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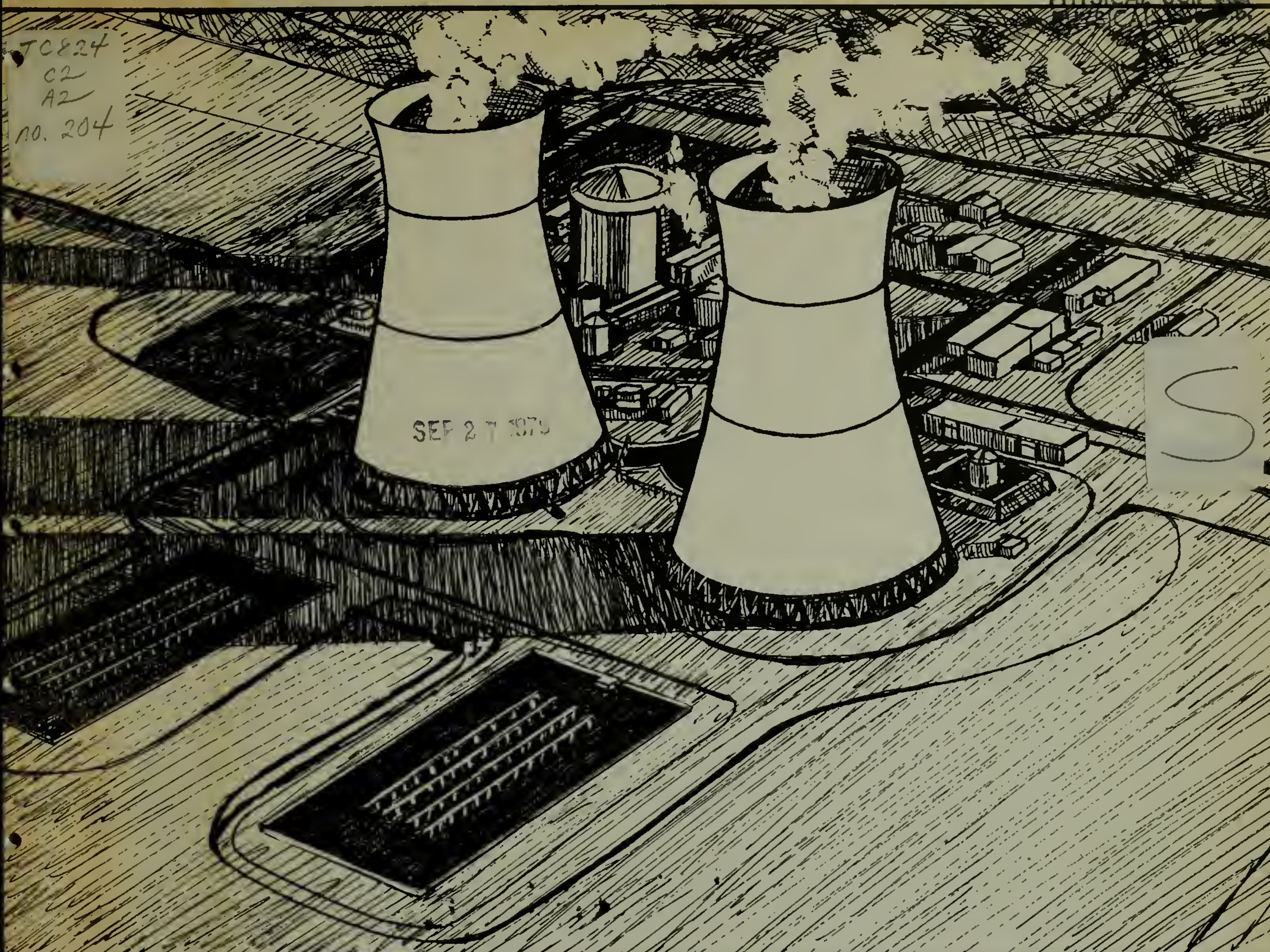
BULLETIN.



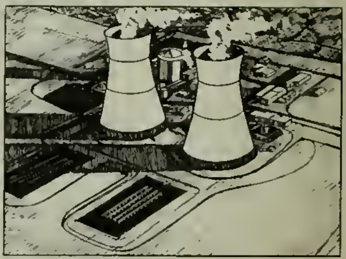
State of California
The Resources Agency

Department of
Water Resources

save water
DWR

Water for Power Plant Cooling

Bulletin No. 204
July 1977



ON THE COVER

Artist's conception of twin cooling towers at Rancho Seco Nuclear Power Plant, Sacramento Municipal Utility District.

Department of
Water Resources

Bulletin No. 204

Water for Power Plant Cooling

July 1977

Claire T. Dedrick
Secretary for Resources

Edmund G. Brown Jr.
Governor

Ronald B. Robie
Director

The Resources Agency

State of California

Department of Water Resources

FOREWORD

Over the next few years, major policy and program decisions regarding the generation of electrical energy will be made by the California Legislature, the State Energy Resources Conservation and Development Commission, the Public Utilities Commission, the electric utilities, and the general public. Knowledge regarding cooling processes, and requirements for and supplies of cooling water, must be reflected in these decisions. This bulletin was prepared to supply information on cooling methods, along with projected demands for and possible sources of cooling water at inland power plant sites.

Cooling water is essential for the operation of electric power plants that use steam to produce the electricity. This is because after the useful heat in the steam is used in the production of electricity in the power plant, the steam must be condensed to water and returned to the power plant heater. In the heater, the water is heated by burning oil or gas, or by using nuclear energy, to produce steam that is again made useful for producing electricity. Such plants produce, on the average, about 75 percent of the electrical energy generated in California today.

Until recently, most of the plants that use steam to produce electricity have been located along the coast, or on connected bays and estuaries, where ample supplies of sea water are available for cooling. Today, however, to comply with air quality standards when burning oil and with seismic criteria when using nuclear energy, many new power plants may have to be located at inland sites.

The construction of new inland plants using oil, gas, or nuclear energy to produce steam would create substantial new demands for cooling water in areas where the competition for available water supplies is intense. To decrease the potential need for water to cool inland power plants would require a concerted effort by electric utilities and appropriate regulatory agencies to develop cooling systems that use less water, such as wet-dry cooling systems.

In California, as in many parts of the west, the demands for fresh water generally exceed available developed supplies. The water management policy of the Department of Water Resources provides in part, "...that the water resources of California shall be managed in a manner that will result in the greatest long-term benefit to the people of the State... (and that) water shall be reused to the maximum extent feasible". In keeping with this policy, the "Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Powerplant Cooling" of the State Water Resources Control Board, and Resolution No. 76-16 "Urging Use of Waste and Brackish Water for Power Plant Cooling Purposes" of the California Water Commission, the Department recommends that agricultural waste water, brackish ground water, or other water not suitable for municipal and agricultural purposes should be used for power plant cooling insofar as possible. In this connection, the Department, assisted by the University of California and in cooperation with the Electric Power Research Institute and three major California utilities, is conducting research and development studies of the use of agricultural waste water for power plant cooling. The results of these studies will be reported about a year from now.

Bulletin No. 204 summarizes projected future demands for cooling water needed for the production of electrical energy; possible sources of cooling water, including agricultural and municipal waste water, brackish and saline interior water, geothermal water, ground water, and fresh surface water; and the various methods of power plant cooling. In addition, plans by California electric utilities to obtain supplies of cooling water for four proposed inland power plants are discussed.

Ronald B. Robie, Director
Department of Water Resources
The Resources Agency
State of California

CONTENTS

CONTENTS (Continued)

Figures

CONTENTS (Continued)

Tables

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The California Water Commission serves as a policy advisory body to the Director of Water Resources on all California water resources matters. The nine-member citizen Commission provides a water resources forum for the people of the State, acts as liaison between the legislative and executive branches of State Government, and coordinates federal, State, and local water resources efforts.

CONVERSION FACTORS

English to Metric System of Measurement

Quantity	English unit	Multiply by	To get metric equivalent
Length	inches (in)	25.4	millimetres (mm)
		.0254	metres (m)
	feet (ft)	.3048	metres (m)
	miles (mi)	1.6093	kilometres (km)
Area	square inches (in^2)	6.4516×10^{-4}	square metres (m^2)
	square feet (ft^2)	.092903	square metres (m^2)
	acres	4046.9	square metres (m^2)
		.40469	hectares (ha)
		.40469	square hectometres (hm^2)
		.0040469	square kilometres (km^2)
	square miles (mi^2)	2.590	square kilometres (km^2)
Volume	gallons (gal)	3.7854	litres (l)
		.0037854	cubic metres (m^3)
	million gallons (10^6 gal)	3785.4	cubic metres (m^3)
	cubic feet (ft^3)	.028317	cubic metres (m^3)
	cubic yards (yd^3)	.76455	cubic metres (m^3)
	acre-feet (ac-ft)	1233.5	cubic metres (m^3)
		.0012335	cubic hectometres (hm^3)
		1.233×10^{-6}	cubic kilometres (km^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
		.028317	cubic metres per second (m^3/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
		6.309×10^{-5}	cubic metres per second (m^3/s)
	million gallons per day (mgd)	.043813	cubic metres per second (m^3/s)
Mass	pounds (lb)	.45359	kilograms (kg)
	tons (short, 2,000 lb)	.90718	tonne (t)
		907.18	kilograms (kg)
Power	horsepower (hp)	0.7460	kilowatts (kW)
Pressure	pounds per square inch (psi)	6894.8	pascal (Pa)
Temperature	Degrees Fahrenheit (°F)	$\frac{tF - 32}{1.8} = tC$	Degrees Celsius (°C)

CHAPTER I. INTRODUCTION

Bulletin No. 204 was prepared, in part, in response to the Waste Water Reuse Law of 1974[1/], which directs the Department of Water Resources to investigate the uses of reclaimed waste water for beneficial purposes -- including the cooling of power plants that use steam to produce electrical energy. The bulletin also provides information on possible future demands for nonocean sources of cooling water and on processes used for power plant cooling.

Summary

Projected energy sales of California's major utilities for 1985 and 1995 have recently been approved by the State Energy Resources Conservation and Development Commission. Energy sales for 1975 are included for comparison:

Year	Projected Energy Sales billions of kilowatt hours[2/]
1975	137.1
1985	206.7
1995	286.5

Because few hydroelectric projects remain undeveloped, about 75 percent of the increased energy generated will probably be provided by plants that use steam to produce electricity. Such plants require large supplies of cooling water. Accordingly to supply sufficient energy to meet the projected sales, the use of cooling water would be significantly higher than at present.

The limited water supplies in most of the West not only dictate economies in overall water use but also, and more specifically, influence the siting of power plants. This is particularly true in California, where, until recently, most power plants that use steam to produce electricity have been constructed along the coast or on connected bays and estuaries, where sea water can be used for cooling.

Today, however, to comply with air-quality standards when burning oil and with seismic criteria when using nuclear energy, many new California power plants may have to be located at inland sites -- probably in either the Central Valley or the southeastern desert -- where the competition for available water supplies is intense. Power plants located at inland sites will most likely be cooled with evaporative systems.

Specifically discussed in this bulletin are:

- Future demands for non-ocean cooling water (Chapter II).
- Types of power plant cooling systems (Chapter III).
- Sources of cooling water for power plants (Chapter IV).
- Plans to furnish cooling water to four proposed inland plants (Chapter V).

1/ *California Water Code: Division 1, Chapter 6.*

2/ *Energy Resources Conservation and Development Commission, "Electricity Forecasting and Planning Report." Adopted March 1977.*

Conclusions

During the foreseeable future:

1. ...the demand for inland cooling water will increase significantly and will conflict with other uses of available supplies.

2. ...the preferred sources of cooling water at inland sites are urban and agricultural waste waters that cannot be returned to water-supply sources for reuse, and other poor-quality water.

Background

When one plans a new power plant, one must consider several factors involving water. These include (1) the availability of cooling water at a proposed plant site, (2) the acquisition of cooling water supplies, and (3) environmental considerations related to the use and discharge of cooling water.

As previously mentioned, most existing large steam-electric power plants in California are located on the coast, salt-water bays or estuaries. Coastal sites have long been favored because ample supplies of cold cooling water are readily available. In recent years, however, a number of utilities have shifted their emphasis on proposed sites to inland locations. This, in turn, has created a substantial unanticipated potential need for inland water.

The use of fresh water for cooling at inland sites generally requires the reallocation of water. This competition for existing limited developed supplies involves significant physical, economic, and institutional obstacles to the development of cooling water at inland sites.

In siting a power plant, the availability of cooling water is often more significant than the price of the available water. If sufficient water is not available at a particular plant site which is acceptable in other respects, water might have to be conveyed a considerable distance to the site or developed at a high cost. Because the cost of cooling water is relatively low compared with other plant costs, fairly large expenditures can be made for water if other plant-siting factors are favorable.

Equally important is the acquisition of the right to use a source of cooling water. At inland sites, most of the available developed surface water has already been appropriated and put to use. Water supplies from these sources might have to be purchased; or an exchange might be arranged, under which the present holder of water rights is provided an alternative supply. Some ground water may be available but in much of the Central Valley, large overdrafts now exist.

It is the policy of the Department of Water Resources that the water resources of California shall be managed in a manner that will result in the greatest long-term benefit to the people of the State and that water shall be reused to the maximum extent feasible. In comparing alternative water management possibilities, consideration shall be given to capital and annual costs, cost effectiveness, economic and social benefits, environmental and ecological effects, and energy requirements. The least expensive alternative will not necessarily be selected as the best.

In August 1976, the California Water Commission adopted a resolution urging the use of waste water and brackish water for power plant cooling, which supports the Department's policy. The resolution states in part: "...the California Water Commission urges the maximum use of agricultural waste waters unsuitable for agricultural reuse, brackish water from natural sources, and inland waste waters of high total dissolved solids for power plant cooling purposes in the San Joaquin Valley and Colorado desert region of California...."1/

The California State Water Resources Control Board2/ has adopted a policy establishing the priority of use of various water supplies that might be used for cooling thermal power plants. This is binding on State agencies. In this policy, inferior quality water supplies and ocean water have been identified as having a higher priority of use for power plant cooling.

In recent years, the use of waste water for irrigation has become increasingly prevalent. Proposals are now being considered for the use of agricultural and urban waste water for power plant cooling.

The Waste Water Reuse Law of 1974 declares the policy that conservation of water resources requires the maximum reuse of waste water in the satisfaction of requirements for beneficial uses of water. Another recent law3/ permits The Metropolitan Water District of Southern California to provide, for use in connection with generation of electrical power, no more than 123 cubic hectometres (100,000 acre-feet) of water per year from the Colorado River, and no more than 74 cubic hectometres (60,000 acre-feet) per year from the State Water Resources Development System.4/ This same law also directs that agricultural waste water, brackish ground water, and other water not suitable for urban or agricultural purposes shall be used for power plant cooling to the extent practical.

A consideration in choice of cooling water is the provision of California water quality law. Restrictions imposed by California's Thermal Plan5/ generally prohibit new discharges from once-through cooling systems to inland interstate waters (primarily the Colorado River), and to enclosed bays and estuaries. Limitations on new discharges of elevated-temperature wastes (water from an evaporative system is cooled before discharge, although it may still be warmer than the intake water) to coastal waters have been imposed to (1) achieve dispersion in the receiving water, (2) ensure maintenance of natural temperatures in receiving water, and (3) protect beneficial uses.

The State Water Resources Control Board has established a policy that "the discharge of blowdown water from cooling towers or return flows from once-

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1/ *Resolution No. 76-16, "Urging Use of Waste and Brackish Water for Power Plant Cooling Purposes," adopted by the California Water Commission on August 6, 1976.*

2/ *California Water Resources Control Board, "Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Powerplant Cooling". June 1975.*

3/ *Metropolitan Water District Act: Section 131.*

4/ *For water to be used within the service area of any agency that has a contract with the State of California for a water supply under the State Water Resources Development System, the prior written consent of such agency and the Director of the Department of Water Resources is required.*

5/ *California State Water Resources Control Board, "Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California." March 1976.*

through cooling system shall not cause a violation of water-quality objectives of waste discharge requirements established by the Regional Board."1/ The State Water Resources Control Board has also set forth a policy that "the use of unlined evaporation ponds to concentrate salts from blowdown water will be permitted only at salt sinks approved by the Regional and State Boards... (and that) the geologic strata underlying the proposed ponds or salt sink will protect usable groundwater".

1/ *California State Water Resources Control Board, "Water Quality Control Policy on the Use and Disposal of Inland Water Used for Powerplant Cooling". June 1975.*

CHAPTER II. PROJECTED DEMANDS FOR ELECTRICAL ENERGY AND COOLING WATER

Chapter II summarizes and briefly discusses projections of future demands for both electrical energy and inland cooling water -- i.e., fresh water, waste water, brackish surface and ground water -- for California power plants. Although these projections are not discussed in detail, the data indicate the extent of the problem of providing sufficient cooling water for inland plants.

Projected energy sales for 1985 and 1995 recently adopted by the Energy Resources Conservation and Development Commission indicate a significant increase from sales in 1975.1/

Energy sales in 1995 are expected to be greater than twice those of 1975.

It is the policy of the Department of Water Resources to develop and encourage energy conservation plans that will minimize the need to generate additional energy, particularly from inland power plants, which require large quantities of cooling water. Despite such conservation policies, the projections of future energy sales indicate that statewide demands for energy will continue to increase.

The Waste Water Reuse Law of 1974 2/ declares that, in the interest of conserving all available water resources, waste water will be reused to the maximum extent to satisfy requirements for beneficial water uses. Most inland power plants will use recirculating cooling systems, which minimize the quantity of water required.3/

It is the policy of the State Water Resources Control Board 4/ to encourage the use of waste water for power plant cooling and that the use of fresh inland water for power plant cooling will be approved only when other water supply sources or methods of cooling would be environmentally undesirable or economically unsound.

Projected Demands for Electrical Energy and Cooling Water

Factors that influence forecasts of future energy use include:

1. The implementation of conservation programs;
2. Environmental and social impacts;
3. Impacts of future prices and rate structures;

1/ *Energy Resources Conservation and Development Commission, "Electricity Forecasting and Planning Report." Adopted March 1977.*

2/ *The California Water Code, Division I, Chapter 6, Section 461.*

3/ *As opposed to once-through cooling systems, in which water is run through condensers and returned to its source. In California, once-through cooling, which requires large quantities of water, is practical only where sea water is available.*

4/ *California State Water Resources Control Board, "Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Power Plant Cooling", June 1975.*

4. Effects of federal and State regulations concerning environmental protection; and

5. Effects of availability and prices of various fuels and technological developments.

The Warren-Alquist State Energy Resources Conservation and Development Act established the Energy Resources Conservation and Development Commission in 1975. The Commission is charged with preparing a biennial report identifying trends related to energy supply, demand, and conservation, and specifying the level of statewide and service-area electrical energy demands for each year of the forthcoming 5-, 10-, and 20-year periods. These forecasts for the forthcoming 5- and 10-year periods shall serve as the basis for planning and certification of facilities proposed by the electric utilities. Additional cooling water will be required for the increased electrical energy generated in inland steam-electric power plants.

The unit cooling water requirements for closed-cycle evaporative cooling systems in recently constructed plants, and those nearing completion, are about 1.6 cubic hectometres (1,300 acre-feet) per billion kilowatthours for fossil-fueled plants, and 2.6 cubic hectometres (2,100 acre-feet) per billion kilowatthours for nuclear-fueled plants. If it is assumed that one-half the future inland plants will be fossil fueled and the other half will be nuclear fueled, the average requirements for cooling water would be 2.1 cubic hectometres (1,700 acre-feet) per billion kilowatthours.

If two-thirds of the additional electrical energy that will be required in 1985 (over that generated in 1975) were generated at inland plants, the projected additional 46 billion kilowatthours produced at inland plants would require 99 cubic hectometres (80,000 acre-feet) of cooling water. By 1995, with two-thirds of the additional energy generated at inland sites, the projected additional 100 billion kilowatthours generated would require 206 cubic hectometres (167,000 acre-feet) of cooling water.

This is lower than the projected 1995 requirements for cooling water presented in Department of Water Resources Bulletin No. 160-74.1/ In this report, the projected cooling water needs, based on the premise that two-thirds of the additional energy would be generated at inland plants, varied from 234 cubic hectometres (190,000 acre-feet) to 592 cubic hectometres (480,000 acre-feet). The more recent lower estimate of energy generation by the Energy Resources Conservation and Development Commission is based on anticipated energy conservation, which would result in lower generation requirements, and thus a reduced need for cooling water.

Location of Demands for Cooling Water

The need for and sources of cooling water are significantly affected by both the type of plant and its location. Hydroelectric plants and gas-turbine plants do not require cooling water, although gas-turbine plants might require a water supply to wash the exhaust gases to comply with air-quality standards. In addition, gas-turbine plants have limited potential because of their low thermal efficiency (less than 25 percent). However, gas turbines can also be operated in combined cycle with conventional steam turbines, thereby substantially increasing their overall efficiency. On the

1/ *Department of Water Resources Bulletin No. 160-74, "The California Water Plan -- Outlook in 1974." Page 74. November 1974.*

Table 1. STEAM ELECTRIC GENERATING PLANTS OF THE CALIFORNIA UTILITIES AS OF APRIL 1, 1977[1]

Plant Name	Location (City)	Installed Capacity, Megawatts	Number of Units	Cooling Water Source	Type of Cooling	Fuel Type
Los Angeles Department of Water and Power						
Harbor	Wilmington	389	5	Pacific Ocean	Once through	Gas and Oil
Haynes	Seal Beach	1 606	6	Pacific Ocean	Once through	Gas and Oil
Scattergood	Playa Del Rey	823	3	Pacific Ocean	Once through	Gas and Oil
Valley	Sun Valley	546	4	City Water	Cooling towers	Gas and Oil
Pacific Gas and Electric Company						
Avon	Martinez	40	1	Contra Costa Water Agency	Cooling towers	Refinery Waste, Gas and Oil
Contra Costa	Antioch	1 276	7	San Joaquin River Delta	Once through	Gas and Oil
Humboldt Bay	Eureka	162	3	Humboldt Bay	Once through	Gas, Oil and Nuclear
Hunters Point	San Francisco	406	3	San Francisco Bay	Once through	Gas and Oil
Kern	Bakersfield	166	2	Wells	Cooling towers	Gas and Oil
Martinez	Martinez	40	1	Contra Costa Water Agency	Cooling towers	Refinery Waste, Gas and Oil
Morro Bay	Morro Bay	1 056	3	Morro Bay	Once through	Gas and Oil
Moss Landing	Moss Landing	2 175	7	Monterey Bay	Once through	Gas and Oil
Oleum	Martinez	80	2	San Pablo Bay	Once through	Refinery Waste, Gas and Oil
Pittsburg	Pittsburg	2 029	7	Suisun Bay	Once through, cooling pond and tower	Gas and Oil
Potrero	San Francisco	318	3	San Francisco Bay	Once through	Gas and Oil
The Geysers	Healdsburg	559	11	Condensate of the Geothermal Steam	Cooling towers	Geothermal Steam
Southern California Edison Company						
Alamitos	Long Beach	1 982	6	Pacific Ocean	Once through	Gas and Oil
Cool Water	Daggett	149	4	Wells	Cooling towers	Gas and Oil
El Segundo	El Segundo	1 016	4	Pacific Ocean	Once through	Gas and Oil
Etiwanda	Etiwanda	931	4	Colorado River Aqueduct	Cooling towers	Gas and Oil
Highgrove	Highgrove	169	4	Wells	Once through	Gas and Oil
Huntington Beach	Huntington Beach	870	4	Pacific Ocean	Once through	Gas and Oil
Long Beach	Long Beach	275	3	Pacific Ocean	Once through	Gasand Oil
Mandalay	Oxnard	435	2	Pacific Ocean	Once through	Gas and Oil
Ormand Beach	Oxnard	750	2	Pacific Ocean	Once through	Gas and Oil
Redondo	Redondo Beach	1 601	8	Pacific Ocean	Once through	Gas and Oil
San Bernardino	Loma Linda	131	2	Wells	Cooling towers	Gas and Oil
San Onofre	San Clemente	450[2]	1	Pacific Ocean	Once through	Nuclear
San Diego Gas and Electric Company						
Encina	Carlsbad	602	4	Pacific Ocean	Once through	Gas and Oil
Silver Gate	San Diego	237	4	San Diego Bay	Once through	Gas and Oil
South Bay	Chula Vista	713	4	San Diego Bay	Once through	Gas and Oil
Station B	San Diego	96	4	San Diego Bay	Once through	Gas and Oil
City of Burbank						
Magnolia	Burbank	70	4	Reclaimed waste water	Cooling towers	Gas and Oil
Olive Avenue	Burbank	99	2	Reclaimed waste water	Cooling towers	Gas and Oil
City of Glendale						
Grayson	Glendale	159	5	Wells and Metropolitan Water District of Southern California	Cooling towers	Gas and Oil
City of Pasadena						
Glenarm	Pasadena	59	2	Wells	Cooling towers	Gas and Oil
Broadway	Pasadena	161	3	Wells	Cooling towers	Gas and Oil
Imperial Irrigation District						
El Centro	Imperial	191	4	All American Canal	Cooling towers	Gas
Sacramento Municipal Utility district						
Rancho Seco	Clay	913	1	Folsom South Canal	Natural draft cooling towers	Nuclear

[1] Does not include combustion-turbine units which do not use cooling water.
[2] Ownership shared with San Diego Gas and Electric Company—Rating given is total capacity.

other hand, cooling water would then be required for the steam turbine portion of the combined-cycle plant.

Most of the near-future demand for additional energy will probably be met by thermal-electric plants, whether nuclear-or fossil-fueled (natural gas, coal, or oil), In April 1977, 39 power plants that use steam to generate electrical energy were operating in California and six are under construction. These plants, along with their sources of cooling water, are listed in Tables 1 and 2.

Table 2. STEAM ELECTRIC PLANTS OF THE CALIFORNIA UTILITIES UNDER CONSTRUCTION AS OF APRIL 1, 1977

Plant Name	*Location*	*Installed Capacity, Megawatts*	*Number of New Units at Site*	*Cooling Water Source*	*Type of Cooling*	*Fuel Type*
Pacific Gas and Electric Company						
Diablo Canyon	San Luis Obispo	2–240	2	Pacific Ocean	Once through	Nuclear
The Geysers Units Nos. 12-15	Healdsburg	406	5	Condensate of the geothermal steam	Cooling towers	Geothermal steam
Southern California Edison Company						
San Onofre Nos. 2 & 3	San Clemente	2–200[1]	2	Pacific Ocean	Once through	Nuclear
Long Beach No. 9	Long Beach	49	1	Pacific Ocean	Once through	Gas and Oil
Cool Water Nos. 3 & 4	Daggett	472[2]	2	Wells	Cooling towers	Oil
San Diego Gas and Electric Company						
Encina No. 5	Carlsbad	292	1	Pacific Ocean	Once through	Gas and Oil

[1] Ownership shared by others. Rating given is total.
[2] Includes 276 megawatts of combustion turbines which do not require cooling water.

Due to present restrictions on siting nuclear power plants in heavily populated and seismically active areas, and reluctance to locate them on the coast, most utilities are concentrating their siting activities in the Central Valley and the southeastern corner of California. Inland areas that appear to best meet licensing requirements for nuclear- or fossil-fueled power plants are shown in Figure 1.1/

The identification of suitable sites for thermal power plants will require detailed studies by the electrical utilities. The Warren-Alquist State Energy Resources Conservation and Development Act requires that each notice of intention to file an application for a thermal power plant shall contain at least three alternative sites. Cooling water for four major California sites now under consideration is discussed in Chapter V.

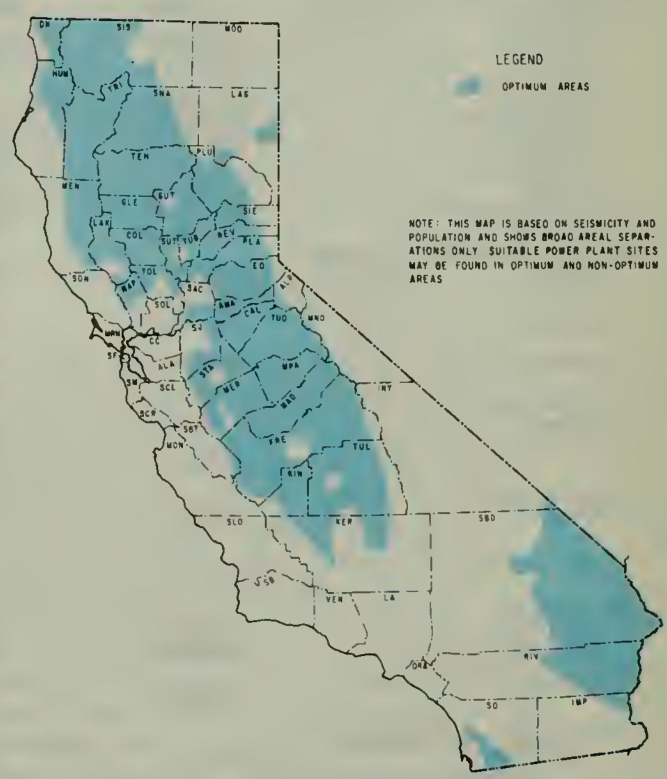


Figure 1. Inland Areas that Best Meet Licensing Requirements for Nuclear and Fossil Fueled Power Plants

1/ *For a discussion of these areas, see State of California, The Resources Agency, "Energy Dilemma." June 1973.*

CHAPTER III. COOLING WATER SYSTEMS FOR STEAM-ELECTRIC POWER PLANTS

The purpose of the cooling-water system in power plants that use steam is to condense the steam after its useful heat has been expended to produce electricity. The cooled water is returned to the power plant heater, where it is heated by burning oil or gas, or by nuclear energy, to produce additional steam, which is used again to produce additional electricity.

In power plants that use either oil or gas, or nuclear energy, to produce steam for generating electricity, the cooling system is an integral part of the steam-supply system (Figure 2). In the power-generation portion of the plant, high-pressure, high-temperature steam passes through the turbine and imparts energy to the turbine shaft, which turns the generator rotor to produce electric power.

The spent steam then leaves the turbine and enters the condenser, where it passes over cooling tubes and is changed back to water. This same water is again heated by a boiler or a nuclear reactor and again becomes high-pressure steam.

The cooling water passes through the cooling tubes in the condenser, where heat is picked up from the condensing steam and carried away. In a once-through system, the heated cooling water is returned to its source, or to another body of water, and a fresh supply of cooling water is continuously pumped to the condenser (Figure 3). In a recirculating system, the heated

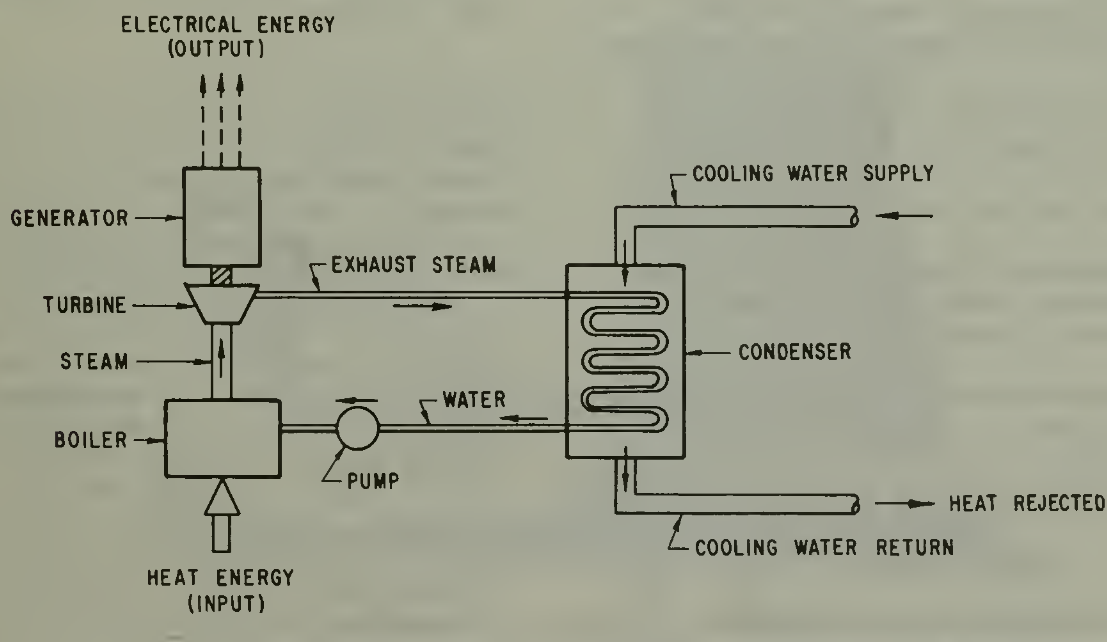


Figure 2. Diagram of the Basic Steam Cycle and Cooling Water Flow for Power Generation

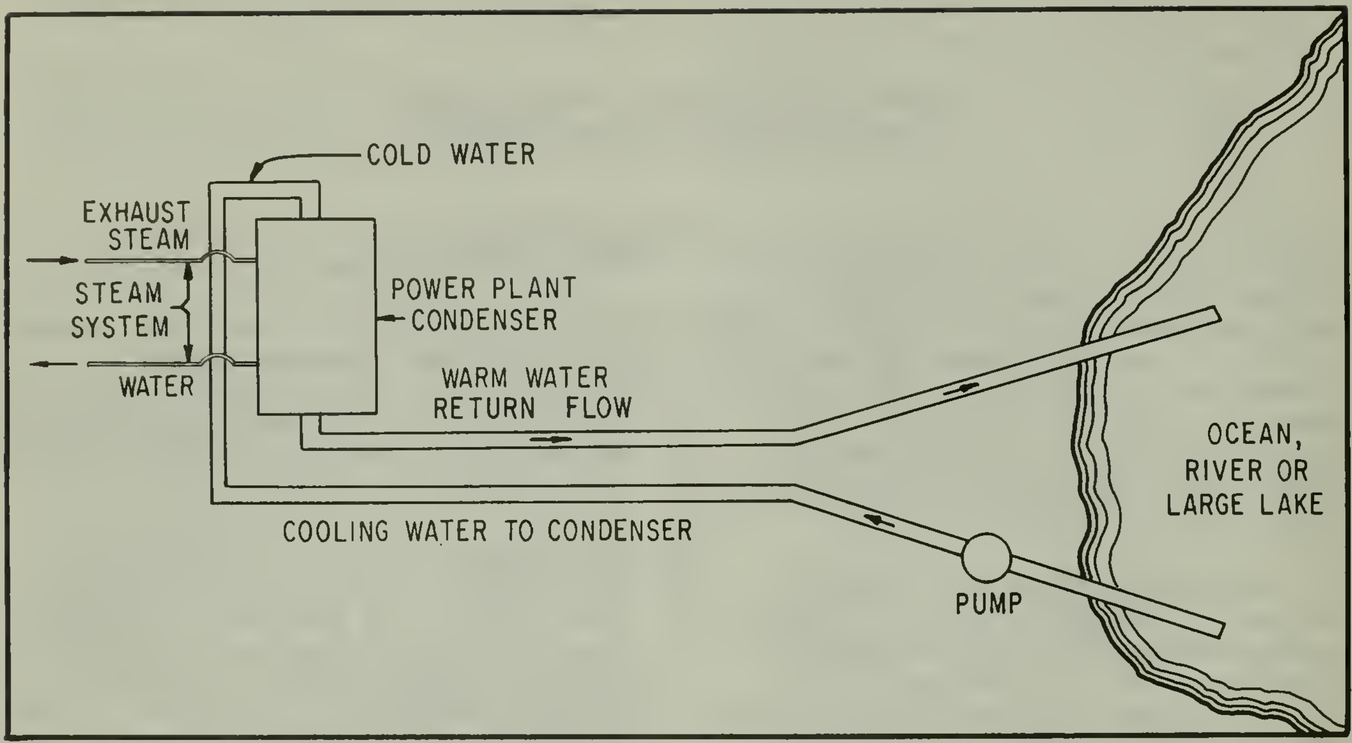


Figure 3. Consenser Cooling Water System with Once-Through Cooling

cooling water is cooled in a tower, pond, or spray canal and returned to the condenser (Figure 4). In the cooling systems, the water used for the generation of steam is physically separated from the cooling water.

The four principal types of cooling-water systems are:

1. Once-through cooling;

2. Closed-cycle evaporative cooling systems, such as evaporation towers, ponds, or spray canals;

3. Closed-cycle nonevaporative (dry) cooling;

4. Combined wet-dry cooling.

<u>Once-Through Cooling</u>

In a once-through cooling system, cooling water is pumped from a large body of water, such as the ocean or bay, as shown in Figure 3. After cooling, the heated water is discharged into the same body of water at a point where the hot water will not be returned to the cooling system or to another body of water.

Once-through cooling uses large quantities of water. A 1 000-megawatt fossil-fueled power plant requires a flow of about 28 cubic metres (1,000 cubic feet) per second. Because of its lower thermal efficiency, a nuclear-fueled plant of the same capacity would require 43 cubic metres (1,500 cubic feet) per second. About 555 cubic hectometres (450,000 acre-feet) of water per year would flow through a 1,000 megawatt fossil-fueled plant operating at 65 percent of plant capacity; the annual flow through a 1,000-megawatt nuclear-fueled plant would be 860 cubic hectometres (700,000 acre-feet), Such quantities are usually available on the coast and only a small part of this water would be lost through surface evaporation after discharge to the receiving water.

Closed-Cycle Evaporative Cooling Systems

Where water supplies are limited or warm-water discharges are prohibited, power plants are often cooled by a closed-cycle evaporative cooling system, which requires far less water than does the once-through method. In a 1 000-megawatt closed-cycle fossil-fueled plant, about 19 cubic hectometres (15,000 acre-feet) of cooling water per year would be evaporated. In a nuclear-fueled plant of the same capacity, about 25 cubic hectometres (20,000 acre-feet) per year would be evaporated.

In the closed-cycle system, cooling water is passed through the plant condensers and circulated to a cooling facility, such as a tower, pond, or spray canal, where the heated water is exposed to the atmosphere and cooled by partial evaporation. The cooled water is then returned to the condensers for another cycle of cooling.

A substantial amount of the cooling water is consumed by evaporation. Smaller quantities are discharged from the system to maintain the desired mineral concentration in the cooling water. (These discharges are called "blowdown." When a cooling tower is used, some water escapes as drift, i.e., droplets of water entrained in the air leaving the tower. All of these losses (evaporation, blowdown, and drift) are replaced with water (called makeup) of a lower mineral concentration.

Three types of cooling facilities used in closed-cycle evaporative systems are briefly discussed in the following paragraphs.

Wet Cooling Towers

In a wet cooling tower, heated water

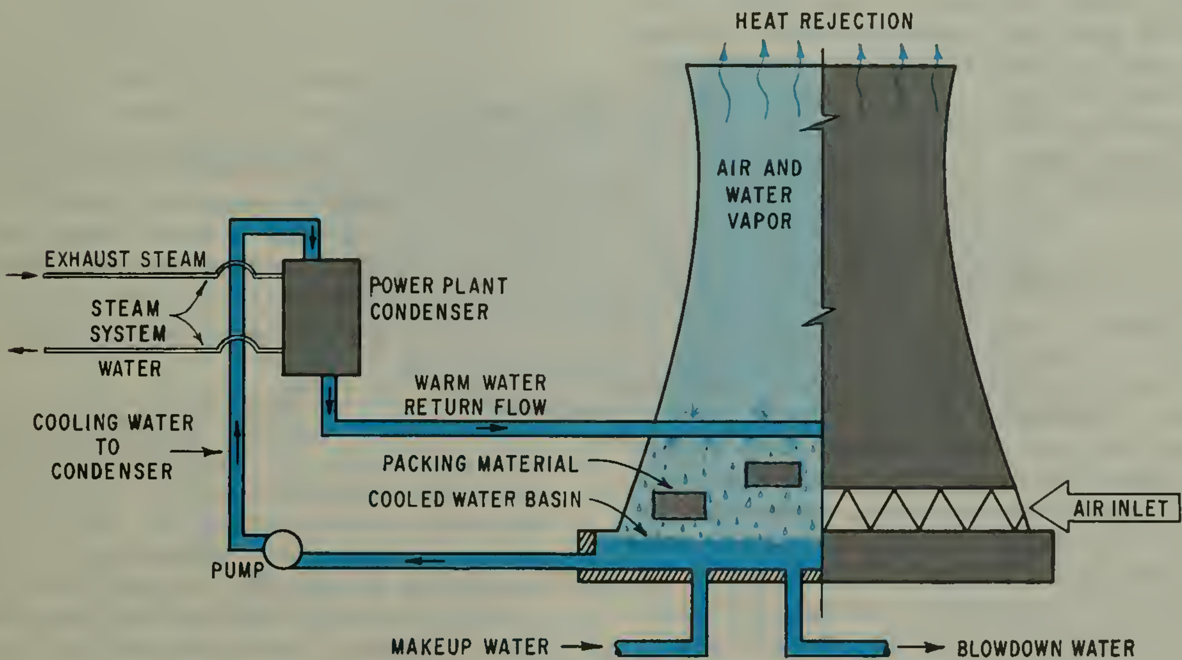


Figure 4. Wet Cooling Tower, Natural Draft

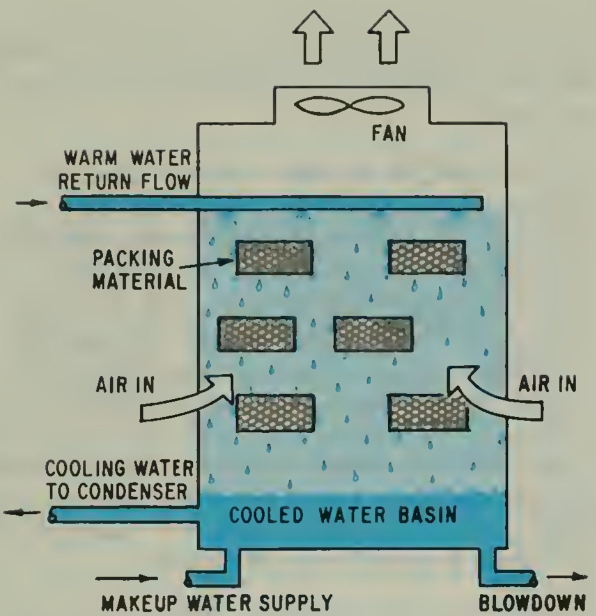


Figure 5. Wet Cooling Tower, Mechanical Draft (Induced)

from the plant condensers is sprayed onto cooling trays in the tower. The water droplets flow downward through packing, or fill, material and are evaporatively cooled by air flowing upward from the base of the tower. The packing provides a large wetted surface area, which facilitates the evaporative transfer of heat. The cooled water is collected at the base of the tower and pumped back to the condensers to complete the cycle.

Two types of cooling towers -- natural draft and mechanical draft -- are shown in Figures 4 and 5. A natural-draft tower is a large-diameter structure with sufficient height and the required shape to induce a strong upward flow of air out the top, causing air to flow in around the base. A large-capacity power plant may require a tower with a 90- to 120 metre (300-to 400-foot) base diameter and a height of 120 metres (400 feet) or greater. A mechanical-draft tower uses fans to provide air flow through the tower.

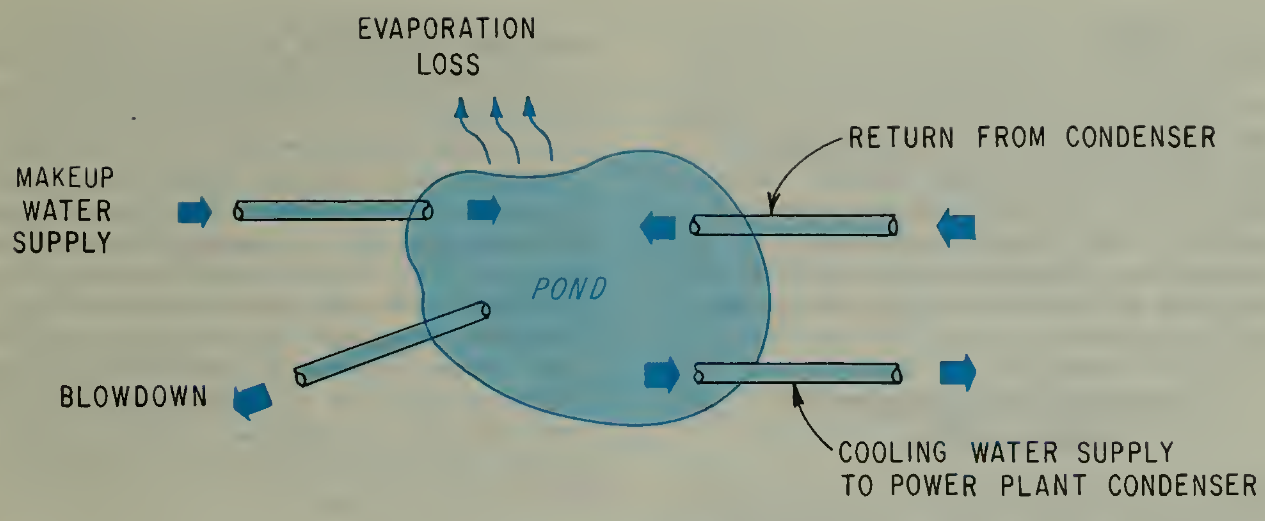
Natural-draft and mechanical-draft towers have both advantages and disadvantages. Both the size and capital costs of a natural-draft tower exceed those for the mechanical-draft tower. On the other hand, energy requirements, and the costs of operation and maintenance, are greater for the mechanical-draft type.

Cooling Ponds.

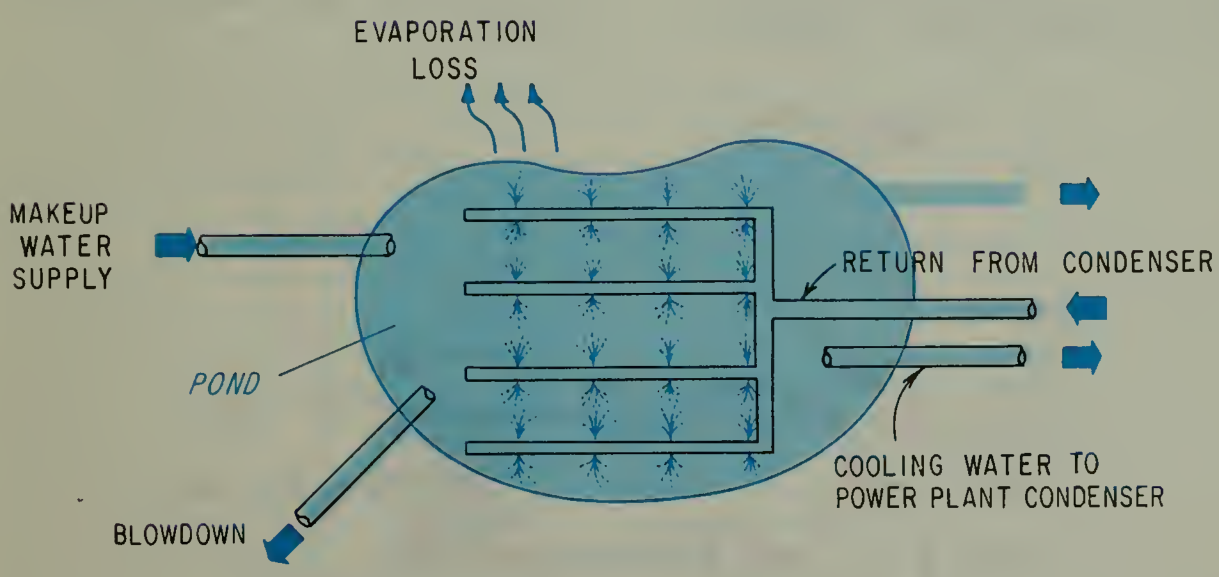
In a cooling pond, the heated water is cooled by evaporation and radiation from a water surface exposed to the atmosphere. Heated water from the plant condensers is discharged to the pond, cooled, and returned to the condensers (Figure 6). The pond must be large enough to permit cooling under the most adverse weather conditions; for example, when humidity is high, evaporation will be reduced.

A pond surface area of 0.4 to 0.8 hectares (1 to 2 acres) per megawatt of generating capacity is usually required, depending on the type of plant and local climatic conditions. For example, a 1 000-megawatt plant would require a pond of 400 to 800 hectares (1,000 to 2,000 acres). In arid parts of the Central Valley and in the Colorado Desert, where evaporation rates are high, the minimum surface areas would be required. A spray system, which increases evaporation, would help to minimize the required pond surface area.

As with all closed-cycle cooling systems, makeup water must be added to replace (1) water lost to evaporation and drift and (2) blowdown removed to control the mineral concentration of the cooling water. Additional makeup water may be required to replace seepage from the cooling pond and water droplets that drift beyond the boundaries of the pond when a spray system is used.



COOLING POND



SPRAY TYPE COOLING POND

Figure 6. Cooling Ponds

Spray Canals

In this system, the heated water flows through a looped or U-shaped canal, where it is repeatedly sprayed into the air by floating pumps and spray nozzles. The water is cooled by evaporation from the water surface and returned to the plant condensers for another cycle.

Closed-Cycle Nonevaporative (Dry) Cooling

Unlike the evaporative cooling systems, in which large quantities of water are used, a nonevaporative system (Figure 7) is a dry cooling system, which operates on the same principle as an automobile radiator. Although in some dry systems, water is used to cool the spent steam, it is not exposed directly to the atmosphere. There is little evaporation loss or deterioration in water quality. Once the system is charged with coolant, little additional water is needed.

The feasibility of dry cooling for large-capacity steam-electric power plants depends on (1) development and improvement of dry-cooling technology required for economic construction and dependable operation, (2) climatic conditions at the plant site, and (3) the availability of and relative cost of cooling water for wet-tower cooling systems. Because of the large surface area required for heat transfer and the large volumes of air that must be passed over the heat exchanger, dry cooling towers are considerably more expensive than are wet towers.

Combined Wet-Dry Cooling

The combined wet-dry tower is a mechanical-draft tower that is adaptable for use as a wet tower, a dry tower, or as a combination of both. A wet-tower combines the features of a wet tower (see Figure 5) and a dry tower (see Figure 6). So far, it has not been used for large-capacity power plants.

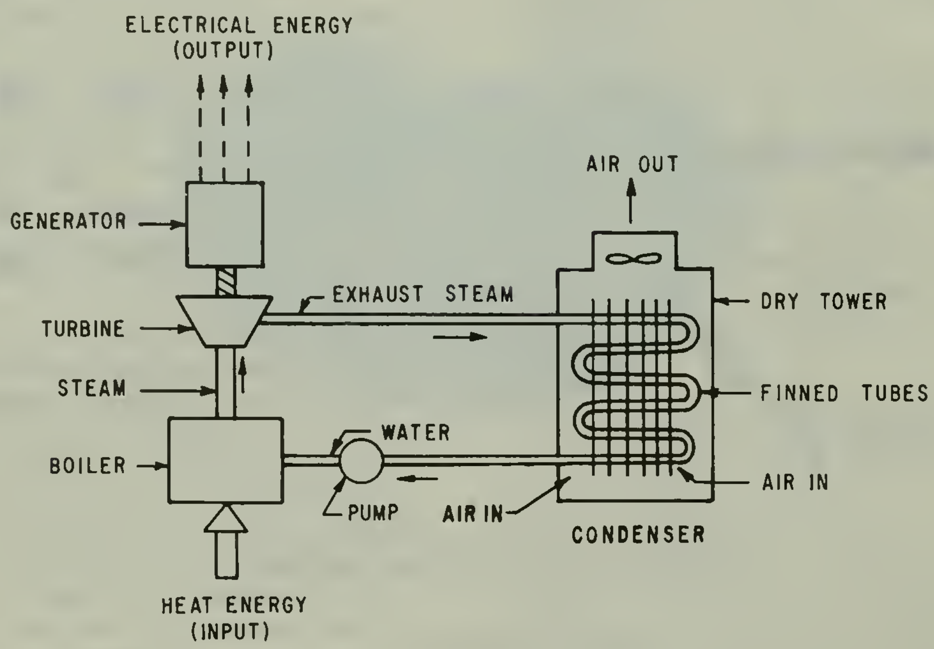


Figure 7. Steam Cycle with Direct Dry Cooling Systems

The system could be operated as a dry tower during cold weather, or during periods when electrical demands are low, or it could be operated as a combined system when full plant output is required, particularly in hot weather. Where climatic conditions are suitable, the combined system could also provide the benefits of wet-tower cooling when needed; it could also conserve water by operating as a dry tower at other times, such as off-peak periods or during cool weather.

A combined wet-dry tower designed to conserve water, located in a hot, dry area, such as Bakersfield, would be expected to use only about 25 percent of the water used by a wet cooling tower.[1/] For example, a 1 000-megawatt nuclear-fueled plant with wet-dry cooling would require about 6 cubic hectometres (5,000 acre-feet) of cooling water per year, compared to 25 cubic hectometres (20,000 acre-feet) per year for a plant of the same capacity with a wet-tower cooling system.

1/ *Rand Corporation (for the California State Assembly). "The Dry/Spray Tower: A Power Plant Cooling Tower Concept for Semi-Arid Locations." January 1973.*

CHAPTER IV. SOURCES OF COOLING WATER

Various types of water are available in California from several sources, ranging from high quality surface and ground waters to saline geothermal and sea water. However, not all of these are available for power plant cooling. The available water is limited by both location relative to suitable sites for steam-electric power plants and other competing uses for the water.

Fresh water should not be used for power plant cooling when waste water or other brackish water is available. Projections of future fresh water demands for California exceed projections of dependable fresh water supplies even when projections of water for power plant cooling are not included.1/

In setting priorities for using different sources of water for power plant cooling, the State Water Resources Control Board has adopted a policy that, depending on environmental factors at the plant site, and technical and economic feasibility, "...power plant cooling water should be obtained from the following sources in the order of priority shown: (1) waste water being discharged to the ocean, (2) ocean, (3) brackish water from natural sources or irrigation return flow, (4) inland waste waters of low TDS (total dissolved solids), and (5) other inland waters".2/

Waste Water

Urban and agricultural waste water could be used for cooling in many locations, but not all of this water is "wasted" in the sense that it has no other uses. Most of the 740 cubic hectometres (600,000 acre-feet) of urban waste water discharged at inland locations is blended with other water supplies and reused; and about 2 220 cubic hectometres (1.8 million acre-feet) of urban waste water is discharged to saline or brackish water (including bays and the ocean) and is lost to further use. It is this waste water, which is now "lost", that could be substituted for fresh water.

The San Joaquin Valley Interagency Drainage Program has reported3/ that the following quantities of saline subsurface agricultural drainage water would be available in the San Joaquin Valley:

year	cubic hectometres	acre-feet
1980	123	100,000
1990	230	185,000
2000	395	320,000

After treatment, much of this agricultural waste water could be used for

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1/ *Department of Water Resources Bulletin No. 160-74, "The California Water Plan -- Outlook in 1974 (Summary Report)", Table 27, November 1974.*

2/ *State Water Resources Control Board: "Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Power Plant Cooling". June 1975.*

3/ *U. S. Bureau of Reclamation, Department of Water Resources, and State Water Resources Control Board, "San Joaquin Valley Interagency Drainage Program-Progress Report No. 1." October 1976.*

power plant cooling.

Studies currently being conducted by the Department of Water Resources on the feasibility of providing treatment to waste waters indicate that most municipal and agricultural waste water could be used for power plant cooling after certain pretreatment. Municipal waste water normally receives primary and secondary treatment before it is released from the municipal waste water treatment and collection system. Agricultural waste water, which is usually highly mineralized, would require treatment to control biological growths resulting from the increased nutrients in the waste water.

An important consideration in the use of waste water for power plant cooling is the general scattered location of the source. Where not already available, a collection system would have to be developed to collect sufficient quantities of waste water to make its use practical. Annual quantities of agricultural waste water will increase with time as more lands are brought under irrigation. However, a substantial amount of this waste water is already available in some areas.

The time when waste water is available at its source is another consideration. Municipal waste water is available at a generally uniform rate throughout the year, although use of treatment facilities by seasonal industries may cause the rate to fluctuate. In most areas, the quantity of agricultural waste water varies on a seasonal basis. Where the waste water supply is available on an irregular basis, regulating storage facilities will be required.

Municipal Waste Water

In 1973, about 2 500 cubic hectometres (2 million acre-feet) of municipal waste water in California, grouped by sources in Table 3, could have been physically used for power plant cooling. During 1973, eighteen municipal and two private treatment plants each produced 25 cubic hectometres (20,000 acre-feet or more of treated waste water. In 15 other locations, it was assumed that the treated municipal waste water produced within an 8-kilometre (5-mile) radius of each location could have been collected to make up 25 cubic hectometres (20,000 acre-feet) or more. As discussed in Chapter III, 25 cubic hectometres (20,000 acre-feet) of cooling water per year would be sufficient to cool a 1 000 megawatt nuclear-fueled power plant with a closed-cycle evaporative cooling system. /A fossil-fueled closed-cycle plant would require 19 cubic hectometres (15,000 acre-feet) per year./

The annual discharge from each treatment plant, the operating entity, and the county in which each plant is located are shown in Table 3. At some of these treatment plants a small portion of the waste water produced is already being directly reused. In addition, many inland plants discharge into water supply sources where the waste water is blended and reused. Figure 8 shows the counties where a minimum of 25 cubic hectometres (20,000 acre-feet) per year could be made available.

Agricultural Waste Water

In some parts of California, large quantities of waste water are drained from irrigated croplands but are too highly mineralized for direct reuse as irrigation water. Three large agricultural areas where substantial quantities of agricultural waste water occur are the San Joaquin, Palo Verde, and Imperial Valleys. The brackish drainage water in these three agricultural Valleys must be removed to prevent the land from becoming increasingly less productive. Research work on the treatment of this brackish waste water is continuing and is discussed later in this chapter under "On-Going Studies of Waste Water."

TABLE 3
TREATMENT PLANTS PRODUCING MUNICIPAL AND INDUSTRIAL WASTE WATER THAT COULD BE USED FOR POWER PLANT COOLING
1973[1]

County	Treatment Plant	Quantity Produced: cubic hectometres		Quantity Produced: 1000's of acre-feet	
Alameda	East Bay Municipal Utility District				
	Combined Plants[2]		131.8[4]		106.9[4]
	Hayward, City of	18.5[4]		15.0[4]	
	Oro Loma Sanitary District	22.8[4]		18.5[4]	
	San Leandro, City of	9.9[4]		8.0[4]	
	Total for group		51.2[4]		41.5[4]
	TOTAL FOR COUNTY		183.0[4]		148.4[4]
Contra Costa	Central Contra Costa Sanitary District		39.9[4]		32.4[4]
	Combined Plants[2]				
	Pinole, City of	1.9[4]		1.5[4]	
	Richmond, City of	11.2[4]		9.1[4]	
	Rodeo, City of	10.0[4]		0.8[4]	
	San Pablo Sanitary District	11.0[4]		9.0[4]	
	Total for group		34.1[4]		20.4[4]
	TOTAL FOR COUNTY		74.0[4]		52.8[4]
Fresno	Fresno, City of		42.1		34.2
Humboldt	Crown Simpson Pulp Co., Samoa		27.6[4]		22.4[4]
	Louisiana Pacific Co., Samoa		36.6[4]		29.7[4]
	TOTAL FOR COUNTY		64.2		52.1
Kern	Combined Plants[2]				
	Bakersfield, City of (3 plants)	20.3		16.5	
	Mt. Vernon County Sanitary District[3]	5.3		4.3	
	North of River Sanitary District No. 1[3]	3.2		2.6	
	TOTAL FOR GROUP AND COUNTY		28.8		23.4
Los Angeles	Hyperion Plant		468.2[4]		379.6[4]
	Los Angeles County Sanitation Dist.[2]				
	Joint Water Pollution Control Plant		496.1[4]		402.2[4]
	San Jose Creek[3]		36.2		29.4
	Combined Plants[2]				
	Long Beach Plant	9.9[4]		8.1[4]	
	Los Coyotes Plant	11.4		9.3	
	Terminal Island	14.1[4]		11.5[4]	
	Total for group		35.4		28.9
	TOTAL FOR COUNTY		1 035.9		840.1
Marin	Combined Plants[2]				
	Marin County Sanitary District No. 1	9.6[4]		7.8[4]	
	Marin County Sanitary District No. 6, Novato	4.2		3.4	
	Marin County Sanitary District	1.2		1.0	
	San Quentin Prison	0.9[4]		0.7[4]	
	San Rafael Sanitary District	4.9		4.0	
	Las Gallinas Valley Sanitary District	4.2		3.4	
	TOTAL FOR GROUP AND COUNTY		25.0		20.3
Napa-Solano	Combined Plants[2]				
	Napa Sanitary District	11.4[4]		9.3[4]	
	Benecia, City of	1.4[4]		1.2[4]	
	Vallejo Sanitation and Flood Control District	11.7[4]		9.5[4]	
	Mare Island Naval Shipyard	1.0[4]		0.8[4]	
	TOTAL FOR GROUP AND COUNTIES		25.5[4]		20.8[4]
Orange	Orange County Sanitation Districts				
	Plant No. 1		66.4[4]		53.9[4]
	Plant No. 2		143.1[4]		116.0[4]
	TOTAL FOR COUNTY		209.5[4]		169.9[4]
Riverside-San Bernardino	Riverside, City of		24.6		20.0
	Combined Plants[2]				
	Chino Basin Municipal Water District				
	Masingale Plant	13.9		11.3	
	Chino Plant	3.5		2.8	
	Corona, City of	4.2		3.4	
	Perris, City of	0.4		0.3	
	California Institute for Women	0.3		0.2	
	Jurupa Community Services District	1.4		1.1	
	Sunkist Growers, Inc., Corona	1.6		1.3	
	Total for group		25.3		20.4
	Colton, City of	3.1		2.5	
	Redlands, City of	3.5		2.8	
	Rialto, City of	2.7		2.2	
	San Bernardino, City of	22.0		17.9	
	Norton Air Force Base	0.1		0.1	
	Total for group		31.4		25.5
	TOTAL FOR COUNTIES		81.3		65.9

TABLE 3 (Continued)
TREATMENT PLANTS PRODUCING MUNICIPAL AND INDUSTRIAL WASTE WATER THAT COULD BE USED FOR POWER PLANT COOLING
1973 [1]

County	*Treatment Plant*	*Quanity Produced* — *Cubic hectometres*		*1000's of acre-feet*	
Sacramento	Sacramento, City of (main plant)		70.9		57.5
	Combined Plants[2]				
	Arden Plant	8.5		6.9	
	Cordova Plant	2.6		2.1	
	North Highlands Plant	2.5		2.0	
	Northeast Plant	18.2		14.8	
	Total for group		31.8		25.8
	Sacramento County Central Plant	21.8		17.7	
	Sacramento City Meadowview Plant	2.0		1.6	
	Total for group		23.8		19.3
	TOTAL FOR COUNTY		126.5		102.6
San Diego	San Diego City Point Loma Plant		137.4[4]		111.4[4]
San Francisco	North Point Plant		88.3[4]		71.6[4]
	Richmond-Sunset Plant		30.7[4]		24.9[4]
	Southeast Plant		31.2[4]		25.3[4]
	TOTAL FOR COUNTY		150.2[4]		121.8[4]
San Joaquin	Stockton, City Main Plant		27.5		22.3
San Mateo	Combined Plants[2]				
	Estero Municipal Improvement District	2.2[4]		1.8[4]	
	Burlingame, City of	6.4[4]		5.2[4]	
	Millbrae, City of	3.3[4]		2.7[4]	
	International airport Plant	1.1[4]		0.9[4]	
	San Mateo, City of	17.1[4]		13.8[4]	
	Total for group		30.1[4]		24.4[4]
	Menlo Park Sanitary District	7.6[4]		6.2[4]	
	Redwood City, City of	11.3[4]		9.2[4]	
	San Carlos-Belmont, Cities of	9.6[4]		7.8[4]	
	Total for group		28.5[4]		23.2[4]
	TOTAL FOR COUNTY		58.6[4]		47.6[4]
Santa Clara	Palo Alto, City of		37.0[4]		30.0[4]
	San Jose, City of		115.0[4]		93.5[4]
	Sunnyvale, City of		23.4[4]		19.0[4]
	TOTAL FOR COUNTY		175.4[4]		142.5[4]
Shasta	Combined Plants[3]				
	Anderson, City of	1.6		1.3	
	Enterprise Public Utility District	2.1		1.7	
	Redding, City of	6.1		5.0	
	Simpson-Lee Paper Co. (Anderson)	15.2		12.3	
	Champion Papers Inc. (Anderson)	2.9		2.4	
	TOTAL FOR GROUP AND COUNTY		27.9		22.7
Stanislaus	Combined Plants[5]				
	Modesto, City of	27.1[5]		22.0[5]	
	Oakdale, City of	1.7		1.4	
	Patterson, City of	1.7		1.4	
	Riverbank, City of	2.7		2.2	
	Salida Sanitary District	0.9		0.7	
	Ripon (San Joaquin County)	2.1		1.7	
	TOAL FOR GROUP AND COUNTY		36.2		29.4
Ventura	Combined Plants[3]				
	Oxnard, City of	15.7[4]		12.8[4]	
	San Buenaventura, City of	6.2[4]		5.0[4]	
	Ventura Regional County Sanitary District	4.2[4]		3.4[4]	
	TOTAL FOR GROUP AND COUNTY		26.1[4]		21.2[4]
	GRAND TOTAL		2 523.1		2,049.4

[1] Department of Water Resources Bulletin No. 68-73. "Inventory of Waste Water Production and Waste Water Reclamation in California, 1973." April 1975.
[2] Treatment plants within a 5-mile radius producing less than 25 cubic hectometres (20,000 acre-feet) of waste water, which could be collected to provide sufficient water for power plant cooling.
[3] A portion of waste water is reclaimed. Source: California Department of Public Health. "Reliability of Wastewater Reclamation Facilities". 1976.
[4] This waste water is discharged to brackish or saline water and could be used in lieu of fresh water for water for power plant cooling.
[5] Includes industrial waste water not reported in DWR Bulletin No. 68-73.

Figure 8. Counties Where Municipal and Industrial Waste Water Treatment Plants Could Provide a Minimum of 25 Cubic Hectometres (20,000 acre-feet) per year (individually or by groups of plants—see Table 3)

In some parts of these areas, agricultural waste water is already being collected and removed from the land. In the northern San Joaquin Valley, some of the waste water flows into the San Joaquin River, which causes a salt problem for users diverting water from the main stem of the river and channels of the Sacramento-San Joaquin Delta. In the Palo Verde Valley, the waste water is discharged into the Colorado River and reused by downstream water users. Waste water in the Imperial Valley drains into the Salton Sea.

Waste water collection systems, although costly to install and maintain, will eventually be needed to meet drainage needs and could be used to collect this saline water and transport it to treatment plants. Substantial quantities of treated agricultural waste water might thus be made available for use as cooling water in power plants that use steam for the production of electricity. Utilities planning power plants will have to develop and finance many of these systems if they are to use waste water for cooling.

The estimated quantities of agricultural waste water available in the San Joaquin, Palo Verde, and Imperial Valleys are discussed in the following paragraphs.

San Joaquin Valley. During three recent studies of the agricultural waste water disposal problem, estimated future quantities of waste water in various parts of the San Joaquin Valley were developed. At the present time, an estimated 86 cubic hectometres (70,000 acre-feet) of agricultural waste water with a salt content of 6 500 to 7 500 milligrams per litre is discharged from subsurface tile drainage systems in the Valley. Over the next 30 to 50 years, however, the quantity of waste water is expected to increase to a range of 615 cubic hectometres (500,000 acre-feet) to 740 cubic hectometres (600,000 acre-feet) per year, although the salt content may be lowered to 2 000 to 3 000 milligrams per litre because most of the accumulated salts will have been removed from the soil.[1/]

In some parts of the Valley, presence of agricultural waste water has lowered the crop growing potential to unprofitable levels. And, as more land is irrigated and more water is applied in the potential drainage problem areas, the drainage and waste-water disposal problems will become increasingly

1/ *Department of Water Resources Bulletin No. 127-74, "Status of San Joaquin Valley Drainage Problems" December 1974. Page 10.*

Table 4.[1] ESTIMATED ANNUAL QUANTITIES OF AGRICULTURAL WASTE WATER IN THE SAN JOAQUIN VALLEY, BY COUNTY 1980–2020

County	*1980–1990*		*1990–2005*		*2000–2020*	
	cubic hecto-metres	*1,000s of acre-feet*	*cubic hecto-metres*	*1,000s of acre-feet*	*cubic hecto-metres*	*1,000s of acre-feet*
Contra Costa	7	6	11	9	12	10
San Joaquin	14	11	23	19	30	24
Stanislaus	16	13	28	23	35	28
Merced	43	35	72	58	83	67
Madera	4	3	5	4	6	5
Fresno[2]	79	64	125	101	130	105
Kings[3]	60	49	86	70	110	89
Tulare	5	4	10	8	19	15
Kern	18	15	31	26	72	58
Subtotal	246	200	392	318	497	401
San Luis Unit	25	20	109	85	167	135
Totals	271	200	501	403	664	536

[1] Department of Water Resources Bulletin No. 127-74, "Status of San Joaquin Valley Drainage Problems." December 1974. (Adapted from Table 3, page 26).
[2] Excludes agricultural waste water from San Luis Unit service area, a large agricultural area on the west side of the San Joaquin Valley; most of the service area is in Fresno County.
[3] Excludes agricultural waste water from San Luis Unit service area and includes a maximum of 49 cubic hectometres (40,000 acre-feet) per year of agricultural waste water from the Tulare Lake bed area.

severe. The data shown in Table 4 were developed by the Department of Water Resources during its San Joaquin Valley Drainage Investigation.

In a more recent study of the potential use of agricultural waste water for power plant cooling, the Department of Water Resources estimated future quantities of agricultural waste water that would be available in parts of Kern, Kings, and Tulare Counties in the southern San Joaquin Valley. The results are summarized as follows:

Year	Annual quantities of agricultural waste water 1/	
	cubic hectometres	acre-feet
1975	78	63,200
1980	110	89,400
1990	172	139,400
2000	251	203,300

The Kern County Water Agency has also reported on a study to determine areas in Kern County where agricultural waste water problems are anticipated, the potential increase in quantities of waste water, and plans for waste water disposal facilities. 2/ The Agency has estimated the follow-

1/ *Department of Water Resources Memorandum Report. "Potential Use of Agricultural Waste Water for Powerplant Cooling." September 1971 (quantities developed from Table 1).*

2/ *Kern County Water Agency. "Summary Report on Agricultural Waste Water Collection and Disposal System, Kern County, California." November 1975.*

ing future quantities of agricultural waste water:

Annual Quantities of Waste Water

Area	1975		1985		2005	
	cubic hecto-metres	acre-feet	cubic hecto-metres	acre-feet	cubic hecto-metres	acre-feet
Southern Area (Buena Vista Lake and Kern Lake beds)	12	10,000	72	58,000	183	148,000
Northern Area (North of Buttonwillow)	10	7,800	38	31,000	94	76,500
Total	22	17,800	110	89,000	277	224,500

The annual quantities of drainage water estimated in these two recent studies of the areas evaluated exceed those reported in Department of Water Resources Bulletin No. 127-74, "Status of San Joaquin Valley Drainage Problems" (see Table 4).

The salinity of the drainage water varies at different times of the year and in different parts of the Valley, and may also vary annually during operation of the proposed waste water disposal system. Information provided the Kern County Water Agency by the U. S. Department of Agriculture indicates that the long-term salinity concentration of drainage water in Kern County would gradually decrease from 6 000 to 4 000 mg/l.1/

Palo Verde Valley. About 490 cubic hectometres (400,000 acre-feet) of brackish agricultural waste water per year (average 1973-1974) is discharged from the Palo Verde Irrigation District into the Colorado River. The discharge varies from a low of 8.5 cubic metres (300 cubic feet) per second during the winter to about 23 cubic metres (800 cubic feet) during the summer.

When Colorado River water is diverted for irrigation in the Palo Verde Valley, its salinity content is about 800 mg/l. The salinity of drainage flows, which return to the river downstream, varies from 1 500 to 2 100 mg/l. The increase in salinity is caused by concentration, leaching of salts, and use of fertilizer in the Palo Verde Irrigation District. Salt in the water supply is concentrated as the water is used for irrigation. Salts in the soil are leached by the irrigation water.

The drainage water is collected in the Palo Verde Drain and discharged into the river, where it is mixed with the river water and diverted again under downstream water rights. Because the use of this drainage water is subject to the downstream water rights, replacement of supplies diverted from the Drain and not returned to the river would be required to satisfy the downstream water rights. If an additional 23 cubic hectometres (17,000 acre-feet) of Colorado River water were released from Parker Dam upstream from the District's river intake, to replace water diverted from the Drain for power plant cooling, the quality of the river water down-

1/ *U. S. Department of Agriculture, Soil Conservation Service. "Agricultural Drainage Study, Kern County". June 1974.*

stream from the Drain outfall would be improved by a reduction in salt content (total dissolved solids) of an estimated 12 mg/l.

Imperial Valley. Agriculture in the Imperial Valley is also irrigated with water diverted from the Colorado River. Excess water and salts in the soil are collected in extensive subsurface drainage systems and conveyed in natural channels and drain canals to the Salton Sea, an inland body of water. Most of the waste water from the Imperial Valley, along with municipal waste water from most urban centers in this part of California and from Mexicali, Mexico, is carried to the Salton Sea in two natural channels -- the Alamo and New Rivers.

From 1943 through 1967, the annual flow of the Alamo River into the Salton Sea varied from a low of 605 cubic hectometres (490,000 acre-feet) to a high of 938 cubic hectometres (760,000 acre-feet). In 1967, the Alamo carried 765 cubic hectometres (620,000 acre-feet), with a salinity content of 2 500 mg/l, to the Sea.[1/]

During this same period, the annual flow of the New River into the Sea varied from 442 cubic hectometres (358,000 acre-feet) to 666 cubic hectometres (540,000 acre-feet). In 1967, the New River delivered 473 cubic hectometres (383,000 acre-feet) with a salinity content of 3 500 mg/l.

In 1968, the total gaged flows into the Salton Sea from the Imperial Valley were 1 353 cubic hectometres (1,097,000 acre-feet). By 1971, the annual inflow had increased to 1 461 cubic hectometres (1,185,000 acre-feet). The total included inflow from Mexico and inflow from the Alamo and New Rivers, San Felipe Creek, and 22 drains and wasteways. The major inflows contain concentrations of total dissolved solids ranging from 2 000 to 4 000 mg/l.[2/]

The stability of the level of the Salton Sea is maintained by a balance between (1) inflows of surface and subsurface water, (2) precipitation, and (3) surface evaporation from the Sea. If the inflow to the Sea were decreased, evaporation would reduce the size of the Sea until a new balance was attained, which would raise the salt concentration of the Sea. Accordingly, if some of the drainage water now entering the Sea were used for power plant cooling, and not compensated for by another source, the level of the Sea would drop and its surface area would be reduced. However, the sea is currently at its highest level ever, and its height is causing problems, particularly the flooding of shoreline developments. Both the positive and negative effects on the Salton Sea should be evaluated in considering the use of Imperial Valley drainage water for power plant cooling.

Other Water Supplies

The other water supplies discussed in this section include ocean water, brackish and saline interior water, brackish estuarine water, geothermal water, ground water, and fresh surface water. The quality of these water supplies varies widely. Salinity ranges from less than 100 mg/l in some rivers to 260 000 mg/l in geothermal water at the Buttes geothermal domain in the Imperial Valley.[3/] Elsewhere in the Imperial

1/ *Department of Water Resources Bulletin No. 143-7. "Geothermal Wastes and the Water Resources of the Salton Sea Area". February 1970.*

2/ *U. S. Department of the Interior and California Resources Agency. "Salton Sea Project." (Feasibility Report) - April 1974. Pages D-8 and D-34.*

3/ *Department of Water Resources Bulletin No. 190. "Water and Power from Geothermal Resources in California -- An Overview." December 1974.*

Valley the salinity of geothermal water varies from about 3 000 to 20 000 mg/l. The average salinity of ocean water is about 35 000 mg/l.

Each of the broad categories of water supplies -- other than waste water -- that might be used for power plant cooling is briefly discussed in the following paragraphs.

Ocean Water

As discussed in the preceding section, the California State Water Resources Control Board ranks ocean water as second in the order of priority for sources of power plant cooling water. The use of ocean water would be practical only at coastal sites, which also include power plants located several miles from the coast itself.

Two advantages of ocean water as a source for power plant cooling are its relatively low temperature and the ample supply of water available. A third advantage is the essentially unlimited capacity of the ocean as a heat sink.

On the other hand, when ocean water is used for cooling, the marine environment must be protected when water is taken from the ocean and when warmed water is returned to the ocean. Other disadvantages are the fouling of the water intake conduits by marine growths and the need to protect the conduits from corrosion caused by the sea water.

In July 1972, the State Water Resources Control Board adopted a water quality control plan for the ocean waters of California.1/ In this policy, the Board declares that protection of the quality of ocean water for the use and enjoyment by the people of California requires control of waste discharges to the ocean.

In September 1975, the Board adopted a water-quality control plan (The Thermal Plan) for control of temperature in California's coastal and interstate water and enclosed bays and estuaries.2/ The Thermal Plan imposes limitations on temperatures of waste discharges into receiving water and on the increase in temperature of the receiving water. Such limitations will influence the design and operation of power plant cooling systems that would discharge into any of the water resources protected by the Thermal Plan and assure protection of the beneficial uses of those water resources.

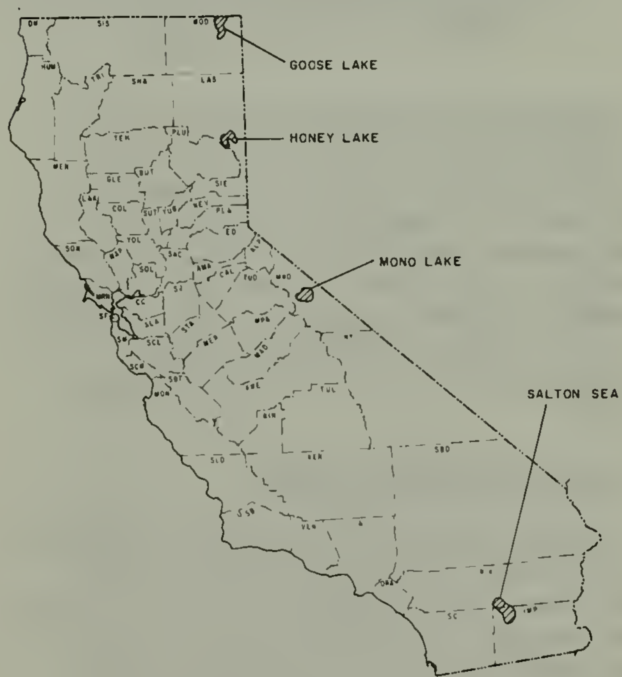

Figure 9. Location of Large Saline Lakes

1/ *State Water Resources Control Board. "Water Quality Control Plan for Ocean Waters of California." July 1972.*

2/ *State Water Resources Control Board. "Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California." September 1975.*

Brackish and Saline Interior Lakes

Four large brackish or saline lakes in California present a possible source of cooling water (Figure 9). Each is located in an interior basin with poor drainage, or no natural drainage outlet, and the minerals in the water entering the lakes are concentrated by evaporation from the lake surface.

The location, volume, and salinity of each lake are as follows:

Name	County	Volume		Total dissolved solids
		cubic hectometres	1,000s of acre-feet	milligrams per litre
Goose	Modoc (Calif.) and Lake (Oregon)	617	500	1 200
Honey*	Lassen	370	300	5 000
Mono	Mono	2 837	2,300	70 000
Salton Sea	Imperial, Riverside	8 017	6,500	38 000

* *Average year when average depth is about 1.5 metres (5 feet). In some years, the lake is dry.*

If cooling water were obtained from Goose Lake, an interstate lake, a closed-cycle evaporative cooling system would be mandatory because all interstate waters, even those that are highly saline, are covered by the State Board's Thermal Plan and Water Quality Control Plans, and Goose Lake is specifically protected by the Thermal Plan.

Brackish Estuarine Water

Estuarine water is water that extends from a bay or the open ocean to the upstream limit of tidal action. Along the California coastline, 77 wetland and estuarine areas have been identified, 47 of which are classified as high (environmental) priority-total exclusion areas.1/

Construction of a power plant at any of the other 30 sites would require specific measures to protect fish and wildlife. The 30 nonrestricted sites are located in the following counties: Humboldt (2 sites), Mendocino (8), Sonoma (1), Marin (1), Santa Cruz (2), Monterey (8), San Luis Obispo (3), Santa Barbara (2), Ventura (1), Los Angeles (1), and San Diego (1).

A power plant site would also have to be far enough from the high-priority areas to prevent disturbance of fish and wildlife there. Moreover, if a power plant were constructed in an estuarine area, the use of once-through cooling would be essentially prohibited under California's Thermal Plan.

In May 1974, the State Water Resources Control Board adopted a water-quality control policy for the enclosed bays and estuaries of California.2/ The purpose of this policy is to provide

1/ *State of California, The Resources Agency. "Energy Dilemma". June 1973.*

2/ *State Water Resources Control Board. "Water Quality Control Policy for the Enclosed Bays and Estuaries of California." May 1974.*

water-quality principles and guidelines to prevent water-quality degradation and to protect the beneficial uses of water in enclosed bays and estuaries.

Geothermal Water

Geothermal water is heated ground water that usually emanates from volcanic or igneous rocks of recent origin. The presence of a geothermal water body is usually indicated by thermal springs or geysers. Although more than 200 thermal springs exist in California, most of them produce insufficient quantities of water for power plant cooling. Recent geothermal investigations indicate that significant reservoirs of geothermal water are limited to the following seven areas (Figure 10):

Geothermal Areas	Location
1. Imperial Valley	Imperial County (central area)
2. Coso Hot Springs	Inyo County (southwestern)
3. Long Valley	Mono County (southwestern)
4. Mono Lake	Mono County (central)
5. Geysers-Clear Lake	Sonoma, Lake Counties
6. Mt. Lassen	Plumas, Lassen Counties
7. Surprise Valley	Modoc County (eastern)

The present use of geothermal water for power plant cooling in California is limited to a few plants where geothermal steam is available for power generation. For example, at the Geysers power plant in Sonoma County, water used in the plant condensers is obtained by cooling geothermal steam. If hot geothermal water were used for cooling, it would have to be cooled and pretreated to control corrosion and scaling.

The subsurface exploration of California's geothermal areas has principally centered on the Geysers area in Sonoma County and in the Imperial Valley. The areal extent, depths, and physical characteristics of the other potential geothermal resources in California remain undefined.

The use of geothermal water for cooling ing would entail several problems:

1. Because of its high temperature, the water is less efficient for cooling.

2. Because most geothermal water is highly mineralized, special treatment would be required to control corrosion and scaling in the cooling system.

3. The salinity of geothermal water is high and would increase during the

Figure 10. Location of Geothermal Reservoirs

cooling process; consequently, special measures would be required for its disposal to protect other water supplies in the immediate area.

4. The extraction of geothermal water might cause local surface subsidence and induce seismicity.

Ground Water

Some 270 ground water basins are located in various parts of California. Many of the basins are full, or almost full, of water. In 97 basins, the storage capacity of each exceeds 1 233 cubic hectometres (1 million acre-feet). In some basins, the water is brackish and would be unusable for irrigation or municipal purposes without expensive treatment.

In many parts of California, ground water is already heavily used for irrigation and as municipal supplies. Some large basins are in a state of overdraft; i.e., the water is being extracted at an annual rate that exceeds the annual rate of replenishment, leaving progressively decreasing quantities of water in the underground reservoirs. In a number of coastal basins, this overdraft permits sea water to intrude into the basin and degrade the water quality.

Ground water basins that might be considered as possible sources of cooling water are located in some parts of the Central Valley, the northeastern volcanic area, and the southeastern desert region. Each of these areas is briefly discussed in the following paragraphs.

Central Valley. The high quality of most of the ground water in the Central Valley means that its use for cooling water would be in competition with other beneficial uses. The Sacramento Valley portion is generally not in a state of overdraft. The northern San Joaquin Valley, however, is experiencing local overdraft conditions; the Tulare Basin, in the Southern San Joaquin Valley, is in a state of serious overdraft.

Four general types of ground water are found in the Central Valley:

1. Water, varying from brackish to fresh, at relatively shallow depths below the ground surface in the trough along the west side of the San Joaquin Valley and in parts of the west side of the Sacramento Valley. Part of this shallow ground water may consist of percolated irrigation water.

2. Confined and unconfined high-quality ground water. The confined water is trapped under confining beds of impervious sediments that prevent vertical movement of the water.

3. Confined and unconfined brackish ground water at greater depths, mainly in the San Joaquin Valley.

4. Deep-lying saline connate water and brines produced by oil production.

These four types of water are not available in all parts of the Central Valley, but those available at potential power plants sites should be evaluated.

Northeastern California. The volcanic areas of northeastern California are characterized by rough surface terrains and recent lava flows. Most of the area is unsuitable for irrigated agriculture, and there is little demand for municipal water supplies. However, geologic investigations would be required to develop firm estimates of the extent of the available ground water.

Southeastern Desert Area. Several valleys in the southeastern desert area contain ground water. The thickness of the water-bearing deposits in parts

TABLE 5. GROUND WATER BASINS IN SOUTHEASTERN CALIFORNIA WITH POTENTIAL FOR PROVIDING WATER FOR POWER PLANT COOLING [1]

Basin name and county	*Area size*		*Storage capacity*		*Average annual replenishment*		*Existing ground water development*	*Potential for development*	*Range in total dissolved solids (milligrams per litre)*	*Water quality problems*
	Square kilometres	*Square miles*	*Cubic hectometres*	*1000s of acre-feet*	*Cubic hectometres*	*1000s of acre-feet*				
Middle Amargosa Valley, Inyo and San Bernardino Counties	1 605	620	8 400	6,800	[3]		Limited for domestic, irrigation and industrial use.	Moderate to high	480–33 000 (14) [4]	Poor for domestic and irrigation use.
Lower Kingston Valley, San Bernardino County	750	290	4 190	3,390	[3]		None	Moderate to high	5 400–8 200 (2) [4]	Poor for domestic and irrigation use.
Upper Kingston Valley, San Bernardino County	700	270	2 630	2,130	[3]		Limited for domestic, and livestock use.	Moderate to high	340–1 100 (12) [4]	Spring water poor for domestic and irrigation use.
Ivanpah Valley, San Bernardino County	780	300	3 810	3,090	[3]		Limited for domestic, irrigation, industrial and livestock use.	Moderate	140–27 500 [5] (44) [4]	Water quality poor
Kelso Valley, San Bernardino County	960	370	6 590	5,340	[3]		Limited for domestic, irrigation and industrial use.	Moderate to high	440–590 (3) [4]	Locally unsuitable for beneficial use.
Soda Lake Valley, San Bernardino County	1 530	590	11 470	9,300	[3]		Limited for domestic, irrigation, industrial and municipal use.	Moderate to high	910 (1) [4]	Poor for domestic and irrigation use
Coyote Lake Valley, San Bernardino County	390	150	9 290	7,530	[3]		Limited for domestic and irrigation use.	Moderate to high	310–4 700 (12) [4]	Poor for domestic and irrigation use.
Fenner Valley, San Bernardino County	1 870	720	6 910	5,600	4.0	3.0	Limited for domestic, industrial and livestock use.	Limited to moderate	120–1 100 (27) [4]	None known
Ward Valley, San Bernardino and Riverside Counties	1 990	770	10 730	8,700	3.3	2.7	Limited for domestic and livestock use.	Moderate	400–21 600 [5] (6) [4]	Locally poor for domestic and irrigation use
Cadiz Valley, San Bernardino and Riverside Counties	1 110	430	5 300	4,300	0.9	0.8	Limited for domestic use	Moderate to high	610 (1) [4]	Poor in vicinity of Dry Lake
Bristol Valley, San Bernardino County	1 840	710	8 630	7,000	2.6	2.1	Limited for domestic and moderate for industrial use.	Limited to moderate	280–390 000 [5] (31) [4]	Water quality poor.
Arroyo Seco Valley, Imperial and Riverside Counties	1 110	430	8 630	7,000	1.9	1.5	Limited for domestic use.	Moderate to high	280–2 000 (10) [4]	Poor for domestic and irrigation use.

[1] Source: Department of Water Resources Bulletin No. 118, "California's Ground Water." September 1975.
[2] Source: Printout of water quality data used for State Water Resources Control Board, *Water Quality Control Plans*: "South Lahontan Basin (6B)," December 1974; "West Colorado River Basin (7A)," October 1974; and "East Colorado River Basin (7B)," October 1975.
[3] Data not available.
[4] Number of wells from which water was analyzed to develop range in total dissolved solids.
[5] Highest concentrations shown are for water wells in dry lake beds.

of the area ranges up to 854 metres (2,800 feet). In a number of ground water basins, however, the usable storage capacity is limited by saline deposits in the water-bearing sediments, and the beneficial use of much of the ground water is limited by its brackish quality.

In some parts of the desert perimeter, ground water is used to supplement imported and meager local supplies of surface water. In some interior valleys, ground water is used to supplement the available small supplies from springs and spring-fed streams.

In a few basins in the eastern desert area only small quantities of ground water are used at present. However, it is estimated that the basins contain sufficient water to cool a 1 000 megawatt power plant -- at a rate of 25 cubic hectometres (20,000 acre-feet) per year -- during the economic life of the plant, i.e., about 30 years.

Figure 11. Location of Ground Water Basins with Potential for Cooling Water Supply in Southeastern Desert Area

Because of the sparse rainfall in southeastern California, the ground-water recharge rate is low. Therefore, ground water would be extracted from the basin more rapidly than it is replaced, lowering the water tables and increasing pumping lifts. As the water tables are lowered, ground water quality may be lowered as well.

The basins with potential for providing water for power plant cooling are shown in Figure 11. Data on ground water in each of the basins are presented in Table 5.

<u>Fresh Surface Water.</u>

About 65 percent of California's total surface water supply of 94 500 cubic hectometres (76.6 million acre-feet) is now used or committed for urban, agricultural, fishery, or environmental purposes.[1] Some 60 percent of present statewide water consumptive requirements are met by surface water;[2] the remainder is met by ground water.

The commitment of in-stream flow to the State Wild, Scenic and Recreational River System, and for environmental protection of the Sacramento-San Joaquin Delta, requires 28 percent[1] of the total surface water supply. The System includes eight rivers; seven of these are north coastal streams, and parts of the American River comprise the eighth.

About 35 percent[2] of the State's total surface water or 3 330 cubic

1/ *DWR Bulletin No. 160-74, "The California Water Plan -- Outlook in 1974. November 1974 (developed from Figure 28).*

2/ *Ibid., p. 91.*

hectometres (27 million acre-feet), is neither developed for use nor committed. However, some 60 percent of this is probably unavailable for out-of-stream use because the water occurs in (1) remote areas, (2) small coastal watersheds where regulatory storage is lacking, (3) interior desert areas where much of the runoff occurs as flash floods, or (4) large flood runoffs that cannot be regulated or conserved.

About 13 500 cubic hectometres (11 million acre-feet) of undeveloped surface water occurs in the Sacramento River Basin. The availability of this water for out-of-stream use would depend on water rights and require additional regulatory and conservation facilities.

The use of existing developed surface water for cooling new power plants would require agreements with holders of water rights for use of exchange of a part of their water supplies. The Metropolitan Water District of Southern California has recently approved the allocation of 123 cubic hectometres (100,000 acre-feet) of Colorado River water to three major Southern California electric utilities for power plant cooling.

On-Going Studies of Waste Water

Department of Water Resources

The Department of Water Resources has begun a research and development study of the treatment of agricultural waste water to make it usable for power plant cooling. A distillation process using low-level heat from a power plant could be an effective method for treating this waste water. This study was based on a proposal[1] by Dr. H. Sephton of the Sea Water Conversion Laboratory, University of California, Berkeley.

The agricultural waste water is first "softened" by an ion-exchange system conceived by G. Klein and T. Vermeulen. In this process, calcium and magnesium, which readily form scale when the water is heated and concentrated, are exchanged for sodium, which stays in solution.

The softened water then serves as makeup to the power plant evaporative system, such as the cooling tower. The blowdown[2] from the cooling tower is desalted by distillation and the water thus produced also served as part of the cooling tower makeup and for other plant needs. The very salty blowdown resulting from the distillation process is used to regenerate the ion-exchange resin that was initially used to soften the agricultural waste water. The blowdown from the system must then be ponded or otherwise disposed of.

A development program managed by the Department of Water Resources to determine the practicability of this system is now in progress. Personnel at the Sea Water Conversion Laboratory have designed and constructed the necessary pilot plant equipment. The individual processes have been checked out separately and combined into an integrated pilot-plant operation. The pilot plant has been moved to the Department of Water Resources' Waste Water Treatment Evaluation Facility at Firebaugh, where the Department, with technical assistance from the University personnel, is operating the equipment using agricultural waste water. The operation is expected to continue for a year in order to field-test the equipment on various salini-

1/ *H. H. Sephton. "The Use of Interface -- Enhanced Vertical Tube Evaporation, Foam Fractionation and Ion Exchange to Improve Power Plant Cooling with Agricultural Wastewater." University of California Proposal, UCB-Eng-3841 dated February 14, 1975.*

2/ *See Page 11.*

ties of waste water that occur during the year.

The Department has contracts with the Los Angeles Department of Water and Power, Pacific Gas and Electric Company, Southern California Edison Company, and the Electric Power Research Institute to give financial support to the work. Each of the four organizations and the Department are committed to provide one-fifth ($118,400) of the total estimated cost of $592,000. The program was initiated in June 1975.

Operation of the pilot plant is expected to provide sufficient information to lead a design of a system that will use agricultural waste water to cool a full-size power plant. This program will require about 2-½ years. Most of the necessary design information is expected to be available within that period.

San Diego Gas and Electric Company

A demonstration water treatment plant is scheduled to begin operation in the spring of 1977, to demonstrate that the proposed treatment system for the Sundesert power plant will provide reliable and economic treatment of brackish agricultural runoff water from the Palo Verde Outfall Drain, which is to be used for cooling water in the proposed power plant. The demonstration plant is one-tenth of one percent of full scale and will operate 12 to 18 months at a site near the proposed power plant site. The make-up water will be clarified and softened before adding it to the cooling water system to control scale formation and corrosion and minimize the volume of waste water discharged from the system.

When the two 950-megawatt nuclear generating units are in operation, 1 400 litres per second (22,000 gallons per minute) of make-up water will be used. The increase in salt concentration in the cooling water (to 28,000 mg/l TDS) will be limited to about 15 times the concentration in the softened make-up water. The addition of several tons of chemicals per day would be required for the softening and clarification processes.

CHAPTER V. COOLING WATER PLANS FOR FOUR PROPOSED POWER PLANT SITES IN CALIFORNIA

Four large steam-electric plants are currently being studied at specific inland sites (Figure 12) by major electric utilities for future development in California. Two of the plant sites are in southeastern California: (1) Lucerne Valley in San Bernardino County, and (2) Sundesert in Riverside County. Two sites are in the San Joaquin Valley: (1) San Joaquin Nuclear Project in Kern County, and (2) Eastern Stanislaus County. Another large nuclear plant is being studied for an undetermined location in the eastern desert area of Southern California. In addition, Pacific Gas and Electric Company is considering four areas in the Sacramento Valley for a coal-fueled plant.

Figure 12. Location of Four Large Steam-Electric Power Plants Under Study by California Public Utilities

Among the four plants under study at specific sites, the largest requirement for cooling water is 99 cubic hectometres (80,000 acre-feet) per year -- for the San Joaquin Nuclear Project. Since each of the sites is a considerable distance from the coastline, the use of either ocean water or brackish estuarine water for cooling would not be feasible.

Department of Water Resources Position On Use of Inland Waters For Power Plant Cooling

In the Waste Water Reuse Law of 1974, State policy calls for the maximum reuse of water in the satisfaction of requirements for beneficial use of water. As stated in Chapter 1, the policy of the Department of Water Resources emphasizes the greatest possible reuse of water but does not prohibit the use of fresh water for power plant cooling if either waste water or brackish ground water is not available -- and to the extent that the demand for cooling water exceeds the supply of waste water and brackish water.

Limitations on Cooling Water from The Colorado River and the State Water Resources Development System

Under current plans[1/] portions of the cooling water supply for the Sundesert Plant and the San Joaquin Nuclear

1/ *The Metropolitan Water District of Southern California, "Annual Report of 1973", page 150; "Annual Report of 1974", page 138.*

Project would be provided by The Metropolitan Water District of Southern California.

On March 9, 1973, The Metropolitan Water District Board of Directors approved the furnishing of up to a total of 123 cubic hectometres (100,000 acre-feet) of Colorado River water each year for cooling power plants in southeastern California, of which 49 cubic hectometres (40,000 acre-feet) per year was intended for use by the Southern California Edison Company.1/ During November 1973, representatives of Southern California utilities agreed that the remaining 74 cubic hectometres (60,000 acre-feet) be allocated as follows:

- 41 cubic hectometres (33,000 acre-feet) per year to the Los Angeles Department of Water and Power.
- 21 cubic hectometres (17,000 acre-feet) per year to San Diego Gas and Electric Company.
- 12 cubic hectometres (10,000 acre-feet) per year, plus any unused portion of the previous 49 cubic-hectometre (40,000 acre-foot) allocation to the Southern California Edison Company.

Letters of intent between The Metropolitan Water District and the utilities provide that the California Department of Water Resources should be given the opportunity to be a 10-percent participant in the proposed power plants that would use cooling water provided by the District. The letters of understanding also provide for participation by the cities of Burbank, Pasadena, Anaheim, Riverside and Glendale.

The Metropolitan Water District is authorized to resell up to 74 cubic hectometres (60,000 acre-feet) per year of water under its contract for water supplies from the State Water Resources Development System, and up to 123 cubic hectometres (100,000 acre-feet) per year of water from the Colorado River, directly to utilities in areas outside the District for use in the generation of electric power. A major portion of the electricity generated must be used directly, or indirectly through exchange, within the District; or for pumping, producing, treating, or reclaiming water for use within the District. Contracts for such use must provide that agricultural waste water, brackish ground water, or other water not suitable for domestic, municipal, or agricultural purposes shall be utilized for power plant cooling to the extent practicable, and if not immediately available, such water, when it becomes available, and to the extent practicable, shall replace the fresh water then being used for such purposes. For water to be used within the service area of any agency which has a contract with the State of California for a water supply under the State Water Resources Development System, the prior written consent of such agency and the Director of the Department of Water Resources is required.

Proposed Plant Sites in Southeastern California

The proposed facilities, and the sources and quantities of fresh water planned to be used for cooling two power plants in southeastern California, are discussed in the following paragraphs. The sources of fresh water would be the Colorado River or the State Water Project.

1/ *Letter of May 25, 1974, from John H. Lauten, General Manager, The Metropolitan Water District, to R. E. Morris, Sr., Vice President, San Diego Gas and Electric Company.*

Lucerne Valley Power Plant

Southern California Edison Company is planning construction of the Lucerne Valley power plant in San Bernardino County. The plant site is about 61 kilometres (38 miles) east of Victorville and 37 kilometres (23 miles) northeast of the community of Lucerne Valley (Figure 13).

Generating Facilities.[1/] The generating facilities will consist of 15 combustion turbine generator sets combined with 3 steam-turbine generator sets. The estimated total plant output capacity of the combined-cycle plant is 1 290 megawatts. The waste heat in the exhaust gas from each combustion turbine will be reclaimed by a heat-recovery steam generator. The steam generators will provide the steam to operate the steam-turbine generators.

Cooling System.[2/] Operation of the steam-turbine generators will require the use of a condenser and a cooling water system to condense the steam exhausted from each steam-turbine. The combustion-turbines will exhaust hot gases, which will not require cooling; instead, the heat will be used to generate steam for the steam-turbines. To increase the efficiency of the combustion-turbines, evaporative coolers will be used to chill the inlet air entering the combustion-turbines during periods of high ambient air temperatures.

When the combustion-turbines are operated without the steam-turbines, the exhaust gases will be emitted directly to the atmosphere. The planned closed-cycle evaporative cooling system will include mechanically induced-draft towers in which the temperature of the circulating water will be lowered 11°C (20°F). Blowdown from the cooling system will be discharged into lined solar evaporation ponds.

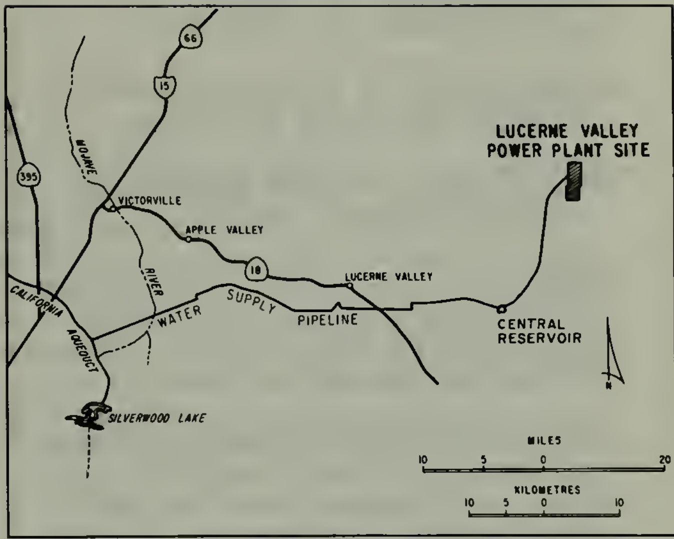

Figure 13. Lucerne Valley Power Plant Site

Cooling Water.[3/] On December 28, 1971, the Mojave Water Agency entered into a water service contract with Southern California Edison to provide water for cooling and other uses at the plant site. In September 1973, the initial contract was amended. Under the amended contract, the Agency will supply water to Southern California Edison for a period of 35 years from the date the last electric generating unit is placed in operation or December 21, 2014, whichever comes first. The water deliveries would be:[4/]

1/ *Lucerne Valley Generating Station Project, Draft Environmental Impact Report, California Public Utilities Commission, March 1976.*

2/ *Ibid., p. III-17, III-19.*

3/ *Ibid., p. VI-21.*

4/ *Ibid., p. VI-23.*

First 15 years: 19 cubic hectometres (15,000 acre-feet) per year;

First 16-20: 17 cubic hectometres (14,000 acre-feet) per year;

Years 21-35: 11 cubic hectometres (9,000 acre-feet) per year.

(The annual use of water for cooling decreases with time, as this power plant would be used less when more efficient plants are in use.)

Mojave Water Agency plans to provide the power plant water supply from its annual entitlements from the State Water Project. The Agency, in cooperation with Southern California Edison, plans to construct a 82-kilometre (51-mile) pipeline from the California Aqueduct to the plant site. The pipeline would serve the power plant and other users within the Mojave Water Agency service area.

The Department of Water Resources believes that water for power plant cooling at this site should be brackish ground water from adjacent ground water basins to the extent practicable. If not initially available, such water when it becomes available, should be used in lieu of State Water Project water for power plant cooling.

Status of Development.[1/] In July 1973, Southern California Edison filed both an environmental data statement for the power plant and application No. 54148 for a certificate with the California Public Utilities Commission. The Commission has prepared an environmental impact report on the Lucerne Valley plant; the report has been distributed for comments. In a March 1976 filing with the California Energy Resources Conservation and Development Commission, Southern California Edison stated that 12 combustion turbines are planned for operation in 1980, three combustion turbines are planned for operation in 1981, and three combined-cycle units are planned for operation in 1985.

Meanwhile, in February 1976, Mojave Water Agency filed suit to invalidate its water supply contract with Southern California Edison. If the suit is successful, Southern California Edison will have to find an alternative source of water, which has not yet been identified. This change is due principally to recent local resistance to development of a large industrial complex in this area. In July 1976, the Assembly Water Committee held two public meetings in Barstow and Victorville. One of the items on which testimony was presented was the contract between the Mojave Water Agency and Southern California Edison Company.

Sundesert Nuclear Power Plant

San Diego Gas and Electric Company is planning construction of the Sundesert Nuclear Power Plant in the southeastern corner of Riverside County (Figure 14).[2/] The site is located on a mesa west of Palo Verde Valley, about 26 kilometres (16 miles) southwest of Blythe and about 4 kilometres (2-½ miles) west of the community of Palo Verde.

Generating Facilities.[3/] San Diego Gas and Electric Company has proposed that the Sundesert project consist of two nuclear units, each rated at about 950 megawatts. The first generating unit would go into service in 1984 and the second unit in the later 1980s.

1/ *Ibid., Sections 1.A.2 and 1.E.4.b.*

2/ *California Public Utilities Commission Sundesert Nuclear Plant, Draft Environmental Impact Report, January 1976. Section 1.2.*

3/ *California Public Utilities Commission, Sundesert Nuclear Plant, Draft Environmental Impact Report, Jan. 1976, Section 2.1.3.*

Cooling System.[1] Cooling will be provided by a closed-cycle system with conventional mechanical-draft cooling towers using treated agricultural waste water. Blowdown from the cooling system will be concentrated to 16 times the average concentration of solids in the makeup water, which will vary from 1 700 to 1 950 mg/l. The blowdown will be discharged to a lined solar evaporation pond. The pond containing the dissolved solids in the waste water discharged during the lifetime of the power plant.

Cooling Water.[2] The cooling water would consist of drainage water from the Palo Verde Irrigation District. Preliminary plans to supply cooling water for the Sundesert Plant are shown in Figure 14. The facilities would provide a flow of 2 cubic metres (70 cubic feet) per second from the Palo Verde Outfall Drain and a backup system to divert water directly from the Colorado River in the event that water is not available from the Drain.

The total estimated quantity of cooling water available to San Diego Gas and Electric Company is 48 cubic hectometres (38,800 acre-feet) per year. This would consist of (a) 21 cubic hectometres (17,000 acre-feet) annually from The Metropolitan Water District to replace drainage water which will be used for cooling but which is currently returned to the Colorado River; and (b) up to 27 cubic hectometres (21,800 acre-feet) per year from reduced consumptive use on irrigated agricultural lands purchased by San Diego Gas and Electric Company. Of the total supply, 6 cubic hectometres (4,800 acre-feet) would be available as a margin of safety.

The 21 cubic hectometres (17,000 acre-feet) per year required for the initial generating unit of the Sundesert Plant would be that allocated to San Diego Gas and Electric Company from The Metropolitan Water District water supplies from the Colorado River. The water supply for the second generating unit would be that obtained through decreased irrigation of agricultural lands owned by San Diego Gas and Electric Company. Consumptive use of water on those lands would ultimately be reduced from 41 cubic hectometres (33,300 acre-feet) to 14 cubic hectometres (11,500 acre-feet) per year.

This water supply arrangement would increase the flow in the Colorado River

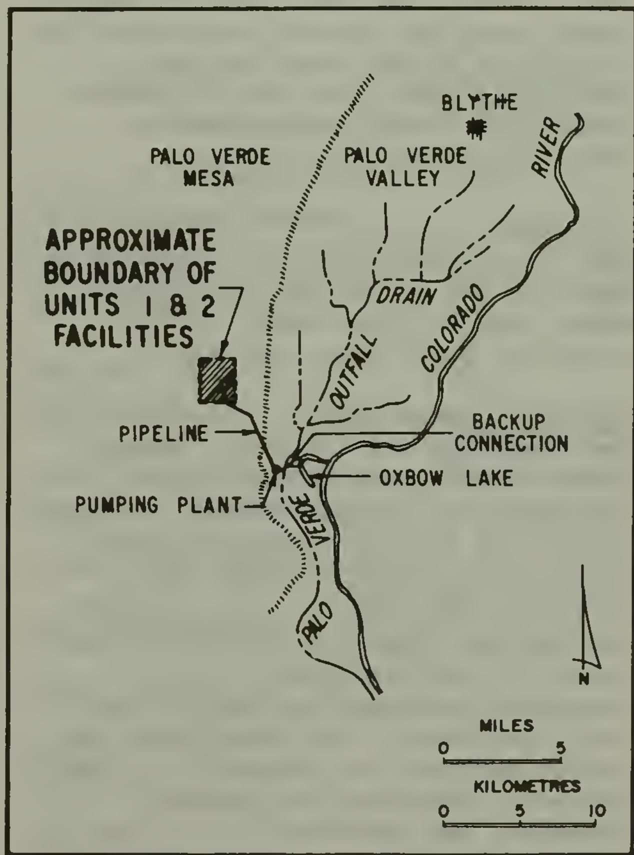

Figure 14. Sundesert Power Plant Site

1/ *Ibid., Sections 2.1.3.2. and 2.1.3.3.2.*

2/ *"Sundesert Nuclear Plant -- Conceptual Engineering -- Cooling System and Water/Waste Treatment Systems". Prepared for San Diego Gas and Electric Company by Stone and Webster Engineering Corporation. October 1975.*

between Parker Dam and the outlet of the Palo Verde Outfall Drain. In addition, salt concentration in the river flow below the Drain would be reduced slightly. The 21 cubic hectometres (17,000 acre-feet) per year purchased from The Metropolitan Water District would not be diverted by the District above Parker Dam, thereby increasing the river flow between Parker Dam and the outlet of the Outfall Drain by that amount. When this is combined with the arrangement for reduced consumptive use within the irrigation district, the utility would obtain the needed cooling water, the quantity of flow in the river below the outlet of the Outfall Drain would remain the same, and the estimated salt load in the river would be reduced by 95,000 tons per year. This would lower the salt concentration in the river downstream at Imperial Dam by about 12 mg/l.

The Department of Water Resources concurs in and supports the arrangements made for use of agricultural waste water from the Palo Verde Outfall Drain for power plant cooling.

Status of Development. In March 1975, San Diego Gas and Electric Company filed both an environmental data statement and an application for preparation of an environmental impact report with the California Public Utilities Commission. In June 1976, the Company filed a notice of intention with the California Energy Resources Conservation and Development Commission. The Commission held public hearings on the matter of the notice of intention in October, November, and December 1976 to obtain input on a wide range of information on the project.

The proposed agreements for the necessary water supplies, between San Diego Gas and Electric Company, The Metropolitan Water District, and the Palo Verde Irrigation District, have been conditionally approved by the other California water contractors having rights to utilize water from the Colorado River and by the U. S. Department of the Interior.1/

Coordination meetings have been held between representatives of Federal and State Governments, The Metropolitan Water District, and San Diego Gas and Electric Company for the purpose of integrating the plans for the Sundesert Plant with the future development of riverfront lands. San Diego Gas and Electric Company and The Metropolitan Water District have been assisting in the formation of a new municipal water district to make possible a permanent supply for California lands fronting on the Colorado River.

By October 1976, prospective participants with San Diego Gas and Electric Company had indicated a 26-percent interest in the Sundesert Project. The participants and their proposed interests are indicated below:

Participant	Ownership share, percent
California Department of of Water Resources	15
City of Anaheim	5
City of Glendale	2
City of Pasadena	2
City of Riverside	2
Total	26

1/ *"Notice of Intention for Sundesert Nuclear Project." San Diego Gas and Electric Company. June 1976.*

Studies and negotiations with other interested utilities are continuing, and the company expects that an additional 24-percent interest in the project will be subscribed to before its application for a facility certification is submitted to the Energy Resources Conservation and Development Commission.[1/]

Power Plant Sites in the San Joaquin Valley

The two proposed sites in the San Joaquin Valley -- the San Joaquin Nuclear Project and Eastern Stanislaus County -- are located in the southern central part of the San Joaquin Valley and in the northeastern part of the Valley, respectively. The proposed generating facilities, cooling systems, water supplies, and status of development of each project are described in the following paragraphs.

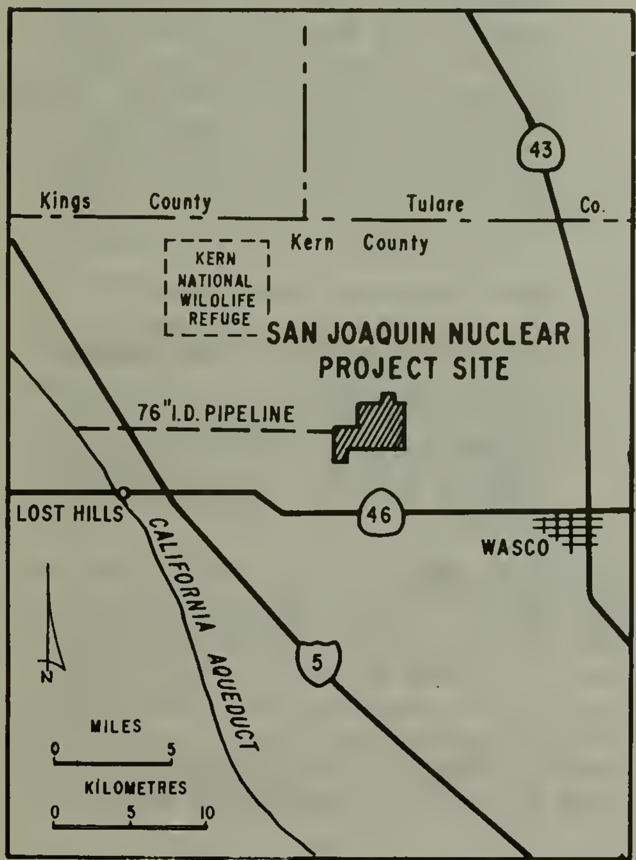

Figure 15. San Joaquin Power Plant Site

San Joaquin Nuclear Project

The San Joaquin Nuclear Project site is located in Kern County approximately 16 kilometres (10 miles) northwest of Wasco and 53 kilometres (33 miles) northwest of Bakersfield (Figure 15). The project would be owned by several utilities and possibly by the State of California.

The City of Los Angeles Department of Water and Power is the lead agency acting as Project Manager and would operate the project when completed. The participants and their proposed ownership shares are listed below:

Participant	Ownership Share, percent
Los Angeles Department of Water and Power	35.5
Pacific Gas and Electric Company	23.0
Southern California Edison Company	22.0
California Department of Water Resources	10.0
City of Anaheim	2.0
City of Glendale	2.0
City of Riverside	2.0
Northern California Power Agency	2.0
City of Pasadena	1.5
Total	100.0

1/ *Ibid.*

Generating Facilities.[1] As proposed, the San Joaquin Nuclear Project will consist of two 1 300 megawatt nuclear units, with possible ultimate expansion to four units, or a total capacity of 5 200 megawatts, depending on the availability of brackish water for cooling. The type of nuclear reactor has not been decided.

Cooling System.[2] The cooling system will be a closed-cycle circulating system with fan-assisted natural-draft cooling towers in which the temperature of the circulating water will be lowered about 17°C (30°F).

A raw-water storage reservoir with a capacity of 6 cubic hectometres (5,000 acre-feet) will be constructed and will provide a reserve water supply that would maintain one generating unit in operation for two months.

Part of the circulating cooling water will be drawn off as blowdown to maintain the mineral concentration in the circulating water at the desired level. The mineral concentration of the makeup water is expected to be 250 mg/l when the source is the California Aqueduct and 7 000 mg/l when the source is agricultural waste water. Blowdown for the first two generating units will be stored in lined solar evaporation ponds with an areal extent of 700 acres. The capacity of the ponds containing the dissolved salts will be sufficient to retain all the solids in the blowdown over the life of the power plant.

Cooling Water.[3] Los Angeles Department of Water and Power has estimated that about 99 cubic hectometres (80,000 acre-feet) per year of cooling water would be required for four 1 300-megawatt generating units. For the purpose of environmental impact assessment, the utility has assumed that the total annual water consumption will be 123 cubic hectometres (100,000 acre-feet).

The final determination of the annual water requirement will depend on the types of nuclear reactors and turbine generators selected.

The sources of water identified for the project are:

(1) Up to 74 cubic hectometres (60,000 acre-feet) per year would be obtained from the California Aqueduct of the State Water Project out of the entitlement of Metropolitan Water District /2 481 cubic hectometres (2,011,500 acre-feet) per year/ under the authority of the Lanterman Act (AB 3140).[4]

(2) The remaining water supply required would be obtained to the extent practicable from agricultural waste water. If sufficient waste water is not available, the plant capacity would have to be limited to two 1 300 megawatts units.

The Department of Water Resources believes that agricultural waste water and brackish ground water should be used for power plant cooling at this site to the maximum extent practicable. If not initially available, such water, when it becomes available, should be used in lieu of State Water Project

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1/ *San Joaquin Nuclear Project, Draft Environmental Impact Report, Los Angeles Department of Water and Power, May 1976.*

2/ *Ibid., Section 1.1.3.5 and 2.1.4.1.3.*

3/ *Ibid., Section 8.1.1.2.3.*

4/ *Ibid., Sections 3.1.4. and 1.1.3.5.1.3.*

water for power plant cooling. The Department has not yet approved the use of The Metropolitan Water District for this project.

Status of Development. The initial draft Environmental Impact Report by Los Angeles Department of Water and power was released in April 1975, followed by a revised draft Environmental Impact Report released in May 1976. The revised draft included additional information on the use of agricultural waste water based on the latest studies of availability and cost.

On December 20, 1976, the Kern County Water Agency advised the Los Angeles Department of Water and Power that action on a letter of intent to provide a joint environmental impact report on the plan to develop agricultural waste water as a cooling water supply would be deferred until the Department of Water and Power's plans can be accepted locally.[1/] The Agency also indicated that it intends to continue with a number of its own studies related to agricultural drainage.

East Stanislaus Nuclear Power Plant

Studies of a nuclear power plant in eastern Stanislaus County have been initiated by the Pacific Gas and Electric Company with the Modesto Irrigation District and Turlock Irrigation District. The proposed site is located approximately 32 kilometres (20 miles) east of Modesto between the Stanislaus and Tuolumne Rivers (Figure 16).

Generating Facilities. The proposed plant would consist of two 1 100-

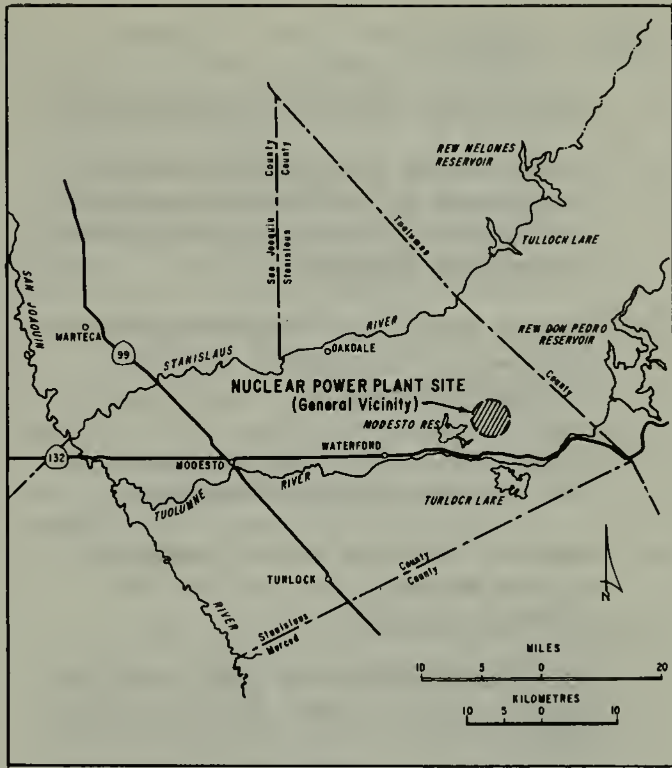

Figure 16. Nuclear Power Plant Site in Eastern Stanislaus County

megawatt nuclear generating units. At present, no detailed information on the power plant is available.

Cooling System. The proposed cooling system would be a closed-cycle evaporative type and include a storage reservoir for the cooling water with a capacity of about 19 cubic hectometres (15,000 acre-feet).

Cooling Water. About 46 to 69 cubic hectometres (37,000 to 56,000 acre-feet) per year would be required for evaporation and seepage from the cooling storage reservoir. Six possible sources of cooling water for the plant are being evaluated by a consulting engineer.[2/]

1/ Letter from Kern County Water Agency to Los Angeles Department of Water and Power dated December 20, 1976.

2/ "Alternative Water Supply Systems to Provide Cooling Water for Proposed East Stanislaus Nuclear Power Plant". Information Brochure, October 1976, URS Research Company.

These include:

a. Federal New Melones Project water;

b. Ground water from shallow wells to be located in the western parts of the Modesto Irrigation and Turlock Irrigation Districts;

c. Ground water from deep wells to be located in the western parts of the two Districts;

d. Sewage effluent from municipalities within the two Districts;

e. Surface drainage water occurring in the western part of the two Districts; and

f. Tuolumne River water available in the vicinity of the proposed power plant.

These sources are summarized in the following paragraphs.

a. Federal New Melones Project Water. The new Melones Project would store water behind a dam being constructed on the Stanislaus River north of the proposed power plant site. A diversion structure on the river and a pipeline 29 kilometres (18 miles) long will be required for use of this high-quality water. Moreover, its availability is uncertain due to other demands for water from the New Melones Project.

b. Ground Water from Shallow Wells. Ground water in shallow aquifers could be pumped from a proposed well field west of Turlock. The quality of this water may range from medium to high quality. The water would be pumped through a pipeline 55 kilometres (34 miles) long to the power plant site.

c. Ground Water from Deep Wells. Ground water in deep aquifers could be pumped from a proposed well field in the western part of the Districts. The quality of this water is expected to be poor, with the concentration of total dissolved solids frequently exceeding several thousand milligrams per litre. This water would be pumped through a 34-mile-long pipeline to the power plant site.

d. Sewage Treatment Plant Effluents. This alternative water supply would consist of effluent from the Modesto and Turlock Sewage Treatment Plants. The effluent from each treatment plant would be pumped to a main conveyance pipeline, where it would be pumped to the power plant site. The concentration of total dissolved solids in the outflow varies from 500 to 1 000 milligrams per litre.

The quantities of effluent from the two plants, which vary seasonably but are greatest during the four-month canning season (July through October), would be insufficient to provide the total supply of cooling water. Therefore, varying quantities of water from other sources would be needed when the outflow from the treatment plants is insufficient to meet the needs of the power plant.

e. Surface Drainage Water. This water would include operational irrigation spills and water pumped from existing drainage wells, which are now discharged into the Tuolumne, Stanislaus, and San Joaquin Rivers. The quality of this water is suitable for most beneficial uses. The water would be collected from various water-carrying laterals and drains within both Irrigation Districts and then pumped through a main conveyance pipeline to the power plant site. In most years this source could provide sufficient water for cooling, but in years of low to moderate flow, additional pumping from drainage wells might be required as a supplementary source.

f. Tuolumne River Water. The existing New Don Pedro reservoir stores high-quality Tuolumne River water.

Some of this water already flows to the Modesto Irrigation District through its main canal. Cooling water could be diverted from the main canal and pumped through a pipeline 0.8 kilometres (0.5 miles) long to the power plant site. The quantity of water from this source that is available to the two Districts for power plant cooling has not been determined. Sufficient water may be available during wet years.

The Department of Water Resources believes (1) municipal and industrial waste water, and (2) brackish ground water, in that order, should be used for power plant cooling at this site. The municipal waste water could be collected from waste water treatment plants in Stanislaus County. The brackish ground water could be pumped from shallow or deep well fields that could be developed in Stanislaus County, between Turlock and the San Joaquin River.

Status of Development. In July 1974, William R. Gianelli, a consulting engineer for the two Districts, completed a report describing the existing drainage and ground-water-collection systems in both districts, along with the costs of alternative shallow and deep-well pumping and conveyance facilities. The report stated that:

". . .adequate water supplies are available from existing drainage water supplemented by pumping from existing drainage wells, or from new shallow and deep wells which would be constructed in the westerly portion of the two districts, to supply cooling water for the two 1 100-megawatt units of a nuclear power plant."[1/]

The consultant also concluded that new drainage wells in western areas of both Irrigation Districts would alleviate current drainage problems and permit more land to be used for agriculture.

In October 1975, the Stanislaus County Planning Commission granted approval for Pacific Gas and Electric Company to drill three deep test wells in the proposed well field area ("c" above).

Pacific Gas and Electric Company has asked the Irrigation Districts to indicate the source or sources of water that the Districts would provide for the East Stanislaus Nuclear Power Plant. URS Research Comapny is continuing to evaluate the six alternative sources of water described in the preceding paragraphs and is assessing the environmental impacts associated with each of them.

1/ *"Investigation of Drainage Water and Well Supplies for Nuclear Power Plant Cooling Water, Stanislaus County." William R. Gianelli, July 1974.*

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