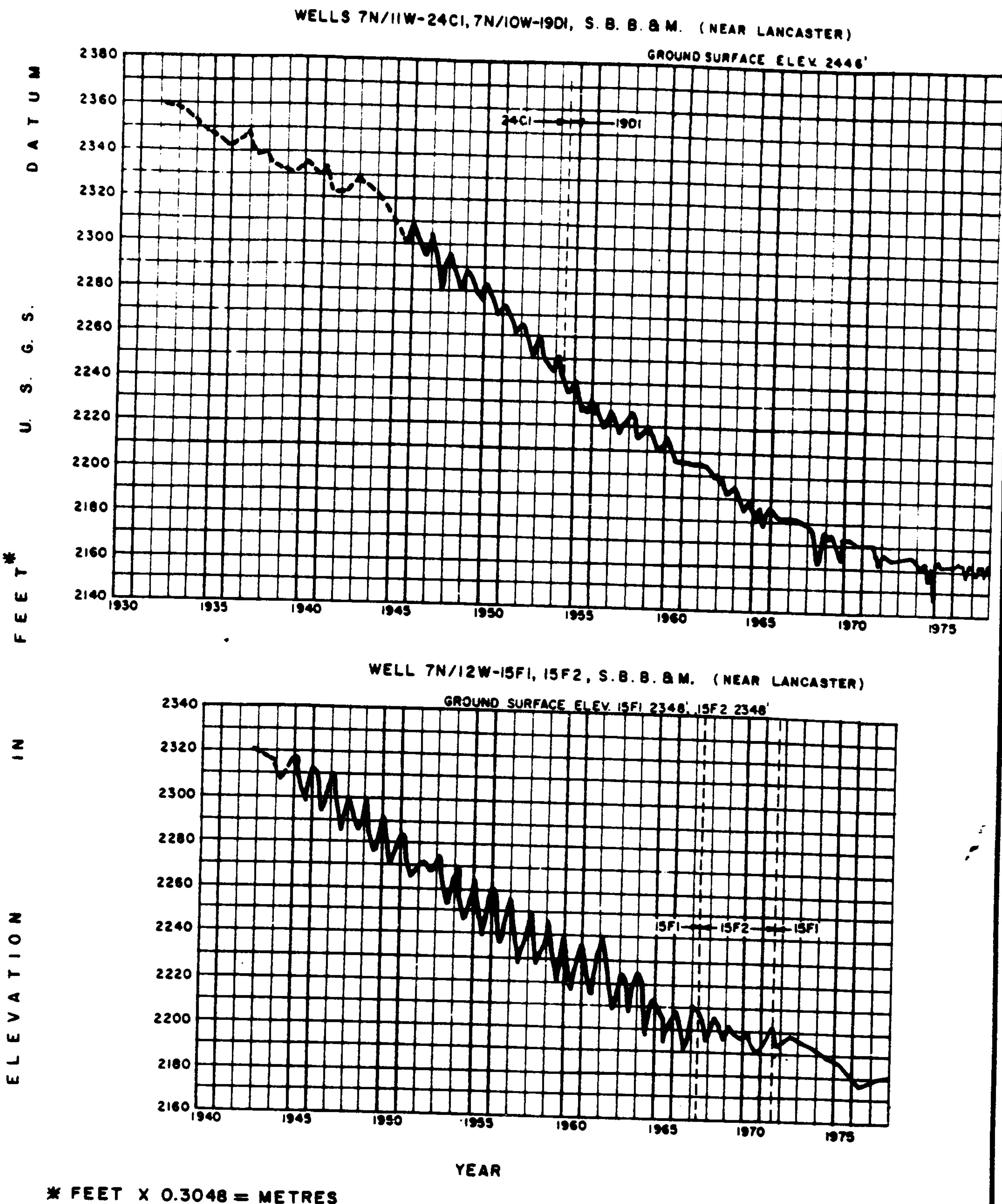


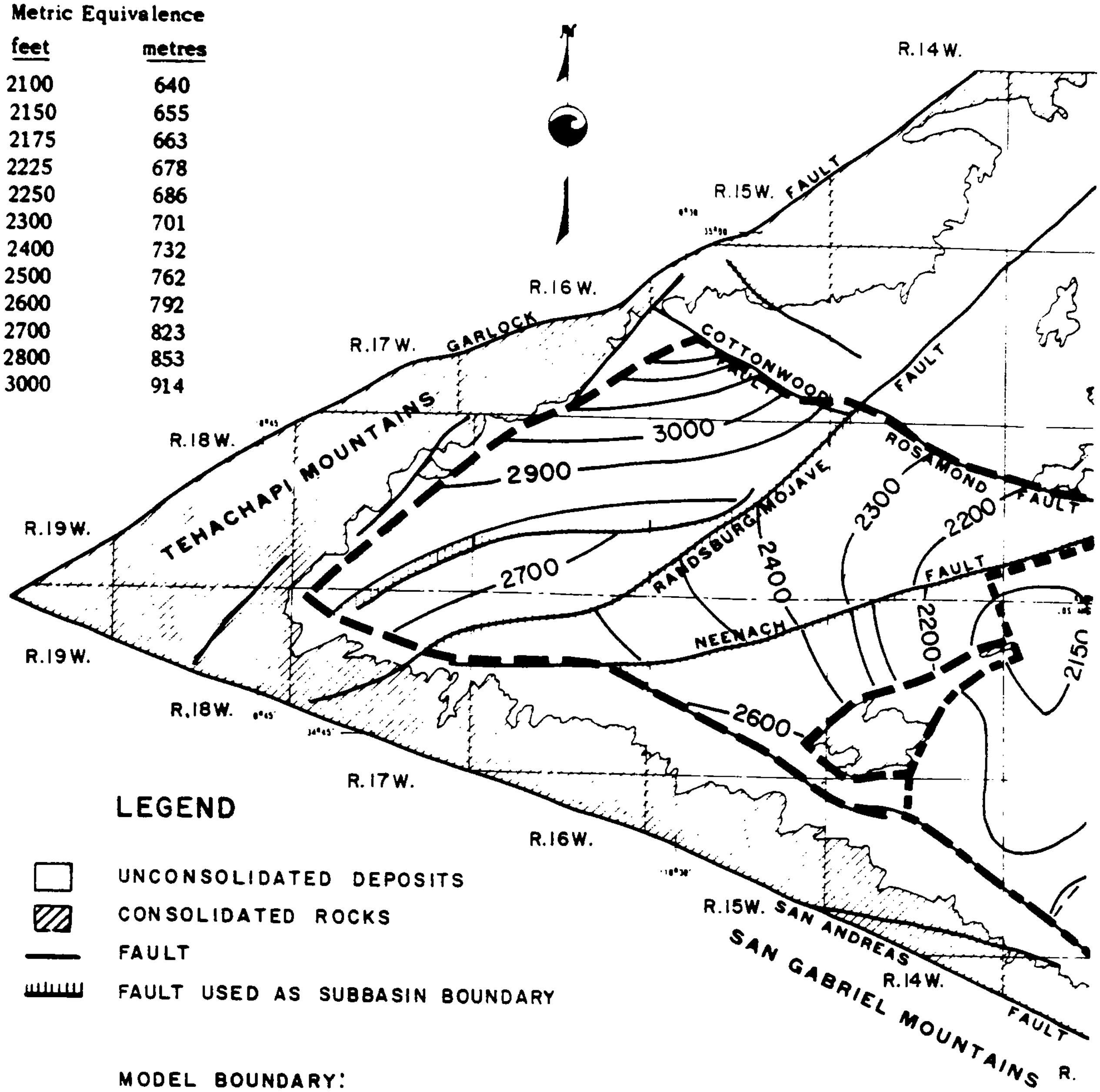
FIGURE 14 -
FLUCTUATIONS OF WATER LEVELS IN WELLS

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1980

PWS-0184-0041

Metric Equivalence

feet	metres
2100	640
2150	655
2175	663
2225	678
2250	686
2300	701
2400	732
2500	762
2600	792
2700	823
2800	853
3000	914



LEGEND

- UNCONSOLIDATED DEPOSITS
- CONSOLIDATED ROCKS
- FAULT
- FAULT USED AS SUBBASIN BOUNDARY

MODEL BOUNDARY:

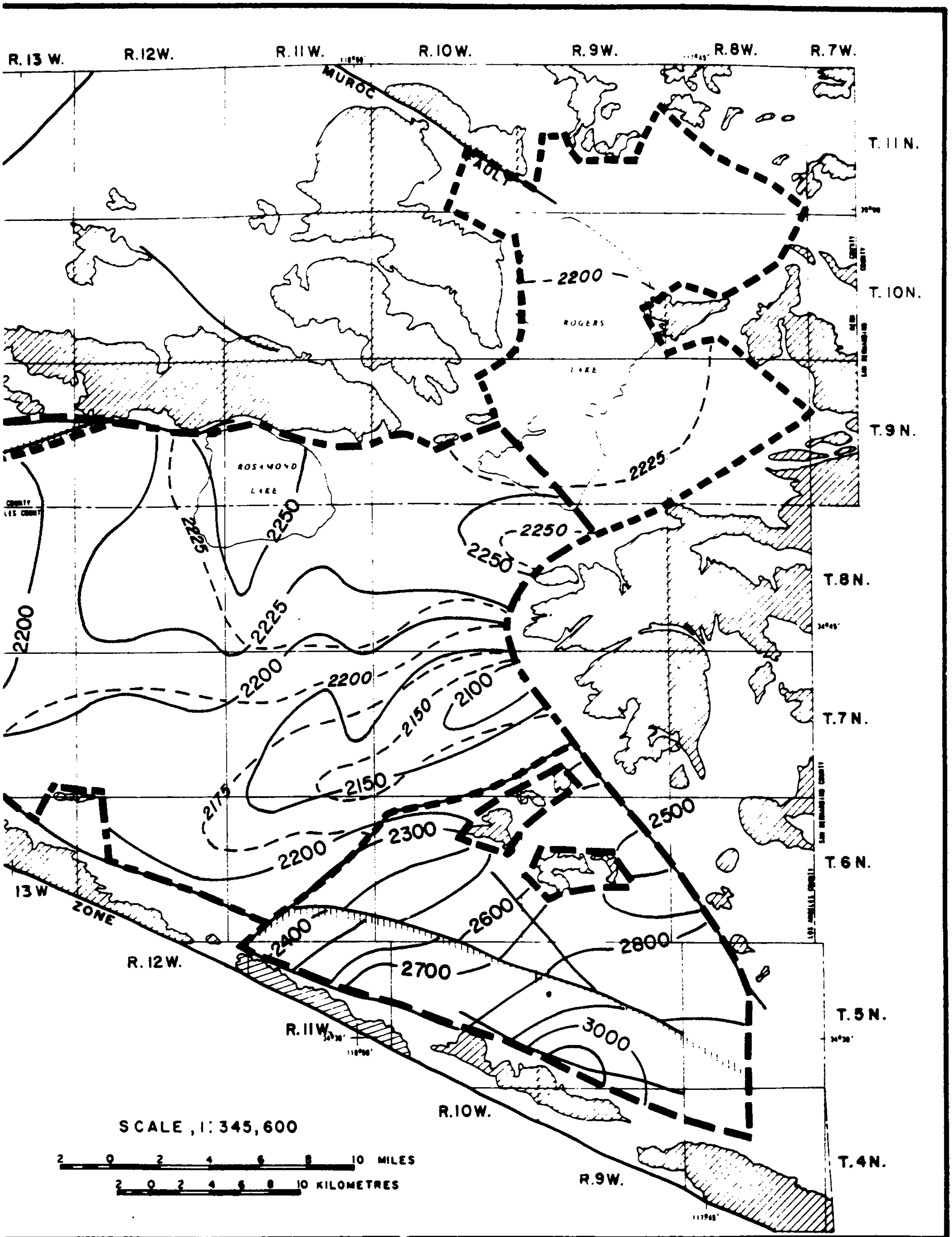
- PRINCIPAL AQUIFER
- DEEP AQUIFER
- COMMON BOUNDARY

— 2200 — PIEZOMETRIC ELEVATIONS IN PRINCIPAL AQUIFER
-- *2200* -- PIEZOMETRIC ELEVATIONS IN DEEP AQUIFER

ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL

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.

PWS-0184-0045

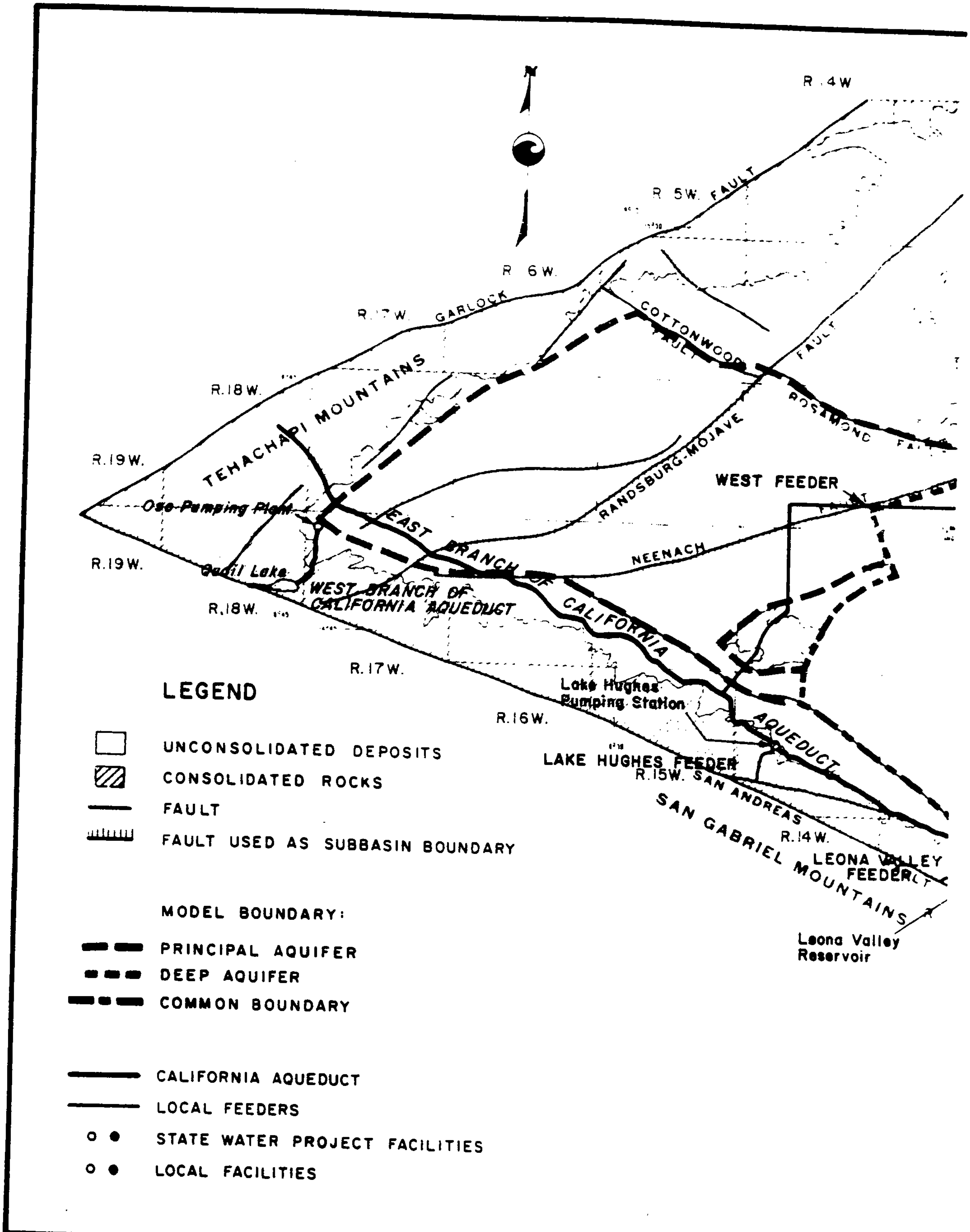
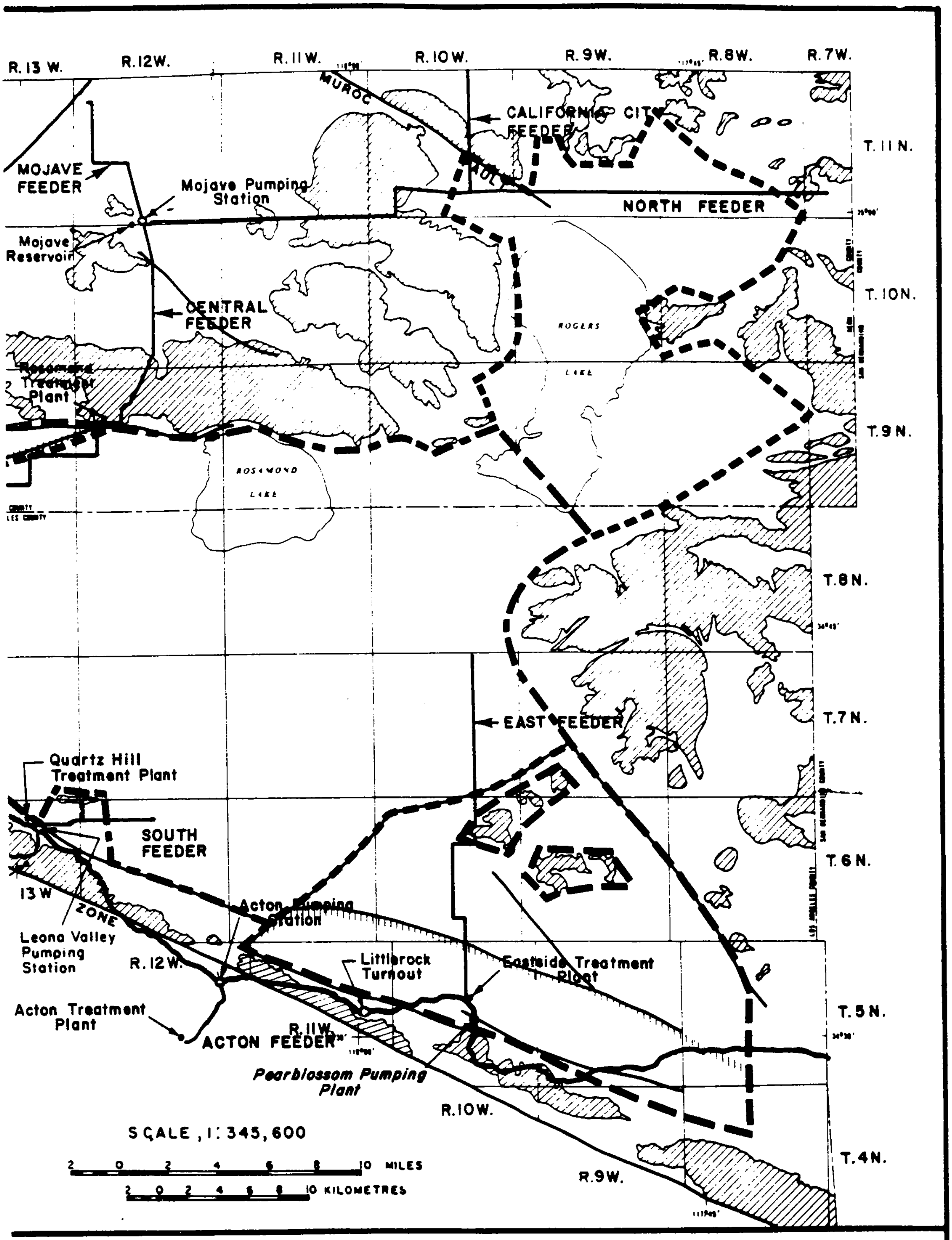


FIGURE 16

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.

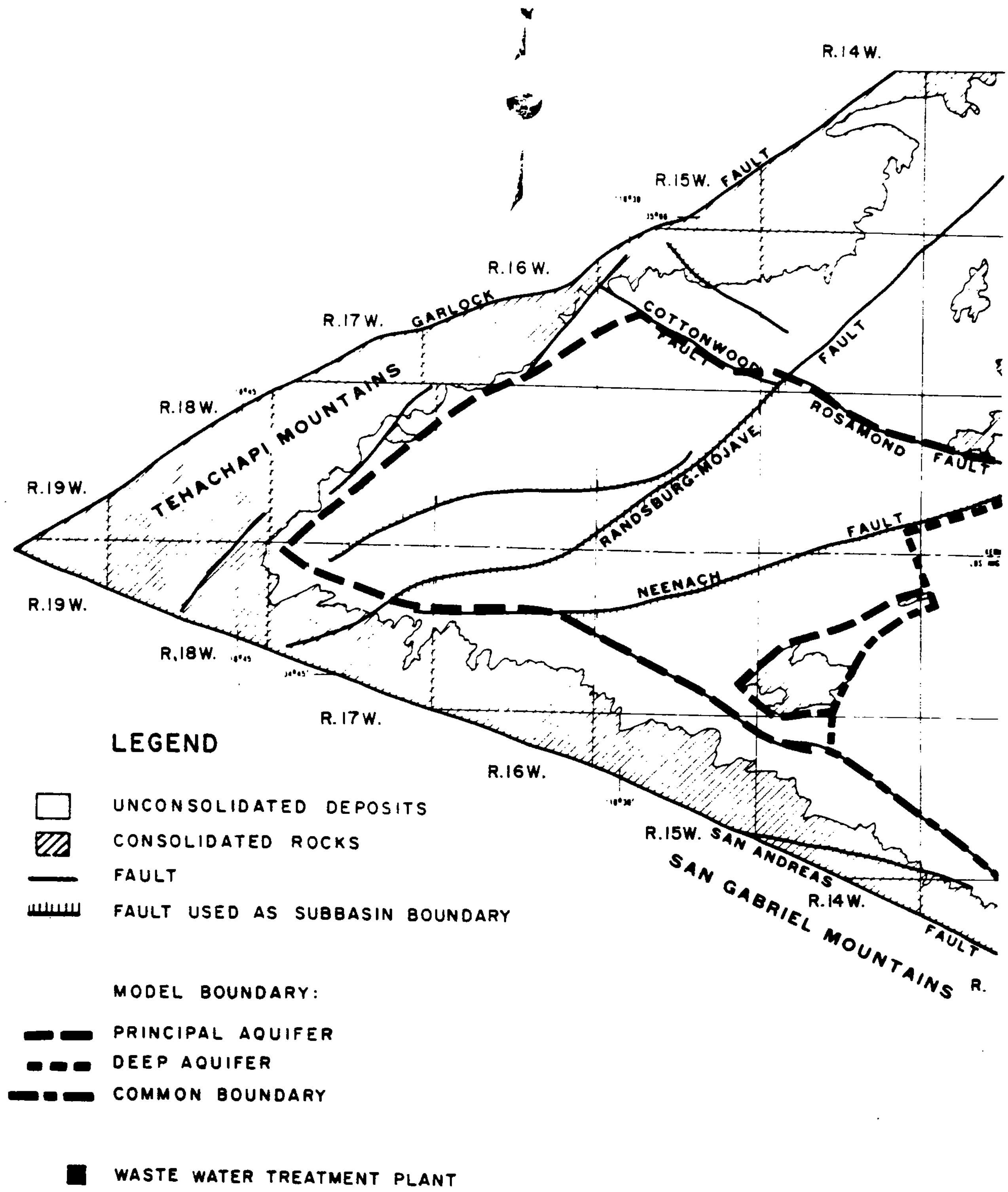
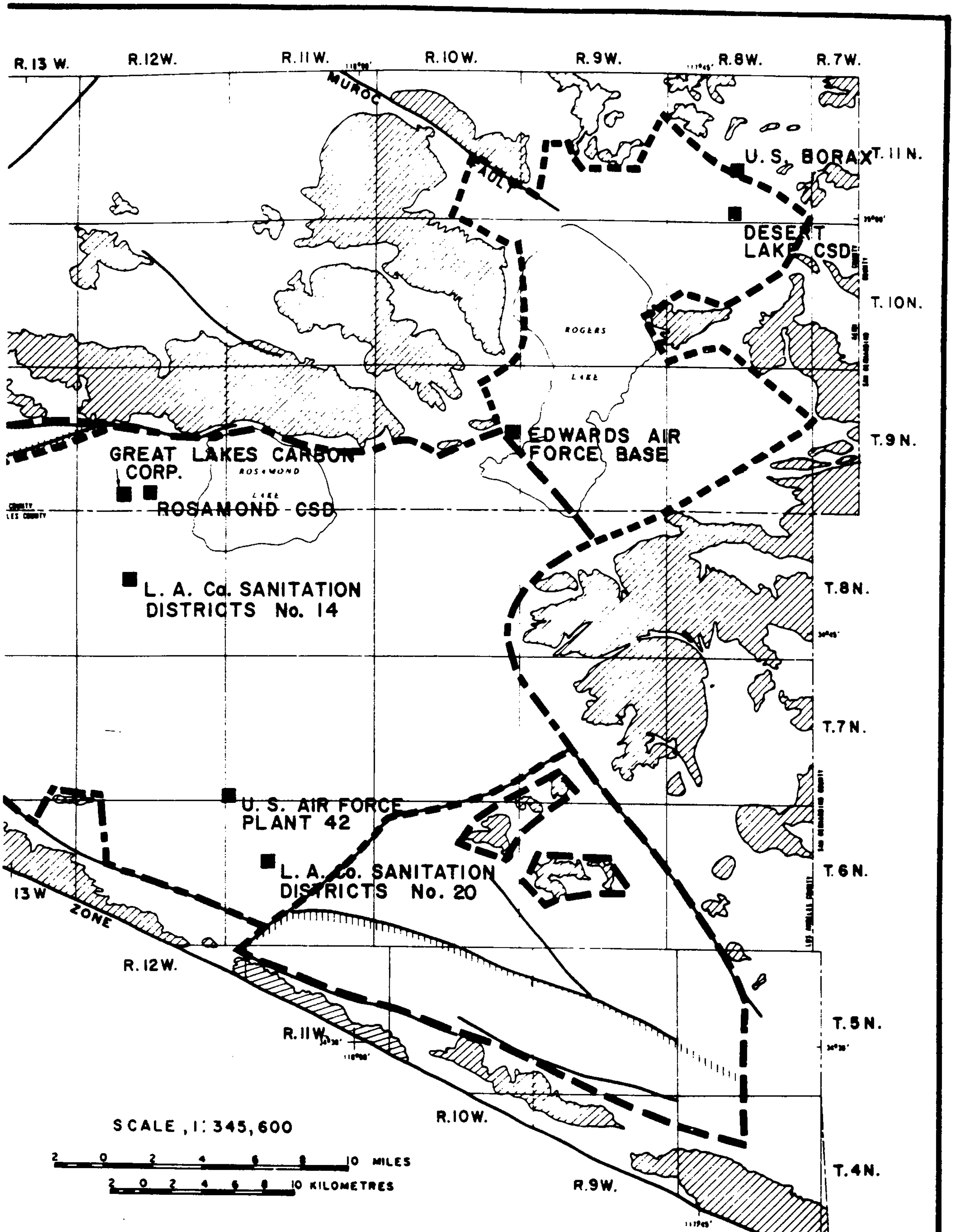


FIGURE 17 - MUNICIPAL AND INDUSTRIAL



WASTE WATER TREATMENT PLANTS

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

Discharger	Population served, in 1000s	Designed capacity	Present flow rate,	Type of waste water**	Treatment facilities**	Uses of reclaimed water
		in million litres per day (in million gallons per day)				
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.

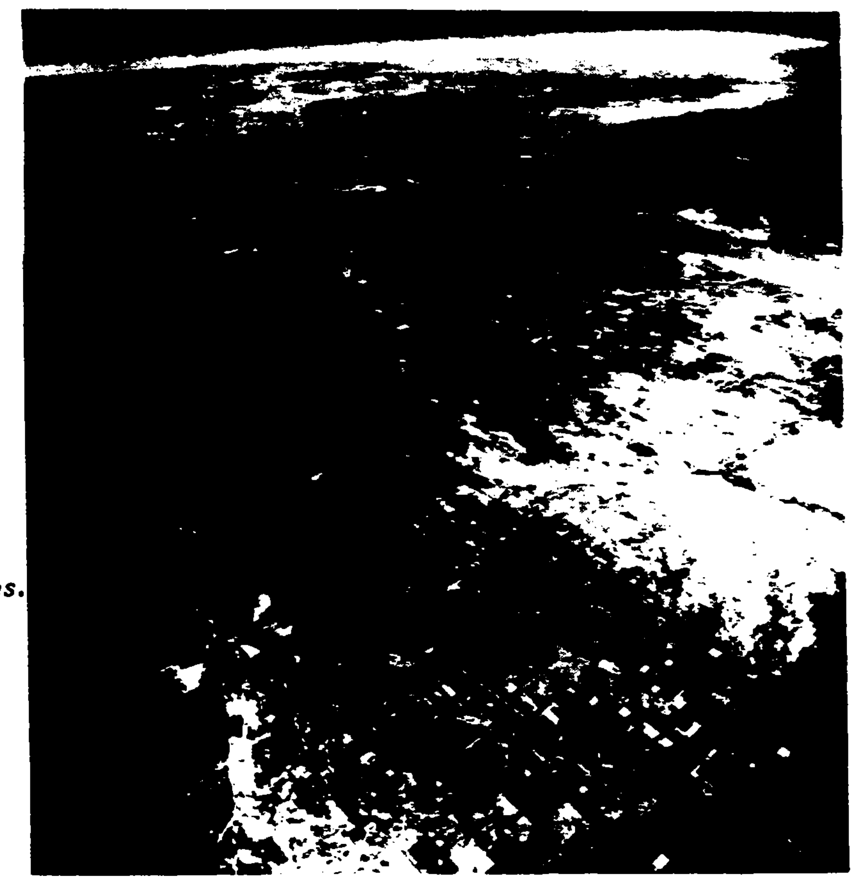
- Condition 6 (Maximum Recharge)

  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--

* 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

	1975	2000	2020
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.

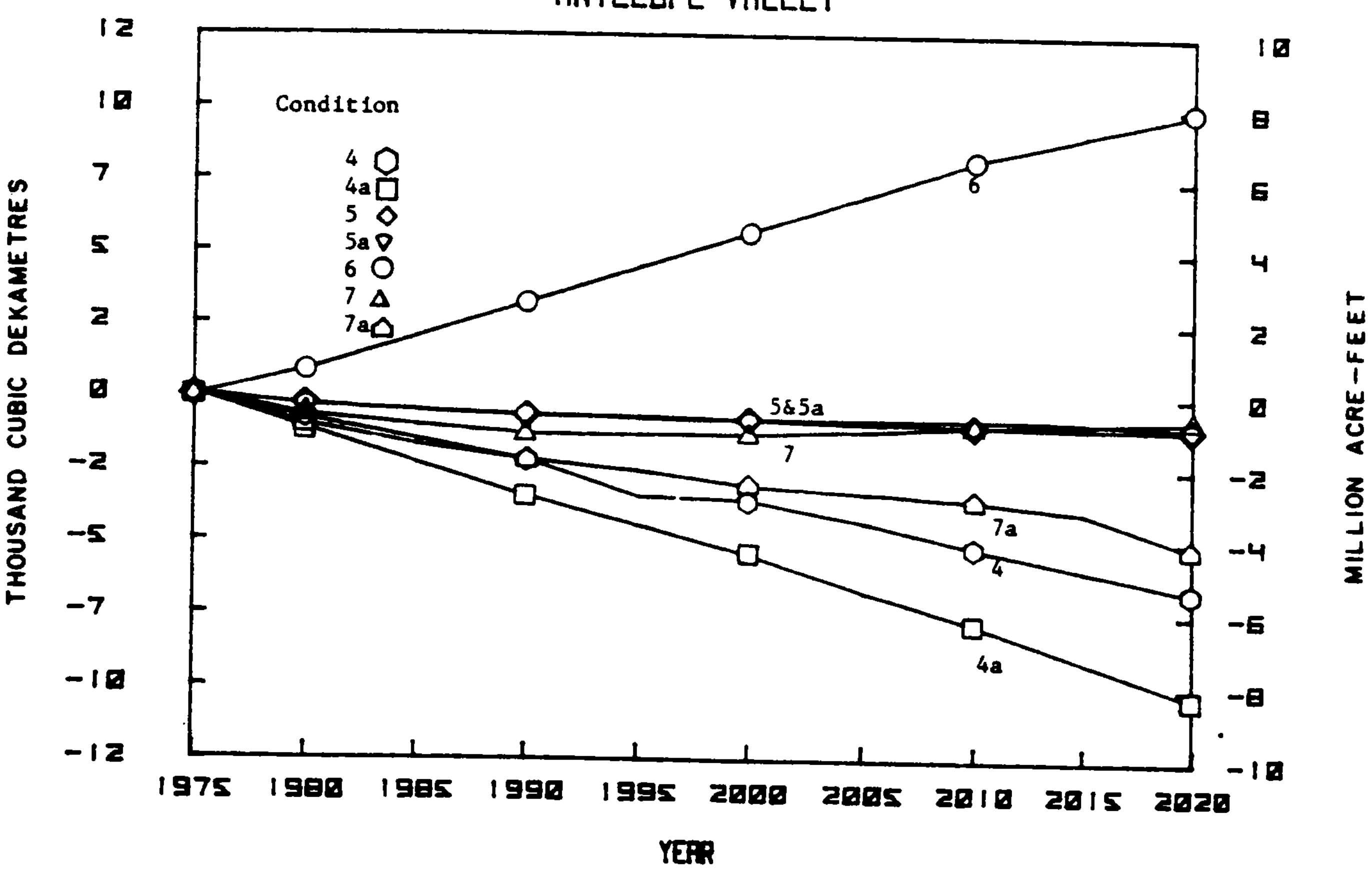
In this study, the results of the aquifer simulation are consistent with what would be logically expected. Figure 18 shows the cumulative change of water in storage for each of the alternatives. In Figure 19, the weighted average water level elevation for Maximum Recharge (Condition 6) depicts an increase 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.

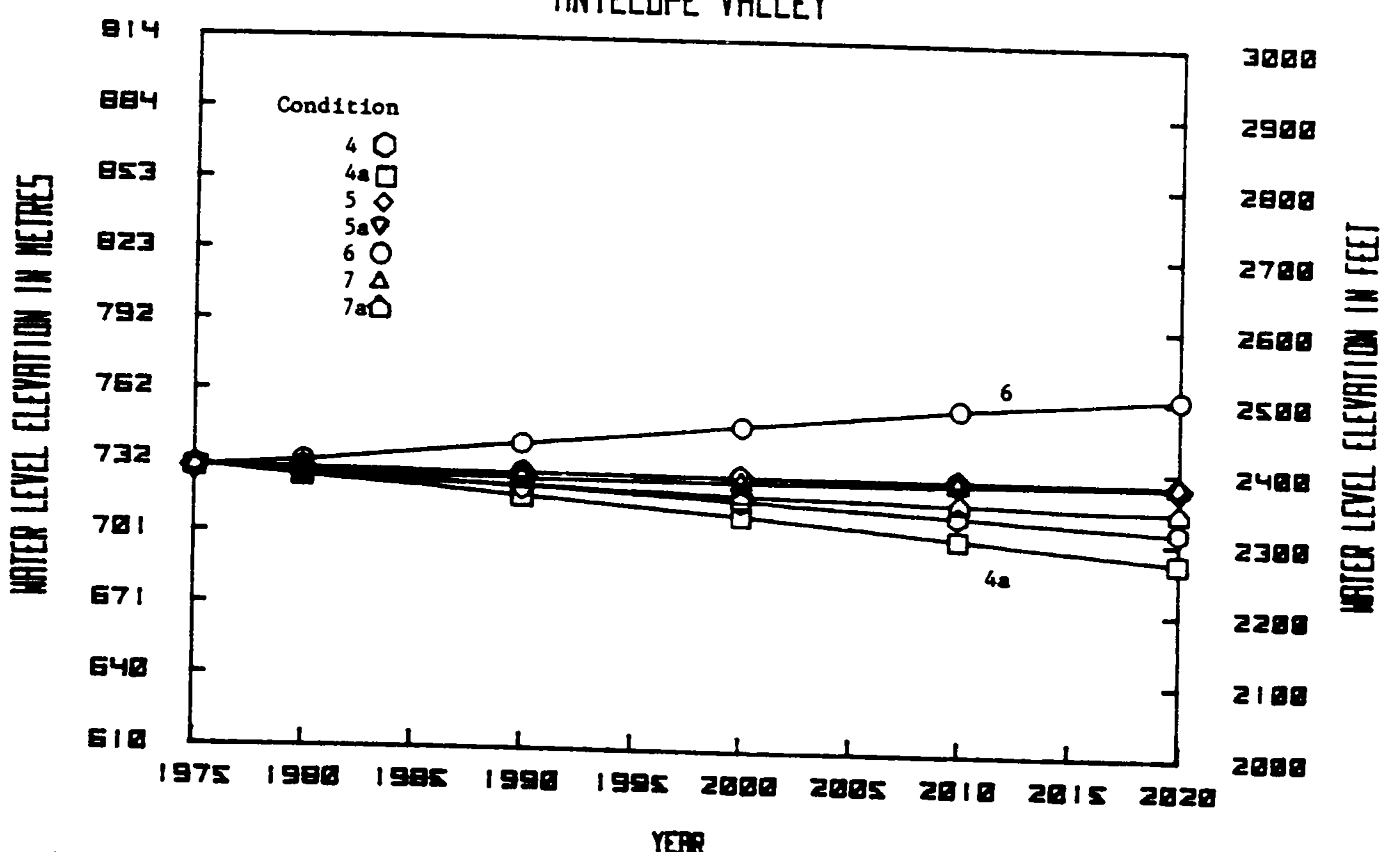
The assumptions made in estimating these costs included: (1) the average well produces 990 cubic dekametres (800 acre-feet) per year, (2) the capital cost of a pumping facility is $65,000, (3) the average life of the pumping facility is 7 years, (4) a booster pump maintains a pumping head of 51.82 metres (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	24[illegible].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.

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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

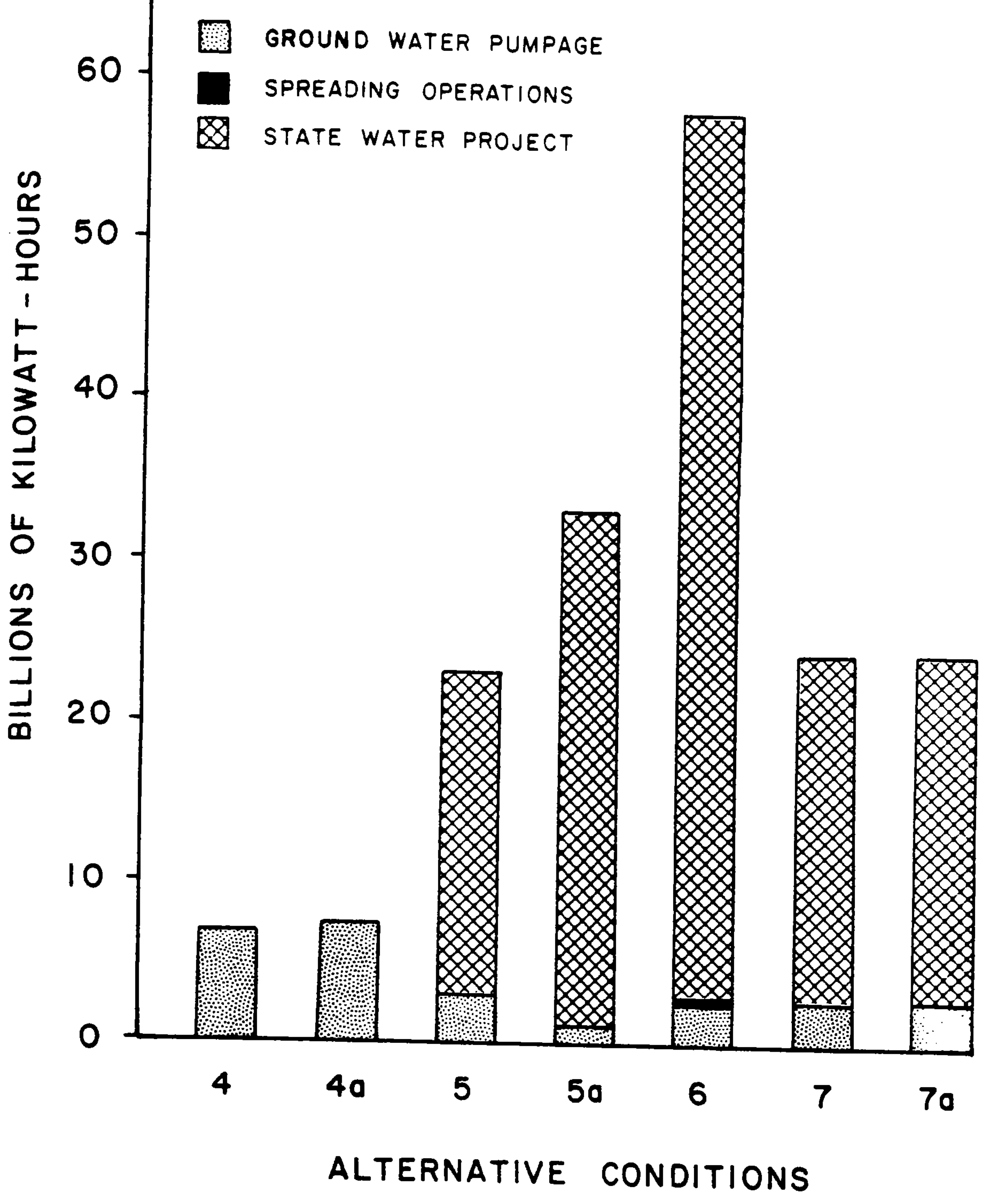

FIGURE 20
ENERGY CONSUMED BY EACH ALTERNATIVE PLAN

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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,

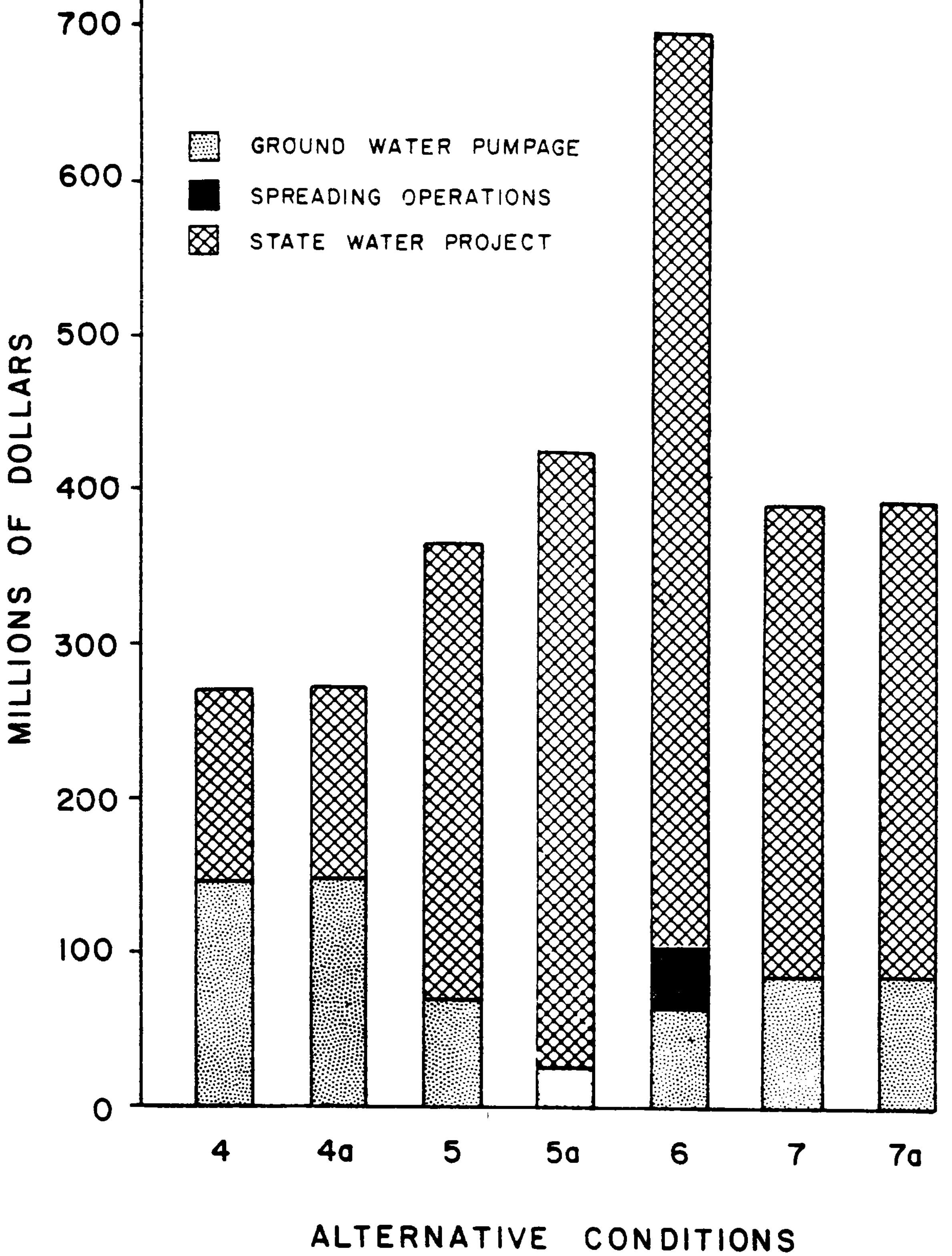

FIGURE 21

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

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Arthur D. Little, Inc. "Palmdale Intercontinental Airport Environmental Impact Study". Volumes 1-4. Prepared for Los Angeles Department of Airports. 1974.

2. Bloyd, R. M., Jr. "Water Resources of the Antelope Valley-East Kern Water Agency Area, California". U. S. Geological Survey Open File Report. 1967.

3. Boyle Engineering. "Engineering Report on the Imported Water Distribution System for the Antelope Valley-East Kern Water Agency, Kern, Los Angeles, and Ventura Counties". 1969.

4. ----. "Engineering Report on Imported Water Distribution System for the Antelope Valley-East Kern Water Agency". 1974.

5. California Department of Health Services, Water Sanitation Section. "Laws and Regulations Relating to Domestic Water Supplies Quality and Monitoring". Excerpts from the California Health and Safety Code and the California Administrative Code.

6. California Department of Water Resources. "Hydrologic Data". Bulletin 130 series, Vol. V. Various years.

7. ----. "Data on Water Wells in the Willow Springs, Gloster, and Chaffee Areas, Kern County, California". Bulletin 91-4. 1960.

8. ----. "Data on Wells in the Edwards Air Force Base Area, California". Bulletin 91-6. 1962.

9. ----. "Report on Feasibility of Serving the Antelope Valley-East Kern Water Agency from the State Water Facilities". Bulletin 119-26. 1962.

10. ----. "Feasibility of Serving the Palmdale Irrigation District and Pearland Area from the State Water Facilities". Bulletin 119-4. 1963.

11. ----. "Water Wells in the Western Part of the Antelope Valley Area, Los Angeles and Kern Counties, California". Bulletin 91-11. 1965.

12. ----. "Feasibility of Serving the Littlerock Creek Irrigation District from the State Water Project". Bulletin 119-20. 1965.

13. ----. "Water Wells in the Eastern Part of the Antelope Valley Area, Los Angeles County, California". Bulletin 91-12. 1966.

14. ----. "California's Ground Water". Bulletin 118. 1975.

15. ----. "Reclamation of Water from Wastes in Southern California". Bulletin 80-5. 1975.

16. ----. "The California State Water Project in 1976". Bulletin 132-76. 1976.

17. ----. "The California State Water Project--1977 Activities and Future Management Plans". Bulletin 132-78. 1978.

18. ----. "Draft Environmental Impact Report on Revocation of the Certificate of Approval, Littlerock Dam and Reservoir". 1977.

19. California Department of Water Resources, Southern District. "Ground Water and Waste Water Quality Study, Antelope Valley, Los Angeles and Kern Counties". A Report to Lahontan Regional Water Quality Control Board, No. 6. 1968.

20. ----. "Desert Area Land and Water Use Survey, 1972". District Report. 1974.

21. ----. "A Preliminary Evaluation of Adequacy of Data for the Formulation of a Mathematical Water Quality Model of Antelope Valley". Technical Information Record 1335-6-A-1. 1975.

22. ----. "A Preliminary Evaluation of Geologic Bases for the Selection of Spreading Grounds in the Antelope Valley Study Area". Technical Information Record 1335-6-A-2. 1976.

23. ----. "A Preliminary Evaluation of Ground Water Quality near Littlerock and Pearblossom in Antelope Valley". Technical Information Record 1335-6-A-3. 1976.

24. ----. "A Preliminary Evaluation of Ground Water in Storage in the Antelope Valley Ground Water Model Area". Technical Information Record 1335-6-A-4. 1977.

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

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

27. ----. "A Preliminary Evaluation and Inventory of Water Supplies in the Antelope Valley". Technical Information Record 1335-6-B-1. 1978.

28. ----. "A Preliminary Evaluation of Ground Water Quality in the Antelope Valley". Technical Information Record 1335-6-A-5. 1979.

29. ----. "A Preliminary Evaluation of State Water Project Ground Water Storage Program: Antelope Valley". Technical Information Record 1610-7-J-1. 1979.

30. California Division of Water Resources. "Report to the Assembly of the State Legislature on Water Supply of Antelope Valley in Los Angeles

and Kern Counties pursuant to House Resolution No. 101 of February 16, 1946". 1947.

31. ----. "Water Conditions in Antelope Valley in Kern, Los Angeles, and San Bernardino Counties". Memorandum Report. 1955.

32. ----. "Antelope Valley Investigation, Lahontan Region". Project No. 55-6-1. Report to Lahontan Regional Water Pollution Control Board No. 6. 1956.

33. California State Water Resources Control Board. "Water Quality Control Plan for the South Lahontan Basin 6-B". 1974.

34. ---- and Lahontan Regional Water Quality Control Board. "Report on Arsenic Occurrence in the North Muroc Hydrologic Basin, Kern County, California". 1969.

35. Chandler, T. S. "Water Resources Inventory, Spring 1966 to Spring 1971, Antelope Valley-East Kern Water Agency Area, California". U. S. Geological Survey Open File Report.

36. Davis, S. N., and DeWiest, R. "Hydrology". John Wiley and Sons, Inc. 1966.

37. Dibblee, T. W., Jr. "Geology of the Rogers Lake and Kramer Quadrangles, California". U. S. Geological Survey Bulletin 1089-B. 1960.

38. ----. "Geology of the Willow Springs and Rosamond Quadrangles, California". U. S. Geological Survey Bulletin 1089-C. 1963.

39. ----. "Areal Geology of the Western Mojave Desert, California". U. S. Geological Survey Professional Paper 522. 1967.

40. Durbin, T. J. "Calibration of a Mathematical Model for the Antelope Valley Ground Water Basin, California". U. S. Geological Survey Water Supply Paper 2046. 1978.

41. Dutcher, L. C. and Worts, G. F., Jr. "Geology, Hydrology, and Water Supply of Edwards Air Force Base, Kern County, California". U. S. Geological Survey. 1962.

42. Ewing, Paul A. "The Irrigation Development of Antelope Valley, California". U. S. Soil Conservation Service, Division of Irrigation. 1945.

43. Johnson, H. R. "Water Resources of Antelope Valley, California". U. S. Geological Survey Water Supply Paper 278. 1911.

44. Kunkel, Fred. "Reconnaissance of Ground Water in the Western Part of the Mojave Desert Region, California". U. S. Geological Hydrologic Investigations Atlas HA-31. 1962.

45. Lantis, D. W., Steiner, R., and Karinen, A. E. "California: Land of Contrast". Kendall/Hunt Publishing Company. 1977.

46. Litz, G. M., Bond, C. F., and Donnan, W. W. "Sprinkler Irrigation Trials-Antelope Valley Soil Conservation District". U. S. Soil Conservation Service, Division of Irrigation and Water Conservation. 1951.

47. Los Angeles County Department of Regional Planning. "North Los Angeles County General Plan, Preliminary Antelope Valley Areawide General Plan". 1977.

48. Los Angeles County Engineer. "Apollo County Park, Wastewater Reclamation Project". U. S. Environmental Protection Agency EPA-600/2-76-022. 1977.

49. Los Angeles County Engineer--Facilities. "Final Report: 208 Water Quality Planning, South Lahontan Basin". June 1979.

50. Mabey, D. R. "Gravity Survey of the Western Mojave Desert, California". U. S. Geological Survey Professional Paper 316-D. 1960.

51. McClelland, E. J. "Aquifer Test Compilation for the Mojave Desert Region, California". U. S. Geological Survey Open File Report. 1964.

52. McMillan, J. F. "Land Subsidence, Antelope Valley Area of Los Angeles County". Los Angeles County Engineer. 1973.

53. Moyle, W. R., Jr. "Geohydrologic Map of Southern California: U. S. Geological Survey, Water Resources Investigations 48-73". Open File. 1974.

54. Muckel, Dean C. "Feasibility of Spreading Water at Mouth of Rock Creek in Antelope Valley, California". U. S. Soil Conservation Service. 1944.

55. Norris, R. M., and Webb, R. W. "Geology of California". John Wiley and Sons, Inc. 1976.

56. Powers, W. R., III, and Irwin, G. A. "Water Resources Inventory, Spring 1969 to Spring 1970, Antelope Valley-East Kern Water Agency Area, California". U. S. Geological Survey Open File Report. 1971.

57. Rantz, S. E. "Mean Annual Precipitation in the California Region". U. S. Geological Survey Basic Data Compilation. 1969.

58. Smith, Merritt B. "Map Showing Distribution and Configuration of Basement Rocks in California (North Half)-(South Half)". U. S. Geological Survey Oil and Gas Investigations Map OM-215. 1964.

59. Snyder, J. Herbert. "Ground Water in California, the Experience of Antelope Valley". University of California, Giannini Foundation, Ground Water Studies No. 2. 1955.

60. Southern California Edison Co. "The Antelope Valley, An Area Inventory". 1961.

61. Stone, R. S. "Ground Water Reconnaissance in the Western Part of the Mojave Desert, California, with Particular Respect to the Boron Content of Well Water". U. S. Geological Survey Open File Report. 1957.

62. Stones, Alan Gale. "Antelope Valley, Mojave Desert, California: A Geographical Analysis". Unpublished master's thesis, University of California, Los Angeles. 1964.

63. Thompson, D. G. "The Mojave Desert Region, California: A Geographic, Geologic, and Hydrologic Reconnaissance". U. S. Geological Survey Water Supply Paper 578. 1929.

64. Thomas, H. E. "Effects of Drought in Basins of Interior Drainage". U. S. Geological Survey Professional Paper 372-E. 1963.

65. ----, and Phoenix, D. A. "Summary Appraisals of the Nation's Ground Water--California Region". U. S. Geological Survey Professional Paper 813-E. 1976.

66. U. S. Bureau of Reclamation. "Interim Report Inland Basins Projects, Antelope and Fremont Valleys, California". 1967.

67. Weir, J. E., Crippen, J. R., and Dutcher, L. C. "A Progress Report and Proposed Test Well Drilling Program for the Water Resources Investigation of the Antelope Valley-East Kern Water Agency Area". U. S. Geological Survey Open File Report.

68. Wiese, John H. "Geology and Mineral Resources of the Neenach Quadrangle, California". California Division of Mines Bulletin 153. 1950.

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
ENERGY COST / VALUE (mills/kWh)					
Hyatt-Thermalito Recovery (all)	0.0	9.0	9.9	11.2	13.0
SCE Exchange	6.8	25.0	25.0	25.0	25.0
Pine Flat	0.0	0.0	0.0	0.0	0.0
MWD Hdro	0.0	24.7	27.8	31.9	37.4
Reid Gardner	0.0	36.2	40.2	45.3	52.1
Bottle Rock	0.0	48.0	62.0	84.0	117.0
South Geysers	0.0	50.0	52.8	64.2	88.4
Honey Lake	0.0	48.6	51.4	62.9	87.1
Edison Purchases	0.0	50.0	52.8	64.2	88.4
Suppliers & CEP (to 3/31/83) / Other Purchase	0.0	58.0	93.0	150.4	242.2
Excess (Potential Sale or Exchange)	3.5	0.0	0.0	0.0	242.2
	0.0	19.3	0.0	0.0	0.0
COMPOSITE COST (mills/kWh)	4.3	23.0	29.8	40.7	60.4
TRANSMISSION CHARGE (mills/kWh)	0.3	3.4	2.7	2.6	2.5
TOTAL COMPOSITE COST (mills/kWh)	4.6	26.4	32.5	43.3	62.9

NOTE: 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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