Evaluation of Nonpotable Ground Water in the Desert Area of Southeastern California for Powerplant Cooling

United States Geological Survey Water-Supply Paper 2343

U. S. DEPARTMENT OF THE INTERIOR
March 3, 1849

DEFINITIONS OF TERMS

Acre-foot is a volume of water equivalent to amount that would cover 1 acre to a depth of 1 foot. 1 acre-foot=325,851 gallons; 1 acre-foot per year=0.6 gallon per minute.

Alluvium is a geologic term describing beds of sand, gravel, silt, and clay deposited by flowing water. Younger alluvium refers to alluvial deposits of late Pleistocene and Holocene age; older alluvium refers to alluvial deposits of late Tertiary and early middle Pleistocene age.

Aquifer is a water-bearing layer of rock that will yield water in a usable quantity to a well or spring.

Artesian is a condition in which the water level in wells tapping a confined aquifer stands above the top of the aquifer. (See definition of confined aquifer below.)

Bedrock is a general term for the consolidated (solid) rock that underlies soils or other unconsolidated surficial material.

Cone of depression is the depression of water levels around a pumping well caused by the withdrawal of water.

Confined aquifer is a body of water-bearing material in which water is under pressure significantly greater than atmospheric, and whose upper limit is the bottom of a (confining) layer of distinctly less permeable material.

Dissolved solids is the quantity of minerals in solution in water, usually expressed in milligrams per liter or parts per million.

Drawdown is the reduction in the water level at a point caused by the withdrawal of water from an aquifer.

Evapotranspiration is the combined processes of evaporation (transfer of water from water surface and moist soil to the atmosphere) and transpiration (loss of water from vegetation to the atmosphere).

Ground water is subsurface water occurring in the saturated zone.

Head refers to the static head, which is the sum of the elevation head and pressure head. This can be thought of as the height water will rise to in a well penetrating an aquifer.

Hydraulic gradient is the change in head per unit distance measured in the direction of the maximum rate of decrease; the slope of the potentiometric surface of an aquifer.

Overdraft is the condition of a ground-water basin where the quantity of water withdrawn exceeds the quantity of water replenishing the basin over a period of time.

Quaternary is the geologic period that includes all geologic time and corresponding deposits from the end of the Tertiary Period.

Recharge is flow to ground-water storage from precipitation, infiltration, and other sources of water.

Saturated zone (or zone of saturation) is the subsurface zone in which all openings are ideally filled with water.

Sea level refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Storage of a ground-water basin is the volume of water that the saturated zone of the aquifer contains.

Water table is the upper surface of the saturated zone, at which the water pressure is atmospheric.

Evaluation of Nonpotable Ground Water in the Desert Area of Southeastern California for Powerplant Cooling

By ANNE C. STEINEMANN

U.S. GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2343

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1989

For sale by the
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center, Box 25425
Denver, CO 80225

Library of Congress Cataloging-in-Publication Data

Steinemann, Anne C.
Evaluation of nonpotable ground water in the desert area of Southeastern California for powerplant cooling / by Anne C. Steinemann.
p. cm.—(U.S. Geological Survey water-supply paper ; 2343)
Bibliography: p.
Supt. of Docs. no.: I 19.13:2343
1. Steam power-plants—California, Southern—Cooling. 2. Water, Underground—California, Southern. I. Title. II. Series: Water-supply paper (Washington, D.C.) ; 2343.
TC801.U2 no. 2343
[TJ403]
553.7'0973 s—dc19 89-600019
[333.79'24'097949] CIP

CONTENTS

METRIC CONVERSION FACTORS

The inch-pound system of units is used in this report. For readers who prefer metric units, the conversion factors for the terms used are listed below.

Multiply inch-pound unit	*By*	*To obtain metric unit*
acres	0.4047	square hectometers
acre-feet (acre-ft)	0.001233	cubic hectometers
acre-feet per year (acre-ft/yr)	0.001233	cubic hectometers per year
feet (ft)	0.3048	meters
gallons per minute (gal/min)	0.06309	liters per second
inches	25.4	millimeters
miles	1.609	kilometers
square miles (mi^2)	2.590	square kilometers

Temperature in this report is given in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by using the formula:

$$\text{Temp. °C} = (\text{temp. °F} - 32)/1.8.$$

Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (μg/L). Milligrams per liter is a unit expressing the solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is about the same as for concentrations in parts per million.

Evaluation of Nonpotable Ground Water in the Desert Area of Southeastern California for Powerplant Cooling

By Anne C. Steinemann

Abstract

Powerplant siting is dependent upon many factors; in southern California the prevailing physical constraint is water availability. Increasing land-use and other environmental concerns preclude further sites along the coast. A review of available hydrologic data was made of 142 ground-water basins in the southeast California desert area to ascertain if any could be feasible sources of nonpotable powerplant cooling water. Feasibility implies the capacity to sustain a typical 1,000-megawatt electrical-power generating plant for 30 years with an ample supply of ground water for cooling.

Of the 142 basins reviewed, 5 met or exceeded established hydrologic criteria for supplying the water demands of a typical powerplant. These basins are: (1) middle Amargosa valley, (2) Soda Lake valley, (3) Caves Canyon valley, (4) Chuckwalla Valley, and (5) Calzona–Vidal Valley. Geohydrologic evaluations of these five basins assessed the occurrence and suitability of ground water and effects of long-term pumping. An additional six basins met or exceeded hydrologic criteria, with qualifications, for providing powerplant cooling water. The remaining 131 basins either did not meet the criteria, or available data were insufficient to determine if the basins would meet the criteria.

1.0 INTRODUCTION

1.1 Objective

Powerplant Siting Evaluated

Ground-water resources in the southeastern California desert could provide powerplant cooling water.

The demand for electric power in California is steadily increasing; projections indicate a growth rate of almost 2 percent per year (California Energy Commission, 1983). To meet these requirements, steam-electric powerplants will provide a large part of future power supplies. Because these powerplants require copious amounts of cooling water, an abundant, accessible water source is vital. In addition to hydrologic factors, powerplant siting depends on many physical, socioeconomic, environmental, and political considerations. Coastal sites are no longer an automatic choice because of recent land-use conflicts and environmental concerns. Consequently, much attention is now focused on inland sites where ground water is a feasible source of cooling water.

Stemming from this interest, the U.S. Geological Survey, in cooperation with the California Department of Water Resources, completed a hydrologic reconnaissance of the ground-water resources in the southeastern California desert area. This report presents the results of the third phase of a study of 142 ground-water basins in the area. The first two phases (Koehler and Ballog, 1979; Koehler and Mallory, 1981) established hydrologic criteria by which to identify suitable ground-water basins. That is, a basin must provide enough recoverable ground water to supply a 1,000-megawatt powerplant with water for 30 years.

The purpose of this study was to evaluate the ground-water resources of the study area to aid in further assessment of potential inland powerplant sites. Of the 142 basins evaluated, 5 basins met or exceeded the established criteria, and 6 met the criteria with qualifications.

The study area (figure 1.1-1) is bordered on the northwest by the Sierra Nevada and on the southwest by the Transverse and Peninsular Ranges. The States of Nevada and Arizona border the study area on the northeast and east; Mexico borders it on the south. The study area encompasses approximately 47,000 mi^2 of mountains and alluvium-filled ground-water basins. In this report the ground-water basins are identified by a name and numbering system prescribed by the California Legislature (California Department of Water Resources, 1952). There are 142 basins, ranging in size from a few square miles to 1,870 mi^2, that may contain a total of more than 410 million acre-ft of ground water in storage (California Department of Water Resources, 1975). About 2 percent of California's population resides in the study area. Urban and agricultural development has largely been confined to areas having water of good quality.

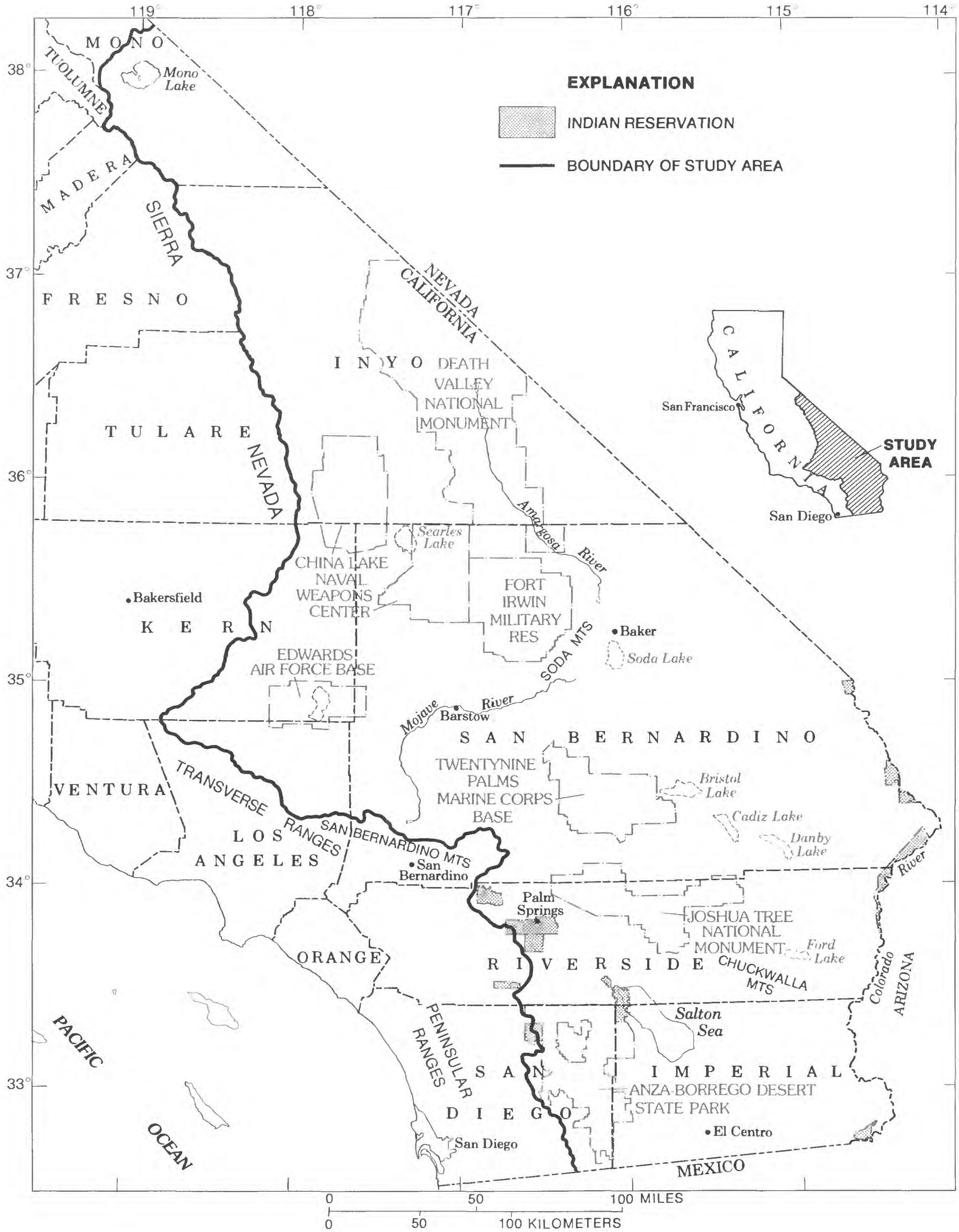


Figure 1.1-1. Location of study area.

Electricity Demand Increasing

Steam-electric powerplants, which will provide most of electrical-energy supplies, will require large quantities of water for cooling.

When Californians first began electrical-power generation at the end of the 19th century, its rapid growth and effects on the environment could hardly have been predicted. Demand for electricity is increasing, primarily due to a steady but gradual rise in population and economic growth.

Most new generating facilities will be steam-electric powerplants (fossil fueled, nuclear, and geothermal, for example). California utilities are planning to retire older, less efficient oil- and gas-fired powerplants as part of their fuel-displacement strategy. Energy needs can be met through increased use of alternative technologies, such as geothermal, cogeneration (the simultaneous generation of electrical energy and low-grade heat from the same fuel), biomass (using plant materials or animal waste as a source of fuel), solar, wind, and fuel cell (a cell that continuously changes the chemical energy of a fuel and oxidant to electrical energy) (fig. 1.2-1). California also retains several contracts to purchase excess power from nearby States (''transfers''). These options will increase the efficiency of California's electricity-generation resources, reduce reliance on oil- and gas-fired generation, and facilitate the replacement of older facilities with state-of-the-art powerplants (California Energy Commission, 1983).

In powerplant-site planning, the number, size, and general location of powerplants (as well as type of plant and cooling system used) determine generating capacity. The quantity of cooling water available commonly dictates the size and siting of a plant; thus new energy development will depend on sufficient water supplies for powerplant cooling. According to the California Energy Commission (1980), the quantity of cooling water required for inland powerplants could increase dramatically—to an estimated 360,000 acre-ft/yr by the year 2000 (fig. 1.2-2).

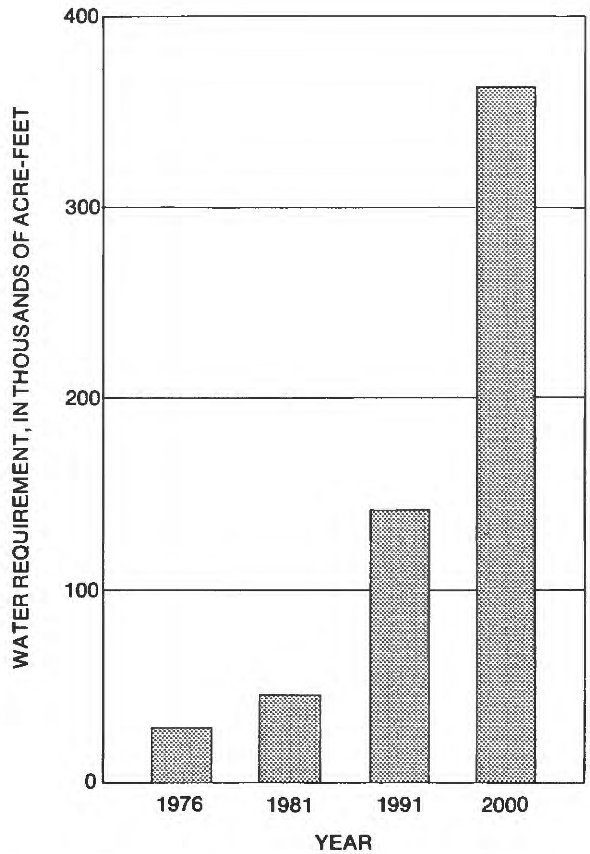


Figure 1.2-2. Statewide water requirements for powerplant cooling towers (modified from California Energy Commission, 1980).

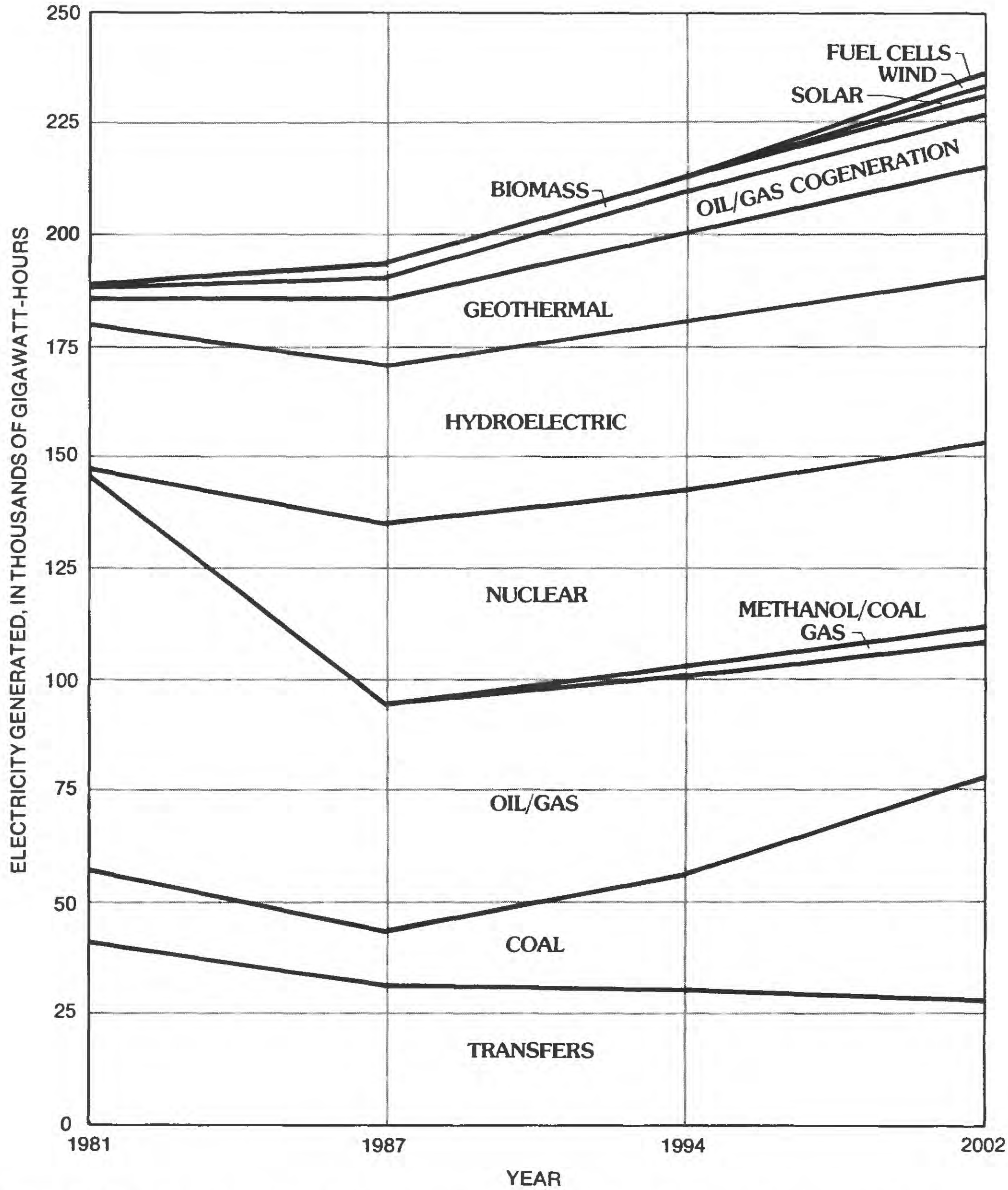


Figure 1.2-1. Projected statewide electricity generation (modified from California Energy Commission, 1983).

1.3 Powerplant-Siting Considerations

Inland Powerplant Sites Favorable

Environmental and land-use concerns may preclude further siting along the coast. The southeastern desert region offers a possible source of cooling water, with less competition for land and resources.

Powerplant siting is complex because many factors influence the selection of an optimal location. In the past, the prime locations were near the coast—close to major load (population) centers and an abundant source of cooling water from the Pacific Ocean. It is usually more desirable to locate generating facilities near load centers so that transmission lines and transportation links are shorter and less costly. In addition, powerplants on the coast that use ocean water have lower cooling costs and higher generating efficiencies. Consequently, powerplants are common along the California coast (fig. 1.3-1).

A limited amount of undeveloped coastline remains, with keen competition for its use. The coastline is a desirable location for many alternative uses, such as recreation, residences, ecological reserves, and esthetic enjoyment. Because a powerplant would preempt valuable land and resources, the acquisition of coastal land for new electricity-generation facilities is extremely difficult.

The concerns over esthetic degradation and environmental impacts are pronounced in highly populated regions. Air pollution caused by powerplant emissions poses a serious public-health hazard. Critical-air areas are located along the southern California coast and in the San Francisco Bay area. Thermal pollution (the result of cooling water being heated, then discharged into a body of water) can adversely affect biological communities. Ground vibration and subsurface conditions are crucial considerations, particularly in seismically active coastal areas (fig. 1.3-1). These concerns have prompted objections to siting powerplants on the coast.

Because of the drawbacks associated with coastal sites, alternative sites inland are being considered. The southeastern California deserts offer a large area in which to seek favorable powerplant sites. Low population density, and consequently less competition for space and resources, makes the area economically and environmentally attractive. The area is remote from major population centers; hence, air-quality standards can more easily be met. California is predisposed to earthquakes; however, much of the southeastern desert area seems to be relatively less susceptible to seismic activity (fig. 1.3-1).

In the southeastern desert area, the most limiting physical factor is an adequate source of cooling water. Only a few water sources could be practically developed for powerplant cooling. Although acquiring water from the Colorado River, municipal suppliers, or State projects is technically possible, it is not likely because of political and economic problems. Because most surface-water rights have been decreed, ground water could provide a likely alternative.

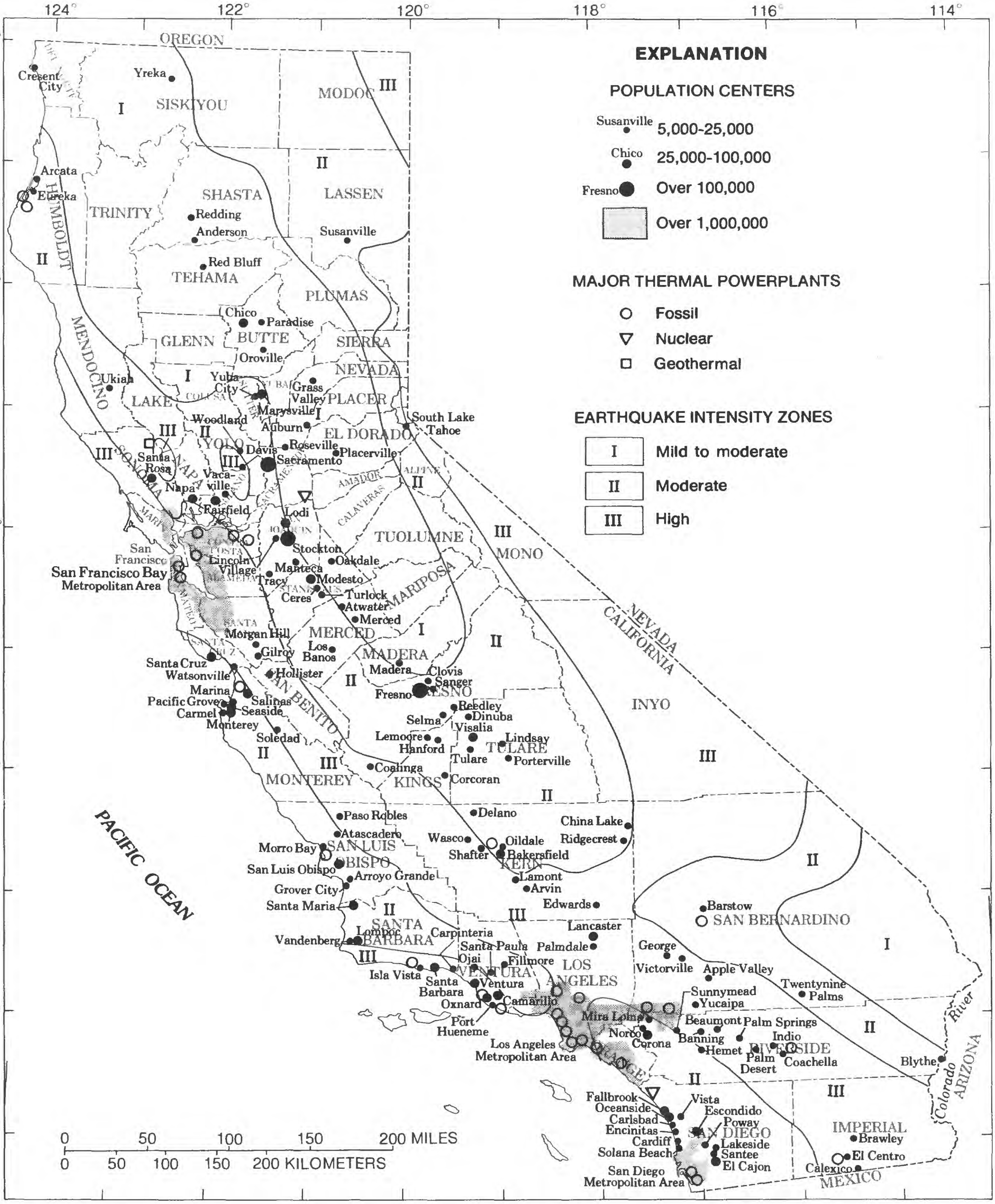


Figure 1.3-1. Location of population centers, major thermal powerplants, and earthquake-intensity zones in California (modified from California Energy Commission, 1973).

Large Quantities of Cooling Water Required

Approximately two-thirds of the energy generated must be dissipated as waste heat via cooling-water systems that use large quantities of water.

Powerplants require water for steam-electric generation and subsequent cooling. Small quantities of good-quality water are heated by burning coal, oil, or gas, or other fuels; by nuclear fission; or from geothermal water. The resulting steam runs a turbine that drives a generator, thus producing electricity. Then large quantities of cooling water condense the steam so that it can be recycled through the system (fig. 2.1-1). However, not all the energy created is converted to electricity. Almost two-thirds of the heat generated is removed as waste heat from the condenser. The thermal efficiency of a cycle is the electricity generated expressed as a percentage of the energy input from the fuel (fig. 2.1-1).

The quantity of cooling water required depends not only on the size and type of powerplant, but also on the type of fuel used, ambient air temperature, water quality, and type of cooling system. Estimates of consumptive water use per megawatt range from approximately 15 to 48 acre-ft/yr for the different fuel types (Davis and Wood, 1974). (See fig. 2.1-2.) The generally high dissolved-solids concentrations in ground water in the desert area and the high ambient air temperature increase the quantity of cooling water required. Therefore, an estimate of 30 acre-ft/yr per megawatt was assumed for this study. A standard powerplant capacity of 1,000 megawatts, which would require 30,000 acre-ft/yr, was used in the analyses.

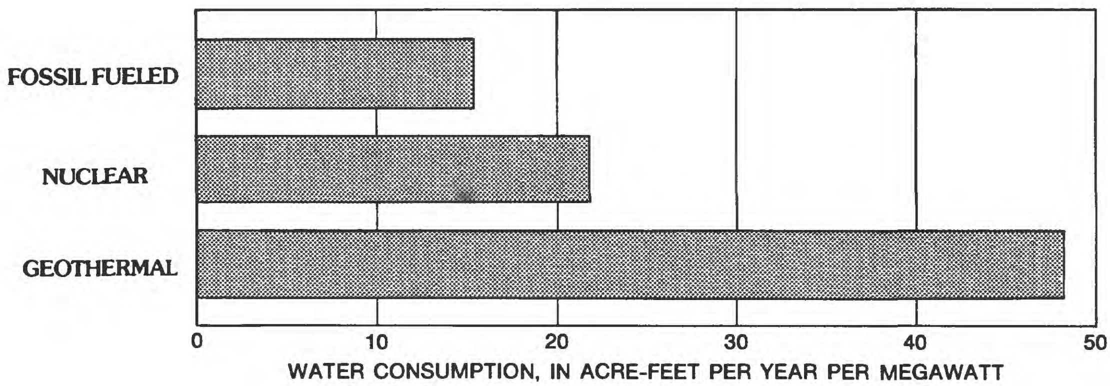


Figure 2.1-2. Water consumption of water-cooled thermal-electric plants (modified from Davis and Wood, 1974).

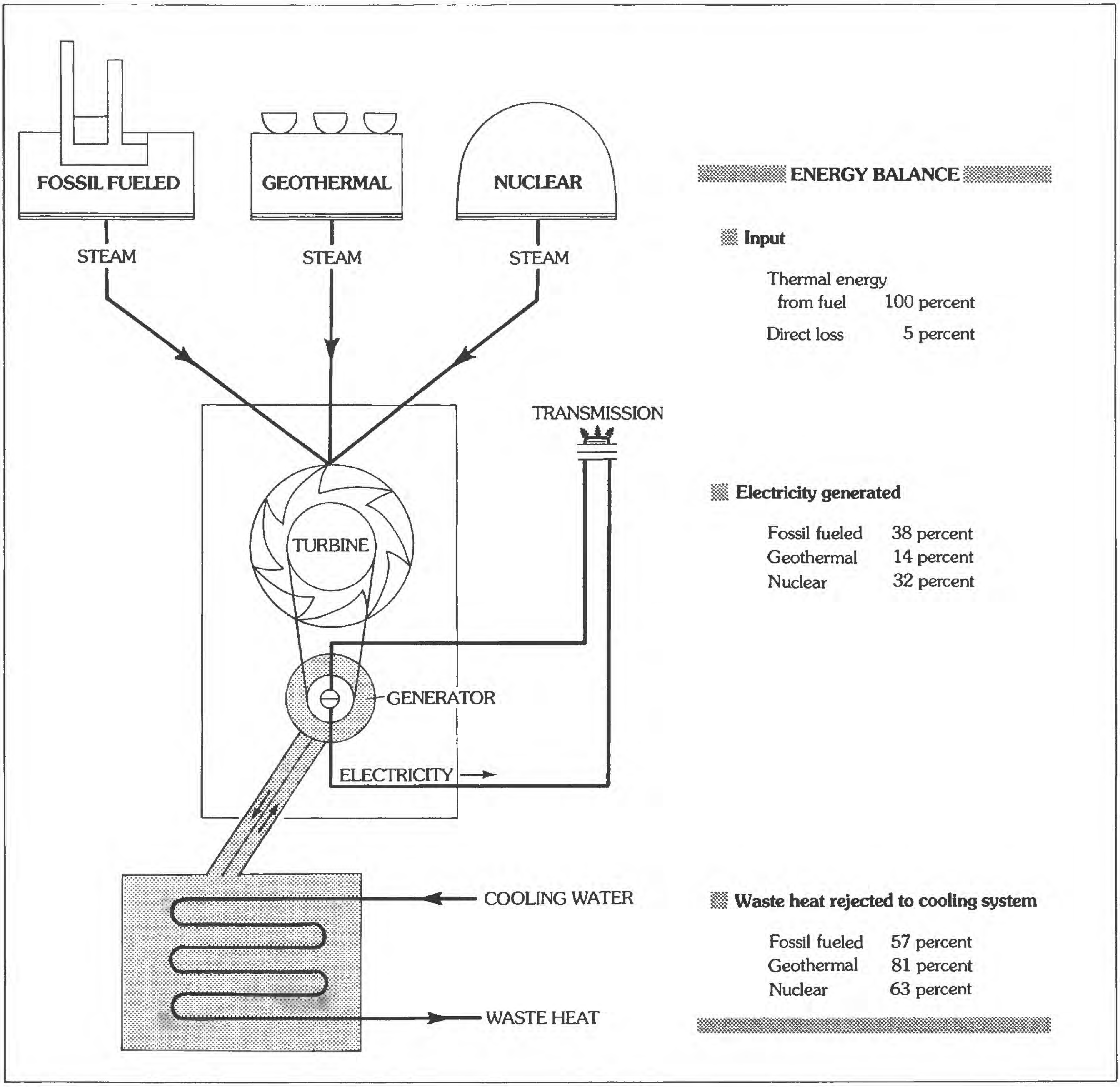


Figure 2.1-1. Electricity-generation schematic (modified from Davis and Wood, 1974).

Waste Heat Transferred to Cooling Water

Once-through and evaporative cooling systems are most commonly used. Once-through systems require a nearby abundant water source; evaporative systems require a smaller quantity of relatively good-quality water.

Powerplants generally use either once-through or evaporative cooling systems. Once-through systems pump water from a large water source; heat is transferred to the cooling water, which is then discharged back into the water body. In evaporative cooling systems, recirculating water transfers waste heat to the atmosphere. An evaporative system requires a smaller quantity of water than a once-through system, but the water must be of relatively good quality. Cooling water that is initially low in dissolved solids can be recycled more times through the cooling system.

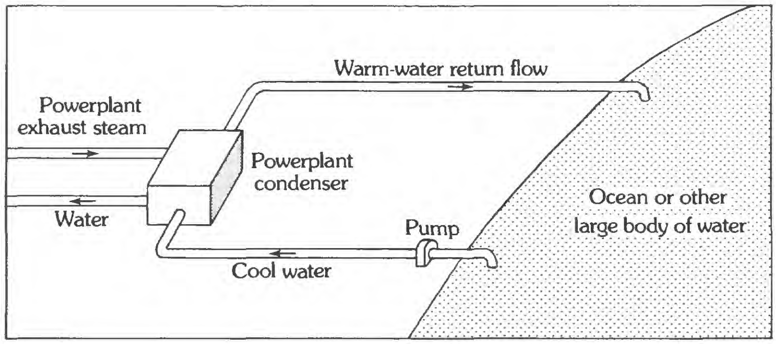
Once-through cooling systems require a nearby abundant water source, such as a large lake, river, or the ocean. As much as 1 million acre-ft/yr of water is needed—although not necessarily good-quality water or freshwater. Cooling water is run through the condenser. Waste heat is transferred to the water, which is then discharged to the large body of water. The ocean provides an almost limitless source of water for this cooling method. Coastal powerplants typically use once-through cooling (fig. 2.2-1*A*).

In evaporative cooling systems, cooling-water temperatures are lowered by evaporation. Common examples of these systems are the pond and spray methods and the wet-tower method. A natural or artificial pond can be used as a heat sink when a large body of water is not readily available (fig. 2.2-1*B*). The circulating water returns to the pond and transmits heat to the atmosphere by evaporation. If the cooling capacity of the pond is insufficient, sprayers can be used to increase evaporation. Cooling ponds for a 1,000-megawatt powerplant would require a surface area of about 1,000 to 2,000 acres.

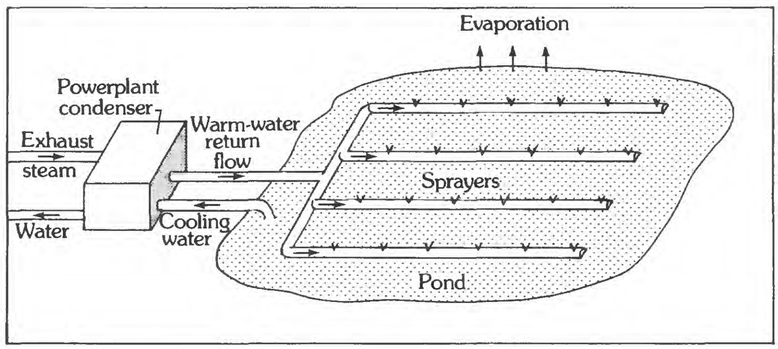
The wet-cooling-tower method uses primarily freshwater of low salinity. About 20,000 acre-ft/yr is required for a 1,000-megawatt plant. The warm cooling water from the condenser is pumped up an elevated tower and then sprayed to form drops that evaporate as they fall through the draft tower. The cooled water at the bottom condenses the steam and is then pumped back through the condenser to continue the cycle (fig. 2.2-1*C*). Heat from the water is removed (primarily through evaporation) by the airstream moving through the tower.

Evaporative systems are generally more expensive to construct and operate than other cooling systems. Concern about thermal pollution of water bodies, however, has led to greater use of closed evaporative systems, cooling towers, ponds, and sprayers.

A. **ONCE-THROUGH COOLING**



B. **EVAPORATIVE COOLING: COOLING POND AND SPRAYERS**



C. **EVAPORATIVE COOLING: WET COOLING TOWER**

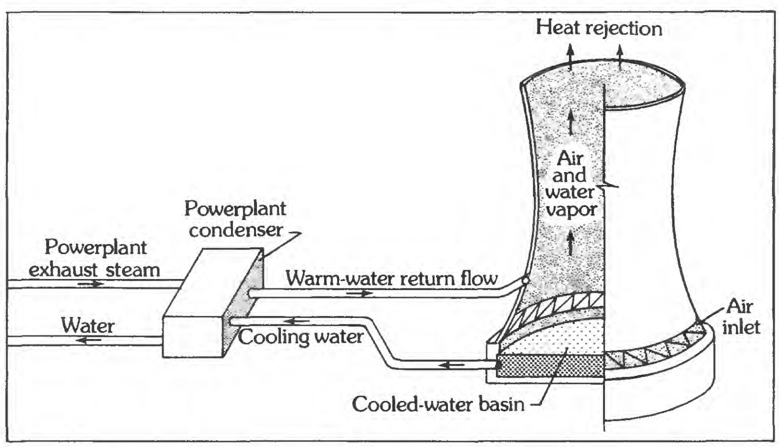


Figure 2.2-1. Cooling systems (modified from California Department of Water Resources, 1977).

3.1 Climate

Hot, Arid Desert Climate

Summer temperatures in excess of 100 °F and annual precipitation less than 4 inches limit the amount of available water.

The climate in the study area is characterized by low annual precipitation and high summer temperatures. Average annual precipitation ranges from less than 4 inches in the lower basins to 40 inches in the higher altitudes along the northwestern edge of the study area (fig. 3.1-1; Rantz, 1969; National Oceanic and Atmospheric Administration, 1974). Most of the precipitation that falls in the higher altitudes runs off into the lower basins. Many basins are occasionally subject to torrential rainfall of short duration that causes flash flooding. Most precipitation that falls on the basin is lost by evaporation or is consumed by plants; the remainder percolates into the sediments and becomes part of the ground-water system.

Summer temperatures in excess of 100 °F (fig. 3.1-1) and large daily fluctuations in temperature are common in the lower altitude basins. Mean daily minimum and maximum temperatures for the southeastern desert area are 32 °F and 60 °F in January, and 76 °F and 108 °F in July (National Oceanic and Atmospheric Administration, 1974). Prevailing conditions are low humidity and clear skies, with rapid heating by day and cooling at night.

The lack of precipitation, along with a high evaporation rate, limits the amount of annual runoff in the desert. Since available surface water generally is less than potential diversions, energy industries would have to compete with other users for the surface-water resources. Hence, ground water may be the only feasible source of water for powerplant cooling, given the many constraints on surface-water use.

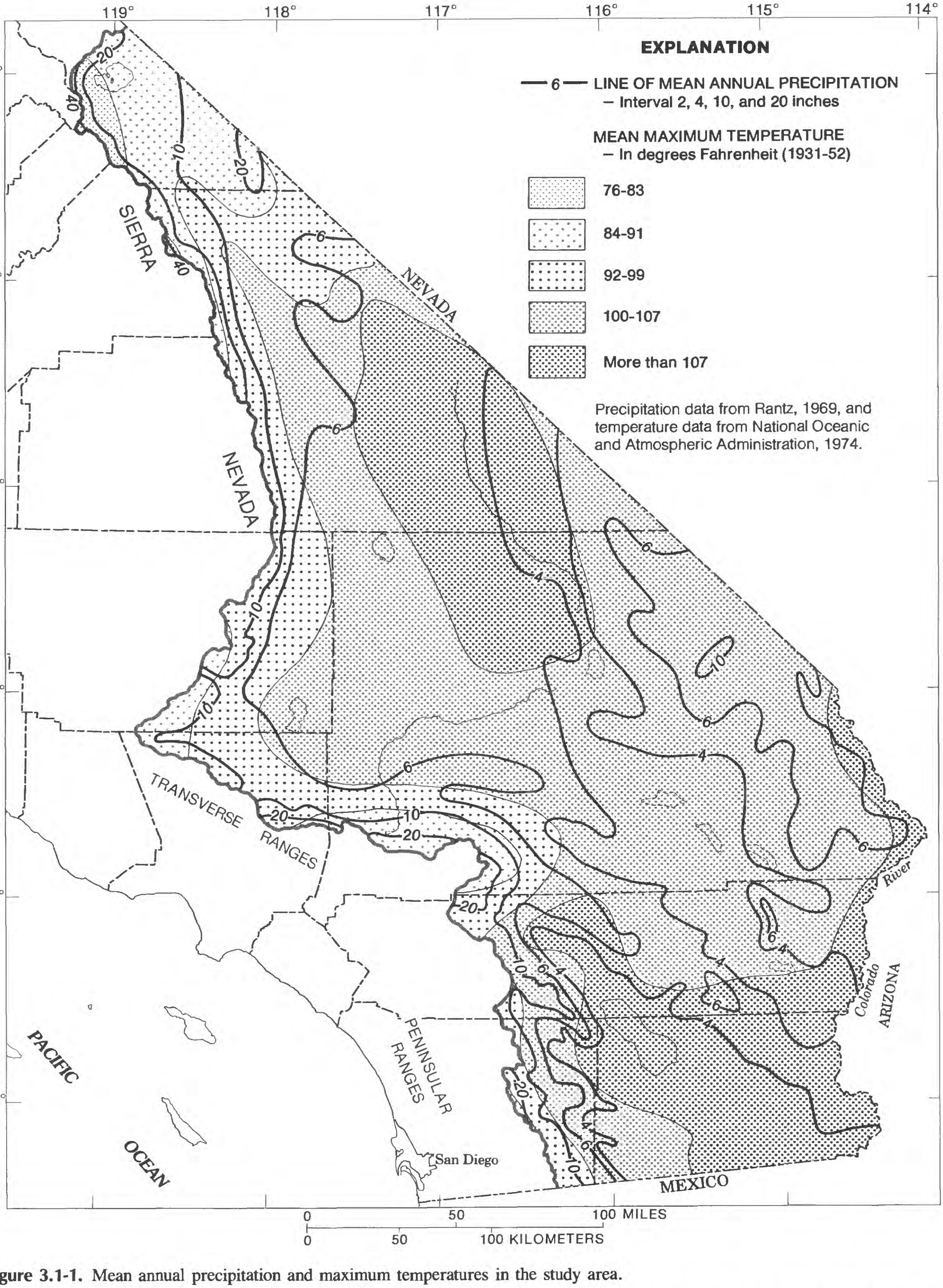


Figure 3.1-1. Mean annual precipitation and maximum temperatures in the study area.

3.2 Geology

Intermountain Basins Filled With Alluvial Deposits

Alluvium may be as much as several thousand feet thick; most basins store water. Faults impede the flow of ground water in many basins.

The present landforms are chiefly the result of the progressive uplift and accompanying erosion of mountains. The intermountain basins are depressions that have received a thick accumulation of erosional products from the surrounding rising landmasses. Quaternary alluvium is exposed in most of the region. The surrounding mountains are composed generally of consolidated rocks (crystalline and metamorphic) that contain little or no water. Surface runoff from these mountains contributes much of the recharge to the ground-water basin and is also the source of alluvial debris deposited in the valley areas. A geologic section of the Mojave River area, as an example of desert areas, is shown in figure 3.2-1.

The basins consist of unconsolidated alluvial sediments composed of boulders, gravel, sand, silt, and clay. Sediments generally grade from predominately coarse in the alluvial fans near the mountains to fine in the central part of the basins.

The alluvial deposits in the basins contain water; the thickness of these water-bearing sediments ranges from a few hundred to several thousand feet. Older alluvium underlies most of the study area and stores a large part of the ground water. Younger alluvium overlies the older materials and ranges in thickness from a few inches to about 100 feet. Generally, the coarser alluvial deposits are highly permeable and yield ground water readily to wells. The older materials have undergone weathering and compaction to some degree, which may limit their permeability.

Northwest-southeast-trending faults associated with the dominant San Andreas and Garlock fault systems occur in many of the desert basins. Water-level measurements indicate that ground-water movement across many of these faults is impeded; the altitude of the water table can be several tens of feet different on opposite sides of the faults.

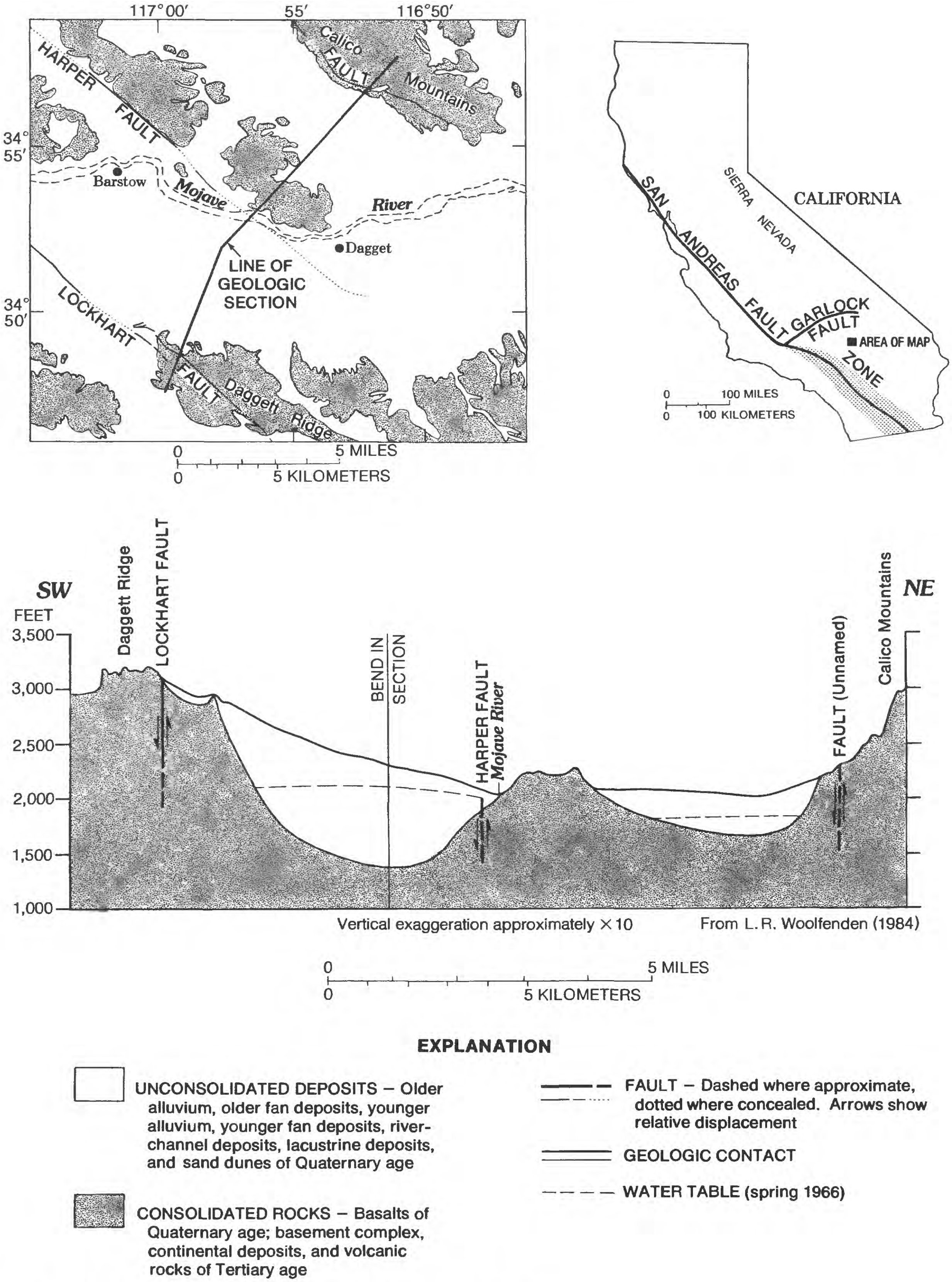


Figure 3.2-1. Generalized geologic section of the Mojave River area.

Large Quantities of Ground Water in Desert Basins

Alluvial aquifers store more than 410 million acre-feet of ground water in desert basins. Recharge to the basins occurs from interactions with streams and lakes, adjacent ground-water basins, some infiltrated rainfall, and occasional floodflow.

Ground water is an important and abundant natural resource that underlies almost 40 percent of California (fig. 3.3-1) and supplies 39 percent of the freshwater used in the State (California Department of Water Resources, 1987). The southeastern California desert area is characterized by dry climate, a high potential evaporation rate, and sparse rainfall. More than 410 million acre-ft of water may be found in ground-water storage within the study area (California Department of Water Resources, 1975). Ground-water basins accumulate infiltrated rainfall from wet seasons, recharge from streams and lakes, and subsurface flow from adjacent basins. The ground water is stored in alluvial aquifers that typically lie between the mountain ranges. Recharge rates are low, owing to the minimal annual precipitation and high evaporation rates.

In this region, ground-water basins are generally of two types: stream-valley and closed (playa) basins. Both stream-valley and closed basins receive subsurface water from higher elevations; surface runoff from the mountains infiltrates the alluvial fans and recharges the ground-water basins. Water leaves stream-valley basins primarily by surface drainage, whereas in closed basins ground water usually leaves through subsurface flow, internal drainage, or evaporation at playas.

In a stream-valley basin, streams may lose and (or) gain water through their interaction with the ground-water system. A "losing stream" contributes to the water table (figure 3.3-2*A*). A "gaining stream" receives water from the aquifer; the water table is above the streambed (figure 3.3-2*B*). A typical stream in an arid region flows during periods of surface runoff, losing water by seepage to the water table (figure 3.3-2*C*). Ground water in stream-valley basins generally is of better quality than ground water in closed basins.

In a closed basin, the subsurface water flows toward and approaches ground surface at a "dry lake" or playa: (fig. 3.3-2*D*). Ground water may rise and evaporate, leaving a highly saline surface. This causes playa deposits to be interspersed with salt lenses. The closed nature of these basins causes most natural discharge to occur by evaporation at playas.

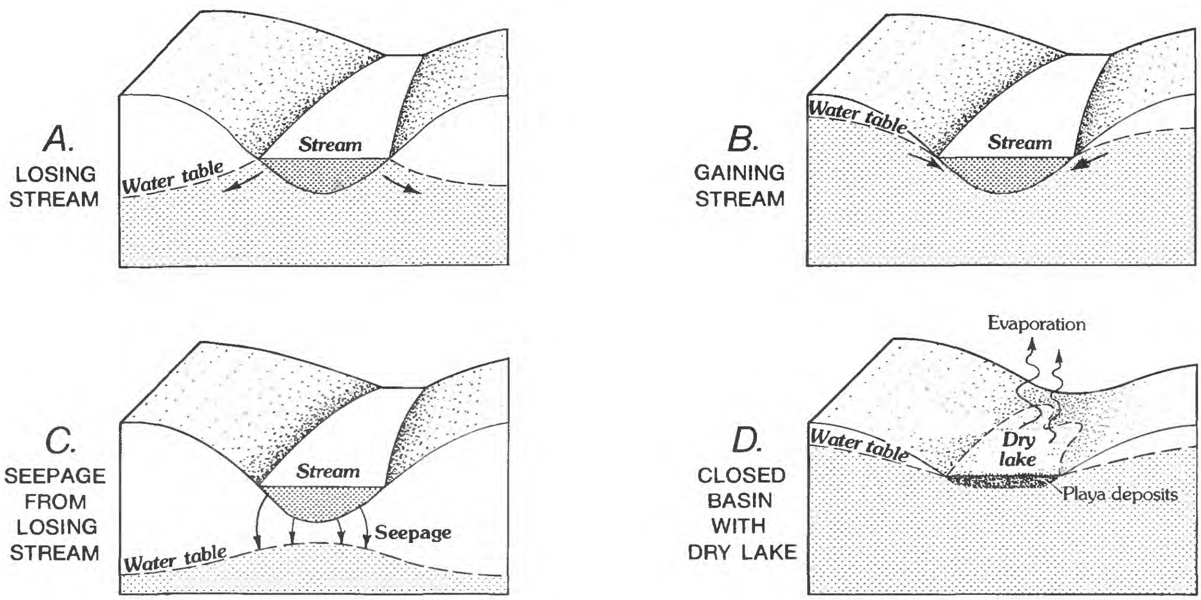


Figure 3.3-2. Surface- and ground-water relations in stream-valley and closed ground-water basins.

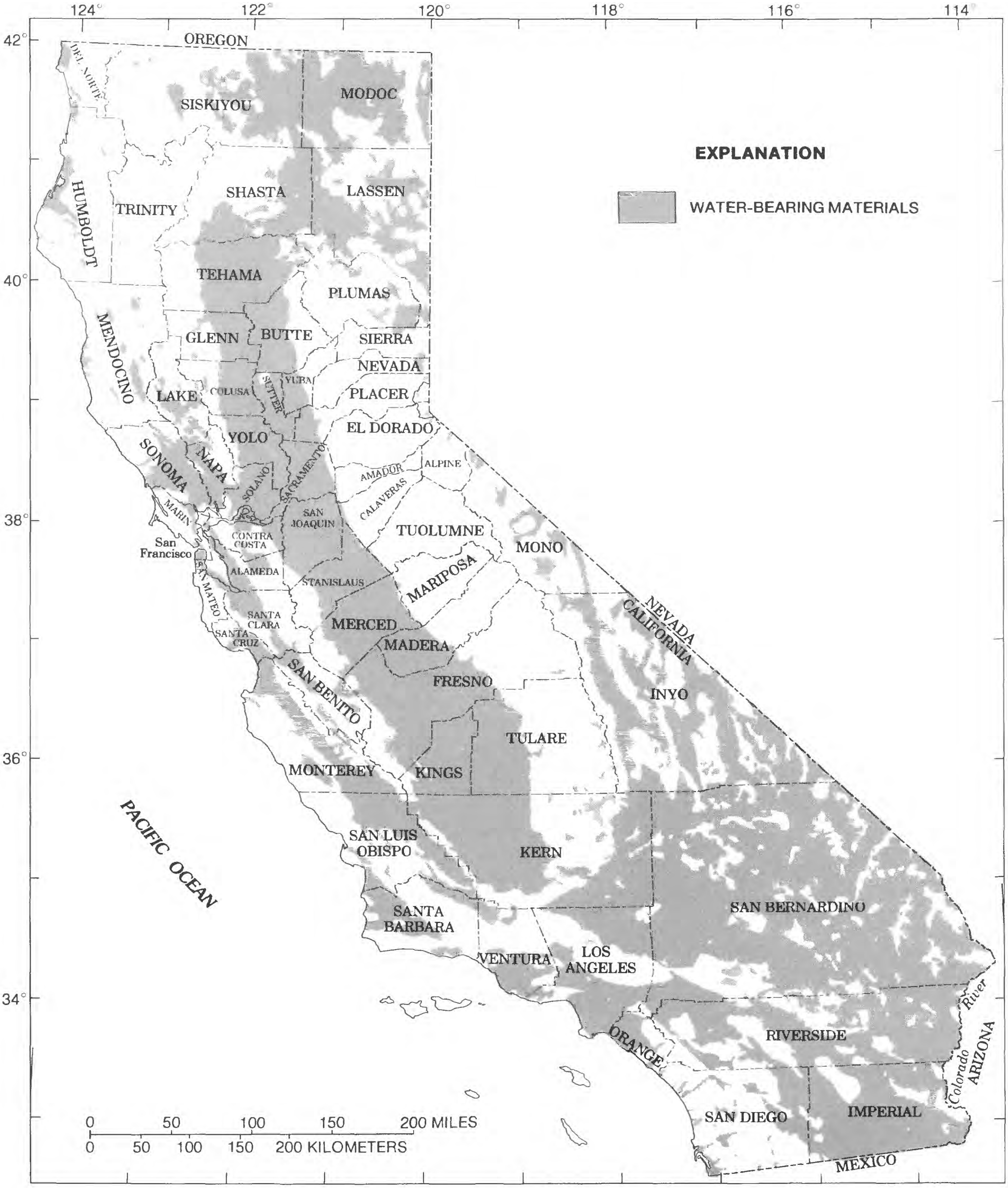


Figure 3.3-1. Ground-water basins in California (modified from California Department of Water Resources, 1975).

Fragile Desert Ecosystem

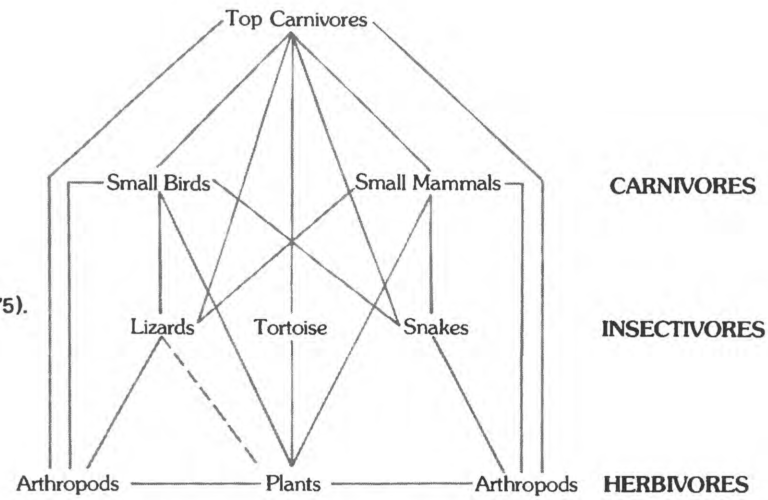
The numerous plant and animal species of the desert form a closely linked web that exists under harsh conditions. Desert ecosystems are fragile and sensitive to alterations in the environment.

Although the desert may appear to be a barren wasteland, in actuality it supports a closely linked and fragile ecosystem (fig. 3.4-1). The plants and animals have developed specialized mechanisms for living under the most severe conditions. The interdependence between species makes them even more susceptible to mild disturbances in the environment. Therefore, powerplant-siting considerations include limiting the impact on these delicate ecosystems.

Plants and animals of the desert are able to subsist in harsh, arid, high-saline surroundings partly due to their low productivity rates and relatively simple food chains. The appearance of spring blooms of annual plants, whose germination is dependent on the amount of rainfall, largely controls the reproductive success of many desert animals. Herbivores—such as the desert tortoise (fig. 3.4-1), which depends heavily on spring ephemeral vegetation—breed first, followed by insectivores, and then carnivores (Luckenbach, 1975).

The plant communities in the desert consist of shrubs, succulents, herbs, and trees with functional and structural adaptations for conserving moisture. The plants in the southern California interior are primarily low shrubs with deep-seated, widespread root systems. The dominant vegetation of the lower altitudes is the Creosotebush scrub (fig. 3.4-1). Various species of cactus are common. Major types of desert herbs are the perennial grasslands and stands of annual forbs and grasses. Trees generally grow at higher altitudes along stream channels. Desert plants require ample, evenly spaced rainfall during the autumn and winter to produce the spectacular wildflower display the following spring.

The animals of the desert are largely dependent on the surrounding vegetation. An estimated 640 species of vertebrates and thousands of invertebrate species inhabit the area; several are unique to the California desert. The most commonly observed wildlife include the desert tortoise, snakes, rabbits, lizards, and small birds. Just as desert plants have developed means for conserving of water, so have animals of the desert environment. Nocturnal and subterranean habits help animals evade the highest temperatures and the dehydrating effect of the midday sun.



Desert ecosystem (modified from Luckenbach, 1975).

Desert tortoise.

Creosotebush scrub.

Figure 3.4-1. Fragile desert ecosystem.

4.1 Hydrologic Criteria and Basin Classification

Hydrologic Reconnaissance Completed

Suitability for sustaining a powerplant with cooling water is evaluated in 142 ground-water basins.

The initial phases of this study established the hydrologic criteria to assess the 142 desert ground-water basins (Koehler and Ballog, 1979; Koehler and Mallory, 1981). The basic water requirements of a typical 1,000-megawatt powerplant over a period of 30 years served as a guide to determine each basin's ground-water suitability. The specific criteria used to evaluate the basins are:

(1) Storage—a minimum of 1 million acre-ft of recoverable ground water in storage. This quantity is required to cool a 1,000-megawatt powerplant over 30 years. In addition to the water in storage, surface and subsurface flow from adjacent basins may replenish the ground-water system during pumpage of water as described in the following section.

(2) Well yield—a minimum well yield of 500 gal/min. At this rate, 37 wells pumping continuously could produce the 30,000 acre-ft/yr of water required for the powerplant. Because any single well field probably could not sustain this rate of withdrawal for 30 years, it may become necessary to establish alternative well fields in the basin.

(3) Water quality—ground water that is chemically suitable for cooling but unsuitable for many other uses. Powerplants do not require the good-quality water that domestic or agricultural users do. However, if the cooling water is initially low in dissolved solids, it can be recycled more times through the cooling system. An upper limit for dissolved solids was set at 30,000 mg/L to avoid restricting the number of times the water could be recirculated. Lower limits were set for some constituents, as follows, to exclude basins with freshwater suitable for other purposes: fluoride, 1.5 mg/L; arsenic, 50 μg/L; boron, 2,000 μg/L; and percent sodium, 75. Also considered were those characteristics (such as hardness) that could impair the cooling system through corrosion or incrustation. See section 7.0 for a summary of the chemical constituents and characteristics that affect water quality.

(4) Basin development—minimal development to avoid conflict among competing uses of the land and ground water. Most basins containing good-quality water have already been developed. Siting a powerplant that withdraws large quantities of water in a developed basin may cause conflict between users.

(5) Established land use—In addition to hydrologic criteria, some basins were eliminated on the basis of land use. Basins that overlap with a national park, monument, or military or Indian reservation, were eliminated from consideration because of established land uses (see fig. 1.1-1).

According to these criteria, each basin was classified by its hydrologic suitability: suitable (meeting or exceeding all the criteria), suitable with qualifications, insufficient data to classify, and unsuitable (fig. 4.1-1). Five basins were judged suitable: middle Amargosa valley (6-20), Soda Lake valley (6-33), Caves Canyon valley (6-38), Chuckwalla Valley (7-5), and Calzona-Vidal Valley (7-41, 7-42). The numbers in parentheses refer to the basin identification numbers assigned by the California Department of Water Resources (1952). A second numbering system is used to identify the surface-drainage province in which the basin is situated (California Department of Water Resources, 1964a). For example, W-9.DO represents the Amargosa Hydrologic Subunit within the Lahontan Drainage Province. Brief summaries and results of the individual basin evaluations are presented in section 6.0.

A further hydrologic investigation of the five suitable basins evaluated the occurrence and suitability of ground water for powerplant cooling and the implications of ground-water pumpage in the basins.

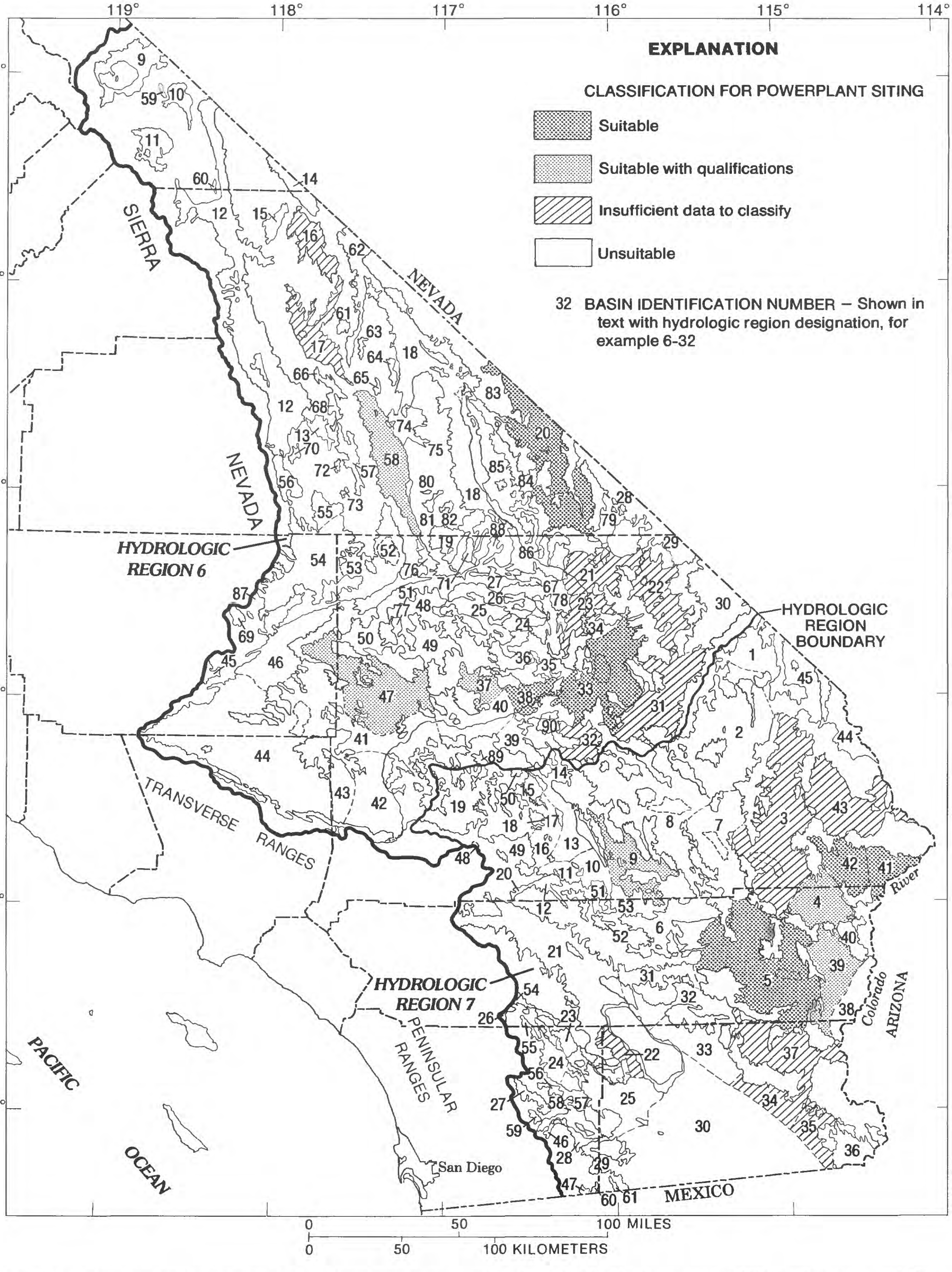


Figure 4.1-1. Basin-suitability classification in the study area (modified from California Department of Water Resources, 1975).

4.2 Effects of Pumping Ground Water

Pumping Can Deplete Ground-Water Storage

The pumped water can come from a decrease in ground-water storage, a decrease in natural discharge, and (or) a possible increase in recharge.

Ground-water systems can be physically described in terms of a water-budget equation; that is, the water coming into the system minus the water leaving the system equals the change in storage of ground water. This equation implies that the rates of recharge and withdrawals can be adjusted to avoid depleting water in storage.

Under natural conditions, ground-water recharge will balance discharges (fig. 4.2-1*A*). Whereas, when water is pumped from a well (unnatural conditions), water in the vicinity of the well is removed from storage and a cone of depression develops. The withdrawal of ground water is balanced by a reduction in ground-water storage (fig. 4.2-1*B*).

As the cone of depression expands outward, it may reach an area where water is naturally discharging from the aquifer. The hydraulic gradient will be reduced toward the discharge area, and the rate of natural discharge will decrease. The pumpage is compensated for in part by a reduction in the rate of natural discharge of ground water (fig. 4.2-1*C*).

After continued withdrawal, natural ground-water discharge may be stopped and water may be induced to move from a water source, such as a stream or lake, into the aquifer (fig. 4.2-1*D*). Ground-water withdrawals can change discharge areas into recharge areas; the growth of cones of depression can reduce natural discharge and increase recharge. This change is an important consideration where the recharge source contains lesser quality water that may migrate into the pumping depression, or where there are prior uses of the source of recharge water. The rate at which water can be withdrawn without doing permanent damage to the ground-water basin or inducing adverse effects on the basin's long-term supply is called the safe yield for that basin (Todd, 1959).

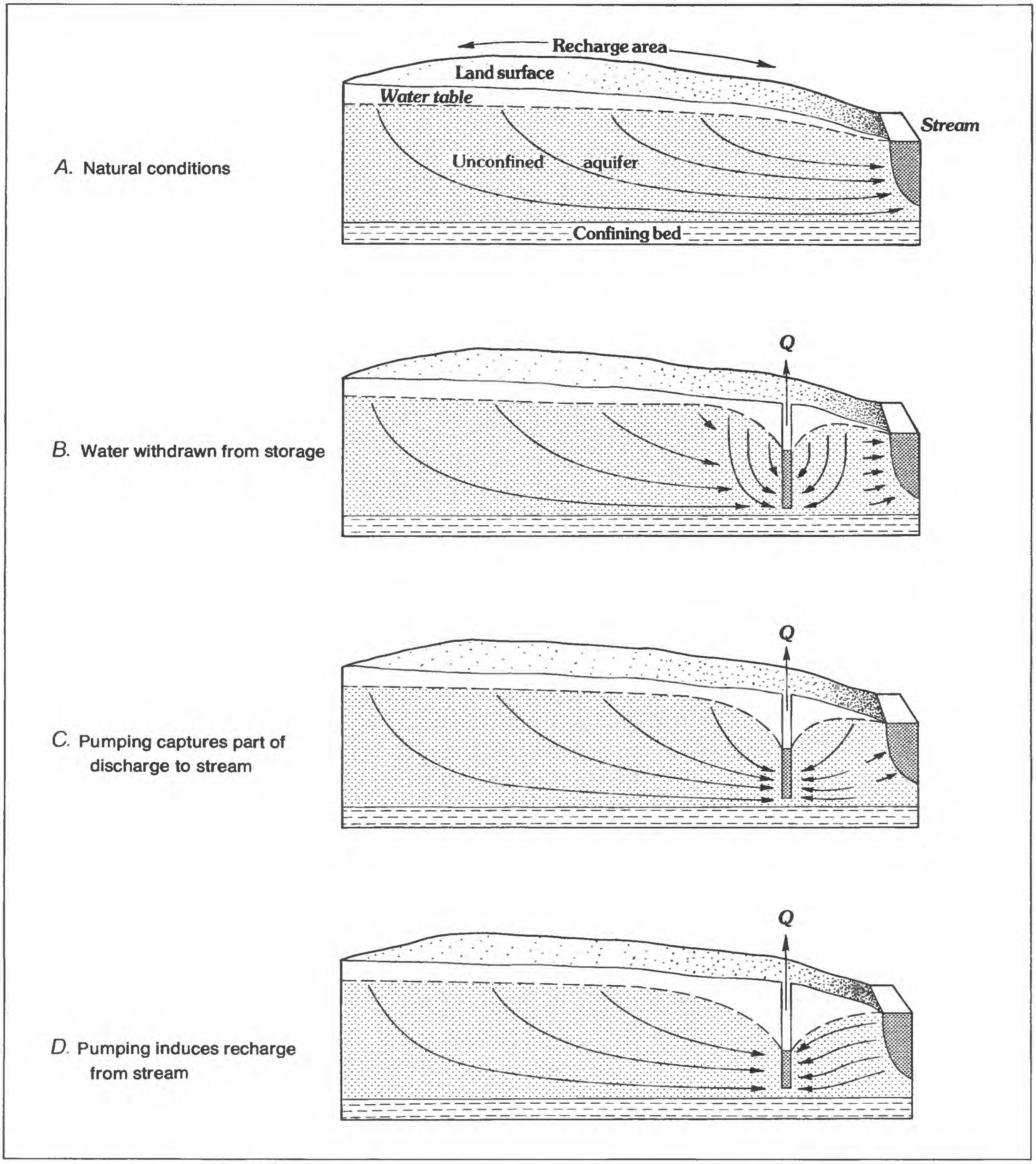


Figure 4.2-1. Aquifer responses to withdrawal of ground water by pumping (modified from Heath, 1983). Q, pumping discharge.

5.1 Middle Amargosa Valley

Northern Part of Basin More Suitable Source of Gound Water

Ground water in storage is estimated to be 18 million acre-feet. Water quality varies considerably. The northern part of the basin probably is a more suitable source of ground water for cooling.

The middle Amargosa valley ground-water basin (fig. 5.1-1) is in the Amargosa (W-9.D2) and Chicago (W-9.D3) Hydrologic Subunits. Total area of the basin is 1,300 mi^2, of which 620 mi^2 is in Inyo County, California, and 680 mi^2 is in Nevada. Access to the basin area is by California State Highway 127 from the south, and California State Highway 190 from the west. Only the part in California was considered in this study.

Ground water in storage in the California part of the basin is estimated to be 18 million acre-ft (Koehler and Ballog, 1979). Average depth to water for the entire basin is about 100 feet. Alluvial deposits are more than 900 feet thick in the basin. The average well yield is about 2,500 gal/min; the maximum is 3,000 gal/min (California Department of Water Resources, 1975).

Water quality varies considerably. The average dissolved-solids concentration is 1,600 mg/L and ranges from 566 mg/L in well 26B1 to 4,660 mg/L in well No. 9; generally, the poorer quality water is near Alkali Flat. Average hardness of the water sampled is 170 mg/L, and hardness ranges from 10 mg/L in well 14M1 to 382 mg/L in well 5F1 (Koehler and Mallory, 1981). Some of the wells and springs in the southern part of the basin produce hot water, as high as 108 °F (Koehler and Ballog, 1979).

Most of the recharge to the area comes from subsurface flow from the northern part of the basin in Nevada. An artesian area in the southern part of the basin probably is recharged by infiltration of rainfall at higher altitudes. Some recharge occurs from infiltration of the Amargosa River's infrequent flow and its tributary streams.

Ground-water discharge occurs as evaporation, transpiration by vegetation, pumping, and subsurface outflow to the south into Valjean valley ground-water basin (California Department of Water Resources, 1964b). Some of the subsurface flow is lost by evaporation of shallow ground water at Alkali Flat. Springs and flowing wells bring water to the surface, where it is evaporated or consumed by vegetation.

The part of the basin north of Eagle Mountain and Alkali Flat probably would be the more suitable source of ground water. The basin is deepest in this area, and subsurface flow from the north would help to maintain water levels. However, increased subsurface flow from the north could adversely affect users in the Nevada part of the basin. The southern part of the basin, with its warm water conditions, would be less suitable; the water would have to be cooled before being used.

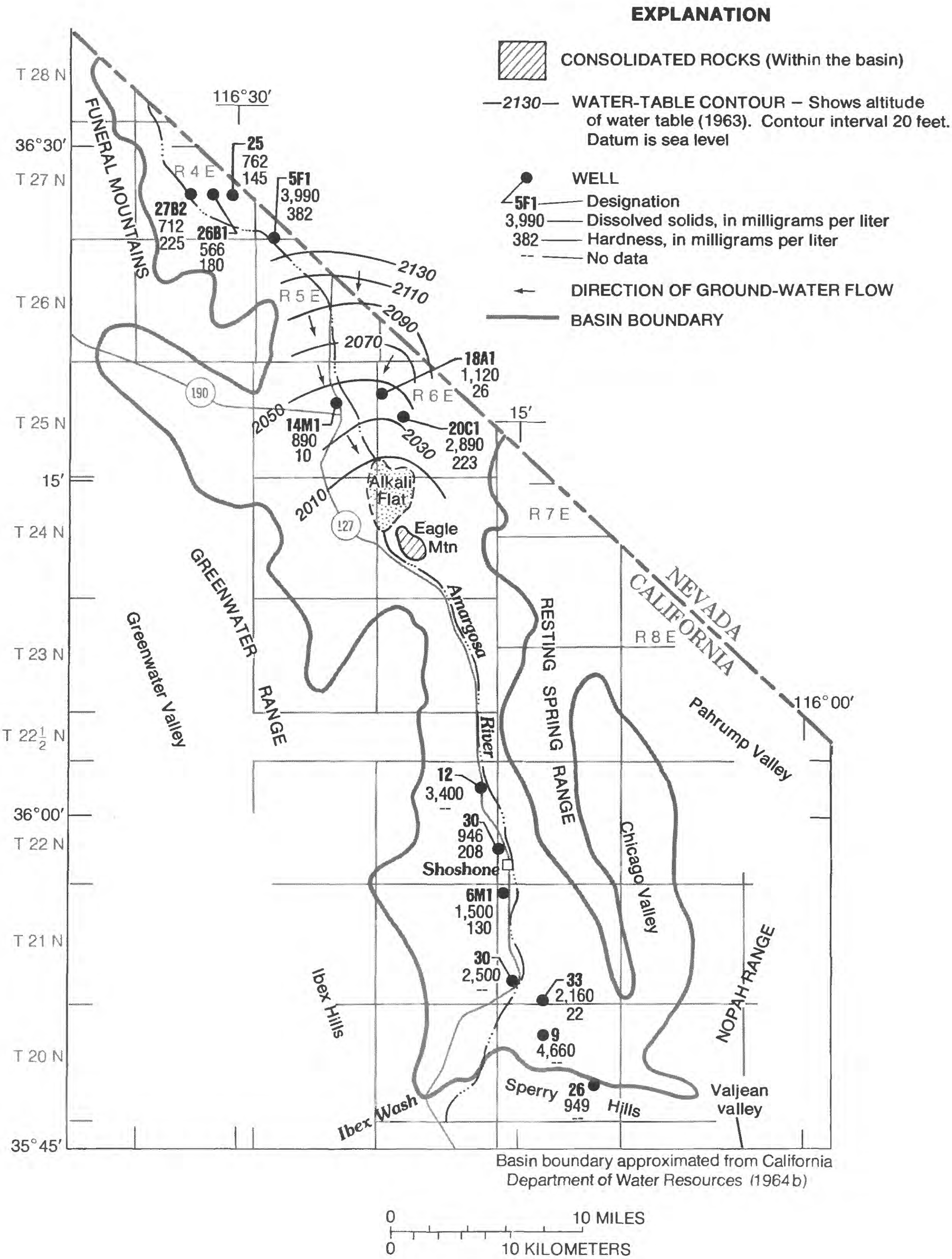


Figure 5.1-1. Middle Amargosa valley ground-water basin (6-20).

5.2 Soda Lake Valley

Suitability Depends on Location and Design of Well Fields

Dissolved-solids concentrations are lower in the Mojave River Wash area. Recharge from adjoining basins would help maintain water levels.

The Soda Lake valley ground-water basin (fig. 5.2-1) is in the Soda Lake Hydrologic Subarea (W-28.H2) of central San Bernardino County. The basin encompasses about 590 mi^2. Interstate Highway 15 approximately parallels the northwest boundary. The Union Pacific Railroad traverses the southern part of the basin in an east-west direction. Access to the basin from the north is by State Highway 127, which ends at the town of Baker.

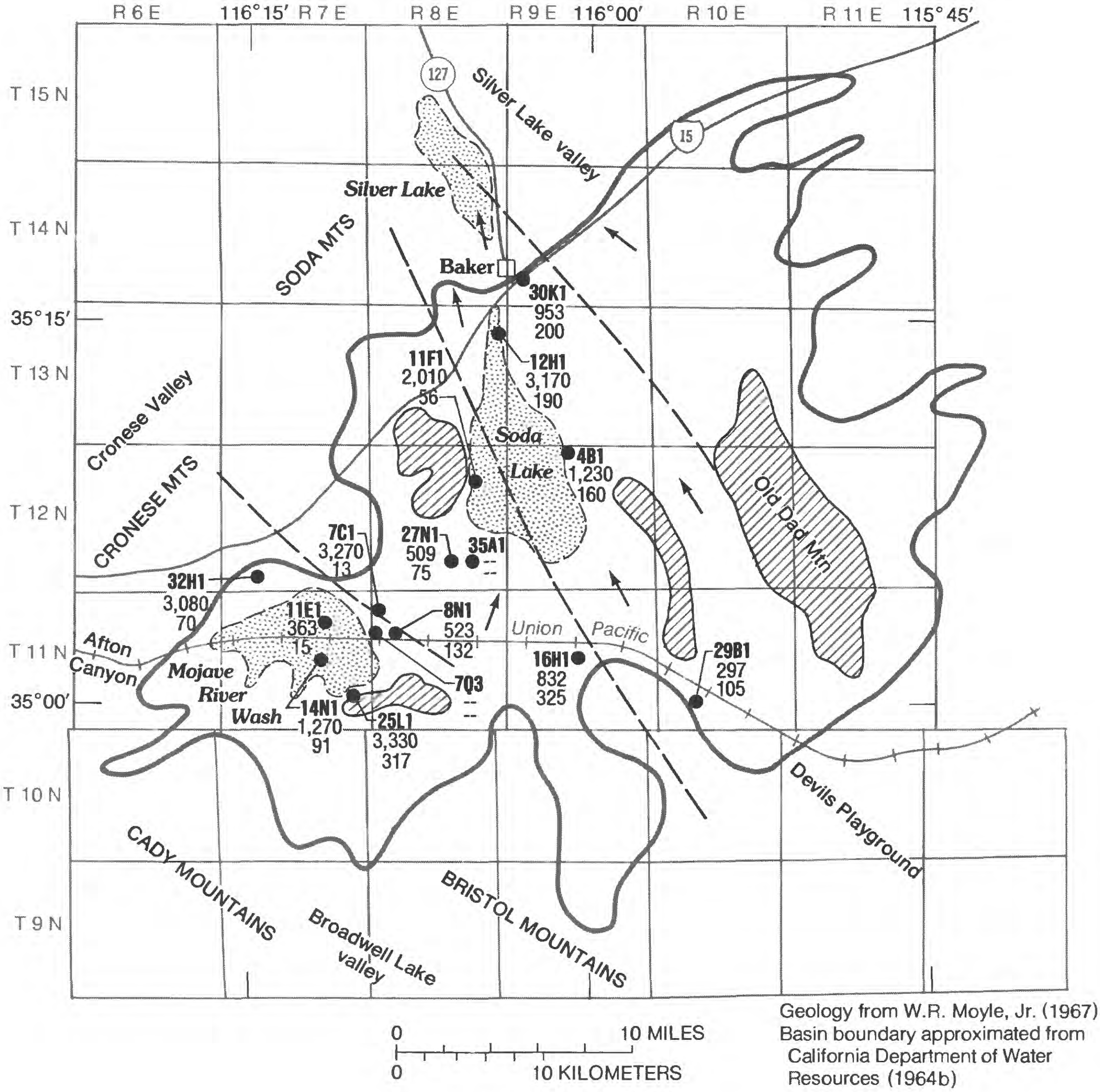
Estimates of ground water in storage range from 4 million acre-ft (Koehler and Ballog, 1979) to 9.3 million acre-ft (California Department of Water Resources, 1975). Alluvial deposits in the basin are at least 400 feet thick from Afton Canyon to Baker. Depth to water ranges from 8 feet below land surface in well 35A1 to 76 feet below land surface in well 30K1. Well yields reportedly are as high as 1,700 gal/min and average 1,100 gal/min (California Department of Water Resources, 1975).

Water quality varies considerably throughout the basin, even in wells only short distances apart—perhaps because of vertical stratification of water of different quality. Dissolved-solids concentration ranges from 297 mg/L in well 29B1 to 3,330 mg/L in well 25L1; the average dissolved-solids concentration is 1,600 mg/L. Hardness ranges from soft (13 mg/L in well 7C1) to very hard (325 mg/L in well 16H1); average hardness is 135 mg/L. High fluoride and boron concentrations (for example, 10 mg/L and 2.2 mg/L, respectively, in well 11F1) make the water in most parts of the basin generally unsuitable for agricultural and domestic uses (Koehler and Mallory, 1981).

Ground water moves from the Mojave River Wash and Devils Playground areas toward Soda Lake, then northward out of the basin. Ground-water movement may be impeded to some extent by three faults that cross the basin in a northwesterly direction (Koehler and Ballog, 1979). Recharge is from rainfall in the basin and subsurface flow from adjoining basins. The average annual streamflow of the Mojave River is estimated to be 3,830 acre-ft (U.S. Geological Survey, 1977). Much of this flow percolates into the ground when it reaches the Mojave River Wash, or just beyond. Flash flooding on the Mojave River carries streamflow to Soda Lake, and on occasion streamflow spills over into Silver Lake valley to the north. Most of the water that reaches the lakes is lost to evaporation, because the lakebed sediments are relatively impermeable. Subsurface flow enters the basin from the Devils Playground, the Mojave River Wash, and possibly from Cronese Valley.

Ground-water discharge occurs by evaporation of water from springs on the west side of Soda Lake. Evaporation of ground water may occur at Soda Lake (a playa) where the water table is near the land surface. Subsurface flow is northward out of the basin through the Baker area and into the Silver Lake valley ground-water basin (Koehler and Ballog, 1979).

If large quantities of ground water were pumped, the water quality might change as water from outside the well field moves into the pumping depression. Previous agricultural developments have failed because of poor water quality. If the well field were in the northern part of the basin, the resulting pumping depression might cause water levels to decline in the wells serving the town of Baker. The ground-water gradient at Baker could be reversed, causing subsurface flow to enter the basin from Silver Lake valley.



EXPLANATION

CONSOLIDATED ROCKS (Within the basin)

— — — FAULT – Approximately located

WELL

27N1 — Designation
832 — Dissolved solids, in milligrams per liter
325 — Hardness, in milligrams per liter
-- — No data

← DIRECTION OF GROUND-WATER FLOW

BASIN BOUNDARY

Figure 5.2-1. Soda Lake valley ground-water basin (6-33).

5.3 Caves Canyon Valley

Favorable Water Quality Near the Mojave River

Low dissolved-solids concentrations and generally soft water typify many of the wells in this basin. Surface flow from the Mojave River recharges the ground-water system.

Caves Canyon valley ground-water basin (fig. 5.3-1) is in the Caves Canyon Hydrologic Subarea (W-28.G1), in the central part of San Bernardino County, about 25 miles northeast of Barstow on Interstate Highway 15. The basin encompasses almost 100 mi^2. The Mojave River traverses the basin in a northeasterly direction. The altitude of the riverbed is 1,760 feet above sea level in the southwestern part of the basin and 1,400 feet at Afton Canyon.

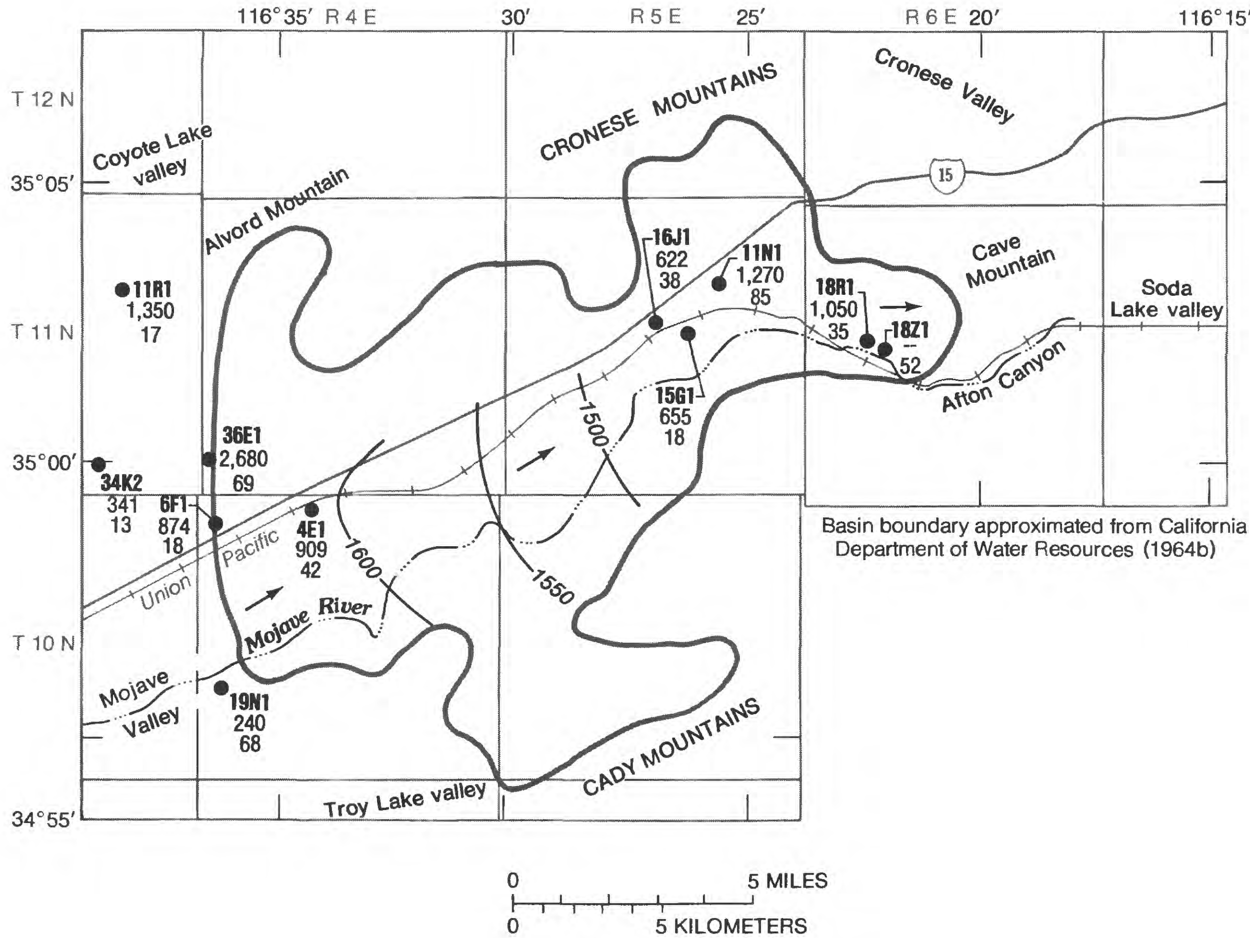
Ground water in storage is estimated to be 2 million acre-ft. The water table is near the surface in the southwestern part of the basin by the Mojave River, nearly 200 feet below land surface in the central part of the basin, and near land surface in Afton Canyon. The average well yield for 10 wells in the southwest part of the basin is 990 gal/min, with a maximum of 1,990 gal/min (Koehler and Ballog, 1979).

The dissolved-solids concentration ranges from 622 mg/L in well 16J1 to 2,680 mg/L in well 36E1. Sodium concentration is high (average is 323 mg/L), making the water unsuitable for domestic and agricultural purposes. Water throughout the basin is generally soft. Average hardness (as $CaCO_3$) is 41 mg/L, and hardness ranges from 18 mg/L in well 6F1 to 85 mg/L in well 11N1 (Koehler and Mallory, 1981).

Ground-water movement is approximately parallel to the Mojave River channel. Much of the surface water, which enters the basin by way of the Mojave River, percolates into the ground water; the remaining surface water leaves the basin through Afton Canyon. Recharge is by percolation of rainfall in the drainage basin, percolation of surface flow along the Mojave River, and subsurface flow from the southwest. Average annual subsurface flow entering the basin from the southwest is estimated to be 1,000 acre-ft (California Department of Water Resources, 1967). The quantity of recharge available from precipitation is limited by scant rainfall and high evaporation rates. Periodically, the Mojave River carries surface flow from flash floods and recharges the ground-water system.

An estimated annual average of 3,800 acre-ft of ground water discharges into the Mojave River near Afton Canyon (U.S. Geological Survey, 1977). Most of the wells in the basin are unused; probably less than 5 acre-ft of ground water is pumped annually (Koehler and Ballog, 1979).

If large quantities of water were pumped from the basin, water levels would decline in and around the well field; this might even stop the flow out of the basin through Afton Canyon. Increased recharge from subsurface flow and Mojave River streamflow would help to reduce water-level declines.



EXPLANATION

—1600— WATER-TABLE CONTOUR – Shows altitude of water table (1963). Contour interval 50 feet. Datum is sea level

← DIRECTION OF GROUND-WATER FLOW

WELL
- 19N1 — Designation
- 240 — Dissolved solids, in milligrams per liter
- 68 — Hardness, in milligrams per liter
- -- — No data

—— BASIN BOUNDARY

Figure 5.3-1. Caves Canyon valley ground-water basin (6-38).

5.4 Chuckwalla Valley

Ground Water in Storage Estimated to be 15 Million Acre-Feet

Well yields average 1,800 gallons per minute. Dissolved-solids concentration in the basin is lowest in the western part.

The Chuckwalla Valley ground-water basin (fig. 5.4-1) encompasses 870 mi^2 in part of the Ford (X-17.A0) and Palen (X-17.B0) Hydrologic Subunits west of Palo Verde Mesa in the eastern part of Riverside County. It is a desert area of internal drainage with no perennial streams and two dry lakes, Ford and Palen, within its boundaries. Access to the basin is provided by Interstate Highway 10 from the east and west, and by the Desert Center-Rice Highway from the north and south.

Water in storage is estimated to be 15 million acre-ft. The main water-bearing materials are unconsolidated sedimentary deposits: alluvial-fan, stream-channel, and lake or playa deposits, and some wind-deposited sands. The average yield for wells in the basin is 1,800 gal/min, and the maximum yield is 3,900 gal/min (California Department of Water Resources, 1975).

Water quality varies markedly in the basin. The water of best quality comes from wells in the western part of the basin, near Desert Center. The average concentration of dissolved solids is 2,100 mg/L, and concentrations range from 274 mg/L in well 29F1 to 8,150 mg/L in well 33C1. The dissolved-solids concentration increases as the ground water moves downgradient and is highest in the central and eastern parts of the basin. Average hardness is 274 mg/L (very hard), and hardness ranges from very soft (3 mg/L in well 29R1) to extremely hard (1,200 mg/L in well 10N1) (Koehler and Mallory, 1981). Several of the wells contain high levels of fluoride and boron that make the water unsuitable for domestic and agricultural purposes. For example, water from well 8F1 had 8 mg/L fluoride, and well 25P1 had 3.6 mg/L boron.

Ground-water recharge is mainly by subsurface flow from Pinto Basin on the northwest and from Cadiz Valley on the north. Recharge also occurs by infiltration of runoff from the slopes of the surrounding mountains and infrequent rainfall on the basin floor.

Ground-water discharge from the basin occurs by evapotranspiration from Ford and Palen Lakes, by subsurface flow eastward out of the basin, and by pumping for domestic and agricultural uses. An estimated 400 acre-ft/yr of subsurface flow moves eastward out of the basin into Palo Verde Mesa (Metzger and others, 1973).

As water levels decline with pumping, subsurface flow from Pinto Basin and Cadiz Valley probably will increase. Some subsurface flow may enter the basin from western Chuckwalla Valley (southwest of Desert Center). If the decline in water level is great, ground-water gradient in the eastern part of the basin could be reversed, thus inducing subsurface flow to enter the basin from Palo Verde Mesa (Koehler and Mallory, 1981).

The limited development in the Desert Center area is not a significant competitive use of the ground water, and the basin is large enough to permit siting remote from the Desert Center wells. A well field located in the center of the basin may induce good-quality water to move from the Desert Center area without deteriorating the quality of water from the existing wells at Desert Center.

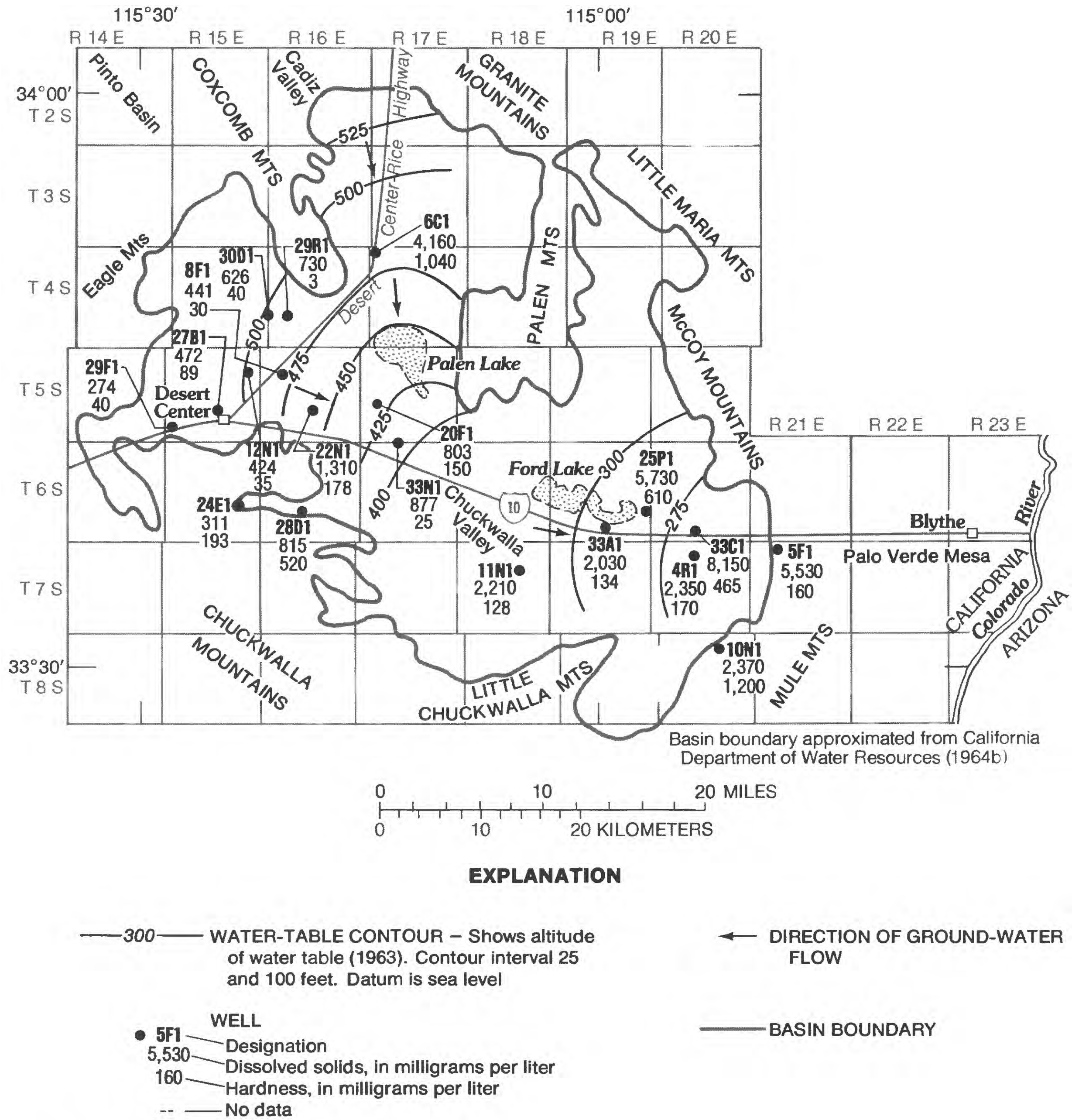


Figure 5.4-1. Chuckwalla Valley ground-water basin (7-5).

5.5 Calzona-Vidal Valley

Favorable Water Quality and High Well Yields Near Colorado River

Large-scale withdrawals near the Colorado River may change discharge areas into recharge areas. Low dissolved-solids concentration in many wells enhances this basin's potential.

The Calzona-Vidal Valley ground-water basin (fig. 5.1-1) is classified as two separate ground-water basins by the California Department of Water Resources (1975). The two basins have similar subsurface characteristics and were previously evaluated as one ground-water basin by the U.S. Geological Survey (Bader, 1969a). Here they will be considered as one basin within a single hydrologic subunit. The ground-water basin is in the Vidal Hydrologic Subunit (X-15.A0) and encompasses 310 mi^2 in the eastern part of San Bernardino and Riverside Counties adjacent to the Colorado River and the Arizona State line. Access to the basin is by U.S. Highway 95 and California State Highway 62.

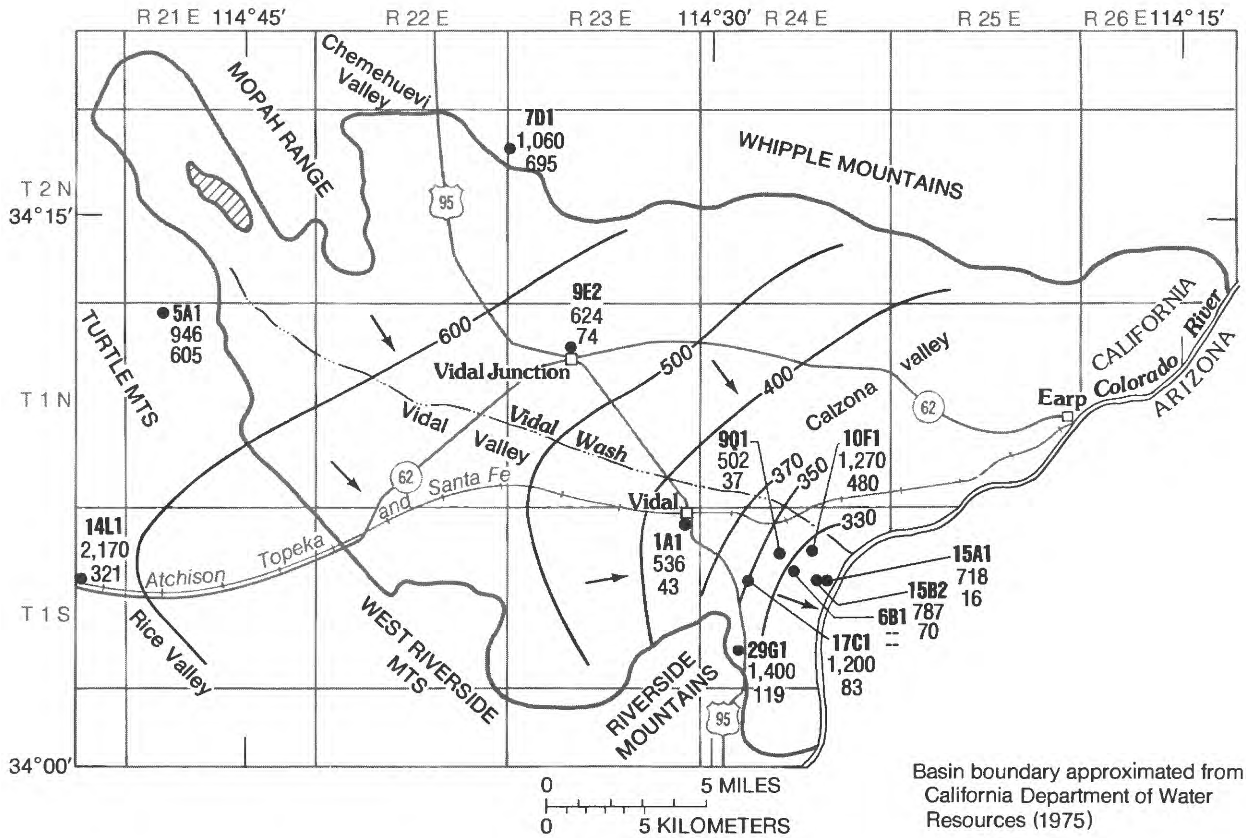
The estimated quantity of ground water in storage is 3.5 million acre-ft. Drillers' logs indicate an average aquifer thickness of 500 feet and average depth to water of 250 feet. Well yields range from 100 gal/min near Vidal Junction to 1,800 gal/min near the Colorado River (Koehler and Ballog, 1979). Most of the wells near the Colorado River have high yields, probably because they penetrate the older alluvium deposited by the Colorado River. The wells in the Vidal Junction area penetrate less permeable formations and, therefore, have lower yields.

Dissolved-solids concentrations range from 502 mg/L in well 9Q1 to 1,400 mg/L in well 29G1 and average 980 mg/L. The water is locally high in fluoride content (in excess of 9 mg/L) in the Vidal area, making it unsuitable for domestic use. A few wells in the southern part of the basin, near the Colorado River, contain soft water (hardness less than 60 mg/L as $CaCO_3$). Average hardness in the basin is 134 mg/L, and hardness ranges from 16 mg/L in well 15A1 to 480 mg/L in well 10F1 (Koehler and Mallory, 1981). The water from the upper part of the older alluvium near the Colorado River is of much better quality than the water at depth.

The flow of ground water is generally southeasterly; no known barriers inhibit the ground-water flow. Recharge to the basin is from infiltration of precipitation on the basin and from surface runoff from the surrounding mountain ranges. Some ground water enters the basin by subsurface flow from Rice Valley on the southwest. There may be some local recharge from the Colorado River along the northeast edge where pumping has caused a lowering of water levels.

Ground water discharges into the Colorado River along the southeast border of the basin. There are several pumping wells near Earp and Vidal Junction that are used primarily for irrigation (near the Colorado River) and some limited domestic use (near Vidal Junction).

To provide sufficient quantities of cooling water, the well field probably would have to be located near the Colorado River. However, ground-water withdrawals near the river probably would curtail subsurface flow out of the basin and increase recharge from percolation of Colorado River water. The hydrologic regime on the Arizona side of the Colorado River could possibly be affected by large-scale pumping in the basin. The legal and environmental ramifications of inducing recharge from the Colorado River would have to be considered before a large well field were located near the river.



EXPLANATION

CONSOLIDATED ROCKS (Within the basin)

—330— WATER-TABLE CONTOUR – Shows altitude of water table (1963). Contour interval 20, 30, and 100 feet. Datum is sea level

WELL

● 29G1 — Designation
1,400 — Dissolved solids, in milligrams per liter
119 — Hardness, in milligrams per liter
-- — No data

← DIRECTION OF GROUND-WATER FLOW

—— BASIN BOUNDARY

Figure 5.5-1. Calzona-Vidal Valley ground-water basin (7-41 and 7-42).

6.0 SUMMARY OF BASIN EVALUATIONS

6.1 Basins Considered Hydrologically Suitable for Powerplants

[Modified from Koehler and Ballog (1979). Basin names and numbers given as assigned by California Department of Water Resources (1975). mi^2, square miles; Do., ditto; acre-ft, acre-feet; ft, feet; gal/min, gallons per minute; mg/L, milligrams per liter]

Basin name and number	Basin size (mi^2)	Storage (acre-ft)	Well yield	Water quality	Basin development	Remarks
Middle Amargosa valley 6-20	620 (Calif. part)	18,000,000, assuming an average saturated thickness of 400 ft.	Average well yields 2,500 gal/min.	Dissolved solids range from 566 to 4,660 mg/L. Locally high in fluoride, boron, or arsenic.	Minimal development in northern part due to poor water quality. Potential for additional development.	The northern part of the basin would probably be most suitable for a powerplant site.
Soda Lake valley 6-33	590	4,000,000, assuming an average saturated thickness of 400 ft in an area of 150 mi^2.	As much as 1,700 gal/min.	Dissolved solids average 1,600 mg/L. Locally high in fluoride and boron.	The only significant ground-water withdrawals are near the town of Baker at the north edge of the basin.	Recharge from adjoining basins would help maintain water levels.
Caves Canyon valley 6-38	100	2,000,000; estimate reported by the Mojave Water Agency.	Average well yields 990 gal/min. As much as 1,990 gal/min reported.	Dissolved solids range from 622 to 2,680 mg/L. Water is high in percent sodium.	Not more than 10 wells are presently being used in the basin.	Basin receives recharge from adjoining basin and from occasional surface flow in the Mojave River.
Chuckwalla Valley 7-5	870	15,000,000, assuming an average saturated thickness of 300 ft.	Average 1,800 gal/min; maximum 3,900 gal/min.	Dissolved solids range from 274 to 8,150 mg/L. Locally high in fluoride, boron, and percent sodium.	Most development is in the vicinity of Desert Center. Agricultural use is declining.	Hydrologic conditions vary considerably in the basin.
Calzona-Vidal Valley 7-41, 7-42	310	3,500,000, assuming an average saturated thickness of 250 ft.	As much as 1,800 gal/min.	Dissolved solids range from 502 to 1,400 mg/L. Locally high in fluoride and percent sodium.	Development primarily in area along the Colorado River.	Basin may receive some recharge from the Colorado River.

6.2 Basins Considered Hydrologically Suitable, With Qualifications, for Powerplants

[Modified from Koehler and Ballog (1979). Basin names and numbers given as assigned by California Department of Water Resources (1975). mi^2, square miles; acre-ft, acre-feet; ft, feet; gal/min, gallons per minute; mg/L, milligrams per liter]

Basin name and number	Basin size (mi^2)	Storage (acre-ft)	Well yield	Water quality	Basin development	Remarks
Coyote Lake valley 6-37	150	5,913,000 reported by Mojave Water Agency.	Data inconclusive.	Dissolved solids range from 310 to 2,480 mg/L. Locally high in fluoride and boron.	Agricultural development limited to the southeastern part of basin.	Additional data on well yield and water quality in the southeastern part of the basin are required.
Harper valley 6-47	510	2,497,000 reported by Mojave Water Agency.	Maximum of about 3,000 gal/min.	Dissolved solids as much as 2,000 mg/L. Locally high in fluoride and boron.	About 500 acres irrigated in 1961; less since then.	Well yield and water quality vary considerably within the basin.
Panamint Valley 6-58	360	About 6,000,000.	Data inconclusive.	Dissolved solids range from 518 to 171,000 mg/L.	No wells known to be in use in the basin.	Well yield may be low because of considerable quantities of silt and clay in aquifer.
Rice Valley 7-4	300	2,500,000 assuming an average saturated thickness of 200 ft.	No data.	Dissolved solids as much as 2,610 mg/L. Locally high in fluoride and boron.	Virtually no development of the basin.	On the basis of drillers' logs, the well yield may be low near the periphery of the basin but higher near the center.
Dale valley 7-9	260	3,400,000, assuming an average saturated thickness of 300 ft.	Data inconclusive.	Dissolved solids range from 1,120 to 326,000 mg/L.	Development limited because of poor water quality.	On the basis of drillers' logs, well yield may be highest in the northwestern part of basin.
Palo Verde Mesa 7-39	280	5,000,000, assuming an average saturated thickness of 300 ft.	Average 1,650 gal/min; maximum 2,750 gal/min.	Dissolved solids as much as 4,500 mg/L.	Agricultural development expanding in part of the basin.	Development is limited to a small part of the basin; water quality may limit the expansion.

6.0 SUMMARY OF BASIN EVALUATIONS—Continued

6.3 Basins with Insufficient Data to Determine Hydrologic Suitability for Powerplants

[Modified from Koehler and Ballog (1979). Basin names and numbers given as assigned by California Department of Water Resources (1975). mi^2, square miles; ft, feet; mg/L, milligrams per liter]

Basin name	Basin number	Basin size (mi^2)	Remarks
Eureka Valley	6-16	160	One well is known in the basin.
Saline Valley	6-17	210	Limited data are available on wells in the basin. Water from Salt Lake has dissolved solids greater than 300,000 mg/L.
Lower Kingston valley (also known as Valjean valley)	6-21	290	One well is known in the basin; it was drilled to 425 ft and did not encounter water.
Upper Kingston valley (also known as Shadow Valley)	6-22	270	Only a few wells are known in the basin; data are limited.
Riggs valley	6-23	100	No wells are known in the basin.
Kelso Valley	6-31	370	Limited data are available on two wells at Kelso. No wells are known in other parts of the basin.
Broadwell valley	6-32	120	Records indicate that 12 wells have been drilled in the basin; however, little or no data are available for these wells.
Ward Valley	7-3	770	Many wells have been drilled on Danby Lake for brine exploration and extraction. Little or no data are available for the remainder of the basin.
West Salton Sea basin	7-22	190	Three wells are known in the basin. No data are available for these wells.
Amos valley	7-34	220	Two wells are known in the basin. No data are available for these wells.
Ogilby valley	7-35	220	Records indicate that 13 wells have been drilled in the basin; however, little or no data are available for these wells.
Arroyo Seco valley	7-37	430	Records indicate that 12 wells have been drilled in the basin; however, little or no data are available for these wells.
Chemehuevi Valley	7-43	440	Only two wells are known in the basin.

6.4 Basins Considered Unsuitable for Powerplants

[Modified from Koehler and Ballog (1979). Basin names and numbers given as assigned by California Department of Water Resources (1975). mi^2, square miles; Do., ditto; acre-ft, acre-feet; ft, feet; gal/min, gallons per minute; mg/L, milligrams per liter]

Basin name	Basin number	Criteria eliminating basin: Storage	Criteria eliminating basin: Well yield	Criteria eliminating basin: Water quality	Criteria eliminating basin: Basin development	Explanation
Mono Valley	6-9				X	The basin is largely owned by the city of Los Angeles; water is exported for urban use in the Los Angeles metropolitan area.
Adobe Lake valley	6-10	X		X		The basin is small (60 mi^2); consequently, storage is limited. Water quality is generally suitable for domestic and irrigation uses.
Long Valley	6-11				X	Some parts of the basin are owned by the city of Los Angeles. Most of the basin is in the Inyo National Forest and is used for recreational purposes.
Owens Valley	6-12				X	The basin is almost entirely utilized as an underground reservoir that supplies water to the Los Angeles metropolitan area.
Back Springs valley	6-13	X				The basin is small (50 mi^2); consequently, storage is limited.
Fish Lake Valley	6-14			X		Water quality is generally suitable for domestic and agricultural uses.
Deep Springs Valley	6-15	X		X		The basin is small (40 mi^2); consequently, storage is limited. Water quality in most of the basin is suitable for domestic and agricultural uses.
Death Valley	6-18				X	Basin is within Death Valley National Monument.
Wingate valley	6-19				X	These basins are largely or totally within U.S. military reservations.
Red Pass Valley	6-24				X	(same as above)
Bicycle valley	6-25				X	(same as above)
Avawatz valley	6-26				X	(same as above)
Leach valley	6-27				X	(same as above)
Pahrump Valley	6-28			X	X	Water quality is generally suitable for domestic and agricultural uses.
Mesquite Valley	6-29			X		Do.
Ivanpah Valley	6-30		X	X		The yield from wells is generally low. Water quality in the basin is generally suitable for domestic and agricultural uses.
Silver Lake valley	6-34	X				The basin is small (40 mi^2); consequently, storage is limited.

6.0 SUMMARY OF BASIN EVALUATIONS—Continued

6.4 Basins Considered Unsuitable for Powerplants—Continued

Basin name	Basin number	Criteria eliminating basin: Storage	Well yield	Water quality	Basin development	Explanation
Cronese Valley	6-35	X			X	More than half of the basin is within a U.S. military reservation. Storage in the rest of the basin is probably less than 1 million acre-ft.
Langford valley	6-36	X			X	Basin is within a U.S. military reservation.
Troy valley	6-39				X	Ground water is being used for recreation.
Lower Mojave River valley	6-40			X	X	Water quality in most of the basin is generally suitable for domestic and agricultural use. Ground water is being used for urban, industrial, and agricultural purposes.
Middle Mojave River valley	6-41			X	X	Do.
Upper Mojave River valley	6-42			X	X	Do.
El Mirage Valley	6-43			X		Water quality is generally suitable for domestic and agricultural uses, except in the immediate area of El Mirage Lake.
Antelope Valley	6-44			X	X	Water quality is generally suitable for most uses. Extensive withdrawals of ground water are being made for urban and agricultural uses.
Tehachapi Valley	6-45	X		X		The basin is small (20 mi^2); consequently, storage is limited. Water quality is generally suitable for most uses.
Fremont Valley	6-46			X	X	Water quality is generally suitable for most uses, except in the immediate area of Koehn Lake, where water extremely high in dissolved solids is being used for the production of salt.
Goldstone valley	6-48	X			X	The basin is small (30 mi^2); consequently, storage is limited. Most of the basin is within a U.S. military reservation.
Superior Valley	6-49		X		X	Well yields are low; the alluvium has a maximum thickness of 250 ft (Moyle, 1971), which limits well yield. Nearly half of the basin is within a U.S. military reservation.
Cuddeback valley	6-50			X		Water quality is generally suitable for most uses, except in the area immediately north and northwest of Cuddeback Lake.
Pilot Knob Valley	6-51				X	The basin is within a U.S. military reservation.

6.4 Basins Considered Unsuitable for Powerplants—Continued

Basin name	Basin number	Criteria eliminating basin: Storage	Well yield	Water quality	Basin development	Explanation
Searles Valley	6-52			X	X	Most of the ground water in the basin has an extremely high dissolved-solids concentration. This water is processed into salt, a major industry in the basin.
Salt Wells Valley	6-53	X			X	The basin is small (30 mi^2); consequently, storage is limited. Most of the basin is within a U.S. military reservation.
Indian Wells Valley	6-54				X	There is moderate urban and industrial development in the southern part of the basin. The northern half of the basin is within a U.S. military reservation.
Coso valley	6-55				X	The basin is within a U.S. military reservation.
Rose Valley	6-56	X		X		The basin is small (60 mi^2); consequently, storage is limited. The water quality in most of the basin is suitable for most uses.
Darwin valley	6-57				X	Most of the basin is within a U.S. military reservation.
Basins 6-59 through 6-90		X				These basins are all small and have insignificant amounts of ground water in storage.
Lanfair Valley	7-1	X	X	X		The water table is deep; therefore, storage in the upper 500 ft of sediments is limited. Well yields are generally less than 35 gal/min. Water quality is generally suitable for domestic and agricultural uses.
Fenner Valley	7-2		X	X		Existing wells have yields of less than 200 gal/min. Water quality is generally suitable for domestic and agricultural uses.
Pinto Valley	7-6	X			X	Depth of water-bearing sediment is only 100 ft. The basin is within the Joshua Tree National Monument.
Cadiz Valley	7-7		X	X		Only low yields are available from the tightly compacted clay and silt associated with the large playa. Water is highly saline; dissolved solids are greater than 200,000 mg/L.
Bristol valley	7-8		X	X		Low yields are due to fine, compacted sediments. Water is highly saline; dissolved solids are greater than 200,000 mg/L.
Twentynine Palms valley	7-10			X	X	Water quality is generally suitable for domestic and agricultural uses in most parts of the basin. Basin is within a U.S. military reservation.

6.0 SUMMARY OF BASIN EVALUATIONS—Continued

6.4 Basins Considered Unsuitable for Powerplants—Continued

Basin name	Basin number	Criteria eliminating basin: Storage	Well yield	Water quality	Basin development	Explanation
Copper Mountain valley	7-11			X	X	Water quality is generally suitable for domestic and agricultural uses.
Warren valley	7-12	X				The basin is small (20 mi^2); consequently, storage is limited.
Deadman valley	7-13				X	The basin is within a U.S. military reservation.
Lavic valley	7-14	X	X			The basin is small (40 mi^2); consequently, storage is limited. Maximum reported well yield is 140 gal/min.
Bessemer valley	7-15				X	The basin is partly within a U.S. military reservation.
Ames Valley	7-16				X	The basin is within a U.S. military reservation.
Means valley	7-17	X		X		The basin is small (25 mi^2); consequently, storage is limited. The water quality is suitable for domestic and agricultural uses.
Johnson Valley	7-18			X	X	Water is marginal for domestic use. High fluoride levels require mixing of the water. 150 to 300 private parties use well water.
Lucerne Valley	7-19			X	X	Water quality is generally suitable for domestic and agricultural uses. There is moderate development in the basin.
Morongo Valley	7-20	X				The basin is small (14 mi^2); consequently, storage is limited.
Coachella Valley	7-21				X	The basin is used extensively for both domestic and agricultural purposes. An overdraft already exists.
Clark Valley	7-23	X	X			The basin is small (40 mi^2); consequently storage is limited. Well yields average 20 gal/min.
Borrego Valley	7-24			X	X	The water is suitable for domestic and agricultural uses. Part of the basin is within the Anza Borrego State Park.
Ocotillo/Lower Borrego Valley	7-25			X	X	The water is generally suitable for domestic and agricultural uses.
Terwilliger Valley	7-26	X				The basin is small (12 mi^2); consequently, storage is limited.

6.4 Basins Considered Unsuitable for Powerplants—Continued

Basin name	Basin number	Criteria eliminating basin: Storage	Well yield	Water quality	Basin development	Explanation
San Felipe Valley	7-27	X				The basin is small (40 mi^2); consequently, storage is limited.
Vallecito-Carrizo Valley	7-28				X	The basin is within the boundary of Anza Borrego State Park.
Coyote Wells valley	7-29			X	X	Water quality is generally suitable for domestic and agricultural uses. Ground water is exported from basin.
Imperial Valley	7-30			X	X	Extensively developed for domestic and agricultural uses. Geothermal development is increasing.
Orocopia valley	7-31		X			Only low yields are available from tightly cemented sediments.
Chocolate valley	7-32				X	About half of the basin is within a U.S. military reservation.
East Salton Sea basin	7-33		X		X	Well yields are limited because the aquifer is thin. Basin has moderate development.
Yuma Valley	7-36		X		X	The thickness of the principal aquifer is only 225 ft. Basin is within the Fort Yuma Indian Reservation.
Palo Verde Valley	7-38			X	X	Water quality is suitable for domestic and agricultural uses; consequently, basin has been extensively developed.
Quien Sabe Point valley	7-40	X				The basin is small (40 mi^2); consequently, storage is limited.
Needles valley	7-44			X	X	Water quality is generally suitable for domestic and agricultural uses. Basin has moderate development.
Piute Valley	7-45		X			Depth to water is 265 to 414 ft below land surface. The sediments are tightly compacted at depth.
Basins 7-47 through 7-61		X				These basins are too small to meet the storage requirements.

7.0 SUMMARY OF CHEMICAL CONSTITUENTS AND CHARACTERISTICS THAT AFFECT WATER QUALITY

7.1 Natural Inorganic Constituents Commonly Dissolved in Water That May Affect Water Use

[Modified from Heath (1983). mg/L, milligrams per liter; >, greater than]

Constituent	Major natural sources	Effects on water use	Concentrations of significance (mg/L)[1]
Arsenic (As).........	Widespread occurrence in nature as arsenides and arsenopyrites.	Most forms of arsenic are toxic to humans.	[2]0.05 (drinking water) [2]0.2 (livestock) [3]0.1 (crop irrigation)
Bicarbonate (HCO_3) Carbonate (CO_3).	Product of the solution of carbonate rocks, mainly limestone ($CaCO_3$) and dolomite ($CaMgCO_3$), by water containing carbon dioxide.	Control the capacity of water to neutralize strong acids. Bicarbonates of calcium and magnesium decompose in steam boilers and water heaters to form scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium, cause carbonate hardness.	150-200
Boron (B)............	Usually found as sodium or calcium borate salt, not in elemental form.	In certain concentrations, can adversely affect sensitive crops.	[2]1.0 (drinking water) [3]5.0 (livestock) [3]0.75 (crop irrigation)
Calcium (Ca) and magnesium (Mg).	Soils and rocks containing limestone, dolomite, and gypsum ($CaSO_4$). Small amounts from igneous and metamorphic rocks.	Principal cause of hardness and of boiler scale and deposits in water heaters.	25-50
Chloride (Cl)........	In inland areas, primarily from seawater trapped in sediments at time of deposition; in coastal areas, from seawater in contact with freshwater in productive aquifers.	In high concentrations, increases corrosiveness of water and, in combination with sodium, gives water a salty taste.	250
Fluoride (F).........	Both sedimentary and igneous rocks. Not widespread in occurrence.	In certain concentrations, reduces tooth decay; at higher concentrations, causes mottling of tooth enamel.	[4]0.7-1.2 (drinking water) 2.0 (livestock) 1.0 (crop irrigation)
Iron (Fe) and manganese (Mn).	Iron present in most soils and rocks; manganese less widely distributed.	Stain laundry; objectionable in food processing, dyeing, bleaching, ice manufacturing, brewing and certain other industrial processes.	Fe >0.3, Mn >0.05
Sodium (Na)..........	Same as for chloride. In some sedimentary rocks, a few hundred milligrams per liter may occur in freshwater as a result of exchange of dissolved calcium and magnesium for sodium in the aquifer materials.	See chloride. In high concentrations, may affect persons with cardiac difficulties, hypertension, and certain other medical conditions. Depending on the concentrations of calcium and magnesium also present in the water, sodium may be detrimental to certain irrigated crops.	69 (irrigation) [5]20-270 (health)
Sulfate (SO_4)........	Gypsum, pyrite (FeS), and other rocks containing sulfur (S) compounds.	May give water a bitter taste; has a laxative effect at high concentrations. In combination with calcium, forms a hard boiler scale.	300-400 (taste) 600-1,000 (laxative)

See footnotes on page 43.

7.2 Characteristics of Water That Affect Water Quality

[Modified from Heath (1983). mg/L, milligrams per liter]

Constituent	Principal cause	Significance	Remarks
Hardness...........	Calcium and magnesium dissolved in the water.	Calcium and magnesium combine with soap to form an insoluble precipitate (curd) and thus hamper the formation of a lather. Hardness also affects the suitability of water for use in the textile and paper industries and certain others and in steam boilers and water heaters.	U.S. Geological Survey classification of hardness (mg/L as $CaCO_3$): 0-60, soft; 61-120, moderately hard; 121-180, hard; more than 180, very hard; less than 60-80, desirable for powerplant cooling water.
pH (or hydrogen-ion activity).	Dissociation of water molecules and of acids and bases dissolved in water.	The pH of water is a measure of its characteristics. Low values of pH, particularly below 4, indicate a corrosive water that will tend to dissolve metals and other substances that it contacts. High values of pH, particularly above 8.5, indicate an alkaline water that, on heating, will tend to form scale. The pH significantly affects the treatment and use of water.	pH values: Less than 7, water is acidic; values of 7, water is neutral; more than 7, water is alkaline.
Specific electrical conductance.	Substances that form ions when dissolved in water.	Most substances dissolved in water dissociate into ions that can conduct an electrical current. Consequently, specific electrical conductance is a valuable indicator of the amount of material dissolved in water. The larger the conductance, the more mineralized the water.	Conductance values indicate the electrical conductivity, in microsiemens per centimeter at 25 degrees Celsius.
Dissolved solids...	Mineral substances dissolved in water.	Dissolved solids is a measure of the amount of minerals dissolved in water and is a useful characteristic in evaluation of water quality. Water containing less than 500 mg/L dissolved solids is preferred for domestic use and for many industrial processes.	U.S. Geological Survey classification of water based on dissolved solids (mg/L): Less than 1,000, fresh; 1,000-3,000, slightly saline; 3,000-10,000, moderately saline; 10,000-35,000, very saline; more than 35,000, briny. Maximum recommended concentration (mg/L)[2]: Drinking water (esthetic and taste characteristics), 500; livestock, 3,000-7,000; crop irrigation, 700.

[1]A range in concentration is intended to indicate the general level at which the effect on water use might become significant.

[2]National Academy of Sciences and National Academy of Engineering, 1973.

[3]U.S. Environmental Protection Agency, 1976.

[4]Optimum range determined by the U.S. Public Health Service (optimum concentration depends on water intake) (U.S. Environmental Protection Agency, 1976).

[5]Lower concentration applies to drinking water for persons on a strict diet; higher concentration is for those on a moderate diet.

8.0 SELECTED REFERENCES

Bader, J.S., 1969a, Ground-water data as of 1967, Colorado Desert Subregion, California: U.S. Geological Survey Open-File Report, 19 p.

——— 1969b, Ground-water data as of 1967, South Lahontan Subregion, California: U.S. Geological Survey Open-File Report, 25 p.

Bader, J.S., and Moyle, W.R., Jr., 1960, Data on water wells and springs in the Yucca Valley-Twentynine Palms area, San Bernadino and Riverside Counties, California: California Department of Water Resources Bulletin 91-2, 163 p.

California Department of Water Resources, 1952, Ground water basins in California: Water Quality Investigations Report 3, 44 p.

——— 1964a, Names and areal code numbers of hydrologic areas in the Southern District: Office report, 57 p.

——— 1964b, Ground-water occurrence and quality, Lahontan Region: California Department of Water Resources Bulletin 106-1, 439 p.

——— 1967, Mojave River ground water basins investigation: California Department of Water Resources Bulletin 84, 151 p.

——— 1975, California's ground water: California Department of Water Resources Bulletin 118, 135 p.

——— 1977, Water for powerplant cooling: California Department of Water Resources Bulletin 204, 43 p.

——— 1987, California water, looking to the future: California Department of Water Resources Bulletin 160-87, 122 p.

California Energy Commission, 1973, Energy dilemma, California's 20-year powerplant siting plan: 129 p.

——— 1980, Assessment of electric utility supply plans, 1978-2000: 246 p.

——— 1983, Securing California's Energy Future, 1983 Biennial Report: 205 p.

Davis, G.H., and Wood, L.A., 1974, Water demands for expanding energy development: U.S. Geological Survey Circular 703, 14 p.

Heath, R.C., 1983, Basic ground-water hydrology: U.S. Geological Survey Water-Supply Paper 2220, 84 p.

Koehler, J.H., and Ballog, A.P., Jr., 1979, Sources of powerplant cooling water in the desert area of southern California—Reconnaissance study: California Department of Water Resources Bulletin 91-24, 55 p.

Koehler, J.H., and Mallory, M.J., 1981, Addendum to: Sources of powerplant cooling water in the desert area of southern California—Reconnaissance study: U.S. Geological Survey Open-File Report 81-527, 28 p.

Lohman, S.W., and others, 1972, Definitions of selected ground-water terms—Revisions and conceptual refinements: U.S. Geological Survey Water-Supply Paper 1988, 21 p.

Luckenbach, R., 1975, What are off-the-road vehicles doing to the desert, *in* Fremontia: Sacramento, California Native Plant Society, v. 2, no. 4, p. 3-11.

Metzger, D.G., Loeltz, O.J., and Irelan, Burdge, 1973, Geohydrology of the Parker-Blythe-Cibola area, Arizona and California: U.S. Geological Survey Professional Paper 486-G, 130 p.

Moyle, W.R., Jr., 1967, Water wells and springs in Soda, Silver, and Cronese Valleys, San Bernardino County, California: California Department of Water Resources Bulletin 91-13, 16 p., 5 app.

——— 1971, Water wells in the Harper, Superior, and Cuddeback Valley areas, San Bernardino County, California: California Department of Water Resources Bulletin 91-19, 99 p.

National Academy of Sciences and National Academy of Engineering, 1973 [1974], Water quality criteria, 1972: U.S. Environmental Protection Agency, EPA R3-73-033, 594 p.

National Oceanic and Atmospheric Administration, 1974, Climates of the States, Volume 11—Western States including Alaska and Hawaii: 975 p.

Rantz, S.E., 1969, Mean annual precipitation in the California region: U.S. Geological Survey Open-File Report, 2 maps, scale 1:500,000.

Todd, D.K., 1959, Ground water hydrology: New York, John Wiley, 336 p.

University of California, Los Angeles, 1977, Study of alternative locations of coal-fired electric generating plants to supply energy from western coal to the Department of Water Resources: 815 p.

U.S. Environmental Protection Agency, 1976, National interim primary drinking water regulations: Office of Water Supply, EPA-570/9-76-003, 159 p.

U.S. Geological Survey, 1977, Water resources data for California, water year 1976: Volume 1, Colorado River basin, southern Great Basin from Mexican Border to Mono Lake basin, and Pacific slope basins from Tijuana River to Santa Maria River: U.S. Geological Survey Water-Data Report CA-76-1, 632 p.

Woolfenden, L.R., 1984, A ground-water quality monitoring network for the lower Mojave River Valley, California: U.S. Geological Survey Water-Resources Investigations Report 83-4148, 58 p.

GPO 685-041/9791