DIGITAL-MODEL EVALUATION OF THE GROUND-WATER RESOURCES IN THE OCOTILLO-COYOTE WELLS BASIN IMPERIAL COUNTY, CALIFORNIA

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WATER-RESOURCES INVESTIGATIONS 77-30

Prepared in cooperation with the

Imperial County Department of Public Works

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A flow model using finite-element techniques has been constructed for an alluvial aquifer in the Ocotillo-Coyote Wells basin. Natural recharge is about 2,600 acre-feet per year, and estimated ground water in storage is 640,000 acre-feet. Pumpage totaled 880 acre-feet in 1975. The computed decline from steady-state conditions in 1925 to December 1975 was 15 feet in Ocotillo. The projected decline from 1976 to 1995 with annual pumpage of 1,000 acre-feet is 6 feet and with annual pumpage of 2,000 acre-feet is 17 feet in Ocotillo. In the latter projection, continued pumping after 1995 may cause saline water to flow toward the potable ground water in and around Ocotillo.

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CONVERSION FACTORS

For those readers who prefer metric units rather than English units, the conversion factors for the terms used in this report are listed below:

Multiply English unit	*By*	*To obtain metric unit*
acres	4.047×10^{-1}	hectares
acre-ft (acre-feet)	1.233×10^{-3}	cubic hectometers
acre-ft/yr (acre-feet per year)	1.233×10^{-3}	cubic hectometers per year
ft (feet)	3.048×10^{-1}	meters
ft^2 (square feet)	9.290×10^{-2}	square meters
ft^2/d (feet squared per day)	9.290×10^{-2}	meters squared per day
ft^3/s (cubic feet per second)	2.832×10^{-2}	cubic meters per second
in (inches)	2.540×10	millimeters
in/yr (inches per year)	2.540×10	millimeters per year
mi (miles)	1.609	kilometers
mi^2 (square miles)	2.590	square kilometers

Degrees Fahrenheit are converted to degrees Celsius by using the formula: $°C = 5/9\ (°F-32)$.

DIGITAL-MODEL EVALUATION OF THE GROUND-WATER RESOURCES IN THE OCOTILLO-COYOTE WELLS BASIN, IMPERIAL COUNTY, CALIFORNIA

By James A. Skrivan

ABSTRACT

A digital model using finite-element techniques simulates ground-water flow in an alluvial aquifer in the Ocotillo-Coyote Wells basin. Calibrated transmissivities range from less than 20 feet squared per day to more than 10,000 feet squared per day. The calibrated storage coefficients range from 0.04 to 0.08.

Natural recharge through infiltration of precipitation is estimated to be 2,600 acre-feet per year, and estimated ground water in storage is 640,000 acre-feet. Pumpage totaled 880 acre-feet in 1975 and was predominantly for industrial use, with lesser amounts for water exported to Mexicali, Baja California, and domestic supply. About 90 percent of the annual pumpage is centered in Ocotillo.

The computed water-level decline from steady-state conditions in January 1925 to December 1975 was 15 feet in Ocotillo. Decline has accelerated in the last 10-12 years because of increased pumpage.

The projected water-level decline from 1976 to 1995 with annual pumpage of 1,000 acre-feet is 6 feet in Ocotillo. In this projection, flow is still eastward across the Elsinore fault which separates potable ground water in and around Ocotillo from saline water several miles east. When a maximum of 2,000 acre-feet of pumpage is used for the projection, the 20-year decline is 17 feet in Ocotillo, and water levels on either side of the fault are about the same. Continued pumping of this magnitude after 1995 may cause saline water to flow toward the potable ground water in Ocotillo.

Dissolved solids in ground-water samples from Ocotillo wells averaged less than 500 milligrams per liter. Dissolved fluoride in ground water in many places throughout the basin is more than 2 milligrams per liter.

The digital model may be used to evaluate water-management plans that could maximize ground-water withdrawal. For example, redistribution of pumping might minimize the threat of saline water degrading ground water in Ocotillo or reduce evapotranspiration or underflow from the basin. Also the model could be used to evaluate the effect of artificial recharge in various areas.

INTRODUCTION

The Ocotillo-Coyote Wells basin, or project area, includes about 300 mi^2 in western Imperial County, approximately 25 mi west of El Centro (fig. 1). The arid climate and desert scenery attract visitors from more urbanized areas.

The western boundary of the project area (fig. 2) is a surface-water drainage divide in the Jacumba Mountains. The drainage divide in the Coyote Mountains forms about half of the northern boundary, with the rest being the line between T. 15 S. and T. 16 S. The eastern boundary is the Westside Main Canal of the Imperial Irrigation District, and the southern boundary is the United States-Mexico border.

Total population of less than 1,000 is centered in Ocotillo and in several subdivisions east and southeast of Ocotillo. Coyote Wells, 1.5 mi east of Ocotillo, consists solely of a service station-grocery store. South of Coyote Wells 1 mi is the Nomirage subdivision of about 100 people. Southeast of Nomirage 3.5 mi is the Yuha Estates subdivision of about eight residences. A slightly larger area, the Painted Gorge subdivision, is northeast of Coyote Wells about 3 mi. Plaster City, 7 mi northeast of Coyote Wells, consists of a gypsum processing plant owned by U.S. Gypsum Co.

Ground water is the only source of industrial and domestic supply in the project area. Water levels have been dropping since significant pumping began in the 1920's. Ground water is potable in the Ocotillo area, but it is highly saline about 3 mi east of Coyote Wells. In addition, ground-water samples in and around Ocotillo have often had higher concentrations of dissolved fluoride than those recommended by the U.S. Environmental Protection Agency (1972).

The U.S. Geological Survey, in cooperation with the Imperial County Department of Public Works, made an appraisal of the ground-water resources in the project area to determine the effects of present and proposed pumping on the quantity and quality of the ground water. This report is the result of that study.

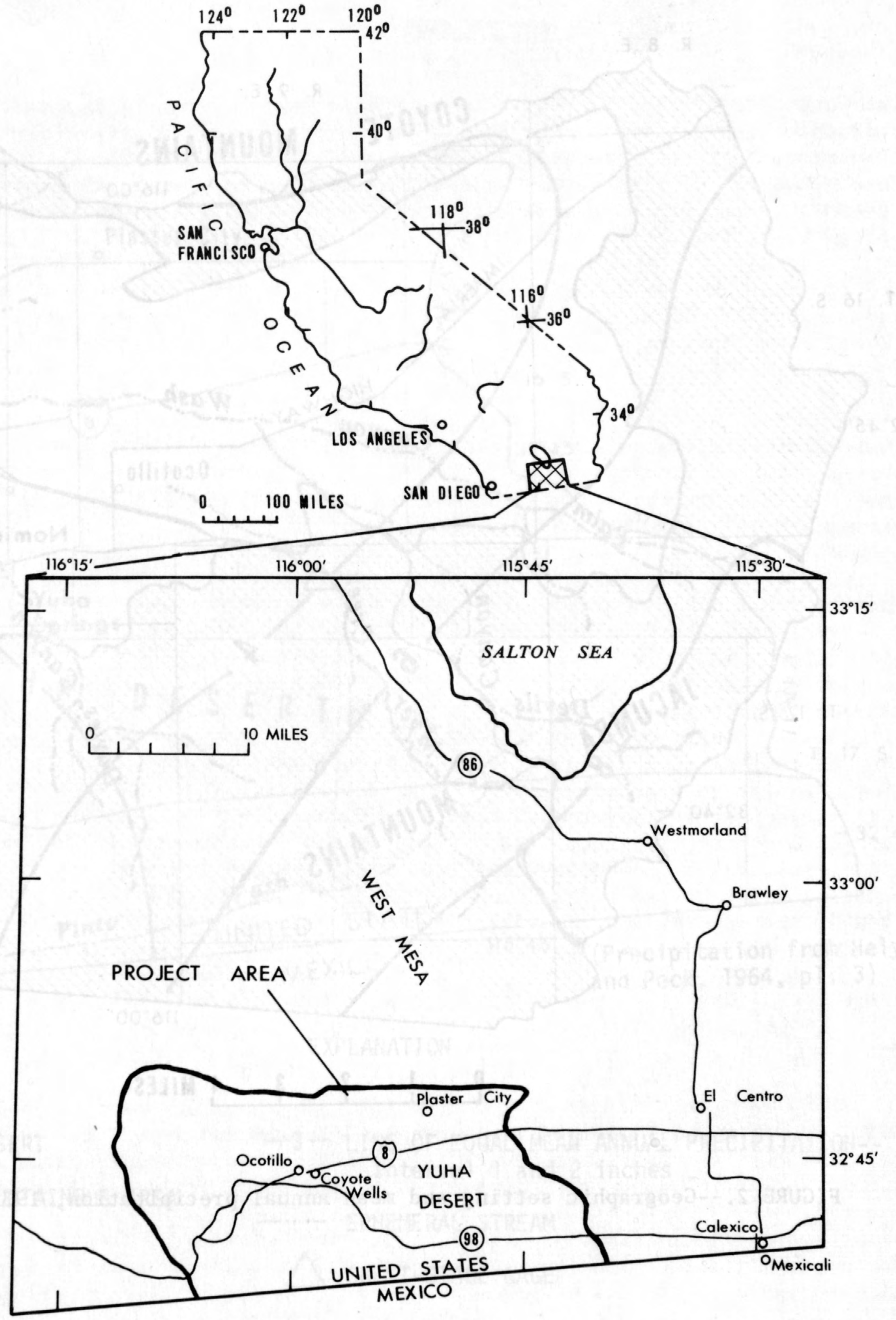


FIGURE 1.--Index map.

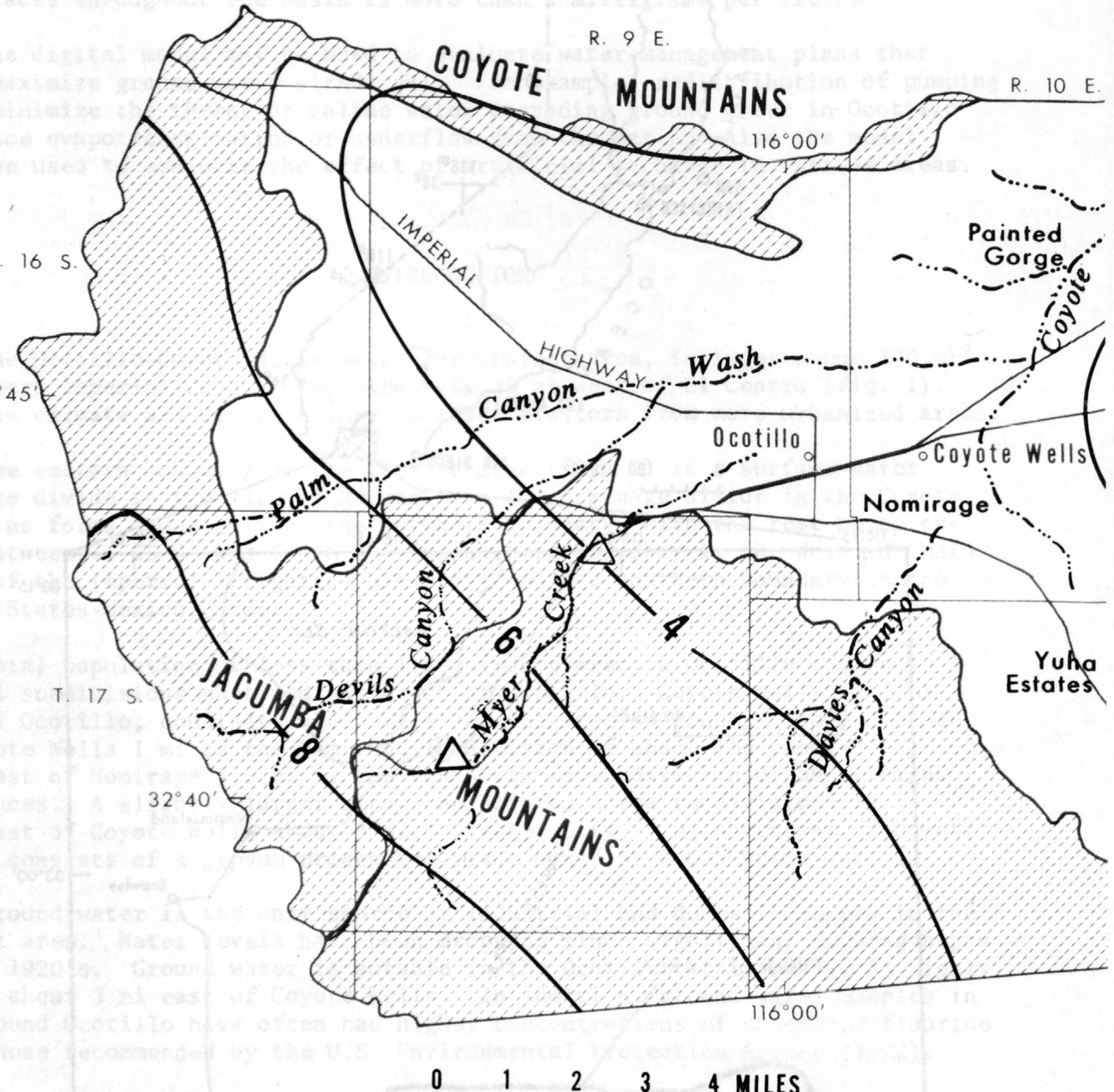
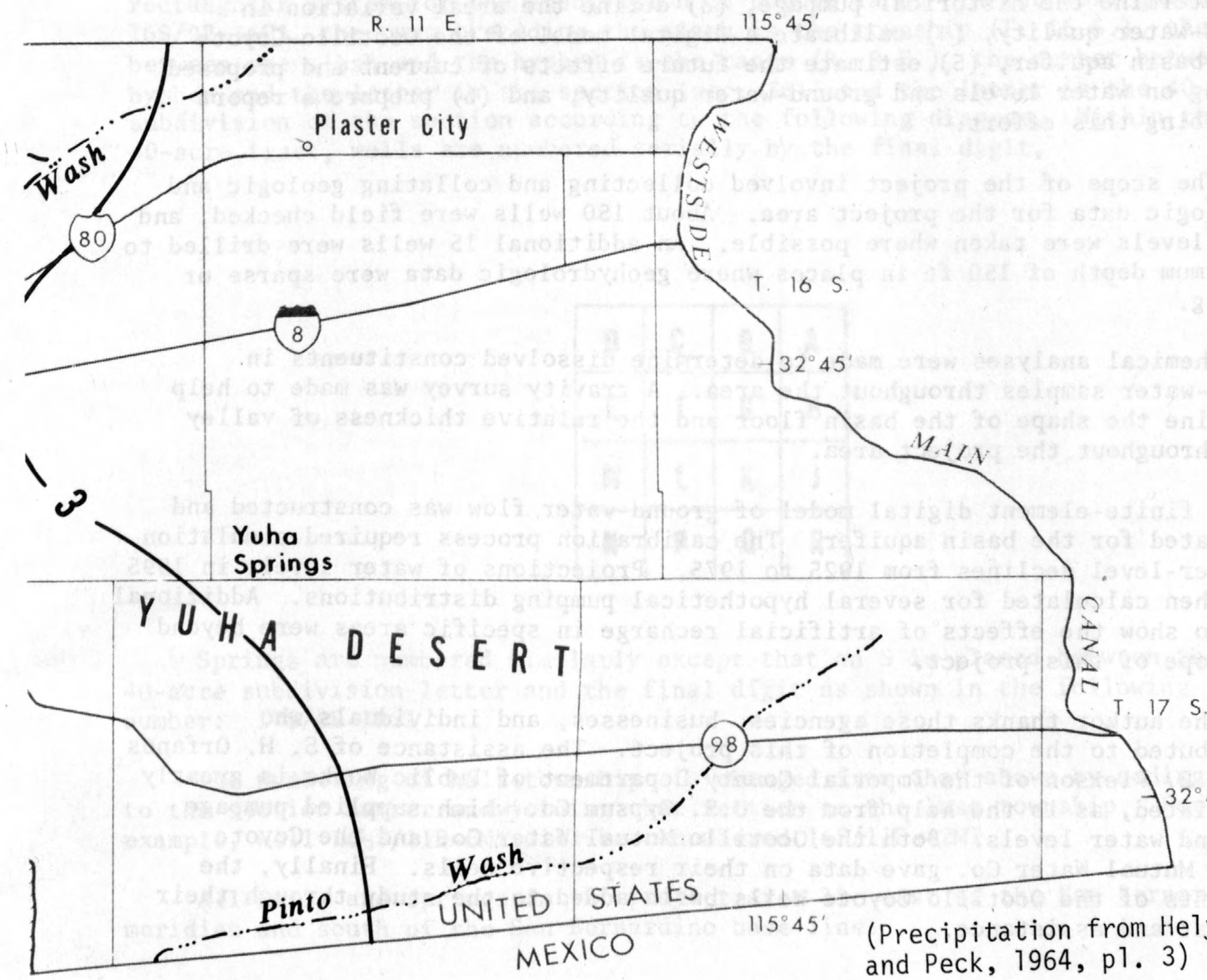


FIGURE 2.--Geographic setting and mean annual precipitation, 1931-60.



(Precipitation from Hely and Peck, 1964, pl. 3)

EXPLANATION

- DESERT
- MOUNTAINOUS AREA
- 3 — LINE OF EQUAL MEAN ANNUAL PRECIPITATION--Interval and 2 inches
- EPHEMERAL STREAM
- CREST-STAGE GAGE

FIGURE 2.--Continued.

Purpose and Scope

The purposes of this study were to (1) define the hydrology of the area, (2) determine the historical pumpage, (3) define the areal variation in ground-water quality, (4) calibrate a digital model of the Ocotillo-Coyote Wells basin aquifer, (5) estimate the future effects of current and proposed pumping on water levels and ground-water quality, and (6) prepare a report describing this effort.

The scope of the project involved collecting and collating geologic and hydrologic data for the project area. About 150 wells were field checked, and water levels were taken where possible. An additional 15 wells were drilled to a maximum depth of 150 ft in places where geohydrologic data were sparse or lacking.

Chemical analyses were made to determine dissolved constituents in ground-water samples throughout the area. A gravity survey was made to help determine the shape of the basin floor and the relative thickness of valley fill throughout the project area.

A finite-element digital model of ground-water flow was constructed and calibrated for the basin aquifer. The calibration process required simulation of water-level declines from 1925 to 1975. Projections of water levels in 1995 were then calculated for several hypothetical pumping distributions. Additional runs to show the effects of artificial recharge in specific areas were beyond the scope of this project.

The author thanks those agencies, businesses, and individuals who contributed to the completion of this project. The assistance of S. H. Orfanos and D. E. Pierson of the Imperial County Department of Public Works is greatly appreciated, as is the help from the U.S. Gypsum Co. which supplied pumpage data and water levels. Both the Ocotillo Mutual Water Co. and the Coyote Valley Mutual Water Co. gave data on their respective wells. Finally, the residents of the Ocotillo-Coyote Wells basin added to the study through their interest and assistance.

Well-Numbering System

Wells in the project area are numbered according to their location in the rectangular system for the subdivision of public land. In the well number 16S/9E-36G3, the part preceding the slash is the township (T. 16 S.), the part between the slash and the hyphen is the range (R. 9 E.), the number between the hyphen and the letter is the section (sec. 36), and the letter is the 40-acre subdivision of the section according to the following diagram. Within the 40-acre tract, wells are numbered serially by the final digit.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Springs are numbered similarly except that an S is placed between the 40-acre subdivision letter and the final digit as shown in the following spring number: 17S/8E-3RS1.

The numbering of half-townships is changed from that above by adding 36 to the section number and joining that section to the last township. For example, well 16½S/11E-6M1 will be renumbered 16S/11E-42M1.

All wells and springs in the project area lie east of the San Bernardino meridian and south of the San Bernardino base line.

GROUND WATER

The geology of the Ocotillo-Coyote Wells basin was discussed by Dibblee (1954), Brooks and Roberts (1954), and Loeltz and others (1975). The reader is referred to those publications for more detailed description.

Ground water in the project area is found principally in the saturated alluvial valley-fill deposits of Quaternary age. Such a saturated geologic formation, capable of yielding significant quantities of water to wells or springs, is termed an aquifer. The consolidated rock that forms the surrounding mountains (fig. 3) and underlies this alluvium contains no appreciable quantities of ground water.

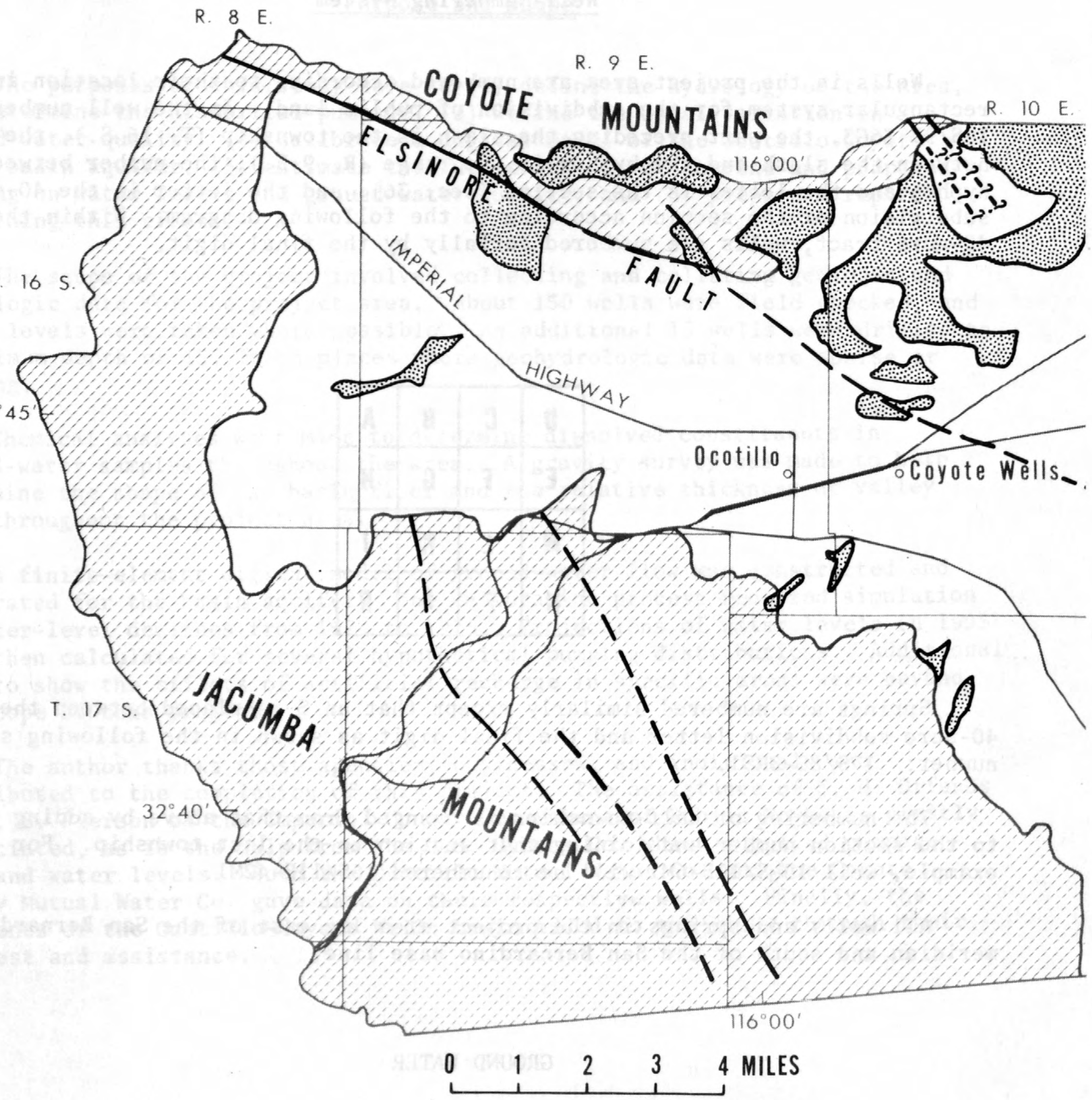
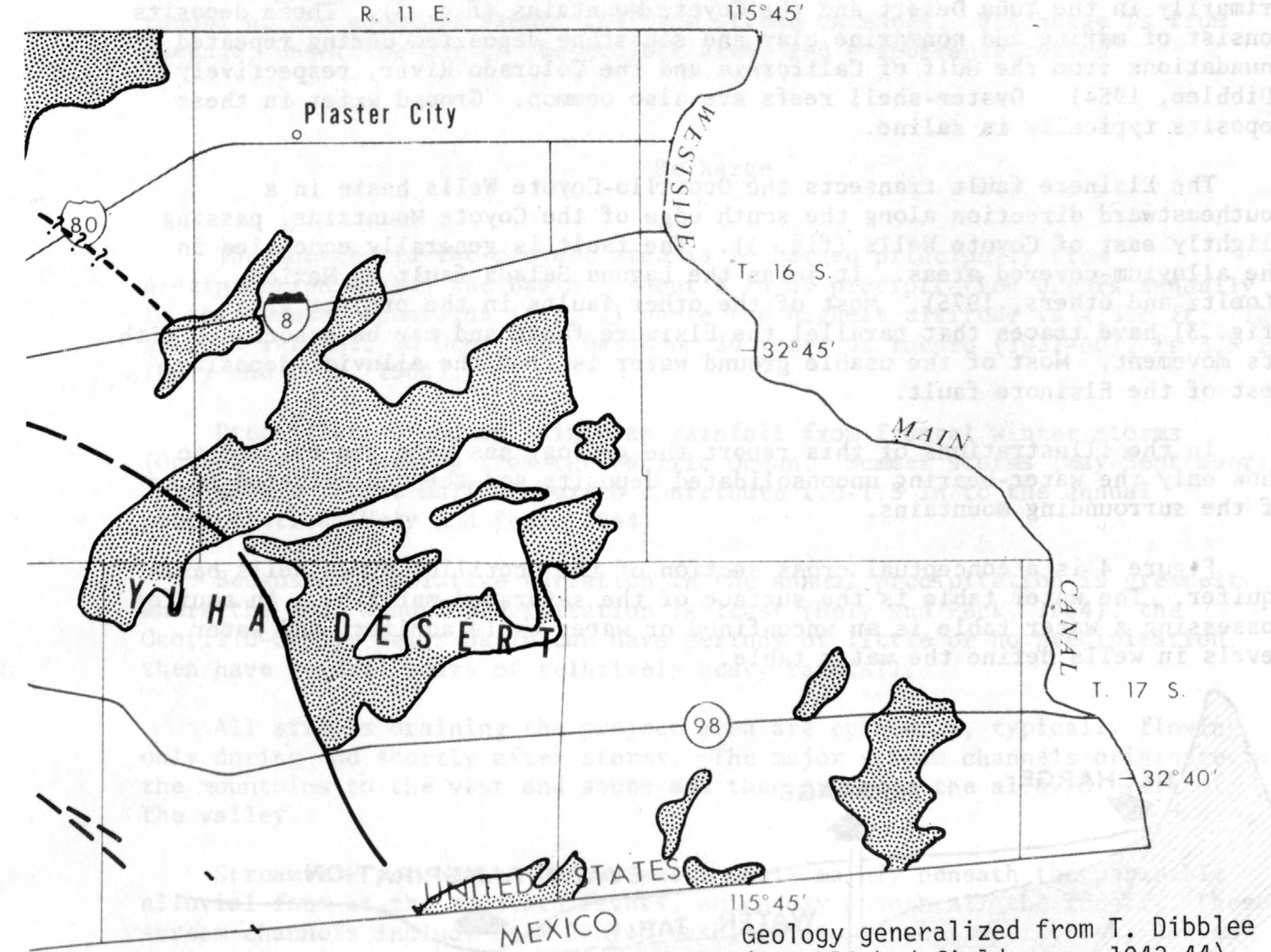


FIGURE 3.--Generalized areal geology.



Geology generalized from T. Dibblee (unpublished field maps, 1943-44) and Brooks and Roberts (1954)

EXPLANATION

ALLUVIUM OF QUATERNARY AGE

SEDIMENTARY DEPOSITS OF TERTIARY AGE

CONSOLIDATED ROCKS OF PRE-TERTIARY AGE

?- FAULT--Dashed where approximately located and concealed; queried where doubtful

FIGURE 3.--Continued.

The valley-fill materials are fine sand and gravel derived from the surrounding mountains. These materials are interspersed with silt and clay of varying thicknesses and areal extent.

Sedimentary deposits of Tertiary age crop out throughout the project area, primarily in the Yuha Desert and the Coyote Mountains (fig. 3). These deposits consist of marine and nonmarine clay and sandstone deposited during repeated inundations from the Gulf of California and the Colorado River, respectively (Dibblee, 1954). Oyster-shell reefs are also common. Ground water in these deposits typically is saline.

The Elsinore fault transects the Ocotillo-Coyote Wells basin in a southeastward direction along the south edge of the Coyote Mountains, passing slightly east of Coyote Wells (fig. 3). The fault is generally concealed in the alluvium-covered areas. It joins the Laguna Salada fault in Mexico (Loeltz and others, 1975). Most of the other faults in the project area (fig. 3) have traces that parallel the Elsinore fault and may be associated with its movement. Most of the usable ground water is from the alluvial deposits west of the Elsinore fault.

In the illustrations of this report the geology has been generalized to show only the water-bearing unconsolidated deposits and the consolidated rocks of the surrounding mountains.

Figure 4 is a conceptual cross section of the Ocotillo-Coyote Wells basin aquifer. The water table is the surface of the saturated material. An aquifer possessing a water table is an unconfined or water-table aquifer, and water levels in wells define the water table.

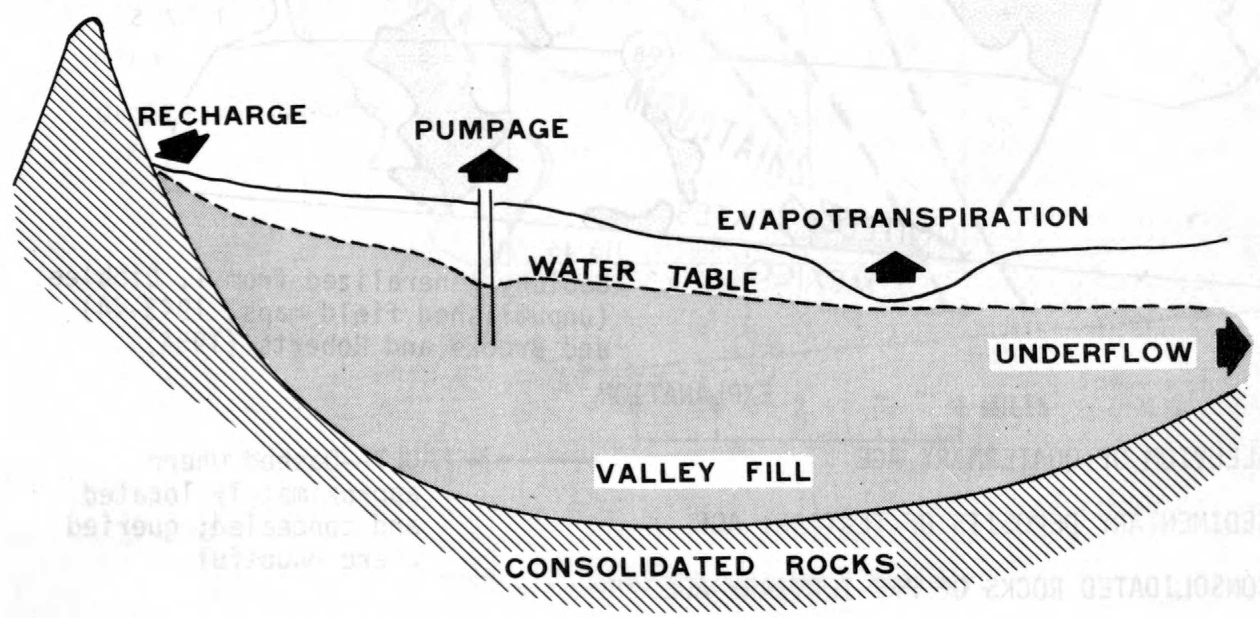


FIGURE 4.--Conceptual cross section, not drawn to scale, showing elements of ground-water recharge and discharge.

Ground water moves slowly through sand and gravel from areas of higher water levels to areas of lower water levels. This movement in Ocotillo, for example, is in tens of feet per year under natural or nonpumping conditions. The generalized direction of flow is from areas of ground-water recharge to areas of ground-water discharge. Recharge is primarily from infiltration of runoff at the mountain fronts and from stream channels. Discharge is from pumpage, underflow out of the project area, and evapotranspiration.

Recharge

The aquifer in the project area is recharged principally from precipitation within the basin. About 8 in of precipitation occurs annually in the Jacumba Mountains (fig. 2) where the highest altitude is 4,500 ft. The average rainfall in Ocotillo, based on 30 years of record (1931-60), is 3.5 in (Hely and Peck, 1964).

Precipitation occurs mainly as rainfall from frontal winter storms (October-April) coming from the Pacific Ocean. Summer storms (May-September) originating in the Gulf of Mexico contribute 1.0-1.5 in to the annual precipitation (Hely and Peck, 1964).

Because the relative variation in the annual precipitation is greatest where the mean annual precipitation is least (Hely and Peck, 1964), the Ocotillo-Coyote Wells basin can have periods of little or no precipitation, then have several years of relatively heavy rainfall.

All streams draining the project area are ephemeral, typically flowing only during and shortly after storms. The major stream channels originate in the mountains to the west and south and then traverse the alluvial fill of the valley.

Streamflow percolates to the water table mainly beneath the permeable alluvial fans at the mountain fronts, which may absorb all the runoff. These stream channels include Palm Canyon Wash, Devils Canyon, Myer Creek, Davies Canyon, and Pinto Wash (fig. 2).

Intense storms can produce streamflow on the valley floor. Some water may percolate to the water table in the valley, but the depth to water is considerably more than the depth on the upper fans. During these periods of increased streamflow, flow also leaves the basin, primarily via Coyote Wash to the northeast (fig. 2). Evaporation losses also increase during periods of streamflow on the valley floor.

The only streamflow measured in the project area is in two small tributaries of Myer Creek, approximately 4 and 7 mi southwest of Ocotillo (fig. 2). Both stations record peak stage near culverts under the eastbound lanes of Interstate Highway 8. The only flow at these sites is during the several storms that might occur annually. The highest recorded flow from 1960 to 1973 occurred August 12, 1965, at both stations. That flow was 21 ft^3/s at the station nearest Ocotillo and 41 ft^3/s at the other station.

Hely and Peck (1964) estimated annual runoff from the mountains in the project area to range from 0.02 to 0.50 in. These estimates are based on modifications to an empirical method of the U.S. Soil Conservation Service [no date] using precipitation data and soil types.

The quantity of recharge to the Ocotillo-Coyote Wells basin aquifer north of the Mexican border and west of the Elsinore fault was calculated to be 2,600 acre-ft/yr. This is equivalent to approximately 0.02 in on the drainage area of 225 mi^2.

U.S. Gypsum Co. is currently (1976) recharging ground water near Plaster City through infiltration ponds. Approximately 90 acre-ft of wastewater was discharged to ponds in 1973 (California Dept. of Water Resources, 1975). The actual quantity of recharge reaching the water table is unknown, however.

Discharge

Pumpage

The history of pumpage in the Ocotillo-Coyote Wells basin parallels the economic development of the region. Because ground water has been the sole source of water supply in the basin, most development has directly affected the ground-water resources. Figure 5 shows the estimated total pumpage in the project area since 1925.

Prior to 1925, the primary ground-water withdrawal was generally restricted to the Coyote Wells area. Adams (1915) mentioned two wells drilled by Henry E. Walker in Coyote Wells. A well 30 ft deep reportedly produced more saline water than a well 65 ft deep.

Brown (1923) described the development in Coyote Wells as including a combined store and post office, a service station, a railway station, and several ranch houses. No estimates are available for total basin pumpage in those early days, but the total can be assumed to be much less than in later years.

In 1925 the San Diego and Arizona Railway drilled a well for locomotive supply. That well was in operation until the early 1960's. Also in 1925, the Pacific Portland Cement Co. drilled a well at Plaster City for an industrial supply. The water, however, was saline, and the well was abandoned.

At about this same time a well for the Plaster City works was drilled in sec. 36, T. 16 S., R. 9 E. It was reported to be a good producer until its failure in 1955 (Imperial Irrigation District, 1958). The U.S. Gypsum Co. purchased the Plaster City facility about 1946 and has since drilled five

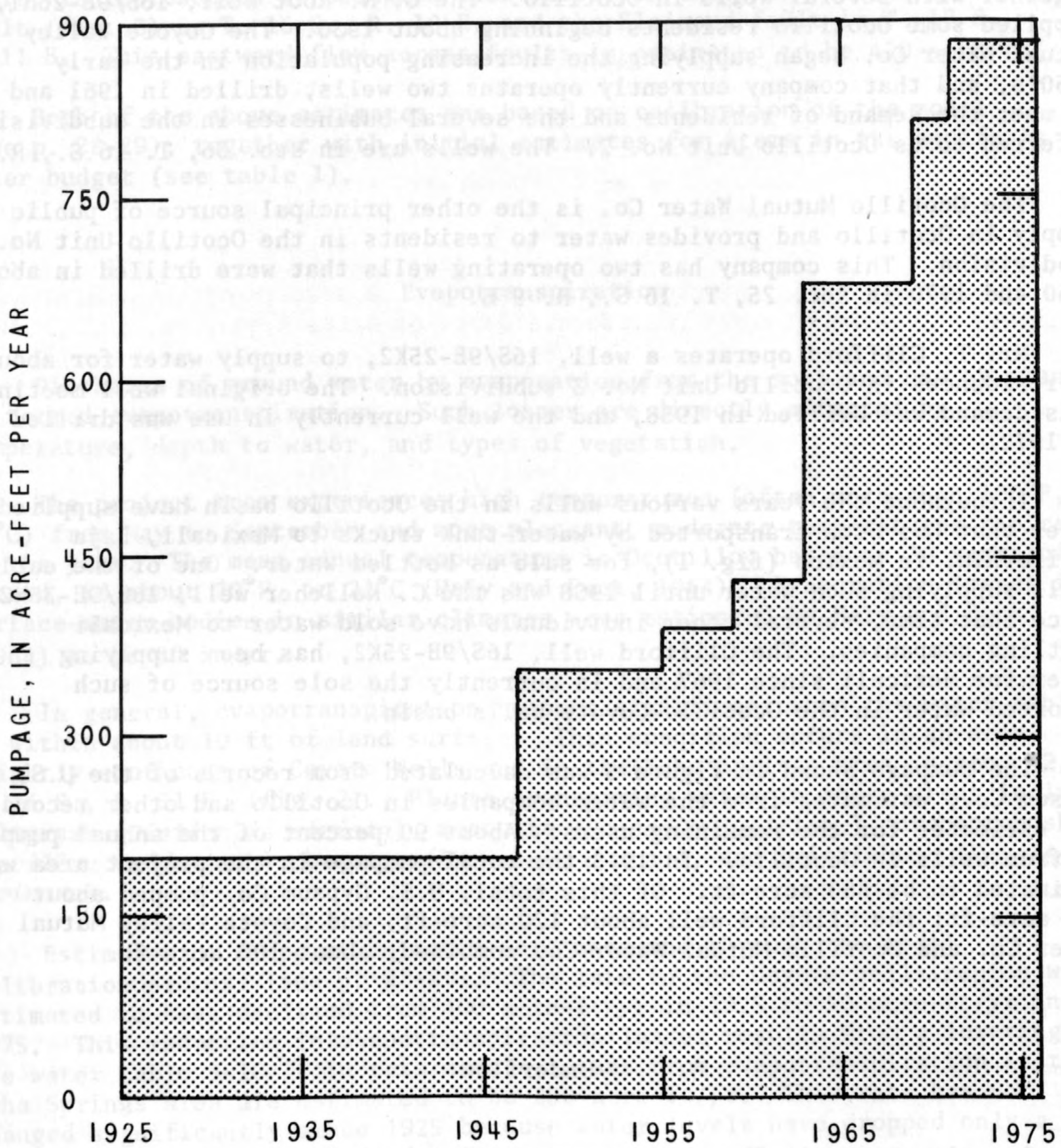


FIGURE 5.--Pumpage in the Ocotillo-Coyote Wells basin from January 1925 to December 1975.

production wells in the Ocotillo area. Two of the wells have been abandoned; the three remaining production wells are in sec. 36, T. 16 S., R. 9 E. Water from these wells is transported to Plaster City by pipeline.

The early domestic supply of water was from wells in Coyote Wells together with several wells in Ocotillo. The G. N. Root well, 16S/9E-26H1, supplied some Ocotillo residents beginning about 1930. The Coyote Valley Mutual Water Co. began supplying the increasing population in the early 1950's, and that company currently operates two wells, drilled in 1961 and 1970, to meet the demand of residents and the several businesses in the subdivision referred to as Ocotillo Unit No. 2. The wells are in sec. 36, T. 16 S., R. 9 E.

The Ocotillo Mutual Water Co. is the other principal source of public supply in Ocotillo and provides water to residents in the Ocotillo Unit No. 1 subdivision. This company has two operating wells that were drilled in about 1960 and 1970 in sec. 25, T. 16 S., R. 9 E.

Mr. T. Clifford operates a well, 16S/9E-25K2, to supply water for about 10 residences in Ocotillo Unit No. 3 subdivision. The original well meeting this demand was drilled in 1958, and the well currently in use was drilled in 1972.

Throughout the years various wells in the Ocotillo basin have supplied water that has been transported by water-tank trucks to Mexicali, Baja California, in Mexico (fig. 1), for sale as bottled water. One of the early wells supplying such water until 1958 was the C. Kelleher well, 16S/9E-35N2. Since that time, several other individuals have sold water to Mexicali bottling companies. The Clifford well, 16S/9E-25K2, has been supplying water for Mexicali since 1967 and is currently the sole source of such exported water in the Ocotillo-Coyote Wells basin.

The pumpage shown in figure 5 was calculated from records of the U.S. Gypsum Co., estimates from the water companies in Ocotillo and other records, and estimates for the remaining users. About 90 percent of the annual pumpage is from wells in Ocotillo. In 1975 the total pumpage in the project area was estimated to be 880 acre-ft. Of this total, U.S. Gypsum Co. pumped about 600 acre-ft; the Clifford well about 120 acre-ft; and Coyote Valley Mutual Water Co. and Ocotillo Mutual Water Co. combined, about 100 acre-ft.

Underflow

Ground-water underflow in the saturated materials generally is flow leaving or entering some area of interest. In the Ocotillo-Coyote Wells basin, significant underflow occurs across the United States-Mexico border. This underflow represents major discharge from the study area and is estimated to be 1,500 acre-ft/yr.

Additional underflow from the aquifer, primarily west of the Elsinore fault, is represented by eastward flow across an extension of the queried fault (fig. 3) in T. 16 S., R. 10 E., and the Elsinore fault in T. 17 S., R. 11 E. This eastward flow across faults is estimated to be 450 acre-ft/yr.

Both of the above estimates are based on calibration of the model (see p. 28-29), together with initial estimates for items in the aquifer's water budget (see table 1).

Evapotranspiration

Discharge of ground water by evaporation from the soil and use by plants is termed evapotranspiration. Such losses are directly affected by temperature, depth to water, and types of vegetation.

The project area experiences high temperatures (often more than 100°F, or 38°C) from May to September and more pleasant, moderate temperatures the rest of the year. The mean annual temperature in Ocotillo, based on 30 years of record, is about 70°F, or 21°C (Hely and Peck, 1964). Evaporation losses from surface-water bodies in similar climates were estimated by Hely and Peck (1964) to be 80 in/yr.

In general, evapotranspiration becomes significant when the water table is within about 10 ft of land surface. This condition occurs in an area slightly southeast of Coyote Wells and in the Yuha Springs area in sec. 42, T. 16 S., R. 11 E. (fig. 2). Plants transpiring water in these areas include saltgrass (*Distichlis stricta*), mesquite (*Prosopis juliflora*), creosotebush (*Covillea tridentata*), bursage (*Franseria dumosa*), and brittlebush (*Encelia farinosa*).

Estimates of evaporation rates were obtained through the model calibration process (see p. 28-29). The rate in the Coyote Wells region was estimated to have declined from 400 acre-ft/yr in 1925 to 50 acre-ft/yr in 1975. This reduction in evapotranspiration losses results from a lowering of the water table 5-10 ft in this area. Losses from evapotranspiration in the Yuha Springs area are estimated to be 250 acre-ft/yr. This rate has not changed significantly since 1925 because water levels have dropped only a few feet over that time period.

Budget

Estimates of recharge and discharge for the study area are summarized in table 1. Values given are for steady-state (1925) conditions as well as for 1975.

TABLE 1.--*Ocotillo-Coyote Wells basin water budget for steady state (1925) and 1975*

[Acre-feet per year]

Item	Steady state (1925)	1975
Recharge		
Infiltration of precipitation	2,600	2,600
Discharge		
Pumpage	0	900
Evapotranspiration	650	300
Underflow to Mexico	1,500	1,450
Underflow eastward across faults	450	450
Total discharge	2,600	3,100
Change in storage	0	-500

Quality

The development of ground-water resources depends not only on the quantity available and the depth to the water table, but also on the quality. Ocotillo is fortunate in having ground water with a dissolved-solids concentration of less than 500 mg/L (milligrams per liter). Table 2 shows the chemical analysis of a ground-water sample from Ocotillo (16S/9E-25K2). The water is a sodium bicarbonate type.

This sample is representative of ground water found in the alluvium west of the Elsinore fault (fig. 3). East of the fault, however, are extensive outcroppings of sediments of Tertiary age consisting mostly of clay, sandstone, and marine fossils (oyster reefs). Ground water in these sediments is commonly saline. Table 2 also shows a chemical analysis of a ground-water sample (16S/10E-16D1) in the Painted Gorge subdivision (fig. 2). This analysis shows high levels of dissolved constituents. This sample is classified as sodium-chloride-sulfate type water.

The Tertiary deposits also crop out west of the Elsinore fault (fig. 3) and most likely occur at depth throughout the study area. Consequently, the ground-water quality may deteriorate with depth west of the fault. Some 600-ft deep wells in Ocotillo tapping these lower levels of the aquifer, however, produce potable water. Exploratory test drilling in the study area would help to determine variations in quality of ground water with depth.

TABLE 2.--*Analyses of ground-water samples from Ocotillo and Painted Gorge subdivision*

[Results in milligrams per liter except pH]

Constituents	Ocotillo 16S/9E-25K2 6-26-75	Painted Gorge 16S/10E-16D1 6-23-75
Silica	36	11
Calcium	18	410
Magnesium	5.1	150
Potassium	4.8	15
Sodium	74	4,300
Bicarbonate	130	110
Sulfate	40	8,100
Chloride	56	2,200
Fluoride	.7	.6
Dissolved solids	307	15,200
pH	7.1	7.7
Hardness	66	1,600

Figure 6 shows an areal distribution of dissolved solids in ground water sampled in the Ocotillo-Coyote Wells basin. These analyses are for ground-water samples obtained from 1974 to 1976 at existing wells and at approximately 10 test holes augered as part of this study. Also included are four samples taken in 1962 and 1964 (Loeltz and others, 1975).

Local variations in dissolved solids shown in figure 6 probably reflect differences in depth of perforated intervals of wells. Some samples are from wells with perforated intervals less than 40 ft below land surface. These analyses generally have higher dissolved solids than neighboring wells in which the upper intervals are cased off. Evapotranspiration may cause the concentration of constituents in the ground water.

Figure 6 indicates that most of the potable ground-water samples are from west of the Elsinore fault. Figure 6 also shows that fluoride concentrations in samples from many wells west of the fault are higher than the U.S. Environmental Protection Agency (1972) recommended maximum fluoride concentration of 1.4 mg/L based on the annual average of maximum daily air temperatures. Dissolved fluoride in the ground-water samples is highest south of Ocotillo, closer to the mountain front.

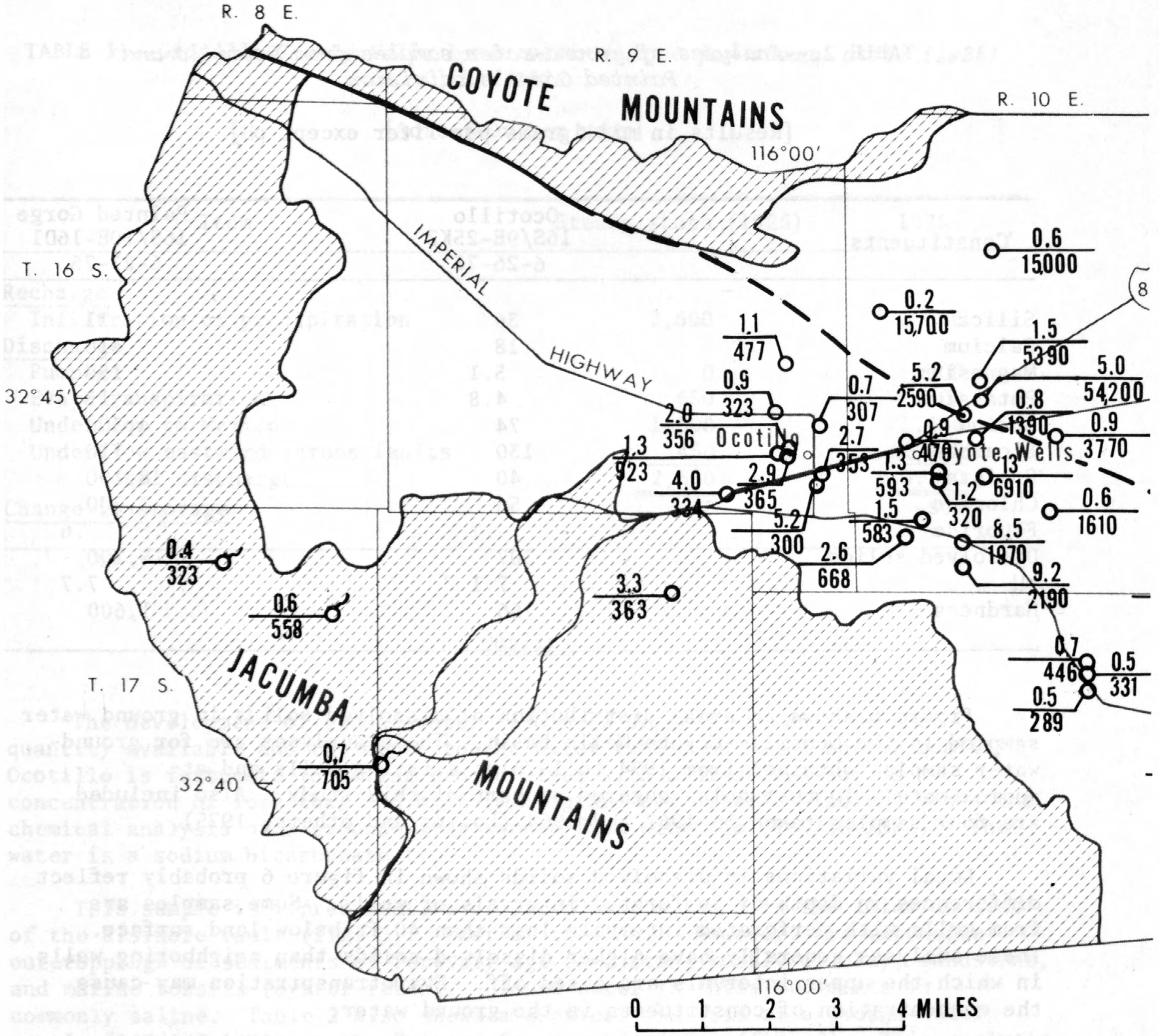


FIGURE 6.--Distribution of fluoride and dissolved solids in ground-water samples.

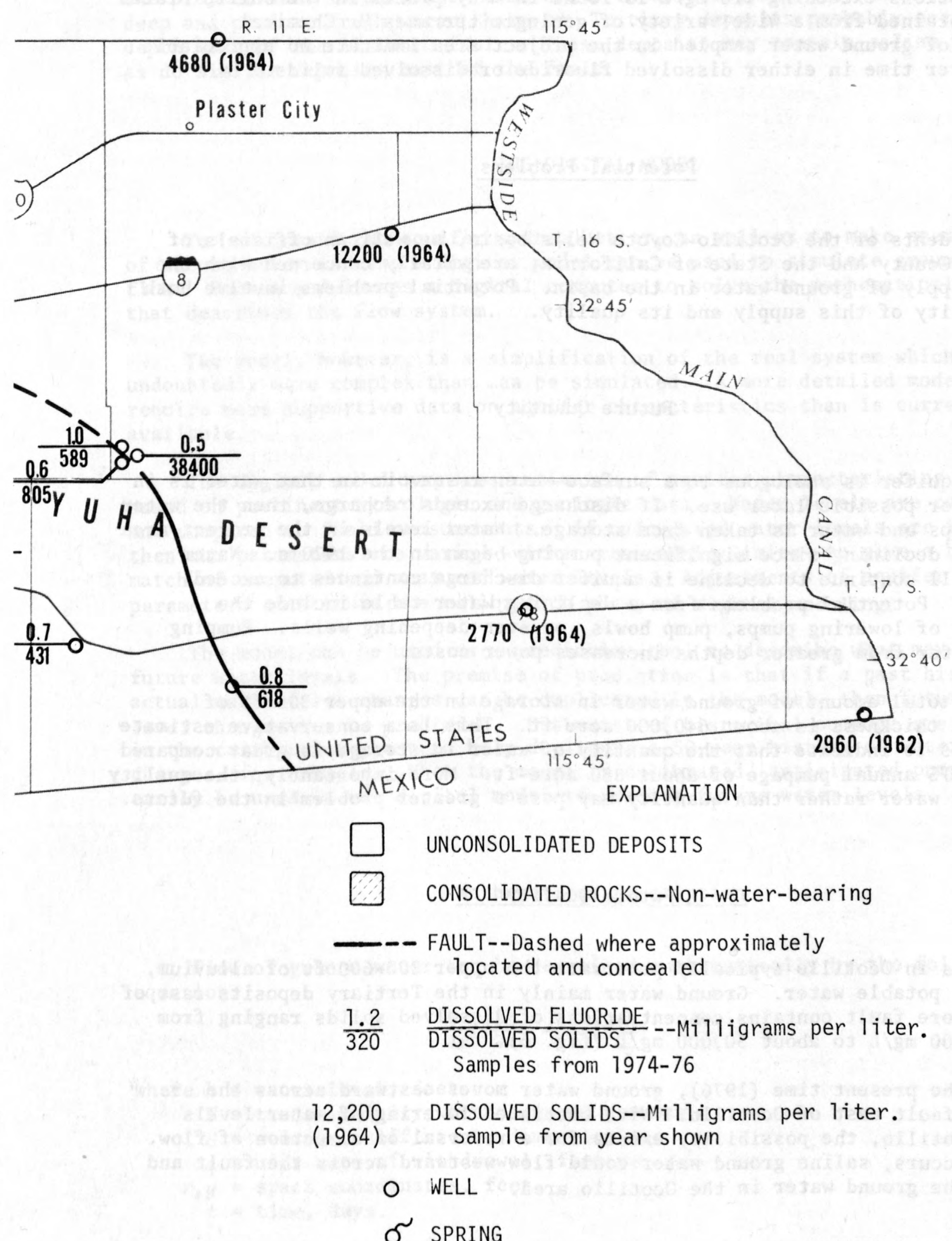


FIGURE 6.--Continued.

The source of the dissolved fluoride in ground water in the study area is not fully understood. Hem (1970) stated: "Ground water containing fluoride concentrations exceeding 1.0 mg/L is found in many places in the United States and is obtained from a wide variety of geologic terranes." Chemical analyses of ground water sampled in the project area indicate no appreciable change over time in either dissolved fluoride or dissolved solids.

Potential Problems

Residents of the Ocotillo-Coyote Wells basin, as well as officials of Imperial County and the State of California, are vitally concerned with the future supply of ground water in the basin. Potential problems involve both the quantity of this supply and its quality.

Future Quantity

An aquifer is analogous to a surface-water reservoir in that water is in storage for possible later use. If discharge exceeds recharge, then the water level drops and water is taken from storage. Water levels in the project area have been declining since significant pumping began in the 1920's. Water levels will continue to decline if aquifer discharge continues to exceed recharge. Potential problems from a declining water table include the necessity of lowering pumps, pump bowls, or even deepening wells. Pumping ground water from greater depths increases power costs.

The total amount of ground water in storage in the upper 200 ft of saturated thickness is about 640,000 acre-ft. This is a conservative estimate but serves to indicate that the quantity of water in storage is great compared to the 1975 annual pumpage of about 880 acre-ft. More importantly, the quality of ground water rather than quantity may pose a greater problem in the future.

Future Quality

Wells in Ocotillo typically penetrate the upper 200-600 ft of alluvium, producing potable water. Ground water mainly in the Tertiary deposits east of the Elsinore fault contains concentrations of dissolved solids ranging from about 4,000 mg/L to about 50,000 mg/L (fig. 6).

At the present time (1976), ground water moves eastward across the Elsinore fault east of Ocotillo. With continued lowering of water levels around Ocotillo, the possibility exists for a reversal of direction of flow. If this occurs, saline ground water could flow westward across the fault and degrade the ground water in the Ocotillo area.

Water quality at levels deeper than those tapped by existing wells in the project area is unknown. Some wells in Ocotillo are more than 600 ft deep and produce fresh water; however, Tertiary deposits probably occur at depth west of the Elsinore fault. These deposits may contain saline water, as do similar deposits east of the fault.

THE DIGITAL MODEL

To understand the aquifer system better, as well as to make predications of future water levels, a digital model can be used to simulate ground-water flow. Such a model uses a digital computer to solve the mathematical equation that describes the flow system.

The model, however, is a simplification of the real system which is undoubtedly more complex than can be simulated. A more detailed model would require more supportive data on aquifer characteristics than is currently available.

The digital model requires estimates of aquifer characteristics initially based on pertinent hydrologic and geologic data. Water levels are calculated and compared to field measurements. If calculated water levels are in error, then the parameters are varied--within reasonable limits--to give a better match of computed and measured water levels. Adjustments of aquifer parameters constitute the calibration phase of digital modeling.

The model can be used as a predictive tool to describe what may happen to future water levels. The premise of prediction is that if a past history of actual water-level changes can be duplicated in the model, then future water-level changes can be predicted. Estimates of historical pumpage are used in the calibration phase to help duplicate a 50-year history of water-level changes, for example. When the model is calibrated, anticipated pumpage can easily be used in the digital model to predict future water levels.

Mathematical Description

Flow of ground water can be described mathematically by the following equation:

$$\frac{\partial}{\partial x}\left(T\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(T\frac{\partial h}{\partial y}\right) = S\frac{\partial h}{\partial t} + q \qquad (1)$$

where h = water level, feet
T = transmissivity, feet squared per day
S = storage coefficient, dimensionless
q = unit rate of withdrawal, feet per day
x,y = space coordinates, feet
t = time, days.

Water levels are calculated as a function of time and location based on estimates of aquifer parameters. Drawdown or water-level-change maps can then be calculated by using these computed water levels and the initial levels. Hydrographs, or plots of water levels at a particular point at various times, can also be calculated.

The finite-element method of solution is a particular numerical technique to solve equation 1. (See Pinder and Frind, 1972, for a complete description.) The computer program used was developed by G. F. Pinder (written commun., 1974).

Grid Network

The method requires that the model of the aquifer be overlain with a grid network of four-sided elements (fig. 7). The corner of each element is a node; additional nodes are specified points on the sides to allow for more curved shapes.

The selection of grid size is based on the location of existing data as well as on the required detail of the model application. Thus, smaller grid size might be used in areas of existing and proposed pumpage. In this way a better definition of the effects of such pumping can be obtained. On the other hand, grid size can be much larger for areas sparse in existing or proposed ground-water development. Narrow elements have been used to simulate faults because of the need to calibrate water-level differences over distances as short as 500 ft.

The Ocotillo-Coyote Wells model was constructed with 136 elements and 246 nodes. The size of the elements ranges from 0.05 to 7.4 mi^2. The average area of an element is 1.5 mi^2.

Aquifer transmissivity and storage coefficient must be specified for each element, and recharge or discharge is given at nodes where applicable. Once boundary conditions are given (see below) and initial water levels are specified for each node, the digital model will then calculate water levels at all nodes as a function of time.

Boundary Conditions

Boundary conditions must also be specified on the edges of the modeled area. Figure 7 shows a no-flow boundary around most of the area, plus constant head or nonchanging water levels along the east and south edges. The no-flow boundary approximates the lateral extent of the alluvium where it pinches out at bedrock.

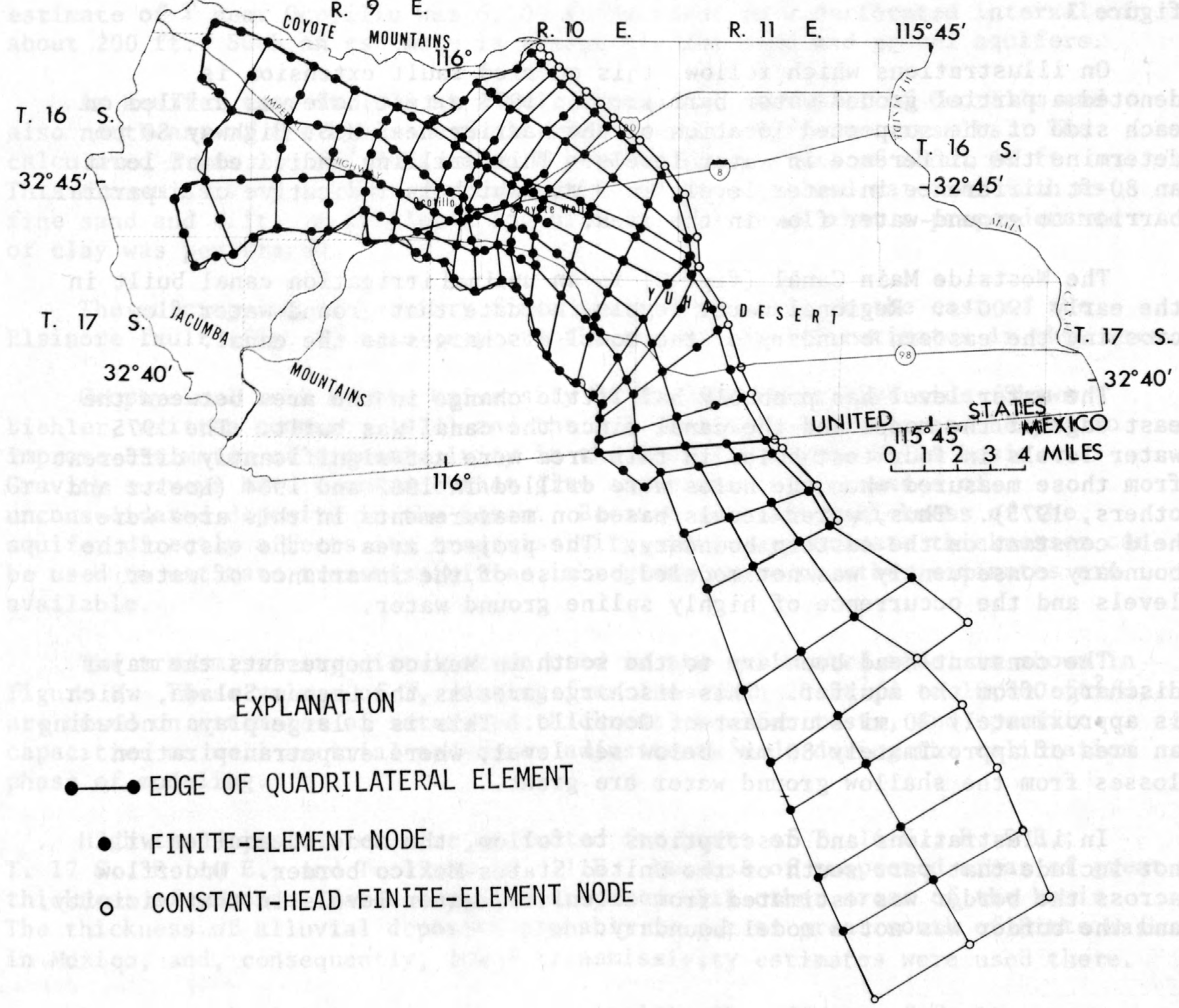


FIGURE 7.--Finite-element grid used in the digital model.

The eastern boundary represents a band of low transmissivity. This boundary in T. 17 S., R. 11 E., coincides with the Elsinore fault, and in T. 16 S., R. 10 E., it coincides with an extension of the queried fault in figure 3.

On illustrations which follow, this queried fault extension is denoted a partial ground-water barrier. In 1975 a test hole was drilled on each side of the suspected location of the barrier near U.S. Highway 80 to determine the difference in water levels. This drilling indicated at least an 80-ft difference in water levels in 2 mi, which is indicative of a partial barrier to ground-water flow in the area.

The Westside Main Canal (fig. 2) is an unlined irrigation canal built in the early 1900's. Regional water levels indicate that ground-water flow crossing the eastern boundary of the model discharges to the canal.

The water level has probably had little change in the area between the east edge of the model and the canal since the canal was built. The 1975 water levels in four test holes in this area were not significantly different from those measured when the holes were drilled in 1962 and 1964 (Loeltz and others, 1975). Thus, water levels based on measurements in this area were held constant on the eastern boundary. The project area to the east of the boundary consequently was not modeled because of the invariance of water levels and the occurrence of highly saline ground water.

The constant-head boundary to the south in Mexico represents the major discharge from the aquifer. This discharge area is the Laguna Salada, which is approximately 20 mi southeast of Ocotillo. This is a large playa including an area of approximately 80 mi^2 below sea level, where evapotranspiration losses from the shallow ground water are great.

In illustrations and descriptions to follow, the modeled aquifer will not include that part south of the United States-Mexico border. Underflow across the border was estimated from calculated water levels in that vicinity, and the border was not a model boundary.

Transmissivity

Transmissivity (*T*) is a major factor controlling the rate at which water is transmitted through an aquifer. Besides the material characteristics such as average grain size and degree of sorting, transmissivity (*T*) is directly proportional to the saturated thickness.

The digital model has been generalized to use a fixed transmissivity and was not adjusted for changes in saturated thickness. Two reasons for this simplification are: (1) Little is known of the aquifer characteristics below the depths of existing wells; and (2) the historical changes in water levels are small in comparison with penetrated saturated thicknesses of 200 ft or more.

Estimates of T can be obtained from aquifer tests, where drawdown is plotted versus time. The specific capacity of a well, which is the pumping rate per foot of drawdown, can also be used to obtain estimates of T. One such estimate of T near Ocotillo was 6,700 ft^2/d based on a perforated interval of about 200 ft. Such an estimate is reasonable for sand and gravel aquifers.

An aquifer test in 1975 at a well about 3 mi northeast of Ocotillo and also northeast of the Elsinore fault yielded quite different results. The calculated T was 270 ft^2/d based on a perforated interval of about 60 ft. This transmissivity is more representative of fine-grained material such as fine sand and silt. A driller's log of this well shows that a preponderance of clay was penetrated.

The outcropping of Tertiary finer grained material to the east of the Elsinore fault (fig. 3) also supports the use of lower T estimates in this area.

Geophysical work by the University of California at Riverside (Shawn Biehler, written commun., 1974) and the U.S. Geological Survey has helped to improve estimates of transmissivity in the Ocotillo-Coyote Wells basin. Gravity surveys have been made that give approximate thicknesses of unconsolidated deposits in the basin. Because saturated thickness of the aquifer directly affects its transmissivity, these approximate thicknesses can be used to estimate transmissivities in regions where no other estimates are available.

The transmissivity distribution used in the calibrated model is shown in figure 8. These values of T, ranging from less than 20 ft^2/d to 10,700 ft^2/d, are based on estimates of saturated thickness, aquifer tests, and specific capacities as well as trial-and-error adjustments made during the calibration phase of modeling.

High transmissivities were estimated for parts of T. 16 S., R. 9 E.; T. 17 S., R. 10 E.; and T. 17 S., R. 11 E., because of suspected areas of great thickness of unconsolidated deposits compared with other areas of the basin. The thickness of alluvial deposits probably is not as great south of Pinto Wash in Mexico, and, consequently, lower transmissivity estimates were used there.

Low transmissivities were used to simulate the effects of faults on ground-water flow because the flow can be retarded by the faults. For example, Tyley (1971) found water-level drops of 30-250 ft across faults in the upper Coachella Valley. These ground-water gradients were much greater than those found in the rest of the valley, thus indicating retarded flow. Similar water-level gradients have been measured across the Elsinore fault and the extension of the queried fault (fig. 3) in T. 16 S., R. 10 E.

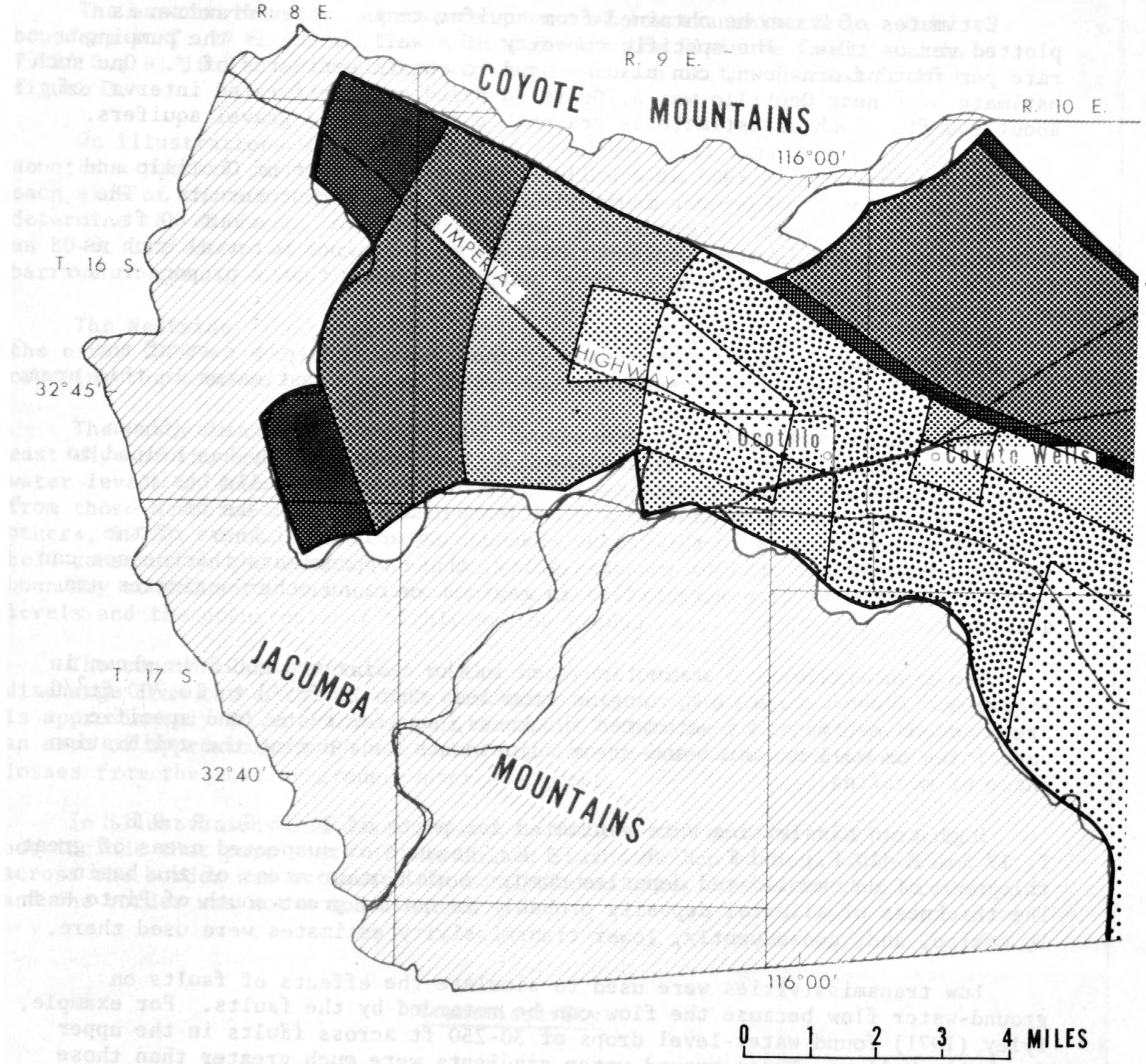
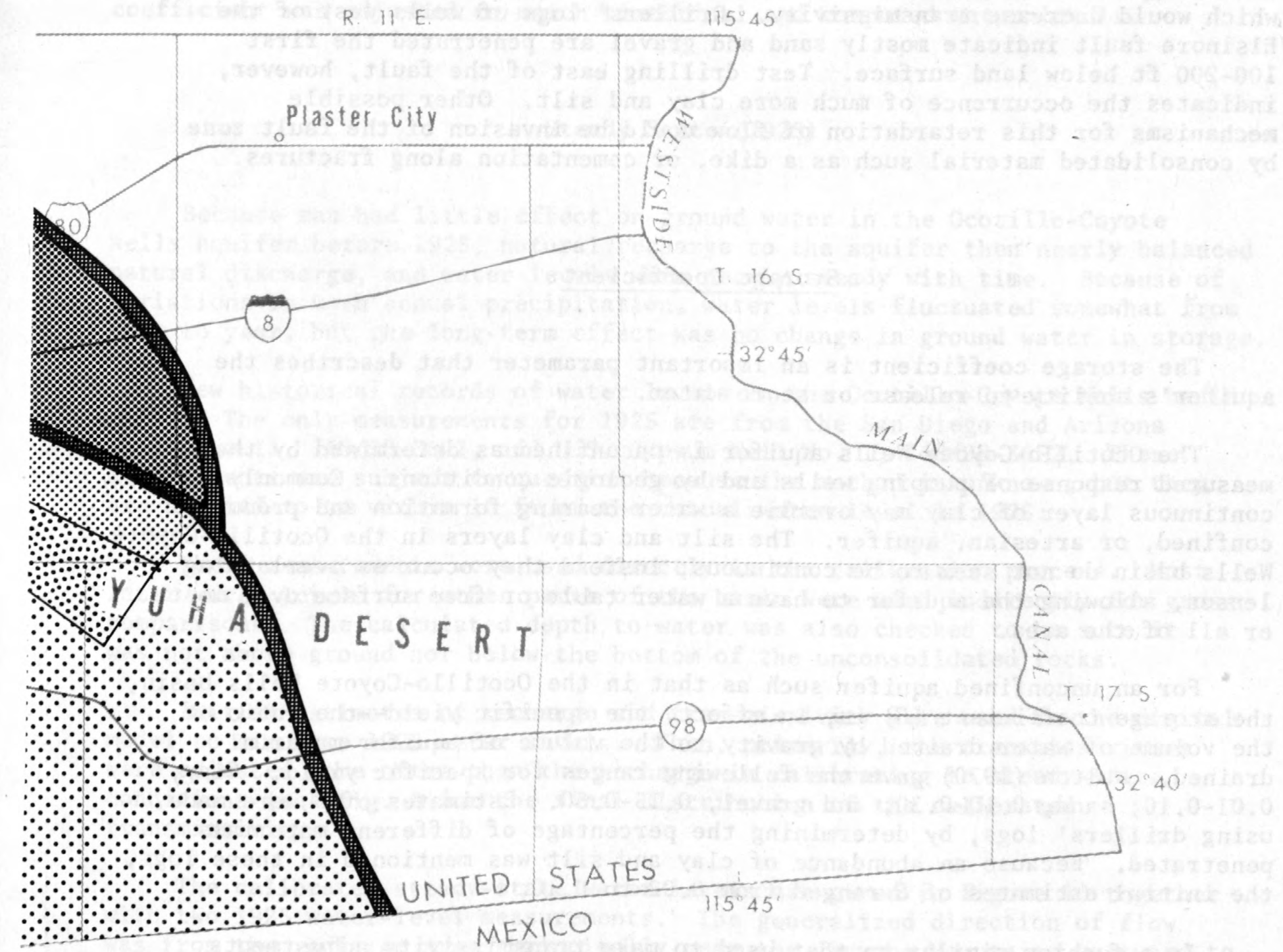


FIGURE 8.--Calibrated transmissivity distribution used in the digital model.



EXPLANATION

UNCONSOLIDATED DEPOSITS

TRANSMISSIVITY, IN FEET SQUARED PER DAY

- 6700-11,000
- 5400-6700
- 3300-5400
- 300-3300
- 20-300
- Less than 20

CONSOLIDATED ROCKS--Non-water-bearing

MODEL BOUNDARY

FIGURE 8.--Continued.

The mechanism of retardation of flow across fault zones in the basin is not fully understood. One method could be by offsetting fine-grained beds which would decrease transmissivity. Drillers' logs of wells west of the Elsinore fault indicate mostly sand and gravel are penetrated the first 100-200 ft below land surface. Test drilling east of the fault, however, indicates the occurrence of much more clay and silt. Other possible mechanisms for this retardation of flow could be invasion of the fault zone by consolidated material such as a dike, or cementation along fractures.

Storage Coefficient

The storage coefficient is an important parameter that describes the aquifer's ability to release or store water.

The Ocotillo-Coyote Wells aquifer is unconfined as determined by the measured response of pumping wells and by geologic conditions. Commonly a continuous layer of clay may overlie a water-bearing formation and produce a confined, or artesian, aquifer. The silt and clay layers in the Ocotillo-Coyote Wells basin do not seem to be continuous; instead they occur as overlapping lenses, allowing the aquifer to have a water table or free surface over most or all of the area.

For an unconfined aquifer such as that in the Ocotillo-Coyote Wells basin, the storage coefficient (S) is, in effect, the specific yield--the ratio of the volume of water drained by gravity to the volume of aquifer material drained. Walton (1970) gave the following ranges for specific yield: Clay, 0.01-0.10; sand, 0.10-0.30; and gravel, 0.15-0.30. Estimates of S were made, using drillers' logs, by determining the percentage of different materials penetrated. Because an abundance of clay and silt was mentioned in these logs, the initial estimates of S ranged from 0.02 to 0.10.

In a fashion similar to that used to make transmissivity adjustments, the storage coefficient was varied by trial-and-error adjustments in the calibration phase. The final calibrated distribution of storage coefficient is shown in figure 9 and ranges from 0.04 to 0.08. Because of lack of data, the storage coefficient in the Mexican part of the model was estimated to be 0.08, which is equal to that used for a large area north of the border (fig. 9).

Calibration

The calibration of the digital model primarily involved adjusting aquifer transmissivities and storage coefficients to match computed and measured water levels reasonably well. The steady-state condition under which water levels virtually do not change with time was first analyzed. During this phase, transmissivities were adjusted because storage coefficient does not affect steady-state water levels. Then the transient-state condition was studied where water levels have changed with time; during this phase, the storage coefficient was adjusted to match historical and computed water levels.

Steady State (1925)

Because man had little effect on ground water in the Ocotillo-Coyote Wells aquifer before 1925, natural recharge to the aquifer then nearly balanced natural discharge, and water levels were nearly steady with time. Because of variations in mean annual precipitation, water levels fluctuated somewhat from year to year, but the long-term effect was no change in ground water in storage.

Few historical records of water levels in the Ocotillo-Coyote Wells basin exist. The only measurements for 1925 are from the San Diego and Arizona Railway well, 16S/9E-36R1, and U.S. Gypsum Well No. 1, 16S/9E-36F2. These measurements are subject to question because the method is unknown, but they are assumed to be within 10 ft of the actual water level in 1925.

These measurements were used directly in the calibration process. Most later water levels for other parts of the basin were used indirectly for gross comparisons. The calculated depth to water was also checked to be sure it was not above ground nor below the bottom of the unconsolidated rocks.

Initial estimates of recharge and transmissivity were used in the digital model to simulate 1925 water levels. Then, primarily, the transmissivities were adjusted more often than the recharge in calibrating to steady-state conditions (see fig. 8 for the final distribution of the calibrated transmissivity).

The calibrated steady-state water levels are given in figure 10 together with two 1925 water-level measurements. The generalized direction of flow was from the recharge areas principally near the Jacumba Mountains eastward to Ocotillo and Coyote Wells. Ground water then flowed southward to the areas of present-day Nomirage and Yuha Estates and then across the Mexican border. There was also some flow eastward across the Elsinore fault.

Areas of ground-water discharge through evapotranspiration were near Coyote Wells and Yuha Springs (fig. 2). The steady-state ground-water budget is given in table 1.

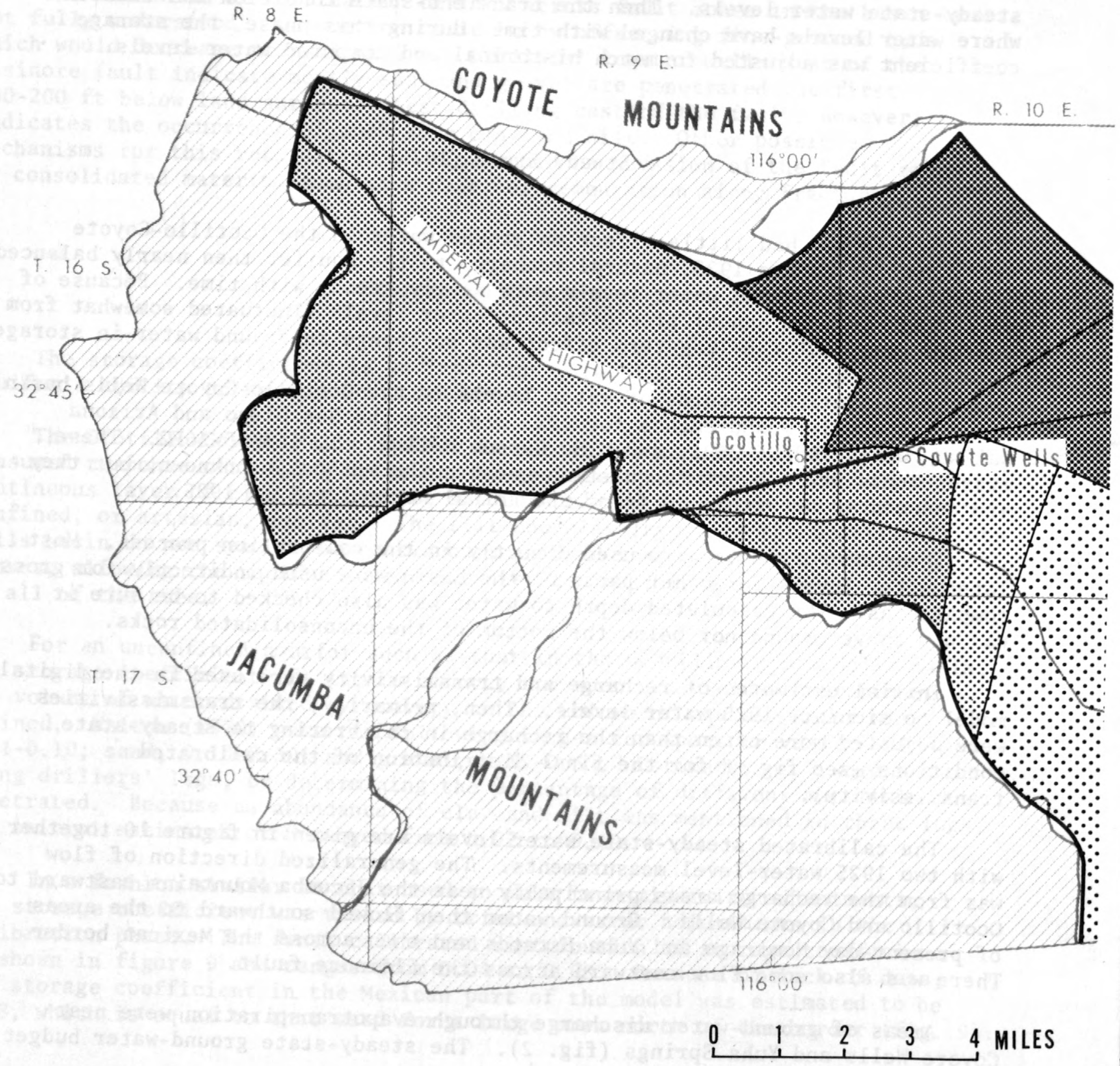


FIGURE 9.--Calibrated storage-coefficient distribution used in the digital model.

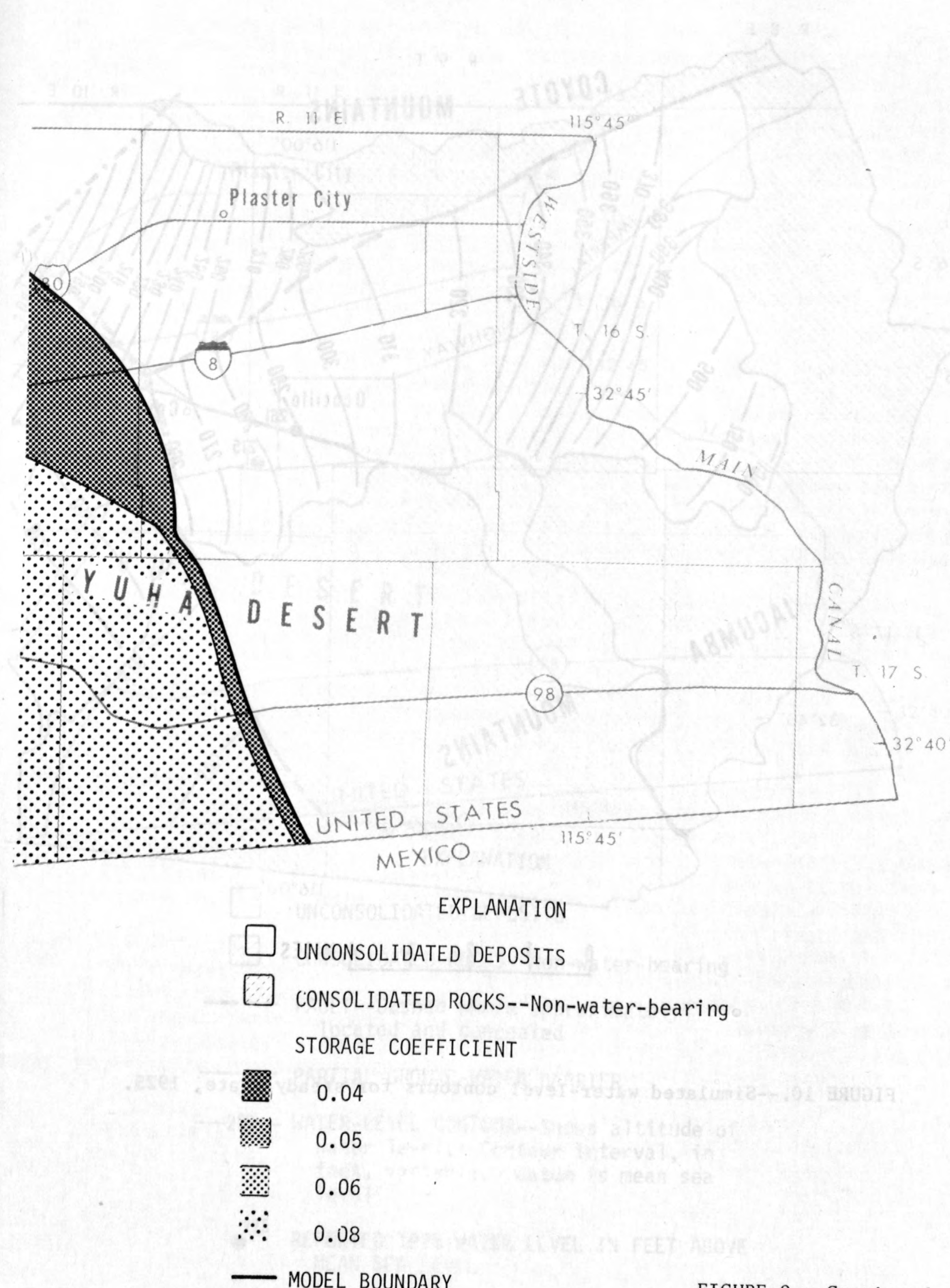


FIGURE 9.--Continued.

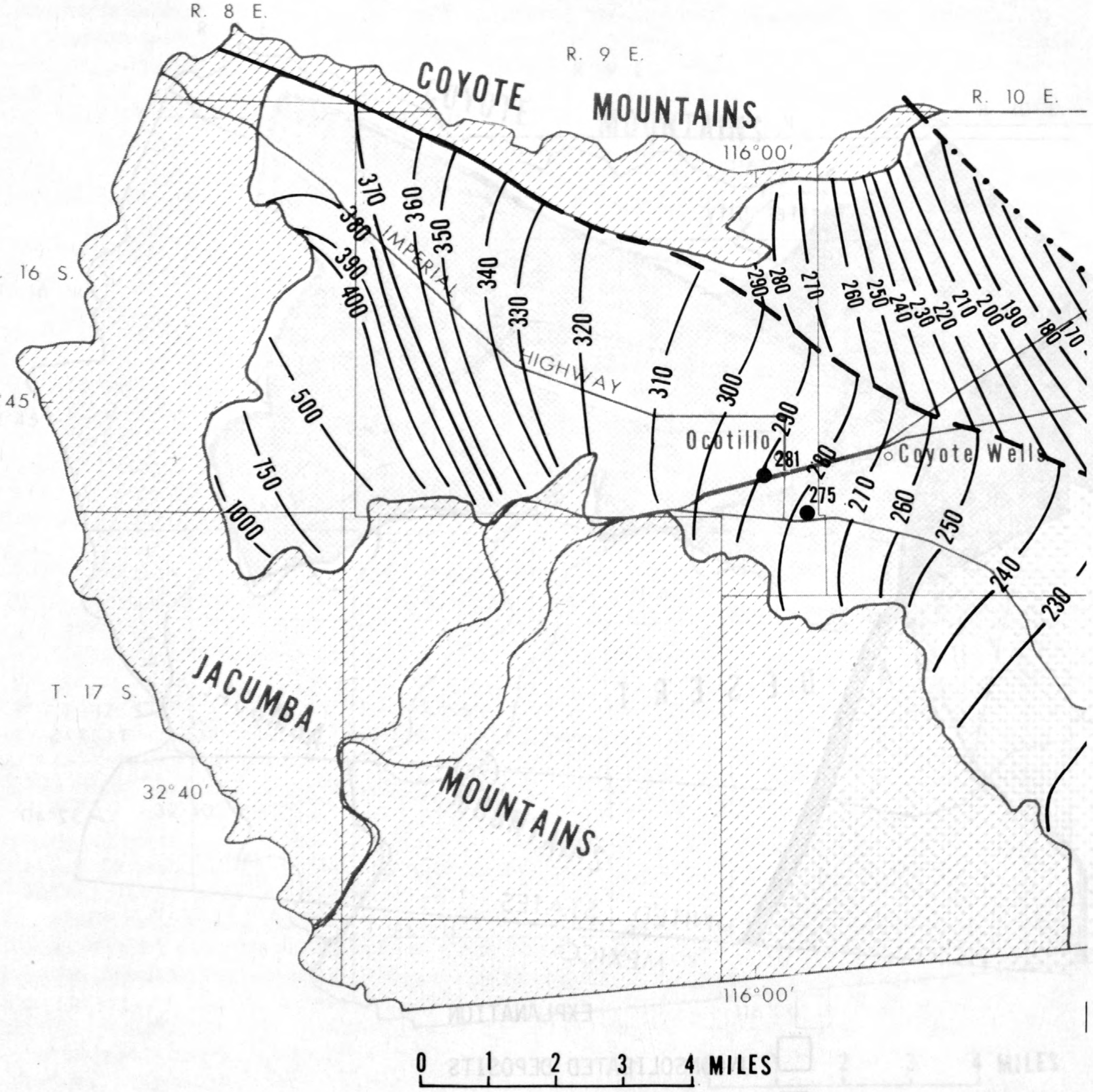
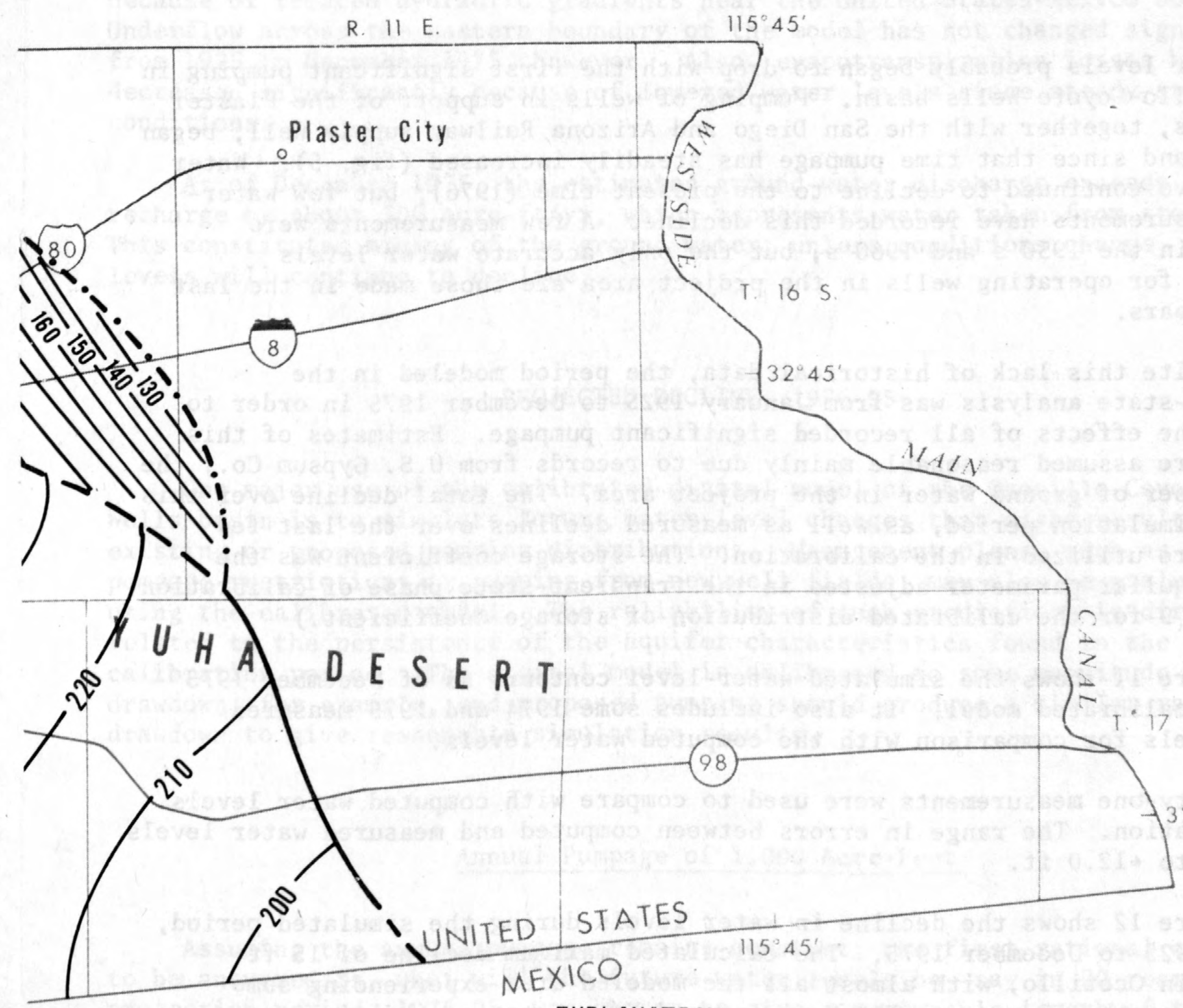


FIGURE 10.--Simulated water-level contours for steady state, 1925.



EXPLANATION

UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCKS--Non-water-bearing

FAULT--Dashed where approximately located and concealed

PARTIAL GROUND-WATER BARRIER

290 WATER-LEVEL CONTOUR--Shows altitude of water level. Contour interval, in feet, variable. Datum is mean sea level

275 REPORTED 1925 WATER LEVEL IN FEET ABOVE MEAN SEA LEVEL

FIGURE 10.--Continued.

Transient State (1925-75)

Water levels probably began to drop with the first significant pumping in the Ocotillo-Coyote Wells basin. Pumping of wells in support of the Plaster City works, together with the San Diego and Arizona Railway supply well, began in 1925, and since that time pumpage has steadily increased (fig. 5). Water levels have continued to decline to the present time (1976), but few water-level measurements have recorded this decline. A few measurements were reported in the 1950's and 1960's, but the only accurate water levels available for operating wells in the project area are those made in the last several years.

Despite this lack of historical data, the period modeled in the transient-state analysis was from January 1925 to December 1975 in order to include the effects of all recorded significant pumpage. Estimates of this pumpage are assumed reasonable mainly due to records from U.S. Gypsum Co., the largest user of ground water in the project area. The total decline over this 51-year simulation period, as well as measured declines over the last few years, were utilized in the calibration. The storage coefficient was the primary aquifer parameter adjusted in the transient-state phase of calibration. (See fig. 9 for the calibrated distribution of storage coefficient.)

Figure 11 shows the simulated water-level contours as of December 1975 from the calibrated model. It also includes some 1974 and 1975 measured water levels for comparison with the computed water levels.

Thirty-one measurements were used to compare with computed water levels in calibration. The range in errors between computed and measured water levels was -9.3 to +12.0 ft.

Figure 12 shows the decline in water levels during the simulated period, January 1925 to December 1975. The calculated maximum decline of 15 ft occurred in Ocotillo, with almost all the modeled area experiencing some decline over the 51 years. The Nomirage and Yuha Estates subdivisions experienced simulated declines of about 9 ft and 4 ft respectively. Water levels east of Elsinore fault toward the Painted Gorge subdivision had calculated declines of only 3 ft or less in 51 years.

Hydrographs of calculated water-level decline from January 1925 to December 1975 are shown in figure 13 for eight nodes. The model nodes plotted are located in figure 12. In general, the hydrographs of nodes near Ocotillo show a gradual increase in yearly declines. This phenomenon is principally due to the increased pumpage shown in figure 5. The nodes around Ocotillo show a calculated decline of about 0.5 ft during 1975.

The estimated ground-water budget as of December 1975 is given in table 1. Underflow to Mexico has been reduced somewhat from steady-state conditions because of reduced hydraulic gradients near the United States-Mexico border. Underflow across the eastern boundary of the model has not changed significantly from 1925 to December 1975, however. Also, evapotranspiration losses have decreased significantly because of lowered water levels since steady-state conditions.

As of December 1975, the estimated ground-water discharge exceeds the recharge by about 500 acre-ft/yr, which represents water taken from storage. This constitutes mining of the ground water; unless conditions change, water levels will continue to decline.

PROJECTED DECLINE, 1976-95

One major use of the calibrated digital model of the Ocotillo-Coyote Wells basin is to simulate future water-level changes that might result from existing or proposed pumping distributions. Management plans, such as pumpage restrictions or pumping from new well fields, may also be evaluated by using the calibrated model. The reliability of such predictions is directly related to the persistence of the aquifer characteristics found in the calibration period. The digital model is calibrated to some magnitude of drawdown, for example, and proposed pumping should produce a similar range of drawdown to give reasonable simulation results.

Annual Pumpage of 1,000 Acre-Feet

Assuming the annual pumpage remains constant, the first rational question to be answered is, what will the future water levels be--say in 20 years? A projection period, 1976-95, was chosen to give a reasonable length of time over which to assess the long-term effects of pumping, but also short enough so that management of the ground-water resource would be effective and timely.

The largest annual pumpage to date in the project area was approximately 1,000 acre-ft in 1972. This magnitude and location of pumpage was used in the first projection. The calculated water-level decline from 1976 to 1995 is shown in figure 14. Additional drawdown over this period is about 6 ft in and west of Ocotillo, with about 4 ft being in Nomirage subdivision and 2.5 ft in Yuha Estates subdivision.

A maximum of 3 ft of decline is calculated to have occurred just east of the Elsinore fault. Hydrographs of nodes shown in figure 12 from 1976 to 1995 are given in figure 15.

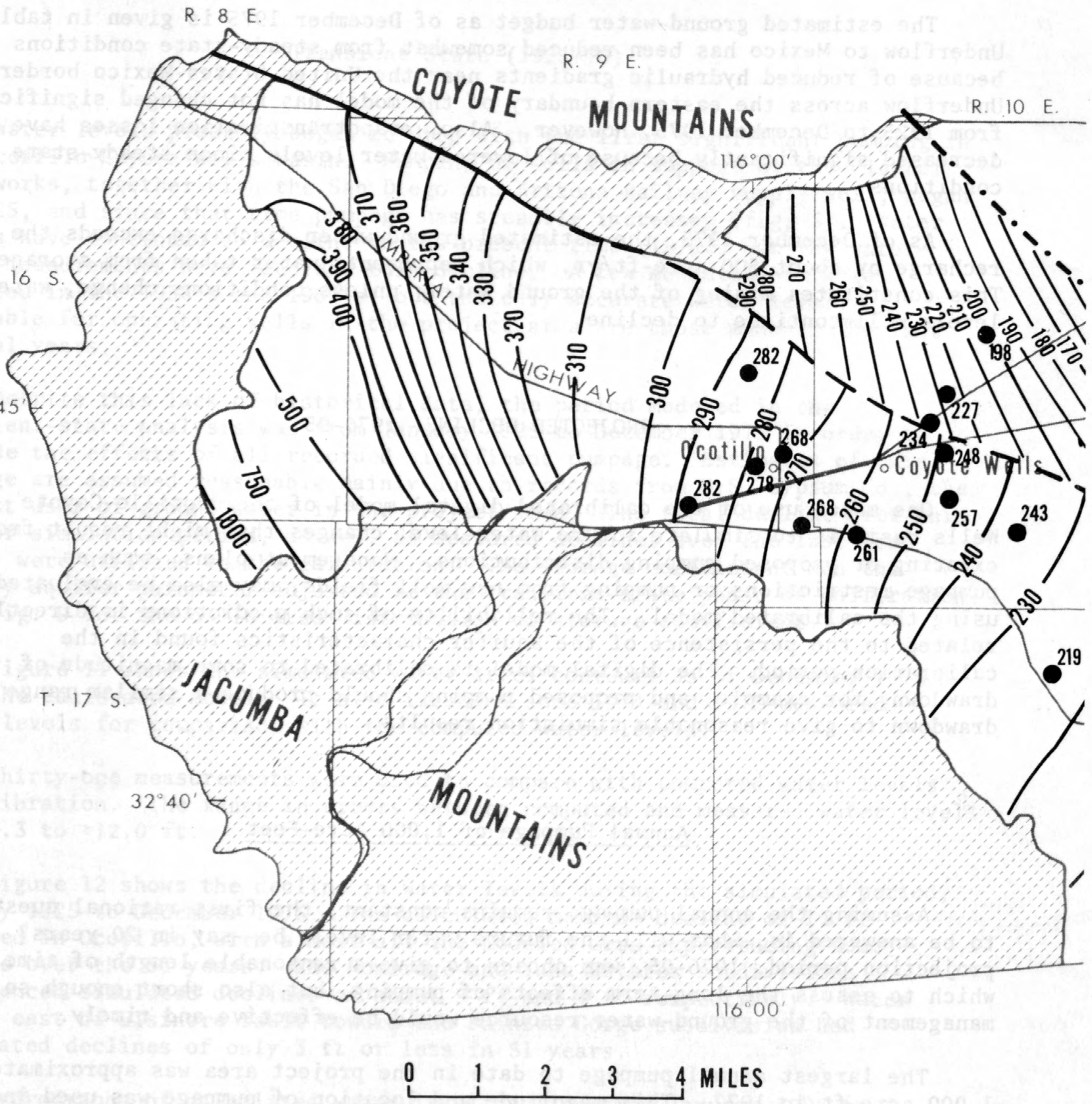
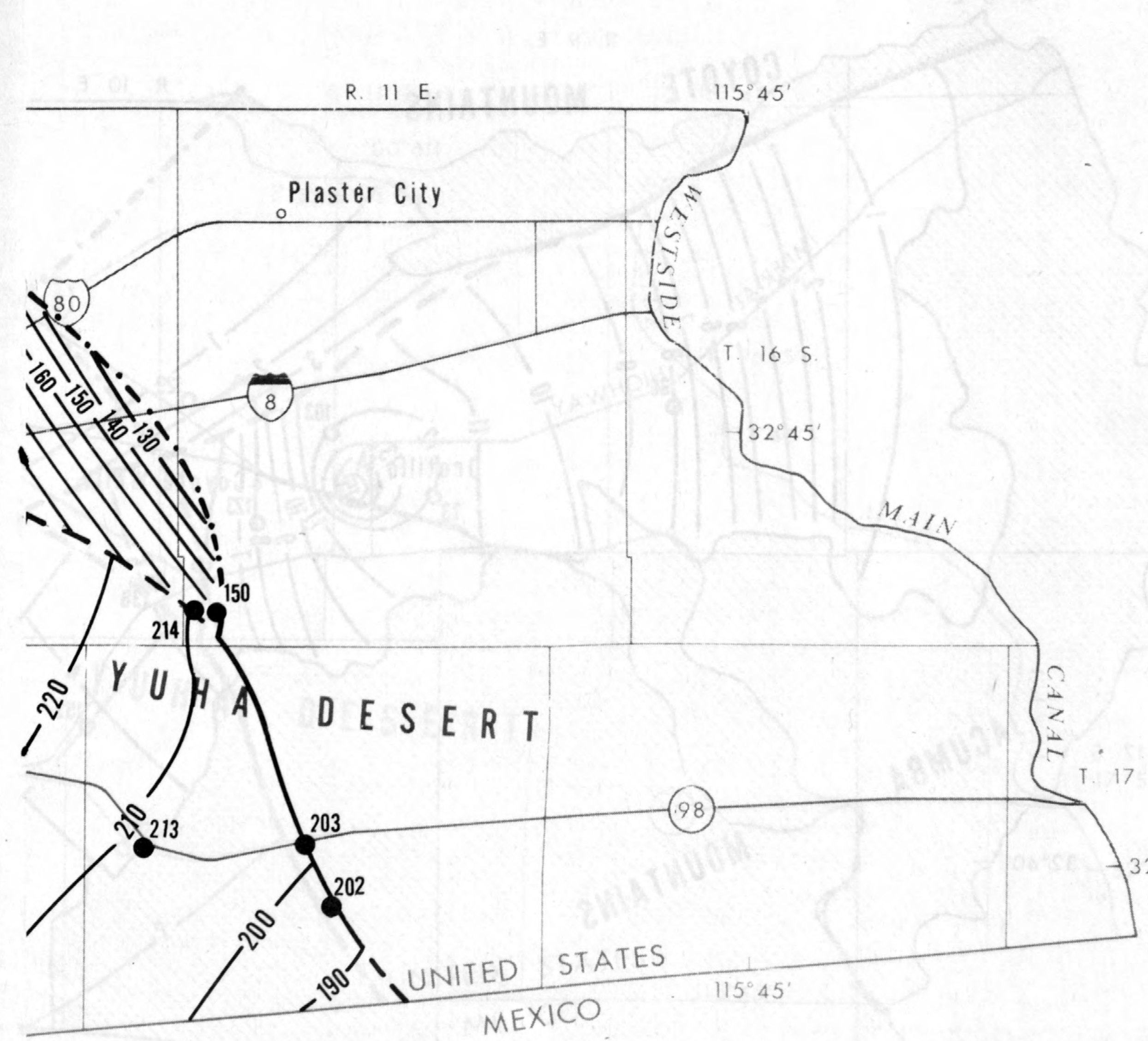


FIGURE 11.--Simulated water-level contours, December 1975.



EXPLANATION

UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCKS--Non-water-bearing

FAULT--Dashed where approximately located and concealed

PARTIAL GROUND-WATER BARRIER

280 WATER-LEVEL CONTOUR--Shows altitude of water level. Contour interval, in feet, variable. Datum is mean sea level

268 1974-75 MEASURED WATER LEVEL, IN FEET, ABOVE MEAN SEA LEVEL

FIGURE 11.--Continued.

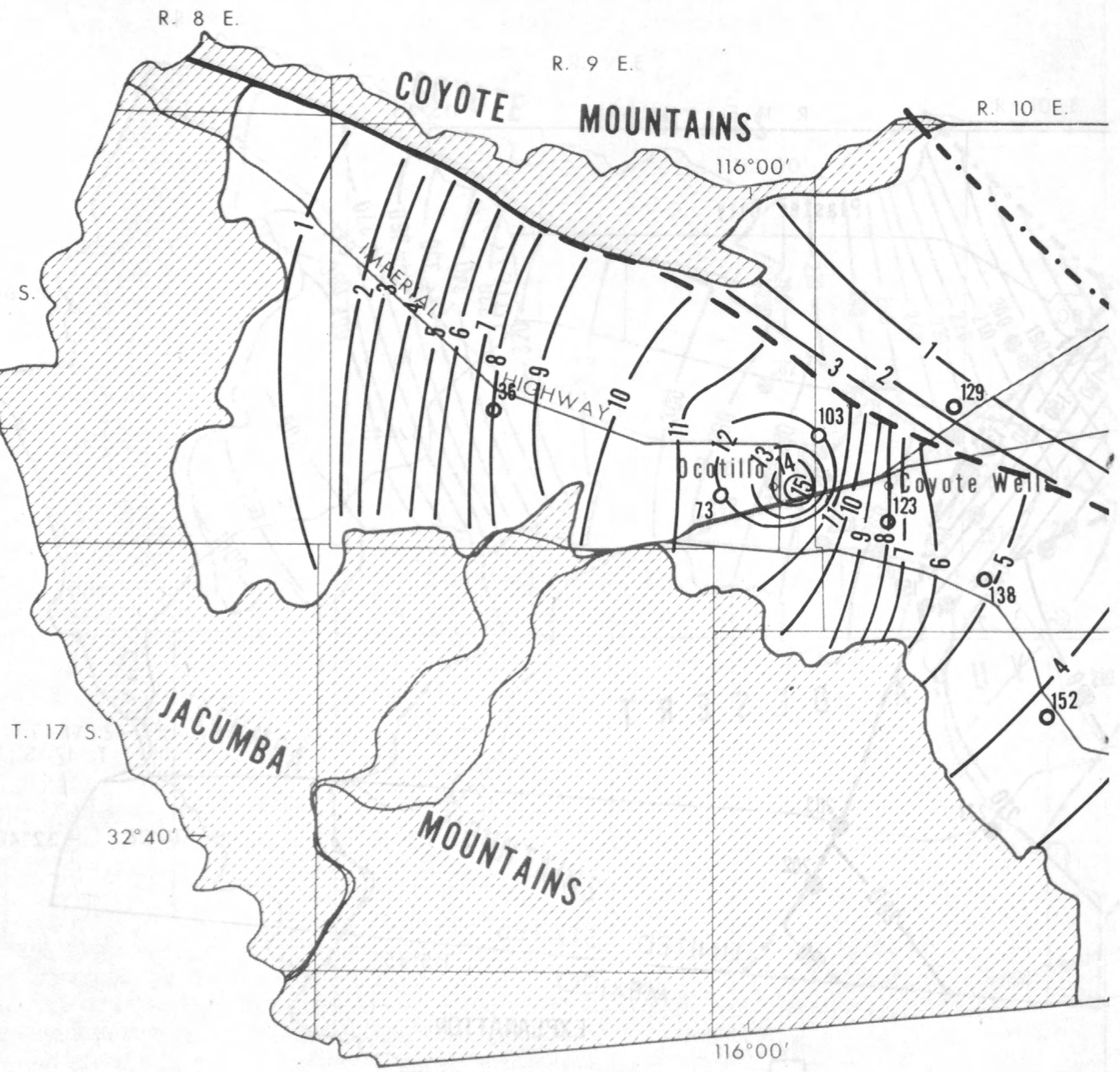
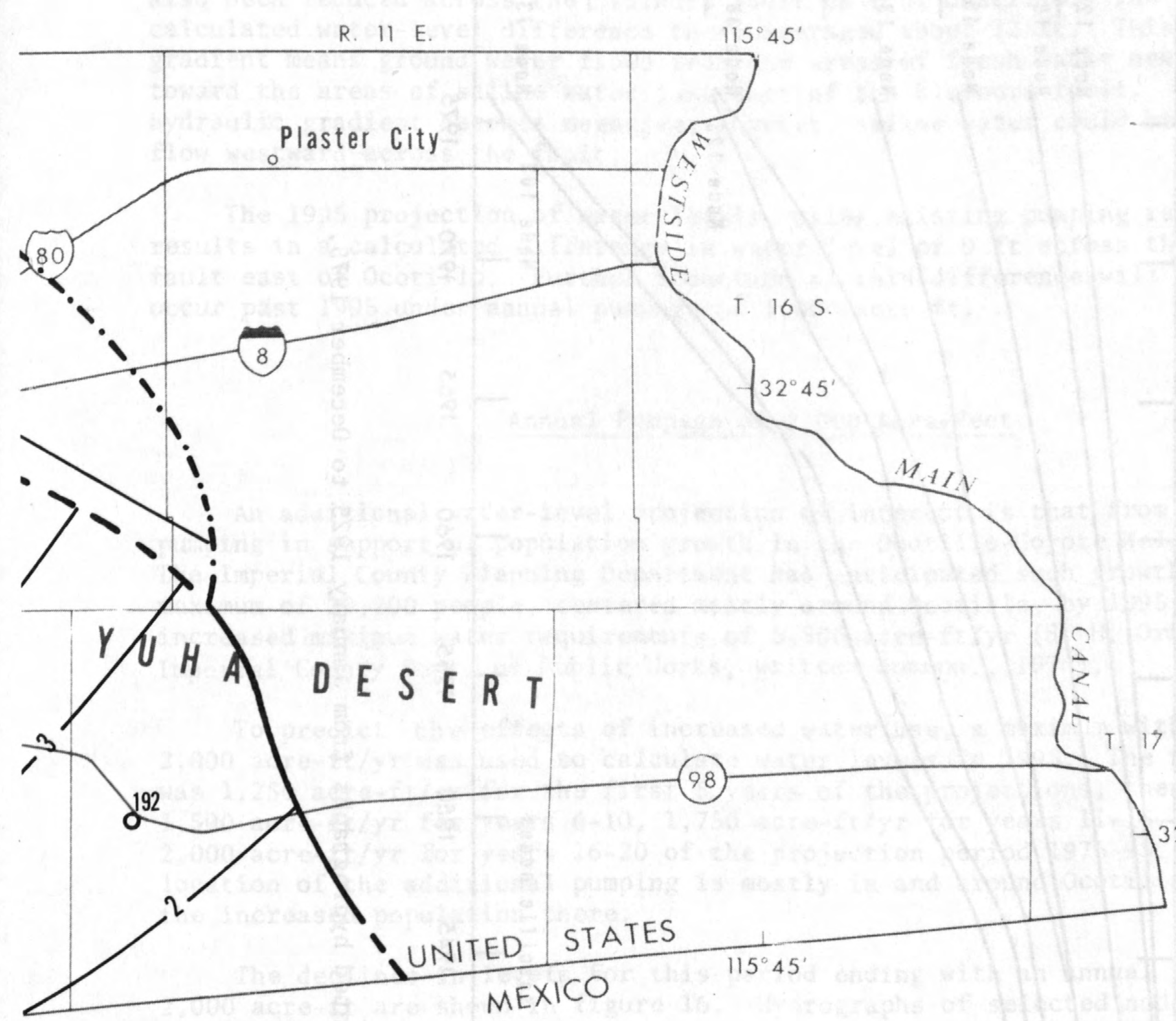


FIGURE 12.--Simulated water-level decline from January 1925 to December 1975.



EXPLANATION

UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCKS--Non-water-bearing

FAULT--Dashed where approximately located and concealed

PARTIAL GROUND-WATER BARRIER

2 LINE OF EQUAL WATER-LEVEL DECLINE--Interval 1 foot

O 138 NODE NUMBER

FIGURE 12.--Continued.

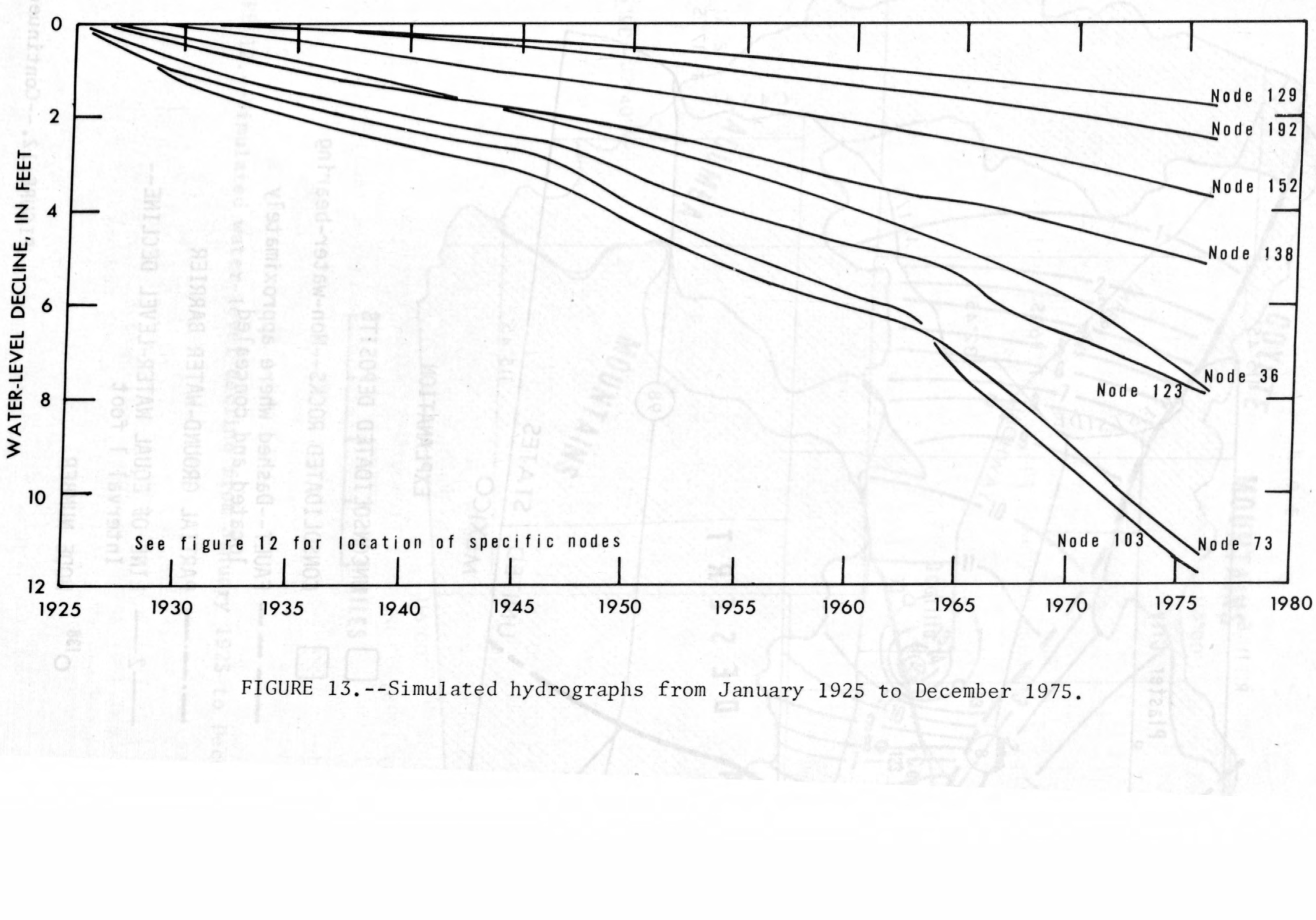


FIGURE 13.--Simulated hydrographs from January 1925 to December 1975.

This decline, projected from existing pumpage, represents loss from storage of about 11,000 acre-ft over 20 years. The hydraulic gradient has also been reduced across the Elsinore fault east of Ocotillo. The 1975 calculated water-level difference there averaged about 12 ft. This positive gradient means ground water flows from the areas of fresh water near Ocotillo toward the areas of saline water just east of the Elsinore fault. If the hydraulic gradient becomes negative, however, saline water could begin to flow westward across the fault.

The 1995 projection of water levels, using existing pumping rates, results in a calculated difference in water level of 9 ft across the Elsinore fault east of Ocotillo. Further reduction of this difference will probably occur past 1995 under annual pumpage of 1,000 acre-ft.

Annual Pumpage of 2,000 Acre-Feet

An additional water-level projection of interest is that from increased pumping in support of population growth in the Ocotillo-Coyote Wells basin. The Imperial County Planning Department has anticipated such growth to reach a maximum of 22,200 people, centered mostly around Ocotillo, by 1995 with increased maximum water requirements of 5,500 acre-ft/yr (S. H. Orfanos, Imperial County Dept. of Public Works, written commun., 1976).

To predict the effects of increased water use, a maximum withdrawal of 2,000 acre-ft/yr was used to calculate water levels in 1995. The pumpage used was 1,250 acre-ft/yr for the first 5 years of the projections, then 1,500 acre-ft/yr for years 6-10, 1,750 acre-ft/yr for years 11-15, and finally 2,000 acre-ft/yr for years 16-20 of the projection period 1976-95. The location of the additional pumping is mostly in and around Ocotillo to support the increased population there.

The declines in levels for this period ending with an annual pumpage of 2,000 acre-ft are shown in figure 16. Hydrographs of selected nodes shown in figure 12 are given in figure 17.

By 1995, using this projection, water levels across the Elsinore fault east of Ocotillo would be approximately equal, so that further pumpage in subsequent years may cause saline water east of the fault to flow toward Ocotillo and eventually degrade ground-water quality there.

POSSIBLE FUTURE STUDIES

The digital model of the Ocotillo-Coyote Wells basin utilizes all available hydrologic data, but it still remains a generalization of a more complex real system. With additional areal coverage of data on water levels

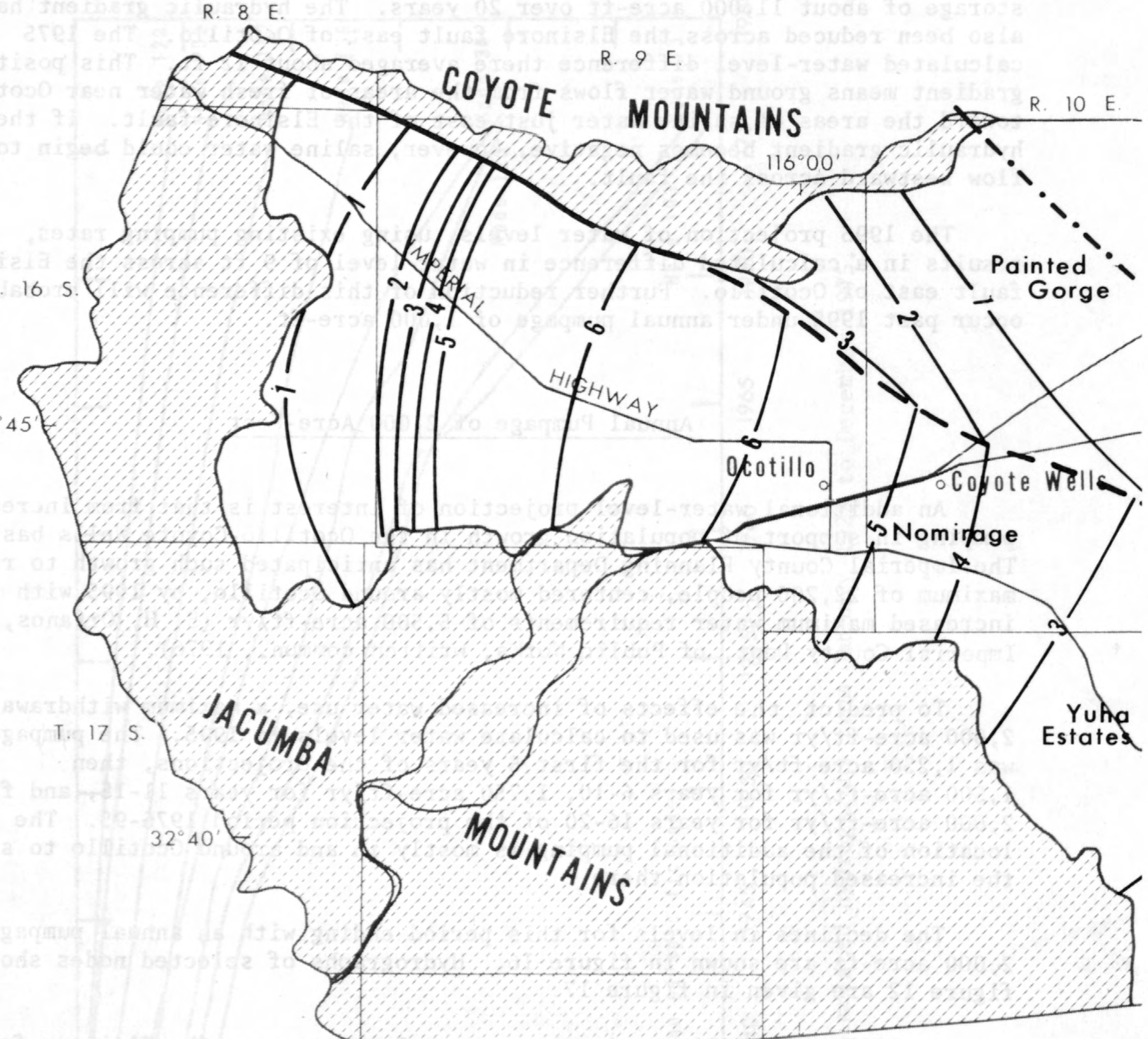
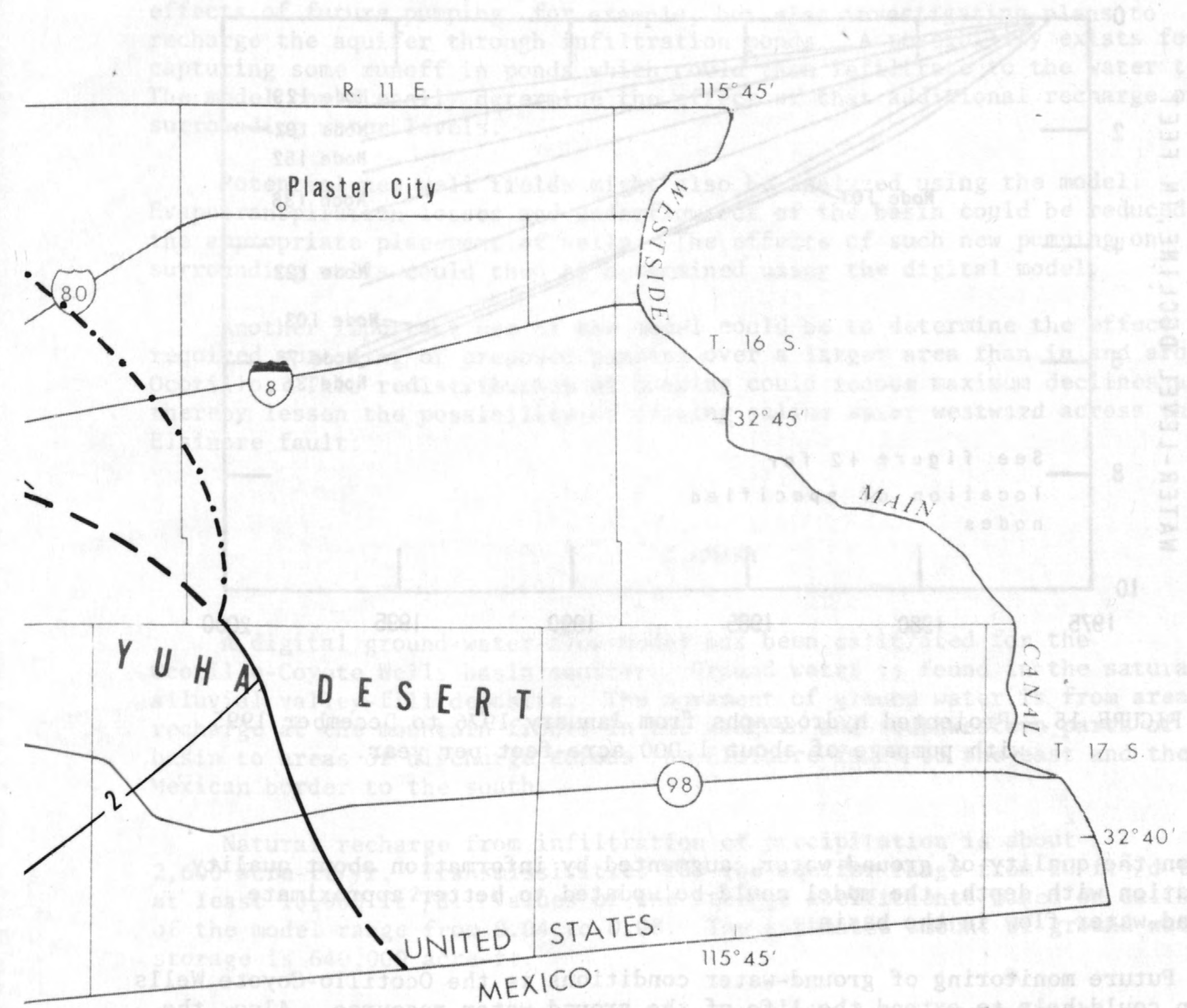


FIGURE 14.--Simulated water-level decline from January 1976 to December 1995 with pumpage of about 1,000 acre-feet per year.



EXPLANATION

UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCKS--Non-water-bearing

FAULT--Dashed where approximately located and concealed

PARTIAL GROUND-WATER BARRIER

6 LINE OF EQUAL WATER-LEVEL DECLINE--Interval 1 foot

FIGURE 14.--Continued.

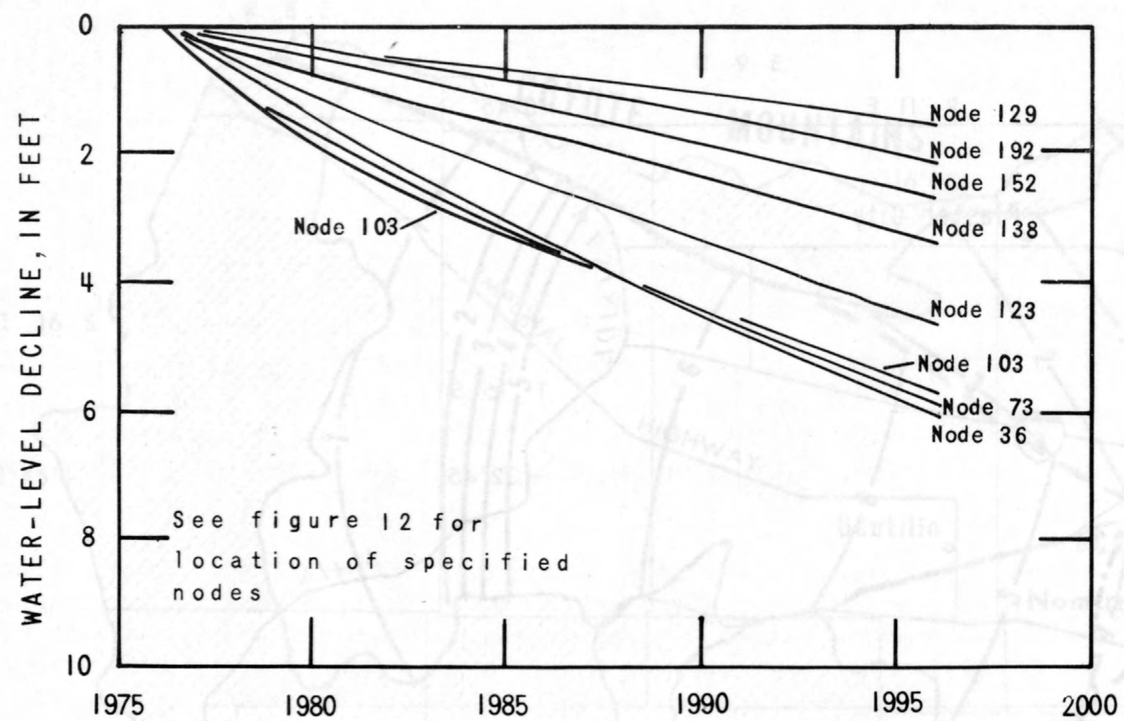


FIGURE 15.--Projected hydrographs from January 1976 to December 1995 with pumpage of about 1,000 acre-feet per year.

and on the quality of ground water, augmented by information about quality variation with depth, the model could be updated to better approximate ground-water flow in the basin.

Future monitoring of ground-water conditions in the Ocotillo-Coyote Wells basin could help to extend the life of the ground-water resource. Also, the potential hazard of drawing saline ground water westward toward Ocotillo across the Elsinore fault could be analyzed using future water levels and chemical analyses.

Additional test holes would better define the head differences across the fault east of Ocotillo as well as identify deteriorating quality in water samples from these and other nearby wells.

Possible uses of the digital model include not only determining the effects of future pumping, for example, but also investigating plans to recharge the aquifer through infiltration ponds. A possibility exists for capturing some runoff in ponds which could then infiltrate to the water table. The model could easily determine the effect of that additional recharge on surrounding water levels.

Potential new well fields might also be analyzed using the model. Evapotranspiration losses and underflow out of the basin could be reduced by the appropriate placement of wells. The effects of such new pumping on surrounding wells could then be determined using the digital model.

Another important use of the model could be to determine the effect of required spreading of proposed pumping over a larger area than in and around Ocotillo. This redistribution of pumping could reduce maximum declines and thereby lessen the possibility of drawing saline water westward across the Elsinore fault.

SUMMARY

A digital ground-water-flow model has been calibrated for the Ocotillo-Coyote Wells basin aquifer. Ground water is found in the saturated alluvial valley-fill deposits. The movement of ground water is from areas of recharge at the mountain fronts in the western and southwestern parts of the basin to areas of discharge across the Elsinore fault to the east and the Mexican border to the south.

Natural recharge from infiltration of precipitation is about 2,600 acre-ft/yr. Transmissivities for the aquifer range from 20 ft^2/d to at least 10,000 ft^2/d. Values of the storage coefficients based on calibration of the model range from 0.04 to 0.08. The estimated amount of ground water in storage is 640,000 acre-ft.

Pumpage in the basin parallels the economic development in the Ocotillo-Coyote Wells area. Prior to 1925, ground-water withdrawal was for domestic supply in the Coyote Wells area. In 1925 a railroad well was drilled for locomotive supply and an industrial well was drilled to support a gypsum plant in Plaster City. Since that time this industrial supply has been augmented by additional wells in Ocotillo.

Pumpage for public supply has also increased to support additional population. Throughout the years several wells have supplied water that was tanked to Mexicali bottling companies. Basinwide pumpage in 1975 was 880 acre-ft with about 90 percent of this pumpage centered in Ocotillo.

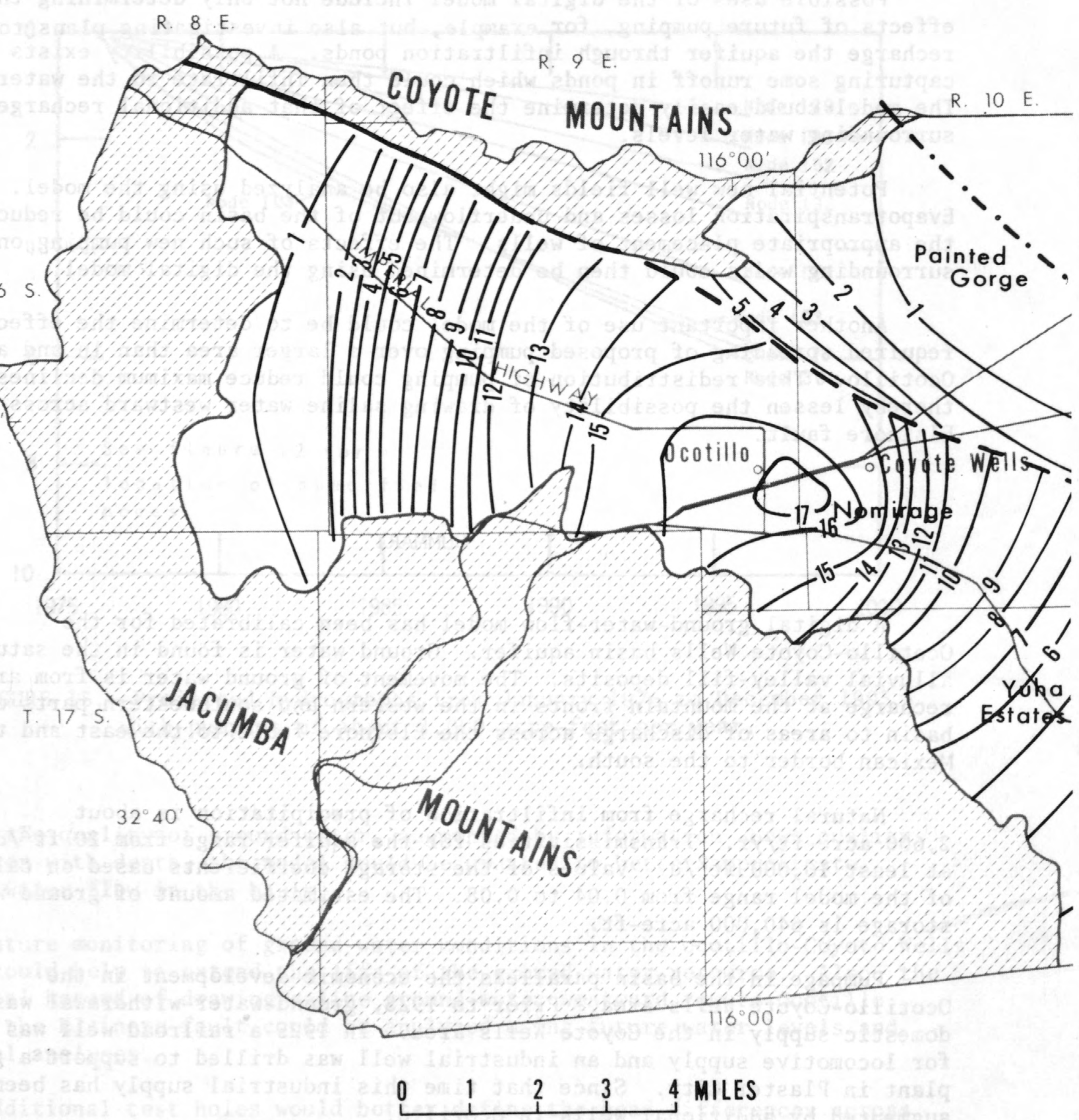
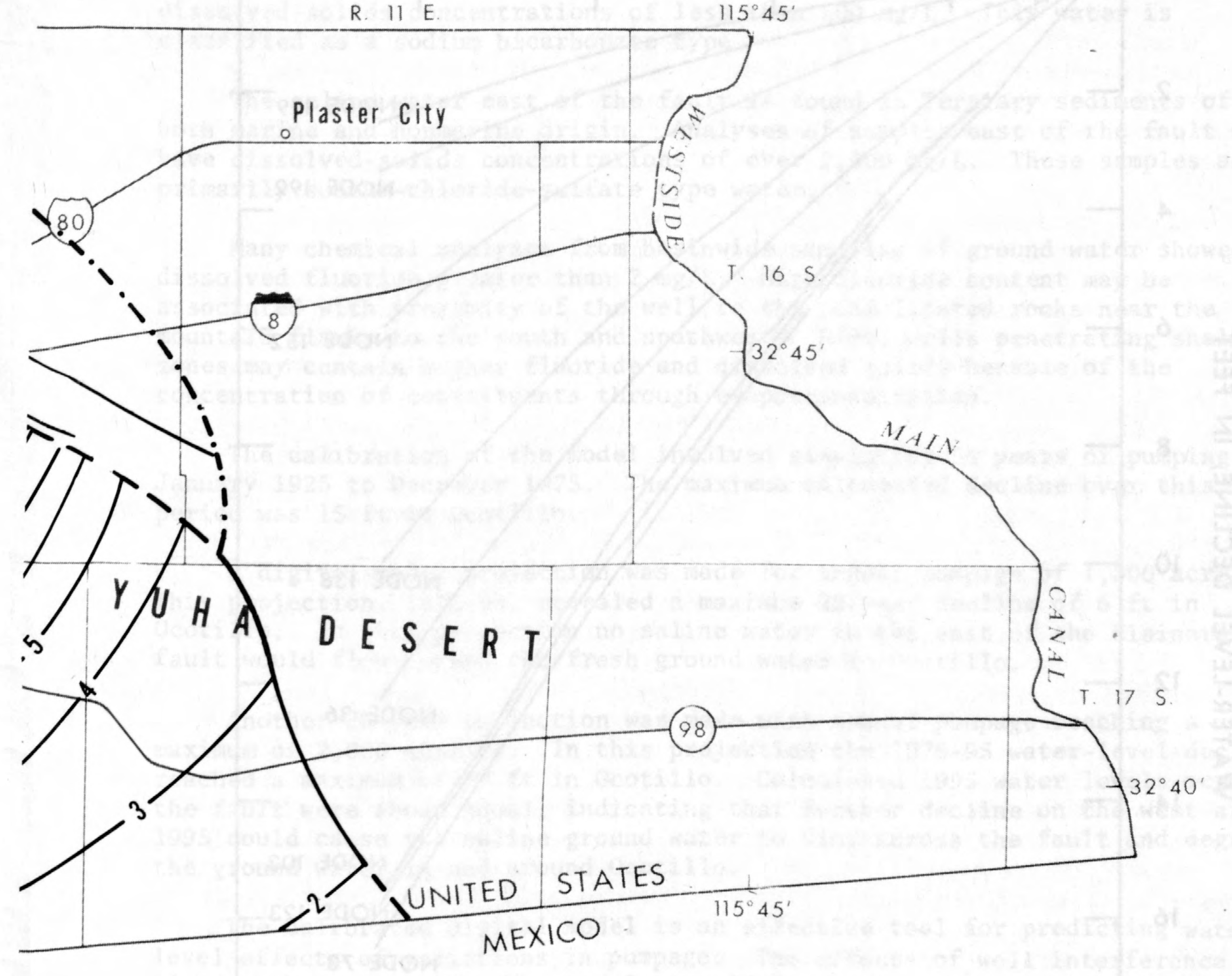


FIGURE 16.--Simulated water-level decline from January 1976 to December 1995 with pumpage reaching a maximum of about 2,000 acre-feet per year.



EXPLANATION

UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCKS--Non-water-bearing

FAULT--Dashed where approximately located and concealed

PARTIAL GROUND-WATER BARRIER

—6— LINE OF EQUAL WATER-LEVEL DECLINE--Interval 1 foot

FIGURE 16.--Continued.

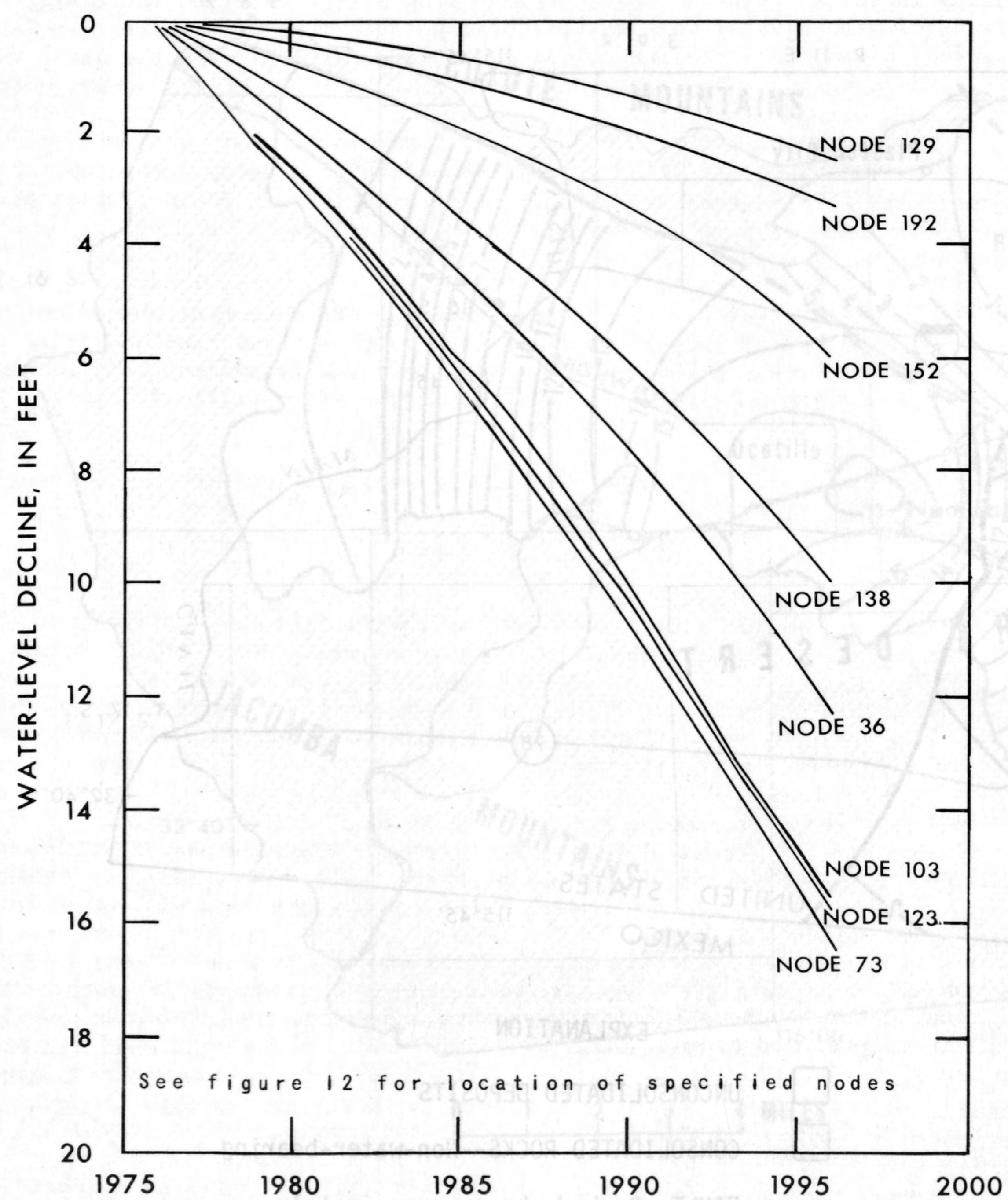


FIGURE 17.--Projected hydrographs from January 1976 to December 1995 with pumpage reaching a maximum of about 2,000 acre-feet per year.

The Elsinore fault separates fresh ground water in the Quaternary alluvium in the western part of the basin from saline water to the east. Analyses of ground-water samples west of the fault most often have dissolved-solids concentrations of less than 500 mg/L. This water is classified as a sodium bicarbonate type.

The saline water east of the fault is found in Tertiary sediments of both marine and nonmarine origin. Analyses of samples east of the fault often have dissolved-solids concentrations of over 2,000 mg/L. These samples are primarily sodium-chloride-sulfate type water.

Many chemical analyses from basinwide sampling of ground water showed dissolved fluoride greater than 2 mg/L. High fluoride content may be associated with proximity of the well to the consolidated rocks near the mountain flanks to the south and southwest. Also, wells penetrating shallow zones may contain higher fluoride and dissolved solids because of the concentration of constituents through evapotranspiration.

The calibration of the model involved simulating 51 years of pumping from January 1925 to December 1975. The maximum calculated decline over this period was 15 ft in Ocotillo.

A digital-model projection was made for annual pumpage of 1,000 acre-ft. This projection, 1976-95, revealed a maximum 20-year decline of 6 ft in Ocotillo. In this projection no saline water to the east of the Elsinore fault would flow toward the fresh ground water in Ocotillo.

Another 20-year projection was made with annual pumpage reaching a maximum of 2,000 acre-ft. In this projection the 1976-95 water-level decline reached a maximum of 17 ft in Ocotillo. Calculated 1995 water levels across the fault were about equal, indicating that further decline on the west after 1995 could cause the saline ground water to flow across the fault and degrade the ground water in and around Ocotillo.

The calibrated digital model is an effective tool for predicting water-level effects of variations in pumpage. The effects of well interference also can be evaluated. The model can aid in evaluating potential sources of additional water, such as infiltration ponds capturing runoff or new well fields in undeveloped areas. Other possibilities include reducing evapotranspiration or underflow from the basin by the appropriate location of new wells.

The digital model of the Ocotillo-Coyote Wells basin aquifer is a simplification of a complex flow system, but it reflects all geologic and hydrologic data currently available. To increase its effectiveness the model will require updating when further data are collected. The existing model, however, can be an aid in evaluating proposed water-management plans in the Ocotillo-Coyote Wells basin.

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