State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES
Southern District

PLANNED UTILIZATION OF WATER RESOURCES IN ANTELOPE VALLEY

District Report

October 1980

Errata for

"Planned Utilization of Water Resources in Antelope Valley"

On page 4, column 1, paragraph 4, last line, the figures within the parentheses should be (30°F to 40°F) rather than (63°F to 72°F).

On page 56, Table 19, last column, the final number should be 5,161,480 acre-feet rather than 1,161,480 acre-feet.

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PLANNED UTILIZATION OF WATER RESOURCES IN ANTELOPE VALLEY

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CONVERSION FACTORS

Metric to Customary System of Measurement

Quantity	Metric Unit	Multiply by	To get customary equivalent
Length	millimetres (mm)	0.03937	inches (in)
	centimetres (cm) for snow depth	0.3937	inches (in)
	metres (m)	3.2808	feet (ft)
	kilometres (km)	0.62139	miles (m)
Area	square millimetres (mm^2)	0.00155	square inches (in^2)
	square metres (m^2)	10.764	square feet (ft^2)
	hectares (ha)	2.4710	acres (ac)
	square kilometres (km^2)	0.3861	square miles (mi^2)
Volume	litres (l)	0.26417	gallons (gal)
	megalitres	0.26417	million gallons (10^6 gal)
	cubic metres (m^3)	35.315	cubic feet (ft^3)
	cubic metres (m^3)	1.308	cubic yards (yd^3)
	cubic metres (m^3)	0.0008107	acre-feet (ac-ft)
	cubic dekametres (dam^3)	0.8107	acre-feet (ac-ft)
	cubic hectometres (hm^3)	0.8107	thousands of acre-feet
	cubic kilometres (km^3)	0.8107	millions of acre-feet
Flow	cubic metres per second (m^3/s)	35.315	cubic feet per second (ft^3/s)
	litres per minute (l/min)	0.26417	gallons per minute (gal/min)
	litres per day (l/day)	0.26417	gallons per day)(gal/day)
	megalitres per day (Ml/day)	0.26417	million gallons per day (mgd)
	cubic metres per day (m^3/day)	0.0008107	acre-feet per day
Mass	kilograms (kg)	2.2046	pounds (lb)
	tonne (t)	1.1023	tons (short, 2,000 lb)
Velocity	metres per second (m/s)	3.2808	feet per second (ft/s)
Power	kilowatts (kW)	1.3405	horsepower (hp)
Pressure	kilopascals (kPa)	0.145054	pounds per square inch (psi)
	kilopascals (kPa)	0.33456	feet head of water
Specific capacity	litres per minute per metre drawdown	0.08052	gallons per minute per foot drawdown
Concentration	milligrams per litre (mg/l)	1.0	parts per million
Electrical conductivity	microsiemens per centimetre (μS/cm)	1.0	micromho per centimetre
Temperature	degrees Celsius (°C)	(1.8 × °C) + 32	degree Fahrenheit (°F)

FOREWORD

Heavy reliance on the local ground water supply is characteristic of many areas in Southern California. The Antelope Valley, which lies astride the Los Angeles, Kern, and San Bernardino County lines, is no exception. Currently, about 90 percent of the total water supply comes from the Valley's ground water basins. The remainder comes from the limited local surface water and reclaimed water and increasing amounts of imported water from the State Water Project. This heavy burden on the ground water basins has resulted in marked declines in ground water levels in the Valley.

At the same time, the choice of Palmdale in Antelope Valley as the site for a proposed major regional airport is expected to result in a significant increase in population.

Recognizing the need for local agencies to develop water resources management plans to cope with these two conditions, the Department of Water Resources in 1972 undertook a comprehensive investigation in cooperation with the County of Los Angeles and the United States Geological Survey to examine various alternative plans for meeting future water demands in the Valley.

The investigation entailed an inventory of the various sources of water supply, examination of factors influencing the demand, and evaluation of management alternatives for 1975-2020.

From this study, a "No-Change-in-Storage" plan is recommended, based on an evaluation of conditions that existed during the early part of 1980. Before a final water management plan is selected by local entities, however, a final assessment of the applicability of the recommended plan, in light of conditions that prevail at that time, should be made by major water users and organizations entrusted with water-related responsibilities. The leadership should be taken by the County Board of Supervisors, with ample opportunities provided for farmers, who are most significantly affected by any water management plan, to be heard.

To make possible implementation of a selected management plan with full cooperation from all concerned, a financial arrangement would be needed to make equitable distribution of both benefits and costs. The establishment of this arrangement should be based on a study to identify the benefited and the damaged and to formulate a plan for equitable distribution. Such a study would ensure that the selected management plan indeed represents a beneficial choice.

Jack J. Coe, Chief
Southern District

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ACKNOWLEDGMENTS

The Antelope Valley Technical Advisory Committee was established at the commencement of the study in 1972 to provide guidance to the investigators. Composed of members directly involved with the future of the study area, it considered a number of significant issues which developed as the study progressed. Its member agencies and individuals who participated in the meeting were:

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SUPPLEMENTAL DATA

The following Technical Information Records (TIRs) were prepared during the course of this study to document pertinent information derived from the investigation. Copies of the TIRs may be read in the Southern District office of the Department of Water Resources, 849 South Broadway, Los Angeles.

"A Preliminary Evaluation of Adequacy of Data for the Formulation of a Mathematical Water Quality Model of Antelope Valley", TIR 1335-6-A-1, 1975.

"A Preliminary Evaluation of Geologic Bases for the Selection of Spreading Grounds in the Antelope Valley Study Area", TIR 1335-6-A-2, 1976.

"A Preliminary Evaluation of Ground Water Quality Near Littlerock and Pearblossom in Antelope Valley", TIR 1335-6-A-3, 1976.

"A Preliminary Evaluation of Ground Water in Storage in the Antelope Valley Ground Water Model Area", TIR 1335-6-A-4, 1977.

"A Preliminary Evaluation of Ground Water Quality in the Antelope Valley", TIR 1335-6-A-5, 1979.

"A Preliminary Evaluation and Inventory of Water Supplies in the Antelope Valley", TIR 1335-6-B-1, 1978.

"A Preliminary Evaluation of Projections of Ground Water Levels Under Alternative Operating Conditions of the Antelope Valley Ground Water Basin", TIR 1335-6-C-1, 1977.

"A Preliminary Evaluation of Historical and Projected Water Demand, Antelope Valley", TIR 1335-6-C-2, 1977.

In addition, the U. S. Geological Survey has prepared a report to complete the earlier phase of the investigation. (See reference 40 in back of report.)

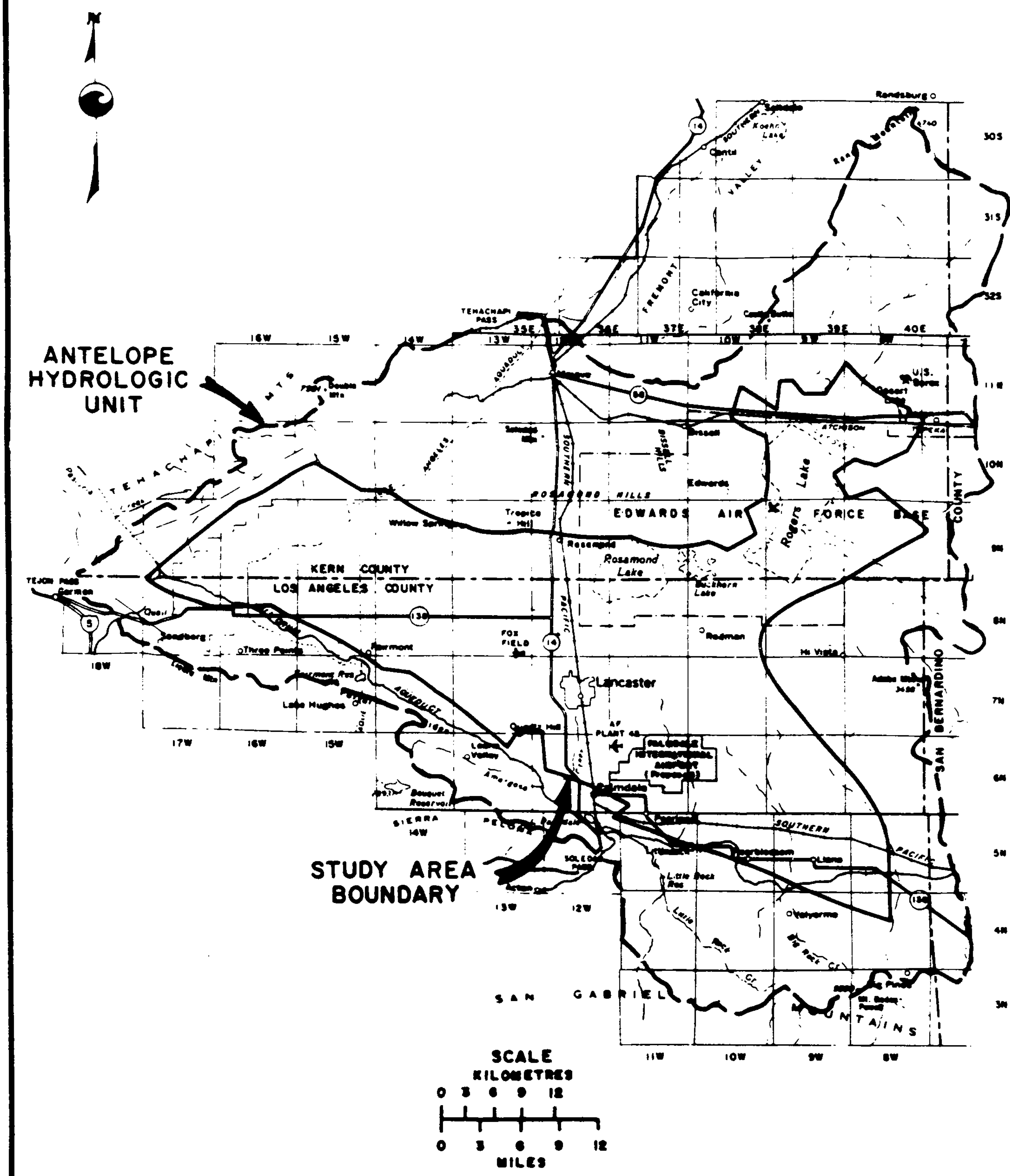


FIGURE 1-STUDY AREA

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1980

I. INTRODUCTION AND SUMMARY

The Antelope Valley (Figure 1), which is one of the few remaining portions of Los Angeles County with large blocks of undeveloped level land, retains portions of the agricultural economy that once dominated the county. Location and climate have served to retard growth in the Antelope Valley, in comparison with the rapid growth which has characterized the coastal and near coastal areas. With the nearly complete urbanization of these areas, new urban development is spilling over into the Valley. The expanding aerospace industry and proposed international airport will accelerate this trend.

The arid climate of the Valley, although conducive to rapid crop growth, dictates a heavy reliance on ground water to satisfy the needs of both the agricultural and urban communities. Since 1900, when the initial steps were taken toward the full development of irrigated agriculture, ground water levels have consistently declined, especially in the heavy agricultural pumping area centered around Lancaster where as much as 60 metres (200 feet) of decline have been found. Increasing pump lifts, coupled with spreading urbanization and the high cost of imported water, will probably reduce the area farmed; however, agriculture will remain a basic part of the Valley's economy for some time to come.

Recognizing the need to prepare a feasible water resources management plan to ease the strain on the heavily burdened ground water supply, the California Department of Water Resources (DWR), the County of Los Angeles, and the U. S. Geological Survey (USGS) entered into a cooperative agreement to conduct an investigation of the Antelope Valley which was carried out in six phases. The last phase has been completed, and the results of the overall investigation are reported here. Details on the various aspects of the study are contained in a series of technical information records, copies of which are available in the Southern District office of DWR.

Objective of Investigation

The objective of this investigation was to formulate and evaluate alternatives for operating the Antelope Valley Ground Water Basin as part of a comprehensive water management plan. These alternatives, which were developed by DWR in close coordination with a technical advisory committee (TAC), can be used by the local agencies to ensure that future water demands can be met.

Scope and Conduct of the Investigation

The three cooperating agencies agreed to share the cost of the investigation as follows: The County of Los Angeles and DWR each provided 35.9 percent of the funds and USGS, 28.2 percent. Involved was a resources and requirements survey of Antelope Valley, culminating in the development of plans for coordinated use of the various supplies available--ground water, imported State Water Project (SWP) water, local surface water, and reclaimed water. The study area (Figure 1) was chosen by the TAC to facilitate the creation of a ground water basin model by USGS. The time frame for the study was 1975-2020. The six phases of the study were:

Phase I. Collect geohydrologic data and develop mathematical ground water model.

Phase II. Develop the study program in cooperation with the TAC.

Phase III. Determine historical water use, update population projections, and cooperate with the TAC in selecting water demand projections to be used in analyzing the alternative plans developed.

Phase IV. Evaluate the local and imported water supplies available including an assessment of the probability of delivering SWP water to the Valley.

Phase V. Formulate areawide alternative plans for water management and, in cooperation with the TAC, select those plans to receive detailed analysis.

Phase VI. Analyze the selected alternatives.

Phase VII. Summarize and prepare the final report.

Basic data such as ground water levels were obtained from the cooperating agencies to estimate water demand, inventory water supplies, and examine the economic costs of the various alternatives. USGS conducted field studies and developed a finite-element mathematical model of the ground water basin. This model was used to examine the flow characteristics and response of basin ground water level elevations under the various pumping and recharge patterns imposed by the alternative plans. The economic evaluations of all plans, as well as consideration of land subsidence, flood hazards, and other environmental aspects of the plans, were done by DWR in concert with the TAC.

In this study, USGS has applied the term "conditions" to the various management plans developed. Thus, in this report, the terms "alternative plans" and "alternative operating conditions" are used interchangeably.

Area of Investigation

The Antelope Valley, a desert basin with internal drainage, is about 64 kilometres (40 miles) north of downtown Los Angeles, astride the Kern, Los Angeles, and San Bernardino County lines. Its more than 5 200 square kilometres (2,000 square miles) lie in the western Mojave Desert, between the Coast Ranges to the west and the Basin and Range Province to the east. It is isolated from the densely populated coastal areas to the south by the Transverse Ranges, which include the San Gabriel Mountains. The Tehachapi Mountains bordering to the northwest separate the Antelope Valley from the rich San Joaquin Valley. The Rosamond and Bissell Hills bound the Valley to the north; a series of granitic hills and buttes form the boundary to the east.

The study area (Figure 1) was defined by the USGS in an earlier phase of the investigation (40)*. It differs from the Antelope Hydrologic Unit used in past DWR reports in that it excludes much of the surface drainage north of the Rosamond Hills including the Mojave area. The two major communities are Lancaster, with a population of 45,625, and Palmdale, with a population of 10,417.** The bulk of the population lives in the Palmdale-Lancaster-Quartz Hill triangle. A small percentage lives in the Kern County towns of Rosamond, Edwards, and Boron.

The main avenues of approach to the Valley are through Soledad Pass (State Route 14) from the south, Tejon Pass (State Route 138) from the west, and Tehachapi Pass (State Route 58) from the northwest. The Valley is served by the Santa Fe and Southern Pacific railroads. The major airfields are William J. Fox Field, northwest of Lancaster, Palmdale International Airport at Air Force Plant 42, and Edwards Air Force Base. The Edwards

* Numbers in parentheses refer to reports listed in the back of the report.
** Los Angeles County Planning Commission estimates as of July 1, 1978.

SITE of proposed Palmdale International Airport is astride the Little Rock Creek wash. In the right foreground is the community of Littlerock.

runways are strictly for military traffic. The City of Los Angeles now plans to build a major regional airport to serve the north county at a site near the present Palmdale International Airport.

Geology

Antelope Valley is part of an untilted fault block lying between the San Andreas and Garlock faults, which intersect near the community of Gorman to the west. The surrounding highlands have been uplifted considerably in recent geologic times and have contributed a large quantity of eroded debris to the Valley floor.

Granitic and metamorphic rocks dominate the San Gabriel Mountains, which rise to 2 865 metres (9,399 feet) at Mt. Baden-Powell on the divide. The Tehachapi Mountains attain an elevation of 2 433 metres (7,981 feet) at Double Mountain.

The Valley floor is broken by remnant peaks protruding through the alluvium and locally termed buttes. Sedimentary deposits fill the basin to depths of as much as 2 400 metres (8,000 feet). (49). Older alluvium, which composes the bulk of the water-bearing deposits, is locally as much as 1 500 metres (5,000 feet) thick (40).

The elevation of the Valley floor ranges from about 910 metres (3,000 feet) along its borders down to 690 metres (2,270 feet) above sea level at Rosamond Dry Lake and 682 metres (2,237 feet) at Rogers Dry Lake.

Unlike other closed basins in the Mojave Desert, such as Searles Lake, Antelope Valley does not generally have saline waters with dissolved solids concentrations greater than 3 000 milligrams per litre (mg/L). The only indications of saline deposits are around Rogers Dry Lake, in the surface clay of Rosamond Dry Lake, and in the soil for several kilometres around its western and southern perimeter (38). This alkali presumably was deposited as ground water evaporated in this area.

The quality of water below the 610-metre (2,000-foot) depth penetrated by the deepest water wells is unknown. The existence of saline clays in the thick sedimentary deposits underlying the Antelope Valley other than around Rogers Dry Lake has been speculated upon; however, evidence from deep oil test holes has indicated no buried lakebeds (38).

Climate

The Antelope Valley has a semiarid desert climate with cool, moist winters and hot, dry summers. Lying in the rainshadow of the mountains, it receives less precipitation than the coastal regions of Southern California, which benefit from orographic rainfall on the windward slopes. About three-fourths of the annual precipitation falls from December through March. Precipitation generally increases with altitude, from less than 250 millimetres (10 inches) on the Valley floor to more than 1 000 millimetres (40 inches) in the higher elevations of the San Gabriel Mountains. The highest mean annual precipitation on the Valley floor is found in the west near Fairmont Reservoir with 380 millimetres (15 inches)--adequate for dry farming. Occasionally, during summer and fall, winds from the east will bring sudden thundershowers and high humidity from the Gulf of California.

The growing season in Antelope Valley averages 215 to 245 days (61), which is not as lengthy as that in the Imperial Valley, San Joaquin Valley, or coastal plains of Southern California.

There are about 350 good flying days per year at Edwards Air Force Base (45).

Isolated from the moderating influence of the ocean, the Valley has a climate that is more extreme than that found along the coast. Temperatures often exceed 38°C (100°F) during the summer and may drop below freezing in winter. They fluctuate as widely as 17° to 22°C (62°F to 72°F) in a single day.

Variable westerly winds prevail for most of the year in Antelope Valley.

The most damaging winds scour the Valley during spring and early summer when young alfalfa is vulnerable; Arizona cypress and other shrubs are therefore planted as windbreaks.

The Valley has an annual net atmospheric-water deficiency, which is characteristic of arid regions. During 1939-59, mean annual pan evaporation at Backus Ranch (T10N, R12W, Section 20), just north of the study area, was 2.90 metres (114 inches, or 9.5 feet), as measured by the U. S. Weather Bureau (2).

Agriculture and Industry

Agriculture in Antelope Valley is fairly diversified, with the emphasis on livestock and feed production. The poultry industry, although declining in recent years, is a major part of livestock production in the Valley. Some of the turkey and chicken breeding industry in Los Angeles County moved north to the Valley as the San Fernando Valley was urbanized.

Wheat and barley are dry-farmed in the western valley. These farms, which are heavily mechanized, average about 4.0 square kilometres (1,000 acres) in size (45). There was a surge in irrigated acreage when Antelope Valley-East Kern Water Agency (AVEK) introduced SWP water to the western Valley in 1972 at prices competitive with the costs of pumping ground water.

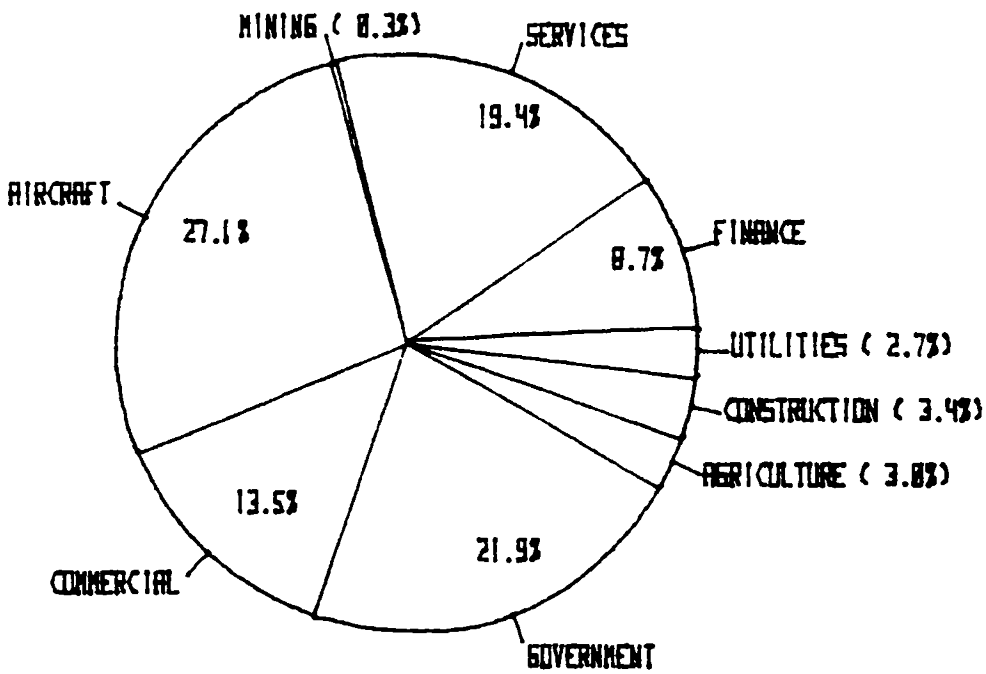
Irrigated agriculture is primarily concentrated in a band in the center of the study area, avoiding the alkaline clay of the lower Valley. Alfalfa is the main crop, often with five cuttings per year. The alfalfa hay is shipped to the Chino-Ontario dairies as well as fed to local stock. The hay market flourished during the past several years of drought because the Valley's irrigated farmlands were able to supply hay to cattlemen hurt by drought-stricken grasslands. Nonetheless, the amount of land in irrigated agriculture has generally been declining since the mid-1960s.

Manufacturing is the main economic activity in Antelope Valley. The aerospace industry, which constitutes the bulk of the manufacturing base, is concentrated in the Los Angeles County portion of the Valley. At Air Force Plant 42 near Palmdale are a number of civil aircraft production and testing facilities where much of the aircraft produced in Southern California is tested. A recent breakdown of employment in the Valley is shown in Figure 2.

FIGURE 2

ANTELOPE VALLEY EMPLOYMENT *

ACTON TO L. A. COUNTY LINE



TOTAL EMPLOYMENT

Agriculture	1,200	Services	7,788
Construction	1,380	Mining	125
Utilities & Transportation	1,084	Aircraft Manufacture	10,829
Finance, Banking, Real Estate, Insurance	3,500	Commercial	5,431
		Government	8,804

Total = 40,141

*Source: Antelope Valley Board of Trade, 1979. Figures apply to period ending 1978.

Edwards Air Force Base covers 1 200 square kilometres (300,000 acres), much of it within the northeastern part of the study area. Established by the Army as a bombing range in the 1930s, it was converted into a flight test center for military aircraft following World War II. There are now production facilities as well as sites for missile research located at Edwards.

Gold is no longer mined at Tropico in the Rosamond Hills, and the mining area is now operated as a tourist attraction. Borax is actively mined near Kramer. Rock and gravel quarrying is conducted in the southeastern part of the Valley along the mountainfront. Clay used for drilling mud formerly was mined from Rosamond and Rogers Dry Lakes.

Summary of Findings

Findings obtained in the Antelope Valley investigation include:

1. The population in Antelope Valley is projected to grow from 94,000 in 1975 to 320,000 by 2020; the amount of irrigated land cannot be reliably projected because of the drastic changes in energy and water costs.

2. Assuming that present trends continue, the projected annual water demand would rise from an estimated 238 000 cubic dekametres (192,600 acre-feet) in 1975 to 316 000 cubic dekametres (255,900 acre-feet) in the year 2020, an average growth rate of 1 800 cubic dekametres (1,500 acre-feet) per year. The increase in demand is expected to be derived solely from growth in municipal and industrial water use because agricultural use is predicted to remain at present levels for the duration of the study period.

3. Urban demand in the study area could be reduced significantly through institution of conservation measures. In a recent study, this reduction was estimated to be as much as 21 percent by 2000 and 23 percent by 2020. Under these projections, the per capita demand would drop from the present 950 litres (250 gallons) per capita per day to 746 litres (197 gallons) per day by 2000 and to 730 litres (193 gallons) per day by the year 2020. Therefore, the adjusted total water demand in Antelope Valley would rise to 290 000 cubic dekametres (235,400 acre-feet) rather than 316 000 cubic dekametres (255,900 acre-feet), by the end of the study period in 2020.

4. In 1975, the Antelope Valley's sources of supply were ground water (92.8 percent of the total), imported water from the SWP (4.5 percent), local surface runoff (2.1 percent), and reclaimed water (0.6 percent), to make up a total 237 580 cubic (192,600 acre-feet).

5. In 1976, 1 540 cubic dekametres (1,250 acre-feet) of reclaimed water was used beneficially for irrigation and recreation. Los Angeles County Sanitation Districts are planning to provide an additional 2 800 cubic dekametres (2,200 acre-feet) annually of waste water from District 14 Water Reclamation Plant near Lancaster, currently discharged to ponds, to an alfalfa ranch to the west.

6. Little Rock and Big Rock Creeks provide approximately 5 060 cubic dekametres (4,100 acre-feet) of local surface water supply annually. One element of this supply network, Little Rock Dam, which now stores 1 233 cubic dekametres (1,000 acre-feet), is currently being investigated by DWR Safety of Dams Division with respect to its safety. The removal of this dam would increase the amount of flood runoff in Little Rock and Big

SAME VIEW IN 1936 AND 1979, looking northeast across the Valley and the community of Palmdale. Major changes include increased development along old Sierra Highway (in middle of both photos), completion of new freeway (lower left in lower photo), and construction of major facilities at Air Force Plant 42, such as the Lockheed plant (upper left in lower photo).

Rock Creeks, posing a threat to facilities in the floodplain.

7. In Antelope Valley, there are three major contractors for State Water Project water: the largest, AVEK, had an entitlement of 43 170 cubic dekametres (35,000 acre-feet) in 1975, which will increase to a maximum of 170 720 cubic dekametres (138,400 acre-feet) in 1991; Littlerock Creek Irrigation District, with 640 cubic dekametres (520 acre-feet) in 1975 rising to 2 840 cubic dekametres (2,300 acre-feet) in 1991; and Palmdale Water District, whose entitlement increases from 6 880 (5,580 acre-feet) in 1975 to 21 340 cubic dekametres (17,300 acre-feet) in 1991.

8. The Antelope Valley ground water basin is subdivided by faults and other physical features into West Antelope, Neenach, Buttes, Finger Buttes, Lancaster, Pearland, and North Muroc subbasins. However, knowledge of the basin is incomplete.

   The largest subbasin, Lancaster, is the only one composed of a two-aquifer system, the principal (upper) aquifer and the deep (lower) aquifer. The aquifers are separated by a series of layers which are mostly clay. In 1975, the principal aquifer supplied 213 200 cubic dekametres (172,800 acre-feet) and the confined deep aquifer 7 200 cubic dekametres (5,900 acre-feet) of water to the Valley.

9. The total ground-water storage capacity of Antelope Valley is estimated to be 84 million cubic dekametres (68 million acre-feet). In 1975, the amount of fresh water estimated to be in storage was 68 million cubic dekametres (55 million acre-feet).

10. Approximately 16 million cubic dekametres (13 million acre-feet) of storage was above the water table, a large part of which is available for future recharge operations. Because the average annual precipitation is less than 250 millimetres (10 inches) on the Valley floor, direct rainfall does not contribute recharge to the ground water basin. Natural recharge is derived largely from streamflow and near surface percolation whose source is precipitation in the surrounding mountains. Mean annual recharge to the basin is estimated to be 50 200 cubic dekametres (40,700 acre-feet).

11. The ground water is generally of good quality, with total dissolved solids (TDS) concentrations less than 500 mg/L. The water is characteristically calcium bicarbonate near the source mountains tending toward sodium bicarbonate in the north. The water from the deep aquifer tends to be sodium bicarbonate in character.

    Water with TDS concentration of 1 000 mg/L or more is found in the North Muroc Subbasin, around the borders of the Lancaster Subbasin, and in shallow wells scattered through the basin.

12. The sampling of wells has led to the discovery of elevated nitrate concentrations around the orchards of Littlerock and Quartz Hill.

13. From the evaluation of the various management alternatives (which covered options ranging from total reliance on ground water to meet demands to recharge of the basin with imported water to restore historic water levels) the following results were found:

    a. Use of the ground water model indicated that the Maximum Pumping Plan (Condition 4), which places total reliance on ground water for supply, will result in an average basinwide decline of 24 metres (78 feet) of water level elevation by 2020. The plan to recharge the basin and restore historic water levels, Maximum Recharge Plan (Condition 6), would yield a rise of 35.2 metres (115.5 feet) by 2020. Between these two conditions, the No-Change-in-Storage Plan (Condition 5) and the Full Entitlement Plan (Condition 7) would tend to stabilize ground water levels.

b. The estimated total energy consumption for 1975 to 2020 would range from 6.9 billion kilowatthours (kWh) under the Maximum Pumping Plan (Condition 4) to 57.5 billion kWh under the Maximum Recharge Plan (Condition 6). For the No-Change-in-Storage Plan (Condition 5), it would be 23 billion kWh and for the Full Entitlement Plan (Condition 7), 24.3 billion kWh.

c. Comparing the present worth of net costs (at 6 percent interest) for each alternative (including costs of ground water, imported water, and spreading program minus the savings in pumping costs after 2020), reveals costs which range from $268.3 million for the Maximum Pumping Plan (Condition 4) to a maximum $699.4 million for the Maximum Recharge Plan (Condition 6). For the No-Change-in-Storage Plan (Condition 5), the cost would be $364.8 million and for the Full Entitlement Plan (Condition 7), $391.0 million.

d. A model simulating the change in ground water quality in Antelope Valley cannot, at this time, be developed because of insufficient data.

14. Under most of the alternative plans, the amount of land under cultivation is likely to diminish, assuming that imported water costs assessed to agricultural users are on a par with the rates applied to municipal and industrial users. A possible exception might be the Maximum Recharge Plan (Condition 6) under which ground water levels would be restored to historic levels--allowing farmers to operate with smaller pumping lifts. (For the study, it was assumed that the area devoted to agriculture will remain at the 1975 level for the duration of the study period.)

Conclusions

Based on the findings made in this study, the following conclusions were drawn:

1. If the management objective is to arrive at a least-cost plan, maximum use of ground water would be the selection; however, to stabilize ground water levels as soon as possible, the coordinated use of ground water and SWP water would be necessary.

2. When the new Palmdale Airport is built, the expected resulting increase in population will generate additional waste water available for reclaiming. Reclaimed water use for agriculture will continue to rise with the increased future production of waste water if the Los Angeles County Sanitation Districts continue to provide it at a price competitive with the cost of pumping ground water.

3. Effects of flood flows in Little Rock and Big Rock Creeks as a result of the removal of Little Rock Dam could be mitigated

by constructing percolation ponds and improving spreading grounds.

4. Effective water conservation measures will reduce the cost of operation as well as total energy consumption in the Antelope Valley.

5. Closer monitoring of water quality is needed in problem areas such as Littlerock and Quartz Hill. In this regard, the Regional Water Quality Control Board, Lahontan Region, has specific objectives of an adequate surveillance and monitoring program to locate and identify sources of water pollution that pose an acute, accumulative or chronic threat to the environment.

6. Additional geohydrologic information would be needed for formulation of a water quality model. For example, the extent of deep percolation of water from the ground surface to the principal and deep aquifers must be determined. The degree of interconnection between the principal and deep aquifers must also be defined.

Recommendations

Based on the preceding conclusions, the following recommendations are made in concert with the TAC:

1. The No-Change-in-Storage Plan (Condition 5) be the plan implemented by the local agencies to provide maximum ensurance of a long-term reliable supply of water for the Antelope Valley. This plan is feasible provided that adequate SWP water is made available. Although this plan uses more energy and has a higher cost than the Maximum Pumping Plan (Condition 4), the advantage is that it halts the decline of ground water levels in the Valley while supplying the users with good quality SWP water.

2. Before a final plan is selected, an assessment be made of applicability of the plan to current conditions. The leadership should be taken by the County Board of Supervisors, with input from farmers and other agencies entrusted with water management responsibilities. Establishment of an additional water agency is not needed.

3. Urban water conservation measures be instituted where possible as a means of reducing water and energy demand, thus delaying the need for additional SWP facilities.

4. The present policy of encouraging appropriate use of reclaimed water as more reclaimed water becomes available be continued.

5. Floodplain management principles be employed to mitigate possible flooding in the floodplain and improve ground water recharge in the upper reaches of Little Rock and Big Rock Washes.

6. To defend against the sudden onset of future water quality problems, the representatives from participating agencies develop a plan to continue the program for data collection and analysis. As a part of this monitoring program, provisions should be made for pooling data for more detailed study such as time-series analysis. In portions of the Valley that are not regularly monitored, yet in which significant water quality changes may be occurring, the system of monitoring certain key wells should be developed. Whenever additional geohydrologic and geochemical information become available, the data should be analyzed. Also the water quality control plan for the Lahontan Region should be considered in future water quality studies.

II. WATER DEMAND AND SUPPLIES

In conducting the investigation, consideration was given first to examining the factors influencing demand, then to inventorying the various sources of water supplies to meet that demand.

Water Demand

The major demands for water in Antelope Valley are for agricultural and municipal and industrial uses. The water demand for recreational purposes is comparatively insignificant.

Historically, municipal and industrial use has been small. Palmdale, Lancaster, Littlerock, and other communities were founded to serve the local farmers. The railroad was the major industry, connecting Valley farmers with the major markets. Since World War II, however, economic growth has been independent of farming, reflecting the expansion of military and civilian aerospace activities, as well as the substantial growth in Southern California as a whole.

The construction of Palmdale International Airport will have a significant impact on future growth rates; the Los Angeles City Department of Airports is planning to build the airport in the early 1980s. Most of the land, at a cost of $80 million, has already been purchased by the City of Los Angeles. Although it has been scaled down to an airport capable of handling 12-15 million annual passengers from the originally envisioned 70 million annual passengers, it will increase the level of development in the Valley by attracting subsidiary industries and people.

The uncertainty and disagreement regarding the Valley's future growth make inevitable the publication of conflicting population projections and irrigated land estimates by various State and local agencies.

Projections

From among several projections of irrigated land for Antelope Valley made by various agencies, the TAC selected the projection of the Los Angeles County Planning Commission (Figure 3).

There has been a steady decline in agricultural land since the 1950s as a result of urban encroachment, increasing water costs, and rising land values. This decline halted in 1972 and the land under tillage has even risen slightly as the result of rising crop prices and the delivery by AVEK of imported water to agricultural users in the western portion of the Valley at prices competitive with the cost of pumping ground water. The availability of imported water to agricultural users is expected to drop sharply after 1983 when the renewal of SWP energy contracts sharply increases the cost of SWP water.

With consideration of this uncertainty in predicting future events, the TAC elected to assume that the cultivated land in the Valley will remain at about 142 000 hectares (35,000 acres) for the projection period of this study. This assumption was a reasonable one when it was made at the time the study was conducted. However, both the cost of energy and prices of agricultural products could significantly affect agriculture; therefore, continual updating is needed to develop an appropriate projection.

From among several projections of population made by various agencies, the most optimistic is given in the 1973

FIGURE 3

HISTORIC AND PROJECTED IRRIGATED ACREAGE ANTELOPE VALLEY

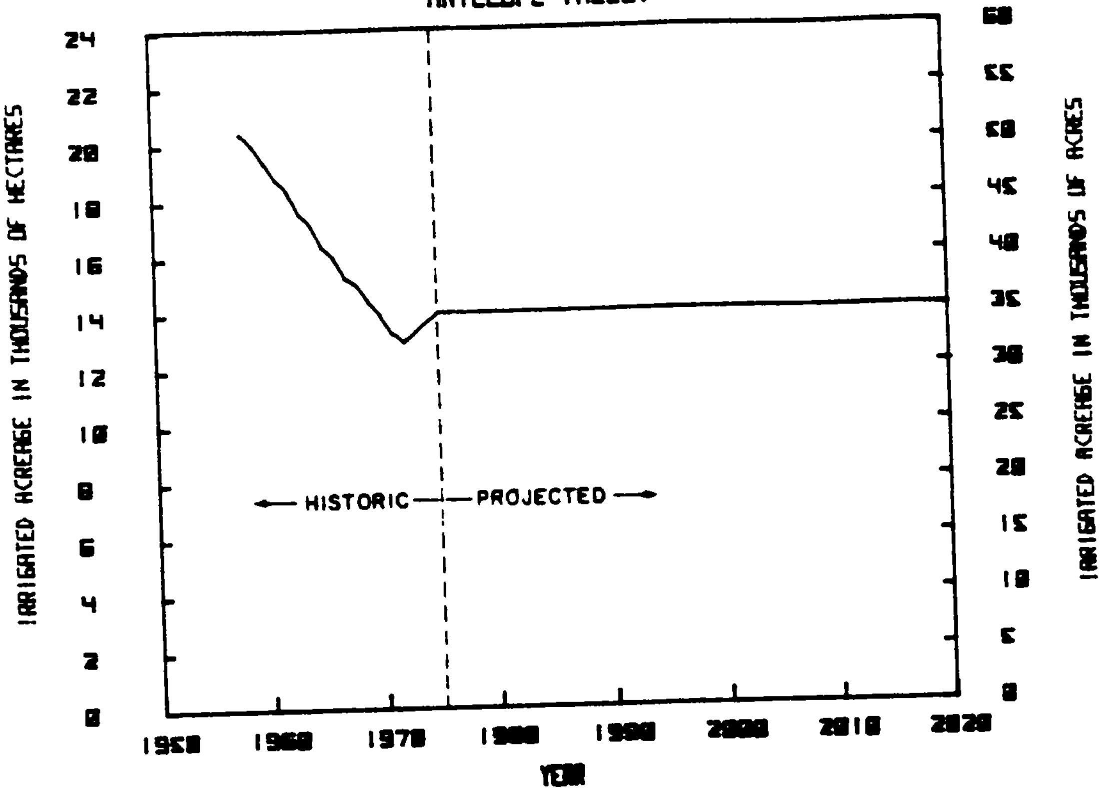
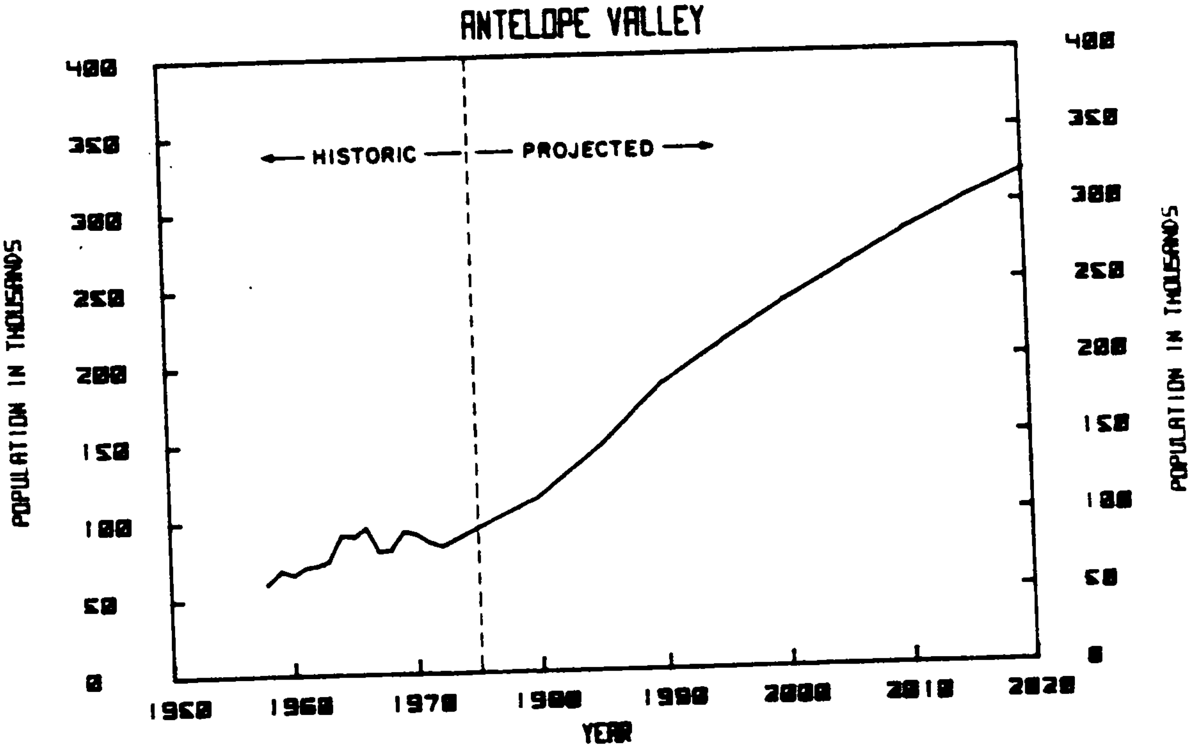


FIGURE 4

HISTORIC AND PROJECTED POPULATION ANTELOPE VALLEY



Water Quality Control Plan--a projection, developed by the Department of Finance and DWR. Projected is a Valley population of 476,000 by year 2000. The lowest growth rate is given in the 1974 Department of Finance E-0 projection under which Antelope Valley is estimated to have a population of 106,000 in 2000. The Los Angeles County Planning Commission has projected a population of 230,000 in the Antelope Valley by 2000.

The Planning Commission's population projections were selected, with adjustments to include the Kern County portion of the Valley and the impact of the proposed Palmdale International Airport. Both the historic and projected populations are shown in Figure 4. The extension of the projection to year 2020 was based on the analyses made on the Kern County Planning Commission's 1976 update.

On the basis of these projections, future water demand was estimated by using an urban unit water consumption rate of 0.95 cubic metre (250 gallons) per capita per day and an irrigation water use factor of 1.45 metres (4.75 feet). Both unit use factors were assumed to remain constant throughout the study period. The projected water demand is illustrated in Figure 5 as an extension of the historic demand.

The total water demand in 1975 was 238 000 cubic dekametres (192,600 acre-feet) and comprised two parts: an agricultural demand of 205 000 cubic dekametres (166,300 acre-feet) and a municipal and industrial demand of 33 000 cubic dekametres (26,300 acre-feet).

Factors That Could Change Projections

Several factors could change these projections:

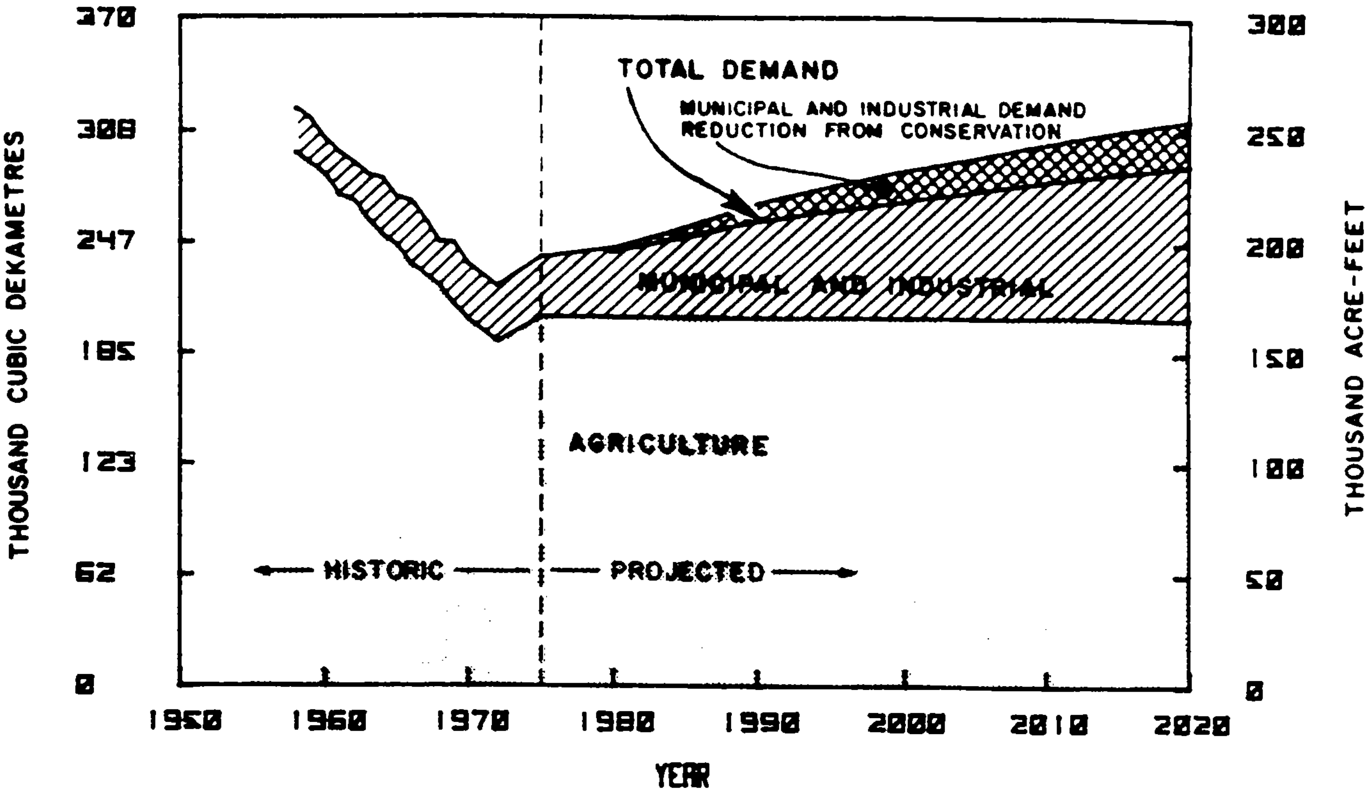
- o Improved irrigation methods and urban water conservation efforts could reduce the projected demands for both agricultural and urban uses. Some possible means of encouraging reduction of water use include the institution of one or more of the following measures:

  1. Install water meters on every pump and home connection, providing a means of assessing costs according to use.
  2. Raise the price of water, including adding surcharges on peak use. A corollary would be to raise the rates selectively to discourage certain types of uses such as irrigation.
  3. Encourage the conversion from high water-consuming crops to lower water-consuming crops.
  4. Encourage the change to more water-efficient equipment, using selective taxation or laws.
  5. Continue to educate water users to water conservation.
  6. Ration water and deny it to certain uses.

  The chief crops, alfalfa and pasture, are both sprinkler- and border-irrigated. Water use may be reduced by encouraging the use of more scientifically precise management of irrigation which may reduce the agricultural water demand in the Valley. Although these measures may not effect true saving of water loss in the atmosphere or to a body of unusable water, they could postpone the need for facilities to import water from external sources and reduce energy consumption.

- o If the growth rate induced by the construction of the airport and by spillover from the Coastal Plain exceeds the county's projected rate, the projections made for future municipal and industrial demand

FIGURE 5
HISTORIC AND PROJECTED WATER DEMAND
ANTELOPE VALLEY



would be low, possibly resulting in the planning of inadequate facilities for the distribution of water supplies.

- On the other hand, the projections made for agricultural water use may be high because of the ongoing displacement of agriculture by soaring land values and the concomitant property taxes, as well as by rising energy costs for pumping ground water.

- Even in the absence of the airport, the diminishing area of inexpensive real estate within the Coastal Plain is pressing developers and manufacturers to look to the interior of Los Angeles County for expansion. The Santa Clara River Valley is already being engulfed by the spillover from the Los Angeles Basin. The relatively long distances from the Coastal Plain to Antelope Valley have, until now, served to isolate the area, but future advances in commuting systems would serve to increase the population in the Valley.

Effect of Water Conservation on Total Demand

The potential reduction in the municipal and industrial water demand of the Antelope Valley by means of mandated and voluntary conservation measures is shown in Table 1 for the period 1980-2020. The reduction of demand is expected from a combination of factors including: the mandated reduction of line pressures and flow rates; requirements that new household appliances be water efficient; more efficient exterior use including the introduction of low-water demand plants; and lower industrial use as older, less water-efficient equipment is replaced.

TABLE I
ANTELOPE VALLEY
REDUCTION IN WATER DEMAND THROUGH MANDATED AND SELF-IMPOSED WATER USE REDUCTION MEASURES
In acre-feet

	Potential reduction, in acre-feet				
	1980	1990	2000	2010	2020
Interior					
New construction	140	2,840	5,440	7,500	9,100
Rehabilitation/Replacement	0	1,260	2,920	3,100	3,200
Retrofit	650	500	350	300	300
Subtotal	790	4,600	8,710	10,900	12,600
Exterior Use*					
More efficient irrigation and elimination of conspicuous overwatering and waste	800	1,100	1,400	1,600	1,800
Expanded use of low-water demand plants	0	770	1,440	2,000	2,500
Pressure reduction	0	600	750	900	1,000
Subtotal	800	2,470	3,590	4,500	5,300
Leak Detection and Repair*					
Utility distribution system to household and other consumer	0	500	1,300	1,600	1,800
Industrial	150	460	600	700	800
Total reduction	1,740	8,030	14,200	17,700	20,500
Total demand - no reduction					
acre-feet	31,640	51,800	66,500	79,100	89,600
gallons per capita per day	250	250	250	250	250
Total demand - with reduction					
acre-feet	29,900	43,770	52,300	61,400	69,100
gallons per capita per day	236	209	197	194	193
% Reduction	5%	16%	21%	22%	23%

*Some of this water percolates to usable ground water basins

In this investigation, initiated in 1972, the projections of water demands, analyses of ground water levels, and cost analyses of each alternative plan were completed prior to the time when conservation was to be considered a serious management factor. Partly as a result of the financial difficulties of the cooperating agencies, no recalculation was made of water levels and costs of alternatives taking conservation into consideration. It may be noted that the relative merits of the alternative plans will not be materially changed because the impact of water conservation on the demand for each alternative was identical. The estimated water demand reduction, however, is reflected in Figure 5. The present goal of the State is to obtain a reduction of 15 percent in the per capita use of water for urban uses. However, studies made by the Land and Water Use Unit of the Southern District of DWR indicate that an estimated 21 percent reduction in the Antelope

TABLE I
REDUCTION IN MUNICIPAL AND INDUSTRIAL DEMAND THROUGH MANDATED AND SELF-IMPOSED WATER USE REDUCTION MEASURES
In cubic dekametres

	Potential reduction, in cubic dekametres				
	1980	1990	2000	2010	2020
Interior					
New construction	170	3 500	6 710	9 250	11 220
Rehabilitation/Replacement	0	1 550	3 600	3 820	3 950
Retrofit	800	620	430	370	370
Subtotal	970	5 670	10 740	13 440	15 540
Exterior Use*					
More efficient irrigation and elimination of conspicuous overwatering and waste	990	1 360	1 730	1 970	2 220
Expanded use of low-water demand plants	0	950	1 780	2 470	3 080
Pressure reduction	0	740	920	1 110	1 230
Subtotal	990	3 050	4 430	5 550	6 530
Leak Detection and Repair*					
Utility distribution system to household and other consumer	0	620	1 600	1 970	2 220
Industrial	190	570	740	860	990
Total reduction	2 150	9 910	17 510	21 820	25 280
Total demand - no reduction					
cubic dekametres	39 030	63 970	82 020	97 570	110 520
litres per capita per day	950	950	950	950	950
Total demand - with reduction					
cubic dekametres	36 880	54 060	64 510	75 750	85 240
litres per capita per day	893	791	746	734	730
% Reduction	5%	16%	21%	22%	23%

*Some of this water percolates to ground water basins and becomes usable.

Valley can be achieved using various water conservation techniques, which is the reduction used in the study. The potential for conservation in agricultural water use is considered to be minor.

Water Supplies

To meet the demand, four sources of water are available: local surface water, ground water, water imported by the SWP, and reclaimed water (Figure 6). As shown in Figure 7, ground water represented 92.8 percent of the total applied water demand in 1975. Water imported by the SWP represents a small, but growing portion of the total supply. Surface and reclaimed water supply growth rates are essentially static and they are minor components of the total supply.

Local Surface Water

The major tributary watersheds to the Antelope Valley are the San Gabriel and Tehachapi Mountains. The San Gabriels provide more runoff because they are both higher and more exposed to the moist southwesterly winds off the Pacific. Figures 8-10 show the rainfall characteristics at selected stations in the Valley. Fairmont and Palmdale, located at the base of the mountains, were recipients of higher totals than Lancaster, located just a few kilometres north. These historic records show a few unusually wet years interspersed between many years with sub-par rainfall.

The mean annual runoff is estimated to be 50 200 cubic dekametres (40,700 acre-feet). More than half is supplied by two streams: Little Rock and Big Rock Creeks (40). Other streams from the San Gabriel Mountains have a combined mean annual flow of about 11 600 cubic dekametres (9,400 acre-feet) per year. Streams in the Tehachapi Mountains provide about 9 500 cubic dekametres (7,700 acre-feet) per year (Figure 11).

Precipitation runoff and spring flow emerging from the mountains converge toward the playas. Streamflow normally infiltrates into the pervious alluvial fans or evaporates within several

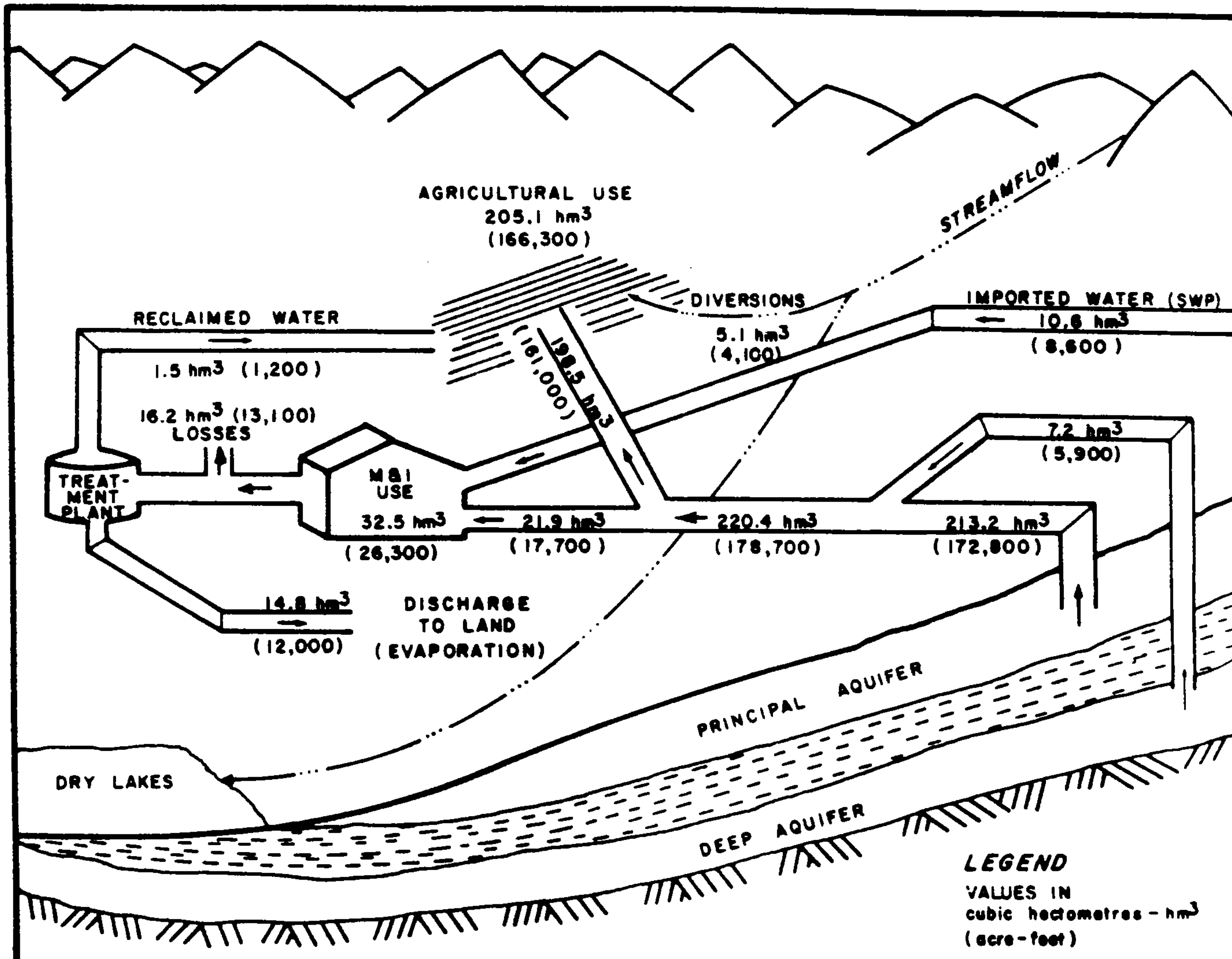
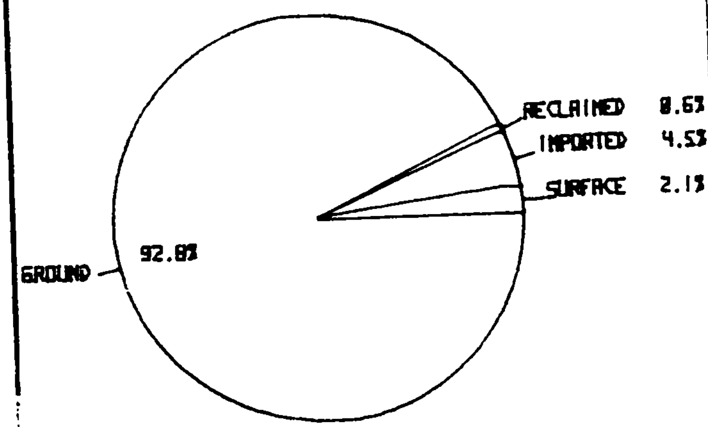


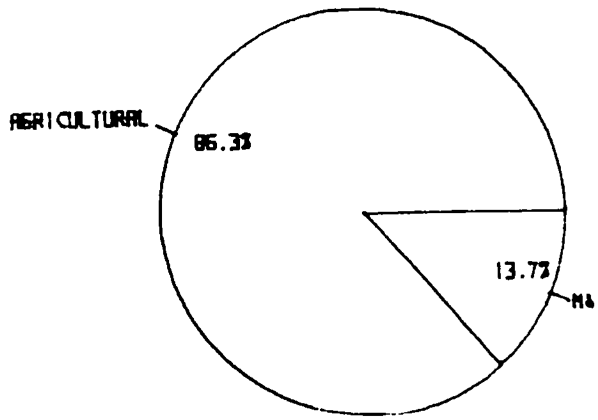
FIGURE 6 - WATER SUPPLY USED IN STUDY AREA IN 1975

COMPONENTS OF WATER SUPPLY IN 1975*



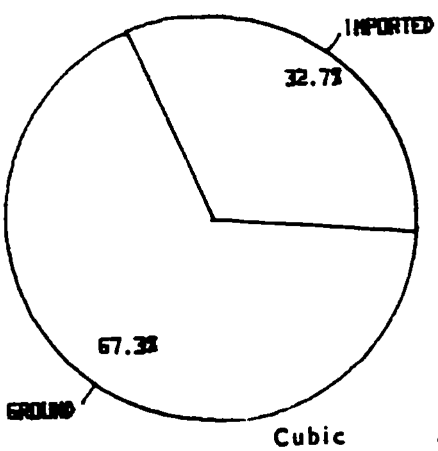
	Cubic dekametres	Acre-feet
Surface diversions	5 060	4,100
Imported water	10 610	8,600
Reclaimed water	1 480	1,200
Ground water	220 430	178,700
Total	237 580	192,600

AGRICULTURAL AND M&I DEMAND IN 1975



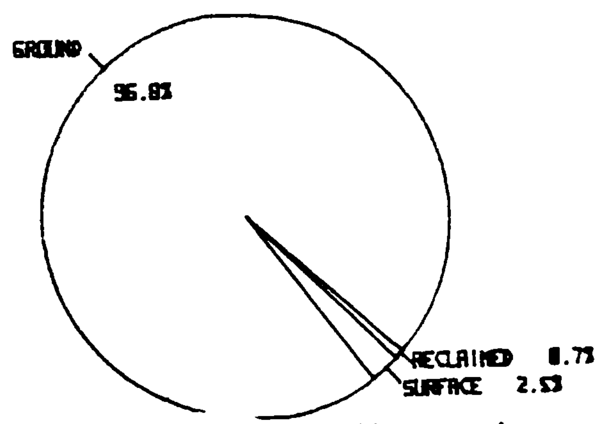
	Cubic dekametres	Acre-feet
Agricultural demand	205 140	166,300
Municipal and industrial demand	32 440	26,300
Total	237 580	192,600

SOURCES OF MUNICIPAL & INDUSTRIAL WATER IN 1975



	Cubic dekametres	Acre-feet
Imported water	10 610	8,600
Ground water	21 830	17,700
Total	32 440	26 300

SOURCES OF AGRICULTURAL WATER IN 1975*

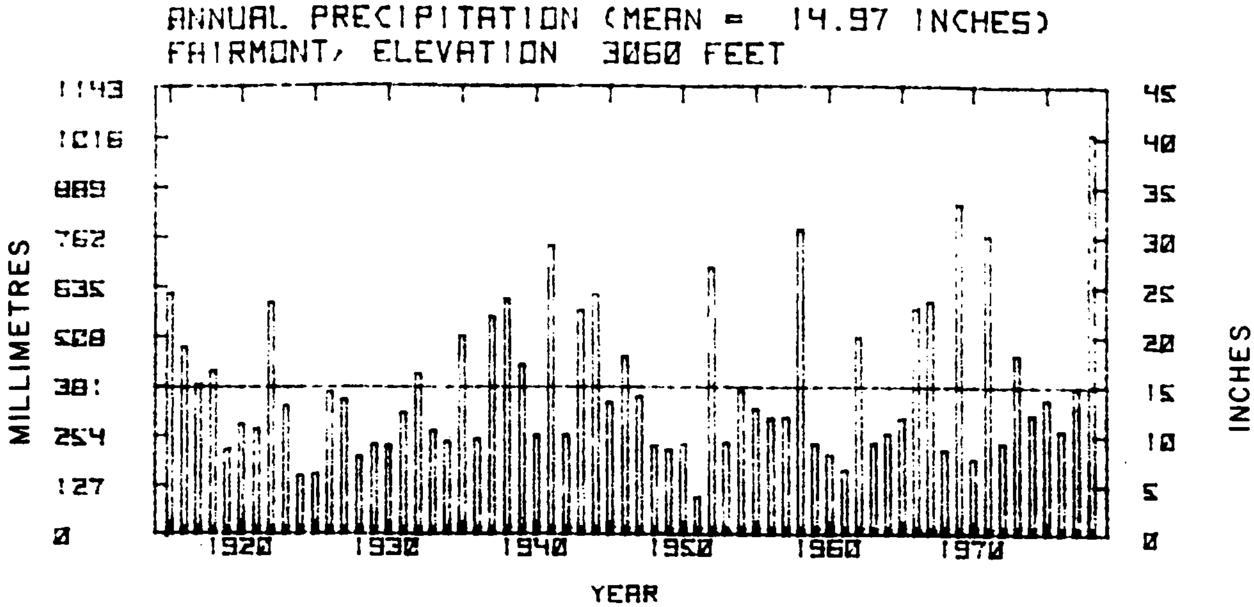


	Cubic dekametres	Acre-feet
Surface water	5 060	4,100
Reclaimed water	1 480	1,200
Ground water	198 600	161,000
Total	205 140	166,300

*Does not include SWP water (above entitlements) used for agriculture—less than 400 acre-feet (about 400 cubic dekametres).

FIGURE 7 - BREAKDOWN OF SUPPLIES USED IN 1975

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1980



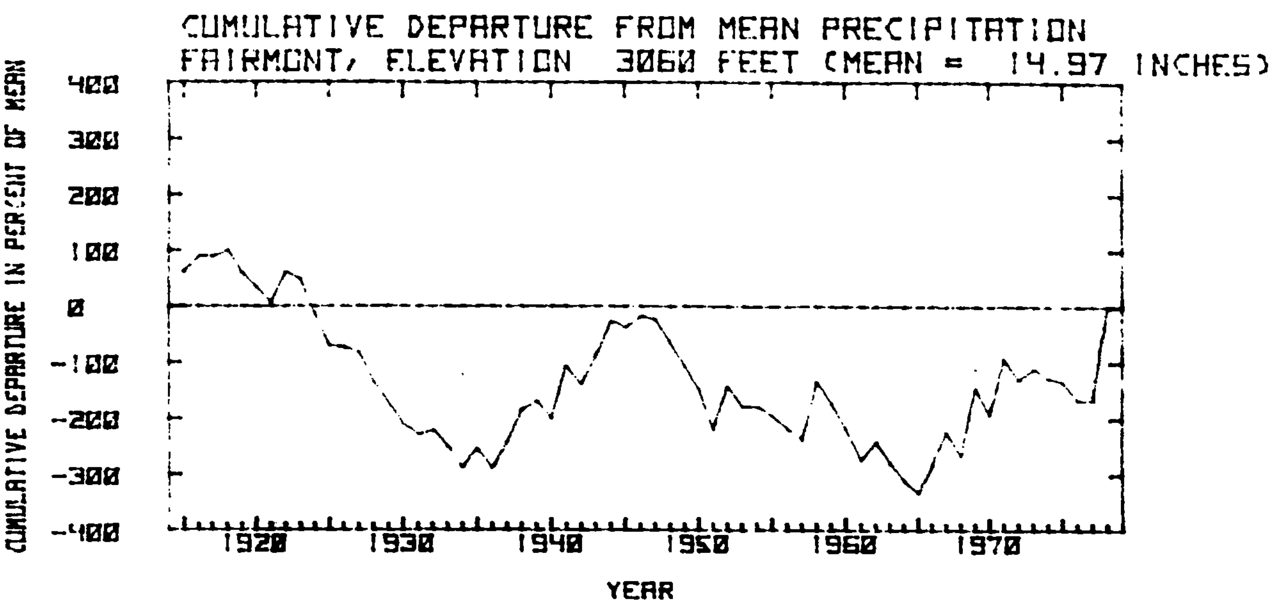
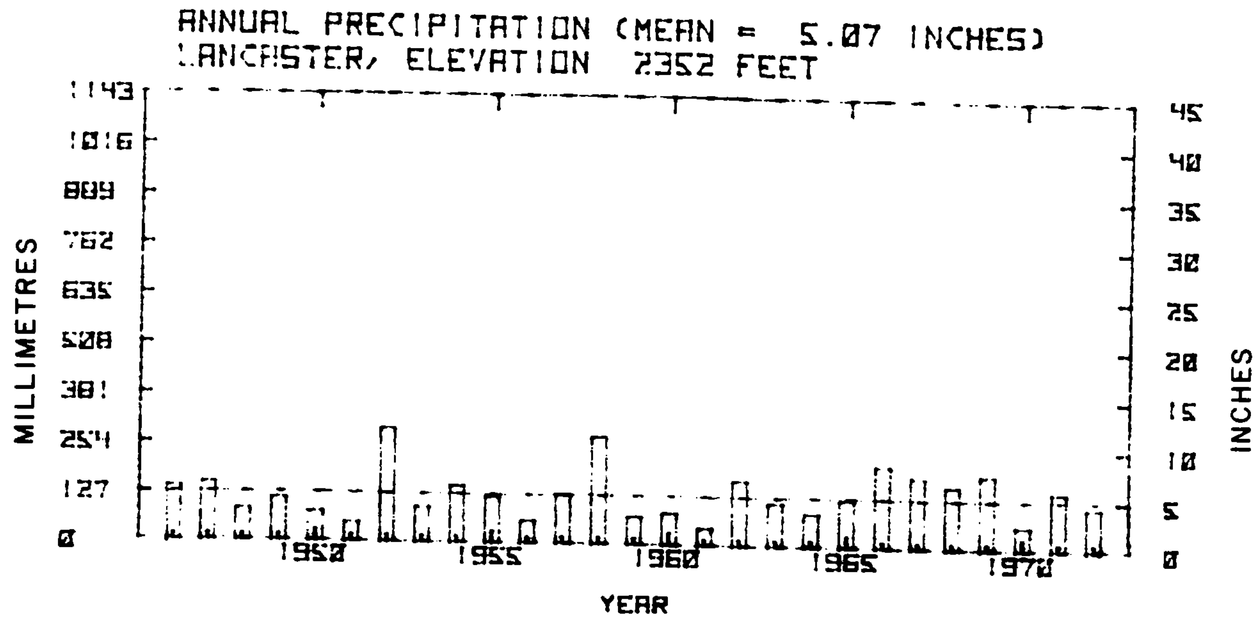


FIGURE 8 - PRECIPITATION SUMMARY: FAIRMONT RESERVOIR



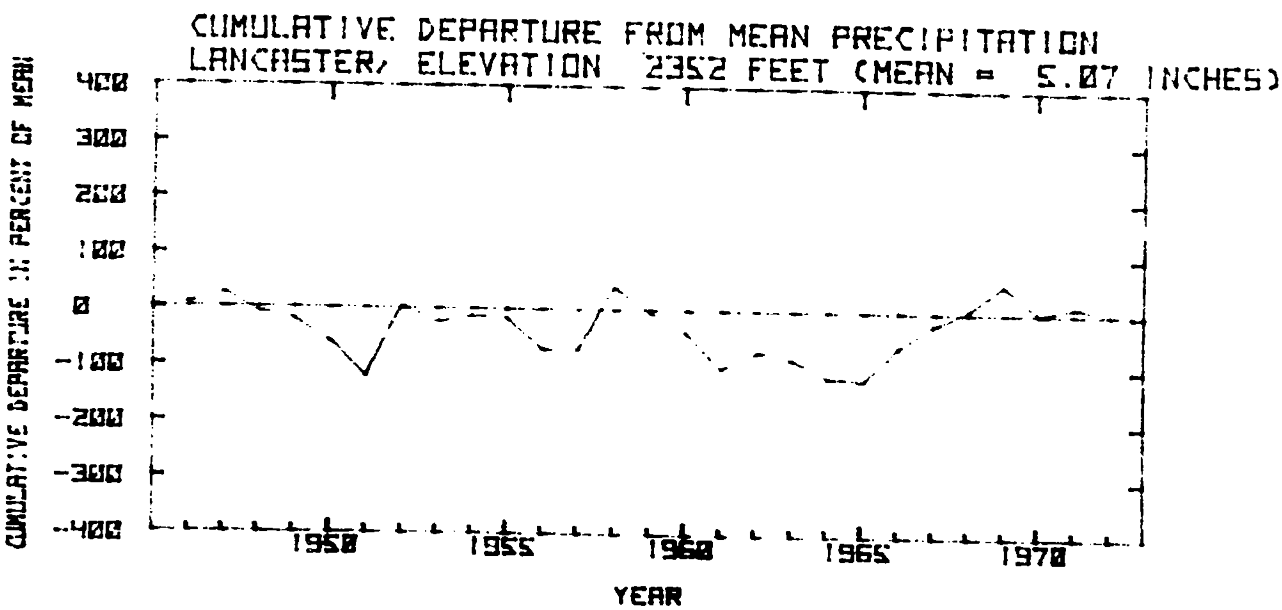
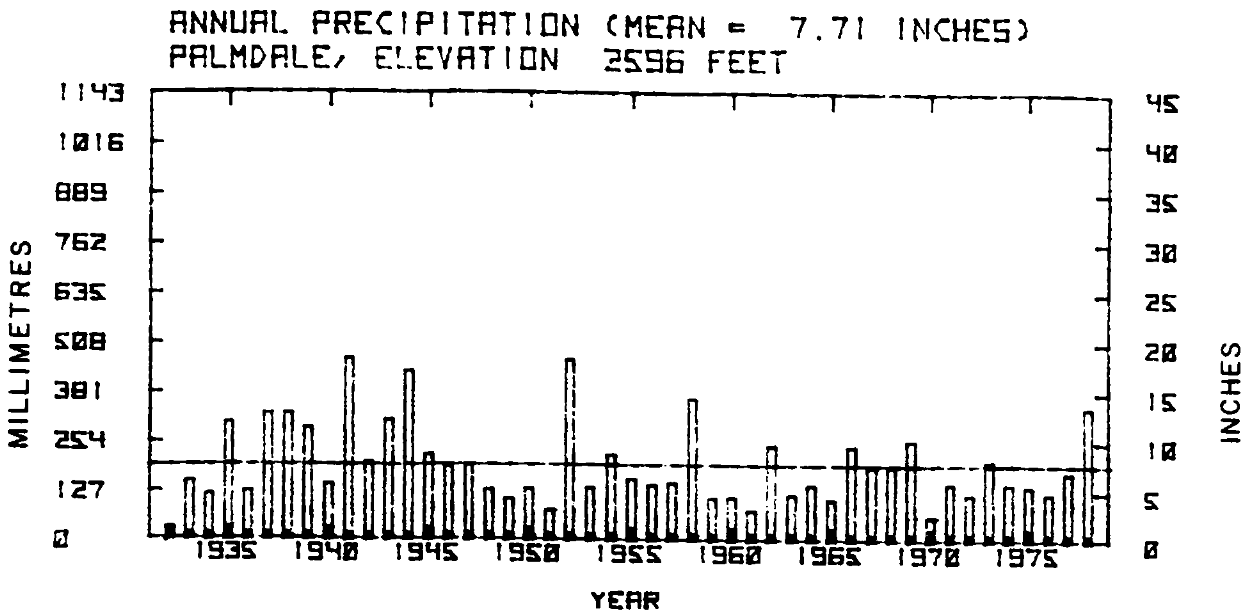


FIGURE 9 - PRECIPITATION SUMMARY: LANCASTER



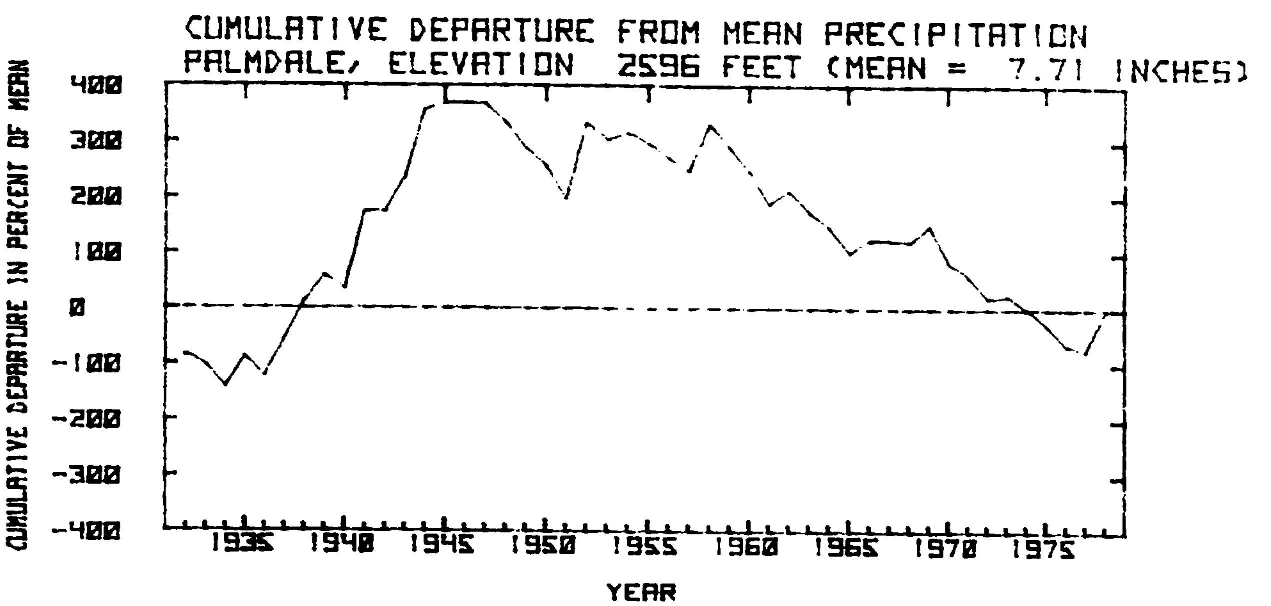
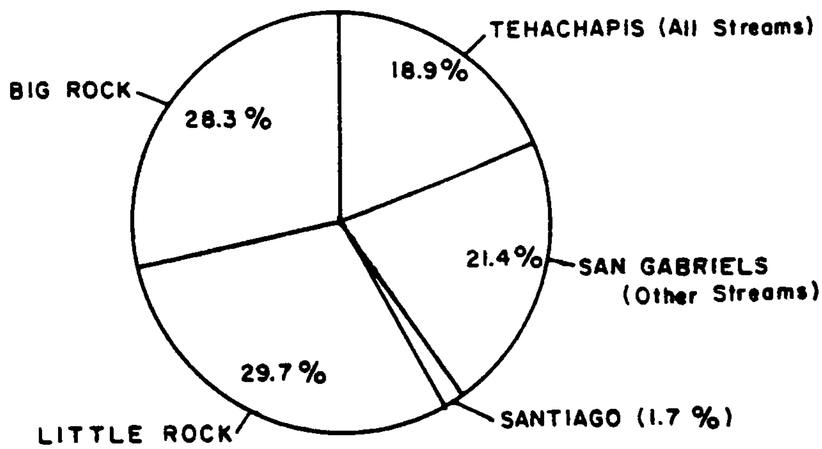


FIGURE 10 - PRECIPITATION SUMMARY: PALMDALE

FIGURE 11

MEAN ANNUAL RUNOFF FROM ANTELOPE VALLEY STREAMS*
WITHIN THE STUDY AREA



Drainage basin	Area		Mean annual runoff	
	In square kilometres	In square miles	In cubic dekametres	In acre-feet
San Gabriel Mountains				
Big Rock Creek	60	23	14 200	11 500
Little Rock Creek	127	49	14 900	12,100
Santiago Creek	28	11	900	700
Other Streams**	451	174	10 700	8,700
Tehachapi Mountains				
All Streams**	332	128	9 500	7,700
Total	998	385	50 200	40,700

*From reference 37

**Estimated runoff

kilometres of the base of the mountains. Flow rarely reaches the playas except during extremely wet winters or after major storms. That water reaching the impermeable playas is also lost to evaporation.

The flow of Little Rock Creek, impounded by 38-metre (124-foot) high Little Rock Dam, is about equally divided between the Littlerock Creek Irrigation District and the Palmdale Water District. They have exclusive rights to the flow.

Littlerock Creek Irrigation District also obtains water from the Cienega well in the San Andreas fault about 3 kilometres (2 miles) below Little Rock Dam, tapping the near-surface flow of Little Rock Creek. Approximately 1 200 to 2 500 cubic dekametres (1,000 to 2,000 acre-feet) of water are annually delivered from the reservoir to local orchards by Littlerock Creek Irrigation District.

The Palmdale Water District diverts about 1 400 cubic dekametres (1,100 acre-feet) annually from Little Rock Reservoir into a ditch terminating at Palmdale Lake, which is now used only for recreation. Palmdale Dam was rebuilt in 1966 to comply with earthquake standards, anticipating the delivery of water from the SWP.

Three ranches, Mountain Brook, Valyermo, and Pallett, have rights to a minimum of 0.35 cubic metre (12.5 cubic feet) per second from Big Rock Creek. In 1973-74, they diverted 3 700 cubic dekametres (3,000 acre-feet). The remaining normal flow is either diverted by downstream users or percolates to ground water.

Although the amount of surface water used by small communities and individuals living in the mountains is unknown, it is believed to be small. Table 2 lists the major existing impoundments in Antelope Valley.

The chemical quality of runoff is good, as the analysis of water from Little Rock and Big Rock Creeks demonstrates. (See Table 3.)

The discharge of wastes into surface waters is prohibited above elevation

TABLE 2
EXISTING STORAGE FACILITIES FOR LOCAL SURFACE WATER IN ANTELOPE VALLEY

Reservoir	Year completed	Owner and-or operating agency	Source of water	Maximum storage, cubic dekametres (acre-feet)
Fairmont*	1912	City of Los Angeles	Los Angeles Aqueduct	9 260 (7,507)
Palmdale	1891 Rebuilt 1966	Palmdale Water District	Little Rock Creek	5 230 (4,240)
Little Rock	1924	Littlerock Creek Irrigation District and Palmdale Water District	Little Rock Creek	5 300 (4,300)**
Pearblossom Spilling Basin	1970	Department of Water Resources	State Water Project	130 (106)

*Tentatively scheduled to be taken out of operation in 1982 because of a fault running through main dam. To be replaced by reservoir with 1/10 present storage at adjacent site.

**Actual capacity is less than 3 080 cubic dekametres (2,500 acre-feet) because of silt deposition. Storage limited to elevation 984 metres (3,228 feet) by Division of Safety of Dams, DWR, reducing active storage to about 1 233 cubic dekametres (1,000 acre-feet).

TABLE 3
RANGE AND AVERAGE CONCENTRATIONS OF CHEMICAL CONSTITUENTS OF SURFACE FLOWS OF LITTLE ROCK AND BIG ROCK CREEKS
In milligrams per litre

Constituent	Big Rock Creek 1951-1963*		Little Rock Creek 1951-1963*		1971**
	Range	Average	Range	Average	
Calcium	36 – 79	57	20 – 59	38	31
Magnesium	15 – 36	23	1 – 15	11	10
Sodium	9 – 28	19	9 – 48	21	15
Potassium	3 – 7	4	2 – 5	3	3
Carbonate	0 – 14	1	0 – 14	2	0
Bicarbonate	171 – 267	214	106 – 224	178	153
Chloride	0 – 23	5	2 – 10	6	5
Sulfate	22 – 187	88	9 – 66	31	19
Nitrate	0 – 12.6	6	0 – 3.5	0.6	0.7
Fluoride	0 – 0.9	0.3	0.1 – 0.7	0.3	0.2
Boron	0 – 0.5	0.15	0 – 0.5	0.08	0.05
TDS	232 – 456	350	140 – 345	240	172
Total hardness	170 – 297	236	83 – 180	141	119

*From reference 19
**Sampling conducted at Little Rock Reservoir

1 070 metres (3,500 feet) to protect beneficial uses of water. Septic tank pumpings and chemical toilet wastes must be discharged to a sewage treatment plant, if one capable of handling such wastes is available in the regional service area. (33)

Ground Water

Numerous faults slice across Antelope Valley, some acting as partial barriers to ground water movement. For example, water level discontinuities of up to 91 metres (300 feet) are found along the Randsburg-Mojave fault in the western part of the Valley. These fault systems, the locations of which are either known or inferred from water levels in wells (40), serve to divide the Antelope Valley ground water basin into subbasins. These are: Lancaster, Buttes, Pearland, Neenach, West Antelope, Finger Buttes, and North Muroc Subbasins (Figure 12).

The two major aquifers, the principal and the deep, are separated by a series of thick, discontinuous layers of lacustrine clay deposits, which serve as a confining bed. A rough outline of that portion of the Valley underlain by this confining bed is shown in Figure 12. Cross sections through the ground water basin are shown in Figure 13.

The unconfined principal aquifer, which overlies the confining bed, supplies most of the water pumped in Antelope Valley. This aquifer extends through all subbasins except North Muroc (Figure 12).

The deep aquifer underlies the North Muroc Subbasin and most of the Lancaster

Subbasin (Figure 12). The deep aquifer is generally unconfined in two areas: north and east of Rogers Lake in North Muroc Subbasin and in the Lancaster Subbasin east of Little Buttes. Most of the deep aquifer underlies the clay aquitard.

In Lancaster Subbasin, numerous clay lenses are found in the principal aquifer. Water levels in wells show semiperched water above these clay lenses.

Water in Storage. The estimated total storage capacity of the ground water basin is 84 million cubic dekametres (68 million acre-feet) (24). The storage capacity is determined for depths ranging from 6 metres (20 feet) below ground surface (to avoid problems associated with a high water table) to the base of the water-bearing sediments. The amount of available ground water storage capacity above the water table and below a 6-metre depth from ground surface, was estimated to be 16 million cubic dekametres (13 million acre-feet) in 1975 (24). Therefore, the total amount of ground water in storage, from the water table to the base of the water-bearing sediments, was an estimated 68 million cubic dekametres (55 million acre-feet) in 1975 (24). Depths-to-water ranged from less than 15 metres (50 feet) at various points along the base of the San Gabriel Mountains and near Rosamond Lake to more than 120 metres (400 feet) at well 6N/11W-19E5 near Palmdale.

Water levels have been declining in the Antelope Valley since the 1920s (Figure 14). In parts of Lancaster Subbasin, ground water elevations have receded more than 60 metres (200 feet) (40). Rates of fall are as much as 1.2 metres (4 feet) per year near Lancaster (40). Partly responsible for these large drops are lowered pressures in confined aquifers tapped by some wells. Figure 15 shows the ground water level elevations in 1974.

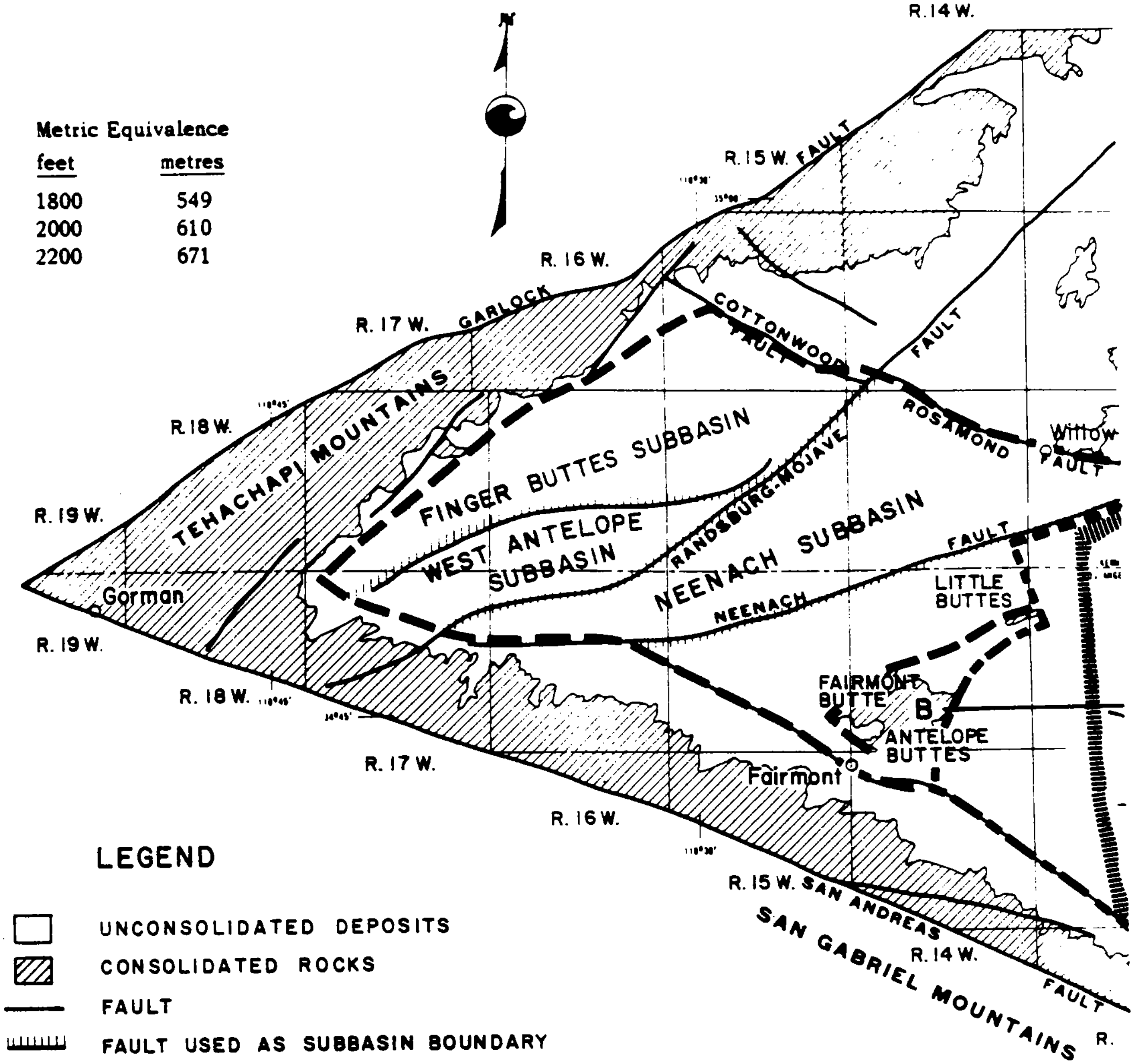
Water Quality. The overall quality of Antelope Valley ground water is currently good, posing few problems for agricultural and municipal and industrial uses. Total dissolved solids (TDS) concentrations generally are under 500 mg/L. Deteriorating water quality in local areas probably results from the recirculation of irrigation return where pumping depressions or other conditions inhibit the movement of ground water (28).

Ground water in Antelope Valley has always been of good quality, with the exception of certain areas paralleling faults and in the northern portion of North Muroc Subbasin, which is affected by the Kramer borate deposits.

Altalfa, the major crop, has affected ground water quality only slightly since its introduction to the Valley; as a nitrogen-fixing plant, it does not require as heavy an application of easily leached nitrogen fertilizer as orchard crops. Some areas planted in orchards show fairly steadily increasing nitrate and TDS concentrations. At certain wells near the orchards of Littlerock and Quartz Hill, nitrates exceed 45 mg/L, probably as a result of irrigation return waters which have leached fertilizer from the soil.

The best quality ground water, with TDS concentrations under 500 mg/L, is found in the southern and western sections of the Valley, where natural recharge is greatest. Ground water is calcium or sodium bicarbonate in character in this portion of the Valley compared to sodium bicarbonate and sodium chloride in the northern half of North Muroc Subbasin. The poorest water, with TDS concentrations of 1 000 mg/L or more can be found in: (1) the North Muroc Subbasin, (2) around the borders of the Lancaster Subbasin, and (3) shallow wells scattered throughout the Valley.

Quality variations between the principal and deep aquifers are difficult to discern because the current practice of gravel-packing wells encourages water



LEGEND

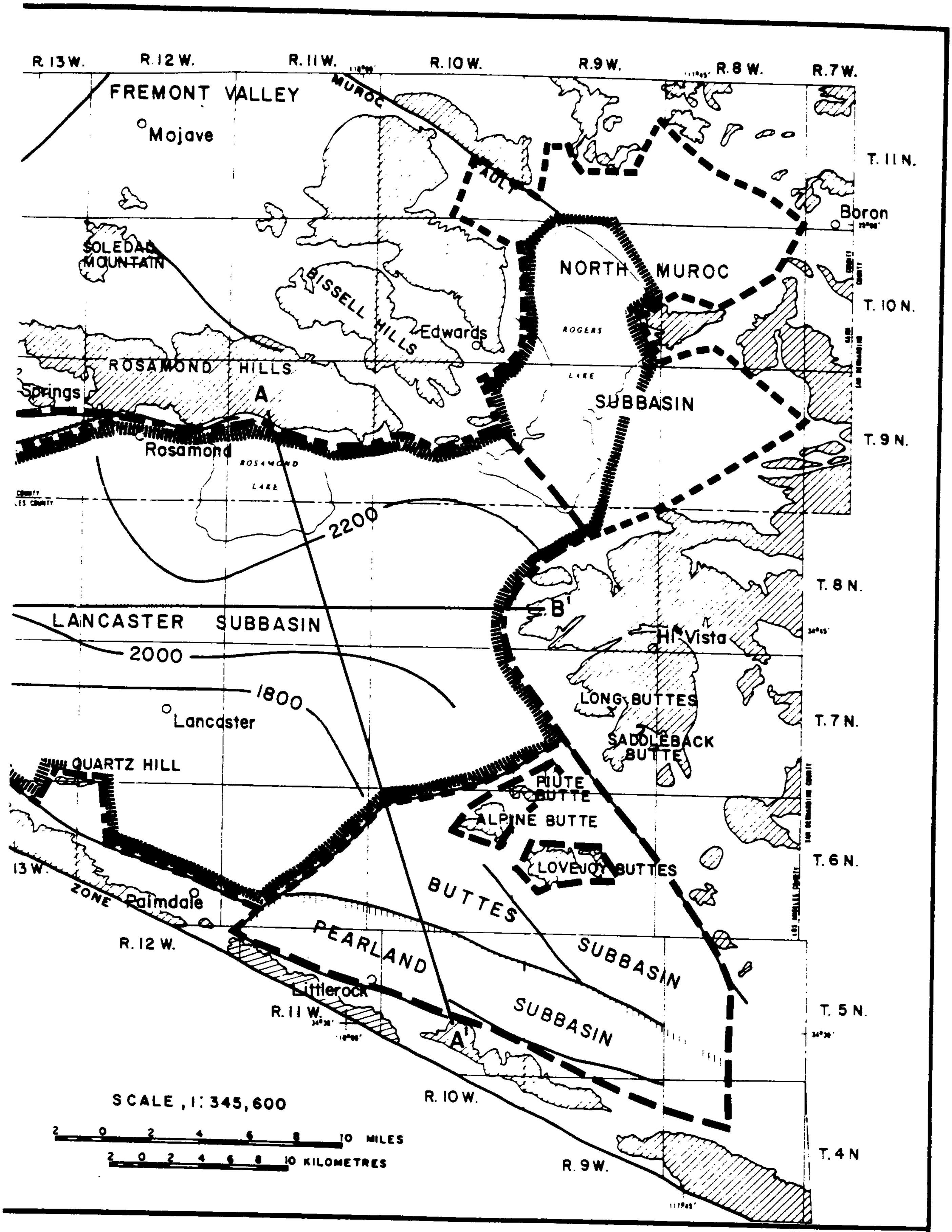
☐	UNCONSOLIDATED DEPOSITS
▨	CONSOLIDATED ROCKS
———	FAULT
╨╨╨╨	FAULT USED AS SUBBASIN BOUNDARY

MODEL BOUNDARY:

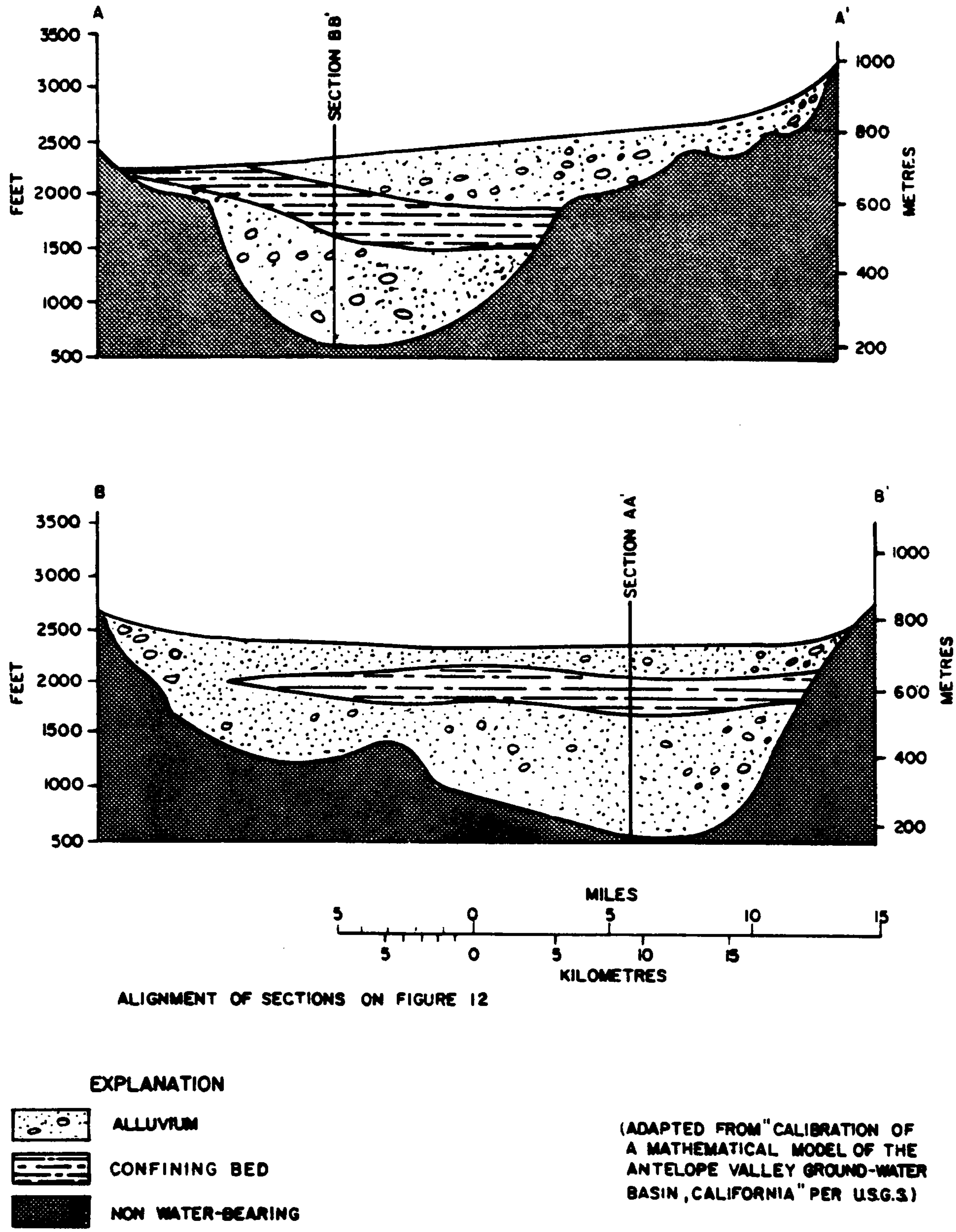
▬ ▬	PRINCIPAL AQUIFER
▪▪▪	DEEP AQUIFER
▬▪▬	COMMON BOUNDARY
—2200—	ELEVATIONS AT TOP OF AQUITARD (IN FEET)
▐▐▐▐	APPROXIMATE EDGE OF AQUITARD
A —— A'	ALIGNMENT OF SECTIONS

FIGURE 12

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1980

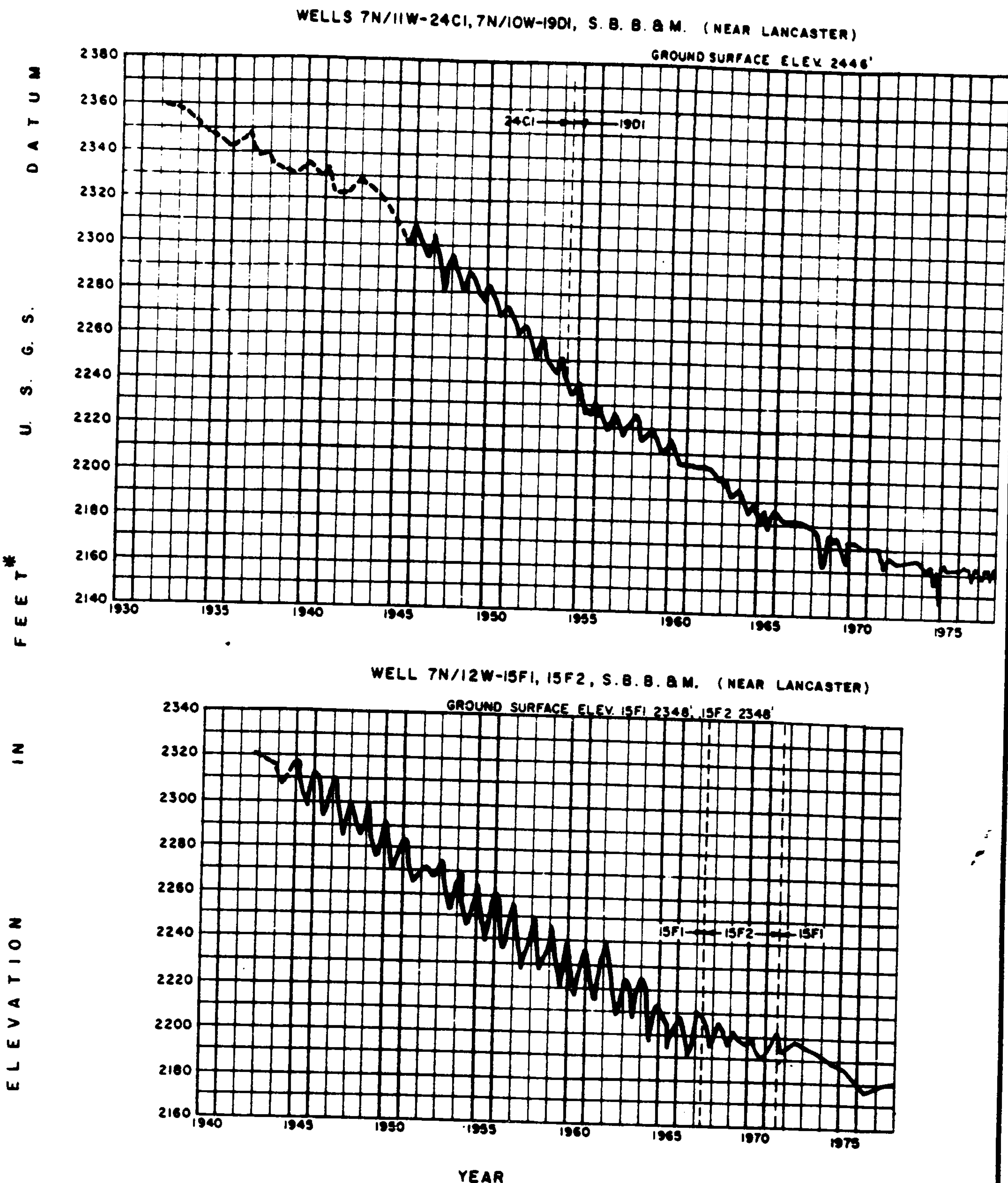


GENERALIZED GEOLOGY



(ADAPTED FROM "CALIBRATION OF A MATHEMATICAL MODEL OF THE ANTELOPE VALLEY GROUND-WATER BASIN, CALIFORNIA" PER U.S.G.S.)

FIGURE 13 – GEOLOGIC SECTIONS THROUGH THE GROUND WATER BASIN



* FEET X 0.3048 = METRES

FIGURE 14 -
FLUCTUATIONS OF WATER LEVELS IN WELLS

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1980

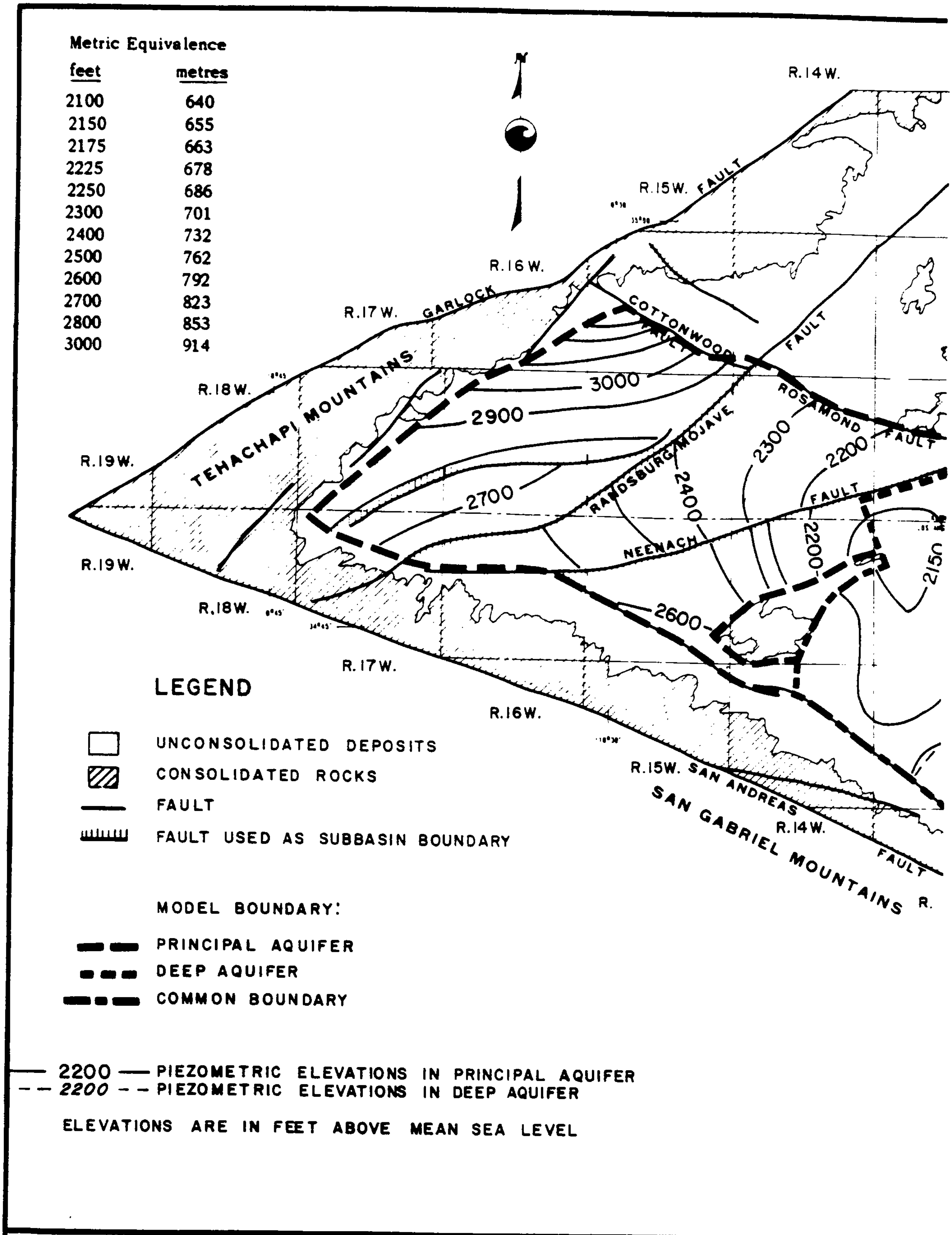
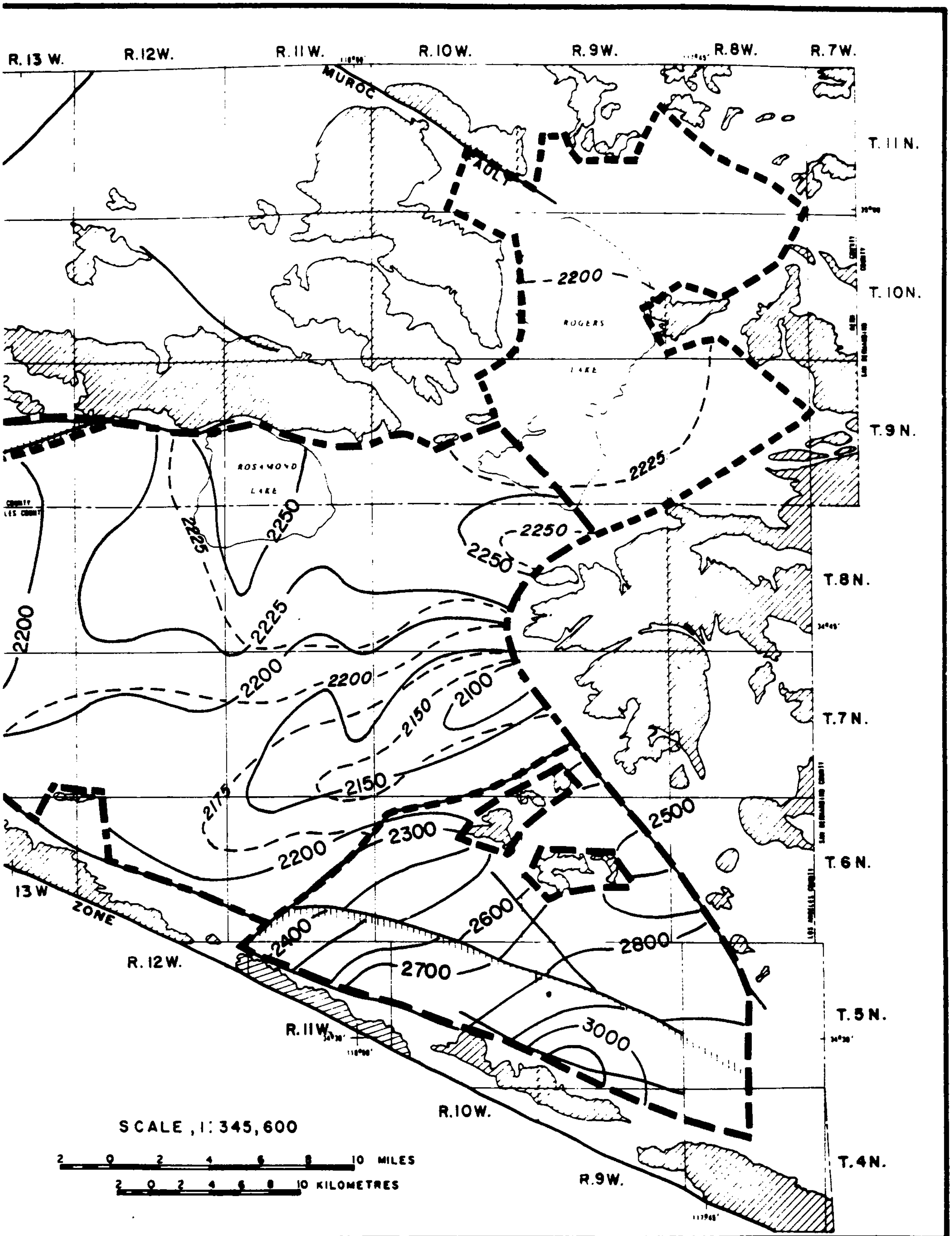


FIGURE 15

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1980



WATER LEVELS FOR 1974 IN ANTELOPE VALLEY from any saturated stratum penetrated to enter the well and mix. The major cation in the principal aquifer is either sodium or calcium. The deep aquifer contains water of sodium bicarbonate character (19).

If the airport is not built, there will likely be a slow decline in agricultural land and slow increases in population, resulting in minor changes from current land use patterns. In such case, the overall quality of ground water is not expected to change rapidly with time.

On the other hand, rapid urbanization spurred by the construction of Palmdale Airport is also not likely to cause long-term changes in ground water quality. New developments will be sewered and the waste water treated and disposed of by the County Sanitation Districts. The water would be degraded only if wastes were spread and allowed to percolate into the ground water basin. This is not likely to occur under the strict guidelines of the Regional Water Quality Control Board, Lahontan Region, which has specific objectives of an adequate surveillance and monitoring program to locate and identify sources of pollution that pose an acute, accumulative or chronic threat to the environment. The reduction in agricultural land corresponding to increasing urbanization would tend to reduce overall demand and the resultant irrigation return.

The completion of the North Feeder by AVEK has resulted in the introduction of good quality SWP water to the North Muroc-Boron area as a replacement of ground water for domestic purposes. Water is already being delivered to the U. S. Borax plant. Boron Community Services District will not receive deliveries until its own pumping facilities are completed in the middle of 1980.

Flow and Recharge. Ground water flows from the Tehachapi and San Gabriel Mountains toward the north-central portion of Lancaster Subbasin, generally paralleling the surface drainage.

Before the widespread pumping of ground water, the hydraulic grade line of the principal aquifer was near ground surface in north-central Lancaster Subbasin. Early developments in irrigated agriculture near Lancaster drew their water from flowing artesian wells. The water table, which was then shallow, permitted capillary action to lift water to the surface with consequent direct evapotranspiration of ground water. Continued pumping lowered the water table, terminating this direct ground water discharge.

Along the western border of the confining bed near Little Buttes, part of the subsurface flow from Neenach, West Antelope, and Finger Buttes Subbasins into Lancaster Subbasin enters the principal aquifer; the other part flows beneath the lacustrine deposits and recharges the deep aquifer.

Ground water flowing from Buttes and Pearland Subbasins enters only the principal aquifer of Lancaster Subbasin.

In the portion of North Muroc Subbasin underlying and south of Rogers Lake, water movement is also toward Lancaster Subbasin. Before the 1940s, the direction of flow was the reverse. By 1961 present flow patterns were entrenched due to the heavy pumpage in Lancaster Subbasin. North of Rogers Lake, water flows into the Fremont Valley (40).

Information is incomplete on the degree of interconnection between the principal and deep aquifers. In the USGS model studies, it was inferred that leakage is downward from the principal to the deep aquifer along the southern and western periphery of the clay aquitard. In the north-central part of Lancaster Subbasin, leakage is upward from the deep aquifer to the principal aquifer and is concentrated in the areas of heavy pumpage (40).

Because mean annual precipitation on the Valley floor is less than 250 millimetres (10 inches) and evapotranspiration rates are high, even though there are seasonal variations, it is believed that the contribution of precipitation on the Valley floor to the direct recharge of the ground water basin is minimal.

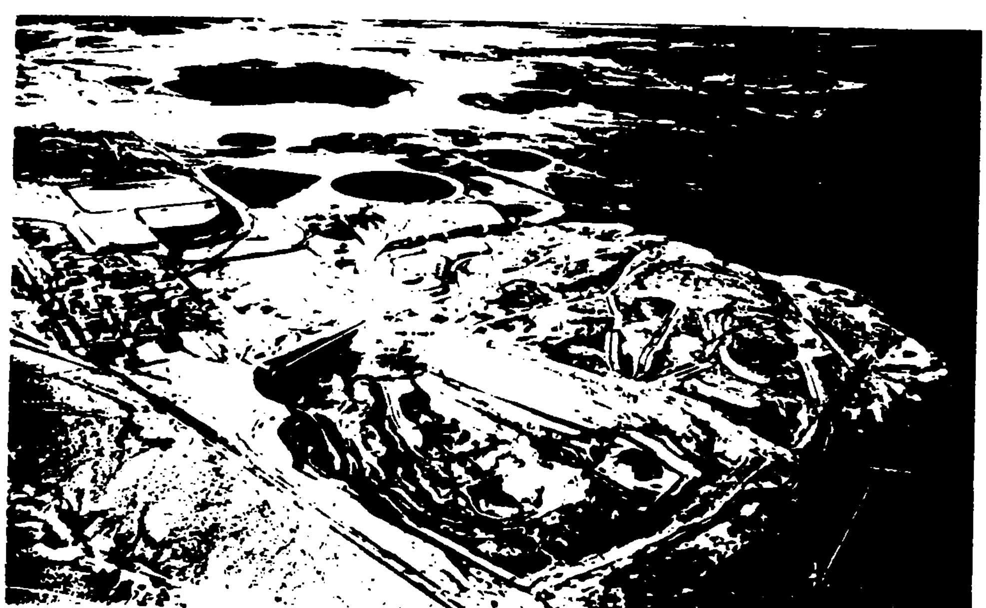
Agriculture is the largest consumer of water in Antelope Valley, but whether percolating return water from agriculture is reaching the principal aquifer is still open to question. Irrigation efficiency in Antelope Valley is estimated by USGS to be about 70 percent, meaning that of the total amount of irrigation water applied to a crop, 30 percent percolates past the root zone and 70 percent is lost to evaporation and transpiration (40). In 1976, USGS conducted a series of neutron probe borings at two sites (one site was 10 kilometres, or 6 miles, east and the other 26 kilometres, or 16 miles, northwest of Lancaster) to ascertain if irrigation return water was reaching the saturated zone. The results were inconclusive. Although percolation rates at the sites were estimated to be 6.4 and 11.0 metres (21 and 36 feet) per year, there were indications that clay lenses might be retarding the downward movement of irrigation return water, forming perched water bodies.

The major source of ground water recharge is infiltration inside and outside stream channels. The net recharge of ground water is equal to the entire surface runoff, plus the total subsurface inflow, less the quantity of water lost from streamflow to evapotranspiration. Because the total volumes of stream evapotranspiration and underflow are uncertain, USGS simply made the assumption, for this study, that subsurface inflow and evapotranspiration are equal; thus the net recharge to the basin is equal to the surface runoff onto the Valley floor and foothill recharge areas, or 50 200 cubic dekametres (40,700 acre-feet) per year (40).

Imported Water

Because of declining ground water levels in parts of the study area, some local agencies have begun purchasing SWP water from AVEK. The other major agencies with entitlements to SWP water are Littlerock Creek Irrigation District and Palmdale Water District.

The imported water distribution system (4) is composed of SWP facilities, local treatment plants, pumping stations, and water transmission and storage facilities (Figure 16). AVEK's distribution



NEAR BORON is the U. S. Borax mine. Tailings ponds are beyond the plant and the tailings dump is next to the open pit. View is toward the northwest.

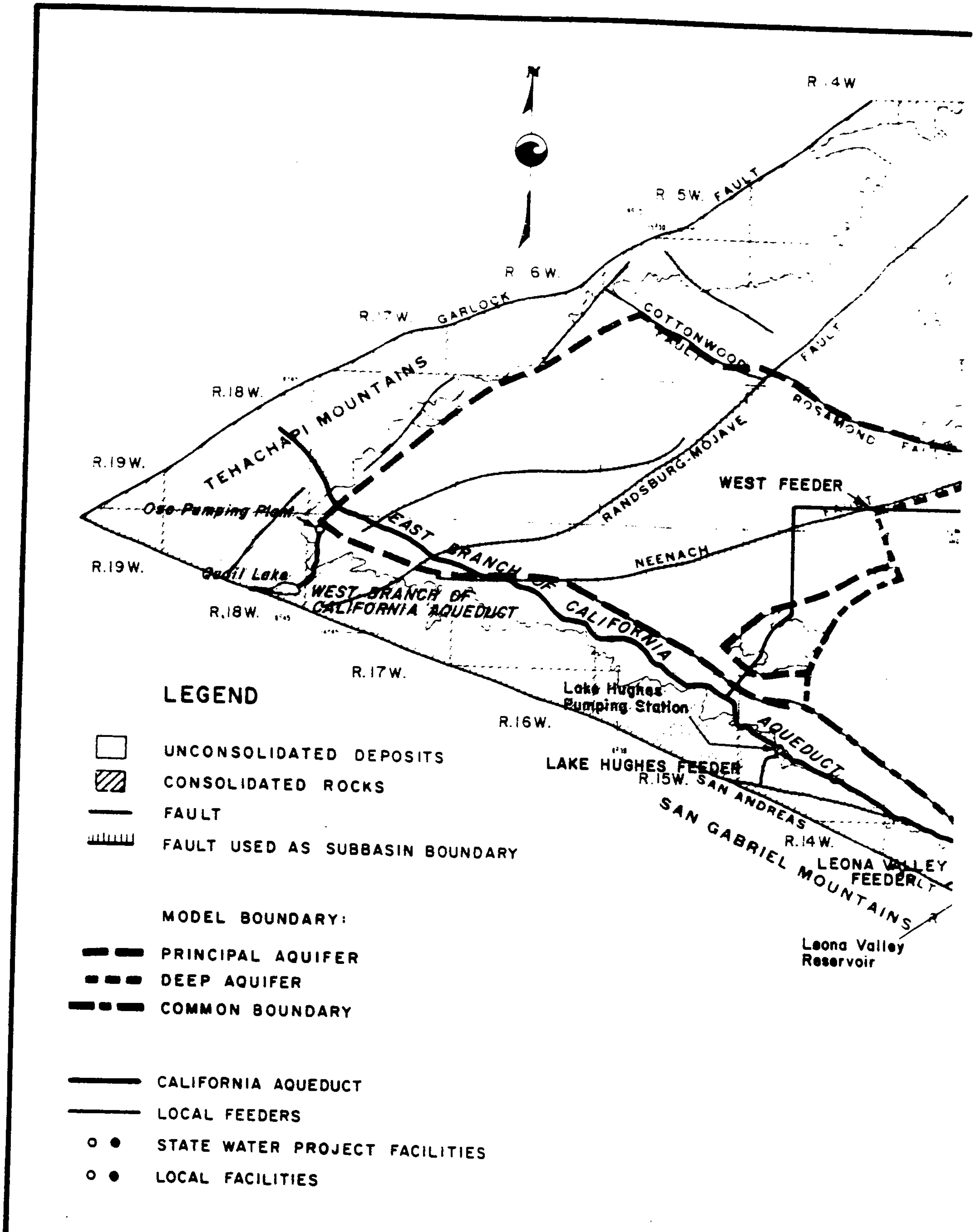
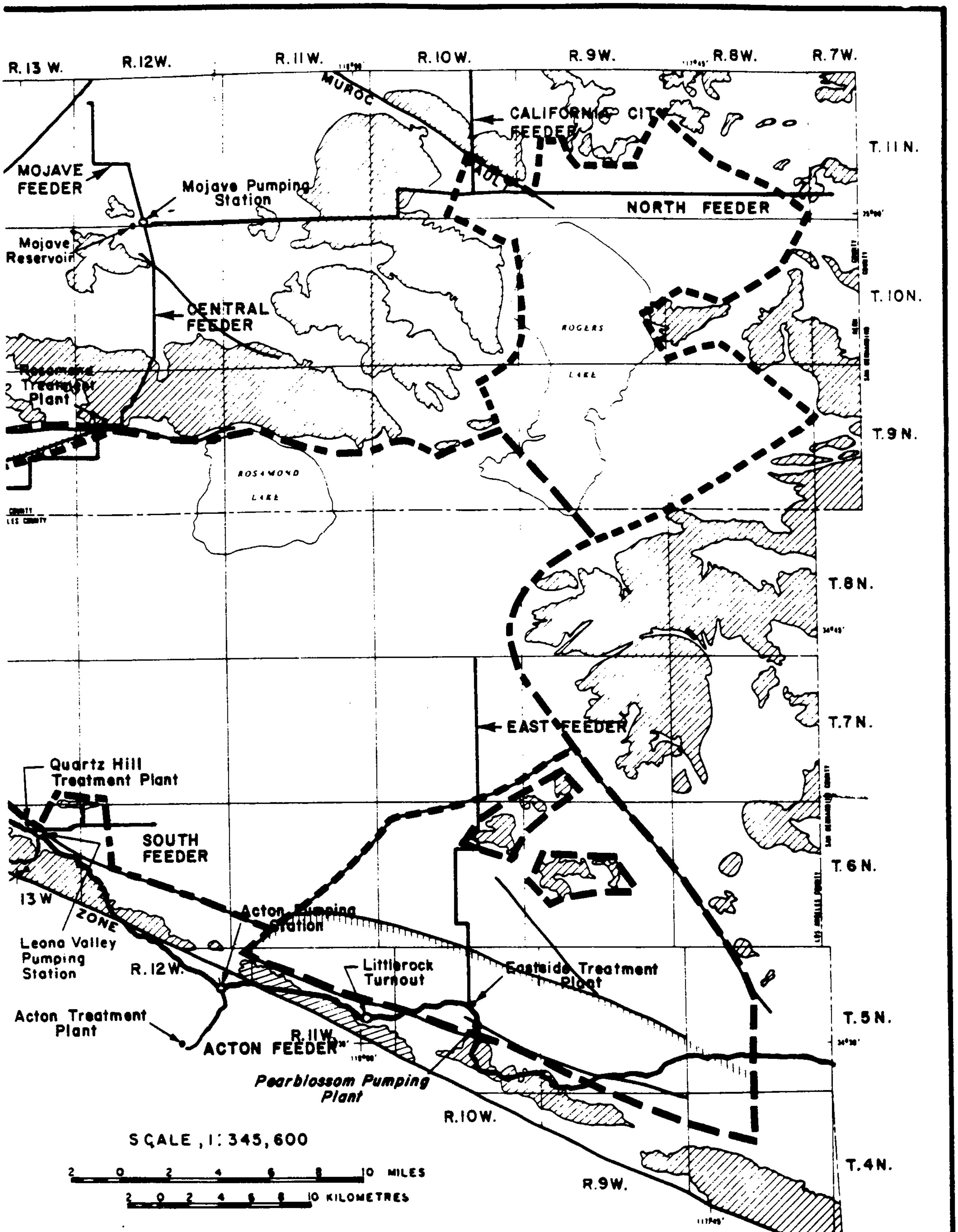


FIGURE 16

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1980



LOCAL WATER DISTRIBUTION SYSTEM

facilities for serving the Valley have been designated as the Domestic-Agricultural Water Network (DAWN) Project.

At this time, AVEK has completed all the facilities of the DAWN Project except for the East Feeder, the Acton facilities, and Eastside Treatment Plant which is under construction. The Eastside Treatment Plant is scheduled for completion in January 1981.

Boron will not be taking delivery until the middle of 1980 when its turnout from the North Feeder and its pumping station will have been constructed.

The annual contracted entitlements of the three SWP contractors, through the year 2035, are listed in Table 4, along with the actual deliveries each has previously received.

Littlerock Creek Irrigation District is currently using its entitlement to augment its supplies at the end of the irrigation season when its reservoir has been drawn down to dead storage. As

TABLE 4
SWP ENTITLEMENTS AND QUANTITIES DELIVERED*
In acre-feet

Calendar year	Antelope Valley-East Kern Water Agency		Littlerock Creek Irrigation District		Palmdale Water District	
	Entitlement	Delivered	Entitlement	Delivered	Entitlement	Delivered
1970	0	0	0	0	0	0
1971	0	0	0	0	0	0
1972	20,000	53	170	338**	1,620	0
1973	25,000	20	290	370**	2,940	0
1974	30,000	1,223	400	400	4,260	0
1975	35,000	8,068	520	876**	5,580	0
1976	44,000	27,782	640	589	6,900	0
1977	50,000	34,324	730	111	8,220	0
1978	57,000		920		9,340	
1979	63,000		1,040		10,260	
1980	69,200		1,150		11,180	
1981	75,000		1,270		11,700	
1982	81,300		1,380		12,320	
1983	87,700		1,500		12,940	
1984	94,000		1,610		13,560	
1985	100,400		1,730		14,180	
1986	106,700		1,840		14,800	
1987	113,000		1,960		15,420	
1988	119,400		2,070		16,040	
1989	125,700		2,190		16,660	
1990	132,100		2,300		17,300	
1991	138,400		2,300		17,300	

Entitlements remain the same through 2035.

*From reference 16

**"Surplus" water is included. See reference 16 for definition.

population within the district grows beyond the capacity of the wells to meet its demand, a treatment plant will be built for SWP water.

Palmdale Water District has yet to tie into the East Branch aqueduct. It relies upon ground water from scattered wells near Palmdale.

There is a possibility that Palmdale Water District will take part in a joint venture with AVEK to develop the Acton facilities.

Reclaimed Water

Eight major waste water treatment plants, varying in size and capability, are located in the Valley. The plant locations are mapped on Figure 17. Table 5 gives their flows and details of their treatment facilities.

The amount of reclaimed water used for irrigated farming, recreation, landscaping, and other beneficial uses was about 3 700 cubic dekametres (3,000 acre-feet) in 1976. Of this,

TABLE 4
SWP ENTITLEMENTS AND QUANTITIES DELIVERED*
In cubic dekametres

Calendar year	Antelope Valley-East Kern Water Agency		Littlerock Creek Irrigation District		Palmdale Water District	
	Entitlement	Delivered	Entitlement	Delivered	Entitlement	Delivered
1970	0	0	0	0	0	0
1971	0	0	0	0	0	0
1972	24 670	65	210	420**	2 000	0
1973	30 840	25	360	460**	3 630	0
1974	37 000	1 510	490	490	5 260	0
1975	43 170	9 950	640	1 080**	6 880	0
1976	54 270	34 270	790	730	8 510	0
1977	61 670	42 340	900	140	10 140	0
1978	70 310		1 140		11 520	
1979	77 710		1 280		12 660	
1980	85 360		1 420		13 790	
1981	92 510		1 570		14 430	
1982	100 280		1 700		15 200	
1983	108 180		1 850		15 960	
1984	115 950		1 990		16 730	
1985	123 840		2 130		17 490	
1986	131 610		2 270		18 260	
1987	139 390		2 420		19 020	
1988	147 280		2 550		19 790	
1989	155 050		2 700		20 550	
1990	162 950		2 840		21 340	
1991	170 720		2 840		21 340	

Entitlements remain the same through 2035.

*From reference 16

**"Surplus" water is included. See reference 16 for definition.

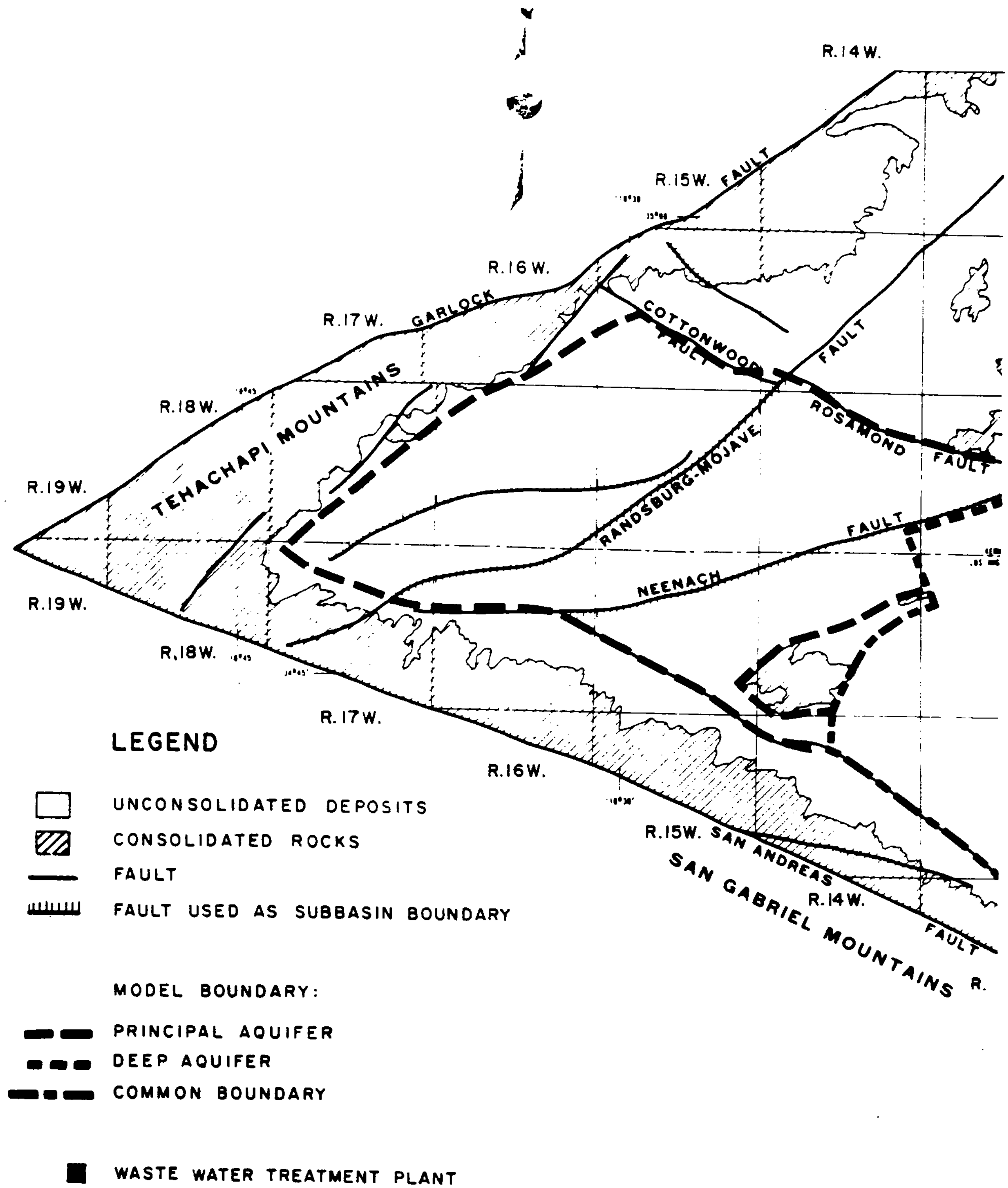
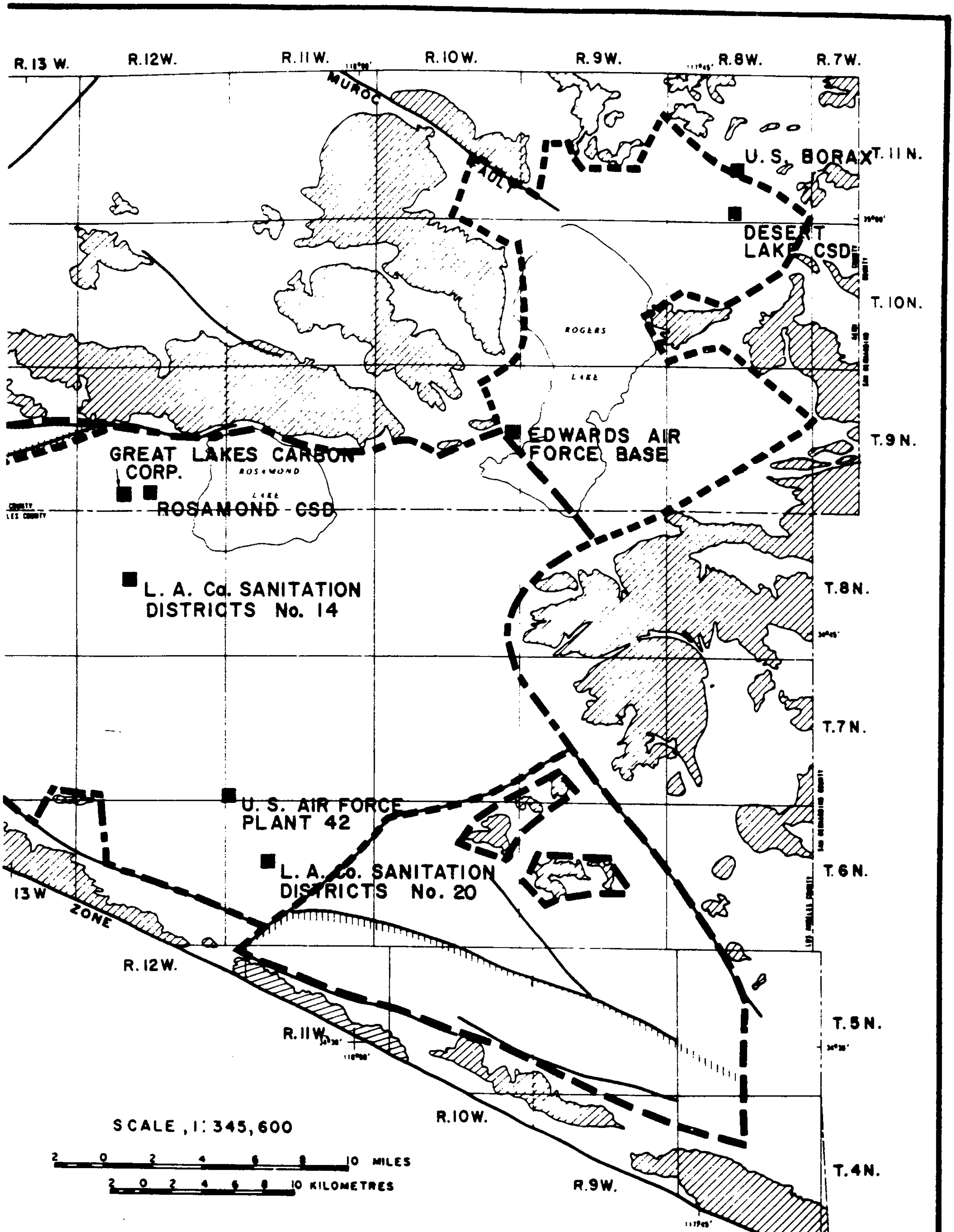


FIGURE 17 - MUNICIPAL AND INDUSTRIAL

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1980



WASTE WATER TREATMENT PLANTS

TABLE 5
ANTELOPE VALLEY
WASTE WATER TREATMENT FACILITIES*
(All discharge to land)

Discharger	Population served, in 1000s	Designed capacity in million litres per day (in million gallons per day)	Present flow rate, in million litres per day (in million gallons per day)	Type of waste water**	Treatment facilities**	Uses of reclaimed water
L. A. County Sanitation District #20	20.9	11.7 (3.1)	6.8 (1.8)	M&I	S	Crop irrigation (1 233 cubic dekametres, or 1,000 acre-feet per year)
USAF Plant #42	4.5	3.9 (1.0)	1.1 (0.3)	M&I	S	None
L. A. County Sanitation District #14	46.6	24.6 (6.5)	15.5 (4.1) 1.9 (0.5)	M&I	S T	Landscape irrigation, recreation (308 cubic dekametres, or 250 acre-feet per year)
Rosamond Community Services District	2.5	1.0 (0.25)	0.7 (0.18)	M	P	None
Great Lakes Carbon Corp.	--	--	8706 (2300)***	I	P	None
Edwards AFB	16.0	5.7 (1.5)	3.9 (1.0)	M	P	None
U. S. Borax & Chem. Corp.		Records destroyed by recent fire				
Desert Lake Community Services District	--	0.8 (0.2)	0.4 (0.1)	M	P	None

*Sources: Reference 33 and response from each discharger to request from DWR, 1977
**P = Primary, S = Secondary, T = Tertiary, M = Municipal, I = Industrial
***In litres (gallons) per day

about 1 540 cubic dekametres (1,250 acre-feet) was used for irrigation and recreation. Alfaifa is irrigated using water from District 20 Water Reclamation Plant of Los Angeles County Sanitation Districts near Palmdale. At District 14 Water Reclamation Plant near Lancaster, about 1 900 cubic metres (0.5 million gallons) per day of the total 15 000 cubic metres (4.1 million gallons) per day is tertiary treated and piped to the lakes at Apollo Park, a nearby recreational area with fishing for trout. The unused effluent (2 800 cubic dekametres, or 2,200 acre-feet) is disposed of to the Piute Ponds situated on the impermeable Rosamond Lake bed. These ponds are used only by migratory birds. Plans are to use this water to irrigate an alfalfa ranch to the west of the ponds.

Potential Change in Water Supplies

Four major factors that can alter future water supplies are:

1. Changes in local surface water supplies,
2. Changes in availability of SWP water,
3. Increase in beneficial use of

reclaimed water, and

4. Effects of ground water basin operating alternatives.

Changes in Surface Water. DWR is considering revocation of the certificate of approval for Little Rock Dam, owned by Littlerock Creek Irrigation District and Palmdale Water District. The safety of the dam is in question from the standpoints of seismic stability and spillway capacity. Revocation would essentially prohibit storage of water behind it. The interim storage limit for the reservoir is about 1 233 cubic dekametres (1,000 acre-feet) (18).

The denial of reservoir storage would compel Littlerock Creek Irrigation District and Palmdale Water District to obtain additional supplies from ground water and the SWP. The resulting free-flowing creek might increase the amount of water available to recharge ground water by about 2 500 to 4 900 cubic dekametres (2,000 to 4,000 acre-feet) annually. However, during periods of heavy runoff, the lack of water and debris storage provided by Little Rock Reservoir would permit siltation of the channel and intensify flooding.

The construction of the Palmdale Airport complex and the accompanying development of the Little Rock Creek floodplain, plus the possible dewatering of Little Rock Reservoir, would require at least partial channelization of the washes; present recharge patterns would be altered.

The impact on ground water supply of various plans for lining Big Rock Creek and Little Rock Creek with concrete have been examined using the aquifer model. The results indicate that should the creek reaches within Buttes and Pearland Subbasins be fully lined, ground water recharge would be shifted downstream toward Lancaster Subbasin (26). If both streambeds are lined along their entire lengths to Rosamond Lake, all recharge from these streams would be lost. Also, Rosamond Lake would be submerged for longer periods each year, reducing its availability to the Flight Test Center. Some peak flow information is listed in Table 6. Therefore, if any of the washes is lined, spreading facilities should be constructed in the upper reaches of the washes, and the unlined reaches should be improved to retain historic ground water recharge. However, the effect on the proposed airport due to the attraction of migratory birds to the spreading ground should be carefully considered.

Changes in Availability of SWP Water. In addition to the annual SWP entitlement contracted for by the water agencies, a certain quantity of surplus water can also be obtained. Table 7 shows the projected annual surplus water deliveries.

To fulfill contracted entitlements in

TABLE 6
U. S. ARMY CORPS OF ENGINEERS PEAK DISCHARGE VALUES*

Gaging station	Drainage area, in square kilometres (in square miles)		100-year storm, in cubic metres (cubic feet) per second	200-year storm, in cubic metres (cubic feet) per second
Little Rock Creek near Littlerock	103.6	(40.0)	481.4 (17,000)	736.2 (26,000)
Big Rock Creek near Valyermo	59.3	(22.9)	235.0 (8,300)	368.1 (13,000)
Little Rock Creek at Little Rock Dam	163.2	(63.0)	566.3 (20,000)	792.9 (28,000)
Big Rock Creek at mouth of Canyon	134.7	(52.0)	368.1 (13,000)	623.0 (22,000)

*From reference 17

TABLE 7
PROJECTED ANNUAL SWP SURPLUS
WATER DELIVERIES*

Agency	1980	Calendar year 1981	1982	1983
	In cubic dekametres			
Antelope Valley-East Kern Water Agency	93 520	31 417	82 181	69 849
Littlerock Creek Irrigation District	204	204	204	204
Total	93 724	31 621	82 385	70 053
	In acre-feet			
Antelope Valley-East Kern Water Agency	75,817	25,470	66,624	56,627
Littlerock Creek Irrigation District	165	165	165	165
Total	75,982	25,635	66,789	56,792

*From reference 17.

the future, it may be necessary to deliver SWP water in excess of projected demands during surplus runoff years. The water could be used in lieu of ground water to reduce depletion of the Valley's ground water reservoirs to provide a cushion against future droughts or other unforeseen events that could interrupt operation of the aqueduct. A study that was conducted has shown recharge on the Valley floor is limited; recharge of a significant amount requires a vast land area, thus it is economically infeasible.

Increase in Use of Reclaimed Water. In Antelope Valley, the volume of reclaimed water used is small compared to the amounts of ground water and imported water used. The single factor that can greatly increase reclaimed water production and use is the construction of new Palmdale International Airport. Currently, the County Sanitation Districts of Los Angeles County have proposed plans for expanding the plants of Sanitation Districts 14 and 20, which are the major waste water treatment plants in the study area. These plans are based upon the answers to two major questions:

1. Will Palmdale Airport be built?

2. Will the districts (Districts 14 and 20, Air Force Plant 42, and a possible future waste water treatment plant for the airport) be consolidated?

There is an imminent plan for District 14 effluent to be used for agricultural irrigation instead of simply discarding it to Piute Ponds where it eventually evaporates. This plan will add about 2 800 cubic dekametres (2,200 acre-feet) per year to the beneficial uses of reclaimed water in Antelope Valley.

Because District 20 near Palmdale has sufficient treatment capacity until 1990 if the airport is not built, plant expansion is not anticipated at this time.

Demand for reclaimed water by irrigated agriculture depends on whether its price is competitive with the price of ground water.

III. ANALYSIS OF ALTERNATIVE OPERATING CONDITIONS

Using the information developed in the inventory of resources, a number of alternative operating conditions were developed as a means of meeting the projected demand. Several were selected for detailed analysis. As noted earlier, the terms "alternative plans" and "alternative operating conditions" are taken to be synonymous.

Prior to the formulation of the basinwide water supply management plans, the TAC conceived Conditions 1 through 3, which were run on the ground water mathematical model for gaining insight into the behavior of the basin ground water levels under the influence of future projects. Projects which may be undertaken include lining some or all Little Rock Creek and Big Rock Creek Washes for flood control and assigning different patterns of pumping based upon varied scenarios of the future in Antelope Valley. The conditions examined in this phase of the study were:

Condition 1. Continued pumping from ground water at 1974 estimated rates. Assumed natural recharge continues at historic average.

Condition 2a. Operate AVEK DAWN Project (Figure 16) and proposed Eastside Agricultural Project.* Assumed agricultural users will continue use of imported water in future. Demand not met with imported water is supplied by ground water.

Condition 2b. Same as Condition 2a without Eastside Agricultural Project.

Condition 3. Same pumping as in Condition 2a through the year 1982. In 1983 increase pumping on the assumption that a portion of westside agriculture will resume mining ground water as increases in energy costs for imported water cause it to be too expensive to use for irrigation.

Alternative Operating Conditions

For each alternative operating condition, the projected figures for local surface and reclaimed water use were held constant because they represent minor elements of the total supply. The analysis focused on the major sources: SWP and ground water. Conditions 4 through 7 were formulated by the TAC specifically to evaluate the economics, environmental aspects, and overall feasibility of several distinct plans for supplying the future water demands of the Antelope Valley. To test the effect on the ground water basin of an absence of return water, Conditions 4a, 5a, and 7a were also analyzed; however, they were not considered to be management alternatives.

The plans selected for analysis are as follows:

- Condition 4 (Maximum Pumping)

  Only ground water is used to meet demand of the Antelope Valley study area. No change from present pumping patterns. Assumed that

---

* Eastside Agricultural Project—a plan by AVEK to distribute imported SWP water to agricultural users in the eastern part of the Valley.

30 percent of total applied water used returns to ground water.

- Condition 4a (Maximum Pumping with No Return)

  Same as Condition 4, with the exception that no recharge would be derived from return water.

- Condition 5 (No Change in Storage)

  Annual net pumping is equal to the net historical natural recharge of approximately 49 000 cubic dekametres (40,000 acre-feet) per year, with SWP water used to meet the rest of the demand. Assumed that 30 percent of total applied water returns to ground water.

- Condition 5a (No Change in Storage with No Return)

  Same as Condition 5, with the exception that no recharge would be derived from return water.

- Condition 6 (Maximum Recharge)

  Same as Condition 5, with the exception that 250 000 cubic dekametres (200,000 acre-feet)* per year of SWP water would be used for artificial recharge to restore historical water levels by 2020. Pumping patterns are adjusted to accommodate this influx of water. Assumed that 30 percent of total applied water returns to ground water.

- Condition 7 (Full Entitlement)

  Full entitlements of SWP water are used. As much ground water as necessary is used to meet demand--

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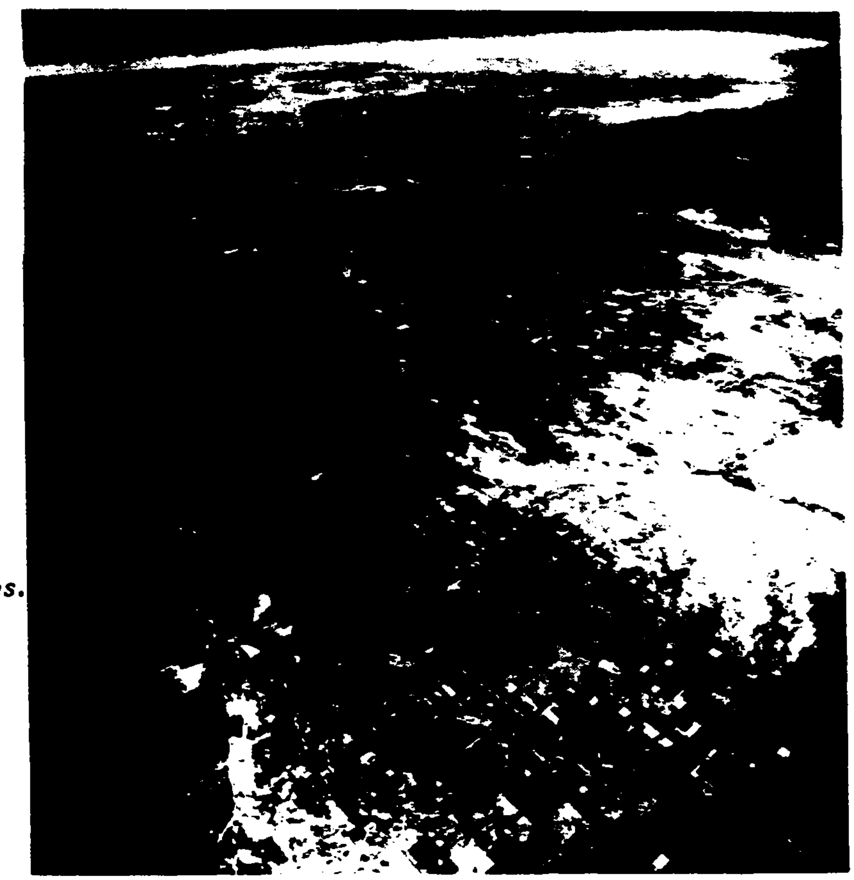
* This amount was estimated without consideration of the limitations imposed by the actual SWP contract entitlements for the three contractors in the study area.



THE TRIANGULAR SHAPE of the Antelope Valley was formed by movement along the Garlock and San Andreas faults. The massive, downfaulted basin is filled with alluvium to depths greater than 1500 metres (5,000 feet). Irrigated agriculture (dark rectangles) is found throughout the Valley, except in the more alkaline soils around the dry lakes.

this could exceed the natural replenishment rate. Assumed that 30 percent of the total applied water returns to ground water.

- Condition 7a (Full Entitlement with No Return)

  Same as Condition 7, with the exception that no recharge would be derived from return water.

The distribution of water supplies under the various alternative plans is given in Table 8.

Analysis of Alternatives

Using the USGS aquifer simulation model, the following physical and economic evaluations for each of the alternative operating conditions were conducted to provide the basis for comparison:

1. Ground water level responses.
2. Energy consumed in pumping ground water.
3. Cost of pumping or recharging ground water.

TABLE 8
DISTRIBUTION OF WATER SUPPLY UNDER ALTERNATIVE PLANS IN 1975, 2000, AND 2020
In thousand acre-feet

	1975	2000	2020
Condition 4			
Surface water	4.1	4.1	4.1
Ground water	187.3	227.5	250.6
SWP water	0	0	0
Reclaimed water	1.2	1.2	1.2
Total	192.6	232.8	255.9
Condition 4a			
Surface water	4.1	4.1	4.1
Ground water	187.3	227.5	250.6
SWP water	0	0	0
Reclaimed water	1.2	1.2	1.2
Total	192.6	232.8	255.9
Condition 5			
Surface water	4.1	4.1	4.1
Ground water	97.5	109.5	116.5
SWP water	89.8	118	134.1
Reclaimed water	1.2	1.2	1.2
Total	192.6	232.8	255.9
Condition 5a			
Surface water	4.1	4.1	4.1
Ground water	39.7*	39.7*	39.7*
SWP water	147.6	187.8	210.9
Reclaimed water	1.2	1.2	1.2
Total	192.6	232.8	255.9
Condition 6			
Surface water	4.1	4.1	4.1
Ground water	97.5	109.5	116.5
SWP water	289.8**	318**	334.1**
Reclaimed water	1.2	1.2	1.2
Total	392.6	432.8	455.9
Condition 7			
Surface water	4.1	4.1	4.1
Ground water	178.7	72.9	92.6
SWP water	8.6	154.6	158
Reclaimed water	1.2	1.2	1.2
Total	192.6	232.8	255.9
Condition 7a			
Surface water	4.1	4.1	4.1
Ground water	178.7	72.9	92.6
SWP water	8.6	154.6	158
Reclaimed water	1.2	1.2	1.2
Total	192.6	232.8	255.9

*Safe yield pumpage

**Includes 200,000 acre-feet for artificial recharge of basin to restore historic ground water levels

4. Energy consumed and cost of energy required for other supplies.

5. Values and costs associated with ground water.

The energy consumed and costs estimated to be incurred in the operation of the ground water basin were then combined with the energy consumption and costs of other sources of water to yield the total energy consumption and costs for each alternative. Costs were generally developed from the viewpoint of delivering a given volume of untreated water to the Valley. An exception is reclaimed water, which must be treated prior to reuse.

Ground Water Level Responses

Water levels, under the various operating conditions, were simulated by the USGS aquifer model. The nodal water levels resulting from the simulation were then grouped into area-weighted averages for each of the seven subbasins. In turn, these values were averaged once again to obtain an overall level for the Valley as a whole. An overall average

TABLE 8
DISTRIBUTION OF WATER SUPPLY UNDER ALTERNATIVE PLANS IN 1975, 2000, AND 2020
In thousand cubic dekametres

	1975	2000	2020		1975	2000	2020
Condition 4				**Condition 6**			
Surface water	5.1	5.1	5.1	Surface water	5.1	5.1	5.1
Ground water	231	281	309	Ground water	120	135	144
SWP water	0	0	0	SWP water	357**	392**	412**
Reclaimed water	1.5	1.5	1.5	Reclaimed water	1.5	1.5	1.5
Total	237.6	287.6	315.6	Total	483.6	533.6	562.6
Condition 4a				**Condition 7**			
Surface water	5.1	5.1	5.1	Surface water	5.1	5.1	5.1
Ground water	231	281	309	Ground water	220	90	114
SWP water	0	0	0	SWP water	11	191	195
Reclaimed water	1.5	1.5	1.5	Reclaimed water	1.5	1.5	1.5
Total	237.6	287.6	315.6	Total	237.6	287.6	315.6
Condition 5				**Condition 7a**			
Surface water	5.1	5.1	5.1	Surface water	5.1	5.1	5.1
Ground water	120	135	144	Ground water	220	90	114
SWP water	111	146	165	SWP water	11	191	195
Reclaimed water	1.5	1.5	1.5	Reclaimed water	1.5	1.5	1.5
Total	237.6	287.6	315.6	Total	237.6	287.6	315.6
Condition 5a							
Surface water	5.1	5.1	5.1				
Ground water	49*	49*	49*				
SWP water	182	232	260				
Reclaimed water	1.5	1.5	1.5				
Total	237.6	287.6	315.6				

*Safe yield pumpage

**Includes 247,000 cubic dekametres for artificial recharge of basin to restore historic ground water levels of cumulative changes of water in storage was also computed.

The results of the simulation should not be misconstrued to be exact representations of the actual future conditions within the aquifer system--even if the ground water basin can be operated precisely as planned. Aquifer simulation can only provide some insights for planners to assess the general responses of the aquifer systems under the influence of different management plans.

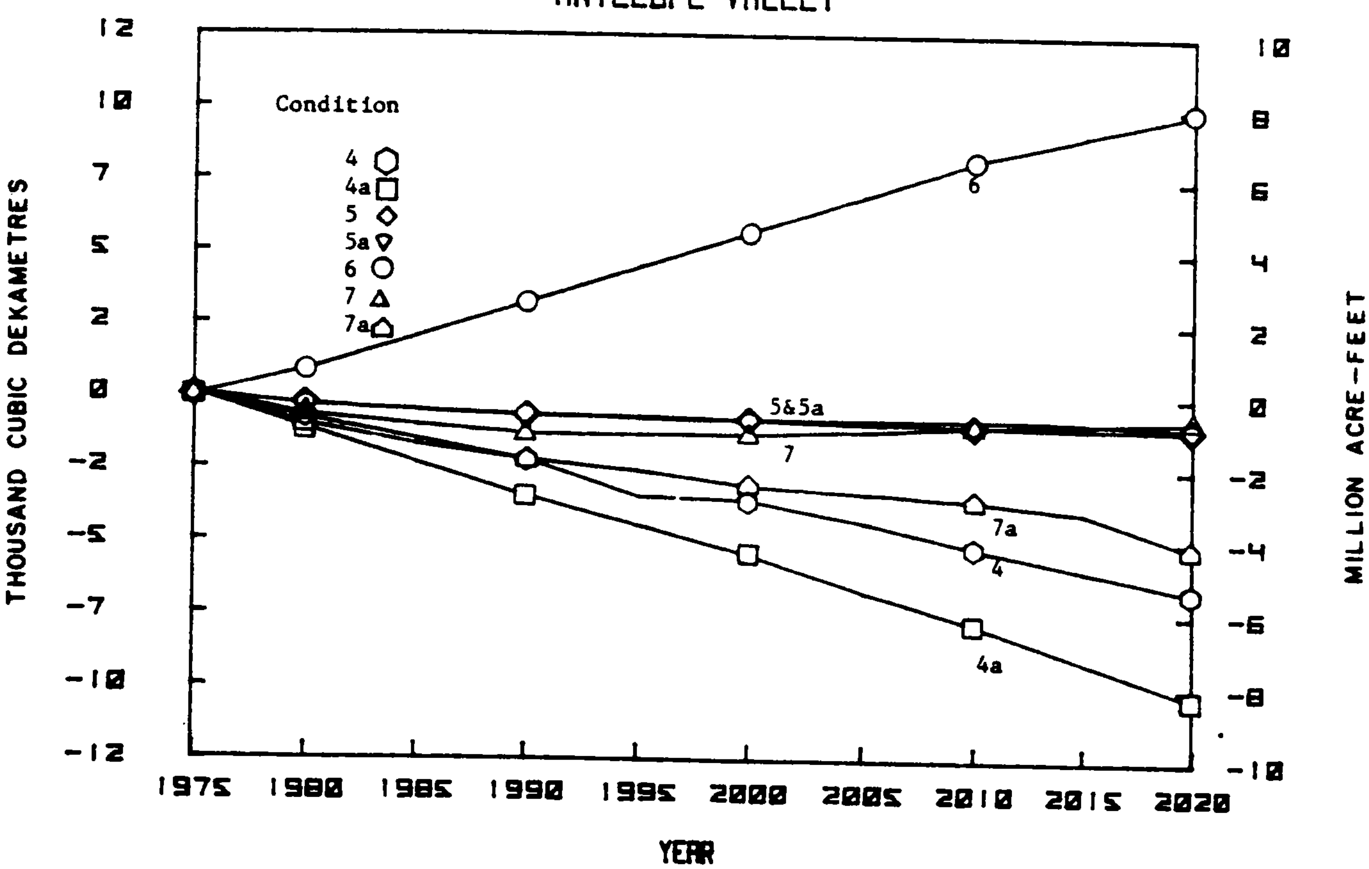
In this study, the results of the aquifer simulation are consistent with what would be logically expected. Figure 18 shows the cumulative change of water in storage for each of the alternatives. In Figure 19, the weighted average water level elevation for Maximum Recharge (Condition 6) depicts an increase of 35.2 metres (115.5 feet) from 1975 to 2020, whereas Maximum Pumping (Condition 4) shows a decline of 24 metres (78 feet) for the same period. The relative positions of the water level elevation plots for other operating conditions are consistent with the amount of pumping proposed.

Energy Consumed in Pumping Ground Water

With pump lifts computed from the simulated water levels and total pumpage volume estimated from projected ground water requirements, the energy consumption for each alternative was evaluated. Total energy consumption values for throughout the study period are in Table 9. Maximum Pumping (Condition 4) has the highest consumption, as expected, with a total of 6.9 billion

FIGURE 18

CUMULATIVE CHANGES OF GROUND WATER IN STORAGE ANTELOPE VALLEY



kilowatthours (kWh). The lowest is achieved by Maximum Recharge (Condition 6) with a total consumption of 2.5 billion kWh.

Cost of Pumping Ground Water

The components considered in the evaluation of ground water pumping costs are: energy consumed by pumps plus the operation and maintenance and capital replacement costs for the wells and pumping facilities used to obtain ground water. These cost components are totaled to obtain an overall cost of ground water in the Antelope Valley.

Table 10 lists the accumulated 1975 present worth costs for ground water. It can be seen that Maximum Pumping (Condition 4) results in the highest cost for ground water because of the steadily increasing pump lifts.

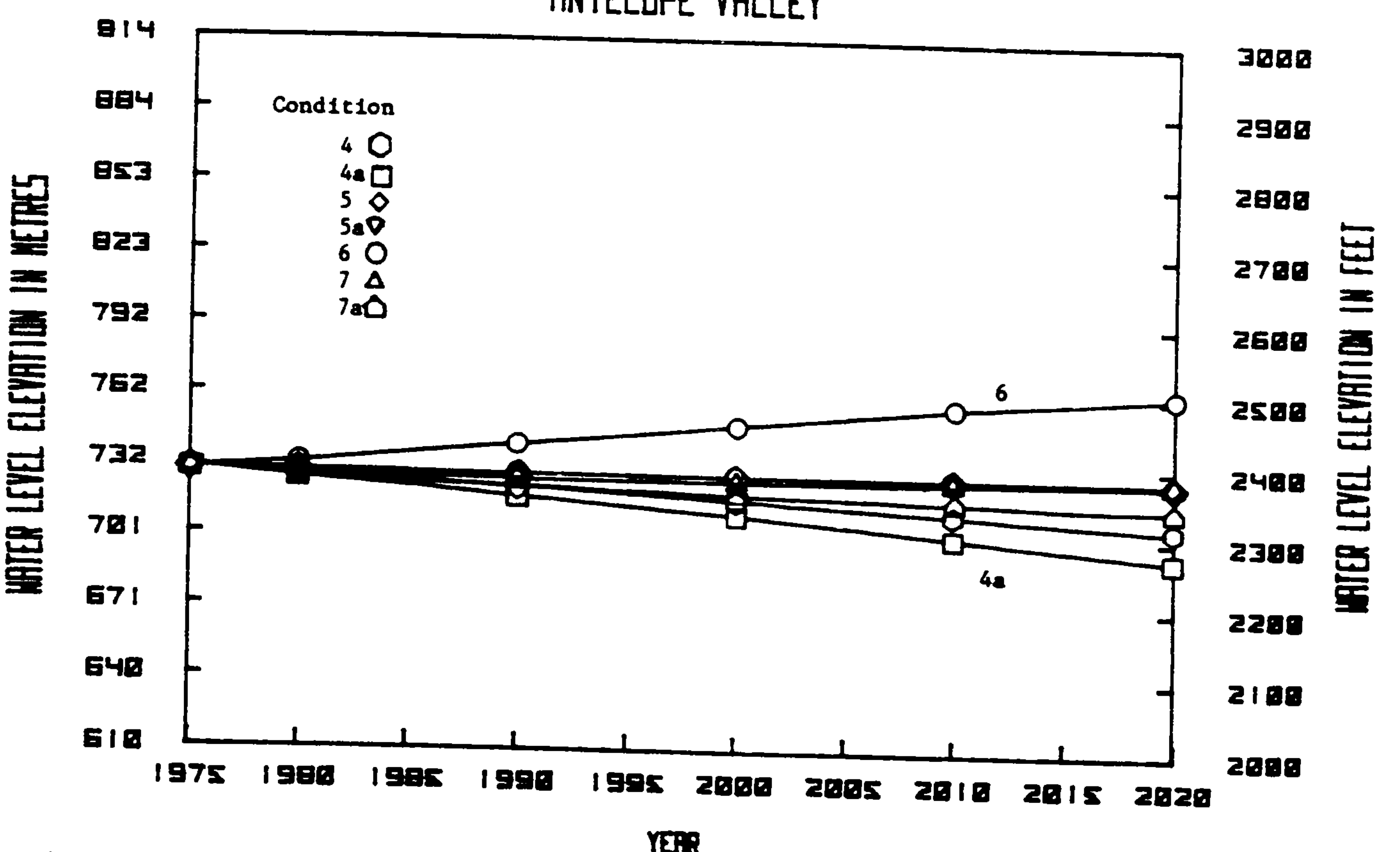
The assumptions made in estimating these costs included: (1) the average well produces 990 cubic dekametres (800 acre-feet) per year, (2) the capital cost of a pumping facility is $65,000, (3) the average life of the pumping facility is 7 years, (4) a booster pump maintains a pumping head of 51.82 metres (170-foot-pound per

TABLE 9
SUM OF ENERGY CONSUMED IN PUMPING GROUND WATER, 1975–2020
In billions of kilowatthours

Condition	Energy consumption
4	6.9
4a	7.3
5	3.0
5a	1.1
6	2.5
7	2.8
7a	2.9

FIGURE 19

WEIGHTED AVERAGE WATER LEVEL ELEVATION ANTELOPE VALLEY



pound), (5) Southern California Edison's energy price schedule PA-1 applies throughout the whole period, (5) the interest rate is 6 percent, and (6) the annual operation and maintenance costs for each facility are $1,000.

The 7-year life span of a pumping facility is based on information obtained by Boyle Engineering Corporation from the farmers in Antelope Valley. The assumption of a longer well life would further decrease the present worth cost of pumping ground water. The interest rate of 6 percent is based on the assumption that Federal loans are available to the farmers.

The current erratic movement of interest rates necessitates estimation of the impact of changing interest rates on the costs of the competing plans. An additional cost study was made based on the assumptions that the life span of a pumping facility is 30 years rather than 7 years, the interest rate is 8 percent rather than 6 percent, and the annual operation and maintenance cost is $2000 per well. The resulting costs are given in Table 11.

TABLE 10

PRESENT WORTH OF GROUND WATER COSTS FOR 1975-2020 AT 6% INTEREST RATE
In millions of dollars

Condition	Energy	O&M + capital replacement	Total
4	$88.5	$56.4	$144.9
4a	91.6	56.4	148.0
5	41.4	28.2	69.6
5a	15.5	10.8	26.3
6*	37.2	28.2	65.4
7	47.6	36.1	83.7
7a	48.8	36.1	84.9

*Not included are the costs of a spreading program.

TABLE 11

PRESENT WORTH OF GROUND WATER COSTS FOR 1975-2020 AT 8% INTEREST RATE
In millions of dollars

Condition	Energy	O&M + capital replacement	Total
4	$67.0	$28.0	$95.0
4a	69.0	28.0	97.0
5	31.9	14.1	46.0
5a	12.1	5.4	17.5
6*	29.2	14.1	43.3
7	38.3	22.2	60.5
7a	39.1	22.2	61.3

*Not included are the costs of a spreading program.

Comparing the total present worth ground water costs derived under the different assumptions (Tables 10 and 11), the cost of ground water drops about one-third with an 8 percent interest rate and a 30-year well life. Most of this difference comes from the rise in interest rate.

Cost of Energy Required for Other Supplies

Ground water is not the only supply which consumes energy. There are also energy costs associated with SWP water and reclaimed water; local surface supplies are delivered by gravity, hence their energy costs are insignificant. Also, because of the small size of reclaimed water and local surface water supplies and the fact that their magnitudes are held constant for all alternatives, they are omitted from the comparison. Thus this analysis concentrates on the comparison of the energy consumption and cost of SWP water and those of ground water for the various alternatives.

Provided in Table 12 are the cumulative values of energy consumption of SWP water for each alternative. Table 13 shows the cost components of this water for Antelope Valley.* Table 14 lists the 1975 present worth costs of the water for each alternative. The present worth cost of SWP water is about

* Cost figures were computed with the cost components given in Bulletin 132-78 (Reference 17). Future energy costs adjustments were not considered. (See Appendix B.)

TABLE 12
SUM OF ENERGY CONSUMED FOR WATER IMPORTATION FOR 1975–2020
In billions of kilowatthours

Condition	Energy consumption
4	0
4a	0
5	20.0
5a	32.0
6	55.0
7	21.5
7a	21.5

TABLE 13
SWP COST COMPONENTS FOR 1975–2020 IN ANTELOPE VALLEY*

Component	Per cubic dekametre	Per acre-foot
Fixed cost		
Delta water	$ 24.36	$ 30.05
Minimum OMP&R**	5.15	6.35
Capital	18.35	22.64
Subtotal	47.86	59.04
Variable cost		
Variable OMP&R**	77.54	95.66
Total	$125.40	$154.70

*Data from reference 16
**OMP&R = operation, maintenance, power, and replacement

20 percent lower at an 8 percent interest rate than at 6 percent. A spreading project would incur a subtantial capital cost, as shown in Table 15. The small difference in the estimated cost at 6 percent and 8 percent interest rates follows as a result of the fact that the capital cost component dominates these estimates.

The total energy consumption of each alternative is shown in Figure 20.

Values and Costs Associated with Ground Water

The value of ground water in storage might be considered as the amount of money that could be saved by having water levels at higher elevation with reference to a base level after 2020.

This determination was made by assuming that all the plans will be operated on a safe yield basis after 2020. For this determination, Maximum Pumping with No Return (Condition 4a), which would have the least ground water in storage in 2020, was selected as the reference plan. First, the annual amount of money saved under each plan relative to the reference plan 4a (as a result of

TABLE 14
1975 PRESENT WORTH OF COSTS FOR SWP WATER FOR 1975–2020 AT 6% AND 8% INTEREST RATES
In millions of dollars

Condition	Fixed cost*		Variable cost**		Total	
	At 6%	At 8%	At 6%	At 8%	At 6%	At 8%
4	$123.4	$96.7	0	0	$123.4	$ 96.7
4a	123.4	96.7	0	0	123.4	96.7
5	123.4	96.7	$171.8	$134.6	295.2	231.3
5a	123.4	96.7	274.6	215.1	398.0	311.8
6	123.4	96.7	474.1	371.4	597.5	468.1
7	123.4	96.7	183.9	144.1	307.3	240.8
7a	123.4	96.7	183.9	144.1	307.3	240.8

*Unit fixed cost is about $48 per cubic dekametre, which includes the Delta water, minimum OMP&R, and capital charges.
**Unit variable cost is estimated to be $78 per cubic dekametre, which consists of the variable OMP&R charges only.

smaller pumping lifts) was obtained and the capitalized amount necessary for continually funding the cost was determined. The 1975 present worth values for this amount were then determined with the results shown in Table 16.

A "penalty" cost is sometimes attached to water supplies with relatively high mineral content under the assumption that certain additional user costs would be induced, such as for added amount of detergents consumed, increased maintenance and repair resulting from scaling and corrosion of metal water pipes and heaters, special treatment such as softening or demineralization, and reduced crop yield or increased irrigation water used for leaching requirements. However, in this investigation, the evaluation of penalty cost was not possible because data were lacking for devising a ground water quality model. Nevertheless, when data become available, the penalty cost introduced by each alternative should be included because it represents a

TABLE 16
SAVINGS IN PUMPING COST AFTER 2020
In thousands of dollars

Condition	1975 present worth	
	At 6%	At 8%
4	$173	$136
4a	0	0
5	462	362
5a	91	385
6	900	705
7	505	396
7a	337	264

TABLE 15
SUMMARY OF COSTS FOR PIPELINES, SPREADING GROUNDS, AND PUMPING ENERGY FOR CONDITION 6*

Item	Quantity	Cost
Required pipe of various diameters	327 kilometres (203 miles)	$15,100,000
Soil excavated	631 000 cubic metres (825,720 cubic yards)	1,200,000
Soil backfilled	587 000 cubic metres (767,263 cubic yards)	1,500,000
Pumping plants	5 plants ranging from 6.7 kW to 492 kW	50,000
Spreading grounds	152 covering 2.82 square kilometres (696.5 acres)	8,000,000
	Subtotal	$25,850,000
Plus 15% for valves, appurtenances, and miscellaneous		3,900,000
Total cost of pipelines and spreading grounds		$29,750,000
Plus 15% engineering and contingency costs		4,500,000
	Total capital cost	$34,250,000

Annual energy cost to operate 5 pumps = $146,148

For 1975–2020:

1975 present worth total at 6% = 15.456 X ($146,148) = $2,258,863
1975 present worth total at 8% = 12.108 X ($146,148) = $1,769,559

Total present worth in 1975 at 6% = $2,258,863 + $34,250,000 = $36,508,863

Total present worth in 1975 at 8% = $1,769,559 + $34,250,000 = $36,019,559

*Details can be found in DWR Southern District Office

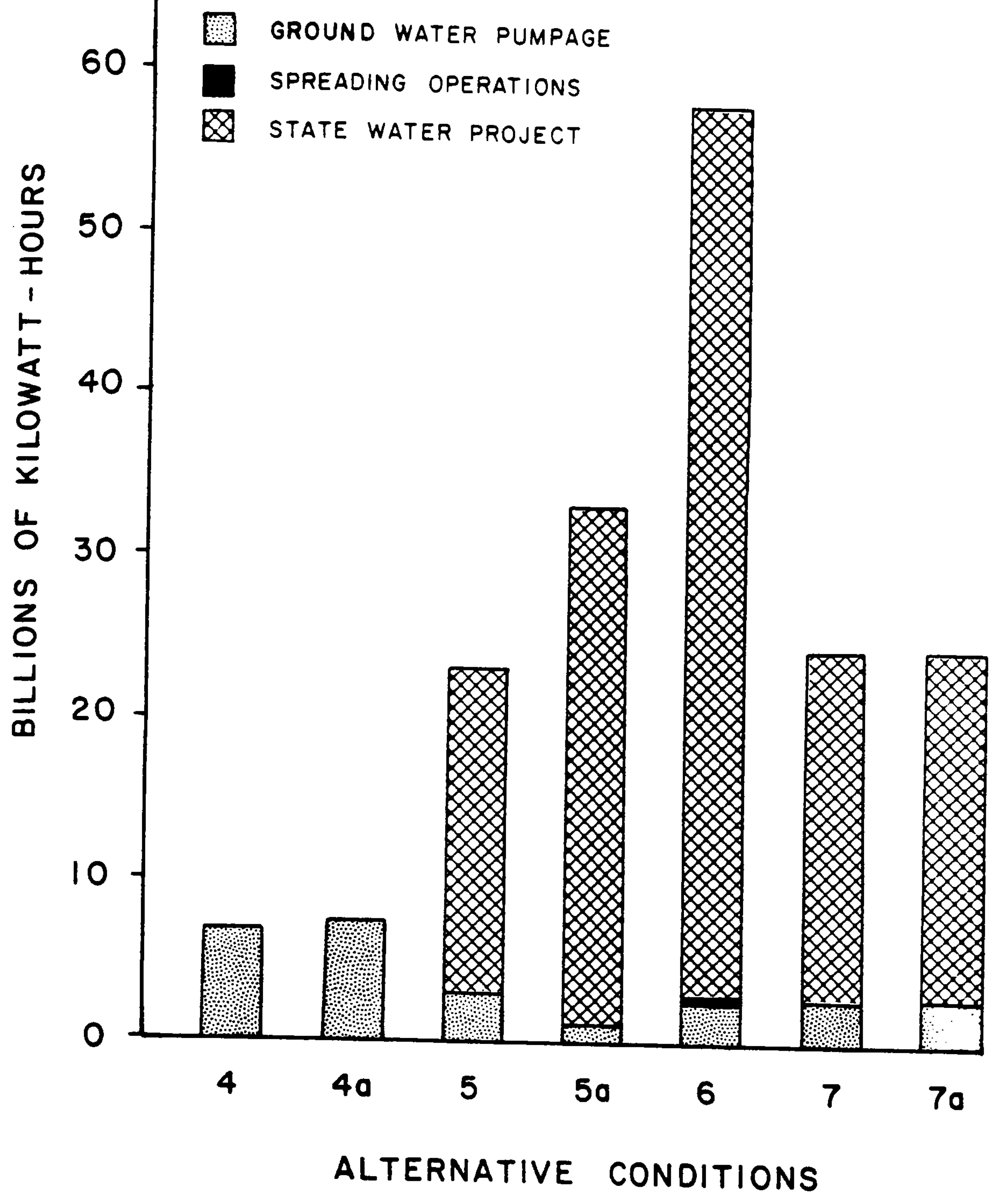


FIGURE 20
ENERGY CONSUMED BY EACH ALTERNATIVE PLAN

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT 1980

TABLE 17
COMPARISON OF 1975 PRESENT WORTH OF COSTS OF OPERATING CONDITIONS FOR 1975–2020
In millions of dollars

Item	4	4a	5	5a	6	7	7a
			At 6% interest				
(a) Cost of ground water	$145.0	$148.0	$69.6	$26.3	$65.4	$83.7	$84.9
(b) Cost of imported water (SWP)	123.4	123.4	295.2	398.0	597.5	307.3	307.3
(c) Cost of spreading program	0	0	0	0	36.6	0	0
(d) Savings in pumping costs after 2020*	0.2	0	0.5	0.5	0.9	0.5	0.3
(e) Net cost =(a)+(b)+(c)−(d)	268.2	271.4	364.3	423.8	698.6	390.5	391.9
			At 8% interest				
(a) Cost of ground water	$95.0	$97.0	$46.0	$17.5	$43.3	$60.5	$61.3
(b) Cost of imported water (SWP)	96.7	96.7	231.3	311.8	468.1	240.8	240.8
(c) Cost of spreading program	0	0	0	0	36.1	0	0
(d) Savings in pumping costs after 2020*	0.1	0	0.4	0.4	0.7	0.4	0.3
(e) Net cost =(a)+(b)+(c)−(d)	191.6	193.7	276.9	328.9	546.8	300.9	301.8
(f) Change between 6% and 8% interests	−29%	−29%	−24%	−22%	−22%	−23%	−23%

*Using Condition 4a as a basis for comparison.

competitive amount, as has been demonstrated in other studies.

Comparison of Energy Consumption Costs

The comparison of energy consumption costs of the operating conditions involves (1) the costs of ground water, (2) costs of SWP water (imported), (3) costs of spreading program, and (4) value of ground water remaining in storage (savings in pumping costs). The total energy consumption for each of the alternative conditions is given in Figure 20. Table 17 provides the values for each of the cost and benefit items for each alternative plan. These values are expressed in terms of present worth in which the present time base is 1975 with interest rates of 6 percent and 8 percent used. Figure 21 shows the total 1975 present worth cost at 6 percent interest for each of the alternatives incurred during the study period 1975-2020.

Secondary Effects of Operating Alternatives

In addition to the more immediate physical and economic effects of the operating alternatives, social and environmental impacts of each plan must also be considered as part of the integrated management plan. The environmental and social issues entering into consideration for this study are:

1. Possible land subsidence,

2. Possible flood hazard,

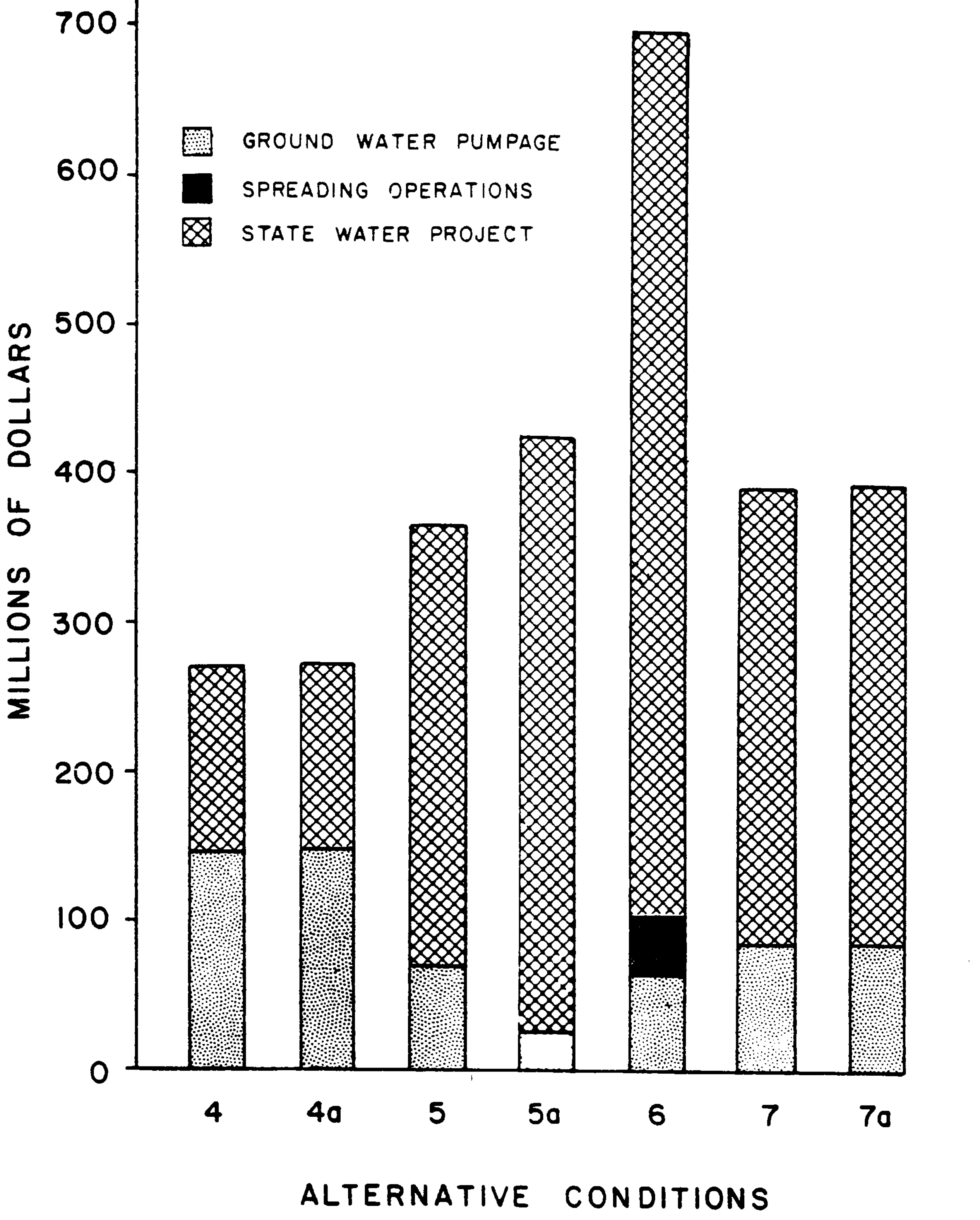


FIGURE 21

COSTS OF ALTERNATIVE PLANS

PRESENT WORTH AT 6% INTEREST

3. Change in land use pattern, and

4. Impairment or enhancement of wildlife habitat.

Possible Land Subsidence

Compaction of soil particles could take place because of heavy pumping of ground water. It should be pointed out that the real concern is not gradual, homogeneous subsidence but rather significant differential subsidence because of its potential for damaging structures. On the basis of available data, it is not possible to predict whether such subsidence will occur.

Under Maximum Pumping with and without return (Conditions 4 and 4a), subsidence could possibly pose some problems because these conditions represent maximum extractions of ground water. Subsidence would be concentrated in areas with heavy pumping. Table 18 shows total amount extracted in each subbasin under these two conditions.

TABLE 18
TOTAL VOLUME OF GROUND WATER EXTRACTED DURING 1975-2020 UNDER CONDITIONS 4 AND 4a

Subbasin	Condition 4	Condition 4a
	In thousand cubic dekametres	
Finger Buttes	237	313
West Antelope	350	501
Neenach	1 283	1 967
Lancaster	3 507	5 908
Buttes	636	867
Pearland	491	623
North Muroc	171	179
Total	6 675	10 358
	In acre-feet	
Finger Buttes	192,000	254,000
West Antelope	284,000	406,000
Neenach	1,040,000	1,595,000
Lancaster	2,843,000	4,790,000
Buttes	516,000	703,000
Pearland	398,000	505,000
North Muroc	139,000	145,000
Total	5,412,000	8,398,000

The stabilization of basin ground water levels under Operating Conditions 5 and 5a would result in reduced possibility of subsidence.

Flood Hazard

At the other extreme, if ground water levels are high, the available space for further ground water storage is reduced. The further reduction in percolation of storm flows may cause flood problems in the area.

Table 19 provides the amount of space available for future storage after 2020 for Maximum Recharge (Condition 6) at the designated subbasins. Under all other operating conditions, the amount of storage space available would be greater.

Change in Land Use Pattern

Conditions 4 and 4a represent maximum reliance on ground water to supply the Valley during the study period. Eventually, the lowering water table would result in the less efficient pumpers being forced out of production until, at some time in the future, extractions equal the natural recharge to the Valley. Agricultural land would either be idled or replanted with higher-return alternative crops. The surviving farms might be consolidated into larger units able to pay for larger pumping facilities. Municipal and industrial pumpers, with a higher payment capability than agriculture, would be able to pump from greater depths.

Conditions 5 and 5a represent the case of allowing only safe-yield pumpage plus the importation of SWP water to supply the Valley. If these conditions are strictly adhered to, agriculture would likely be diminished because of the lesser ability of agriculture to pay for the SWP water. Water levels in the ground water basin would likely stabilize. Because of the limited ground water pumping allowed, anyone without access to SWP water would

TABLE 19
AVAILABLE STORAGE SPACE AFTER 2020 RESULTING FROM OPERATING CONDITION 6

Subbasin	Water level elevation	Ground surface elevation	Storage space from 6 metres* below ground surface to water table	Storage space from 15 metres* below ground surface to water table
	In metres		In thousand cubic dekametres	
Finger Buttes	967	1 049	1 195	1 051
West Antelope	896	913	79	15
Neenach	768	822	1 925	1 560
Lancaster	718	739	2 208	883
Buttes	806	845	850	613
Pearland	871	955	1 444	1 274
North Muroc	665	713	1 240	971
Total			8 941	6 367
	In feet		In acre-feet	
Finger Buttes	3,172	3,440	969,441	851,838
West Antelope	2,939	2,996	64,106	12,128
Neenach	2,518	2,691	1,560,516	1,264,590
Lancaster	2,356	2,426	1,790,025	716,010
Buttes	2,644	2,772	688,713	497,041
Pearland	2,858	3,132	1,170,931	1,032,958
North Muroc	2,182	2,340	1,005,503	786,915
Total			7,249,235	~~1,161,480~~ [illegible]

*6 metres = 20 feet: 15 metres = 50 feet

either be forced to shift to dry farming, allow the land to remain fallow, or find some other use for it.

Condition 6 represents the case of restoration of historic ground water levels by spreading SWP water and limiting the pumping which may be conducted. Under this plan, ground water levels would rise, artesian pressures would be restored in many areas, and, with the high ground water levels, phreatophytes such as salt grass would reappear in the lower parts of the Valley. The remaining agriculture would benefit from decreased pumping lifts, which would drastically reduce pumping costs. It would be difficult to identify the pumpers who would directly benefit from the decreased pump lifts.

Under Full Entitlement with and without return (Conditions 7 and 7a), changes would come as urban population expands into the open spaces. The decline in ground water elevation would be retarded and the survival of the present level of agricultural activity would be prolonged. The changes in land use would probably occur gradually over the span of the study period. The proposed Palmdale International Airport is the major potential catalyst for rapid population growth and development in the Valley.

Impairment or Enhancement of Wildlife Habitat

Under Maximum Pumping with and without return (Conditions 4 and 4a), there would be an increase in wildlife habitat as fallow land grows wild. As the grasslands succeed presently cultivated land, wind erosion would likely be reduced.

Under Maximum Recharge (Condition 6), marshes and springs which develop due to a high water table would attract migratory birds and other animals. The numerous recharging ponds and the intricate distribution system necessary to percolate the imported water would disturb a sizable amount of land but might be compensated for by the increase in wildlife habitat.

APPENDIX A

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APPENDIX B

PROJECTED ENERGY COSTS FOR STATE WATER PROJECT

(Prepared by Department of Water Resources Energy Division, March 14, 1980)

DEPARTMENT OF WATER RESOURCES
PROJECTED ENERGY COSTS

CALENDAR YEAR	1980	1985	1990	1995	2000
TOTAL ENERGY REQUIREMENTS (millions of kWh)	5,820	7,503	9,465	9,923	10,000
ENERGY SOURCES (millions of kWh)					
Hyatt-Thermalito Recovery	0	2,300	2,300	2,300	2,300
Devil Canyon	923	905	920	884	828
Cottonwood	0	99	101	100	97
Castaic	294	352	738	872	916
Pyramid	0	213	445	527	553
Other	126	152	149	234	266
SCE Exchange	0	1,451	1,291	1,178	1,098
Pine Flat	0	423	423	423	423
MWD Hydro	0	255	317	342	340
Reid Gardner	0	1,216	1,216	1,216	997
Bottle Rock	0	372	372	372	372
South Geysers	0	186	372	372	372
Honey Lake	0	361	361	361	361
Edison Purchases	0	0	459	741	981
Suppliers & CEP (to 3/31/83) / Other Purchase	4,477	0	0	0	95
Excess (Potential Sale or Exchange)	0	-782	0	0	0
Total	5,820	7,503	9,465	9,923	10,000
PERCENTAGES					
Hyatt-Thermalito Recovery	0.000	30.654	24.300	23.178	23.000
Devil Canyon	15.859	12.063	9.720	8.909	8.280
Cottonwood	0.000	1.319	1.067	1.008	0.970
Castaic	5.052	4.691	7.797	8.788	9.160
Pyramid	0.000	2.839	4.702	5.311	5.530
Other	2.165	2.026	1.574	2.358	2.660
SCE Exchange	0.000	19.339	13.640	11.871	10.980
Pine Flat	0.000	5.638	4.469	4.263	4.230
MWD Hydro	0.000	3.410	3.351	3.456	3.408
Reid Gardner	0.000	16.207	12.847	12.254	9.970
Bottle Rock	0.000	4.958	3.930	3.749	3.720
South Geysers	0.000	2.479	3.930	3.749	3.720
Honey Lake	0.000	4.811	3.814	3.638	3.610
Edison Purchases	0.000	0.000	4.859	7.468	9.810
Suppliers & CEP (to 3/31/83) / Other Purchase	76.924	0.000	0.000	0.000	0.352
Excess (Potential Sale or Exchange)	0.000	-10.434	0.000	0.000	0.000
Total	100.000	100.000	100.000	100.000	100.000
NERGY COST / VALUE (mills/kWh)					
yatt-Thermalito ecovery (all)	0.0	9.0	9.9	11.2	13.0
CE Exchange	6.8	25.0	25.0	25.0	25.0
ine Flat	0.0	0.0	0.0	0.0	0.0
WD Hdro	0.0	24.7	27.8	31.9	37.4
eid Gardner	0.0	36.2	40.2	45.3	52.1
ottle Rock	0.0	48.0	62.0	84.0	117.0
outh Geysers	0.0	50.0	52.8	64.2	88.4
oney Lake	0.0	48.6	51.4	62.9	87.1
dison Purchases	0.0	50.0	52.8	64.2	88.4
uppliers & CEP (to 3/31/83) / Other Purchase	0.0	58.0	93.0	150.4	242.2
xcess (Potential Sale or Exchange)	3.5	0.0	0.0	0.0	242.2
	0.0	19.3	0.0	0.0	0.0
OMPOSITE COST (mills/kWh)	4.3	23.0	29.8	40.7	60.4
ANSMISSION CHARGE (mills/kWh)	0.3	3.4	2.7	2.6	2.5
TAL COMPOSITE COST (mills/kWh)	4.6	26.4	32.5	43.3	62.9

TE: Does not include future arrangements for the sale or exchange of energy temporarily in excess of requirements. Sale shown for 1985 is estimated fuel costs for Reid Gardner (implies reduction of Reid Gardner generation).

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