounding sedimentary rocks. The fine-grained nature of these materials allows water to be transmitted at a relatively slow rate, whereas the eastern portion of the subarea has high yields and high permeabilities and is composed of coarse detritus eroded mainly from the granitic Basement

Complex. This eroded debris is generally very coarse; in places boulders up to three feet in diameter are relatively common. The deposits are essentially sand and gravel with some fines in the interstices. These materials constitute about one-third of the surface area of the ground water reservoir and contain about two-thirds of the water in storage in the San Fernando Hydrologic Subarea.

Western Portion. In the western portion of the subarea, there are several faults which may or may not have an effect on the movement of ground water in the vicinity of Devonshire Street and Topanga Canyon Boulevard in the proximity of the town of Chatsworth. The most prominent of these faults extends northeasterly beneath the valley fill. This fault has displaced the nonwater-bearing materials forming a ground water cascade on the order of 80 feet in height. The area is underlain at shallow depths by Cretaceous sandstones northwest of the fault and the Modelo shale at greater depth south of the fault. The small northwesterly trending fault in the water-bearing series in this area must be inferred in order to contour the ground water elevations in a logical manner. It is not known whether the water-bearing materials have been affected. This feature is parallel to the Northridge Hills fault and lies south of it. Both faults have cut the nonwater-bearing Cretaceous sandstones to the north.

The effect of the Northridge Hills fault on the movement of ground water is unknown; however, the fault forms a barrier or partial barrier to the movement of ground water either by offsetting permeable beds or by bringing less permeable materials closer to the surface. The upper portion of the easterly extension of the fault has presumably been removed by erosion by the combined action of Pacoima and Tujunga Creeks.

The small arcuate fault shown westerly of the intersection of Balboa Boulevard and Ventura Boulevard has no known effect on the movement of ground water. The existence of this fault is based primarily on the apparent vertical offset of the upper member of the Modelo formation that crops out on the north side of the fault.

An area of shallow ground water levels is present in the western portion of the hydrologic subarea. The area is bounded on the east by Reseda Boulevard, on the south by the Los Angeles River and to the west by De Soto Avenue. The northern boundary is somewhat L-shaped following Saticoy Street to the vicinity of Tampa Avenue then northerly to Parthenia Street. This area was studied in detail by the United States Department of Agriculture Soil Conservation Service, Research, during the period 1947 through 1950.[21/]

Their investigation pointed out the following conclusions: water level fluctuations in the piezometers installed by the Soil Conservation Service are cyclic with precipitation; these water levels also respond to irrigation water applied in excess of the consumptive use; and deep artesian and/or pressure wells within the area leak into the shallow zone to the extent that small ground water mounds were developed around certain wells. The source of the confined water appears to be from aquifers in the Saugus formation. The Saugus formation presumably underlies the alluvium at relatively shallow depths. These aquifers are recharged by precipitation on the surface exposure of the Saugus formation to the north.

Small localized pressure effects found in the western portion of the subarea are due to gravel lenses confined by clay strata.

Eastern Portion. The permeable character of the alluvial-fan deposits below Hansen Dam has been altered by faulting. Gravel beds displaced by thin clay seams in the fault planes have been observed at the 130 foot level in the Arrow Rock Products gravel pit south of well 4916B. These sheared gravels do not represent the main trace of the Verdugo fault; however, they illustrate how the associated faults may act as partial barriers to the movement of ground water.

There are two steps in the water surface in this area. The first step is immediately below Hansen Dam and appears to be a ground water cascade flowing over the northerly dipping Modelo sandstones and into the deeper portion of the area near the gravel pits. Well 4914, located about 1,000 feet south of Hansen Dam, and the exploratory drill holes for the dam indicate that water-bearing rocks are at about 900 feet elevation, whereas approximately 10,000 feet south of Hansen Dam near the Verdugo fault zone the base of the water-bearing series is about 600 feet deeper, lying between elevation 200 and 300 feet above sea level. The water surface drops about 300 feet in elevation between the axis of the dam and wells in grid 4916.

As of January 20, 1945, there was a 75-foot difference in the elevation of the water table observed between wells 4895 and 4905A. These wells straddle the Verdugo fault and are 3,000 feet apart. The difference in ground surface elevation between the wells is 28 feet. Considering the high permeability of the aquifers tapped by these wells and the lack of heavy draft in the area, a water table with an overall slope of 150 feet per mile, about 2-1/2 times as great as the surface slope, seems improbable when compared to the normal water table slope in the northern part of San Fernando Valley which is about 15 feet per mile or about one-third the surface slope. These facts alone warrant the assumption that the Verdugo fault zone is a partial barrier to the free underflow of water. Observations of this condition were initially reported by Warren N. Thayer of the Los Angeles County Flood Control District in a report dated March 15, 1945, entitled "A Resume of Present Knowledge of Ground Water Conditions in the Vicinity of Hansen Spreading Grounds".[6]

Between the southeastern corner of the Mission Hills and the southwestern side of the Pacoima Hills, there is a very sharp break in the water surface of approximately 250 feet. This discontinuity in water levels is discernible between wells 4841 and 4842. This feature is assumed to be a ground water cascade due to a difference in the elevation of the nonwater-bearing materials. Very little is known about this feature due to a lack of well data in the vicinity.

Another ground water cascade is present in the Sunland area adjacent to Tujunga Wash. This cascade apparently is due to faulting in the nonwater-bearing series with the water surface being about 50 feet lower on the Tujunga Wash side of the feature.

A step-like water surface is present below the Verdugo submerged dam of the City of Glendale. The steps in the water surface are due to offsets in the Basement Complex along the Verdugo fault zone. No evidence of the faults forming a barrier to the movement of ground water has been found. The water surface elevation at Verdugo well 3963A is generally about 90 feet higher than well 3963, which is located about two-thirds of a mile downstream, and the water levels at well 3954 are 250 feet lower than at well 3963. Well 3954 is about two-thirds of a mile downstream from well 3963.

The water-bearing deposits of the Los Angeles River Narrows are very permeable. The City of Los Angeles has two well fields in the area. Due to heavy pumping, large depressions or pumping holes have been created in the ground water surface. The largest of these pumping depressions is located at the large bend in the Los Angeles River where the river begins its southerly course through the Narrows. This well field, called the Crystal Springs well field, and the City of Glendale Grandview wells immediately north of the Crystal Springs well field, have created the pumping depression indicated on Plate 30. The second pumping hole, created by heavy pumping of the Pollock well field of the City of Los Angeles, is not shown on the plate due to its being developed during 1959 and 1960.

The rising water which has occurred historically is due in part to the reduction in the cross-sectional area as the stream approaches the

F-57 gage. The maximum depth of water-bearing materials at Huron Street (Gage F-57) is about 110 feet, whereas the maximum depth at the Pollock well field is 260 feet. A comparison of the two areas is shown by sections K-K' and L-L' on Plate 5D.

Some instances of rising water have been noted in the past in the vicinity of Los Feliz Boulevard. This occurrence is probably due in part to a constriction or reduction of the cross-sectional area of water-bearing materials. The constriction is caused by the small buried hill of nonwater-bearing material which is depicted on Plate 6, Contours on the Base of the Valley Fill, and is located just downstream from Los Feliz Boulevard.

Movement of Ground Water. The slope of the water surface and direction of ground water movement in the unconfined zones of the San Fernando Hydrologic Subarea is easterly toward the Los Angeles River Narrows. Ground water contours for the fall of 1931, 1938, 1944 and 1958 are shown on Plates 27, 28, 29 and 30, respectively. The direction of movement of ground water is normal to the contours and downslope therefrom.

The waters in general move away from the surrounding hill and mountain groups where the runoff percolates into the porous portions of the alluvial fans. The water then in transit moves downward to the main water body.

Water level fluctuations in the San Fernando Subarea are depicted by the hydrographs of wells shown on Plates 34A and 34B. The location of the following wells utilized are shown on Plate 18:

2771H	3740	3914H
3600	3753	3938B
3691A and C	3830B	4838

Sylmar Hydrologic Subarea

Formations. The nonwater-bearing rocks that form the northern boundary of the subarea are composed essentially of Basement Complex; however, in the northwestern portion of the area, rocks of the sedimentary Repetto formation are faulted against the Basement Complex. The Repetto formation also occurs along the southeastern boundary and again in the Mission Hills (see Plate 4), where it is overlain by a thin section of nonwater-bearing Pico formation.

The water-bearing deposits in the Sylmar Subarea consist of the Saugus formation, Older alluvium and Recent alluvium. The Saugus formation is about 6,400 feet in thickness and is composed of strata that vary greatly in terms of porosity and permeability. Some members of the formation make good aquifers while others are aquicludes. The Older alluvium may have a maximum thickness of between 500 and 1,000 feet west of the San Fernando Veterans Hospital. These materials are composed of coarse detritus derived from the Basement Complex; however, in some places residual clays have developed as a result of weathering. The Recent alluvium attains a thickness of 50 to 60 feet in Pacoima Wash where the erosive action of the stream has incised the previously mentioned water-bearing units and then backfilled the eroded area with very coarse granitic debris. In the remainder of the subarea, where Recent alluvium occurs it constitutes only a thin veneer on top of Older alluvium and Saugus formation.

Structure. The geology of the Sylmar Subarea is greatly complicated by faulting and folding. The nonwater-bearing materials to the north of the subarea have been faulted and in part thrust southerly over portions of the water-bearing Saugus formation. The compressive forces that are related to the thrust faulting are also related to the formation of the Little Tujunga syncline,(Plate 5J)the most important feature of the subarea. At least 6,000 feet of Saugus formation and an even greater thickness of older nonwater-bearing sediments have been folded into an asymmetric syncline with the north limb overturned. This syncline has been truncated by erosion and covered by a veneer of Older and Recent alluvium. The southeastern boundary of the subarea, as hereinbefore noted, is formed by the steep, north-dipping beds of the nonwater-bearing Repetto formation that is part of the same synclinal structure. The Repetto formation is exposed in both banks of the Pacoima Wash at the topographic constriction, which is the site of the Pacoima submerged dam located about 2.5 miles south of Pacoima Dam. These strata continue westerly under the cover of Older alluvium and are exposed in roadcuts near the intersections of Gladstone Avenue and Maclay Avenue, and Foothill Boulevard and Fernmont Street (see Figure A-1). All of the previously mentioned outcrops have similar attitudes. From the intersection of Foothill Boulevard and Fernmont Street to the Mission Hills there are no outcrops of the Repetto formation; however, the logs of wells 5969B and 4850B, located in this section indicate materials thought to be Repetto formation at depths of 310 and 321 feet, respectively. These depths indicate that the wells are located westerly of the projected trace of the Repetto strata and are within the Sylmar Subarea.

<u>Field Investigation</u>. Within the section between Foothill Boulevard and Mission Hills there is a very marked discordance in water levels. In order to locate more accurately the break in the water surface, 20 bucket auger holes were drilled. Nine of the twenty holes were drilled under the direction of and at the expense of the City of San Fernando, five by the City of Los Angeles, and the remaining six by the Referee. Representatives of the Board were present at the drilling of all holes and prepared detailed logs of each boring. The location of the test holes is shown on Figure A-1. The logs of the test holes are included in the well log section of the basic data. The results of the drilling program were utilized to construct a peg model which aided the analysis. The boundary of the subarea was delineated in the gap area on the basis of water levels. The analysis of available water level data, data obtained from the test holes and the geology of the area indicate the following:

1. Water levels northwesterly of the break in the water surface are about 50 feet higher than those to the southeast of the break (see Plate 30).

2. Water levels northwesterly of the break are related to the eroded ends of confined aquifers in the Saugus formation.

3. Water levels southeasterly of the break are free ground water levels and are associated with coarse alluvial deposits which had the Pacoima drainage as a source area.

4. The discordance in water levels is related to the eroded south flank of the Little Tujunga syncline which has been covered with a thin veneer of alluvium.

SAN FERNANDO VALLEY REFERENCE

LOCATION OF TEST HOLES AND IMPEDIMENTS TO FLOW OF GROUND WATER

STATE WATER RIGHTS BOARD

5. Subsurface flow from the Sylmar Subarea to the San Fernando Subarea has been found to occur only at two places: namely, the Sylmar and Pacoima Notches (see Plates 5 and 5H). There is hydraulic continuity between the confined aquifers and the veneer of alluvium that overlies the eroded south flank of the Little Tujunga syncline.

6. Continuity exists between the Sylmar and San Fernando Subareas through the saturated alluvium in the two notches.

7. The configuration of the break in water surface through the Sylmar and Pacoima Notches is not sharp as would be caused by a fault but is a steep gradient which is similar to that found in a ground water cascade.

Occurrence and Movement of Ground Water. The information obtained from the test holes greatly aided the understanding of the occurrence and movement of ground water within the subarea. The noticeable pressure rise of the water surface which took place in several of the test holes during and immediately after drilling, coupled with the fact that there are historic records of artesian flows for the Mission well field and the City of San Fernando well field at Fourth and Hubbard Streets, indicate that a confined water system exists within the Sylmar Subarea. A free ground water area is present between the aforementioned well fields as determined during the test drilling. All wells in the subarea derive their water supplies from the confined aquifers of the Saugus formation. In 12 of the test holes, the Saugus formation was penetrated before saturated materials were reached.

There is a decline in water levels in the free ground water area in the Sylmar Subarea coincident with heavy pumping of the Mission well field.

Therefore, on the basis of the short period of record available, it is concluded that the free ground water area is in hydraulic continuity with the confined aquifer.

The Sylmar and Pacoima Notches (Plate 5H) are the principal areas of subsurface escape from the subarea. The slope of the water surface through the Sylmar Notch is suggestive of a ground water cascade where small quantities of water are spilling over a relatively impermeable lip or barrier. Data on the slope of the water surface below the Pacoima Notch are not available. These two features are described in detail in Appendix P.

The exact location and extent of the forebay or recharge area for the confined aquifers are not definitely known; however, the porous alluvial deposits in Pacoima Wash are in a favorable position to recharge the dipping aquifers of the Saugus formation which are in contact with the stream gravels in the incised and backfilled portion of Pacoima Wash. These permeable deposits act as a sponge, holding water for release into the aquifers of the Saugus formation. Ground water contours (Plates 27 through 30) indicate that there is a slope of the water surface from Pacoima Wash toward the lower portion of the subarea where the majority of extractions are made. Routing studies made by the staff of the Board on the Sylmar Subarea indicate that the water supply from Pacoima Creek that could remain in the water-bearing materials above the Pacoima submerged dam would not be sufficient to maintain the water levels in the area through a period of wet and dry years. Deep percolation of precipitation, applied water and runoff from hill and mountain areas are also major sources of recharge. Such recharge would percolate through the alluvial blanket and enter some of the truncated aquifers of the Saugus formation.

The hydraulic gradient under static conditions indicates that it is improbable that Lower San Fernando Reservoir contributes water to the subarea. Records of well 4830, about 2,000 feet east of the reservoir, show that water levels have dropped below elevation 1,120 feet (high water surface of Lower San Fernando Reservoir) only six times between 1932 and 1954. Under pumping conditions, the water levels are lowered about 90 feet and a favorable gradient can be developed in various aquifers that strike between the Mission well field and the Lower San Fernando Reservoir. Information now available is insufficient to support a conclusion that flow occurs under pumping conditions.

It is possible that movement of ground water in a westerly direction can occur in the Saugus formation from the vicinity of Kagel and Lopez Canyons which lie immediately to the east of Pacoima Wash, since a favorable hydraulic gradient exists and the synclinal structure of the Saugus formation plunges westerly. The amount of water that could be derived from the Kagel-Lopez area would be relatively small since the area of tributary drainage adjacent to the permeable formation is small. Wells of the Glenhaven Cemetery, located in the upper Kagel Canyon area, penetrated the Saugus formation to depths of approximately 900 feet. Since the yields of these wells are very poor and water levels are declining, it may be inferred that a ground water mining operation exists.

Since the recharge from the Pacoima Wash area, coupled with deep percolation of precipitation and delivered water on the remaining surface of the subarea, appears to have been of sufficient magnitude to maintain water levels at their historic levels, historic recharge from Lower San Fernando Reservoir or Kagel and Lopez Canyons is improbable. However, substantial withdrawal from the subarea might bring about conditions more favorable to recharge from Lower San Fernando Reservoir.

Water level fluctuations within the Sylmar Subarea are represented by hydrographs of wells 5939, 5969 and 5989A, which are shown on Plate 34C. Water levels in the lower portion of the subarea have only declined about 25 feet below the 1944 high water level.

Verdugo Hydrologic Subarea

The water-bearing materials of the Verdugo Subarea are surrounded by a complex of granitic and metamorphic rocks which have been highly fractured. Previous geologic work by Miller (1934)[11/] mapped the rocks in two main groups, the Wilson granodiorite and the San Gabriel formation. These units have been, for purposes of the report, called Basement Complex because of their general lithologic similarity and nonwater-bearing characteristics. The Basement Complex yields only small amounts of water to springs and tunnels from fracture systems which in turn are supplied by infiltration of precipitation. The overall average flow from each of these tunnels and springs was estimated to be about 20 gpm during September 1959.

The valley fill is composed essentially of coarse detritus which has been deposited in a series of coalescing fans. The principal source area has been the San Gabriel Mountains. Well logs indicate a fairly high content of sand, gravel and boulders; however, numerous notations indicate that there is considerable clay in the matrix of some of these materials. It should be noted that the material in the area north of Foothill Boulevard has a lower specific yield. Wells in this portion of the basin have much lower production than those located in the lower portion of the basin (vicinity of Verdugo City and Montrose).

The northern portion of the ground water basin is traversed by a member of the Sierra Madre fault zone. This fault is not known to have displaced any of the valley fill materials. The La Crescenta Valley fault bounds the southern portion of the valley fill. This fault is inferred on the basis of topography. The depression in the bedrock surface as shown on Plate 6, Base of Water-Bearing Series, may be related to the existence of this inferred feature.

Numerous faceted spurs along the Verdugo Mountains furnish additional criteria for postulating the existence of the fault. Miller (1934)[11] extends this fault down into Verdugo Canyon; however, evidence for such an extension appears to be tenuous.

The main portion of the Verdugo Basin represents a graben between the Sierra Madre and La Crescenta Valley faults. This graben has been modified by erosion and connected to the San Fernando Basin by Verdugo Canyon. In the canyon, bedrock is much nearer to ground surface at the submerged dam than at the Glorietta well field, which is located in the upper reach of Verdugo Canyon. This may be related to tilting caused by movements of the

Verdugo fault. Historically, the occurrence of springs in the area above the present day submerged dam is probably related to this reduction in cross-sectional area of permeable material.

The Verdugo and La Crescenta Valley faults are not known to have affected the water-bearing series. There are no known natural impediments to ground water movement other than a bedrock ridge which extends between the mouth of Goss Canyon and the granitic outcrop located at the intersection of Foothill Boulevard and Briggs Avenue in the Verdugo Subarea.

A series of cross sections and bedrock contours drawn through the subarea indicate that the bedrock is lower in the La Canada-Pickens Canyon area and that a buried ancestral Pickens Wash slopes to the Monk Hill Basin. Available ground water levels indicate that the ridge obstructs the flow of ground water to the Verdugo Subarea under low water table conditions such as in the fall of 1958; however, the water is above the ridge in high water table years such as 1944.

Geologic studies to date do not indicate that there are any sources of native ground water other than that which is derived from precipitation. No indications of juvenile water or water transported from outside the watershed along faults or fracture systems have been found.

Direction of Ground Water Movement. The ground waters in the Verdugo Subarea move southerly from the mouths of canyons in the San Gabriel Mountains toward Verdugo Canyon. The majority of extractions of ground water are made by wells of Crescenta Valley County Water District along the southwest side of the area, by the City of Glendale in Verdugo Canyon at the Glorietta well field (3971), at the Verdugo submerged dam and finally by the Verdugo well (3963A). There is also some movement of ground water from the Pickens Canyon area into the Monk Hill Basin, which is discussed in more detail in Appendix F.

Water level fluctuations within the Verdugo Subarea are represented by the hydrograph of well 5058, which is shown on Plate 34C.

<u>Eagle Rock Hydrologic Subarea</u>

The Eagle Rock Hydrologic Subarea is treated herein as a separate ground water unit; however, it should be noted that the computation description of hydrologic items for this subarea were included with the data for the San Fernando Subarea.

The Eagle Rock Subarea is located in the eastern portion of the Los Angeles River drainage basin adjacent to the Los Angeles River Narrows. The surface drainage flows generally towards the vicinity of Eagle Rock Boulevard then southwesterly to the Los Angeles River. The total tributary drainage of the area above the Raymond fault and its intersection with Eagle Rock Boulevard is about 2,910 acres.

The subarea is an artesian basin in which all present-day pumping is located at the lower end of the pressure area in the vicinity of York Boulevard.

<u>Formations</u>. Topanga and Puente (Modelo) formations are the principal nonwater-bearing rock units cropping out in the area surrounding the water-bearing series. Highly fractured Basement Complex is present in

the hill area north of the Eagle Rock fault and a small severely broken knob of the same material occurs on the north side of York Boulevard between Mt. Pleasant Street and Avenue 49.

The water-bearing materials are essentially composed of older alluvial deposits of sand, gravel and considerable clay. Recent alluvium only constitutes a thin veneer along the stream channels.

The Eagle Rock and Raymond faults are the main fault features of the area. The Eagle Rock fault separates the Basement Complex to the north from the Topanga formation to the south and is a vertical or high-angle reverse fault with the vertical movement in the magnitude of several hundred feet. No alluvium has been displaced by the Eagle Rock fault.[5/]

The Raymond fault separates the Topanga formation in the northern upthrown block from the Puente formation in the south block. The trace of the fault is concealed by the Older alluvium along York Boulevard but an approximate location is indicated by outcrops near the fault zone. This fault is very likely a high-angle reverse fault as indicated by the deformed beds in the Topanga formation along the Arroyo Seco. There is no surface indication that movement on the Raymond fault has affected the Older alluvium; however, some movement must have occurred prior to the deposition of the gravelly aquifer materials to cause the change from the essentially fine-grained materials of the lower aquiclude. It is quite probable that traces of such movement have been buried during the deposition of the upper aquiclude material (see Plate 5H, section S-S').

Occurrence and Movement of Ground Water. A detailed study of well logs, water level data and geology has lead to the conclusion that a simple artesian basin exists in the Eagle Rock Subarea. The lower end of the aquifer abuts against the Raymond fault and the nonwater-bearing Puente formation. The pressure area extends northerly toward Colorado Boulevard. Evidence for hydraulic continuity was established between well 3986B located on Ridgeview Avenue and the only active wells (3987A, 3987B, 3987C, 3987D, 3987E and 3987F) in the subarea, which are located 3,000 feet to the south along the north side of the Raymond fault. A water level recorder was installed on well 3986B during 1937 and 1938 by the Los Angeles Department of Water and Power. These records indicate a definite recovery pattern when the active wells were not pumping over week ends and holidays. The recorder charts for the weeks ending March 1, 1938 and March 8, 1938 are interesting in that they show a recovery of 2.85 feet in 40 hours during the storm of March 2, 1938. This recovery took place during the period of the storm and indicates that the forebay or recharge area for the pressure aquifer is in the near vicinity. Another water level recorder was installed by the Referee on the same well from June 3 to June 6, 1960 and a record was obtained that verified the earlier recovery pattern exhibited by the Los Angeles Department of Water and Power recorder charts as being due to cessation of pumping over a week end. The starting or stopping of the pumps of the wells at the lower end of the area affected the piezometric surface in well 3986B within one hour.

Due to a lack of data in the upper portion of the pressure area northerly of well 3986B and in the forebay, an accurate determination of the extent of the pressure area cannot be made at this time. For the purposes of this study, it is estimated that the pressure area has an area of approximately 250 acres and the forebay has an area of about 530 acres. Based on the above 250 acres in the pressure area, a thickness of 10 feet and a specific yield of 19 percent, the storage in the pressure aquifer is estimated to be 475 acre-feet. All wells located within the assumed pressure area have had a record of artesian flows.

Study of the U. S. Department of Agriculture Soil Survey of the Los Angeles Area, California, 1919,[22] indicates a long, narrow area of Chino clay loam extending northerly in the vicinity of Eagle Rock Boulevard.

This organic soil probably represents an area in which there were phreatophytes and hydrophytes. The water to sustain these plants would represent the overflow from a full pressure aquifer. The aquifer being full and having no additional capacity for the storing of water, any additional water would be rejected and would occur as effluent flow near the upper limit of the pressure area. Pumping by the various defendants in the lower portion of the pressure area would in effect create available storage and would decrease the amount of effluent flow, thus decreasing the amount of water that would be lost in evapotranspiration or consumptive waste. Another area of Chino clay loam is located on York Boulevard to the east of the area covered in this report. It is not considered to be related to the Eagle Rock Subarea as it is adjacent to the Avenue 50 drainage which is tributary to the Arroyo Seco. This feature is of interest in that its presence has been caused by a constriction in the Older alluvium which would exclude any appreciable amount of underflow from the east along York Boulevard. Any underflow entering the Eagle Rock Subarea would have to pass through a limited cross-sectional area that has a low average permeability and under a very low hydraulic gradient of 0.003 which may or may not exist between the Arroyo Seco and well 3987F.

The Eagle Rock artesian system is supplied from percolation of runoff and deep percolation of applied water into the forebay area. This area extends along Colorado Boulevard and easterly of Eagle Rock Boulevard along Yosemite Drive. These waters recharge the pressure aquifer which has lost about four feet of pressure head since 1941 (measured at well 3986B). This indicates that the draft on the system has not been excessive and that the subarea probably has not been pumped in excess of the safe yield within the base period.

Direction of Ground Water Movement. The ground waters in the Eagle Rock Subarea move southerly from the forebay areas into the pressure area. The direction of movement within the pressure aquifer is southerly to the vicinity of the pumping wells located along York Boulevard. There is no known subsurface escape of ground water from the pressure aquifer.

Water level fluctuations in the Eagle Rock area are represented by the hydrograph of well 3986B, which is the only well in the subarea with a long period of well measurements.

Geologic Defenses

In compliance with Item I, 2, of the Order of Reference, a detailed geologic study has been made in connection with those affirmative defenses, hereinafter referred to as geologic defenses, claimed by certain defendants. The defenses are listed as follows:

A - Defendant has independent water sources below bedrock.

B - Defendant has independent water sources in stratigraphic traps.

C - Defendant has independent water sources in fault block reservoirs.

D - Defendant takes water from source unrelated to the Los Angeles River.

For purposes of this investigation, the preceding geologic defenses have been analyzed and defined in accordance with accepted geologic definitions.

Bedrock has been defined in Appendix A as constituting the formations grouped within the nonwater-bearing series. The formations within the nonwater-bearing series do not absorb, transmit or yield water readily. These formations are:

Basement Complex rocks.
Cretaceous and Tertiary sediments of the Chico, Martinez, Domegine (Meganos), Topanga, Modelo (Puente), Repetto and Pico formations.

Stratigraphic trap is defined in the American Geological Institute Glossary of Geology and Related Sciences, 1957, as "A type of trap which results from variation in lithology of the reservoir rock, a termination of the reservoir (usually on the updip extension) or other interruption of continuity."

The American Geological Institute further defines trap as "A body of reservoir rock completely surrounded by impervious rock; a closed reservoir. Some traps are structural, having been formed by movements of the earth's crust; others are varying permeability ('stratigraphic') traps in which the change in permeability is due to original sedimentation, ground water activity, or by truncation and sealing. Many traps are created by a combination of varying permeability and structural agencies."

Fault block is defined in the American Geological Institute glossary as "A mass bounded on at least two opposite sides by faults; it may be elevated or depressed relatively to the adjoining region, or it may be elevated relatively to the region on one side and depressed relatively to that on the other." For purposes of this investigation fault block reservoir is defined in terms of a reservoir within a fault block.

It should be noted at this point that the terms "stratigraphic trap" and "fault block reservoir" are not generally accepted as terms applicable to ground water geology. These terms are widely used and accepted in petroleum geology and it must be appreciated that differences arising from the very distinct and different respective properties of oil and water can result in entirely different concepts and meanings in the interpretation of geologic features.

In the application of the terms "stratigraphic" and "fault block trap", as used in the affirmative defenses with respect to ground water geology, it is tacitly assumed that the traps are sealed above, below and laterally. It is then further assumed that waters within a trap are not replenished from any external source after entrapment.

In each of the geologic defenses, the defendants have claimed "independent water sources" deep in the earth, completely unrelated to water sources of meteoric origin originating within the Upper Los Angeles River Basin. This is interpreted to mean that the waters within the alleged "stratigraphic" and "fault block traps" claimed by the defendants, originated at sources topographically outside of the Upper Los Angeles River area or from deep-seated sources developing Juvenile or similar water (see Appendix H).

The tabulation and brief summary in Table A-2 include a list of defendants claiming geologic defenses, their well numbers including well numbers of test holes or other wells (active or inactive), the geologic defense claimed indicated by "X", and summary of the physical facts found in connection with the defendants' geologic defenses.

TABLE A-2

SUMMARY OF PHYSICAL FACTS FOUND IN
CONNECTION WITH GEOLOGIC DEFENSES

Defendant number	Defendant name	Affirmative defense claimed A	B	C	D	Well number and diversion	Date of field inspection	Total depth of well	Depth to nonwater-bearing material	Perforations	Summary remarks
7	La Canada Irrigation District	-	-	-	X	5069D	6-21-59	323	310		1. The defendant's wells are situated within the Verdugo Hydrologic Subarea, which is a part of the Upper Los Angeles River area. 2. The defendant's wells are located in the valley fill which, when saturated, would be in direct hydraulic connection with surface and/or subsurface flow which, under natural conditions, would flow toward the Los Angeles River Narrows. 3. The defendant derives water from tunnels that penetrate joints, fractures and other openings in the Basement Complex. 4. The total length of each of the defendant's tunnels is entirely within the topographic boundaries of the Upper Los Angeles River area. 5. Production from each of the defendant's tunnels appears to vary with precipitation. 6. To the extent that water is extracted from sources other than the valley fill, additional water is required to replenish the same. Such recharge occurs from precipitation on the area which might otherwise be available to provide surface runoff to the valley fill.
						5069G		221	208		
						5077A		401	401?		
						5078		116			
						5078A		264	139		
						5078C		124	97		
						Pickens Canyon					
						Snover Canyon					
						Hall Beckley Canyon					
8	Crescenta Valley County Water District	-	-	-	X	5036A	6-21-59				1. Same as those listed for Defendant No. 7.
						5036B					
						5047					
131	Aurora Carlson }	-	-	-	X	5047B					
171	Irena Minkler } Well No. 5069J	-	-	-	X	5047D		262	262?	100-123	
										127-164	
201	Steve Urquidez }	-	-	-	X	5058		124		227-254	
202	William Urquidez}	-	-	-	X	5058A					
						5058B		192			
						5058C					
						5058D		205		90-192	
						5058E		211		82-134	
										160-168	
						5058F					
						5058H		276	265	112-258	
						5058J		615	615?		
						5066A		205	140		
		-	-	-	X	5069F					
						5069H		285	295	195-275	
						5069J					
						5077					
						Pickens Canyon					
						Dunsmore Canyon					
12	American Security and Fidelity)	X	X	X	-	3947	6-20-60	173	167		1. The defendants' wells are extracting water from water-bearing sediments within the Upper Los Angeles River area. 2. The defendants' wells Nos. 3874G through 3884S are located at the defendants' Hollywood Hills Cemetery, where the water table has been lowered as a result of pumping in the Headworks area. 3. The defendants' wells are located in the valley fill which, when saturated, would be in direct hydraulic connection with surface and/or subsurface flow which, under natural conditions, would flow toward the Los Angeles River Narrows.
38	Forest Lawn Cemetery)	X	X	X	-	3947A		179.6	179		
39	Forest Lawn Company)	X	X	X	-	3947B		162	160		
40	Forest Lawn Memorial Park)	X	X	X	-	3947C		176	160		
						3947D		160	160?		
						3947E		150	134		
						3874G		195	195?	50-173	
						3874H		172	172?	67-94	
										100-147	
						3884I		193	192	60-170	
						3884Q		195	185	60-98	
						3884R					
						3884S		160		40-136	
						3884T		205	205?	50-167	

Table A-2

SUMMARY OF PHYSICAL FACTS FOUND IN CONNECTION WITH GEOLOGIC DEFENSES
(continued)

Defendant number	Defendant Name	Affirmative defense claimed A	B	C	D	Well number and diversion	Date of field inspection	Total depth of well	Depth to nonwater-bearing material	Perforations	Summary remarks
141 142	Maxine Duckworth John W. Duckworth, Jr.	- -	- -	- -	X X	5997A 5998 5998A Surface diversion	6-20-60	464 437.5		190-450 210-620	1. The defendants' wells are in the Pacoima Wash area, within the Sylmar Hydrologic Subarea, in the Upper Los Angeles River area. 2. The defendants' wells extract water from the water-bearing series. 3. The defendants' wells are located in the valley fill which, when saturated, would be in direct hydraulic connection with surface and/or subsurface flow which, under natural conditions, would flow toward the Los Angeles River Narrows.
164 165	E. E. Mahannah Hazel Mahannah	X X	X X	X X	- -	5076	2-10-60	445			1. Same as those listed for defendant No. 122.
168	Celest McCabe	-	-	-	X	3852 3852D	11-15-58	233		150-227	1. The defendant's wells are situated within the Upper Los Angeles River area. 2. The defendant's wells extract water from the water-bearing series. 3. The defendant's wells are located in the valley fill which, when saturated, would be in direct hydraulic connection with surface and/or subsurface flow which, under natural conditions, would flow toward the Los Angeles River Narrows.
37 64	Frank X. Enderle, Inc. Oakwood Cemetery	X X	X X	X X	- -	4674 4674A 4684B 4684C	5- 5-60	900 1,000 345	0 4 3	0-1,000	1. The defendants' wells are situated within the topographic boundaries of the Upper Los Angeles River area. 2. The defendants' wells penetrate and derive water from joints, fractures, cracks along bedding planes, and other openings in the nonwater-bearing Chico formation. 3. The recharge areas for these wells cannot be determined, however, every likelihood indicates that they are within the Upper Los Angeles River Basin. 4. To the extent that water is extracted from sources other than the valley fill, additional water is required to replenish the same. Such recharge occurs from precipitation on the area which might otherwise be available to provide surface runoff to the valley fill.
41 185 Doe 16 Doe 17	Fresh-Puro (Pur-O-Spring) Julia Nathan L. W. Block M. J. Block	X X X X	X X X X	X X X X	- - - -	3987E	2-10-60 5- 5-60				1. Same as those listed for Defendant No. 34.
43	Glen Haven Memorial Park	X	X	X	-	6028 6028A 6028C 6028D 6028E 6029 6029A	6-20-60	784 1,214 700 653 600 775 798		814-1,214 410-608 180-543 543- ? 30-350 350-720 720-750 750-790	1. The defendant's wells are situated within the Upper Los Angeles River area. 2. The defendant's wells derive water from the water-bearing Saugus formation. 3. The defendant's wells are very poor producers. 4. The lowering of the water levels in these wells by pumping, indicates that the ground waters in this area are being mined. 5. To the extent that water is extracted from sources other than the valley fill, additional water is required to replenish the same. Such recharge occurs from precipitation on the area which might otherwise be available to provide surface runoff to the valley fill.
49	Lakeside Golf Club	X	X	X	-	3845A 3845B 3845C 3855D	6-16-60	140 140 205			1. The defendant's wells are situated within the Upper Los Angeles River area. 2. The defendant's wells extract water from the water-bearing series. 3. The defendant's wells are located in the valley fill which, when saturated, would be in direct hydraulic connection with surface and/or subsurface flow which, under natural conditions, would flow toward the Los Angeles River Narrows.

Table A-2

SUMMARY OF PHYSICAL FACTS FOUND IN CONNECTION WITH GEOLOGIC DEFENSES (continued)

Defendant number	Defendant Name	Affirmative defense claimed A	B	C	D	Well number and diversion	Date of field inspection	Total depth of well	Depth to nonwater-bearing material	Perforations	Summary remarks
34 186 187	Deep Rock Artesian Water Company) Paul Pendelton) Evelyn Pendelton)	X X X	X X X	X X X	- - -	3987C 3987D	2-10-60 5- 5-60				1. The defendants' wells are situated in the Eagle Rock Hydrologic Subarea, the surface drainage of which is tributary to the San Fernando Hydrologic Subarea. 2. See Appendix A of the Report of Referee under Eagle Rock Hydrologic Subarea. 3. To the extent that water is extracted from sources other than the valley fill, additional water is required to replenish the same. Such recharge occurs from precipitation on the area which might otherwise be available to provide surface runoff to the Los Angeles Narrows.
82	Technicolor Corporation	X	X	X	-	3864C	12-18-59	315		114-129 133-144 202-219 242-272 277-303	1. The defendant's wells are situated within the Upper Los Angeles River area. 2. The defendant's wells extract water from the water-bearing series. 3. The defendant's wells are located in the valley fill which, when saturated, would be in direct hydraulic connection with surface and/or subsurface flow which, under natural conditions, would flow toward the Los Angeles River Narrows.
						3864D		351		134-163 205-224 241-264	
						3864G				278-335	
97	Toluca Lake Property Owners	X	X	X	-	3845P 3855A	6-16-60	200 -150	185	50- 55 68- 98 103-145	1. Same as those listed for Defendant No. 49
100 101 102	Valhalla Mausoleum Park) Valhalla Memorial Park) Valhalla Properties)	X X X	X X X	X X X	- - -	3830F 3830H	6-15-60	800		290-360 528-560 570-608 724-756	1. Same as those listed for Defendant No. 49.
						3830J		380		175-293 316-358	
						3830K 3830L 3830M					
104	Van de Kamps Holland Dutch Bakers	X	X	X	-	3958C	5- 6-60	202		172-196	1. Same as those listed for Defendant No. 49.
106	Warner Bros. Pictures, Inc.	X	X	X	-	3864A 3864B 3865	6-15-60	156	156?	44- 92 92-142	1. Same as those listed for Defendant No. 49.
117 140	William Bartholomaus) Ellen DuBois)	X X	X X	X X	- -	4921	6-27-60 7-28-60 8-23-60	296	286	200-213 221-286	1. Same as those listed for Defendant No. 49.
122 123	E. M. Bishop) W. E. Bishop)	X X	X X	X X	- -	5077B	2-10-60				1. The defendants' well is situated within the Verdugo Hydrologic Subarea, which is a part of the Upper Los Angeles River area. 2. The defendants' well extracts water from the underflow to the Monk Hill Basin (See Appendix P).

Table A-2

SUMMARY OF PHYSICAL FACTS FOUND IN CONNECTION WITH GEOLOGIC DEFENSES (continued)

Defendant number	Defendant Name	Affirmative defense claimed A	B	C	D	Well number and diversion	Date of field inspection	Total depth of well	Depth to nonwater-bearing material	Perforations	Summary remarks
54	Lockheed Aircraft Corporation	X	X	X	X	3840G 3850E	6-15-60	125 760		 215-308 546-568 589-603 623-638 654-689 719-724 729-736	1. Same as those listed for Defendant No. 49.
						3850F		302		180-250 270-288	
						3871E		235		68- 76 90-124 173-178 190-192 223-228	
						3871F		200		73-129 154-158 165-178	
78	Sparkletts Drinking Water Corporation	-	-	-	X	3987A 3987B 3987F	2-10-60 5- 5-60 6- 4-60 9-28-60	214 278		69-214 126-130 145-151 216-266	1. Same as those listed for Defendant No. 34. 2. Two wells in addition to those listed here, were drilled to the rear of the present day plant to a depth of approximately 600 feet and were completely dry (as per Mr. Max Alex of Sparkletts Corporation).
172 173	D. P. Moordigan) Kiang Moordigan)	X X	X X	X X	- -	5939	5- 5-60	184			1. The defendants' well is situated in the Sylmar Hydrologic Subarea, which is within the Upper Los Angeles River area. 2. The defendants' well extracts water from the water-bearing series. 3. See Appendix A of the Report of the Referee, under Sylmar Hydrologic Subarea. 4. The defendants' wells are located in the valley fill which, when saturated, would be in direct hydraulic connection with surface and/or subsurface flow which, under natural conditions, would flow toward the Los Angeles River Narrows.
198	Sidney Smith	-	-	-	X	Pickens Canyon	6-21-59				1. The defendant derives water from a tunnel that penetrates joints, fractures and other openings in the nonwater-bearing Basement Complex. 2. The total length of the defendant's tunnel is entirely within the Upper Los Angeles River area. 3. Production from the defendant's tunnel appears to vary with precipitation. 4. To the extent that water is extracted from sources other than the valley fill, additional water is required to replenish the same. Such recharge occurs from precipitation on the area which might otherwise be available to provide surface runoff to the valley fill.
204	Warner Ranch Company, Inc.	X	X	X	-	3590 3600 3601	6-15-60	216 264 300	74 119 165		1. Same as those listed for Defendant No. 49.

Note: Defense numbers A, B, C, and D listed on page A-59.

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APPENDIX B

SOILS

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SOILS

Soil surveys of the San Fernando Valley area have been made in considerable detail by the United States Department of Agriculture. The results of the surveys are contained in two reports, entitled "Soil Survey of the San Fernando Valley Area, California", 1917, and "Soil Survey of the Los Angeles Area, California", 1919. These reports have been reviewed and the maps and data contained therein used in a broad classification of the soils of the basin.

The soils which are described in the above noted publications were placed into three groups according to their relative infiltration capacities. The system used to group the soils is similar to that utilized by Musgrave (Water, The Yearbook of Agriculture, 1955, U.S.D.A., page 151) and takes into account the depth of soil, relative drainage, ability to retain moisture and degree of permeability based on grain size. The three groups and the soils included therein are as follows:

A = High Infiltration Group

- Riverwash
- Holland stony loam
- Holland coarse sandy loam
- Holland loam
- Ramona stony, sandy loam
- Hanford stony, sandy loam
- Hanford gravelly, sandy loam
- Hanford loamy, coarse sand
- Tujunga stony sand
- Tujunga gravelly sand
- Tujunga sand
- Tujunga sandy loam
- Tujunga fine, sandy loam

B = Medium Infiltration Group

- Ramona sandy loam
- Hanford sandy loam
- Hanford fine, sandy loam
- Hanford silty loam
- Yolo gravelly, sandy loam
- Yolo gravelly loam
- Yolo sandy loam
- Yolo fine, sandy loam

C = Low Infiltration Group

Altamont clay, loam	Yolo silty loam
Diablo clay, adobe	Yolo clay, loam.
Diablo clay, loam	Yolo silty clay, loam
Ramona fine, sandy loam	Dublin loam
Ramona loam	Dublin clay, loam
Sites sandy loam	Dublin clay, adobe
Yolo loam	Chino clay, loam

The areal distribution of the soils within the foregoing three groups, based on the aforementioned soil surveys of the United States Department of Agriculture, is delineated on Plate 3. The general extent of each group with respect to its source material is described below.

The coarse-grained soils of High Infiltration Group A are in general derived from source areas in the Basement Complex rocks. The principal streams depositing such material are Pacoima, Little Tujunga and Big Tujunga Creeks. These deposits cover much of the valley floor surface in the vicinity of North Hollywood and Burbank. The riverwash classification, found along the channels of these streams, has the highest relative infiltration capacity of soils within the group. Materials deposited by Verdugo Wash in the vicinity of Glendale are also derived from Basement Complex rocks but have been included in the Medium Infiltration Group B because they are older deposits and have been subject to a long period of weathering.

The soils of the Medium Infiltration Group B appear to be derived from the harder sedimentary rock units, and in part result from the reworking of the coarse-grained Pleistocene deposits such as Older alluvium and Saugus formation. Areas in this soil group are found in close proximity to the Cretaceous sandstones in the vicinity of Chatsworth and northerly of the Encino Reservoir where Topanga conglomerate is a source. A north-south band of soils in this group, located in the vicinity of Pacoima Wash, appears to result from an interfingering of the fine alluvial materials of the western portion of the valley with the coarser-grained deposits of the eastern portion of the area.

The fine-grained soils of Low Infiltration Group C occur in the western portion of the San Fernando Valley westerly of Pacoima Wash. Soils in the vicinity of Reseda are typical of this group. These materials are derived for the most part from sedimentary rocks which are relatively fine-grained.

The Eagle Rock area overlies alluvial materials derived from the coarse-grained sources. However, because of the higher degree of weathering of soils in this area there is a greater proportion of clay with a resultant lower infiltration rate. Soils in this area were placed in the medium infiltration group.

The finer soils of Group A predominate within Sylmar Subarea, whereas the coarser soils in Group A are found along the Tujunga and Pacoima Washes where they traverse the San Fernando Subarea.