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VENTURA COUNTY FLOOD CONTROL DISTRICT
REPORT
ON
VENTURA COUNTY WATER RESOURCES MANAGEMENT STUDY
GEOHYDROLOGY OF THE VENTURA RIVER SYSTEM: GROUND WATER HYDROLOGY

A. P. STOKES
DIRECTOR OF PUBLIC WORKS

J. B. QUINN
DEPUTY DIRECTOR
FLOOD CONTROL & DRAINAGE

PREPARED BY
JOHN M. TURNER
HYDROLOGIST

FOR
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VENTURA COUNTY DEPARTMENT OF PUBLIC WORKS

FLOOD CONTROL DISTRICT

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GEOHYDROLOGY OF THE VENTURA RIVER SYSTEM:

GROUND WATER HYDROLOGY

BY

JOHN M. TURNER - HYDROLOGIST

This Technical Information Record was prepared to document pertinent information as it was developed during the Ventura County Water Resources Management Investigation.

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Objectives of the Investigation

The objective of this investigation was to determine total groundwater storage capacity and actual groundwater storage for the most recent period of available data for major groundwater basins in the Ventura River System. To accurately determine storage capacity it was necessary to: 1) evaluate water quality; 2) delineate the areal extent of water-bearing materials; 3) construct a map depicting the effective base of the fresh water reservoir; 4) prepare numerous water level maps; 5) determine average specific yield and prepare a contour map to illustrate areal variation in specific yield; 6) prepare a nodal grid system (network) to enable accurate determination of the above parameters for computation of groundwater storage.

The purpose of this technical information record is to record and preserve information developed during the investigation so that these data may be utilized during preparation of the final bulletin.

Previous Investigations

The initial evaluation of groundwater resources of the Ventura River System was performed by the State Division of Water Resources and published in 1933 as Bulletin No. 46 - "Ventura County Investigation". In 1952 a more comprehensive evaluation of ground and surface water resources of this area was included in Bulletin No. 12 also entitled, "Ventura County Investigation" published by the State Water Resources Board. This publication contains much valuable general information concerning groundwater resources of the Ventura River System.

Numerous additional studies, generally of limited areal extent, have been conducted by other investigators (Appendix A).

Location

The Ventura River System is located generally North and East of the City of Ventura. Major groundwater basins within this system are the Ojai, Upper Ojai, Upper Ventura, and Lower Ventura River Basins. The general location and configuration of these basins is shown in aforementioned Bulletin 12, Appendix 2, Plate 11.

ithologic Units

During this investi on rock units were subdivided into two series; water-beari ınd nonwater-bearing. Water-bearing rocks constitute the grou apable of yielding greater than 50 gallons per minute (g.p.m.) for sustained periods to wells while non-water-bearing rocks comprise the group which yield less than 50 g.p.m. to wells or contain waters of inferior quality for most beneficial uses.

Water Bearing Rocks

Water-bearing rocks of the Ventura River System consist of unconsolidated to semi-consolidated alluvial materials of Pleistoce and Recent age. These interstratified deposits are largely compose of sand, gravel, boulders, sil and clay which when saturated yield appreciable volumes of sh water to wells. Water-bearing materials of the Ventura River System are primarily unconfined however confined conditions occur in small areas overlain by a relatively impermeable clay cap. One confined area is found south-east of the City of Ojai where well 4N/22W-7C5 became artesian following extensive recharge during the 1969 season.

Recent Alluvium and Fan Deposits - Alluvial materials of variable thickness are extensively exposed over all of the water-bearing areas in the Ventura River System. When saturated below the water table these deposits yield greater quantities of fresh water than underlying Pleistocene materials. Evidence of this is found by examination of electric logs of several wells in the Ojai Groundwater Basin. Spontaneous potential curves of these logs indicate that Recent deposits have a greater relative porosity than underlying Pleistocene water-bearing sediments. Although high porosity is not necessarily an indication of high permeability (e.g. clay), it is generally agreed that in similar water-bearing materials high porosity is related to high permeability.

The distinction between Recent alluvium and fan deposits in the Ventura River System is largely academic since subsurface information indicates that lithologically and hydraulically these two units are similar. The most extensive alluvial fan deposits occur in the eastern portion of the Ojai Groundwater Basin. Source materials for this fan were derived primarily from deposition of sediments from Horn and Senor Canyons. Another notable alluvial fan occurs adjacent to the Ventura River about 1.5 miles south of Matilija Dam where a decrease in slope of debris laden water derived from Cozy Dell Canyon has resulted in accumulation of coarse fan deposits. Since fan deposits normally occur above the water table, their primary importance is their high permeability which allows runoff and direct precipitation to readily infiltrate and recharge the groundwater basins. Recent alluvial materials reach a maximum thickness of greater than 300 feet in the central portion of the Ojai Basin (Plate 1, Section A-A' (in pocket).

Terrace Deposits - Well logs indicate that these deposits consist of coarse fractions such as gravel, or boulders in which the interstities have generally been filled with or altered to clay, resulting in deposits of lower groundwater storage and yield capability than that of other water-bearing sediments described. These non-marine terrace materials were deposited by streams during Pleistocene time when this area was at a higher base level. When they were deposited they were quite extensive, however, subsequent erosion has largely removed these deposits in the vicinity of the present day Ventura River. These deposits are extensively exposed above the east bank of the Ventura River from Oak View north and beyond McDonald Canyon. They also extend in an easterly direction from the Ventura River to the City of Ojai. Terrace deposits are also known to occur in the Upper Ojai Basin.

Pleistocene Alluvium - These deposits constitute the most reliable groundwater supply in the Ventura River System. During dry periods water levels decline and in many areas lower the water table to an extent that overlying Recent alluvial materials are nearly or completely dewatered.

Pleistocene terrestrial deposits (Saugus Formation or it's equivalen are composed of similar materials as those of previously mentioned deposits. This lithologic similarity makes them very difficult to distinguish from overlying terrace and alluvial deposits.

As would be expected these older alluvial deposits are more highly weathered, compacted, and cemented than Recent alluvial materials. Physical and chemical weathering has resulted in a higher percentage of clay than is present in Recent materials. These combined processes have resulted in a lower storage capacity and well yield per unit volume.

Nonwater-Bearing Rocks

This group consists primarily of marine-continental sedimentary rocks of Tertiary age which, in much of the Ventura River System, have undergone a complex history of structural evolution. Grouping of these rocks into a nonwater-bearing series was done by using water quantity and quality criteria. During this investigation materials incapable of yielding greater than 50 gallons per minute (g.p.m.) or containing water of inferior quality for most beneficial uses were considered nonwater-bearing. Locally, where these rocks are pervious or fractured, initial yields of fresh water may exceed 50 g.p.m.; however, the rate of production is usually only temporary because of limited recharge to the storage system. Highly permeable Recent sediments of the Lower Ventura River are considered nonwater-bearing because of consistently poor water quality.

Geologic Structures Affecting Groundwater Parameters

Water-bearing rocks in this system were deposited relatively late in geologic time and as a result have not undergone as complex a history of structural evolution as have older nonwater-bearing rocks. The nonwater-bearing sequence of rocks has been structurally delineated by numerous investigators because of intense interest in petroleum production within the Ventura River System. Unfortunately, accurate subsurface data for the more recent materials is not as abundant. The primary structural features affecting water-bearing rocks have been faulting and folding.

Faulting - The most important fault zones present in the Ventura River System are the Santa Ana and San Cayetano Fault Zones. Areal location of these zones are shown on Plates 2a and 2b.

The Santa Ana Fault is essentially an east-west trending structure which has probably been active until the Recent epoch of geologic time. The relative displacement along this zone has been such that the northerly fault block has been lowered relative to the southerl block allowing accumulation of relatively thick Pleistocene water-bearing sediments during and possibly after active movement. Maximum vertical displacement of water-bearing deposits occurs in the south central portion of the Ojai Ground Water Basin where displacement may approach 500 feet (Plate 2b). This fault extends westerly and has disrupted Pleistocene sediments of the Upper Ventura River Ground Water Basin. Well logs and historic accounts of abundant rising water in the river northwest of Mirror Lake constitute evidence for extension of the fault zone across the Ventura River. Well logs indicate that the downthrown northerly block contains Pleistocene and Recent sediments greater than 200 feet thick whereas the southerly side contains only Recent alluvial materials reaching a maximum thickness of 60 feet. The greater cross sectional water-bearing area of the northerly block causes rising water during wet periods.

The San Cayetano Fault Zone is a dominant structural feature traceable for a distance of some 30 miles beginning in the Ojai Valley and ending a few miles northeast of Piru. Lack of adequate subsurface data in the Ojai Valley precludes determining exact location or termination point of this zone. Stratigraphic throw along this fault is reported to reach 30,000 feet (Fine, 1954), although displacement of water-bearing sediments and effect upon ground water movement is believed to be minor. In the area of investigation, the San Cayetano Fault Zone is a steep north-dipping thrust zone (Bush, 1956 unpublished masters thesis). Recent movement of this zone is indicated by displacement of Recent river terraces north of the Upper Ojai Valley (Putnam, 1942).

Folding - The magnitude and attitude of folding is in a large degree responsible for the ground water storage capacity and direction of movement of ground water. All water-bearing materials in the Ventura River System except those recently deposited have been folded to some degree. As would be expected the older or

deeper deposits are more highly folded. The prominent trend of fold axes in the Ventura River System is believed to be east-west as evidenced by the trend of older nonwater-bearing rocks and contours on the base of fresh water (Plate 2b). Although the trend of previously deposited nonwater-bearing rocks is somewhat reliable, use of base of fresh water contour maps may be misleading as the present configuration of these contours may be due in part to topographic irregularities existing at the time of deposition of water-bearing materials.
The degree to which water-bearing materials have been folded is further complicated by the lenticular (discontinuous) nature of these deposits making lithologic correlation of key beds or horizons over even short distances impossible. The most prominent folding of water-bearing sediments occurs in the Ojai Valley. Here it consists of downwarping or synclinal structural deformation. Beginning at the Santa Ana Fault Zone in the southeast corner of Section 4, Township 4 North, Range 22 West, the fold axis extends in a northwesterly direction for about 0.7 miles where the axis divides into two axes; one trending east-west to the City of Ojai and one with a southwest trend. The east-west trending branch was previously identified and appropriately named the Ojai Syncline by Eckhart and Leach (Eckhart and Leach, 1954). Another notable synclinal feature also initiates on the North side of the Santa Ana Fault in the northwest corner of Section 14, Township 4 North, Range 23 West and extends westerly into the Ventura River.

GROUNDWATER QUALITY

The native quality of groundwater occurring in the Ventura River System is greatly influenced by the quality and quantity of runoff water which reaches the groundwater reservoir. Other factors which affect water quality include: 1. the age, rock type and geologic structures which affect groundwater movement and, 2. the quality and quantity of agricultural, sewage and other waste waters which percolate to the groundwater reservoir. Groundwater quality determinations used during this investigation consisted of samples largely collected and analyzed by the California Department of Water Resources as a portion of their water quality monitoring program. The field locations of sampled wells mentioned in the following discussion are shown on United States Geological Survey base maps available for inspection at the Ventura County Flood Control District.

The quality of groundwater in the Ventura River System is in most areas suitable for beneficial domestic, agricultural and industrial uses. Since much groundwater of the Ventura River System is classed "very hard" by the California State Board of Public Health, softening is required for many domestic and industrial uses.

A detailed discussion of water quality within each basin follows.

Ojai Basin

Mineral analyses reveal that ground water within the Ojai Basin is of acceptable quality for domestic,irrigation and industrial uses. Good water quality and relatively large storage capacity makes the Ojai Basin the most desirable area for the storage and extraction of groundwater within the Ventura River System:

The chemical character of ground water here is the sodium-bicarbonate type. The TDS (total dissolved solids) concentration ranges from about 400 to 800 ppm (parts per million) with an average at approximately 650 ppm. Nitrate concentration is in some areas quite high. An analysis of Well 04N/22W-06Q1,sampled in April of 1961,indicated a nitrate concentration of 51.0 ppm. Analysis of groundwater from well 04N/22W-5L8 samples in June of 1959 further indicated a nitrate concentration of 46.0 ppm, however analysis of a later sampling in October of 1965 indicated that this concentration had reduced to 30.0 ppm. The average concentration of nitrate at 10 to 15 ppm falls well within the upper recommended limit of 45 ppm prescribed by the United States Public Health Service. Nitrate in non-polluted groundwater is usually found only in concentrations up to several ppm. Higher concentrations present in the Ojai Groundwater Basin are attributed to leaching of fertilizers by downward percolating water and on site sewage disposal.

The allowable fluoride concentration in drinking water is variable depending upon the mean annual temperature. The mean annual temperature at Ojai for a 64 year period is 61.4°F. The upper limit of fluoride concentration recommended by the Californi Board of Public Health at 60°F. is 1.0 ppm. All ground water quality analyses fall below this upper limit of concentration, the average being about 0.3 ppm. The average TDS concentration at about 650 ppm combined with low fluoride and acceptable nitrate concentration places these waters in a "permissible" category for domestic use.

Unlike the Upper Ojai Basin, boron concentration in the Ojai Basin is quite low, averaging less than 0.5 ppm. This low boron concentration combined with a TDS concentration averaging only 650 ppm places these waters in Class 1 -"excellent to good," for irrigation use.

Upper Ojai Basin

The chemical character of ground water in the Upper Ojai Basin is the bicarbonate type, with cations of calcium or sodium predominating. The TDS concentration is lowest in the eastern portion of the basin and becomes higher in a westerly direction. Analyses of wells in the eastern half of the basin average about 650 ppm TDS, while limited data indicates that those in the western half average about 1200 ppm TDS.

Although nitrate concentrations are high, they are in most areas well below the upper limit of 45 ppm for drinking water as prescribed by the United States Public Health Service.

Well 4N/22W-09R4, sampled in July of 1954, temporarily exceeded these standards with a concentration of 49.7 ppm. The most recent analysis of this well in April of 1958 indicated that the nitrate concentration had been reduced to only 2.5 ppm.

The quality of groundwater in the Upper Ojai Basin is generally acceptable for most domestic and irrigation uses although high total dissolved solids concentrations in the western half of the valley place these waters into the State Board of Public Health's "temporary permit" category for drinking water. The suitability of water for irrigation in the Upper Ojai Basin is determined by the boron and total dissolved solids concentration. Groundwater in the western half of the basin is placed in Class 2 - "good to injurious", because of high TDS concentration. Although data is not abundant, high boron concentration appears to be related to well location with respect to the axis of the valley. Wells near the axis exhibit a greater boron concentration than those located higher on the flanks. Since boron concentration near the axis of the valley generally ranges from 0.5 to 2.0 ppm these waters are also placed in Class 2 - "good to injurious", in the eastern portion of the valley.

Upper Ventura River Basin

Groundwater of this basin is of similar quality as that of the Ojai Ground Water Basin, however concentation of boron and TDS are somewhat greater. As in the Ojai Basin the predominant chemical character of ground water is calcium bicarbonate. Total dissolved solids concentrations range from about 400 to 1000 ppm with higher concentrations occurring downstream from the confluence of San Antonio Creek and the Ventura River. With an average TDS concentration of about 700 ppm and low fluoride and nitrate content the upper Ventura River Basin constitutes a suitable domestic water supply.

Boron is the constituent which determines the degree of suitability of these waters for irrigation in the Upper Ventura River. Although boron concentration varies slightly the average concentration of 0.5 ppm. places these just within the low ranges of Class 2 - "good to injurious".

Lower Ventura River Basin

Sedimentary materials in this basin contain ground water which is considered unsuitable for most beneficial uses. The quality and occurrence of groundwater in this area was first studied by the California Division of Water Resources and reported in their Bulletin 46, "Ventura County Investigation" published in 1933. During this early investigation only two wells, located approximately 1 and 2 miles from the ocean, were analyzed. Analysis of a sample obtained from Well 3N/23W-33N1 penetrating only shallow alluvium in May of 1931 indicated a sodium chloride character with a conce ration of sodium at 467 ppm and chloride at 1260 ppm. Analysis of this well in August of 1964 indicated a sodium sulfate character with sodium at 780 ppm and sulfate at 1560 ppm. The TDS concentration of the most recent analysis was 2682 ppm. Other analyses of groundwater from alluvial wells indicate a sodium sulfate or chloride character with recent total dissolved solids concentrations ranging from 2000 to about 3500 ppm. Since oil field operations of the Ventura Avenue Oil Field were initiated long before the first water quality analysis it is difficult to determine whether the poor water quality of alluvial materials is due to oil field operations, such as brine disposal, or natural percolation of connate waters from adjacent and underlying marine formations. The poor water quality of alluvial materials cannot be attributed to sea water intrusion because of: 1) the chemical character of ground water and 2) the consistent elevation of the water table above sea level.

Groundwater of poor quality and limited areal extent also occurs beneath alluvial materials near the mouth of the Ventura River. Available geologic maps indicate that these deposits are within the San Pedro Formation and should technically be included with water-bearing deposits of the Mound Ground Water Basin. Electric log of Well 2N/23W-5L1 indicates a thick clay cap and resulting lack of hydraulic continuity between upper stream alluvium and lower water-bearing strata of the San Pedro Formation. Water quality analyses show a substantial increase in total dissolved solids concentration from a low in 1952 of 1261 ppm to a high in 1966 of 1840 ppm. The chemical character is sodium sulfate however chloride is also high at 415 ppm. The inferior quality of water and continued degradation is attributed to the percolation of connate or brackish water into the San Pedro Formation.

Water samples from Well 2N/23W-5P1 located about 0.2 mile nearer the ocean exhibit the same sodium sulfate character during 1952, however by 1956 the character had been altered to sodium chloride. The most recent sample of June 1966 contained 975 ppm chloride and TDS concentration of 2940 ppm. This change to chloride character may be attributed to sea water intrusion caused by extraction of water by the above mentioned wells.

San Antonio Creek - The ground water of San Antonio Creek is generally of marginal quality for domestic purposes but is of acceptable quality for most irrigation useage.
The TDS concentration ranges from about 1000 to 1500 ppm while sulfate and chloride concentrations generally fall between 250 and 500 ppm. Based upon the above dissolved solids concentrations this area is placed within the "temporary permit" category for domestic use.
Because these waters have a boron content which averages about 0.7 ppm and high TDS concentration they are placed in Class 2 "good to injurious", for irrigation use.

Groundwater Storage Capacity

The storage capacity of water-bearing materials is determined by their thickness, areal extent, and specific yield. These parameters are determined primarily by interpretation of electrical well logs and drillers' logs of an area. The initial phase of this type of determination is delineation of the effective base of the groundwater reservoir.

Effective Base of Fresh Water

As used in this study the effective base of fresh water is the elevation below which appreciable amounts of fresh water cannot be extracted. Tertiary sedimentary rocks of low permeability form the effective base of fresh water in the Ventura River System. These materials may be recognized at depth by the character of electrical well logs or the lithologic description found in drillers records. Electrical well logs provide the most reliable source of subsurface data for they accurately record the physical properties and water quality of formations penetrated. Since these records are largely lacking in the Ventura River System, drillers reports were heavily relied upon. The primary problem of interpreting drillers reports is the range of descriptive terms used by different drillers to describe the same lithologic material. However, descriptions such as "hard", "tight", or "tough", indicating material of reduced permeability, are useful guides in determining the base of fresh water. Additional useful information includes the perforated interval(s), zones sealed against contamination and the areal variation in total depth of wells.

The areal distribution of the effective base of fresh water is depicted by contours derived by interpolation between data points, both of which are shown on plates 2a and 2b . It should be emphasized that the elevation points are referenced to sea level requiring determination of surface elevation to obtain thickness. In areas where data points are dense the configuration is more detailed. The lack of sufficient data in the Upper Ojai and Lower Ventura River basins precludes developing base of fresh water contours. Fortunately these areas are of minor importance because of low storage capacity and poor water quality respectively

General Configuration - The configuration of the effective base of fresh water has been produced by erosion prior to deposition of water-bearing materials and folding and faulting prior to and during deposition of water-bearing materials. Generally those produced primarily by erosion may be recognized by elongation of contour patterns in a north-south direction such as those in the Ventura River and San Antonio Creek. Those features with a pronounced elongated trend in an east-west direction, such as the Ojai Basin, are produced primarily by folding and faulting prior to and during deposition of water bearing materials (Plate 2b).

Thickness of Water-Bearing Alluvium

The thickness of water-bearing materials may be determined at any point if the elevation of effective base of fresh water and ground surface elevation are known.

The greatest accumulation of water-bearing sediments is found within the south-central portion of the Ojai Basin where sediments approach a thickness of nearly 700 feet. The greater thickness of alluvial deposits in the Ojai Valley is attributed to synclinal folding and downfaulting prior to and during sedimentation. Another notable area of considerable thickness due to synclinal folding is at Mira Monte located east of the present course of the Ventura River where water yielding sediments may exceed 250 feet in thickness. Lack of abundant subsurface data from Mira Monte - Meiners Oaks to the east side of the City of Ojai precludes reliable determination of thickness of water-bearing units. Geologic maps of the area show more complex folding in Tertiary non water-bearing rocks, however these features may be largely lacking in overlying water-bearing deposits.

In the Upper Ventura River Basin alluvial materials reach a thickness of greater than 200 feet just North of the Santa Ana Fault. This greater thickness is attributed to preservation of Pleistocene alluvium caused by down faulting and folding in this area. Downstream of the Santa Ana Fault,channel filling alluvium is of Recent age and attains a maximum thickness of only about 65 feet.

The Upper Ojai Basin was not contoured because of insufficient data, however after inspection of available well logs the average thickness of Recent water bearing alluvium is estimated at 55 feet.

San Antonio Creek acts primarily as a conduit between rising water at Camp Comfort and its lower convergence with the Ventura River. Its limited areal extent and maximum alluvial thickness of about 35 feet make this area quantitatively unimportant.

Water Well Hydrographs

When numerous well hydrographs are available for the same time period, they are useful in evaluating and comparing hydraulic characteristics in different groundwater areas. During this portion of the investigation four well hydrographs were constructed for the period 1951 through 1970 (figures 1 through 4).

The most obvious feature of any hydrograph is the amount of water level fluctuation with time. The amount and character of water level fluctuation serves as a basis for comparing and classifying hydrographs. Generally, water level recoveries in the Upper Ventura River System are of greater magnitude and occur more rapidly than declines.

Ojai Basin Hydrograph - The hydrograph of well 4N/22W-5L8 was selected as being representative of hydraulic conditions in the Ojai Basin (figure 1). The outstanding characteristic of this hydrograph is the rapid and large recovery in water levels following periods of above average precipitation. Maximum recovery began late in 1951 and continued through 1952. During this period a rise in water level greater than 200 feet was recorded. Recovery of this magnitude is characteristic of unconfined groundwater basins with heavy pumpage and limited

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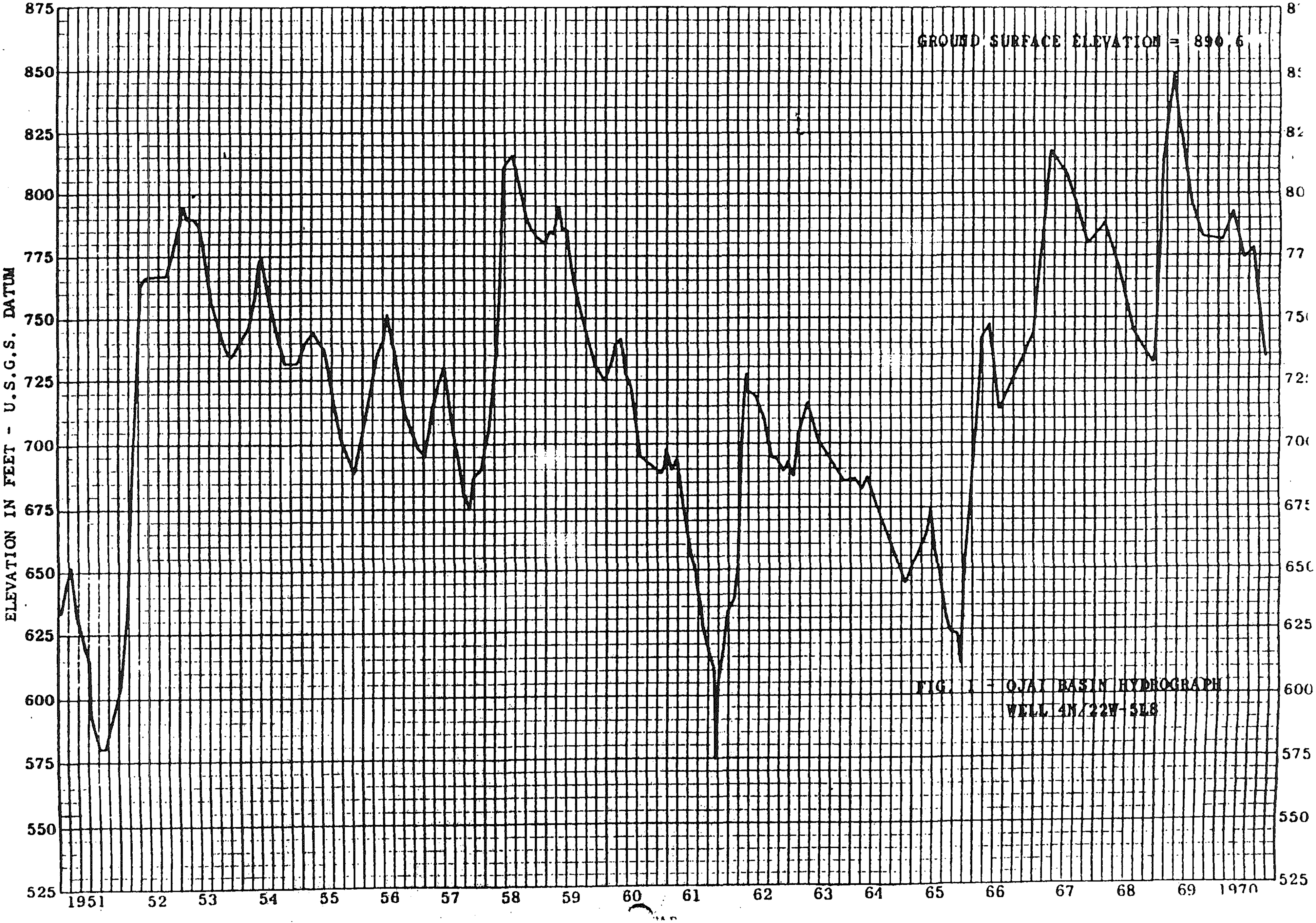

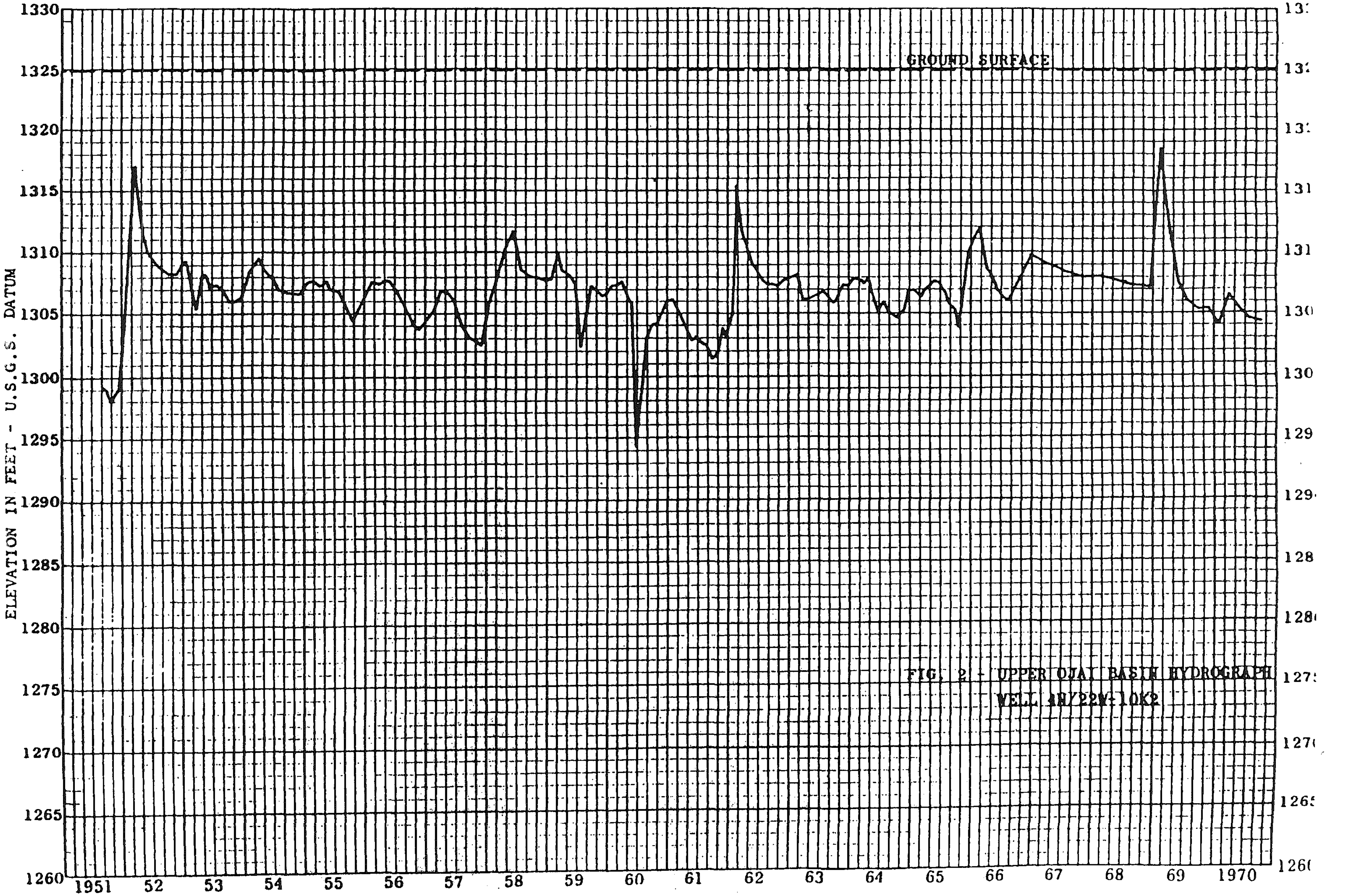

FIG. 2 - UPPER OJAI BASIN HYDROGRAPH
WELL 4N/22W-10K2

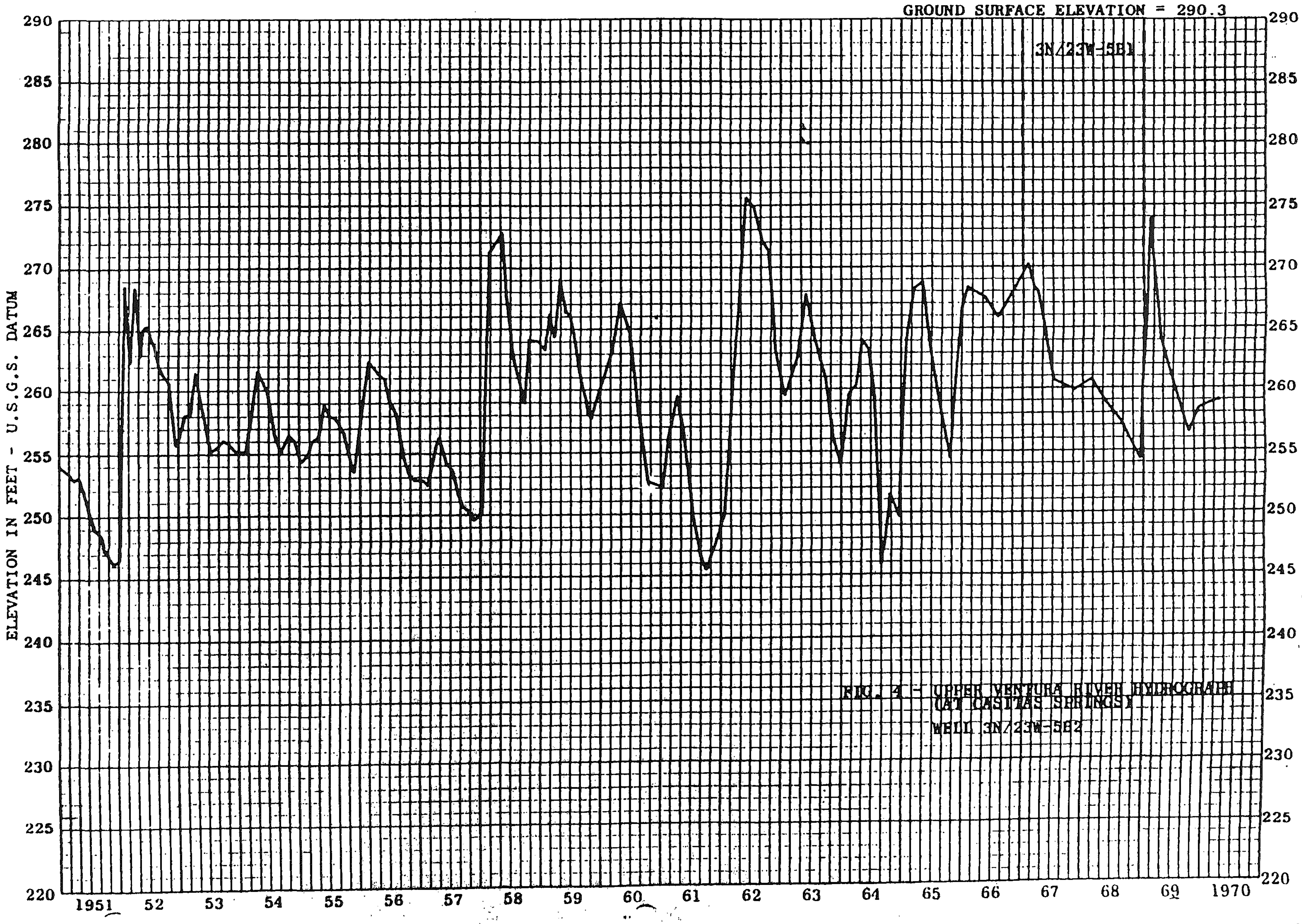

FIG. 4 - UPPER VENTURA RIVER HYDROGRAPH (AT CASITAS SPRINGS)
WELL 3N/23W-5B2

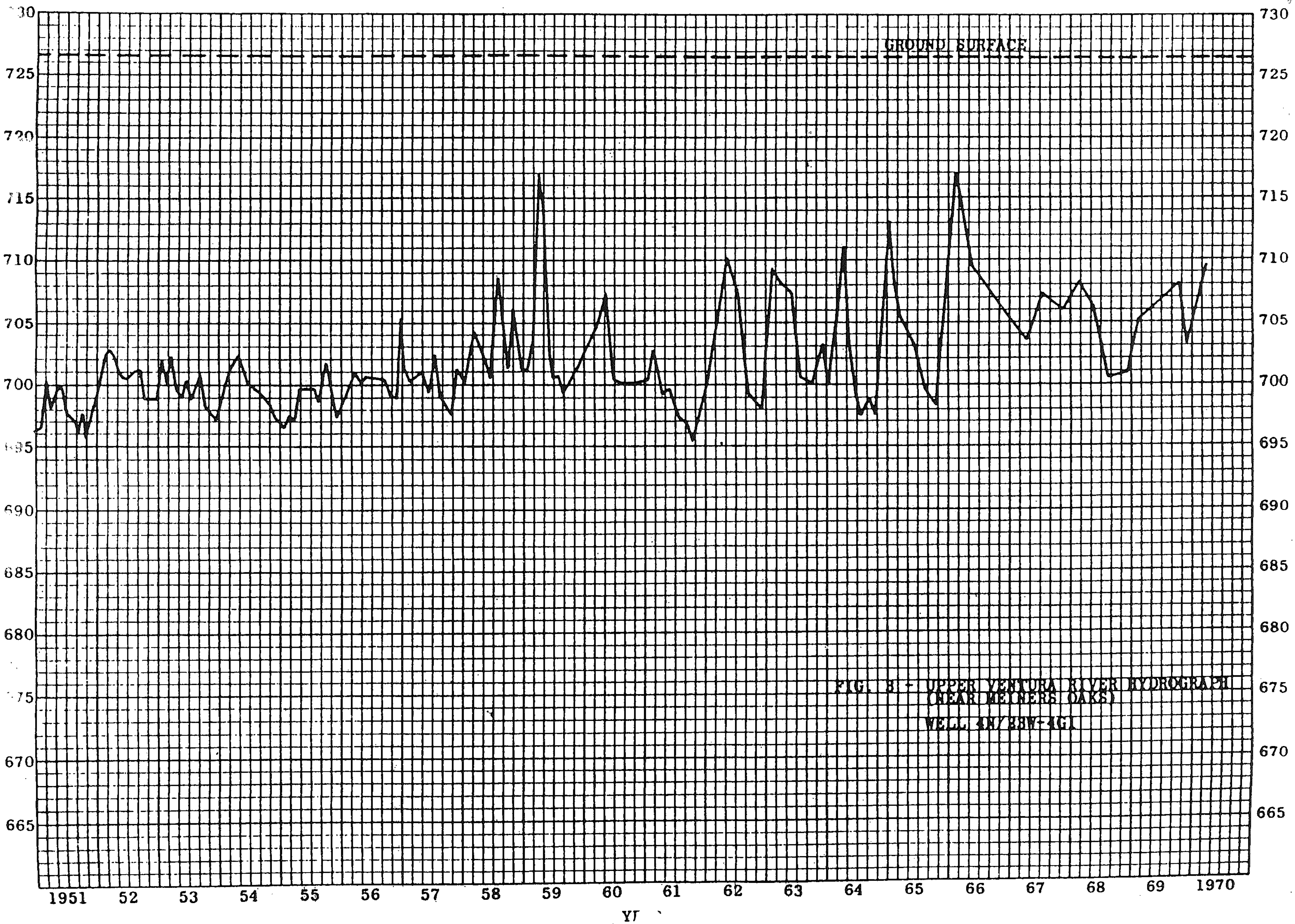

FIG. 8 - UPPER VENTURA RIVER HYDROGRAPH
(NEAR MEINERS OAKS)
WELL 4N/23W-4G1

storage capacity. During periods of substantial precipitation the basin is almost immediately recharged by percolation of direct precipitation and runoff through very permeable materials. Maximum lowering of water levels occurred during a 10 month period in 1960 when a decrease of almost 125 feet was recorded. Declines of this magnitude are indicative of heavy pumpage and limited storage capacity.

Upper Ojai Basin

Records of well 4N/22W-10K2 were selected to represent historic water levels of the Upper Ojai Basin (Figure 2). Maximum water level recovery for the period began late in 1951 and continued into March of 1952. During this period a rise in water level of almost 25 feet was observed. During most years water level fluctuates less than five feet, indicating a relatively static condition within the basin.

Upper Ventura River Basin - Two hydrographs were selected to represent this area because of the differing character of water level fluctuation between upper and lower portions of this basin. Well 4N/23W-4G1 (Figure 3) located near Meiners Oaks shows less water level fluctuation than that of well 3N/23W-5B2 (Figure 4) located at Casitas Springs. The greater annual water level fluctuation at Casitas Springs is caused by greater extraction of groundwater in this vicinity.

Water Level Contour Maps

A series of five water level contour maps were prepared by use of existing water level monitoring data. These maps representing the periods Fall 1957, Spring 1958, Fall 1968, Spring 1969 and Spring 1970 are included in chronological order as Plates 3a through 7b. The most interesting feature of these contour maps is the rapid change in contour configuration and direction of flow over much of the Ojai Basin following above average precipitation. Plates 3b and 4b illustrate the changes which occurred between the Fall of 1957 and the Spring of 1958. The map of the Fall of 1957 illustrates a period of relatively low water levels in the Ojai Basin. During this period two distinct water level troughs due to heavy pumpage appeared near the central portion of the basin, resulting in a partial reversal of subsurface flow. By the Spring of 1958, above average rainfall and resulting recharge to the groundwater reservoir had eradicated pumping troughs and returned the natural contour configuration resulting in groundwater movement in a southwesterly direction. During this six month period, water level recovery exceeded 150 feet in a part of the basin. This extremely rapid recovery rate is attributed to the high infiltration rate of surface materials and unconfined (free ground water) condition over most of the basin.

Water level maps are also a valuable aid in groundwater storage determinations. During this investigation the Spring 1970 map was utilized for determination of storage.

Nodal Network

During this investigation a network consisting of 31 nodal areas was constructed (Plate 8 in pocket). This network, consisting of Thiessen Polygons, conforms to the required configuration for any future studies involving construction and verification of a mathematical groundwater basin simulation tool. This network was used to determine average values of parameters to determine total groundwater storage capacity and groundwater storage in the Spring of 1970.

Storage Determinations

Total storage capacity and storage at any period of sufficient available water level data may be determined by the basic form:

$S = sy. \times t \times a$ where:

S = storage (acre-feet)

Sy = Average specific yield

t = Thickness of water bearing strata

a = Surface area (acres)

The difference between total storage capacity and storage at any given time is the difference in saturated thickness and extent of the groundwater reservoir. The total storage capacity is a theoretical maximum capacity since the groundwater reservoir is assumed to be completely filled. In steeply sloping unconfined reservoirs, such as portions of the Ojai Valley, this condition could not be reached because widespread rising water would occur prior to filling of the entire reservoir. Though the total storage capacity is in many cases only a theoretical upper limit it is useful when utilized as a comparative tool.

The actual storage capacity may be determined for any period in which sufficient water level data is available. During this investigation the most recent (Spring 1970) water level contour map was used.

Area - By inspection of the previously discussed groundwater storage equation it is evident that the area of water-bearing material is a necessary parameter. The area in acres was determined by the cut and weight method for each of the 31 polygonal areas. For the total storage capacity determination, the total alluvial potentially water-bearing area per node was determined. Most of the nodal areas had to be redetermined for Spring 1970 storage because the areal saturation limit within most areas was considerably less than under total storage capacity conditions. Analysis of results indicates that the cut and weight method resulted in an error of less than one percent.

Specific Yield - Is the percentage of water a saturated sediment will yield when drained under the force of gravity. In unconsolidated sedimentary rocks the specific yield is dependent upon grain size and uniformity (degree of sorting). Fine grained sediments, such as clay, have a low specific yield value. On the other hand uniform coarse sands generally have the highest values. Higher specific yield values result in higher yield per unit volume. The initial step in this type of study is determination of representative specific yield values for the various rock types present in the subsurface. The values of specific yield used in this area were taken and slightly modified from publications by Eckis (1934) and Johnson (1967), and represent laboratory analyses of numerous rock samples by many investigators. The resulting values used during this investigation are shown on Table 1 . These values were next applied to each lithologic horizon indicated on driller logs from ground surface to the effective base of fresh water.

TABLE I

VENTURA RIVER SYSTEM

SPECIFIC YIELD VALUES

SPECIFIC YIELD %	LITHOLOGIC DESCRIPTION
27	COARSE SAND
26	MEDIUM SAND
25	SAND (Undiff.), WATER SAND
23	FINE GRAVEL (Pea Gravel)
22	GRAVELLY SAND (Sand & Rocks; Sand & Gravel)
21	FINE SAND, QUICKSAND
15	MEDIUM GRAVEL
15	GRAVEL (Undiff.) (Sand, Gravel & Boulders)
13	COARSE GRAVEL (Pebbles)
12	BOULDERS (Cobbles)
7	CEMENTED SAND (Dead Sand)
7	CEMENTED GRAVEL (Tight, Set, Hard, or Packed Gravel or Rocks)
5	SILT (Silt and Sand, Soil, Loam) Clay streaks of sand or gravel
3	SANDY CLAY (Gravelly Clay; Boulders in Clay, Clay in Gravel)
2	CLAY (Adobe; Hardpan; Shale, etc.)

Mixtures of non-even volume - i.e. CLAY and BOULDERS 20%
(80% - 20%)
2% (.8) + 12% (.2) = 1.6 + 2.4 = 4.0%

This data was then processed by high speed electronic computers resulting in average specific yield value for each of approximately 120 deep well records in the Ventura River System. This data was then used to construct a contour map of average specific yield (Plates 9a & 9b).

Generally areas of higher average specific yield are found in or near present day stream channels while lower values are found in peripheral areas.

The highest specific yield values are found in the Upper Ventura River where average values reach 16%. The lowest values occur between the City of Ojai and Meiners Oaks - Mira Monte where areal specific yield averages less than 4%.

Reservoir Thickness - To establish this parameter it was necessary to determine average nodal elevations of the effective base of fresh water, average ground surface and average water level contour elevations. Average nodal ground surface elevation was used for determination of total storage capacity while average nodal water levels were used in Spring 1970 storage computations.

Total Storage Capacity - The Ojai Ground Water Basin has the greatest total storage capacity with a capacity of greater than 83,000 acre-feet. As would be expected alluvial storage capacity is the least in San Antonio Creek at only 1,441 acre-feet. The total capacity of Recent alluvial materials is estimated to be greater than 5600 acre-feet. Total storage capcity by node is tabulated on Table 2, Pages 23 thru 25. The combined total storage for the useable ground water reservoirs is greater than 125,000 acre-feet.

Groundwater Storage (Spring 1970) - The actual storage capacity may be computed for any desired time period if historic water level records and previously developed parameters are available. Table 3, pages 26 thru 28 shows results of groundwater storage computations for April (1970). Total storage in the Ventura River System for this period was almost 89,000 acre-feet or about 71% of the total storage capacity. As would be expected the Ojai Basin contained the largest amount of storage with nearly 64,000 acre-feet.

TABLE 2 - TOTAL GROU' JATER STORAGE CAPACITY

OJAI BASIN

NODE NUMBER	NODAL AREA (ACRES) X	AVERAGE SPECIFIC YIELD (%/100) X	(AVERAGE (GROUND SURFACE - (ELEVATION		AVERAGE) ELEVATION BASE) OF FRESH WATER) =	STORAGE CAPACIT (ACRE-FT./ NODE)
1	258	.027	800	(101)	699	704
2	275	.024	945	(87)	858	574
3	266	.028	830	(118)	712	879
4	395	.033	800	(200)	600	2,607
5	564	.067	1006	(228)	778	8,616
6	495	.065	910	(310)	600	9,974
7	579	.053	1117	(267)	850	8,193
8	264	.037	1362	(122)	1240	1,192
9	336	.041	1161	(221)	940	3,045
10	367	.061	995	(462)	533	10,343
11	409	.061	853	(439)	414	10,953
12	431	.066	793	(434)	359	12,346
13	414	.060	743	(361)	382	8,967
14	347	.041	738	(259)	479	3,685
15	220	.040	699	(126)	573	1,109
16	152	.031	680	(65)	615	306
					Total Storage Capacity =	83,493 Acre/Feet

TOTAL GROUNDWATER STORAGE CAPACITY (Cont'd)

UPPER OJAI BASIN

NODE NUMBER	NODAL AREA (ACRES) X	AVERAGE SPECIFIC YIELD (%/100) X	(AVERAGE (GROUND SURFACE - (ELEVATION		AVERAGE) ELEVATION BASE) OF FRESH WATER) =	STORAGE CAPACITY (ACRE-FT./ NODE)
	1878	.055		(55)		
				Total Storage Capacity =		5,681 Acre-Feet

UPPER VENTURA RIVER

NODE NUMBER	NODAL AREA (ACRES)	AVERAGE SPECIFIC YIELD (%/100)	GROUND SURFACE ELEVATION		BASE OF FRESH WATER	STORAGE CAPACITY (ACRE-FT./NODE)
17	127	.107	866	(26)	840	353
18	539	.094	807	(25)	782	1,267
19	421	.092	673	(77)	596	2,982
20	632	.050	768	(143)	625	4,519
21	402	.032	770	(100)	670	1,286
22	314	.047	706	(202)	504	2,981
23	613	.066	635	(190)	445	7,687
24	402	.082	588	(119)	469	3,923
25	348	.104	479	(49)	430	1,773
26	249	.060	597	(117)	480	1,748
27	510	.111	405	(59)	346	3,340
28	348	.121	311	(48)	263	2,021
29	249	.113	245	(44)	201	1,238
				Total Storage Capacity =		35,118 Acre-Feet.

TOTAL GROUNDWATER STORAGE CAPACITY (Cont'd)

NODE NUMBER	NODAL AREA (ACRES)	X	AVERAGE SPECIFIC YIELD (%/100)	X	(AVERAGE (GROUND SURFACE (ELEVATION	-		AVERAGE) ELEVATION BASE) OF FRESH WATER)	=	STORAGE CAPACITY (ACRE-FT./ NODE)
SAN ANTONIO CREEK										
30	437		.109		498		(14)	484		667
31	273		.109		391		(26)	365		774

Total Storage Capacity = 1,441 Acre-Feet

Combined Total Storage Capacity = 125,733 Acre-Feet

TABLE 3 - GROUNDWATER STORAGE (SPRING 1970)

OJAI BASIN

NODE NUMBER	NODAL AREA (ACRES)	X	AVERAGE SPECIFIC YIELD (%/100)	X	(AVERAGE (GROUNDWATER (ELEVATION	-		AVERAGE ELEVATION BASE OF FRESH WATER)	=	STORAGE CAPAC (ACRE-FT./ NODE)
1	215		.029		707		(46)	661		287
2	84		.027		790		(30)	760		68
3	210		.031		754		(77)	677		501
4	323		.037		746		(194)	552		2,318
5	338		.073		780		(283)	497		6,983
6	271		.070		795		(245)	550		4,648
7	305		.059		899		(195)	704		3,509
8	79		.037		1032		(68)	964		199
9	322		.049		1023		(205)	818		3,234
10	319		.064		859		(372)	487		7,595
11	333		.068		790		(470)	320		10,643
12	391		.069		766		(446)	320		12,033
13	397		.061		708		(341)	367		8,258
14	343		.041		682		(203)	479		2,855
15	196		.044		637		(75)	562		647
16	157		.031		610		(12)	598		58

Total Storage (April 1970) = 63,836 Acre-Feet

UPPER OJAI BASIN

	NODAL AREA (ACRES)	AVERAGE SPECIFIC YIELD (%/100)	
	1878	.055	(40)

Total Storage (April 1970) = 4,111 Acre-Feet

GROUND WATER S' AGE (SPRING 1970)

UPPER VENTURA RIVER

NODE NUMBER	NODAL AREA (ACRES) X	AVERAGE SPECIFIC YIELD (%/100) X	(AVERAGE (GROUNDWATER (ELEVATION		- AVERAGE ELEVATION BASE OF FRESH WATER) =	STORAGE CAPACITY (ACRE-FT./ NODE)
17	68	.141	833	(18)	815	173
18	246	.126	735	(15)	720	465
19	316	.095	652	(104)	548	3,122
20	589	.053	670	(47)	623	1,467
21	304	.034	671	(20)	651	207
22	309	.047	582	(78)	504	1,133
23	615	.066	547	(102)	445	4,140
24	396	.082	550	(81)	469	2,630
25	357	.104	472	(42)	430	1,559
26	229	.062	538	(60)	478	852
27	489	.115	384	(44)	340	2,474
28	367	.121	288	(27)	261	1,199
29	250	.113	236	(35)	201	989
			Total Storage (April 1970)		=	20,410 Acre-Feet

GROUND WATER STORAGE (SPRING 1970)

UPPER VENTURA RIVER

NODE NUMBER	NODAL AREA (ACRES)	X	AVERAGE SPECIFIC YIELD (%/100)	X	(AVERAGE (GROUNDWATER (ELEVATION	-	AVERAGE) ELEVATION BASE) OF FRESH WATER)	=	STORAGE CAPACIT (ACRE-FT./ NODE)
					SAN ANTONIO CREEK				
30	132		.115		500	(21)	479		319
31	199		.115		370	(11)	359		252

Total Storage (April 1970) = 571 Acre-Feet

Combined Storage (April 1970) = 88,948 Acre-Feet

FINDINGS

Most basins within the Ventura River System contain appreciable amounts of groundwater of acceptable quality for beneficial domestic, irrigation and industrial uses.

Water-bearing rocks consist of non-marine Recent and Pleistocene sand, gravel and clay which since deposition have been structurally affected by the processes of folding and faulting. These processes have greatly influenced the occurrence and movement of groundwater.

The best quality groundwater is found in the Ojai groundwater basin while the poorest quality groundwater occurs in the Lower Ventura River Basin.

The specific yield, which determines the recoverable water per unit volume, is generally higher in and near present day stream channels. The highest specific yield values occur in the Upper Ventura River.

The total groundwater storage capacity of the Ventura River System (excluding the Lower Ventura River Basin) exceeds 125,000 acre-feet. Groundwater storage within this system during April of 1970 was greater than 88,000 acre-feet.

APPENDIX A

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