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CALIFORNIA POWER PLANT SITING STUDY

Volume II

Prepared for
**RESOURCES AGENCY
STATE OF CALIFORNIA**
Contract No. 30-22
and
U. S. ATOMIC ENERGY COMMISSION

May, 1973

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2. INTRODUCTION

Electric power consumption in California has consistently increased in greater proportion than the increase in population growth. The trend has been so great that some projections indicate the demand will double every 8 to 9 years. Factors which may tend to refute such forecasts include the possibility of recent census information pointing to a reduction in the rate of increase in population and industrial expansion, and in the per capita consumption of electrical energy. While factors such as these bear on the magnitude of the change, there is little doubt that the trend is upward and that a significant increase in demand must be anticipated. Of additional concern in planning for increased power demand and the need for new power plants is the fact that approximately 10 years are required to establish nuclear power facilities from the time sites are selected and environmental studies are begun. Therefore, it is necessary to begin site acquisition, design, and procurement actions today for plants which must be on line in the early 1980's.

The consumption of electrical power in California is concentrated in two major load areas, Los Angeles/San Diego and San Francisco/Sacramento. According to data filed by the utility companies with the California Public Utilities Commission,* the power forecasts of annual peak loads in these two general areas and in other areas over the next 20 years are as follows:

	<u>Megawatts</u>		
	<u>1972</u>	<u>1981</u>	<u>1991</u>
Southern California	15,319	29,667	56,060
Northern California	11,343	20,003	37,827
Others	<u>495</u>	<u>930</u>	<u>1,600</u>
Total	27,157	50,600	95,487

The power will be supplied by means of many energy sources including hydroelectric, fossil fuel, geothermal, and nuclear. There are plants today using all of these sources, but it is clear that because of the environmental impact of fossil-fueled plants and projected domestic shortages of low cost fossil fuels, most next generation major power plants must utilize nuclear fuel to obtain thermal energy. This means that of the 23,500 megawatts (Mw(e))** increase required by 1981 and an additional 44,800 Mw(e) required by 1991, most of that demand will be met by large central station nuclear plants. Considering downtimes

*General Order No. 131 Reports filed March 1, 1972.

**One megawatt equals one million watts.

for refueling, maintenance, and repair, utility companies forecast that to meet the demands, additional capacities of 28,300 Mw(e) by 1981 and 51,700 Mw(e) by 1991 will be necessary. The California Public Utility Commission estimates that without insurmountable licensing problems, nuclear power plants will provide over 19 percent of all power plant capacity in California by 1982 and might provide as much as 35 percent by 1992.

Currently nuclear power plants are being designed to use one or two 1,100 Mw(e) units in an initial installation. Utility companies planning for longer range growth indicate that four to six units at one site could be reasonable, depending on plant proximity to population centers. With a capacity at each site averaging about 2,000 to 3,000 Mw(e), perhaps 10 new sites are needed over the next 10 years and another 20 sites needed for the subsequent 10 years.

2.1 SITING FACTORS

Some of the factors which have been significant in the past in seeking sites for nuclear and fossil fuel power plants include a source of large quantities of cooling water and close proximity to load centers. Additionally, in California, nuclear plants require sites with particularly favorable seismologic characteristics as well as locations which are remote from populated areas to meet the requirements of licensing regulations. Environmental impact has become a particularly prominent factor in seeking plant sites.

There are a number of ways in which the plant reject heat can be dissipated, most relying on some form of evaporation. Oceanwater may be passed directly through the condensers and the heated water returned to the original body of water where it is cooled by mixing and evaporation at the surface. Other evaporative cooling systems include wet cooling towers (natural or mechanical draft), cooling ponds and reservoirs; but for these the same water is recycled in the system and only about 2 percent of the total is replenished for evaporation losses and purging. The choice of system depends on water availability, economics which vary from site to site, and the environmental impact. Obviously there is a great abundance of oceanwater and its use for cooling purposes has been common practice. As land use has changed and environmental impact has become a major concern, there have been increased objections to continuing the location of power plants in many coastal areas just for the availability of natural waters.

In assessing the location of plants in relation to load centers, it is apparent that in California most of the load is concentrated in and

around the principal cities of San Diego, Los Angeles, Sacramento, and San Francisco and much of the coastal areas connecting them. Power plants located reasonably near these centers incur minimum transmission costs. However, transmission lines also provide power to other locations at greater distances where there are no closer generating facilities to serve the load, or are connected to transmission interties to increase reliability throughout a system as seen in Figure 2-1. The intertie with networks in other states is also shown. Each end of the California grid is extended to tie into a major hydroelectric plant in Oregon or in Nevada. The southern end also extends to a joint ownership fossil plant at Four Corners, the intersection of Colorado, Utah, Arizona, and New Mexico. Therefore, it appears that plant locations need not only be near the load centers.

The nuclear power plant must not be located so close to the general population that it presents a hazard to the public. In practice, to date, most nuclear plants have been located at least 5 to 10 miles from population centers of 25,000 or more. Although there is no AEC guide or requirement yet for revising these distances, it is possible that greater experience or use of alternative plant siting concepts could alter acceptable distances.

A significant constraint placed on the selection of suitable nuclear power plant sites is the impact of anticipated seismic activity or ground motion. Locations are more desirable if this activity is forecast as small and would not impose exceedingly high cost penalties resulting from aseismic design that otherwise would be required in areas of greater activity. Some alternatives to current siting concepts might offer less susceptibility to ground motion than others and thereby potentially increase the number of acceptable sites to include more seismically active areas than would normally be considered.

The significance of geology and seismology in the siting of power plants is discussed later.

The coastline of California is a particularly desirable location for many uses in addition to power plant siting. These include parks and other recreational developments, residential developments, conservation and preservation of scenic values, and refuges for wildlife and endangered species or communities. The environment is shared by many living forms. The construction of nuclear plants as exists today in some locations may conflict with these other land uses or with the

FIGURE 2-1

MAIN TRANSMISSION NETWORKS

biota that occupy the land or adjacent waters. Adverse effects on the ecology do not necessarily occur only during operation. They might also be exhibited during the long construction period or plant shutdown following long periods of operation. The plants usually disturb the natural aesthetics of the area. They may preclude the development of the adjacent property, often for safety reasons, and sometimes may degrade land values in adjacent areas.

These siting factors may not be limiting, however, With planning and investigations at specific locations, it might be shown that multiple land uses or alternative plant siting concepts would result in more acceptable solutions. Perhaps with little cost penalty a solution is available; a reasonable compromise that may permit the operation of power plants at various locations throughout the State without preempting other potential uses in close proximity. This, then, is the goal of the power plant siting study.

2.2 STUDY SCOPE

To meet the stated goal, the study was pursued to assist the State of California in the development of long range plans for siting of electric power generating plants. The subjects covered in the study are very diversified and each capable of being investigated in great depth. It has been the intent in this study to avoid optimization and in-depth investigation on individual facets. It was deemed of greater value at this time to cover the spectrum of siting and siting concepts and the evaluation of the principal acceptability factors of each on a common basis to place them in proper perspective so that resources can be directed toward preferred siting concepts.

Criteria for siting plants include variations in aboveground concepts such as low profile, hillside, and inland plants; underground concepts; and offshore concepts including man-made or natural islands, seabed and undersea plants, and floating plants. Factors considered for each were technical feasibility, environmental acceptability, aesthetics, economics, and safety.

A number of concept studies have been performed and articles written to reflect the many ideas and considerations that seem appropriate to this study. These were identified from literature and interview sources and are listed in the bibliography presented in Appendix A.

Interviews were obtained with siting representatives of the larger California utility companies to obtain their siting philosophies and the results of their studies which are pertinent to this work. Discussions were also held with representatives of the nuclear steam supply system manufacturers who provided data relative to their products, studies they have performed relative to this work, and information on research and development being performed for advanced reactor systems and on siting concepts that may be applicable to the study. Further, the work performed by a number of other organizations was reviewed with them to obtain results of recent studies as might be related to this project. Finally, representatives of the Sierra Club were interviewed to obtain their views on siting and environmental impact, and discussions were held with representatives of the U. S. Atomic Energy Commission's Reactor Development and Technology and Licensing Divisions to obtain their views on the licensability of the alternative siting concepts which have been suggested.

It is important in this study that consideration be given to the evaluation of siting concepts which are suited to location in California. Naturally, a concept which is not compatible with California topography, hydrography, geology, seismology, and other physical and biological factors which might be peculiar to California sites is not of particular interest.

A great deal of coastal information is well documented by Federal and State agencies and was a major source from which data particularly related to this study was extracted. The coastal zone is not uniformly defined, but in the study the area to about one-quarter mile inland was investigated and, to a lesser degree, the area seaward about 3 miles from the shore was also reviewed including the offshore islands at somewhat greater distances. However, in reviewing the potential siting of power plants, consideration has been given to their possible coastal location as far inland as 1-1/2 miles.

Using the siting requirements for each considered concept and the inventory information, sites are identified in Sections 3 and 4 that appear to be well suited for locating each of the concepts. The existence of a sufficient number of these sites was investigated. Particular attention was given in the scope of work to identifying sites which might be considered for underground concepts and which are representative of segments of the California coastline. The main thrust has been given to determining candidate coastal areas in each of three soil types as follows:

1. A massive or moderately jointed igneous rock in formations best suited for underground excavation and support.
2. A massive sedimentary rock also well suited for underground excavation and support.

3. Unconsolidated sediments in a beach environment.

Other prevalent soil or geologic conditions have been assessed to reflect additional portions of coastline. These are also presented.

Economically feasible layouts and design aspects of underground plants were investigated as they might vary in the different coastal rock media existing in California. Implicit in this task was an assessment of the cooling and transmission lines and other elements associated with the concepts, as well as the construction and operating aspects. In addition, definition was given in Section 5 to aboveground and offshore concepts as well as their associated cooling water and transmission lines and other auxiliary systems or facilities. The selection of suitable facility materials, layouts for facility sizing, and site area requirements was identified as a basis for subsequent evaluations. Most major equipment systems in the plant also were identified since they affect the facility size and use for each concept. In addition, multiple uses of land or uses of reject heat, if applicable, were also identified so that each might be considered when assessing the acceptability of the concepts.

Transmission line design is changing as a result of demands to be more compatible with the environment in which they are placed. This forces consideration of alternatives to the high line approach, which has been used in populated areas most often in the past. In addition, the demand for higher capacity lines has generated research and development of systems with greater cooling capacity so that wire sizes can be minimized. The literature was reviewed and manufacturers interviewed to gain an understanding of the merits of the lines being contemplated and their potential availability. This is discussed in Section 5. These include aboveground high lines, low profile and underground lines, and submarine lines.

Alternative nuclear and fossil fuel power generation systems were also considered and are discussed briefly in Section 6. Feasibility was judged mainly against their potential acquisition in this century. In the United States, most existing designs for nuclear plants use the light water reactor system based on boiling water or pressurized water concepts. However, the high temperature gas-cooled reactor system has now reached the application stage. Also, a great deal of research and development effort is being directed to perfect more efficient breeder systems. It is possible that these nuclear steam supply systems may be called on for use in the siting concepts being considered in this study. Therefore, it was important to assess the effort required to perfect these systems by the year 2000 and to estimate the extent to which they will impact on the requirements of siting concepts or site criteria.

The nuclear reactor systems in use today or likely to be available to generate steam by the year 2000 are defined in Appendix B. For light water reactors, the pressurized water system was arbitrarily used as the base line in the assessment of siting concepts. Major components and safety systems are identified since they were the basis for sizing the facilities. Process flow sheets and brief system descriptions are included to identify interfaces with the facilities, site, or environment. In Appendix B, the main differences between the boiling and pressurized water reactor systems are identified. The gas cooled reactor system, including both the steam cycle and closed loop gas turbine applications, is also identified showing differences in facility requirements and environmental impact. Breeder reactors are presented with the greatest emphasis given to the liquid metal fast breeder system since the others appear to have less probability of development for commercial application.

The complexity of nuclear power plants, their environmental impact, and the siting factors which can be applied to reach an indication of acceptability dictate that a formalism be developed to make that judgment as objective as possible. Several approaches can be taken in the decision making process for ranking siting concepts; but unless the assessments for judgment are quantified, the ranking will be subject to greater question. An assessment was made of formalisms which have been used in the past, with the idea of selecting one, or developing another, to provide a framework for a formal evaluation, yet giving flexibility in the quantification being implemented. The resultant methodology used in the study is discussed in Appendix C.

The evaluation process began first with the assignment of evaluation factors, weights, then derivation of a measure of merit for each factor and a quantification of that measure for each concept. Every quantification was used to rate acceptability of the factors for each concept, and all factor ratings for each concept were then combined in the prescribed evaluation approach to permit comparison between concepts and ranking.

This report consolidates the work accomplished in the study and contains the concept layout drawings; major equipment and material identification; and the detailed evaluation information including cost, environmental impact, feasibility, and risk. It also contains study conclusions and recommendations for action or for follow-on work.

3. COASTAL SITING

An evaluation of the pertinent aspects of the environment of the coastline of California includes consideration of physiography, land use, geology and seismology, oceanography and meteorology, and biology and ecology. The following sections, supplemented with maps and figures provide a brief description of the general environment of the California coastal region.

In preparing this section, the Comprehensive Ocean Area Plan, the California Coastline Preservation and Recreation Plan, National Shoreline Study - California Regional Inventory, and the Geologic Atlas of California were heavily drawn upon. It is not the intent of this environmental overview to provide the bases upon which specific site selection decisions can be made, but rather to provide an environmental framework within which the siting concepts can be evaluated. The descriptions which follow are, therefore, limited in scope to the features which appear most pertinent to the basic purposes of this study, and in depth to a degree only to suggest potential regions, not to select specific sites.

3.1 ENVIRONMENTAL CHARACTERISTICS

3.1.1 Physiography

The terrain of the California coastline varies from flat marshland to nearly vertical cliffs. Harbors and bays are found all along the coast. An illustration of shore type is shown in Plate 3-1. Major drainage, estuaries and bays, and areas prone to landslides are also indicated. Siting constraints included in this subsection and detailed on Plate 3-1 may not necessarily preclude areas from nuclear power plant siting. For example, with appropriate plant design and site preparation, landslide potential may be removed from the actual plant area.

The major estuaries are Humboldt Bay in Humboldt County; Bodega Harbor in Sonoma County; Tomales Bay, Drakes Estero, and Bolinas Lagoon in Marin County; San Francisco Bay; Monterey Bay; Morro Bay in San Luis Obispo County; Los Angeles/Long Beach man-made harbor; and Mission and San Diego bays.

Three major physiographic provinces are found along California's 1,072-mile-long coast. The Coastal Ranges, extending from the Oregon border to Santa Maria Valley, are bounded by the Pacific Ocean on the west and the Great Valley on the east. The Transverse Ranges extend from the Coastal Ranges to the Los Angeles basin. South of the Los Angeles basin to the Mexican border, the Peninsular Ranges are found.

Beginning at the Oregon border, predominantly narrow sandy beaches backed by low lying terraces extend 4 miles into Del Norte County to the Smith River. Sand dunes up to 40 feet in height fringe a 4 to 6-mile wide coastal plain down to Point St. George. Point St. George is a rocky promontory surrounded by sea stacks and small islands. The coastal plain extends past Crescent City to the Redwood National Park.

From the redwoods to Trinidad, in mid-Humboldt County, the coastline is rugged, sloping in many areas to elevations over 1,000 feet. Some pocket beaches and offshore rocks are found along this stretch. About 20 miles south of Point St. George, the Klamath River enters the Pacific. Three lagoons south of Orick all have been isolated from the sea by sandbars.

The stretch between Trinidad and Cape Mendocino is an almost continuous narrow sandy beach, broken only by the wide area at Clam Beach and the entrance to Humboldt Bay. North of the bay, coastal plains at elevations of 100 to 200 feet are found behind the beaches, while to the south is the 8-mile wide Eel River floodplain extending 12 miles inland.

From Cape Mendocino south to Tomales Bay in Marin County, the coastline is typified by sinuous rugged headlands sloping to elevations of 1,000 to 4,000 feet and a few scattered sandy beaches. Receding sea cliffs and discontinuous remnants of elevated wave-cut terraces generally mark this section of the shore. Some landslides are also found in this stretch.

South of Tomales Bay to Point Reyes the shoreline is generally narrow sandy beach, backed by dunes. From Point Reyes to the entrance to San Francisco Bay, the coast is again rugged, with occasional beaches and offshore rocks backed by 50 to 100-foot high cliffs. Bolinas Lagoon, almost blocked by a sandy spit, is found about 15 miles to the north.

The shore along San Francisco County is generally sandy beach backed by dunes or 50 to 75-foot cliffs. Northern San Mateo County is typically very rugged with small pockets of sandy beach backed by steep 100 to 200-foot cliffs and some landslides.

From Half Moon Bay to Pescadero Point, mostly wide continuous sandy beaches backed by several indistinct wave-cut 50 to 100-foot terraces are found. From Pescadero Point to Santa Cruz, discontinuous beaches are backed by hills sloping to elevations over 1,000 feet.

The sandy beaches of Monterey Bay, from Santa Cruz to Pacific Grove in Monterey County, are backed by wide coastal plains, including the Elkhorn Slough and the Salinas River Delta.

The stretch from Pacific Grove to Morro Bay in San Luis Obispo County is one of the most rugged along the California coast. With some offshore rocks and occasional beaches, the coastal slopes rise abruptly to elevations of 1,200 feet. Dune sands on a broad terrace connect Point Sur to the mainland. Southward, the beaches are discontinuous, narrow, and rocky; and the shore is typified by rugged, pointed headlands, sequestered coves, and sea stacks backed in places by 1,000-foot nearly vertical cliffs.

San Luis Obispo Bay has a sandy shore backed by 40-foot sand dunes, low terraces, and the Santa Maria River. Morro Bay is similar except that it is blocked by a sandbar.

Santa Barbara County north of Point Conception is characterized by prominent rocky headlands separating stretches of narrow sandy beach backed by wave-cut terraces reaching to about 100 feet in height. Point Conception is the point of change between the dominant north-south trend of the coastline to the north and the nearly east-west trend to the south. The east-west trend is characteristic of the Transverse Ranges of California. This province extends along the coast from the Santa Maria Valley to Santa Monica and then inland toward San Bernardino.

The northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa) have shorelines consisting of pocket beaches backed by 50 to 200-foot cliffs. Occasional low plains are also found. These islands, members of the Transverse Ranges, trend east-west.

From Point Conception to central Ventura County, sandy beaches along most of the shore are backed by 20 to 50-foot bluffs or terraces. From Central Ventura County to Point Mugu, sandy beaches are backed by low marshlands. South of Point Mugu, down to Santa Monica, intermittent narrow sandy beaches, backed by the Santa Monica Mountains reaching to elevations over 2,000 feet, are interrupted by rock headlands. The Los Angeles basin again marks the northwest-southeast trend in the coastline and the beginning of the Peninsular Ranges province.

The Santa Monica Bay shoreline is sandy beach backed by predominantly residential development. Palos Verdes Peninsula is generally rocky beach backed by 13 distinct wave-cut marine terraces, the highest of which is 1,300 feet above sea level.

The southern Channel Islands (San Clemente, Santa Barbara, San Nicolas, and Santa Catalina) are similar to the northern islands with respect to beach character, but trend northwest-southeast as to the Peninsular Ranges of which they are a part.

The Los Angeles/Long Beach Harbor area has been mostly man-made; however, some sandy beaches are found.

South of Los Angeles to La Jolla, the coastline is generally narrow sandy beach backed by 50 to 100-foot high terraces. Occasionally, marshes and steep bluffs are found. Some landslides have occurred in northern San Diego County.

From La Jolla to Point Loma, except at the entrance to Mission Bay, sandy beaches are backed by 100 to 400-foot cliffs; south of Point Loma is San Diego Bay. From the Island of Coronado to the Mexican Border, there are sandy beaches backed by developed areas or low marshes.

The continental shelf is the gently sloping submerged marginal zone of the continents extending from the shore to an abrupt increase in slope (continental slope). Three general offshore provinces are found along the California coast.

From the Oregon border to Cape Mendocino the shelf averages 15 miles in width, generally wider than elsewhere to the south. Relatively few submarine canyons are found in this section; the Eel Canyon forms the notable exception.

The stretch between Cape Mendocino and Point Conception is more characteristic of the continental margin of the western North and South American continents. Although it has a maximum width of about 30 miles off San Francisco, near Monterey the shelf narrows to less than 2 miles. Many submarine canyons, including some of the largest in the world, dissect this reach.

South of Point Conception, the shelf narrows averaging 4.5 miles in width. Beyond the shelf is found a broad zone of underwater mountains and valleys similar to the basin and range province of southeastern California, Nevada, western Utah, and southern Arizona. Some of the mountains have sufficient relief to form the southern California islands.

There are a limited number of shallow water areas which are 3 miles or more from shore. These few miles with 40 to 60 feet of

depth occur principally offshore from San Francisco, Ventura, and La Jolla. In most coastal zones, the 40 to 60-foot depth occurs about a mile or so from the shore, with a number of these situations considerably closer.

3.1.2 Land Use

Land use has been divided into three categories: populated, agricultural, and undeveloped. Plate 3-2 indicates the approximate distribution of each of these as well as archeologic and historic sites, parks, education and research sites, and major cities.

Generally, north of Santa Barbara most of the coast is relatively unpopulated; development is sparse and intermittent. Notable exceptions occur at and near the cities of San Luis Obispo, Monterey-Carmel, Santa Cruz, San Francisco, Eureka, and Crescent City. Except for a few locations in Ventura County, the shore is developed and populated south of Santa Barbara to San Clemente in northern San Diego County. From Oceanside south to Imperial Beach, virtually all the coastline is populated.

Archeologic and historic sites which are of significant cultural value occur along the coastal region. Historic eras in California include the Indian Era (15,000 B. C. to about 1850), the Hispanic Era (1525 to 1850), and the American Era (1800 to the present). About 60 known historic sites span the coastline of California. Future research may reveal additional sites of value which must be considered in planning.

State and national parks and beaches, individually ranging from less than 1 to more than 30 coastline miles, are found all along the California shoreline. Most of these, however, are found in the central and southern counties.

About 40 education and research sites are located on or planned for specific areas along the coastline. These sites, individually ranging in extent from a few hundred feet to over 10 miles, primarily represent areas of value to marine-oriented research and educational activities. Their environs should be maintained in their natural state if current value is to be maximized. The majority of these sites are located in the central and southern portions of the coastline.

3.1.3 Geology

The coastline of California can be separated into three geological provinces: the Coastal Ranges, the Transverse Ranges, and the Peninsular Ranges. Two of these, the Coastal Ranges and the Transverse Ranges, have distinct aspects within their province.

The Coastal Ranges in California extend from the Oregon border south to about San Luis Obispo, at which point the province turns inland. The Coastal Ranges can be separated into northern and southern segments at San Francisco. The segment from the Oregon border to San Francisco can be subdivided for discussion purposes into three aspects.

The first aspect extends from the Oregon border to Humboldt Bay. Here eugeosynclinal rocks (clastic and volcanic assemblages) of Franciscan or mid-to-late Mesozoic Age are associated with ultramafic basement complexes. The second aspect reaches from Cape Mendocino south to Point Arena where the ultramafic basement complexes are absent from the Franciscan sequence. The third aspect, from Point Arena to San Francisco, is typified by granitic basement complexes on the west side of the San Andreas fault and ultramafic basement complexes on the east associated with Cenozoic marine sedimentary rocks and some Franciscan material. The trace of the San Andreas fault closely follows the coastline in this area.

The southern Coastal Ranges, extending from San Francisco to San Luis Obispo, can be subdivided into two aspects. The northern aspect, from San Francisco to about mid-Monterey County, is similar to the section from Point Arena to San Francisco in the northern Coastal Ranges except that more granitics are found.

The southern aspect of the south Coastal Ranges is similar to the northern aspect of the north Coastal Ranges. Here, again, the eugeosynclinal clastic and volcanic rocks are associated with ultramafic basement complexes.

The Franciscan rocks are generally quite shattered and friable. Some durable sandstones and volcanics are found; however, for the most part, these rocks have the reputation of being prone to sliding.

Past the Santa Maria River Valley, the general structural fabric of the coastline changes from predominantly northwest-southeast to east-west. The east-west fabric marks the Transverse Ranges' province.

This province extends from about Point Arguello on the north to the Los Angeles basin on the south. Two distinct aspects can be distinguished in the Transverse Ranges. The northernmost, ranging from Point Arguello to the Oxnard Plain, is comprised of massive durable sandstones interbedded with cherty or siliceous shales. South of the Oxnard Plain, and including the northern Channel Islands, the Transverse Ranges are typified by less durable clastic rocks associated with volcanics.

The southern islands, plus the Palos Verdes Peninsula, represent another distinct zone. The structural fabric changes back to northwest-southeast. Franciscan rocks are found on Palos Verdes Peninsula and on Santa Catalina Island. Volcanics are found on San Clemente and Santa Barbara islands. Cenozoic marine sedimentary rocks, mostly shales with some sandstones, are found on San Nicolas Island and on the Palos Verdes Peninsula.

South of the Santa Ana River the Peninsular Ranges extend through the remainder of the State. Cenozoic marine sedimentary rocks, generally weak and friable, overlie more indurated Mesozoic sedimentary rocks. The basement complex here is Mesozoic granitic rock; however, no granite is found on the coast.

Six major basins are found along the coastline in which very young continental sediments are found. These basins are the Humboldt Bay area, the San Francisco Bay area, the Salinas River Valley, the Santa Maria River Valley, the Oxnard Plain, and the Los Angeles basin.

The general geology of the sea floor can be inferred by projecting some of the faults and rock types found on the mainland and offshore islands to the sea. Information is minimal for most offshore areas except the Santa Barbara Channel and the Los Angeles basin where extensive oil exploration has occurred, and information is published. Some additional information may be available from the utility and oil companies which have done work in specific areas.

A generalized setting of the engineering aspects of the geology is presented in Plate 3-3. For the purpose of this description, the geologic formations along the coast have been grouped into nonmassive semihomogeneous soil, massive to nonmassive heterogeneous rock, and massive homogeneous rock.

Heterogeneous rocks comprise the majority of the coastline associated with only minor amounts of semihomogeneous soil. Heterogeneous rocks include the Franciscan sediments, volcanics, and metamorphics as well as poorly to well cemented sedimentary

rocks of all ages including shales, sandstones, and conglomerates. Some of the rocks in this category are quite massive and capable of forming durable cliffs and rugged topography, while others are fractured, foliated, and prone to landsliding or severe erosion. Massive to nonmassive heterogeneous rock can be expected to be quite varied. Even though geologic maps indicate the same formation in two areas, excellent foundation support could be found in one area where massive rock is exposed, but unsatisfactory support could exist in another area of nonmassive rock. Vertical excavations may be made in areas of very flat bedding and no joints; but in areas of dipping, bedding, or jointed rocks, excavations may have to be sloped appropriately or artificially supported with rock bolts or other systems. Groundwater also may be encountered in this environment. Pockets of gas, brine, and other fluids can be found in some occurrences of permeable sedimentary rocks such as sandstone.

Massive homogeneous or igneous rock occurs along the coast in only three counties: Marin, San Mateo, and Monterey. Due to past tectonic deformations near the coast, most of the rocks, including the granitics, are at least somewhat fractured. The massive homogeneous rocks, such as granite, generally can provide excellent foundation support and stand in unsupported vertical cuts. Because all rocks in the Coastal Ranges have been somewhat fractured, rock bolting or other techniques may be required to support underground openings. The degree of fracturing can be expected to vary widely within the same geologic formation. Problems involving groundwater and gas can be expected to be minimal in this environment.

The nonmassive, semihomogeneous soil segments indicated on the coastal geology map are represented by sand dunes, marsh muck, river deltaic deposits, and generally very young alluvial materials. The environment for facilities in nonmassive semihomogeneous soils would probably provide satisfactory foundation support; however, some densification or other preparation may be necessary for economical design. Excavations on land in this material probably would not be able to stand with vertical sides for any significant height, and all backfill would need to be compacted for acceptable support. Problems that may be encountered during work in this type of soil are groundwater occurrence or pockets of low density material.

Regional ground subsidence can be attributed to withdrawal of large volumes of fluids (water or oil) from subsurface strata. With the exception of the subsidence of the Wilmington field near Los Angeles/ Long Beach Harbor, and the Huntington Beach field in Huntington Beach, few California offshore or onshore fields appear to be subject to major

subsidence (a number of other locations exhibit lesser degrees of subsidence, however). Water injection to replace oil now being withdrawn has successfully stabilized subsidence in the Wilmington area; but future production from these fields, and possibly from fields yet to be developed, could cause future problems.

Because soft bottom deposits probably will not provide satisfactory foundation support for dikes or man-made islands in shallow water, this material will have to be removed.

3.1.4 Seismology

The margin of the Pacific Ocean forms a trace of significant historic seismic activity. A majority of the world's recorded earthquakes have occurred along the Pacific Rim. Instrument recording techniques for strong motions, however, were not developed until the early thirties; prior to that time, earthquake effects were measured by severity of damage. By using the scale of damage (Table 3-1, Modified Mercalli Intensity Scale of 1931), the earthquake record for California can be extrapolated for a prior period of almost 200 years. California earthquakes of Intensity V and greater are shown on Plate 3-3. In general, three modes of failure can result from seismic activity. Earthquakes can:

1. Generate destructive vibratory ground motion.
2. Cause ground failure.
3. Generate seismic sea waves.

Vibratory ground motion causes damage to structures by inducing stresses not anticipated in design. Earthquakes close to a structure can generate short period, high frequency ground motion. Distant earthquakes can generate long period, low frequency ground motion of long duration. A nearby earthquake will have a higher intensity at a particular site than a distant earthquake of the same magnitude; however, the San Andreas fault zone, historically capable of generating a magnitude 8.5 earthquake, is within damaging range to ordinary structures of a considerable portion of the coastline. Therefore, a large earthquake on the San Andreas fault may be more damaging at a site than a closer, though lower magnitude, earthquake.

Four different kinds of ground failure can be precipitated by earthquakes: surface rupture, mass movement, liquefaction, and tectonic movement. Surface ruptures, or fault breaks, can be

TABLE 3-1

MODIFIED MERCALLI INTENSITY (DAMAGE) SCALE OF 1931

I.	Not felt except by a very few under especially favorable circumstances. (I Rossi-Forel Scale.)
II.	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel Scale.)
III.	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel Scale.)
IV.	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably. (IV to V Rossi-Forel Scale.)
V.	Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel Scale.)
VI.	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel Scale.)
VII.	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars. (VIII Rossi-Forel Scale.)
VIII.	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed. (VIII+ to IX- Rossi-Forel Scale.)
IX.	Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken (IX+ Rossi-Forel Scale.)
X.	Some well built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel Scale.)
XI.	Few, if any, structures (masonry) remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII.	Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown upward into the air.

particularly destructive if they occur directly beneath a structure. Mass movements, i. e., landslides, mudflows, and rockfalls can be caused by earthquake activity. A saturated, loosely compacted granular material can lose its strength if earthquake shaking causes the load on the soil to be transferred from grain-to-grain contact to the pore water. This phenomenon is commonly called "liquefaction." California, unlike Alaska or Chile, has not recently experienced major tectonic movements (uplift or subsidence) that can be associated with seismic activity. Large crustal blocks (thousands of square miles) have uplifted or down-warped as much as 15 to 50 feet in some places in Alaska and Chile within recorded history.

Seismic sea waves (tsunamis) usually generated by distant submarine earthquakes can also cause damage along coastal areas. Earthquake triggered submarine landslides can generate large sea waves. Seiches (locally generated sloshing) can cause damage in enclosed or partially enclosed areas. These are discussed in the next section.

Structures in seismically active areas must be designed according to established criteria and for a given level of acceptable risk. Faults represent a key factor of interest. "Active" faults are usually defined as those associated with geologically recent earthquakes. The Atomic Energy Commission has defined active faults as those on which one movement has occurred in the last 35,000 years or two movements in the last 500,000 years.* Active faults can also be inferred from the location of recorded earthquake epicenters. Determining the activity of faults can be difficult and nonconclusive, depending upon the extent and methods of investigation.

Referring to Plate 3-3, the major fault zone in California is the San Andreas rift zone. This fault enters California in the Imperial Valley near El Centro and trends northwest through San Bernardino and Palmdale. Near the town of Gorman, the fault trends nearly west into San Luis Obispo County and then turns again northwest. Near Monterey, the fault approaches the coast, finally intersecting the coastline south of San Francisco. From there the San Andreas closely follows the shoreline into southern Mendocino County. The fault continues its northwest trend a short distance offshore until it approaches Cape Mendocino in southern Humboldt County at which point it turns west and heads out to sea in the Mendocino fracture zone.

* 10CFR100, Appendix A, November 3, 1971 (Proposed)

Many other faults are found near the California coastline. North of Point Conception the faults are generally parallel to the great San Andreas. From Point Conception to Santa Monica, including the northern Channel Islands, the trend is generally east-west. South of Santa Monica, including the southern Channel Islands, the major direction is again north-west. Offshore areas are faulted similarly to their adjacent onshore areas, but the faults are only approximately located and all may not be known.

While instrumental earthquake records have been collected for a relatively short period of time, methods are available for evaluating seismic activity. Before the consequence of seismic activity can be assessed realistically for any particular site, detailed site characteristics, such as material densities, viscoelastic properties, and material geometries, must be known. Field, laboratory, and theoretical methods exist for determining these properties. Some zones in the State have been more seismically active than others in the recent past.

Earthquake data may be displayed in several ways to give some idea of the relative activity existing in various areas. One method is presented on Plate 3-4, which is an isoseismal map of California showing areas which have been shaken by damaging (Modified Mercalli Intensity = VIII or greater) earthquakes from 1769 to 1972. This presentation can be used in an analysis of seismic hazard by assuming that most future earthquakes will follow historic patterns, i.e., that the largest historic earthquakes will recur at the same locale. The presentation does not give guidance as to what might be expected different from what has occurred in the past. Based on this assumption, areas of expected low, moderate, high, and damaging intensities along the coast are also shown. Another method of presenting data is shown on Plate 3-5. This method* outlines zones where given maximum intensities can be expected, but it is also historically based. It has the same limitations as the isoseismal map even though it incorporates some interpretation of the historic data. Despite these obvious limitations, the maximum credible earthquake used as a basis for seismic analysis is developed by practicing seismologists integrating historic seismic data with known geologic structure.

3.1.5 Oceanography and Meteorology

An overview of the oceanography and meteorology of the coast is presented in Plate 3-6.

The California Current, a continuation of the Aleutian Current and the North Pacific Drift, moves cold water southeastward along the coast. The prevailing northwesterly winds during the spring and summer force

*"Urban Geology - Master Plan for California, Phase I," State of California, Division of Mines and Geology, December 1971.

surface water obliquely along the shore resulting in an offshore movement. Nutrient-rich colder water rises to the surface close to shore to replace the surface waters and thereby plays an important role in the life cycle of marine organisms and sea mammals which feed on these nutrients. The upwelled colder water is also an important factor to the climate of the coastal zone. Surface temperatures along much of the California coast are partially equalized in the autumn when the warm Davidson Current replaces the colder upwelling water.

During the winter, large waves generated by storms in the northeast Pacific strike the coast, opening some river and stream mouths that are closed during the summer. The smaller waves of summer cannot remove all the sediment that travels down the rivers and streams, resulting in sandbars or spits that cut off the estuaries from the sea.

The predominant direction of littoral drift along the coast is north to south. This pattern is very general, and eddies and reversals are common. Plate 3-6 summarizes the volume of transported sand in thousands of cubic yards per year. An alongshore current is created by the oblique angle at which the waves strike the shore. The sand, carried in the zone of turbulence, travels very close to the beach until it reaches submarine canyons along certain portions of the coast where it is lost to the system.

Some damaging waves can be generated by storms in the South Pacific. The beach along the Oxnard coast has been notably affected by these short period waves. Severe erosion and cliff retreat can result from the storm surges. Seiches (locally generated oscillatory waves) can also cause damage in enclosed or partially enclosed areas such as Humboldt Bay.

Tsunamis (seismic sea waves) are usually generated by distant earthquakes and submarine avalanches. Occasional earthquakes in Chili, Japan, Siberia, or Alaska generate tsunamis which periodically affect the California coastline. Generally, earthquakes in California do not create sea waves which affect its own coast. Table 3-2 gives recorded maximum tsunami rise or fall heights at selected stations along the coast.

The surface sea temperature during the winter months generally varies from about 52 F near Cape Mendocino to 58 F near Santa Monica. The summer temperatures vary from 50 to 55 F in northern California to 65 to 69 F in southern California.

TABLE 3-2

MAXIMUM TSUNAMI RISE OR FALL HEIGHT AT SELECTED
STATIONS FOR RECENT LARGE EARTHQUAKES*

Maximum Tsunami Height (feet)				
Earthquake	Kamchatka	Aleutian	Chile	Alaska
Date	11/4/52	3/9/57	5/23/60	3/28/64
Magnitude	8.3	8.0	8.5	8.4
California Stations				
Crescent City	6.8	4.3	10.9	16.4
San Francisco	3.5	1.7	2.9	7.4
Avila Beach	9.5	3.5	---	10.4
Santa Monica	3.6	3.0	9.1	6.5
Los Angeles (Berth 60)	2.0	2.1	5.0	3.2
La Jolla	0.8	2.0	3.3	2.2
San Diego	2.3	1.5	4.6	3.7

* After Wilson, 1969.

The coastal zone is marked by relatively warm winters and cool summers due to air moving westerly to northwesterly across the warm Davidson Current in the winter and the cool California Current in the summer. The winds are generated by the semipermanent high and low pressure areas of the north Pacific Ocean. In the winter, the high pressure area (Pacific High) is located to the south or west of its summer position resulting in migrating storms which penetrate California from the strong low pressure area (Aleutian Low). The summer in the coastal zone is nearly rainless because, as the continent warms, the Pacific High expands forcing the Aleutian Low northward.

Fog or low clouds frequently are found during the summer as the moist Pacific air moves over the upwelling colder water along the shore. In addition, occasional temperature inversions may prevent air at lower elevations from mixing with the upper layers and thereby encourage the collecting of polluted air, or smog, in the lower zones. These temperature inversions also form in many of the plains or basins along the coast.

Average annual minimum and maximum air temperatures are also shown on Plate 3-5 for the various stations. The average annual air temperatures vary from about 52 F near Eureka to about 62 F in southern California.

The average annual rainfall, also indicated on the map, ranges from nearly 100 inches near the Oregon border to less than 10 inches in southern California.

3.1.6 Biology

A highly generalized picture of California coastal biology is presented in Plate 3-7 showing rare or endangered and certain additional key species. These include the southern bald eagle, the Guadalupe fur seal, the American peregrine falcon, the Morro Bay kangaroo rat, the California least tern, the Santa Cruz long-toed salamander, the San Francisco garter snake, three varieties of rail, and the brown pelican. Habitats for these are noted on Plate 3-7. Also, four species of whales migrate along California coastal waters. No attempt has been made to list California's numerous rare or endangered plants; many of these do not have common names and occur at numerous, scattered locations along the coast. The famous Pismo clam beds and the sea otter habitats are also located on Plate 3-7; while not classified as rare or endangered, these receive considerable public attention. Kelp beds and the marine community they support are also of great significance,

as are the various attached marine algae in rocky areas, but they are not located because of their wide distribution.

Seven principal vegetative on-land communities include coastal strand, coastal sagebrush, north coast grasslands, north coast scrub, maritime pine forest, redwood forest, and urban agriculture. These communities provide habitat for seven relatively distinct groups of wildlife.

The coastal strand community, usually associated with sand dunes, is generally comprised of low or prostrate vegetation containing some shrubs. Characteristic to this community are the Western and California gulls, the sanderling, the snowy plover, and the sand crab. This community is found in the north, central, and south coast counties.

The coastal sagebrush community, usually found on dry, rocky, gradual slopes, is characterized by shrubs up to 5 feet high with some cacti. Characteristic are the squirrel, two varieties of rats and mice, species of hummingbird, wren, and lizard, and two species of sparrows and snakes. This community is found at various places along the coast south of San Francisco.

North coast grasslands are found along the Mendocino and Humboldt coasts and just north of San Francisco in Point Reyes National Seashore. These grasslands are composed of dense, medium tall, meadow-like grasses and are found on western slopes in the northern counties. Typical wildlife found here are ground squirrels, rabbits, larks, gopher snakes, and crickets.

The north coast scrub community includes bushes and grasses. The bushes seldom reach 6 feet high, and the grassy areas are often extrusive. Characteristic wildlife are deer, racoon, rabbit, mountain lion, fox weasel, skunk, chipmunk, gopher, rat, wren, jay, goldfinch, sparrow, lizard, snake, and salamander. This community is found between the coastal strand and the redwood communities and at some isolated places in the central counties.

Pine and cypress trees are the dominant members of the maritime pine forest community found adjacent to and south of the redwoods in Humboldt County. Isolated occurrences of this community are found at various places along the coast, such as at Cambria in San Luis Obispo County and at Torrey Pines near San Diego. The Pygmy Nuthatch may be found in this community.

The redwood community, located in southern Del Norte County and northern Humboldt County, is generally protected by national park status. Other occurrences are in Marin and Monterey counties. Elk, deer, bear, mountain lion, coyote, weasel, skunk, beaver, squirrel, wren, quail, goose, woodpecker, snake, and salamander are the characteristic land animals and birds of this community.

Steelhead, salmon, shad, and trout are the characteristic fishes living in the cold water streams of this area. These anadromous fishes also require suitable water quality in the ocean, especially near the entrances to rivers and streams, in order to successfully complete their life cycles.

These fishes are not confined to the redwood community. All described communities could have anadromous fish runs depending upon seasonal water supply and a minimum flow in upstream areas throughout the year.

The urban agricultural community is typified by the developed areas such as in the San Francisco and Los Angeles/Long Beach areas. Here, development has almost completely eliminated natural vegetation.

The coastal marine environment consists of three coastal types: rocky shore, sandy beach, and bays and estuaries, plus the offshore region of the open ocean. The coastal types include the intertidal zone, between the limits of high and low tide, and the subtidal zone from the low tide limit seaward.

The rocky shore intertidal zone is characterized by the rock louse, red, green, and brown algae, barnacles, limpets, mussels, turbin snails, shore crabs, anemones, starfish, sculpins, and sea gulls. The rocky subtidal zone includes abalone, starfish, anemones, urchins, red and brown algae, lobster, crabs, octopus, sponge, shrimp, bass, rockfish, sea lion, and otter.

The sandy beach intertidal is typified by the beach louse, sand flea, sand crab, red beach worm, bean clam, pismo clam, and shore birds. The sandy subtidal includes the sand dollar, pismo clam, sand start, moon snail, shrimp, flatfish, stingray, grunion, and surf perch.

Bays and estuaries are characterized in the intertidal zone by the shore crab, gaper clam, ghost shrimp, seal slug, chione, soft shell clam, arrow gaby, eel grass, and numerous shore birds. The subtidal includes the sea pen, Washington clam, sea hare, bent nose clam, burrowing anemones, tube worms, and spiny dogfish.

The open ocean is typified by mackerel, barracuda, anchovy, tuna, shark, porpoise, whales, and petrel.

The foregoing is intended to provide a brief overview of the biological character of the California coastal region. No evaluation has been made as to the sensitivity of individual species to the effects of power plant construction or operation. In the case of biological communities, sensitivity to thermal and other effects may be undetermined, or at least controversial. Some species may be adaptable to a changing environment but may depend for food on other species which are not adaptable. Ecosystems and food webs must, therefore, be considered as functional units; evaluations cannot be limited to single species. Also, evaluations cannot be limited to the effects of a single plant; cumulative and long-term effects are pertinent. The usefulness of the biological data presented herein is therefore severely limited. In subsequent evaluations of impact, gross judgments have been made based on assumptions relative to the sensitivity of individual species of particular concern, such as those noted herein. It is of the utmost importance that several proposed sites be carefully considered for possible negative biological effects before final site selection. It is equally important that after such selection, accurate biological investigations be conducted, which will indicate methods to reduce or eliminate undesirable ecological side effects.

3.2 SUMMARY OF SITING CONSIDERATIONS

3.2.1 Seismic Activity

Siting considerations for plants in California are quite different from siting in most other areas of the United States. In California, it is most often necessary to consider the seismic factor before other siting parameters. Considering the present state of the art for design of nuclear plants to withstand both ground motion and displacement, there are large areas of California which would have to be either excluded entirely or studied in great depth to assure that plants could be operated in the area with acceptable risk. Seismic considerations of this depth are well beyond the scope of this study; where seismic exclusion areas are presented in the study, they are based on only a cursory review of recorded data.

All of California has experienced some ground motion generated from regional earthquakes, and a large portion of the State has faults which could be interpreted as "active." The AEC regulations for seismic criteria are rather specific. Since the presence of active faults specified by the AEC imposes design criteria constraints, and may preclude

licensing, the seismic question becomes most critical. This has, and will continue to have, a pronounced effect on the future siting of nuclear power plants in the State of California.

Certain areas of the State can be excluded readily because they are in close proximity to well known and understood active faults such as the San Andreas. Seismic risk analyses become most complex in areas where the degree of confidence in dating of faults is low, and where ground motion records may not be complete or reliable. Many such areas exist both along the California coast and inland which would otherwise provide attractive sites from the standpoint of most other criteria to be considered in plant siting. The problem facing the utility is that if the site is selected within one of these unproven areas, a great deal of time and effort may have to be expended in order to generate the proof required to satisfy the AEC siting regulations. There is always the possibility that a license may not be granted because of disagreement regarding the degree of proof actually required and a possible emotional reaction among the general public over the problem of siting the plant in a seismically active area. In addition, there may be substantial disagreement among the experts over acceleration design criteria.

In the case of underground siting, it has been noted that additional faulting may be exposed in the cavities developed for various components of the facility. Each such fault would need to be carefully examined and dated in order to satisfy regulations. It is possible that this process could make the licensing of an underground facility even more difficult to obtain than for an aboveground facility at the very same site.

Offshore plants, particularly those supported on the sea floor (such as a plant sited on an artificial island or one whose foundation is on or extends to the floor), will require extensive original seismic investigation. This is because existing offshore data has been limited mostly to areas of specific industrial interest. Certainly little historical data are available for actual ground faults offshore and there are no data available for subsea ground motion during the great historic California earthquakes. Therefore, offshore concepts would require substantial seismic investigation which would almost certainly lead to conclusions and design seismic criteria which inherently would have to be more conservative because of the lower degree of confidence resulting from a lack of historic data. In the case of a floating offshore concept where only the breakwater rests on the bottom, the problem may not be so critical because a breakwater fracture would not necessarily encourage penetration of wave forces, nor inhibit the protection from ship collisions. In this case, other problems may also apply which are now being considered carefully in the design of the Atlantic station off the

New Jersey coast. For instance, wave-induced liquefaction of soil supporting the breakwater is a phenomenon for which study is required, and would almost certainly become an important consideration in conjunction with liquefaction induced by seismic activity.

3.2.2 Land Use

Although proximity to centers of population is an extremely important and critical criterion to be considered in the siting of a plant, it is one which is readily identifiable by the layman. The exercise of good judgment and prudence in this regard will probably lead to a satisfactory site choice in most cases. The advanced and sophisticated demographic analyses now required by the Atomic Energy Commission are not so much to prove that the plant is sufficiently far from people as it is to develop data on which radiation dose can be computed, and this, in turn, affects plant design. It would be relatively simple to exclude portions of the State in which the distances to population centers are less than for plants elsewhere which have been successfully licensed.

Other aspects of land use, also important criteria when considering licensing, include park sites, Indian reservations, biological and other research stations, historic sites and monuments, and a wide variety of other land uses. While some of these uses might exclude the operation of a nuclear plant on that property, many uses may not constrain the location of a plant on land immediately adjacent. An exception might be a biological research station where plant effects on biota would invalidate the research effort. There are also preserves for fish and wildlife which become important ecological considerations.

3.2.3 Biota

Rare and endangered species are important, but there are numerous species of wildlife for which there is general concern. It is necessary to show that each plant will have essentially little effect on any species, on a case by case basis, except perhaps for the removal of a small amount of habitat; or that the benefits of the plant outweigh the importance of the biotic community in that area to society as a whole. It is not likely that the existence of one or even a number of power plants in California would generate sufficient risks to a single species that the species would be lost from the earth forever. This is stated in consideration of the fact that in conjunction with construction of a plant, habitats of many such species in nearby areas may be enhanced by improved wildlife management programs undertaken to balance the effects of the plant on the various ecological communities. Public exclusion areas

created around nuclear plants will provide more habitat for species such as the rare clapper rail which is forced to avoid public beach areas. It may be difficult, however, to prove in advance the success of such management programs when wildlife is abundant in these areas, but whose habitat is fast disappearing elsewhere.

In the case of the California coastline, numerous aquatic and terrestrial species exist that are important to the overall ecological balance and, therefore, through the food chain to man. Beyond the rare and endangered list, such species as the abalone, the sea otter, the clams at Pismo and other beaches, and the redwoods on land to the north are examples of biological communities which receive wide public attention and whose sensitivity to plant effects must be analyzed in the siting process. Indeed, so many such species are distributed along the coast that no coastal position should be considered free from the need for ample attention and study. Kelp, bordering vast stretches of the coastline, is a most critical example in this regard. To exclude all of the kelp areas from plant site possibilities would remove much of the otherwise acceptable areas of coastline. The problem, therefore, may become one of cooling waterline design, and of consideration of the tolerances the kelp has to water temperature increases.

In the case of a single plant, an outfall design may prove totally effective in avoiding any damage whatsoever to the kelp, except perhaps for temporary damage in laying the outfall during construction. In consideration of a large number of nuclear plants all along the coast, however, the thermal problem becomes more significant to some of the more temperature-sensitive species of which kelp may be one. Such species might possibly be endangered even though each individual plant is satisfactorily designed in consideration of its own individual effects. But synergistic and cumulative effects of numerous plants must be considered in the management of the coastline as a whole.

No criteria have been developed on which to base decisions for the maximum tolerable thermal input along the coastline considering all of the important biotic communities, particularly those which include nonmobile species which have no alternative habitats. Conversely, even mobile species that adjust to the elevated temperature around outfalls could be damaged by a plant shutdown and the associated rapid temperature decrease. Even if proper siting and design are accomplished to successfully reduce the risk to such species, and the communities which depend upon them, to acceptable levels, the problem of entrainment of sensitive forms of larvae and microorganisms in the intake system has not been solved.

3.2.4 Aesthetics

Another consideration encountered in site selection is one of aesthetics. This area is almost wholly subjective and incorporates opinions so wide-ranging as to make a unanimous choice virtually impossible. If one takes the viewpoint that any intrusion upon the presently existing landscape is aesthetically unappealing, an underground plant may be the only reasonable choice for a siting concept. However, while minimizing one controversy, that solution may initiate others. This would be most important in areas which are considered to be of great scenic beauty and which are visited by large numbers of people for that reason. Such areas in California might include essentially the entire coastline as well as large portions of the interior of the State. At an inland site, where a natural draft cooling tower might be considered, the intrusion on the natural scene is substantial. However, some people might view the current design of a natural draft cooling tower as extremely interesting and appealing. The utility must, however, consider that such opinions may be in the minority. Also, it is not satisfactory for the utility or any opposing group to simply say that the measure of the intrusion (or aesthetic damage) is that portion of the viewer's outlook which is occupied by the plant or cooling tower. Additional factors must be considered, including how well the structure relates in form, color, and texture to the surrounding landscape; or how much in context it may be with like construction in the region. The aesthetic problem, therefore, cannot be precisely regulated and some controversy will always exist. But it is an important consideration in siting and in the selection of a site concept, i. e., underground, aboveground, or partially buried. In addition, the method of evaporative cooling might be largely controlled by the problem of aesthetics and of public reaction however subjective it may be.

3.2.5 Cooling Sources

For cooling systems which rely on water as the heat transfer agent, and most economical systems currently do, the choice of a site which is proximate to a water source becomes important not only because of economic but also because of environmental impact. The ecological, aesthetical, and other effects of a cooling water transmission system must also be considered in the context of the total plant siting concept. There are a number of water sources, but the most abundant source available to California is the Pacific Ocean. However, it requires the use of coastal lands for siting of a power plant and this land is subject to a number of alternative, and sometimes competitive, uses.

Also, the ocean contains many biological communities which could be affected by use of the ocean for cooling water. Because of these factors, and the potential for alternative locations and concepts, one simply cannot consider the plant itself; it is the total system which will have impact.

3.2.6 Transmission System

It is usually more economical to locate generating facilities as close to centers of demand as possible so that transmission lines are short. Furthermore, it is environmentally advantageous because there are aesthetic and land use considerations associated with transmission lines that may take precedence over considerations directly related to the generating station. The transmission line may consume considerable land for which there may be greater commitments. Also, it may be that the touring motorist would rather encounter an isolated generating station, even one with a natural draft cooling tower, which he can see, pass, and forget, than have to drive through miles of natural landscape where the panorama contains transmission lines carrying electricity from that station to the nearest tie point. However, it should be noted that a transmission line right-of-way is often used for additional purposes, such as plant nurseries, horseback riding, bicycle and motor-bike trails, and parks. In many cases, the secondary use may never have been developed were it not for the transmission lines.

3.3 SUMMARY OF REGIONAL CHARACTERISTICS

Information was presented earlier relative to the California coastal environment, and that data would almost certainly influence the choice of sites or of a design concept for sites. Specific feasible sites are not defined because of the depth of study required to prove that any such site would be licensable. However, regions having particular characteristics can be identified as the most probable areas where suitable sites might be found for each of the siting concepts that are presented in the next section. This does not exclude the possibility that suitable sites could be found in other areas, but only identifies those areas which appear to have the most favorable combination of characteristics. Identification of specific sites must include consideration of factors such as cost trade-offs and requirements of individual owners.

To define these regions it is first necessary to summarize the principal criteria. This is discussed below and presented in Plate 3-8 which reflects the characteristics of the coastal zone from Oregon to

Mexico. The size of the zone covered is not precise and, depending on the location, varies up to about 1-1/2 miles in width on land.

3.3.1 Topography

Topography, shown on the first line in Plate 3-8, is important in selecting beach, or low profile, sites and also in identifying hillside areas which provide tunnel access in preference to vertical shaft access into underground facilities. The topography represents stretches of relatively low or high relief within the coastal zone defined above.

3.3.2 Faults and Areas of Seismic Activity

The chart shows seismically active and faulted zones. The fault zones should be avoided since they present a potential hazard of possible ground rupture. For the purpose of this study, seismic activity has been separated into low, moderate, high, and very high intensities. A low-activity seismic zone might be characterized by a predicted maximum horizontal ground acceleration of 0.20 g or less. Acceleration in a moderate-activity zone might range between 0.20 and 0.35 g. A high-activity seismic zone might require consideration of accelerations up to about 0.50 g, and very high zone even greater.

The horizontal bars on the line generally represent the intersection of faults with the coastline. Notable exceptions to this are the bars in southern Mendocino, Sonoma, and Marin counties and in southern Ventura and northern Los Angeles counties. The San Andreas fault closely follows the coastline north of San Francisco in Marin, Sonoma, and part of Mendocino counties. While it does not exactly lie on the coastline, it is within a few miles. The Santa Monica Mountains, located in southern Ventura and northern Los Angeles counties, are highly faulted. Actually, more than twenty faults are represented by the single bar.

3.3.3 Geology

Each of the four geologic conditions along the coast is plotted. These conditions are massive igneous, or homogeneous, rock; massive sedimentary, or heterogeneous, rock; unconsolidated, or nonmassive semihomogeneous, soil; and other nonmassive heterogeneous materials.

The massive homogeneous rocks, such as granite, generally can provide excellent foundation support and stand in unsupported vertical cuts. Because all rocks in the coast ranges have been somewhat

fractured due to past tectonic deformations, some support, such as rock bolts, may be required for underground openings. The degree of fracturing can be expected to vary from place to place within the same geologic formation. Problems involving groundwater and gas can be expected to be minimal in this environment. However, age-dating faults, which occur exclusively within granitic rock, can be very difficult because of the lack of indicators such as fossils. The effects of seismic motion in this environment will be similar to the effects in massive heterogeneous rock.

Massive sedimentary rock is expected to be quite varied from place to place throughout the same formation. Excellent foundation support generally can be found in some of this type of material. Again, vertical excavations may be made in areas of very flat bedding and no joints; but in areas of dipping beds or jointed rocks, the excavations may be required to be sloped appropriately or artificially supported. Groundwater, pockets of gas, or brine may also be found in this environment. The effect of seismic activity on rocks of this type generally is less severe than the nonmassive category.

The unconsolidated soil sites could provide satisfactory foundation support; however, some densification or other preparation may be necessary for more economical design. Excavations in this material probably would not be able to stand with vertical sides of any significant height, and all backfill would need to be compacted for acceptable support. Occurrences of groundwater and pockets of low density material are problems that may be encountered during working this type of soil. Densification of foundation material and backfill is required in order to preclude the possibility of liquefaction during seismic shaking.

Nonmassive heterogeneous rock, similar to massive sedimentary rock, is expected to be quite varied even though geologic maps indicate the same formation in two areas. Excellent foundation support could be found in one area where the rock is more indurated, but unsatisfactory support could exist in another area of the same formation. Vertical excavations may be made in areas of very flat bedding and no joints; but in areas of dipping, bedding, or jointed rocks, excavations may have to be sloped appropriately or artificially supported with rock bolts or other systems. Groundwater, pockets of gas, brine, and other fluids might also be encountered in this environment. Further, earthquake activity may cause ravelling of rocks on slopes cut in this material unless some preventive measures are taken.

3.3.4 Unstable Landforms

Unstable landforms represent areas of landslides, river floodplains, or historic subsidence. The majority of the bars represent the Franciscan material which is prone to landsliding. It is most likely that places exist within the areas marked as unstable that are suitable for the location of a power plant. However, precisely locating them would require extensive field investigations. For the purpose of this study, a more prudent approach is to acknowledge the probable existence of suitable locations within the potentially unstable zones and to consider them only when a region of interest occurs nearby. It should be further recognized that landslide problems are often correctable although movements involving very large masses of material may not be economically solvable for most industrial applications.

3.3.5 Land Use

There are other coastal features which are important considerations when seeking plant sites.

Proximity to areas of high population density is of concern since the AEC requires identification of distance to areas having a population of 25,000 or more. Land areas used for agricultural purposes or which are undeveloped as defined in the COAP* are shown as well as archeologic and historic sites, coastal parks, and education and research sites.

Archeologic and historic sites represent significant reminders of past cultures which affected the development of California or which are otherwise of interest. These sites are locations of former Indian cultures, old missions, and forts. Location of a nuclear power plant near an archeologic or historic site, especially if the plant were not visible from that site, might be acceptable.

Coastal parks are indicated on the next line of the summary sheet. These include State or national parks and beaches. Some additional coastal land which has been acquired by the State has not been advanced to park status and is not indicated on the summary. The names of the coastal parks are indicated by number in Table 3-3. Placement of power facilities might be acceptable within or adjacent to the boundaries of a park if the environment were not adversely altered.

*"Comprehensive Ocean Area Plan," State of California, The Resources Agency, Department of Navigation and Ocean Development, Inter-Agency Council for Ocean Resources (ICOR), 1972.

TABLE 3-3
COASTAL PARKS

County	Number	Park	Shoreline Miles Presently Owned	Shoreline Miles Planned
Del Norte	A 1	Pelican SB	0.2	0.2
Del Norte	1	Lake Earl SP	0.1	6.8
Del Norte/Humboldt	2	Redwood National Park	34.0	34.0
Humboldt	3	Humboldt Lagoons SP (including Dry Lagoon SB)	8.1	8.5
Humboldt	4	Patrick's Point SP	7.0	7.7
Humboldt	5	Trinidad Head SP (including Trinidad SB)	2.3	3.1
Humboldt	A 2	Little River SR	0.8	0.8
Humboldt	6	Azalea SR	0	0
Humboldt	A 3	Fort Humboldt SHP	0	0
Humboldt	7	South Humboldt Bay SP	0.2	4.8
Humboldt	8	Kings Range Coast National Wilderness Area	1.1	9.7
Mendocino	A 4	Westport-Union Landing SB	3.3	3.3
Mendocino	9	10-Mile River SP (including MacKerricher SB)	3.8	8.3
Mendocino	10	Mendocino Coast SP (including Russian Gulch and Van Damme SPs)	1.8	8.0
Mendocino	11	Point Arena SP (including Manchester SB)	5.0	8.7
Sonoma	12	Salt Point SP (including Salt Point SP and Kruse Rhododendron SR)	3.2	13.5
Sonoma	A 5	Fort Ross SHP	0.9	0.9
Sonoma	A 6	Sonoma Coast SB, north end	9.3	9.3
Sonoma	13	Sonoma Dunes SP (including south end Sonoma Coast SB)	2.0	2.0
Marin	14	Point Reyes National Seashore (including Tomales Bay SP)	23.0	42.0
Marin	15	Bolinas Lagoon SP	1.2	8.2
Marin	A 7	Stinson SB	1.1	1.1
Marin	17	Farallon Islands National Wilderness	0	0
Marin	16	Marin Headlands SP	4.3	4.3
Marin	A 9	Marin Headlands SP	3.8	3.8
Marin	A 8	Mount Tamalpais SP	2.4	2.4
San Mateo	A10	Thorton SB	0.6	0.6
San Mateo	A11	Sharp Park SB	0.2	0.2
San Mateo	A12	Gray Whale Cove SB	0.1	0.1
San Mateo	A13	Montara SB	1.0	1.0
San Mateo	A14	Half Moon Bay	1.7	1.7
San Mateo	A15	San Gregorio SB	0.7	0.7
San Mateo	18	Pescadero SP (including Pescadero SB)	2.0	2.8
San Mateo	A16	Pomponio SB	1.5	1.5
San Mateo	A17	Bean Hollow SB	1.6	1.6
San Mateo/ Santa Cruz	19	Point Ano Nuevo SP (including Ano Nueva SR, coastal portion - Big Basin RSP, State Wildlife Conservation Bd. Greyhound rock fishing access)	6.5	12.0
Santa Cruz	20	Terrace Point SP (including Natural Bridges SB)	0.7	2.3
Santa Cruz	A18	Twin Lakes SB	1.2	1.2
Santa Cruz	A19	New Brighton SB	0.9	0.9
Santa Cruz	A20	Seacliff SB	1.3	1.3

LEGEND

SB State Beach
SP State Park

SR State Reserve
SHP State Historic Park

TABLE 3-3 (continued)

County	Number	Park	Shoreline Miles Presently Owned	Shoreline Miles Planned
Santa Cruz	A21	Manresa SB	1.8	1.8
Monterey	A22	Sunset SB	1.3	1.3
Monterey	21	Monterey Bay SP (including Salinas River SB)	3.5	9.5
Monterey	22	Asilomar SP (including Asilomar SB)	1.5	2.0
Monterey	A24	Monterey SB	0.5	0.5
Monterey	23	Point Lobos SP (including Point Lobos SR, Carmel River SB)	5.5	11.5
Monterey	24	Big Sur SP (including Pfeiffer Big Sur SP, Andrew Molera SP, Julia Pfeiffer Burns SP)	10.0	25.0
Monterey	A25	John Little SB	0.4	0.4
San Luis Obispo	A26	Hearst San Simeon SHP	0.1	0.1
San Luis Obispo	A27	Morro Strand SB	1.3	1.3
San Luis Obispo	A28	Atascadero SB	1.9	1.9
San Luis Obispo	25	Morro Bay SP (including Morro Bay SP, Montana de Oro SP)	7.3	11.0
San Luis Obispo	26	Santa Maria Dunes SRA (including portion - Pismo SB)	3.4	5.7
San Luis Obispo	A29	Pismo SB	3.4	3.4
Santa Barbara	27	Point Sal SP (including Point Sal SB)	0.9	7.4
Santa Barbara	28	Gaviota SP	5.4	7.4
Santa Barbara	A30	Refugio SB	1.1	1.1
Santa Barbara	A31	El Capitan SB	1.8	1.8
Santa Barbara	A32	Carpinteria SB	0.8	0.8
Ventura	A33	Emma Wood SB	2.5	2.5
Ventura	A34	San Buenaventura SB	2.2	2.2
Ventura	30	McGrath Lake SP (including McGrath SB)	2.0	2.0
Ventura	31	Point Mugu SP	7.0	7.0
Los Angeles	32	Leo Carrillo SP (including Leo Carrillo SB)	1.4	1.4
Orange	33	Anaheim Bay SP	2.0	2.0
Orange	34	Ship Rock Marine Reserve (Santa Catalina Island)	0	0
Orange	35	Farnsworth Bank Marine Reserve (Santa Catalina Island)	0	0
Orange	A35	Bolsa Chica SB	2.9	2.9
Orange	36	Upper Newport Bay SP	0	0
Orange	A36	Huntington SB	2.1	2.1
Orange	A37	Doheny SB	1.2	1.2
Orange	A38	San Clemente SB	1.1	1.1
San Diego	A38A	San Onofre SB	1.0	1.0
San Diego	A39	Carlsbad SB	0.8	0.8
San Diego	A40	Leucadia SB	1.0	1.0
San Diego	A41	Moonlight SB	0.3	0.3
San Diego	A42	San Elijo SB	0.1	0.1
San Diego	A43	Cardiff SB	0.7	0.7
San Diego	37	Torrey Pines SP (Torrey Pines SR expansion)	4.5	4.5
San Diego	38	Tijuana River SP	0.9	2.0

Education and research sites have been or are being situated along the coast to provide areas of value for marine-oriented research and educational activities. The location of a power plant near one of these sites may cause a change in the environment and thereby tend to degrade the educational value of the site. Conversely, offshore areas around power plant outfalls could be used as additional research sites to study the effects of such outfalls and to investigate the possibility of introducing certain species for economic development. The education and research sites are listed in Table 3-4.

3.3.6 Key Species

Bars representing areas in which are located examples of rare or endangered, and some key species, such as the redwoods, the sea otter, and the clams at Pismo and other beaches are shown in Table 3-5. These are some of the species which may receive public attention if any habitat intrusion is attempted. Some rare and endangered migratory marine animals, such as whales, are seasonally found along the coast of California, but they are not shown. Kelp occurs in many locations along the near shore coastal zone; it also not shown. Complete avoidance of ecologically sensitive areas can be assumed, but may not be mandatory in nuclear power plant siting. However, each plant must be designed to avoid adverse impacts on sensitive environments upon which they may impinge. It is emphasized that all of the California coast supports life which must be of concern. The discussions herein are limited to certain species only for brevity.

3.4 CANDIDATE SITES

From the prior data it is possible to identify regions which appear to have suitable site characteristics, and also appear to conform with the regulations or constraints that might govern their future acceptability. The potential siting concepts which are presented in the following section fall into three categories: aboveground, underground, and offshore. Variations in their characteristics pertinent to identifying potential sites for the concepts are the basis for locating candidate regions.

In each case, after the basic site features and the potential zones were identified, portions of these zones were eliminated if they contained coastal faults or were in areas of destructive ground motion. Also, portions in close proximity to population centers were identified by not showing them as solid bars. Population centers were determined by identifying cities or areas having populations in excess of 25,000. Since plants licensed today are no closer to population centers than

TABLE 3-4
EDUCATION AND RESEARCH SITES

County	Number	Name	COAP Sheet	Shoreline Miles
Humboldt	1	Big Lagoon - Stone Lagoon	6 and 7	6.8
Humboldt	2	Trinidad Head - Trinidad Bay	8	5.2
Humboldt	3	South Humboldt Bay	12	3.5
Humboldt	4	Eel River Mouth	12 and 14	5.8
Humboldt	5	Cape Mendocino	15	4.1
Sonoma	6	Bodega Head	37	1.9
Sonoma/Marin	7	Estero Americano	37 and 38	4.0
Marin	8	Point Reyes National Seashore		
		a. Point Reyes Headland	41	3.8
		b. Limantour Lagoon	41	4.0
Marin	9a	Bolinas Point - Duxbury Reef	44	4.1
Marin	9b	Bolinas Lagoon	44	2.0
San Mateo	10	Moss Beach - Frenchman Reef- Pillar Point	48 and 49	4.3
San Mateo/Santa Clara/Alameda	11	San Francisco Bay National Wildlife Reserve	---	Inland
San Mateo	12	Ano Nuevo Island	52	Island
San Mateo/Santa Cruz	13	Pigeon Point - Point Ano Nuevo - Greyhound Rock	51 and 52	14.0
Santa Cruz	14	Zmudowski State Beach	56	(1.7)
Monterey	15	Elkhorn Slough - North Moss Landing	56	(1.3)
Monterey	16	Monterey Canyon (area described in Item 16 includes area described in Items 14 and 15)	56 and 57	12.1
San Luis Obispo	17	Piedras Blancas Point	67 and 68	6.1
San Luis Obispo	18	Morro Bay	71 and 72	6.1
San Luis Obispo	19	Montana de Oro	72	3.9
San Luis Obispo	20	Lion and Pecho Rocks	73	6.6
San Luis Obispo	21	Dune Lakes (Inland - 1/2 mile from shore)	75	(2.0)
Santa Barbara	22	Mussel Point - Point Sal	76 and 77	7.0
Santa Barbara	23	Point Conception - Jalama Beach	79 and 80	9.6
Santa Barbara	24	Naples Reef	83	1.7
Santa Barbara	25	University of California, Santa Barbara, West and Main Campuses	83	0.5
Santa Barbara	26	Goleta Slough	83	4.0
Santa Barbara	27	Sandyland Marsh and Tidelands	85	1.3
Ventura	28	Mugu Lagoon	89	6.7
Los Angeles	29	Leo Carillo State Beach	90	1.4
Los Angeles	30	Point Dume - Paradise Cove	91 and 92	6.6
Los Angeles	31	Malibu Lagoon	92	0.4
Los Angeles	32	Palos Verdes Peninsula	95	1.9
Orange	33	Anaheim Bay	98	1.5
Orange	34	Upper Newport Bay	99 and 100	Inland
Orange	35	Newport Marine Life Refuge	101	0.7
Orange	36	Dana Point Marine Life Reserve	102	0.8
San Diego	37	Penasquitos Marsh and Lagoon	107	0.8
San Diego	38	Scripps Shoreline Black Beach and Canyon, Sumner Canyon and Beach	107 and 108	1.1
San Diego	39	Kendall - Frost - Mission Bay Marsh Reserve	108	Bay
San Diego	40	Point Loma	109	3.6
San Diego	41	South San Diego Bay	109 to 111	3.5
San Diego	42	Tijuana River	111	2.2
Santa Barbara	43	Prince Island	112	Island
Santa Barbara/Ventura/Los Angeles	44	North Channel Islands	112 to 127	Islands
Los Angeles	45	USC Santa Catalina Island Sites	120 to 122	Islands

TABLE 3-5
KEY SPECIES

1.	Redwood
2.	Clapper Rail
3.	Garter Snake
4.	Salamander
5.	Sea Otter
6.	Pismo Clams
7.	Morro Bay Kangaroo Rat
8.	Least Tern

about 5 miles, this distance was used in the study as the minimum to be excluded in siting considerations.

Site physical criteria corresponding to siting concepts is as follows:

1. Aboveground Concepts

- a. Beach or Low Terrace - Low elevation, close to shore, suitable for coastal concept.
- b. Hilly or Rugged - Relief exceeding 200 to 300 feet, within 1 to 1-1/2 miles of shore, suitable for hillside and low profile concepts.
- c. Lagoon - Low elevation, adjacent to shore, containing lagoon or capable of being dredged, suitable for floating lagoon concept.

2. Underground Concept

- a. Massive Igneous Rock, Hilly - Relief exceeding 300 feet, within 1 to 1-1/2 miles from shore, granitic materials.
- b. Massive Sedimentary Rock, Hilly - Relief exceeding 300 feet, within 1 to 1-1/2 miles from shore.
- c. Unconsolidated Materials, Beach - Low elevation, near shore.
- d. Nonmassive or Poorly Cemented, Hilly - No constraint on relief dimensions, within 1 to 1-1/2 miles from shore.
- e. Massive Rock, Faulted Zone - Relief exceeding 300 feet, within 1 to 1-1/2 miles from shore, massive igneous or sedimentary rock, in faulted zones.

3. Offshore Concepts

- a. Shallow Water (40 to 60 feet) at 3 Miles - Suitable for floating shallow and artificial island concepts.

- b. Shallow Water (40 to 60 feet) Close-In - Less than 3 miles from shore, suitable for floating shallow and artificial island concepts.
- c. Moderately Shallow Water (250 to 300 feet) at 3 Miles - Suitable for seabed.

Plate 3-8 provides an initial identification of regions which may include potentially acceptable sites. Regions which are indicated as being hilly contain occasional low terraces or beaches which are too small to identify on the Summary Sheet. Detail maps would reveal these pocket sites which might be suitable in size for a plant location. Diablo Canyon south of Morro Bay and the proposed site north of Davenport are examples of this situation.

Initial searches for suitable areas can utilize Figure 3-8 as a tool. However, it is again noted that each of the candidate regions requires detailed site investigations to validate its suitability for the concepts later discussed. This includes a geologic exploration and seismologic survey as well as a detailed assessment of the other environmental factors, many of which are summarized on Plate 3-8 under Land Use and Key Species. It also should be noted that detailed investigations of the same depth in some of the areas, not identified as candidate areas, might produce some suitable sites.

PLATE 3-1
PHYSIOGRAPHY

PLATE 3-2
LAND USE

PLATE 3-3

GEOLOGY AND SEISMOLOGY

PLATE 3-5
EARTHQUAKE INTENSITY

PLATE 3-6
 OCEANOGRAPHY AND METEOROLOGY

PLATE 3-7

RARE OR ENDANGERED AND SOME
KEY BIOLOGICAL SPECIES

* LIST REPRESENTS ONLY A FEW EXAMPLES OF THE MORE WELL KNOWN SPECIES

PLATE 3-8

COASTAL SITE SUMMARY

4. INLAND SITING

Principal consideration has been given to the coastal environment and to the opportunities for siting power plants along the coastline of California at both onshore and offshore locations. However, the prior section indicates that relatively few areas of the California coastline are specifically suited to development of what might best be termed conventional aboveground nuclear generating stations. There may be additional miles of coastline which might be suitable upon extensive study and investigation, but it is clear that the coastal areas represent a resource which is of great concern to the public because it offers substantial opportunities for many uses.

Land use conflicts may be significantly less in portions of the interior, especially since the interior offers a greater area from which to seek suitable plant sites. The inland portions of the State do not necessarily represent a less valuable resource than the coastal portions, but if value simply were to be measured in terms of what people are presently willing to pay for land, this might appear to be true. However, economics is only one factor: the other significantly important factors relate to a search for less seismically active areas; sites removed from population centers; and, perhaps most importantly, areas where people are less likely to seek out land uses which conflict with the presence of a power plant. Further, considering ecological and related factors, the search becomes one for sites where the construction and operation of a generating station might involve smaller environmental impact.

4.1 ENVIRONMENTAL CHARACTERISTICS

A general overview is provided here of the inland portions of California with particular reference to features which are conducive to siting aboveground plants. The information contained in this section is intended to be only as extensive as is necessary to identify the principal environmental features affecting site selection and evaluation, and to provide guidance for locating regions providing the greatest potential for suitable sites.

4.1.1 Physiography and Geology

California is a State of great topographic and geologic diversity. Included within its limits are an assemblage of physiographic features that reflect a complex geologic history and a wide variety of rock types

and structural elements. The State can be divided into the following natural provinces, shown on the inset in Plate 4-1, each with its own distinct characteristics:

1. Klamath Mountains, a rugged area in northwestern California.
2. Cascade Range, an area of fault block mountain ranges and past volcanic activity.
3. Modoc Plateau, an area of fault block mountain ranges, flat-floored basins, and recent volcanic activity.
4. Sierra Nevada Range, a high, rugged, north-trending mountain range.
5. Coastal Ranges, characterized by separate ranges with several intervening valleys.
6. Transverse Ranges, east-west trending ranges, and small valleys.
7. Peninsular Ranges, a westward-tilted plateau broken by several major fault zones.
8. Great Valley, an immense, flat-floored, alluviated plain in central California.
9. Mojave Desert, an arid region consisting of mountain ranges and enclosed valleys.
10. Colorado Desert (Salton Trough), an elongate, low-lying depression.
11. Basin Range (Great Basin), characterized by north-trending fault-bounded ranges, valleys, and basins.

The first seven provinces can, for the most part, be eliminated from consideration due to their topography of high relief and ruggedness. A few valleys of moderate size in the Modoc Plateau, Coastal Range, and Transverse Range Provinces are suitable from the standpoint of topography, but most of these have close proximity to urban centers or prohibitive land use and are not of interest. Notable exceptions are the Salinas Valley and the Cuyama Valley in the southern Coastal

Ranges both relatively near the San Andreas Fault Zone, the Scott Valley in the Cascade Range, and several valleys in the Modoc Plateau. The Salinas and Cuyama valleys are well located with respect to load centers, but seismicity and land use alternatives may rule them out. While far from urban centers and in areas of abundant water supplies, the valleys of the Cascade Range and Modoc Plain lie in areas of recent faulting and volcanic activity. The Great Valley, Mojave Desert, Colorado Desert, and Basin Range Provinces contain substantial areas of suitable topography.

4.1.1.1 Great Valley - The Great Valley, a nearly flat alluvial plane about 450 miles long and an average of 50 miles in width, comprises over one-tenth of the area of California. For the most part, the valley is flat and low but rises gradually to the Sierra Nevada on the east and south, and more abruptly to the Klamath mountains and coastal ranges on the north and west, respectively. Elevations of the plain are generally less than a few hundred feet above sea level but increase to over one thousand feet near the margins of the province. The north portion of the valley is drained by the Sacramento River and the south portion by the San Joaquin River. These empty into San Francisco Bay after joining flow westward. The Kern River in the southern extremity of the San Joaquin Valley, however, drains into a sink.

Geologically, the Great Valley is a large, elongate, northwest-trending asymmetric structural trough that has been filled with a tremendously thick sequence of sediments, ranging in age from Jurassic to Recent. This geosynclinal trough has a long, stable eastern shelf, supported by the subsurface continuation of the Sierra Nevada Mountains, and a short western flank. The basin has a regional southward tilt. The White Wolf fault was the causative fault for the 1952 Arvin-Tehachapi earthquake.

The present flat valley floor is composed of gravel, sand, silt, and clay sediments deposited primarily by streams and shallow lakes. The principal landforms in the valley are river floodplains, overflow lands and lake bottoms, low alluvial plains and fans, and dissected alluvial uplands.

Major areal ground subsidence has occurred in three extensive areas between Sacramento and the south end of the valley. Most of the subsidence has been due to oxidation of peat lands in lowland areas of the delta at the confluence of the Sacramento and San Joaquin rivers and to intensive pumping of confined aquifers between Los Banos and Wasco and also south of Bakersfield.

Subsidence of local extent has occurred in the valley caused by near-surface compaction of low density alluvial fan deposits.

Subsidence from the removal of oil and gas in California has occurred in the past, but the injection of water to replace the petroleum has ceased the subsidence in some of the fields. The implementation of programs to halt subsidence, however, sometimes requires extended periods of time as well as legal efforts.

4.1.1.2 Mojave Desert - The Mojave Desert region is a fault-bounded, triangular-shaped area characterized by mountain ranges of varied trends between which are enclosed valleys. The valleys lack external drainage and often contain playas. While areas adjacent to the Colorado River are only a few hundred feet in elevation, most of the desert basins lie between 1,000 and 3,000 feet elevation.

The Mojave Desert region consists of a wide variety of Precambrian to Late Mesozoic sedimentary, metamorphic, and igneous rock. Middle and upper Cenozoic igneous rock and sedimentary strata deposited mainly in separate basins indicate a complex history of basin formation.

Much of the province lies between the Garlock fault on the north and the San Andreas fault on the southwest. Within the province are north to northeast-trending folds, steeply dipping faults, and some thrust faults of Middle Jurassic to Late Cretaceous age and of late Cenozoic Age. Some faults in the western Mojave show evidence of recent movement; most of these are northwest-trending, high angle faults.

A wide variety of landforms and lithologies are found in the desert, each with their own engineering considerations. Chemical and physical alterations of the wide variety of rock types present in the desert produces a diversity of sedimentary environments. These environments lead to the development of erosional and depositional features such as sand dunes, alluvial fans, stream channels, lake beds, and evaporite deposits.

4.1.1.3 Colorado Desert - The Colorado Desert is an elongate, low-lying depression whose alluviated floor is separated from the Gulf of California by the Colorado River delta and is in part occupied by the Salton Sea. Elevations range from about 230 feet below sea level to over 300 feet above sea level. Much of the province is below sea level.

The province consists of Cenozoic marine, lacustrine, and alluvial fan deposits and volcanic rock resting upon igneous and metamorphic rocks of preCenozoic age. The northeast margin of the province is traversed by several subparallel breaks of the San Andreas fault zone while its western margin is in part outlined by the Elsinore, San Jacinto, and other major fault zones that trend northwest. Many of the faults cut or offset rocks as young as Quaternary. The Imperial Fault and the Superstition Hills Fault in the southern portion of the valley have had movement as recently as 1940 and 1951, respectively.

4.1.1.4 Basin Range Province - The Basin Range Province is characterized by north-trending ranges, intervening valleys and basins, and interior drainage. Elevations in the Basin Range Province vary widely, from 282 feet below sea level in Death Valley to over 14,000 feet in the mountains. Most basins lie between 3,000 and 7,000 feet elevation. The geologic section is very complex and includes igneous, metamorphic, and very thick sequences of sedimentary rock. Many of the ranges are essentially fault blocks and some of the valleys are fault-bounded troughs. Widespread Quaternary faulting is reflected in many juvenile features of the present topography. In 1872 an earthquake on the Owens Valley fault system did severe damage to the town of Lone Pine.

4.1.2 Seismology

California is well known as an area of high seismicity. Evidence of seismically active areas is of two types:

1. Historical or instrumented records of earthquakes.
2. Geologic evidence of recent movement along faults.

Many of the major known faults of California are shown on Plate 4-1. The most significant and famous fault zone in California is the San Andreas rift zone. Other major fault zones include the Elsinore, San Jacinto, Nacimiento, and others subparallel to the San Andreas. The northeast-trending Garlock fault, the Owens Valley system faults and north-trending faults of the Basin Range province, and the northwest-trending faults of the Western Mojave Desert represent tectonic activity throughout widespread areas. Individual faults that have experienced historic movement include the Imperial and Superstition Hills faults in the Colorado Desert and the White Wolf fault in the southern Great Valley.

Of the four provinces described above, the western Mojave Desert, the Colorado Desert, and the Basin Range provinces contain a considerable number of known active faults. The Great Valley province and the eastern Mojave Desert appear to contain fewer active faults. Nearly all of the Colorado Desert and Basin Range provinces are in relatively close proximity to known recently active faulting. Since the presence of active faults imposes design criteria constraints and may preclude licensing, highly detailed geologic investigations will be necessary in areas of known faulting.

Earthquake data can be utilized in several ways to give some idea as to the relative earthquake activity of various areas. Plate 3-4, which is an isoseismal map of California, shows areas which have been shaken by damaging earthquakes since 1769. Interpretation of historic data and geologic information has yielded zones where given maximum intensities can be expected. These zones are presented on Plate 3-5. Although suitable sites may be found in the higher Seismic Intensity Zone III regions, design criteria constraints may be greater and foundation conditions may have to be better than would be necessary in lower intensity zones.

The northern and the east-central portion of the Great Valley and the east-central portion of the Mojave Desert lie in Seismic Intensity Zone I (Modified Mercalli Intensity VI and VII). The majority of the remaining area of the Great Valley and the central portion of the Mojave Desert lie within Intensity Zone II (Modified Mercalli Intensity VII and VIII). The extreme southern portion and several small areas of the Great Valley and the northern and western fringe of the Mojave Desert lie within Intensity Zone III (Modified Mercalli Intensity IX and X). All of the Colorado Desert and the Basin Range provinces lie within Intensity Zone III.

4.1.3 Hydrology and Water Resources

The California water supply problem essentially is one of maldistribution of supply and use. The supply of water is greatest in northern areas of the State, whereas the demand is greatest in southern areas. This problem has brought about extensive water projects to redistribute and conserve water supplies. Plate 4-2 indicates the complex drainage and transport systems in the inland regions and presents the hydrologic areas and major aquifers which together constitute the hydrologic regime of current water sources for inland sites.

4.1.3.1 Great Valley - The Great Valley is drained by two major rivers, the Sacramento in the north, and the San Joaquin in the south. The valley also contains large tributary rivers (Kings, Merced, Tuolumne, Stanislaus, Mokelumne, American, and Feather) and encloses or is peripheral to thirty major reservoirs and many aqueduct systems which are shown on Plate 4-2. Groundwater is extensively used for irrigation and public supply in the Great Valley, and overdraft conditions have occurred in some central and southern areas. Increased water use in the southern part of the valley would likely require additional imported water. However, increased utilization of groundwater sources may be feasible in the northern portion of the valley.

4.1.3.2 Mojave Desert - The Mojave Desert contains the Mojave River, Havasu Lake, Imperial, Laguna, and Bouquet reservoirs; the California, Los Angeles, and Colorado aqueducts; and the Palo Verde Canal. The Colorado River borders the desert on the east. Rainfall in the region is very low, and surface drainage commonly terminates in playas. In some valleys groundwater supplies, although of low quality, are extensive and might be feasible water sources. However, recharge is generally small in relation to potential withdrawal.

4.1.3.3 Colorado Desert - The Colorado Desert contains the Salton Sea and the Coachella, East Highland, Westside Main, and All American canals. No reservoirs exist within the region. Agriculture in the area is entirely dependent upon imported water and will be in competition with any potential major users for increased imports. As a result of a recent Supreme Court decision, annual net diversions from the Colorado River are projected to decrease from the present 4.0 million acre-feet to 3.85 million acre-feet. Extensive untapped groundwater deposits exist. It has been estimated that in excess of one billion acre-feet could be recoverable.

4.1.3.4 Basin Range Province - The Basin Range province contains several lakes in the far northern part of the State (Mono and Owens lakes), three major reservoirs (Bridgeport, Haiwee, and Lake Crowley), and the Los Angeles Aqueduct. The principal aquifers are sand and gravel bearing members of basin alluvial fill. Stream runoff and recharge are greatest along the east slopes of the Sierra Nevada Mountains.

4.1.4 Meteorology

Marked variations in climate from place-to-place are found in California. A number of factors influence and modify the climate

and local weather conditions in the State, among which terrain, elevation, and proximity to the ocean are highly significant. Coastal and inland mountain ranges which act as rain barriers to inland valleys profoundly influence the climate, vegetation, and wildlife of California. The mountains also affect air flow patterns which influence temperature inversions in localized areas.

While the Colorado and Mojave Deserts are very arid, usually receiving less than 5 inches of precipitation annually, the Basin Range province varies from arid to semiarid. The Great Valley is arid in the southern one-third part and is semiarid in the north, with a few areas in the far north of the valley that receive over 20 inches of precipitation per year. The mountains receive most of the precipitation in the State, with some areas averaging over 100 inches annually.

Inland areas have wider variations in seasonal temperatures than the coastal section. Average January temperatures are approximately 44 degrees for the Great Valley and 44 to 52 degrees for the desert areas. Average July temperatures are 72 to 80 degrees in the Great Valley and 80 to 92 degrees in the desert areas.

Because of the pronounced variability of meteorological influences, it is impossible to generalize wind speed, direction, and atmospheric stability for broad areas. Each candidate site requires individual evaluation in terms of location in relation to topography, elevation, and other aspects of the environment which could significantly alter the local climatic regime.

When considering nuclear power plants, meteorological conditions generally will not impose major constraints upon siting. The low humidity and consequent high evaporation rates of the deserts and inland valleys will allow efficient operation of supplemental wet cooling facilities, but will thereby produce a high makeup water demand. Fogging of the atmosphere from increased humidity produced from cooling towers is unlikely in most of the desert areas. Northern areas may have greater incidence of this problem during certain periods of the year and therefore place greater demands on tower performance.

Meteorological conditions are a much more important consideration in the siting of fossil-fueled plants. A well defined and quite strongly capping temperature inversion is usually found over arid and semiarid regions at some altitudes during daylight hours; and during the night a strong, ground-based inversion is found. Under either

condition the inversion layer resists the passage of combustion by-products and tends to keep them concentrated in a thin atmospheric layer. The emissions can accumulate to high concentrations in the local atmosphere and can also reach the ground. Frequently, fossil-fueled power plants require greater stack heights and additional control equipment to prevent these unwanted effects.

Meteorological conditions which vary drastically can be designed for, but the severity of problems and their economic impact on the project requires careful evaluation based on local conditions.

4.1.5 Biology

The diversity of California biota is as wide as that of the topography and climate. Eight vegetative communities prevalent in the areas of interest are discussed.

The Great Valley was originally carpeted by mixed perennial native bunch grasses. Most native grasses, through overgrazing, farming, and development have been replaced. Willows, sycamores, and cottonwoods remain along the streams. Animals typically encountered are deer, ground squirrels, cottontail rabbits, gophers, and moles. Streams of the valley are spawning grounds for steelhead, salmon, and striped bass.

The southern oak woodland is a very attractive widespread community found in interior valleys. Its general aspect is open stands of oaks separated by fields of native grasses. Because this community is situated in the most favorable areas, it is rapidly being lost to subdivisions and may eventually be reduced to scattered remnants. Deer, mice, skunks, rabbits, tree squirrels, and many species of birds are associated with the community.

The deserts of Southern California support the shadscale and creosote bush scrub communities. Both communities are found in areas of low rainfall (2 to 8 inches per year). Shadscale scrub consists of low shrubs growing in coarse soils at elevations between 3,000 and 6,000 feet. Creosote bush scrub is found in well drained or alluvial soils below 3,500 feet. Its shrubs are 2 to 10 feet tall and largely dormant during the drier portions of the year. Plants in both communities are widely spaced, due to the lack of available water. Even with little free water, a surprising number of animals may be found including the kangaroo rats, desert tortoises, several species of snakes, several species of birds including roadrunners, antelope jack rabbits, lizards,

and the coyote. Many of these species also range into the higher desert woodlands.

At higher desert elevations, and interspaced between the scrub communities, are found Pinyon-Juniper and Joshua Tree woodlands. The Joshua Tree woodlands community is founded on well drained slopes and mesas 2,500 to 4,000 feet or higher where annual rainfall averages 6 to 15 inches. Joshua trees which can grow to 30 feet in height are generally surrounded by scattered herbs and small shrubs.

In contrast, Pinyon-Juniper woodlands are found at elevations between 5,000 to 8,000 feet where precipitation averages between 12 to 20 inches a year. The general aspect of this community is open stands of trees to 30 feet tall, generally in rugged terrain. Animals typically encountered are deer, ground squirrels, cottontail rabbits, gophers, and moles.

In addition to the six previously described communities, two others (Sagebrush scrub and Chaparral) are found throughout California. Sagebrush scrub prefers deep soils with an average precipitation of 8 to 15 inches a year (falling mostly as snow) and elevations of 4,000 to 7,500 feet. Perhaps the most ubiquitous California community is the chaparral, a broad-leaved vegetation which in older, mature stands forms nearly impenetrable barriers 6 to 10 feet high. Preferred conditions are fairly rocky or gravelly soils on sunny slopes with rainfall averaging 14 to 25 inches.

As these communities are widespread, the animals that occupy them are diverse and include coyotes, chipmunks, rats, racoons, weasels, mountain lions, and a highly diverse bird fauna. Table 4-1 lists ten key species of animals found primarily in the interior areas of California.

4.1.6 Population and Land Use

The major population centers of California are the large metropolitan areas of Los Angeles, San Francisco, and San Diego; scattered urban coastal areas; and urban centers of the Great Valley. Major cities in the Great Valley are Sacramento, Stockton, Fresno, Bakersfield, Modesto, and Lodi. Of these, Sacramento and Stockton are economically linked to the Pacific by dredged channels capable of passing oceangoing vessels. Although other small cities and towns are located throughout the valley, much of the population is located in the central and southeast quarter of the valley.

TABLE 4-1

KEY SPECIES

1. California Condor
2. Southern Bald Eagle
3. American Peregrine Falcon
4. Mohave Ground Squirrel
5. San Joaquin Kit Fox
6. Fresno Kangaroo Rat
7. Colorado Squawfish
8. Humpback Sucker
9. Black Toad
10. Blunt-Nosed Leopard Lizard

Most of the land in the Great Valley is used for agricultural and livestock production. Irrigation of large parts of the valley makes possible extensive crops of fruits, cotton, hay, vegetables, and grains. Use of land for grazing is important in many parts of the valley which are not irrigated. Light manufacturing and food processing also are important industries in many areas. Parks, recreation areas, historic monuments, and similar uses are fewer in the Great Valley than along the coastal and mountain areas. Parks, historic sites, and wildlife refuges in this and other inland areas are listed in Table 4-2.

The Mojave Desert is a region of low population and minor land use. Irrigation has allowed agricultural production of a small percentage of the land, mostly in the Lancaster, Victorville, and Blythe areas. Only a few cities, all small, are located in the desert. There are several large areas in the western, northern, and central Mojave which are designated as military camps and test ranges. Although few areas have been set aside by the State or Federal Government, the desert also contains many areas of scientific and educational value.

As a result of extensive irrigation, a large part of the Colorado Desert is now used for agricultural production. Several small cities serve the agricultural community and are year-around resorts.

As with the Mojave Desert area, the Basin Range province is an area of low population and minor land use. While grazing is the principal land using activity, areas of scientific and educational interest also are present. Death Valley National Monument is one such area that has been set aside.

The characteristics of the inland desert or relatively flat areas of California are summarized on Table 4-3 for each of the four provinces.

4.2 CANDIDATE REGIONS

The inland siting concept reviewed in the study is an aboveground plant similar to those now being planned, built, or operated in the United States. On that basis, large areas of the State virtually can be eliminated if they do not contain some of the basic site requirements characteristic of licensed plants.

TABLE 4-2
AREAS OF RESTRICTED LAND USE

<u>County</u>	<u>Site</u>
Tehama	William B. Ide Adobe S.H.M.
Tehama	Woodson Bridge
Butte	Bidwell Mansion S.H.M.
Glenn-Colusa	Sacramento N.W.R.
Colusa	Colusa N.W.R.
Colusa	Delevan N.W.R.
Colusa	Colusa-Sacramento River S.P.
Sutter	Sutter N.W.R.
Sacramento	Brannan Island S.P.
Contra Costa	Frank's Tract S.P.
San Joaquin	Caswell Memorial S.P.
Stanislaus	Turlock Lake S.P.
Merced	G.J. Hatfield S.P.
Merced	Fremont Ford S.P.
Merced	McConnell S.P.
Merced	San Luis N.W.R.
Merced	Merced N.W.R.
Tulare	Pixley N.W.R.
Kern	Kern N.W.R.
Kern	Tule Elk S.P.
Kern	Kern River S.P.
Los Angeles	Joshua Tree S.P.
San Bernardino-Inyo	Death Valley N.M.
San Bernardino	Mitchell Caverns S.P.
San Bernardino	Chemehuevi Indian Reservation
San Bernardino	Lake Havasu N.W.R.
San Bernardino-Riverside	Joshua Tree N.M.
Riverside	Agua Caliente Indian Reservation
Riverside	Torres-Martinez Indian Reservation
Imperial	Pichaco S.P.
Imperial	Imperial N.W.R.
Imperial	Salton Sea N.W.R.
Imperial	Fort Yuma Indian Reservation
Inyo-Mono	Ancient Bristlecone Pine Area

Key to Abbreviations Used:

S.P.	State Park
S.H.M.	State Historic Monument
N.M.	National Monument
N.W.R.	National Wildlife Refuge

TABLE 4-3

SUMMARY OF ENVIRONMENTAL CHARACTERISTICS

Province	Description	Seismic Intensity Zone	Water Resources*	Unstable Landforms	Land Use	Future Land Use Conflicts
Great Valley	Flood Basins, Low Alluvial Plains, Alluvial Fans, and Dissected Uplands	I - Northern and East-Central Portions	Existing Reservoirs and Aqueducts, Major Rivers Possible Groundwater Sources in Northern Portion, Future Increases in Imports Planned	Subsidence in Areas of Intense Groundwater Pumpage, Mudslides, Landslides, Flooding in Low Areas, Isolated Areas of Known Active Faulting, Some Areas of Poor Foundation Conditions	Extensive Agriculture and Grazing, Scattered Urban-Industrial Centers of Some Historic and Recreation Sites, Wildlife Refuges	Moderate Residential and Recreational Development
		II - Southern and West-Central Portions				
		III - Extreme Southern Portion and Isolated Small Areas				
Mojave Desert	Mountain Ranges, Interior Basins, Alluvial Aprons	I - East-Central Portion	Several Existing Aqueducts, Principal Reservoirs on Colorado River; Possible Groundwater Sources But Low Recharge	Mudflows and Landslides, Flooding in Arroyos and Playas, Large Areas of Known Active Faulting, Local Areas of Poor Foundation Conditions	Some Grazing, Agriculture in Few Irrigated Areas, Indian Reservation, Military Camps and Test Sites, Few Recreation Areas, Few Small Urban Centers, Wildlife Refuges	Scattered Areas of Unusual Scientific and Educational Value, Some Areas Suitable for Agriculture With Irrigation, Some Residential and Recreational Development
		II - Central Portion				
		III - Northwestern and Southwestern Margin				
Colorado Desert	Low Alluvial Plain and Alluvial Apron	III - All of Province	Several Existing Aqueducts, Salton Sea but no Reservoirs, Possible Extensive Groundwater Sources, Planned Increased Imports to Western Portion	Mudflows, Known Active Faulting Widespread, Local Areas of Poor Foundation Conditions	Extensive Agriculture Recreation Areas, Few Small Urban Centers, Wildlife Refuges	Some Residential and Recreational Development
Basin Range	Mountain Ranges, Basins and Alluvial Apron	III - All of Province	Few Lakes and Reservoirs, Los Angeles Aqueduct Possible Groundwater Sources	Landslides and Mudflows, Flooding in Arroyos and Playas, Known Active Faulting Widespread; Local Areas of Poor Foundation Conditions	Some Grazing, Death Valley N.M. Wildlife Refuges	Areas of Unusual Scientific and Educational Value, Few Areas Suitable for Agriculture With Irrigation

* It is noted the availability of water will be subject to negotiation because most California surface waters are used under water right or under contract.

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* It is noted the availability of water will be subject to negotiation because most California surface waters are used under water right or under contract.

Earlier it was noted that of the eleven provinces in the State, seven can be eliminated from consideration due to their topography of high relief and ruggedness, their close proximity to urban centers, prohibitive land use, or predominance of seismically active areas within their bounds. The remaining provinces are the Great Valley, Mojave Desert, Colorado Desert, and the Basin Range. Within these provinces four principal constraints can be identified for siting of inland aboveground nuclear power plants. These are superimposed on Plate 4-1. The first criterion which has been identified for potentially suitable regions is topography. Conventional designs are considered only for areas which are relatively flat and which offer no great topographic obstructions to design or construction. Mountainous or otherwise relatively inaccessible regions have been eliminated from consideration. These and the seven provinces which were eliminated are represented by the hatched areas.

The second principal constraint is population and land use, represented by the cross-hatched zones. Areas identified as major parks, monuments, reservations, preserves, and refuges are eliminated from consideration as are those areas having high population densities. The sizes of populated zones eliminated relate to areas having populations greater than 25,000. No attempt has been made to identify smaller areas having population centers which most likely would also be avoided.

The third principal constraint identified is seismic activity. The seismic intensity contours and the major known faults are plotted on Plate 4-1. Regions are shaded to represent areas having high seismic risk resulting from close proximity to major known active faulting, to subsurface conditions conducive to transmitting high amplitude ground motion, or where the historic record indicates damage has occurred in the past. Detail investigation for any potential development may very well lead to the conclusion that there are many regions outside the shaded areas delineated on Plate 4-1 which must be excluded because of active faulting not presently identified or because of their potential for high amplitude ground motion and accelerations. It should also be noted that the areas identified as high seismic risk may also include zones which, because of a specific geologic character, may be considered to have less risk than the general area which surrounds them. Regions known to be subject to ground subsidence further are eliminated and the suitable area is further reduced.

The "white" areas remaining on Plate 4-1 after consideration of topography, population and land use, and seismicity suggest locations where suitable sites might most easily be found. It is recognized that many potentially suitable locations might be found to have more severe

restrictions than those identified herein, and that areas apparently less suitable might offer additional site development potential.

Water resource availability has been considered as shown on Plate 4-2. It is not possible to assure that ample cooling water will be available wherever required in the inland areas noted. However, water might be provided to a location in a number of ways. These include reassignment of existing water allocations, development of groundwater basins, collection of irrigation drainage, and additional water transport from areas of high precipitation. It requires the expenditure of funds for obtaining the water from an existing or newly developed source and that investigation is beyond the scope of this study. However, the cost for that development, as reflected in purchased water cost, is later considered in the evaluation of inland plants as compared with coastal units. It is apparent from Plate 4-2 that of the two apparently most suitable regions, the Great Valley is closer to a larger number of water sources than is the Mojave Desert. Therefore, when new water sources are required, it may be well to consider locations in the southern part of the Great Valley in preference to sites in the Mojave Desert so as to reduce the water development costs.

PLATE 4-1
INLAND SITE SUMMARY

PLATE 4-2

INLAND WATER RESOURCES

5. SITING CONCEPTS

The coastline of California and the offshore zones provide a diversified environmental background which may be summarized as:

1. The topographic features on land vary from low elevation beach areas to high cliff and mountainous terrain, the latter being prevalent.
2. Seismic exposure ranges from low to very high ground motions.
3. The materials contained in these profiles vary from saturated or dry unconsolidated soils to massive rock moderately jointed.
4. The land is used for many purposes. However, over 60 percent of it is almost completely undeveloped and unpopulated. Some of it is heavily populated and used for residential, industrial, or commercial purposes, and much of the land use falls somewhere between the two extremes.
5. There is a large number of animal species in the coastal area, some of them rare and endangered, sharing the coastal environment with humans.
6. The vegetation throughout the coastal zones is generally sparse and of low profile, with forested areas predominantly limited to the northern part of the State.
7. The offshore zones are typified by a continental shelf which drops off rather rapidly from the shoreline. There are shallow water depth contours offshore, but only a limited portion of the coast has a shallow area at a distance of about 3 miles from the shore; there are almost no shallow areas at greater distances.
8. Most of the water out to about 3 miles is at least 200 to 600 feet deep and, in general, is substantially in excess of that at 12 miles out, the State and Federal jurisdictional limits, respectively.

9. There are several islands located offshore which add to the diversity of the California coast.

A number of alternatives to an aboveground coastal nuclear power plant have been studied. Many of these require particular siting conditions in order to offer advantages. Collectively, these conditions constitute a wide variation in the physical features of sites, but fortunately there are many areas in the State with these features. Therefore, all of these alternatives can be considered for siting in California.

In evaluating concepts, a distinction must be made between those that merely extend proven practices, those which appear technically feasible but have a lack of experience in application, and those which do not appear to be attainable within the time frame covered by this study. The latter two groups may not be acceptable according to AEC licensing standards. Some of the more prominent, and perhaps more attainable, concepts are identified in this study.

The siting concepts are grouped by their general location aboveground, underground, or offshore. In the evaluation process, each of these is compared to a typical aboveground coastal plant which is the base line. For this study, a facility and location similar to the planned San Onofre Unit No. 2 south of San Clemente has been selected as the base line concept. These other concepts are as follows:

1. Aboveground
 - a. Coastal (base line plant)
 - b. Inland
 - c. Hillside
 - d. Low profile
 - e. Floating, onshore lagoon
2. Underground
 - a. Massive igneous rock
 - b. Massive sedimentary rock
 - c. Unconsolidated, beach
 - d. Nonmassive, poorly cemented
 - e. Rock, faulted

3. Offshore

- a. Floating, shallow
- b. Floating, deep
- c. Seabed
- d. Undersea
- e. Artificial island
- f. Natural island
- g. Tuned sphere

The inland concept is included to suggest that an alternative to supplying power to coastal load centers from coastal plants could be an aboveground plant located at an inland site. It is assumed for the inland plant that sufficient quantities of water could be obtained from rivers, purchased from existing allocations, or that future developments can provide water at costs comparable to today's commercial costs. In-depth studies of water use, population growth, mineral content, resource allocation, and water rights would be required to quantify the availability, both current and future.

The floating concept situated in an onshore lagoon is suggested from studies made relative to the offshore floating platform. Although it is grouped with land-based plants, this concept is discussed for convenience after the offshore floating concept.

Underground plant concepts are extremely dependent on the media in which they are located and, therefore, several concepts are considered. These are discussed later in this section.

Most of today's power plants rely on the combustion of fossil fuels to generate steam. Of the potential heat sources, in the foreseeable future most plants will utilize either fossil or nuclear fuel systems according to the availability and allocation of national resources. While some assessment is given in Section 7 of the impact of a fossil energy system on siting concepts, the emphasis in this study has been on use of nuclear energy systems; in particular, nuclear energy within today's technology as applied through 1990.

Most of the new nuclear plants in this decade will utilize light water reactor (LWR) systems as the heat source. There are two of these systems, the pressurized water reactor (PWR) and boiling water reactor (BWR). The differences between the two systems are small

with respect to this study and are insufficient to warrant separate analysis of the two. The PWR reactor has arbitrarily been selected as the LWR system on which facilities have been sized. However, details of the PWR plant system and differences from the BWR are presented in Appendix B. The purpose of presenting these is to define interfaces between facilities which house them and the environment, so that they might be considered in the study.

There are other nuclear systems which very likely represent energy sources for power in this century. The high temperature gas reactor (HTGR) with a steam cycle is now operating and being designed for large central station utilization. Less developed systems include the breeder reactors, in particular, the liquid metal fast breeder reactor (LMFBR); and the HTGR with a gas turbine. These are all discussed in Section 6. Their differences from the PWR, as they affect facilities or sites, are presented in Appendix B.

Discussions which follow for each of the siting concepts include an identification of the type of site to which the concept is particularly well suited and some of the special site requirements. The basic advantages of each concept are noted. If special methods for constructing the facilities are required, or special exploration efforts are required to find suitable sites, these also are discussed. General discussions of materials and equipment are presented where they differ from the description given in Appendix B. Where advantageous and meaningful, facility layouts are included indicating areas used by the major systems. Disadvantages of each concept and uncertainties in acquisition or licensing are also noted and are considered in the evaluation section later in the report.

All concepts presented are based on a single unit, 1,100 Mw(e) nominal capacity. Corrections to quantities presented were adjusted in the evaluation process as necessary to reflect operating characteristics peculiar to siting areas or manufacturers' standards.

Ocean intake and discharge cooling systems are discussed first since they apply to most land-based coastal plants. Then, transmission line alternatives are presented since they too are common in many of the concepts.

5.1 ONCE-THROUGH COOLING

The coastal plants are characterized by their location near the ocean where most of the intake seawater is moved from a shoreline

pumping station to the turbine steam condensers. The water is returned to the ocean from the condensers in a closed pipe loop. The difference in elevation between sea level and the shore-based plants is small; and, therefore, the pumps normally supply the required flow without having to overcome a large static head encountered with other concepts which normally would be located at higher elevations. More horsepower also is needed in a loop system such as used with a wet cooling tower. In the latter system, the pumps raise the water to the condensers and additionally to an elevated level in the cooling tower where it is dispersed over an evaporation surface and permitted to free-fall into a collection basin.

It is economical to locate the plant as close to the shore as possible when using once-through cooling and, at low elevations, to minimize line lengths and friction loss between the pumps and the plant.

The supply water is provided through a large intake line, 18 to 20 feet in diameter, and it extends out from shore several thousand feet where cooler water is obtained from the greater depths and intake of animal or plant life which is more abundant in shallower water is minimized. Two purposes are thus served within the larger environment offered where water depths are greater: first, damage to aquatic organisms, kelp, and other plant life is minimized since their population density is often lower there; and second, the removal of the larger animal forms and bottom material before transfer into the system is also minimized. Solids intake is further reduced by incorporating screens and mechanisms into the pumphouse systems to remove entrapped materials. Also, periodic reversal of intake and discharge line flows between the pumphouse and ocean removes many life forms tending to occupy the intake conduit.

The lines between the pumps and the plant are generally smaller diameter and greater in number to reduce burial problems, to provide redundancy, and to interface better with a number of condenser points. The return line to the ocean is of large diameter and extends into the ocean sufficient distances to minimize the impact of the discharge water on the environment and on the system.

The temperature rise across the condensers is 15 F to 20 F and the discharge water temperature is about that much higher than the

intake temperature. Therefore, it is necessary to separate sufficiently the intake and discharge points so that the discharge water will mix without raising the temperature of the intake water.

The higher temperature of the discharge water also affects marine species which are sensitive to small temperature changes. Studies* indicate that in some cases the upwelling caused by heated discharges at depth would cause the lifting of nutrient-rich seawater to the surface and would enhance the production of animal protein. This would then increase productivity in these zones. On the other hand, marine species vary in their thermal tolerance in these zones. All must be able to withstand temperatures within the natural occurring ranges. In its natural waters temperature plan, the State has placed limits of 4 F as the change in temperature at the shore resulting from discharge water; it also places a 20 F limit on temperature rise at the discharge point. Both constraints insure that the thermal effects of plant operation will be limited to the area close to the discharge.

The intake and discharge lines being proposed for San Onofre Nos. 2 and 3 are 3,400 and up to 8,500 feet long, respectively. These dimensions have been used as typical of the land-based coastal plants in this study. The offshore plants in this study are presumed to have intake lines of about 200 feet and discharge lines of 1,000 feet in length. Exceptions are noted.

5.2 TRANSMISSION LINES

Overland transmission lines can be grouped into three categories:

1. Overhead bare conductor.
2. Underground, insulated, single, or multiconductor cable.
3. Aboveground, low profile, insulated, single, or multiconductor cable.

The overhead bare conductor is the lowest in cost. However, it requires a large amount of right of way for towers and removal of surface effects and is vulnerable to lightning effects. Further, it is under considerable environmental impact scrutiny. It may be assumed

*Isaacs, J. D., and Schmitt, W. R., "Stimulation of Marine Productivity with Waste Heat and Mechanical Power," University of California, San Diego, Scripps Institute of Oceanography, La Jolla, California.

that for future planning, overhead lines will be permissible only in sparsely settled or undeveloped areas, and that in developed communities 138 kv and 230 kv underground lines will be required. Use of 345 kv and higher voltage underground systems will be limited since that size is predominantly used in the outlying areas where overhead lines are not so objectionable.

Underground lines are presently installed in direct buried ducts in a number of locations, but these are lower voltage, low power capacity lines making short road crossings. The large central station power plants now being planned require greater carrying capacities in the transmission lines to minimize their cost and environmental impact. Better insulation and use of forced cooling permit increases in capacity.

Oil-cooled or compressed-gas insulated systems appear to provide a possible solution, for at least short runs in the future. Research and demonstration installations using sulphur hexafluoride (SF_6) as the insulator/coolant have shown that voltage levels through 500 kv are feasible and could be economical for runs of several miles in length. The system has application to underground installations as well as aboveground low profile installations. Figures 5-1 and 5-2 indicate two 345-kv systems now operating. The first is in pipes in a trench, buried in 2 to 3 feet of thermal sand, and the second is in pipe located just abovegrade and carried on low support structures. These are 300 and 400-foot-long installations, respectively, but lengths of several miles appear to be economical. In these lines the cable is supported in the center of each pipe, and SF_6 flows between the cable and pipe wall. By locating the lines aboveground, but at low profile, it is possible to reduce the cost by eliminating excavation, backfill, and corrosion protection required in buried systems. Large capacity lines longer than a few miles, as would be required by many future plants, now require that a number of lower capacity circuits be used.

There are a number of alternatives being developed for longer, larger capacity lines. Pipe-type cable may be able to carry as much as 1,200 Mw. Gas-dielectric or vacuum-insulated systems might carry 2,000 Mw. Cryogenic systems will probably be required for higher capacities. Supercooled lines using helium potentially have the ability to carry large loads. Another form of cryogenic cable is the superconducting type that also is being developed. As the temperature of a conducting material approaches absolute zero, its resistance decreases to a theoretical zero minimum. Thus, a cable conductor need only be large enough for physical strength as its current carrying capacity approaches infinity so long as the temperature is held

FIGURE 5-1
AN UNDERGROUND GAS-INSULATED SYSTEM FOR
AN EAST-COAST UTILITY

FIGURE 5-2

TWO GAS-INSULATED CIRCUITS ABOVEGROUND
IN THE SUBSTATION OF A MIDWEST UTILITY

sufficiently low. While this method is definitely promising, much more development will be required to achieve a practical system that is economically sound in both cost and operation. If the demand for this system is very large, supplying a sufficient amount of helium could be a problem.

Resistive-cryogenic systems using liquid nitrogen and having much larger capacity than the other noncryogenic systems might be more practical because the liquid nitrogen coolant would be more available. The General Electric Company will continue research and development of these cryogenic-cooled cables during the next 6 years, under a program sponsored by the Edison Electric Institute and the U. S. Department of Interior. Present indications are that the configuration may be as shown in Figure 5-3. It would consist of three flexible cables mounted inside a double-walled, insulated steel pipe approximately 20 inches in diameter. The conductors are likely to be hollow aluminum tubes with liquid nitrogen circulated through the center. This system would require intermediate stations, perhaps every few miles, at which points the liquid nitrogen temperatures would be maintained and the liquid pumped through the next increment. Since these stations can be low in profile and quiet in operation, the system may be acceptable in populated areas. This system is being targeted for availability in the 1980's. It will be considerably higher in cost per mile than others in use, but its advantage is a far greater capacity that otherwise may not be possible, or may be possible only with a larger number of circuits which makes the total cost of the conventional system high.

Submarine high voltage lines are becoming of more concern because of plans to install floating power plants on the east coast and the need there for transmission lines to shore. Today, high voltage submarine lines are pipe and oil-filled types. They are presently in service in locations in the east. However, the runs are short (about 12 miles maximum), the voltage levels are limited to 138 kv, and the line capacities are limited to 300 mva. The manufacturers have generally indicated that similar approaches can be taken for high voltage lines with about 1,100 Mw capacity as required for the floating plant concepts through use of more than one circuit. However, there is no precedence for reliability locating and maintaining these lines in as much as 300 feet of water as may be required in California conditions.

SF₆ gas-insulated transmission systems are being investigated for larger capacity submarine applications in the early 1980's. Short

PROPOSED RESISTIVE CRYOGENIC CABLE
(COURTESY GENERAL ELECTRIC COMPANY)

FIGURE 5-3

PROPOSED RESISTIVE CRYOGENIC CABLE

sections of large diameter pipe containing the three-phase aluminum cable pipes would be used with SF₆ flowing in all pipes. Connection details during construction may present the major problems. Also, in shallow water zones the system would have to be buried in the ocean bottom for safety from anchor dragging or scouring; if the water is sufficiently deep, the line could lay on the bottom material. Here again, if distances between the plant and shore become too great, then underwater intermediate compressor stations may be required and this would complicate the system.

It is seen that a number of transmission line alternatives are in various phases of development. However, it appears that with a demand for providing underground, low profile, or submarine high voltage lines with large carrying capacities, suitable systems can be made available in the time frame required.

In this study, it is assumed that the on-land transmission line from the switchyard to the offsite substation is common to all of the concepts and therefore, is not considered in the comparisons made. In practice, however, the acceptable technique used in each case would depend on the distance to the coastal road or main travelled road, land use, and whether the line would be visible.

Underground circuits from underground installations are assumed to run up shafts to the surface where they terminate in a facility that enables the transition from underground to overhead, low profile, or underground transmission runs. Underground electrical distribution lines are assumed from the switchyard to the pumphouse since these will cross the coastal road and would otherwise be visible.

Submarine circuits with backup are assumed for the offshore concepts, extending from the plants to a shoreline terminal substation. As the offshore lines near shallow water, they would be buried for protection but in highly permeable material. The route to shore will have to be selected to avoid severe hydrography and the watertight lines placed in a configuration amenable to slight motions from underwater currents should they exist, or from seismic motions so as not to jeopardize the long term integrity of the transmission system. The onshore continuation of the transmission lines would be the same as for the land-based plants and therefore is ignored in the evaluations.

Costs used in this study for underground and underwater transmission lines assume a number of low capacity, oil-filled pipe lines since this type is in use today and is representative. Use of alternative

transmission line concepts in development as discussed above will increase line capacity and, therefore, reduce the required number of circuits. Although unit costs may increase for the future lines, the number of circuits otherwise required will be reduced, thereby maintaining the cost feasibility of the larger capacity lines.

5.3 ABOVEGROUND CONCEPTS

5.3.1 Coastal

This aboveground plant would normally be located near the shoreline at a relatively low elevation, such as would occur at beach or low terraced areas. These locations near the shoreline minimize the condenser cooling water line and pumping costs. The area used to site most of the buildings is about 15 to 20 acres with 14 additional acres required for laydown, parking, and storage during construction. This area would be common to more than one unit in an expanded plant. The balance of the area is used for exclusion purposes. The size of the exclusion zone is a function of a number of site-dependant variables, such as meteorology and geography, but readily licensable 1,100 Mw(e) plants having reasonably standard safeguards commonly have an exclusion radius of about one-half mile. An area of about 200 acres is assumed for the amount of land required, or about 150 acres if located on the shoreline where the ocean provides a part of the exclusion to permanent occupancy. As the facility is expanded up to six units, the total acreage consumed would be about 600 acres including exclusion zones.

Access to the facility is provided from the public highway adjacent to the property. Rail access is also provided, but marine docking facilities are not required.

A 20-foot elevation of the general grade might represent a minimum to assure safety from potential storm or tsunami action. Additional protection may be provided by a reinforced concrete seawall of a height dependent on the specific site. Heights of 25 to 30 feet can be anticipated in some cases.

The principal facilities on the site are the reactor containment building, auxiliary building, turbine generator area, switchyard, administration, shops, and warehouse buildings. A plan layout of the site is shown in Plate 5-1 located at the end of this section and a perspective is seen in Figure 5-4.

FIGURE 5-4
ABOVEGROUND - COASTAL

5.3.1.1 Facility Description. Plates 5-2 through 5-6 reflect the main facilities of a typical coastal plant. The reactor containment building is a reinforced concrete structure on the order of 138 feet outside diameter and 203 feet high in the shape of a cylinder with a dome roof. The cylinder and dome are prestressed to eliminate concrete cracking and thereby retain shield integrity. The interior of the containment shell is lined with about 1/4-inch thick steel plate continuously welded to provide a gas tight facility. This containment structure might have 4-foot thick walls at the base and a 3-1/2-foot thick dome, and provides biological shielding for normal operating conditions. It is normally designed to contain internal pressures of up to 60 psi, resulting from a loss-of-coolant-accident. Some reactor system designs incorporate additional containment cooling systems to reduce the pressures. The design-basis leakage of the vessel during an accident is often selected not to exceed 0.3 percent of the building volume in 24 hours. The internal structures and compartment arrangement provide equipment missile protection and biological shielding for maintenance personnel. The reactor containment building houses the reactor, steam generators, pressurizer, pumps, drain tanks, and nuclear safety systems equipment.

Adjacent to the containment building is the auxiliary building in which the nuclear fuel storage and transfer facilities are located, as well as radioactive waste storage systems, pumps, tanks, and the control room. It also contains the sampling and testing laboratories associated with the nuclear processes. It is contiguous with the electrical and piping penetration rooms into which all such penetrations from the containment building are made. The facility is about 50 feet x 275 feet x 100 feet high and is a reinforced concrete structure designed to permit safe shutdown of the reactor under any predictable adverse event as is the containment building.

The complex includes a turbine generator facility, which is about 150 feet x 350 feet x 120 feet high and contains the turbine, generator, condenser, condenser cooling lines, reheaters, and the transformer switchgear. With an overhead crane, the turbine deck is outside and the three levels below are enclosed in a steel framework.

The exterior to these facilities are locations for condensate tanks, borated water tanks, emergency diesel generator units, and other ancillary equipment.

The switchyard, an open area containing oil-filled switchgear, encompasses an area of approximately 150 feet x 750 feet.

Major reductions in equipment sizes are possible by utilizing recently developed sulphur hexafluoride gas (SF_6) as the coolant instead of oil.

Administrative office space, warehouse buildings, and shops occupy about 5,000 square feet. The site also includes a visitor center to support public interest in the facility.

Radiation limits would be in conformance with AEC criteria. The direct radiation from the reactor is shielded by the reactor vessel, concrete shield, and by the containment building walls and dome. The normal and emergency air handling systems filter all potential radioactive sources for solid particles and sample the air for noble gases. Gases are either held in compression tanks for radiation decay and/or are released in safe concentrations through filters to a 180-foot high stack adjacent to the containment building.

Solid and liquid wastes from filter systems are collected and stored, then processed and diluted for release, or are shipped off-site. Diluted liquid wastes are released into the condenser cooling water system. Solid wastes are drummed and shipped off-site.

Reactor spent fuel elements are held in pools in the auxiliary building and are shipped in casks.

5.3.1.2 Considerations - To date the aboveground plant has been the conventional approach to providing nuclear power plants, and some have been located on large rivers or lakes rather than on the ocean as indicated here. Their feasibility is accepted; construction methods and materials are conventional, and construction costs are reasonably well known.

The coastal based plant may be subject to seismic motions, earth slides, floods, and other natural phenomena, depending on location. However, siting and design can reduce the effect of these exposures.

The aboveground plant is more vulnerable to missile attack from the air than are some of the underground concepts, should such be a consideration. On the other hand, it is perhaps no more vulnerable to modes of sabotage than other concepts.

The location of aboveground coastal plants is an important environmental impact issue. This issue may soon become one of the

more limiting constraints when considering plant visual image and use of some valuable coastal lands.

5.3.2 Inland

The inland plant would be in a relatively remote location away from the coastal zone and remote from populated areas. In this concept the plant would supply power to the coastal zone and may be connected to the high voltage intertie network as a means of reaching that zone. Cooling water can be provided a number of ways; but is assumed here to be obtained by recirculation from natural draft evaporative cooling towers on the site. Make-up water could be obtained from a canal which feeds an on-site reservoir. The reservoir is sized so that during periods when the canal flow is stopped for canal maintenance or other reasons, there is sufficient make-up water in the reservoir to continue operation for awhile. The Rancho Seco plant, used as a basis in this concept, utilizes a 160-acre, 2,600-acre-foot reservoir to supply make-up water for at least 45 days. This reservoir also can be used as a recreational facility for fishing, picnicking, and other allied activities. Based on a review of potential siting regions shown in Plate 4-1, the site is assumed to be located about 100 miles from the intertie or substation near the load center.

The facility would be serviced by highway and rail transportation systems.

As seen in Figure 5-5, the perspective of the plant area is such that the cooling towers dominate the site structures. (Use of mechanical draft fans, which are also feasible with evaporative cooling towers, would lower the overall plant profile.) Other principal facilities include the containment building, auxiliary building, turbine generator area, administration building, warehouse and shops, switchyard, and spray ponds. These are seen in Plate 5-7 within the fenced area. External to this area is the standby cooling water reservoir and a visitor center.

5.3.2.1 Facility Description. The reactor containment building and other facilities such as the turbine generator area, switchyard, auxiliary building, and various tankage at the site are the same as for the aboveground coastal plant. Plates 5-8 through 5-11 show the similarity in facility sizes to the coastal plant. Differences exist, however, from the once-through cooling system of the coastal plant.

FIGURE 5-5
ABOVEGROUND - INLAND

Several alternative cooling systems are available. Large evaporative cooling reservoirs, spray ponds, and wet or dry cooling towers using mechanical or natural draft systems constitute the types which are considered feasible. It is beyond the scope of this study to analyze the application of these alternatives as they pertain to potential sites. However, there are a number of studies* which make such evaluations. The natural draft wet cooling tower is assumed in this study since it had proven to be the most economical for the design of the Rancho Seco plant.

The cooling tower system is based on a yearly average 52 F wet bulb and 60 percent relative humidity. For a 963 Mw(e) plant the circulating water pumps are sized for about 450,000 gpm and a maximum head of 82 feet. Two hyperbolic natural draft cooling towers, 325 feet in diameter at the base, 425 feet high, and 195 feet in diameter at the top operate at half capacity.

Because of the dry location and the lack of a natural source of cooling water, spray ponds are provided for safe shutdown conditions. The ponds cool water to the reactor building, emergency diesel generators, and reactor system. Each pond cools 16,000 gpm of recirculated water from 109 F to 87.2 F with a 70 F wet bulb. They are each 354 feet x 188 feet in size, of reinforced concrete and contain 2,700,000 gallons of water.

The remoteness of the facility enables aboveground, elevated transmission lines to be used until reaching the large inhabited areas nearer the load and population centers.

The plant area required for this single unit is about 75 acres including space for cooling towers, emergency water spray pond areas, parking, and construction staging. An additional 100 to 200 acres is used by the reservoir. Considering the exclusion zone, the total area required for a unit would be at least 400 acres.

The operating water requirement is dictated by make-up of evaporation losses and blowdown from the cooling towers. This make-up might be 15 to 20,000 gpm depending on site conditions, or about 25 to 30,000 for an 1,100 Mw(e) plant.

*Beck, R. W., & Associates, "Cost Comparison of Dry-Type and Conventional Cooling Systems for Representative Nuclear Generating Plants," prepared for AEC, TID 26007, March 1972.

Radiation impacts in this plant are the same as for the coastal plant with principal protection from direct radiation offered by the concrete shielding around the reactor and by the containment building.

For an inland plant with limited natural water resources for plant liquid effluent, it is desirable to have a closed cycle radioactive liquid waste system designed for no liquid discharge containing radioactivity of plant origin. This is a unique feature of Rancho Seco and is an option that is only recently being offered by NSS vendors for current designs. Gaseous and solid wastes are handled similarly to the coastal plant.

5.3.2.2 Considerations. This type of plant has proven itself to be economically and technically feasible in the United States and several other areas of the world where once-through cooling water cannot be used. Conventional materials and construction techniques are employed.

The facilities are located in remote inland areas where land use conflicts may be a much less serious factor than in the coastal zones. Also, a greater number of inland locations provide needed flexibility for avoiding the more seismically active areas placing a constraint on many of the coastal zones. These inland, flat locations are usually not subject to many of the natural hazards that some coastal plants may be exposed to, including liquefaction, mudslides, and tsunamis.

The location inland eliminates once-through cooling using intake and discharge facilities and pumping plants to meet the operational and emergency cooling requirements. The inland plant requires cooling towers, emergency cooling spray ponds, emergency water supply, water handling, and control systems for moving the water between each of these systems, and a standby water supply which is not normally in use. In some locations, the environment might not be conducive to efficient, evaporative cooling. During certain periods of the year, fogging of the atmosphere might result from the increased humidity. A combination wet-dry tower could be designed to reduce fogging effects or alternatively it could be designed to minimize water consumption.

The water demand may be in competition with other water demands and may require reallocation, additional water conveyance, or additional water supplies in some areas of the State. Alternatives to the use of river or canal water brought from other locations include the development of waste irrigation water as a source.

5.3.3 Hillside

The hillside concept for siting a power plant is based on maximum utilization of favorable topography. In its most economical application, the plant would be an aboveground concept nestled in the depressed or valley portion of hilly terrain, inland of the coastal road. Elevations of the area surrounding the plant would be at least several hundred feet.

The area would be reached by access road from the coastal highway. Figure 5-6 shows a perspective of the concept where the plant is aboveground and situated in such a way that it is not visible from the highway.

There are many coastal zones well suited to this approach. It merely requires that the plant layout be configured so that it makes good utilization of the depressed grades to minimize the excavation that will be required to develop building and tankage areas. This may result in a somewhat random site layout and many of the buildings may be located at different grades.

The hillside location will require special earthcuts and drainage structures to control flood or rainwaters flowing into the site and to prevent mudslides in the area or undermining of structures.

The concept necessitates longer cooling water intake and discharge lines and pumps operating under higher heads since the facility will probably be located inland as much as one mile and elevated perhaps several hundred feet above sea level.

5.3.3.1 Facility Description. The buildings, their contents, and area facilities are the same as for the aboveground plant. The utility systems which extend between facilities have longer runs as do service roads and fencing that are required, because the buildings and tanks are spread out to more closely fit the natural terrain. However, sea wall construction is not required because of the higher elevation of these sites.

This concept occupies more area than the other aboveground coastal plants. A single unit might require 400 acres including the storage reservoir to site the same facilities than an aboveground coastal concept can site in about 200 acres.

FIGURE 5-6
ABOVEGROUND - HILLSIDE

5.3.3.2 Considerations. The plant is feasible in that aboveground concepts are presently in use. The development of hillside areas for large projects is not uncommon in California as evidenced in the Palos Verdes, Sepulveda Pass, and other southern California and San Francisco Bay areas.

Advantages of this concept include a higher degree of visual acceptability because it is hidden from the coastal road. Also, there is a great deal of hillside area available in the coastal zone inland of the coastal road, and therefore use of this concept substantially increases the availability of plant sites.

The purchase price of undeveloped land of this type in the uninhabited areas of the coast will be substantially less than other coastal property.

Intake and discharge lines are more costly in this concept than the other land-based coastal plants because of the added length and more rugged terrain. Also, pump sizes are increased due to the higher head at these elevated sites.

The hillside concept likely will be subjected to greater natural hazards such as landslides or mudslides than the plants at the beach. Seismic ground motion will have to be carefully considered although no particular penalty over the coastal concept is foreseen. Expenditures will be necessary for earthwork and flood control structures to obtain safe drainage. Brush fires may also be a hazard in these hillside areas, depending on the location.

5.3.4 Low Profile

Aboveground concepts can be made less obtrusive by lowering their profile. This can be accomplished by attempting to minimize the building heights in facility design. However, that approach appears to be somewhat futile because of the need to substantially overcome the 200-foot height of the functionally designed containment building. It is more feasible to lower the profile by major excavation to place the facilities at a lower elevation. The need for excavation is minimized by selecting sites which are naturally depressed, then increasing their depression by excavation. A perspective of this approach is shown in Figure 5-7 as viewed from the coastal road toward the ocean, but the location may be even more applicable on the landward side of the road. Deep side and end cuts, similar to that shown in Figure 5-8, would often be required. Although not eliminating the plant view,

FIGURE 5-7
ABOVEGROUND - LOW PROFILE

FIGURE 5-8
SAN ONOFRE POWER PLANT

this approach reduces the visual impact of the facilities and could improve its public acceptability.

5.3.4.1 Facility Description. The plant layout is identical to the aboveground coastal plant. However, it may be necessary in some cases to protect the earth-cuts in poorly cemented materials by using extensive retaining wall construction or flatter side slopes to avoid slides.

Each facility in the plant is the same as described in the coastal aboveground concept.

5.3.4.2 Considerations. The feasibility of this concept is limited only by the availability of terrain which is suited to this approach and to the environmental impact of the major excavation involved. Desirable locations for the low profile concept are envisioned as existing where advantage can be taken of hills and depressions. Sites would be at elevations starting about 100 to 150 feet above sea level and preferably first sloping up from the coastal road before dropping down in elevation. While seemingly demanding, there are many miles of California coastline with these characteristics.

Most advantages of this concept are the same as for the coastal aboveground concept. However, this concept additionally reduces the profile of the plant and thereby adds to the aesthetic acceptability of the project.

5.4 UNDERGROUND CONCEPTS

Underground locations have been suggested as possible alternatives to aboveground plants. This application to underground power plants is not without precedence. Studies* have surveyed the application of underground locations for power plants and have noted a number of nuclear plants in Norway, Sweden, France, and Switzerland. In all of these cases, however, the sites have more favorable rock conditions and are not subjected to the seismic conditions encountered in California. Therefore, some additional precautions may be necessary in selecting sites having sound rock integrity to avoid the need for seismic design of the formation. This type of design might prove to be difficult, if not impossible, to provide the necessary assurance for licensability of the plant.

* Watson, M. B., Kammer, W. A., Langley, N. P., Selzer, L. A., Beck, R. L., "Underground Nuclear Power Plant Siting," Aerospace Corporation and Environmental Quality Laboratory, Cal Tech, EQL Report No. 6 (September 1972).

There are investigations* which indicate that seismic induced ground motions decrease with depth below surface. When determining motions at the surface, values are increased as a result of surface reflections, as well as in the presence of materials less consolidated or homogeneous than the material below. However, there appears to be a lack of field data sufficient to convince regulatory agencies in the near future that a reduction in seismic loading with depth could be permitted.

In addition to the question of seismic loading underground, there is a question as to the feasibility of assuring that no active faults exist within the site so that the faults or the ground motion potentially initiated by them need not be considered in the design. Furthermore, such assurance is subject to reversal from the continuing exposure of faces during excavation in the underground environment even though smaller exploration advances would be incorporated in the work. The investment made in excavation would be sacrificed should active or potentially active faults be uncovered and the site subsequently abandoned. These factors must be examined when considering the potential application of an underground location for siting a nuclear power plant.

The underground concepts are very dependent on the material in which they are located. Most concepts investigated to date have been limited to locations in competent rock, but other media are also feasible. As shown in the prior section, relatively few coastal sites in massive igneous rock exist, although there are some. At the other extreme, there are a number of miles of unconsolidated materials where an underground plant might be possible. The remaining geology is a mixture of poor to well cemented materials which also could be considered for underground plants. These variations in media impose requirements for design differences in the plants.

In earlier phases of this study underground concepts considered were based on a number of design approaches including surface excavation, underground mining, and various schemes for supporting surface fill. The apparent cost effective approaches, selected for greater definition, are included here.

5.4.1 Massive Igneous Rock

The nuclear power plant is situated in massive igneous rock, moderately jointed. The sites are in hilly terrain, preferably in areas

* Leeds, D., "The Underground Seismic Environment," Proc., Rapid Excavation and Tunneling Conference, ASCE, Chicago, 1972.

of low groundwater table adjacent to the coast where the terrain rises sharply inland. This environment permits development of horizontal access tunnels from which the cavities that will contain the plant facilities can be mined. Horizontal access is selected in preference to vertical shafts from the surface since shafts are generally of smaller dimension for sidewall stability and much more time and cost would be consumed in hauling muck from the excavation.

The depth of facility cover is determined in two ways. First, the cover above each facility must be sufficient for the rock roof to be self-supporting with the aid of rock anchors and rock bolts. This will avoid costly roof support during construction. The roof thickness for this purpose depends largely on the jointing of the material and is not determinable without extensive exploratory drilling and testing.

Preliminary investigations in this study indicate that with the use of rock anchors, the roof thickness below the zone of weathered materials should be at least equal to the clear span or about 120 to 150 feet to provide the strength for spanning without structural support. With the thickness of rock cover so great, it is desirable to consider increasing it sufficiently to resist internal pressures in the containment building resulting from an accidental energy release and thereby reduce containment building wall and roof thicknesses. In order to withstand internal pressures of about 60 psi with granitic or sedimentary rock as exists in California, and considering the lithostatic pressures from this material, thicknesses on the order of 150 to 200 feet below weathered materials are required.*

The thickness of roof was also investigated in the referenced study for its suitability in condensing vapor containing radioactive materials which leak into the formation joints as a result of a hypothetical accident. It was determined that 150 to 200 feet of cover would supply ample safety factor against atmospheric releases. However, in the concepts presented, it is assumed that it may not be possible to license a plant without a gas tight enclosure as is used in a surface plant; therefore, the enclosure is included.

* Watson, M. B., Kammer, W. A., Langley, N. P., Selzer, L. A., Beck, R. L., "Underground Nuclear Power Plant Siting," Aerospace Corporation and Environmental Quality Laboratory, Cal Tech, EQL Report No. 6 (September 1972).

Other facilities in the excavation are located with respect to elevations of the containment building, with the turbine generator building at the lowest possible elevation to reduce pumping requirements.

The plant is shown in perspective in Figure 5-9. All mining operations are accomplished from the horizontal tunnels which also become service roads during operation of the facility. The front of the administration building is flush with the plant access and provides an unobtrusive office building appearance.

A pump house is buried at the shoreline several hundred feet away from the turbine. The water intake and discharge lines would be in underground tunnels connecting the two facilities. Electrical power lines extend vertically to the surface over the electrical switchyard in shafts and connect to the transmission system at the surface.

Five plant ventilation structures would penetrate the surface; one to accommodate the containment purge exhaust system, radwaste area exhaust, and radiochemistry/health physics laboratory; one each intake and exhaust for the air conditioning system; one from the turbine building; and one from the switchyard area. Their diameters would be small, but their height would depend on the site characteristics and the drafts required to be developed.

All new fuel, spent fuel shipping casks, and radwaste removal drums would be transported through the fuel-auxiliary building access tunnel. Personnel would travel to the control room, laboratories, and fuel and turbine buildings through the administration building access tunnel. In addition, access to the turbo-generator and switchyard areas would be through the turbine building access tunnel. Tunnel access is also provided to the containment facility equipment hatch for installation of equipment and components within the building. An access road to the pumphouse also will be required.

In summary, the total plant is underground with surface penetrations for the administration building (frontal elevation flush with the side of a hill), five access roads, five vent structures, and a pumphouse subway entrance at the shore. In addition, a construction operations area will be required on the surface near the facility.

FIGURE 5-9

UNDERGROUND-MASSIVE IGNEOUS ROCK

5.4.1.1 Facility Description. The plant is constructed in six underground caverns, as shown in Plates 5-12 through 5-14:

1. Containment building.
2. Fuel-auxiliary building.
3. Turbine-generator building.
4. Transformer and switchyard area.
5. Control building.
6. Administration building.

The arrangement takes advantage of the surface contour rising from the coastal road with the turbine condenser intake at a minimum height above sea level and a 150-foot rock overburden above the turbine crane at this station. The reactor-steam generator components in the containment building are located at a point of horizontal penetration into the hill where about 200 feet or more of cover is available. Other rooms are separated from the containment building to provide adequate rock pillar support in a fan shape pattern which would follow common contour lines at the entrance to each underground area. Greater rock thickness over the buildings will affect vertical penetration costs but have little impact on overall cost.

All components and subsystems in this plant are similar in size to those required in an aboveground plant.

Conventional drilling and blasting methods using multi-deck jumbos, modified by application of "smooth wall" or "presplitting" techniques in crowns and ribs (domes and walls), are well adapted to excavation of the entries and the major chambers. Tunnel boring machine capability for strong rock headings in excess of 20 feet in diameter has not yet been proven; however, time and cost can be saved by use of raise boring machines for excavation of ventilation and utility shafts, especially for smaller diameters.

In order to provide protection to personnel from spalls, rock conditions which typically might be encountered could require 6-foot long rock bolts installed on 5-foot centers in access tunnel arches, and the surface finished with wire mesh and 2 to 3 inches of

shotcrete (see Plate 5-13). All bolts would be installed from the gantry jumbo and grouted after tensioning to inhibit corrosion. In the major building chambers and switchyard area, 100-foot long rock anchors on 15 to 20-foot centers and 30-foot long rock bolts on 5-foot centers might be installed in the arches or domes; and 6 to 10-foot long rock bolts might be driven into the side walls on 10-foot centers similar to that shown in Plate 5-14. Rock anchors are clusters of high strength cables anchored at the ends of tangential drill holes and tensioned prior to grouting. All the rock bolts support wire mesh. Except for the containment building, the arch surfaces would be finished with 8 to 12 inches of shotcrete. The floors are reinforced concrete with foundation footings for equipment and structures.

A 1/4-inch thick leaktight steel liner is fabricated inside the containment building with a 12-inch annular space between it and the rock (see Plate 5-14). Right circular liner sections are assembled first, welded, and inspected from the inside; and concrete is poured in the annular space to a level just below the top of the cylinder portion to permit welding of the next section. This process is repeated up to the head sections with joints at the concrete section interfaces. A 4-foot diameter manhole is provided at the top center of the dome with final closure being accomplished by pressure grouting through sealed fittings in the manhole cover plate.

Access to the facility from the outside is achieved through the fuel-auxiliary building, administration building, turbine-generator building, and also directly to the containment building if required (see Plate 5-13). Instrumentation and control cables and sampling lines are routed through a tunnel between the control room and containment building. The tunnel also provides personnel access through the 7-foot diameter airlock. Air conditioning and utility lines run through tunnels from the control complex to the fuel and turbine buildings. They also contain personnel walkways.

The fuel transfer tube enters the containment building from a tunnel at the same relative location as the reference plant. However, its length is extended to permit an adequate rock pillar between rooms. This tunnel also contains utility lines and a personnel walkway for inspection and maintenance.

Electrical and piping penetration rooms occupy two levels and are oriented to be compatible with the location of the control room

and turbine building. Two main steam and condensate return lines, 30-inch diameter and 20-inch diameter respectively, are routed in the 25-foot diameter pipe tunnel between the containment and turbine buildings. In addition, the tunnel also contains ten 4-inch diameter component cooling water heat exchanger lines, two steam generator blowdown lines, two 8-inch diameter auxiliary feedwater pump (condensate) lines, a personnel walkway for maintenance and inspection, and utility lines. Condenser cooling water is supplied from the underground pumphouse at the shore through four 10-foot diameter lines in two separate 29-foot diameter intake tunnels. Each of these tunnels also contains one 30-inch diameter line to the two component cooling water heat exchangers, one 4-inch diameter line to the plant fire protection system, utility lines to the pumps and grinder in the pumphouse, and a personnel walkway for maintenance and inspection. These tunnels would be as shown in Plate 5-19 except that they would also contain the lines and utility trays shown in the utility tunnel.

The containment building is the same size as in the coastal plant and contains all the equipment and subsystems planned for that building with no compromise of laydown areas or assembly-disassembly space. Orientation of the fuel transfer tube with respect to the reactor-steam generator arrangement will also be the same; however, the piping and electrical penetration rooms are slightly relocated around the containment perimeter on two levels. All penetration seals and isolation valve arrangements are the same as the coastal plant design. The containment building equipment hatch is shown relocated circumferentially from the reference plant design to minimize access tunnel length according to the surface contour. Air is supplied from the control room area, and the containment purge exhaust system vent structure will run vertically to above the surface at a point located conveniently to the containment and fuel handling buildings and the control room laboratories. All safety feature systems in the facility are the same as in the above-ground plant.

The fuel-auxiliary building is similar to the coastal plant and is used to receive and store the incoming fuel; to transfer elements to the containment building; and to receive, store, and package spent fuel in casks for shipment. This area also contains a hot shop; the radwaste system; and various pumps, compressors, ion exchange units, and tanks for chemical storage, volume control,

primary plant make-up water, refueling water storage, coolant polishing, and sump collection. All equipment in this building will be at the same level relative to the reactor as planned for the coastal plants. However, the arrangement on each level will vary to conform with the shape of the area. Air is supplied to this room through the entrance tunnel and exhausted out the vent structure at the containment building.

The turbine-generator building is sized to the same basic configuration as the coastal plant with two exceptions:

1. The condensate return line point heaters on the third and fourth levels have been relocated, thereby reducing the building span to 130 feet.
2. The length of the building has been extended 120 feet to accommodate items usually located outside this area in surface plants. This includes two diesel generator units and fuel tank, the condensate storage tank and two auxiliary feed pumps, two component cooling water (CCW) heat exchangers and 32 other heat exchangers which are serviced by the CCW system, batteries and on-site auxiliary transformers from the off-site power transmission lines. This is designated as the turbine generator auxiliary equipment area.

The condenser cooling water lines from the pump house enter this building below the turbine condenser box, and the saltwater cooling lines continue on to the component cooling water system heat exchangers located in the 120-foot long extended area. The 18-foot diameter intake and outlet lines extending into the ocean from the pumphouse are the same as for the coastal plant.

Electrical power lines are distributed from the generator area to all plant facilities through the appropriate access tunnels. Power from the generator is fed through transformers in the switchyard area for transmission to the system grid lines. The switchyard area size is reduced significantly from the coastal plant switchyard and is based on the use of SF₆ cooled gear to conserve space. Access to this room is through the turbine-generator area.

The main entrance to the plant is through the administration building which has the frontal elevation flush with the side of a hill. The control room is entered through a tunnel at the rear of the administration building, with access tunnels provided to the fuel and turbine buildings at the control room entrance. These tunnels also carry ventilation and utility lines.

The control room building contains the basic heating, ventilating, and air conditioning equipment; the computer room; chemistry laboratory; the control console; the radiochemistry laboratory; sample hoods; a machine shop; personnel showers; and locker room. Two vent structures are provided, one each for supply and exhaust from the air conditioning equipment.

During the construction period, approximately 30 acres will be required on the surface for various equipment and service operations such as shops, materials preparation, mine tailings, temporary offices, and parking lots.

The underground plant will occupy approximately 20 acres (surface profile) with another 5,000 square feet at the coastline for the underground pumphouse, not including the exclusion areas.

In the event future expansion is required, one multiplant configuration could consist of several units, each with a layout similar to the single unit facility, arranged in circular pattern according to the desired location underneath the varying surface contours.

5.4.1.2 Considerations. In general, the technologies required for design, excavation, construction, and operation of the underground nuclear power plant described are within the present state of the art. However, the span widths of 130 and 140 feet in the turbine building and containment building, respectively, are quite large and unprecedented for permanent facilities. Spans of 80 feet or so represent the limit of experience to date, but extensive testing and rock instrumentation during excavation and quality assurance during excavation, rock bolting and shotcreting, could validate the acceptability of longer spans.

Assuming verification of adequate structural integrity of the rock, conventional mining techniques would be used to excavate the buildings and tunnels and insure the integrity of the rock surface. Special techniques may be required for construction of the containment steel liner and concrete liner, but they also appear feasible.

Since access to the underground sections is achieved by horizontal tunnels, all heavy components such as the reactor pressure vessel, steam generators, pumps, and turbines will be installed with greater time and cost and required in a surface plant.

During operation, system efficiencies will be slightly reduced due to the increased distance between buildings, but these are not severe penalties. Overall plant ventilation and air conditioning requirements are increased underground. This is especially true in areas normally in the open in a surface plant where electrical equipment and emergency systems would be located, such as the turbine building and switchyard area.

Current procedures in underground blasting indicate that in the event multiple plants are considered, it would not be necessary to shut down the first plant while cavities for subsequent plants are being blasted. Small, accurately calculated and placed charges reduce the hazard to only the immediate area of work and will not jeopardize a plant located several hundred feet away.

Other advantages typical of underground facilities are protection from surface accidents (missiles, airplanes, weather disturbances) and isolation of the turbine in a separate rock containment area (improved protection from rotating element failure).

A reduction in predicted ground motion over surface motion, if accepted as a design basis, would provide a decrease in costs attributed to aseismic strength built into the facility.

The rock cover provides additional shielding from direct radiation. However, this is not particularly advantageous because even aboveground plants must provide sufficient shielding to be well below permissible operational and accident exposure limits. Also, it is believed that this facility affords no improvement, compared to the surface plant, in protection from leaks through surface penetrations in case of a loss-of-coolant accident. In the unlikely event of a core meltdown, this concept may provide a more acceptable mode for considering burial and abandonment should it become necessary.

One disadvantage of this concept is the increased schedule requirement caused by mining and construction operations. Discussed in Section 7, this might add as much as 2 years to the construction period. Also, overall plant design, construction costs, and interest during construction will be increased due to a difference in construction

approach from the surface plant design. The increased costs are somewhat offset by reducing the construction of some of the building walls.

Other disadvantages of underground facilities are longer piping and cable runs due to the extended distance between buildings (causes a slight reduction in system efficiency) and increased air conditioning and ventilation requirements. Also the facility distance to shore would normally be greater than for a coastal surface plant, adding to cooling line costs.

Perhaps one of the greatest concerns is the large investment in excavation costs before it can be proven that the site does not contain faults, and that the material is sufficiently massive and unjointed to be acceptable in cost and for licensing.

5.4.2 Massive Sedimentary Rock

The plant in this concept would be constructed in unfaulted massive consolidated sediments, such as sandstone, in hilly terrain above the groundwater table. As in the case of igneous rock locations, the ground contour would rise inland sufficiently to provide cover over all facility buildings.

In general, with selection of sites containing sedimentary rock having strengths approaching igneous rock, the burials and plant layout would be the same as that shown for the underground massive rock concept. Siting in the stronger sediments will reduce rock support costs. However, some rearrangement of the underground caverns may be required according to the strike and dip of the layered sediment. In perspective, therefore, it would be similar to the view shown in Figure 5-9.

Assuming adequate integrity of the sandstone sediment, many mining and construction operations could be the same as for the massive rock site with the rock serving as structural containment for all buildings. However, planar structures in sedimentary rocks could present problems in overbreak which would require support. Occasionally, unique problems, such as pockets of gas or water, could be encountered in the sedimentary environment, requiring extensive remedies.

In summary, the total plant is underground in six basic caverns with the same surface penetrations and access routes as the underground massive igneous rock concept.

5.4.2.1 Facility Description. All building arrangements and functional interrelationships in this facility are the same as for the massive igneous rock concept.

The impact of this concept on the environment will be the same as the massive igneous rock concept. The area requirements, unit expansion possibilities, surface penetrations, access roads, construction operations, and effluents released to the environment will be the same as previously discussed.

5.4.2.2 Considerations. Assuming that the structural integrity of the sediment is adequate to permit mining and excavation of underground caverns to the sizes shown on the drawings, all technologies required for this concept are the same as the massive igneous rock facility.

The advantage of this concept over the igneous rock location appears to be that in California more sites are available in this consolidated sedimentary rock than in igneous rock. The disadvantages of this concept include those of the massive igneous rock facility, increased by the potential encounter during excavation of water, brine, or gases; by the possibility of excessive overbreak during blasting and excavation; and by the possibility of requiring excessive ground support in the facility.

5.4.3 Unconsolidated Materials, Beach

The plant would be constructed in an unfaulted zone consisting of unconsolidated soils located in a high groundwater table and located at a beach site with soils having a high degree of permeability.

The entire plant would be buried with a 3-foot cover over all buildings in a large pit which has been backfilled with excavated soil following construction of all plant facilities. A perspective view of the plant is shown in Figure 5-10. Excavation techniques and layouts of plant buildings are based in part on a study* performed in 1970 of an underground nuclear power plant at a beach site. That underground plant study investigated caisson, stepped slurry wall, and ground freeze wall techniques for construction. Economic trade-off studies indicated the freeze wall approach to be the most feasible.

* Bechtel Corporation for Southern California Edison.

FIGURE 5-10
UNDERGROUND - UNCONSOLIDATED MATERIALS, BEACH

5.4.3.1 Facility Description. The plant is constructed with all equipment and subsystems normally found in the containment, fuel-auxiliary, and control room buildings located in one large structure, a containment-auxiliary building, which is 230 feet in diameter and 235 feet deep (see Plates 5-15 and 5-16). The inner area contains the reactor, steam generators, pressurizer, and coolant pumps; the fuel handling, radioactive waste systems, and air conditioning equipment are located in the outer areas. The control room, water storage tanks, and emergency power units are on the upper levels. The annular cells of the containment-auxiliary building are maintained at a pressure greater than the inner space housing the reactor, which is less than atmospheric so air or gas leakage would be inward. The outside concrete walls, floors and roofs are designed to support saturated soil and seismic loads and will contain a 60 psi internal pressure in the event of reactor coolant line rupture. The use of an ice condenser safety system could limit this peak pressure to 30 psi.

The office and shop building and transformer-switchyard building are also circular in shape to better resist soil pressures. The turbine-generator building is rectangular because of constraints imposed by the long equipment.

The plant buildings are separated a minimum of 120 feet to allow enough room for the freeze wall construction operations. Flat roofs are used to reduce depths of burial. Access between buildings is provided by 20-foot diameter reinforced concrete pipe tunnels below the surface, and each building has an elevator entry at the surface for personnel and equipment. The containment-auxiliary building main access tunnel to the highway is 30 feet in diameter. Surface roads will extend to each building elevator from the main parking area entrance surface penetrations.

A pumphouse is buried at the shore with underground water intake, discharge, and utility lines in tunnels to the turbine building. Because of the close proximity to the coastal road, off-site transmission lines would be low profile surface or underground lines.

All plant buildings are buried so that they are not visible from the surface. Necessary surface penetrations such as are required for personnel access, equipment replacement, electrical

transmission lines, and ventilation can be appropriately designed to deemphasize their presence.

An access road will be required to the area from the coastal road, servicing both the personnel and equipment entrances. During construction of the facility, an additional 30 acres will be required for equipment and service operation as in the other underground concepts.

The underground plant occupies approximately 22 acres of land at the site and another 5,000 square feet at the coastline for the pumphouse, with a right of way between the plant and pumphouse for the condenser coolant lines. Additional acreage is needed for the exclusion area.

5.4.3.2 Considerations. In general, the basic technologies required for the design and the construction of facilities under reasonably solid soil conditions are within today's state of the art. To obtain solid materials at sites having saturated soils, the freeze technique has been used with success, particularly in mine shaft excavation projects. It has not been previously demonstrated to this magnitude. Preparation of the site for excavation using freeze wall techniques will require adequate demonstration that the process is feasible, as would any of the more conventional, alternative construction approaches for a project of this size.

The other disadvantages of this concept are basically the same as discussed for the underground massive rock concept. The difficulty of construction in this media will take on greater proportions and have greater risk than the other underground concepts. Also, permanent dewatering systems for the facilities will be required to prevent uplift of foundations. The material density must be at 80 to 85 percent relative density to preclude liquefaction of materials under floors and behind walls under seismic shaking conditions.

5.4.4 Nonmassive and Poorly Cemented Materials

The concept would be underground in fractured and poorly cemented materials not capable of being mined without considerable structural support during construction. Using a site typical for California, it would be located in undulating foothills, above the groundwater table, in an unfaulted zone within a mile or so of the shore. Construction would be cut and cover, attempting to balance cut and fill quantities to minimize off-site haulage. The concept is shown in perspective in Figure 5-11.

FIGURE 5-11

UNDERGROUND - NONMASSIVE POORLY CEMENTED MATERIALS

The facility layout and building designs are similar to the concept in unconsolidated materials, previously described. However, the absence of groundwater greatly relieves building design and construction requirements. The walls will still be designed to resist lateral soil pressures and, therefore, circular building cross sections are preferable where feasible for equipment requirements.

All buildings are covered with a 3-foot backfill with vertical surface penetrations for vent structures. Access to all buildings would be through covered passageways, with service roads and parking facilities provided for the hillside tunnel penetrations. A shore-based pumphouse and a pipe line tunnel right of way also will be required as in the other underground concepts.

The facility site would be selected within the foothills so that the parking area and surface penetrations would be hidden from view at the coastal road. The completed backfill would be landscaped to provide a pleasing appearance.

5.4.4.1 Facility Description. The size and arrangement of plant buildings are similar to the underground beach concept previously described. However, the transformer and switchyard and turbine-generator auxiliary equipment buildings are transposed to conform with the location and terrain presented, and access to each building is provided through horizontal tunnels rather than elevator entries at the surface. The foundation of each plant building is at a level similar to the foundation of the large containment-auxiliary building, which is located approximately two-thirds of its height (170 feet) below the original sloping grade. Additional surface excavation to this depth in a downhill direction provides the soil materials which cover the entire facility to a minimum of 3 feet using a 1 in 2 slope between buildings. Whereas the underground beach buildings had flat roofs, these buildings will have domed roofs to simplify fill support design requirements.

The area required for the underground facility and construction equipment is similar to that required for the unconsolidated materials facility, 22 and 30 acres, respectively.

5.4.4.2 Considerations. In general, the technologies required to construct and operate this facility are within the present state of the art, however, few if any, structures of this magnitude have been designed for cut-and-cover installations.

The advantages of this concept are similar to those for the underground massive igneous and sedimentary rock concepts. Of particular importance in this concept is the greater number of potential sites in the coastal zone to which underground facilities might be applied.

One disadvantage of this concept is that structures must be designed with roofs and walls strong enough to support the fill loads, whereas the igneous or sedimentary rock surrounding the facilities in other concepts are self-supporting.

5.4.5 Massive Rock, Faulted

The utilization of a site presumed to have been subjected to slight faulting is presented because in California many sites in rock will contain discontinuities that can be interpreted as faults. If, from a licensing viewpoint, the faulting is limited to a few inches, the site might be worth considering if design measures preclude unacceptable damage to an underground nuclear power plant at that location. This might substantially increase the number of potential sites.

The elements of the system to be specially protected are the Category I items as specified by AEC; these are items necessary to accomplish and maintain safe shutdown of the reactor under accident conditions and to prevent the uncontrolled release of fission products. The features include the containment and plant equipment necessary to maintain the safe shutdown condition, and systems involved in emergency coolant operations such as storage, piping, pumps, and heat exchangers. Of prime importance among these elements are the "umbilicals" consisting of vital piping that extends from one building to another.

The faulting motions that have to be considered may have both vertical and horizontal components. It should be understood at the outset that the design for faulting displacements is less developed than the design for ground shaking. The characteristics of the faulting motion are not well understood. It is not known whether these movements occur slowly or as a series of impacts, and the effects of such motion may be additive to the basic earthquake motions. In several of these areas some research and development effort is needed to produce a satisfactory fault-resistant engineering design.

Since the strength of most homogeneous rock formations is considerably in excess of the strength of any practical structure

that can be constructed within, fault movements that rupture the rock will also rupture the structure unless the structure is at least partially decoupled from the fault displacement. The usual means for providing such decoupling is to provide an annular space surrounding the structure of a dimension suitable to accommodate the anticipated displacement and to mount the structure on a sand material. In cases when this annular space extends near to the ground surface, the facilities and excavation would be enclosed at the surface by a roof supporting a fill. Tentatively, it is considered desirable to isolate this roof with a rattlespace to permit the fault displacement to occur from below or the sides without reacting on the fill. The rattlespace for the roof and containment may be a void or may be filled with a crushable material such as polyurethane or frangible concrete. When using crushable materials, the rattlespace must be increased by a factor of 2 or more because all such materials lock at strains in the order of 50 percent or less. There are a number of other disadvantages to the use of such materials, including variation of their property with time and exposure to the elements, effect of saturation, and variability in placement. There are also problems in installation and replacement of the material once it has been crushed. The reason for using such materials, is to take advantage of the cushioning effect to alleviate both the fault motions and the ground shaking. However, it is to be noted that once these materials have crushed, voids are lost, thus reducing subsequent material effectiveness. It is also to be noted that in crushing, such materials apply pressures to the walls of the containment although such pressures are much less than those that would exist with the containment in contact with the rock surface. For these reasons, it is well to consider only the use of a void rattlespace, thus eliminating the maintenance, cost, and inadequacies of filler materials.

In general, the minimum rattlespace provided should be not less than twice the anticipated horizontal fault displacement plus an additional allowance for tilt due to the vertical component of displacement. A lesser amount of rattlespace might be provided; however, with this reduced amount of rattlespace, there is the possibility that horizontal fault displacements approaching the design values would cause the cavity wall to contact the reactor wall, thus promoting sliding of the containment.

A very thick base slab is needed to successfully resist the effects of vertical faulting by allowing the structure to tilt as a unit. It is desirable that the base slab not project beyond the limits of the containment walls so as to avoid contact with horizontally displaced

rock. This requirement could be waived if the rattlespace is increased by the amount of the footing projection beyond the wall. It is recognized that some projection beyond the wall may be desirable from the view-point of stability of the containment underground shaking.

It is perhaps worth noting at this point that an annular space of 3 feet or more would be required to accommodate fault displacements of a 3 inch size. It is also worth noting that rock debris at the rupture plane in the rock could encroach on the annular space and possibly exert high local pressures on the containment wall.

If the various other enclosures of the facility are separated from the containment, then it is almost inevitable that a number of umbilical features will be required to interconnect the various enclosures. If these are enclosed in tunnels and shafts, then the dimensions of these tunnels and shafts must be sufficiently oversize to tolerate the differential movements caused by the faulting. Unfortunately, since umbilicals attach from structure to structure, the determination of the movements to be provided for in the umbilicals is considerably more complex than the determination of the movements to be provided for in the annular spaces surrounding the structures. This arises from the fact that the six components of movement of the structure (three displacements and three rotations) cannot be accurately defined; and unfortunately, the stresses in the umbilicals are sensitive to variations in the magnitude of these six quantities. Furthermore, while upperbound worst-case conditions may be postulated, it may not be feasible to design for the resulting very severe movements. The possibility for success in this regard is enhanced when the faulting movements are small.

Survivability of umbilicals is strongly dependent on the amount of flexibility that can be built into the system. The most attractive way for achieving such flexibility is through increases in length and use of bends and loops. Special joints such as bellows and other special connections can be used where close coupling does not permit bends and loops or large lengths.

The nuclear power plant would be constructed in well cemented, but possibly faulted materials in the hills, and generally above the groundwater table. All buildings are constructed in underground caverns with similar foundation, wall, and roof designs, but having greater resistance to ground motions than the aboveground coastal plant. The layout would be as shown in Figure 5-9, the same as developed for the underground facility in rock. However, the rock roofs and walls would be excavated to provide 3 feet of rattlespace clearance around all buildings to facilitate construction of walls and structures

and also to preclude damage to any equipment or subsystems from shifting foundations in the event of fault dislocation. Therefore, the rock is not used as the outer building wall.

Liner walls around critical Category I connecting lines which must retain functional integrity to provide safe shutdown will also be a few feet away from the rock. All Category I components and equipment will be located on a common foundation in each building.

5.4.5.1 Facility Description. The plant, shown in Plates 5-17 through 5-20, is basically the same arrangement as for the massive igneous rock concept. All buildings are constructed in underground caverns in which the rock domes and walls are excavated to provide a rattlespace around all buildings, lines, and equipment. Assuming verification of the competency of the materials to be well cemented and therefore self-supporting, the mining and excavation techniques described in the underground rock concepts will be utilized in this concept.

In order to provide protection for personnel in the material which might typically be encountered, rock bolts of length equal to half the span are installed on 5-foot centers in access tunnel domes, and the surface is finished with wire mesh and 6 to 8 inches of shotcrete (see Plate 5-18). All bolts would be installed from the gantry jumbo and grouted after tensioning to inhibit corrosion. In the major building chambers and switchyard area, 135-foot long rock anchors on 15-foot centers and 30-foot long rock bolts on 5-foot centers are installed in the domes. Also, 12 to 15-foot long rock bolts are driven into the sidewalls on 10-foot centers (see Plate 5-19). All the rock bolts support wire mesh. All dome surfaces including the containment building are finished with 15 to 24 inches of shotcrete. The containment building dome is finished in this manner to minimize the risk of large rocks falling on the buildings. The containment building foundation thickness is increased to about 18 feet. Both the fuel-auxiliary and containment buildings would be located on a 1-foot thick bed of sand which would help to distribute fault motions from below should they occur.

The fuel transfer tube incorporates bellows at the end joints and a telescopic connection in the middle to accommodate potential fault movement.

The 120-foot long turbine-generator building extension, which is the auxiliary equipment area is covered and is on a single

foundation since it contains Category I components and subsystems that are required to operate long enough to insure safe shutdown of the reactor system. These items include auxiliary condensate feedwater pumps, component cooling water heat exchangers, condensate storage tanks, and standby diesel generators and tanks. The on-site power transformers are also located in this area and are connected to the off-site transmission lines.

The component cooling water heat exchangers are required to operate continually during normal operation and also serve in the emergency mode to cool the containment building safety systems until safe shutdown is attained. Since these heat exchangers draw cooling water from saltwater pumps located in the pumphead house at the coastline, the lines are routed in a separate utility tunnel from the condenser intake lines to the turbine generator building extension pad as compared with the unfaulted rock concept where they are contained in the intake tunnel (see Plate 5-19). The utility tunnel is also used for the two 4-inch diameter screen wash pump lines which serve as backup to the fire protection system. The lines are covered with protective plates, and the pumps located in the headhouse would also be protected from falling rocks.

The pipe tunnel connecting the containment and turbine generator buildings carries the main stream and condensate return lines and also houses heat exchanger lines to the containment safety systems, utility trays, and auxiliary condensate feedwater lines to the steam generator, both Category I systems. Metal plate covers are provided to protect the Category I lines and also to prevent large pieces of rock from falling on the steam and condensate lines causing their rupture and signaling plant shutdown.

5.4.5.2 Considerations. All technologies required for these concepts are the same as the underground unfaulted concepts. However, it does not appear feasible to field test the adequacy of this approach to withstand moderate faulting effects. Its application would have to be based on theory without full-scale experience.

5.5 OFFSHORE CONCEPTS

The offshore nuclear generating stations offer several advantages. Offshore siting opens up a great many new, previously unusable sites for consideration in utility siting plans and provides a potential for locating plants closer to load centers by virtue of the large unpopulated area surrounding the plant. Siting of the plant offshore provides a large,

deep body of seawater in which to dissipate reject heat, thereby perhaps reducing its effect on the environment. Thermal effects on shore waters are perhaps eliminated due to the remoteness of the plant. Also, in many of the prefabricated concepts, there are no great disturbances to the shore area during most of the plant construction period. Another advantage might be the repetition of facility design for a number of plants, in many respects, independent of most site characteristics. The construction of a standardized plant in a facility away from the ultimate installation will permit separation of the licensing of the plant from the site and thereby may serve to expedite the licensing process.

A number of offshore concepts which have been studied in the past typically extend the state of the art in some way. In some cases, there has been no experience with the placement of mechanical or electrical systems in remote facilities such as are suggested. In other cases, operating systems have been used in similar applications but never to the scale of a central station nuclear power plant. Further, some of the construction or fabrication of facilities are not routinely accomplished and therefore cause a lack of confidence in the application. Each element of inexperience or lack of application adds to the uncertainty of the acquisition and licensability of the system.

Considering the difficulty of comprehensive submarine geologic and seismic explorations, proving that a submarine transmission line or offshore plant concept is immune from submarine landslides or from severity of seismic activity might not be assurable. Isolation from ocean travelled routes also is difficult to assure for offshore concepts. Further, the less varying temperatures farther from shore suggests that cooling water discharges farther offshore may tend to increase the impact of this concept on the marine biology. However, concepts are presented to indicate the opportunities available for increasing acceptable power plant siting and to direct future attention to the concepts which appear more meaningful. These, then, might be given greater development to establish their credibility and to increase the likelihood of acceptability and licensing.

5.5.1 Floating - Shallow

The nuclear power plant is mounted on a floating platform within a breakwater where the depth is relatively shallow. The basic plant design, shown in perspective in Figure 5-12, is the concept proposed by Offshore Power Systems. The concept requires water depths of at least 44 feet for the 31-foot platform draft and for tide

FIGURE 5-12
OFFSHORE - FLOATING SHALLOW

changes and storm surges. As depths are increased, the breakwater costs substantially increase. Studies of hydrography indicate very few miles of coastal areas available at the 3-mile limit with 44 to 60 feet. Therefore, to provide a more reasonable quantity of shallow depth required, the concept is placed at about 1 mile from shore. One impact of this is to require a discharge pipe length greater than 1,000 feet assumed for other offshore concepts. A line about 3,300 feet long and extending away from shore would compare with the 8,500-foot long line assumed for the land-based coastal plants.

The plant design is a conventional nuclear generating station, mounted on a floating platform, and moored within a protective breakwater located offshore. The breakwater surrounds the plant and creates a basin in which the plant floats. Multiple plant sites and multiple units in one breakwater offer some economies of scale.

The breakwater communicates with the open sea so that the plant's circulating water is taken from the basin inside the breakwater and is discharged outside of the breakwater. With the plant floating, the mooring system, circulating water discharge, and electrical power connections would accommodate the movement of the plant due to tides, winds, and other environmental phenomena.

The sequence of manufacture in this facility would be quite similar to that of a shipyard. Fabricated structural members would be assembled into a complete platform structure in a graving dock where equipment and structures within the platform also would be installed. The platform would then be launched from the graving dock and moved through a series of erection and outfitting stations where the plant is built on the platform in stages. The final station would be a testing area where systems and equipment testing is completed. Nuclear fuel loading would be done after the plant is towed to the owner's site for installation within the breakwater.

5.5.1.1 Facility Description. The plant layout is shown in Plates 5-21 through 5-23. The platform structure and plant facilities displace 150,000 tons, supporting the power plant with a 400-foot by 378-foot by 40-foot deep grillage arrangement of longitudinal and transverse bulkheads and side shear webs separating a bottom shell (considered the zero-foot level) and the strength deck at the 40-foot level. The height is 209 feet overall. The platform structure consists of a plate-stiffener framing system of all welded steel construction designed to meet the requirements of the American Bureau of Shipping

Rules for Building and Classing Steel Vessels and Barges. The 40-foot deep bulkheads divide the platform into a total of 60 separate compartments which are grouped into some 31 watertight compartments sized in accordance with the United States Coast Guard criteria for a two-compartment standard of subdivision. The platform has a steel bulwark around the periphery extending from the strength deck at the 40-foot level to the 70-foot level, designed as a weatherproof barrier to provide protection from waves which may be encountered during the towing operation.

The major structures on top of the platform are the containment building, turbine building, and auxiliary areas similar to what is found in land-based plants. Concrete is used only in areas where shielding is required such as the containment, fuel pit, auxiliary nuclear systems, and safeguards areas. The general superstructure is structural steel of similar design to a conventional land plant.

The containment is located near the center of the platform with the other structures arranged around it to provide an acceptable distribution of weight over the structure as well as an optimum arrangement of associated systems structures and facilities. In general, most of the equipment and structures are on or above the platform top deck. Items which are below the top deck include the containment keyway for the in-core instrumentation, pumps which require net positive suction head, and some storage tanks and related pumps.

The plant electrical power system includes main transformers delivering 345 kv from a sulphur hexafluoride (SF_6) gas insulated substation on the platform to pot heads. This permits connection from the platform to the flexible underwater cables going to shore. The substation includes circuit breakers and associated isolating and ground switches, coupling capacitors, and lightning arrestors.

The floating nuclear power plant will occupy approximately 4 acres of ocean surface and up to 26 acres including the breakwater, with the outside perimeter at 50-foot depth. In the event future expansion is required, pairs of units can be operated within a common breakwater with mutual interconnections and functional commonality features similar to those discussed in the underground concepts. Additional expansion could then progress through multiple paired facilities according to the load center demand along the coast. There would be a requirement for more area onshore for docking and switchyard facilities.

5.5.1.2 Considerations. When considering the design and operating basis conditions for this plant, a number of criteria are applicable here and they differ from the criteria for design of land-based plants.

For meteorological and oceanic phenomena such as wind, waves, and tides, operating basis values might have to be associated with a recurrence interval of 100 years, whereas design basis values with a recurrence interval of as much as 1,000 to 10,000 years might be required. However, justification for these positions must be developed.

The design of the platform-mounted plant is concerned that under oceanic phenomena, there will be sufficient depth below the platform to ensure that it will not contact the bottom of the basin under the most adverse conditions. This would require depths of about 31 feet plus surge; say 44 feet minimum.

The plant would be restrained by mooring lines tied to breakwater. Within the breakwater basin, waves, and seiche would be greatly reduced, if not eliminated, so that motions to the platform are perhaps much less than 1 degree in pitch and less than that in roll amplitude.

The forces acting inside a breakwater system during a seismic event are complex. Horizontal and vertical components of ground shaking cause transmittal of hydrodynamic forces on the barge bottom and, to some degree, on the breakwater mooring thus reflecting on the barge. Breakwaters are not usually damaged by earthquakes and could be repaired readily. Faulting potentials further complicate the forces to which the barge may be called on to respond. Movements of the mooring line anchor points and of the breakwater impose unique forces to which land-based plants are not subjected.

The concept is based upon the construction of a standard plant in a production-line manner on a repetitive basis. A key element in this offshore nuclear plant concept is having a sufficient demand on the west coast for floating plants, and the availability of a west coast shipyard-like manufacturing facility for their construction.

Although the concept solves many of the problems inherent in land-based nuclear plants, whether surface or underground, other problems are delineated which must be satisfactorily answered either analytically or by demonstration to ensure the necessary degree of safety and reliability that will be demanded of this concept. Shipwrecks, sea storms, and tidal waves are hazards that must be considered in the

floating plant system. These are a minor concern to the land-based coastal plant. The shallow water conditions may also require special thermal diffusion techniques especially for multiple units; however, coastal plants face similar problems and also require longer outfall lines.

Public acceptability of an offshore facility may also prove to be as difficult to obtain as the land-based plant; some opposition to the proposed New Jersey locations already has been voiced.

The relative inaccessibility of the plant will require a higher degree of self-sufficiency than a coastal plant. Operations similar to offshore oil drilling platforms will be required.

The west coast continental shelf drops off at relatively short distances from the coastline and therefore fewer candidate sites are available to California than may be available elsewhere for a floating plant concept in shallow water. This becomes more critical when searching for areas at this shallow depth large enough to locate a number of plants.

5.5.2 Floating - Deep

The offshore floating platform-mounted nuclear plant previously described is designed for location in relatively shallow waters characteristic of the continental shelf off the Atlantic coast. The waters off California become quite deep within a short distance of the shoreline. Recognizing that protection of the plant is necessary, a method other than a breakwater must be provided to be economically feasible.

A floating ring concept, strong enough to stop ocean vessels at a half mile radius around a floating platform, was considered in a study* of deep water nuclear power plant siting for the National Science Foundation. It was concluded that concepts for this protective ring were possible and costs were extremely high due to mooring problems associated with maintaining the required relationship between the ring and platform under varying sea states and projected ship collisions.

*Okrent, D., et al., "Offshore Siting Study," Unpublished, UCLA, 1972.

Similar conclusions can be drawn from an investigation completed by the U. S. Navy* to determine the feasibility of transportable breakwater concepts. It was concluded that full-depth, continuous barriers were the most likely sources for broadly effective breakwaters at fully exposed locations. The investigation indicated that flat plate, partial depth, intermittent, or other unique alternatives to the full depth breakwater are at best between 20 and 80 percent effective in attenuating wave action. The probability of finding an effective alternative system seems low and in need of a great deal of demonstrable research.

More recently, semisubmersive platforms have been provided for drilling operations in deep water and in locations with adverse sea conditions. These are towed to the site and have a capacity for larger deck loading than the fixed and jack-up platforms. Figure 5-13 shows an artist's concept of such a moored platform designed for use in the North Sea by Zapata Marine Drilling, Inc., and Bethlehem Steel Corporation. It is valued at \$25 million and has a 3,000-ton capacity. Projecting costs for this type of installation to support a power plant weighing as much as 140,000 tons indicate a platform cost perhaps in excess of \$200 million.

A more favorable method of protecting the nuclear plant in deep water offshore sites would be to arrange the major buildings in a long, narrow configuration, and to package the entire facility within the hull of a ship, similar to a large oceangoing tanker. The concept is shown in Figure 5-14. The ship could be towed to the desired location within the 3-mile State limit and moored in place in the same manner as are large bulk oil carriers utilizing heavy duty deep water mooring terminals. Many of these terminals are designed to hold 300,000-ton ships fast in 18-foot waves and 56-knot winds. A similar concept was evaluated by Oak Ridge National Laboratory** for a floating nuclear seawater desalination/electric power generating station in 150 to 2,000 feet of water.

5.5.2.1 Facility Description. Individual plant structures such as the containment building, turbine building, and auxiliary areas which are described in the offshore floating-shallow concept can be reconfigured within the hull of a ship which is about 600 feet long and

* "Transportable Breakwaters - A Survey of Concepts," Naval Facilities Engineering Command, Naval Civil Engineering Laboratory, Report R727, Port Hueneme, California, May 1971.

** Arnold, H. G., et al., "Feasibility of Offshore Dual-Purpose Nuclear Power and Desalination Plants," ORNL, ORNL-TM-1329, January 1966.

FIGURE 5-13
SEMISUBMERSIBLE PLATFORM

FIGURE 5-14
OFFSHORE - FLOATING DEEP

has an 180-foot beam. The ship would be moored and would naturally rotate to head into the current.

Transmission lines would run from the vessel to the mooring station where universal couplings would make the transition to flexible submarine lines which extend to shore, similar to offshore fueling and oil transfer stations presently in use. The cooling water discharge line could use a similar approach, although its diameter would be considerably larger, and therefore the transition system would be considerably more complex and costly.

The containment-fuel auxiliary complex is located amidships with the same relative position maintained between the refueling and reactor cavities. The transformer-switchyard, turbine generator areas, and mooring equipment areas are located in the forward section; and the offices, crew quarters, control room, and shops are located aft. The ship has a low drag with respect to the basically square, floating concept in shallow water, and is suitable in locations where current velocities are high.

The hull can be constructed of either steel or concrete. If facilities are not available on the west coast to fabricate the hull in one piece, the lower portion could be constructed on the building ways with the upper sections completed afloat.

The vertical arrangement of equipment and structures is essentially the same as the relationship between these items in the shallow water platform-mounted nuclear plant. Similarly, all major subsystems such as the nuclear steam supply system, radwaste, containment, containment spray, turbine generator, and electrical power-transmission systems are the same as for the shallow water concept. The total facility would displace approximately 160,000 tons.

This shipboard nuclear power plant configuration occupies less ocean surface than the platform-mounted plant and breakwater facility. However, assuming it is on a 400-foot long mooring line, it could swing on a 1,000-foot radius covering approximately 18 acres. Future expansion would be accomplished by locating more vessels in the same general area with separate mooring terminals and adequate clearance between potential swing radii to preclude collisions. For example, six ships would occupy a minimum of 108 acres; however, allowing 1,000-foot clearance between swing radii would enlarge this requirement to several hundred acres, depending on the arrangement of the ships. It would also be necessary to expand the docking and switchyard facilities onshore.

5.5.2.2 Considerations. With the exception of a concrete hull, fabrication and operation of this system is within present state of the art, including the subsystems and equipment, large tanker, and deep water mooring designs. However, omnidirectional ocean currents and severe sea state conditions will complicate the tanker-mooring system design, making it more costly to provide in some offshore areas.

In addition to the advantages stated earlier, this facility would have improved towing characteristics, be more easily relocated to a different site, and might even be moved to shore for major modifications, if required.

Some equipment for this concept would have to be specially designed in these sizes to withstand the motions to which the vessel will be subjected. It is anticipated that such a program would require a significant demonstration activity to show that the systems can safely function and be shut down under adverse sea conditions.

Perhaps the principal disadvantage of this concept is the absence of a protective breakwater and this increases the risk of collision with other vessels. It is uncertain whether a reliable collision deterrent can be designed within the realm of economic feasibility and whether it would increase the likelihood of licensing the plant.

5.5.3 Seabed

The ocean underwater environment has long been acceptable for structures and, in particular, structures containing nuclear power plants. Nuclear-powered submarines, having significantly lower power plant capacities and smaller physical dimensions than would be applicable to central station plants, are reliable and are used at depths much greater than would be used for sites in the coastal zone of California. Recently, Japan seriously considered an undersea nuclear plant of a size comparable to the 1,100 Mw(e) unit in this study. Also, a study* was completed to investigate the feasibility of such a facility and concluded that the concept is feasible and, in many respects, preferable to land-based plants.

* Electric Boat Division, General Dynamics, Unpublished.

The concept envisioned in this study is a plant fabricated and outfitted in a coastal shipyard similar to the approach taken in fabricating a large oceangoing vessel. The vessel would be sufficiently seaworthy to be towed to a predetermined, and perhaps preprepared, seabed area and then lowered into place by compartment flooding or ballasting. The water depths available at sites within the 12-mile limit are great, extending in many areas to greater than 600 feet. Even within the 3-mile limit, depths of 300 to 600 feet are reached rapidly. Since one of the principal considerations in selecting concepts is to minimize the visual impact of the power plant, the seabed concept is placed in a depth sufficient to completely cover the plant, but is provided a surface station for normal operational use.

5.5.3.1 Facility Description. Long-range maintenance problems associated with an underwater steel structure might not provide the assurance for integrity that would be necessary and, therefore, the plant is contained in a reinforced concrete vessel about 850 feet long and 150 feet wide. Experience in underwater concrete structures consists of large outfalls and transit system tunnels which range in widths to 35 or 40 feet. This project would set a precedent for construction of a concrete vessel this size.

Figure 5-15 indicates the 140-foot diameter horizontal tube extending the full length of the plant. The 85-foot diameter containment building rises about 100 feet above the horizontal cylinder and extends down to the base of the cylinder. Stability is provided the plant by the flat-bottomed and squared sides of the base structure, the ends of which are shaped to ease transport of the facility to the site. The internals of the two main cylinders are lined with steel plate which acts as the internal form for concrete and also as the water sealant, even though the external water pressures tend to seal the concrete. In the case of the containment building, the steel liner also provides a leak seal as used in aboveground plants.

Equipment is removed through concrete tubes extending to the surface, and normal access and egress for personnel is provided through elevators and emergency stairwells in similar vertical tubes. Air supply and exhaust is also provided through these tubes, which culminate at the surface on a platform supported from columns extending to the base support below. The platform is located about 50 feet above the mean water line to provide protection from maximum storm waves. Surface facilities include laydown area, shops, heliport, and docking capability. Overhead and jib cranes on the platform assist in equipment, fueling, and supplies handling.

FIGURE 5-15
OFFSHORE - SEABED

One end of the plant contains the turbine generator area, transformers, and the switchyard which feeds the underwater high voltage transmission line. Below this portion of the facility are process equipment areas, the condenser cooling pumps and piping, and ballast compartments.

Process equipment surrounds the lower areas around the reactor containment facility. Located on the other side of the containment facility are the fuel servicing building, control rooms, shops, heating, ventilating, and air conditioning equipment.

5.5.3.2 Considerations. The area required to locate as many as six underwater plants of the type described is about 50 acres, providing ample space for separation of units. Obviously, there is an abundance of such deep water areas, although the sites narrow when selecting those with geology, seismology, and marine soils suitable for supporting the plant. The plant weight is estimated to be about 200,000 tons. If the site is prepared to provide a uniform surface, the plant would impose bearing loads in excess of 3,000 psf. With the likelihood that a uniform base is not attainable over the supporting plane, loading will be significantly greater than 3,000 psf and the supporting soil may be one of the limiting site selection factors. It is critical that the sea floor deposits be located to properly found the unit. This would require detailed subsurface soils studies, including deep water drilling and sampling. A nonuniform base will also impose greater structural design constraints on the vessel, thus increasing its cost. It also would be necessary to carefully study by geophysical surveys the location of all faults and determine their potential for surface rupture. Based on current AEC criteria, no potentially active faults could be within a specific site.

During normal operations, the direct radiation from the reactor will be no more a hazard to operating personnel than is now experienced in aboveground plants. In fact, there would be a decrease in direct radiation due to the vessel structure and the sea environment. However, the levels involved are already low and the added shielding is of little advantage.

There is limited precedent for floating power plant size structures into place and lowering them into underwater sites. Large diameter concrete pipes, caissons, and tunnel sections are sometimes constructed this way, but these are much smaller than the plants discussed here. As an alternative to concrete, there is precedent for the use of structural steel, although steel would present greater maintenance problems. There is, however, a step change in the sheer

magnitude of the facility in the application. It is not apparent that a research and development program, in lieu of experience, would substantially improve the acceptability or licensability of this new approach.

The underwater concept offers a number of potential advantages, including economies of shipyard construction where production line techniques and controls can be applied. Some minor savings are also possible in design of the plant air conditioning systems, relying on ocean water to assist in the condensing phases. However, the ocean environment demands the use of more corrosive resistant materials than would be used on land; therefore, labor savings may be offset by added material costs.

The facility under water would be more sensitive to seismic ground motions than some of the other offshore concepts. There would be difficulty in the evaluation of seismic and geologic factors. Few records of offshore seismic activity are available which indicate low activity. Therefore, the number of potential sites at which it might be located would have to be reduced to zones of known relatively low seismic activity.

The water pressure design approach necessitates a long, cylindrical section. Since the facility would be built at shore, there would be an inherent hazard in towing the long, narrow plant in the open seas and lowering it into place while being subject to encountering unfavorable sea conditions over the period of time required for these activities.

This concept has an inherent increased cost over an above-ground plant because of the need for watertight fabrications and use of corrosion resistant materials. Also, the location of the facility offshore would increase access costs during operations, limiting it to the use of helicopters or boats capable of landing on or tying to the facility. During periods when plant safety is jeopardized or an accident has occurred, it might be necessary to gain immediate access to the facility and this would be more difficult and time consuming in this location.

In addition to the effects of the cooling system that should be considered on the marine environment, detailed study would also need to be given to the affects on benthic biota associated with the sea floor.

An inherent hazard with the system is the vulnerability of the surface platform to impacts from oceangoing vessels. Breakwaters

founded on the sea bottom or floating are not practical additions to this deep water concept.

5.5.4 Undersea

To alleviate the land use problem encountered in many coastal locations having suitable geologic media, an undersea location reasonably close offshore offers a potential solution. Unfortunately, undersea construction would be costly; and when considering this approach, a geologic environment should be selected to reduce that problem. A material such as rock, which is fairly stable when mined and is impermeable, is highly desired. Even if the rock has minimal jointing, these joints might be grouted to seal off water intrusion or to reduce in-flow to a level which can be collected and removed. Other media requiring structural support during construction and which permit large quantities of water to flow through the formation may be much more costly and time consuming in construction.

The site model for this concept is a competent igneous or sedimentary rock, under several hundred feet of water, located 3 miles offshore for remoteness. The facility would be constructed in the seabed through tunnels originating onshore. These tunnels become the permanent access for personnel and equipment, as well as for air, gas, power transmission, and other interfaces with the surface. Therefore, the plant shown in Figure 5-16 would not interfere with any of the operations that might be encountered in the waters above.

The rock roof thickness required for support and for containment during a loss-of-coolant accident is the same as for the typical rock underground concept, about 150 to 200 feet, depending on the competency of the material. That cover thickness, the 200-foot nominal depth of the containment building, and a 200 to 300-foot depth of water place the base of the facility about 700 feet below sea level. This will impose additional hydrostatic and lithostatic pressures on the facility and its appurtenances, especially if the cavity face cannot be sealed off from water intrusion.

5.5.4.1 Facility Description. The facility layout has most of the constraints which will exist in an underground facility onshore. Therefore, it would resemble the underground plant previously described for location in rock.

To eliminate potential hazards to ocean traffic of overhead shafts and platforms in the waters above, all such extremities would be through tunnels daylighting onshore. This will require a vehicle

FIGURE 5-16
OFFSHORE - UNDERSEA

access tunnel from existing shore networks. The tunnel might be provided in a hillside area and would be less evident than if a beach access was to be provided.

Utility and transmission corridors would also extend to the shore where lines could be continued underground, on ground, or overhead as determined by the land use there. Also, the waste gases would be vented through a stack at the shore end of a vent duct.

During construction and repair or maintenance phases of the project, all equipment would be moved in through the access tunnels, necessitating sufficient lateral and overhead clearances for maneuvering the large, heavy items.

The large condenser cooling water intake and discharge lines would terminate in structures located overhead on the ocean bottom. Hydrostatic pressures at the steam condensers may be about 300 psi and therefore require greater tube strength and perhaps special techniques for fastening them to the tube sheets. Other equipment is estimated to be essentially the same as for the underground plants, with some attention given to more environment-resistant materials used in their manufacture.

The transmission line could be considered as a submarine cable as discussed for the floating plants. However, since a tunnel to shore will be required for access, the transmission line is more economically placed and maintained in the tunnel.

The area required undersea is about 20 acres for a single unit, or say 120 acres to locate an ultimate of six units. In addition, about 50 acres would be required on the shore end of the facility for access areas, parking, construction materials and equipment laydown, and other construction support. Also, as much as 30 acres might be used for access tunnels from the shore.

Demands placed on constructing this facility are, in general, the same as for the underground facility located onshore. However, because of the hydrostatic head and likelihood of water intrusion, special care will be required in grouting off the formation and in sequencing those operations with the mining activities to ensure the safety of the workmen and the integrity of the completed installation.

The construction laydown and shop areas are best developed at the tunnel portal on the shore side. This area would be larger than for an aboveground plant concept to account for support to mining and grouting operations. Muck transfer stations, perhaps tailings

stockpiles, and a grout plant, together with maintenance facilities attendant with those operations will be located there.

5.4.2 Considerations. As in the case of underground plants onshore, this concept is within the current state of the art. The roof spans contemplated for this installation are greater than is customarily found in underground construction but not so excessive as to disallow its feasibility. Subsurface construction in marine materials is often accomplished for vehicular tunnels and in material substantially less competent and less consolidated than contemplated here.

None of the plant equipment for this installation will require design beyond the state of the art. The steam condensers will have to be designed for higher hydrostatic pressures than normally encountered in nuclear power plants, but nuclear submarines encounter greater pressures although the condensers are smaller units in that case.

In the undersea environment, the installation is relatively immune from surface hazards such as aircraft, vessel or missile impacts, or storms, hurricanes, and other natural surface phenomena.

Aesthetically, the main plant is acceptable because it is not seen. Portions of the plant, such as the access and utility tunnel portals, will be exposed onshore but can be either hidden from view or made to be aesthetically acceptable.

It is extremely important that the material selected for the plant site media be as impervious as possible to water intrusion from above. Assurance must be provided that most fractures which exist can be permanently grouted so that water intrusion is held to quantities which are readily removed by a permanent pumping plant. Such assurance may be difficult to achieve for these depths, since the greater depth is subject to a large volume of intrusion zones.

Seismic design factors would be difficult to develop because of the small amount of data available. The seismic recording networks have not provided this information because of the generally low seismic activity offshore, except for limited areas.

Exploratory geologic investigations would have to be extensive for this project, including detailed drilling of the sea floor and detailed geophysical studies, in order to find the media and to prove out its competency and the feasibility of grout sealing. It is possible that investigation cannot be satisfactorily completed without a large

monetary commitment for tunneling and cavity excavation from which some of the exploration would have to be performed.

5.5.5 Artificial Island

Offshore sites for nuclear power plants include at least two suggestions for stable masses on which to place the facility. One is an island made of fill materials and the other is similar to platforms used for drilling operations.

Drilling platforms have been successfully used for many years. Many of the platforms presently in use are towed into place and then caisson legs are lowered to the sea floor. Then the platform is jacked up on its legs a safe distance above the high tide and storm waves. Conventionally, these platforms are about 200 feet on a side, sometimes three-sided and often four-sided. Their cost is about \$10 million.

Another platform used is rectangular, of steel fabrication, with caisson legs, all constructed at the site. This version has no jacking capability and therefore is less costly, about \$7 million to \$8 million.

Cost elements for these platforms are a function of deck size, deck capacity, pile requirements and supporting soil characteristics. It is likely that a 4-acre platform in 50 feet of water would be extremely costly, even without jack-up legs. In view of this high cost, a man-made island with greater stability is used in this study as the basis for an artificial island.

The 1,100 Mw(e) plant, shown in perspective in Figure 5-17, occupies approximately 11 acres and, as in the case of the floating plant in shallow water, would be located about a mile from the shore. Shown in Figure 5-17, but not incorporated in the concept cost, the island could be provided with a causeway to make it more readily accessible at greater cost, and to carry utility and transmission lines.

The containment fuel building complex is located near the center of the island, with the turbine generator facility and switchyard areas on one side, and shops, a utility building, control room, and laboratory on the other. An office building occupies one corner of the island and a laydown area is provided at the opposite corner.

5.5.5.1 Facility Description. The island consists of a sandfill surrounded by rock revetment. Precast concrete tribars or rock would

FIGURE 5-17
OFFSHORE - ARTIFICIAL ISLAND

be used as armor. Finished grade would be at Elevation 20 and the top of the revetment would be at Elevation 30 on three sides and at Elevation 20 on the coastal side of the island.

The proposed power plant buildings and equipment would be the same as for the offshore floating platform facility, but spread out over a larger area to facilitate access and with more shop and office space provided to improve operations. The plant layout is shown in Plates 5-24 and 5-25, respectively.

The reactor containment and fuel auxiliary structures will be supported on the ocean bottom, requiring allowable bearing values of 4,000 to 5,000 pounds per square foot. Piles may be required for support, depending on location. The power plant turbine pedestals would be supported on pilings and large mat foundations on fill below finished grade. Required allowable bearing value of the fill below the pedestals is about 4,000 pounds per square foot. Most other structures would be supported on continuous or shallow spread footings two to five feet below finished grade.

The portion of the fill above water level and the subgrades for large foundations may require compaction. Vibratory rollers or similar conventional equipment should be satisfactory; vibroflotation or similar techniques could prove ideal. Compaction testing would be performed during island construction. Well points, surcharge fills, or other methods may be used if additional compaction is required.

Excavation for containment vessels is made after completion of the island fill. A conventional type, multistage, well point dewatering system would be installed as the excavation proceeds. Side slopes are benched for installation of well points and headers. Top of the excavation would be far enough from the nearest edge of the island to ensure stability.

Barge unloading facilities are incorporated in the island design. The facilities consist essentially of a protected fill area, on the coastal side of the island at approximately sea level, and a suitable ramp. At high tide, a barge would be floated over the level area and sunk by flooding the bilges. Reactors and other heavy equipment such as the steam generators, main transformers, and shop fabricated sections of the flash evaporators could be unloaded or skidded off the barge onto the ramp and up onto the island.

Buildings are furnished for plant services, maintenance and warehousing, nuclear auxiliary facilities, control rooms, and administration.

Freshwater tanks are provided for make-up, refueling, and condensate storage, for heat exchangers, general power plant use, and fire protection.

5.5.5.2 Considerations. The earthwork in this project will impact on the shore area near this site. Support equipment, materials stockpiles, and logistics will interfere with other onshore activities, probably requiring a support area of about 20 acres during construction.

The offshore island can be improved aesthetically and even could be expanded to provide a recreational marina environment. Examples of islands are those used for drilling in the Long Beach Harbor in California, where the islands are located as close as 1,000 feet to the shore. Figures 5-18 and 5-19 indicate two of these islands. One is landscaped and with waterfalls to make it a pleasant addition to the area.

No new technologies are required for construction of the island or the nuclear power plant. As in the case of land-based concepts, the artificial island requires sites not located near active faults or zones of high ground motion intensities.

5.5.6 Natural Island

In the California area there are a number of offshore Channel Islands which might be considered as potential locations for nuclear power plants. The proposed advantage of locating there is the remoteness from heavily populated areas and therefore the added protection which such distances might afford. The least costly approach using natural island locations would be the aboveground concept, provided the topography was suitable. There are a limited number of suitable locations, as discussed previously, and one of these is Santa Cruz Island located 23 miles from the coast. It is used as a basis for developing the evaluation of this concept, recognizing that other potential potential uses on the island might be preempted because of the focus of the nuclear safety question in such a confined locale.

The production plant layout and perspective is identical to the coastal aboveground concept. Additional needed facilities are a helicopter landing pad, vessel dock facilities for supplies transport and receiving, transloading facilities at the dock and a road net connecting

FIGURE 5-18

ARTIFICIAL ISLAND, OFFSHORE AT LONG BEACH

FIGURE 5-19
ARTIFICIAL ISLAND, OFFSHORE AT LONG BEACH

these and the plant. Also, some special terminal facilities would be needed for the submarine cable at each end of the ocean run. A submarine communication cable to the maintained system is also required to provide assured contact with the facility.

5.5.6.1 Facility Description. Each facility and area usage described for the aboveground plant is applicable to this concept. Additionally, the helicopter pad requires less than a 100-foot square paved area. There would be no service facilities for this aircraft, since the main modes of transportation to the mainland would be by vessel.

Most often a 60-foot vessel can be used to support the operation from the mainland shore. The vessel would normally operate between the island and the Long Beach Harbor and would probably be used solely for this project, transporting supplies and personnel. A dock about 150 feet long should be suitable for vessel, barge and small boat ties. The dock area would contain a jib crane and a minor amount of ancillary handling equipment to load and off-load fuel casks, drums, and other wastes, as well as supplies.

Because of the remoteness, more extensive living quarters probably will be required for some personnel staying at the site for brief continuous periods. Therefore, a facility is needed to house, feed, and otherwise support about 40 people at the site during operations.

The area requirement for the production portion of the plant is similar to the coastal aboveground concept. However, it is necessary to utilize additional acreage for dock side handling and storage, and for coolant pumping and refrigeration facilities. On the island, about 10 additional acres will suffice, most of it being used for dock-associated facilities. This space need not be duplicated for each unit, although some 1 to 2 acres might be added per unit.

Cooling water requirements are the same as for the coastal plant. However, freshwater production facilities would be required on the island. The quantity would be sufficiently small that it could be served easily by packaged desalination units as part of the support services required.

5.5.6.2 Considerations. Since gaseous releases under normal operations are made within regulations, and well below levels of concern, the added distance from shore in this concept is not a significant factor in reducing radiation doses. Also, liquid wastes

could be diluted and released into the ocean in quantities within regulation. Solid wastes will be drummed and spent fuel will be shielded and shipped from the island to shore. There is a risk in shipping these materials over water for disposal at AEC approved sites; but, should an accident occur which causes the encased material to be lost in sufficiently deep water that it cannot be retrieved, the consequence probably presents no hazard to the mainland inhabitants. Some added encasement design requirements might be necessary to provide the assurance needed.

Of the offshore concepts, the use of a natural island affords the most stable and reliable platform, with less vulnerability to many of the natural and man-induced hazards faced by the other concepts. Additionally, it increases the remoteness from mainland population centers by being offshore 23 miles.

Because of the distance offshore, cooling water intake and discharge lines may be much shorter than would be required at the mainland shore since dispersion can be achieved more readily in the deeper waters adjacent to the island.

The concept has a number of disadvantages over the other coastal concepts. Its cost of construction will be increased by at least the labor travel time between the mainland and the island, and the cost of transloading and shipping materials and equipment. Added costs are incurred by the required marine operations and the dockside support needed for those operations. Operating costs similarly will be greater. The submarine transmission line system to shore would not be capable of spanning the deep canyons existing between the island and the mainland, and would be longer in being rerouted around them.

In particular, the offshore islands appear to be seismically active and may present problems by imposing undue design criteria against ground motion and faults. Detailed on-site investigations would be necessary to determine the significance of this factor.

5.5.7 Tuned Sphere

The tuned sphere could have a minimum motion and be capable of having a natural roll frequency lower than the waves in its environment as a result of the spherical shape of the platform and optimal distribution of its center of mass toward the bottom of the sphere. Sanders Nuclear Corporation proposed a concept which was considered for use in support of offshore drilling operations and which appears to be similarly applicable to supporting a nuclear power plant.

The concept uses the features of a floating spherical body to good advantage; namely, a fixed center of rotation remaining at the geometric center of the sphere, regardless of mass distribution. All forces on the sphere act through the center of rotation. With the center of mass located low in the sphere, wave forces acting on the body may cause it to move horizontally and vertically but essentially it will not rotate. Roll is minimized by increasing the period of the platform such that imposed wave forces do not excite the platform. The spherical geometry could also more favorably respond to vessel impact loading by "rolling off" the blow than would otherwise be possible with a rectangular structure.

The facility would be prefabricated in a shipyard where best use of production line techniques and quality control could be applied to improve the feasibility of the concept. Then the completed facility would be towed to its site and anchored for long term use.

5.5.7.1 Facility Description. The structure would be slightly more than a hemisphere, having a diameter of about 300 feet and a height of about 190 feet to the deck. Figure 5-20 indicates the partial sphere and also the superstructure which supports a water tank, used to tune the mass, located about 260 feet above the deck. The facility would be moored to an anchored system to prevent it from drifting. The cable anchored system would be sufficiently "soft" to permit gimbaling action for the minor rolls and allow the sphere to rise and fall with tide changes and swells. The structure could be constructed of reinforced concrete or steel, the latter having a greater precedence in vessel and marine facility construction.

The design and plan layout within the shell, while containing the same features as in the other concepts, requires greater attention to equalizing the loads so that righting is assured in the completed facility without the use of a large vessel ballast for trimming. This necessitates locating the center of reactor, steam generators, and other heavy equipment loads near to the center of the vessel, much the same approach taken as in the design of vessels.

The sphere's shell would be supported by a network of radial bulkheads and stiffening structures. To reduce costs for maintaining the structure's exterior, and to preclude a need to dock the facility periodically for steel maintenance, it is proposed that the shell be constructed of reinforced concrete, with the interior of composite concrete and structural steel. Techniques for pouring

FIGURE 5-20

OFFSHORE - TUNED SPHERE

large, curved surfaces are available today and, as an example, are employed when constructing concrete cooling towers.

The deck of the platform would house a heliport landing pad and auxiliary vessel docking facilities used for resupply and personnel transportation. Handling equipment for fuel cask transfers and equipment replacement would also be located on the deck.

The area required to locate a tuned sphere concept is the most compact of the considered offshore concepts, because of the spherical geometry on which it is based. However, the splaying of an anchoring system increases the surface projected area to perhaps 60 to 70 acres required for an 1,100 Mw(e) plant, assuming water depths of about 300 feet.

As in the case of land-based plants, direct radiation protection is afforded by the shielding placed around the reactor and in the case of a loss-of-coolant accident, by the steel-lined concrete structure of the containment building. The facility would be designed to contain 60 psi pressures resulting from the accident and could release the pressures to the atmosphere or to ocean waters offshore.

Construction of the facility would have to take place in a shipyard, specially fitted for the facility and therefore would become more economical if such a yard is provided for a number of platforms. Because of the size of the sphere and the hazard in transporting it, the construction would have to take place on the west coast. The sphere would be towed to the site and anchored to a previously prepared mooring system.

5.5.7.2 Considerations. The tuned sphere concept derives its logic from extensive work accomplished in ocean programs. A number of large instrument platforms have been in operation for some time, and the sea-structure interface for spherical bodies in the ocean is fairly well understood. The extension of this knowledge from 20 to 30-foot diameter platforms to 300-foot diameter platforms probably would demand a large demonstration project to show feasibility.

The design and construction of the spherical concrete vessel also extends the state of the art in concrete design. Precedence exists for the design of large concrete shells, but not for large shells subjected to the erratic forces of wave action in open waters.

The construction of the sphere somewhat extends current practice in reinforced concrete construction, and even the design may

be complicated by the structural indeterminacy of many floors and walls intersecting a large, thin-shelled sphere with uneven loading from wave forces. This is not to say that an analysis would be meaningless, but rather to point out the unknowns and, therefore perhaps, the conservatism which may have to be built into the design to compensate for these unknowns.

This facility provides an opportunity for relocating plants when they are no longer best suited for supplying power to a particular area. This relocation would require new construction of mooring systems, condenser cooling lines and, perhaps, power transmission lines.

Because of its shape, the sphere would be more seaworthy than other concepts. In the event of an impact with a seagoing vessel, the sphere might be subjected to less damage due to the force vectors acting on a sphere. Located in deeper water, the concept would be less sensitive to earthquake motions transmitted through the water. However, moored offshore, it is subject to the natural hazards associated with any open ocean location; that is, storms, erratic wave forces and high winds in combination with these. Oceangoing vessels usually successfully operate in these adverse environments, and it is reasonable to assume that the sphere would perform even better because of its shape. However, there is no experience in finely adjusting the frequency of extremely large spheres for the purpose of tuning out the great number of wave frequencies to eliminate almost all motions and forces.

5.6 ABOVEGROUND FLOATING - LAGOON

The discussion in Section 7, regarding seismic effects on floating nuclear power plants, suggests that there is an advantage in using these concepts because the horizontal high frequency component is probably not transmitted through the mooring lines to the platform, although sloshing in an enclosed water body may induce horizontal forces on the side of the platform. This concept is therefore presented to utilize the potential advantages of the platform-mounted nuclear plant, when placed in an inland lagoon. A number of potential lagoon sites exist in California. If possible, a site near sea level would be selected. A 500-foot wide by 45-foot deep canal would be constructed from the shore to an area adjacent to the foothills, if possible, so that the lagoon site would be hidden from view at the highway.

The plant is shown in perspective in Figure 5-21. Access to the facility would be by road and bridge or by boat. Condenser cooling

FIGURE 5-21
ABOVEGROUND-FLOATING LAGOON

water intake would be from the lagoon and discharge will be through an underground outfall line offshore as described for the land-based plants. Although power could be transmitted by standard overhead-type cable from the potheads, to improve the aesthetics electric power is assumed to be transmitted across the lagoon in a submarine cable to underground or low profile surface transmission lines extending to the substation for transmission to the network grid.

5.6.1 Facility Description. The power plant facility is identical to the offshore floating, shallow concept previously described. The platform-mounted plant occupies approximately four acres, and another four and one-quarter acres would be required for the lagoon plus the length of the channel required to the lagoon.

5.6.2 Considerations. All technologies required for this concept are within today's state of the art.

This concept is extremely conducive to joint use of the lagoon and water channel for boating facilities, and has been shown with this dual use in Figure 5-21.

This concept has the advantage that candidate west coast sites can be sought without concern for the depth of the continental shelf because the required depths would be excavated. These locations would be more accessible than those that are offshore, thereby reducing the logistical self-sufficiency requirements inherent with offshore locations. Furthermore, they would not be subjected to the storm hazards or ship collision potential prevalent in the other offshore concepts, and have an inherent reduction in seismic exposure due to the floating pressure. However, attention to special hydraulic design to mitigate the possible increased tsunami effects might be required.

Due to the probable increase in lagoon water temperature (condenser intake) over that found offshore, plant efficiency would be slightly reduced relative to the offshore facilities.

PLATE 5-1
ABOVEGROUND - COASTAL
SITE PLAN

PLATE 5-2

ABOVEGROUND - COASTAL

PLAN AT TURBINE DECK LEVEL

PLATE 5-3

ABOVEGROUND - COASTAL
PLAN AT CONDENSER LEVEL

PLATE 5-4
 ABOVEGROUND - COASTAL
 PLAN AT CONDENSER BOX LEVEL

PLATE 5-5
 ABOVEGROUND - COASTAL
 SECTION THROUGH FACILITIES

0 10 20 30 40 50
GRAPHIC SCALE - IN FEET

PLATE 5-6
ABOVEGROUND - COASTAL
SECTION THROUGH FACILITIES

PLATE 5-7
ABOVEGROUND - INLAND
SITE PLAN

PLATE 5-8

ABOVEGROUND - INLAND

PLAN AT TURBINE DECK LEVEL

PLATE 5-9
ABOVEGROUND - INLAND
PLAN AT CONDENSER LEVEL

PLATE 5-11
ABOVEGROUND - INLAND
SECTION THROUGH FACILITIES

PLATE 5-12
UNDERGROUND - MASSIVE IGNEOUS ROCK
PLAN AT TURBINE DECK LEVEL

PLATE 5-13

UNDERGROUND - MASSIVE IGNEOUS ROCK
PLAN AT CONDENSER LEVEL

PLATE 5-14
 UNDERGROUND - MASSIVE IGNEOUS ROCK
 SECTION THROUGH REACTOR AND
 TURBINE BUILDINGS

PLATE 5-16
 UNDERGROUND - UNCONSOLIDATED
 MATERIALS, BEACH
 SECTION THROUGH FACILITIES

PLATE 5-17
 UNDERGROUND - MASSIVE ROCK FAULTED
 PLAN AT TURBINE DECK LEVEL

UNDERGROUND - MASSIVE ROCK FAULTED
SECTION THROUGH FACILITIES

PLATE 5-20
UNDERGROUND - MASSIVE ROCK FAULTED
SECTION THROUGH FACILITIES

PLATE 5-21
OFFSHORE - FLOATING SHALLOW
COMPOSITE LEVEL PLAN

ELEVATION SECTION A-A

PLATE 5-22
 OFFSHORE - FLOATING SHALLOW
 SECTION THROUGH FACILITIES

ELEVATION SECTION B-B

PLATE 5-23

OFFSHORE - FLOATING SHALLOW
SECTION THROUGH FACILITIES

PLATE 5-24
OFFSHORE - ARTIFICIAL ISLAND
PLAN AT TURBINE DECK

ELEVATION SECTION A-A

ELEVATION SECTION B-B

0 10 20 30 40 50
GRAPHIC SCALE

PLATE 5-25
OFFSHORE - ARTIFICIAL ISLAND
SECTION THROUGH FACILITIES

6. ALTERNATIVE POWER SYSTEMS

Alternative power plant systems were reviewed to identify the major plant characteristics, points of interface with the environment, and difference between the alternative systems which might affect the relative acceptability of the various siting concepts.

There are two basic types (excluding geothermal) of central station thermal power plants depending on the process used as the energy source. Nuclear power plants depend on the fissioning of uranium atoms, or other fissionable material; fossil-fueled plants produce heat from combustion of coal, oil, or gas. Coal-fired plants are not used in California, except in remote desert areas, due to high transportation costs for the coal; and the air pollution resulting from stack effluents. Only low-sulfur oil or gas has been able to meet the stringent requirements for gaseous discharge. As supplies of natural gas have become less available, many plants have been converted to the use of oil.

Nuclear power plants are in use or being developed based on three different reactor systems depending on the fluid used to transport heat from the reactor core. Light water reactors (LWRs) use highly purified ordinary water as the heat transport fluid, under an overpressure (pressure greater than the equilibrium pressure for the fluid temperature) in the pressurized water reactor (PWR), or at equilibrium pressure in the boiling water reactor (BWR). Both the PWR and BWR produce saturated steam (recent designs for PWR steam generators have achieved approximately 50 F of superheat), which provides a less efficient thermal cycle than that of modern fossil-fueled plants operating on superheated steam.

High temperature gas reactors (HTGRs) use pressurized helium as the heat transport medium. The third reactor-system type, now in an intensive development program, uses liquid sodium as the transport fluid. It operates with minimal neutron moderation giving it the ability for breeding new fuel; hence, its name, liquid metal fast breeder reactor (LMFBR). Both the HTGR and the LMFBR operate at temperatures suitable for production of superheated steam, which increases the thermal efficiency into the range of the fossil-fueled plants.

Other potential breeder-reactor systems are not included in this study because their commercial application by 1990 is unlikely.

All large (above 600 Mw(e)) central power stations now in use or being designed for construction employ steam as the working fluid to drive turbine-generators. Some smaller fossil power plants are based

on open-cycle, gas turbines or a combination of steam and open-cycle turbines. The high temperature gas available in the HTGR system, in addition to being suitable for generation of steam as in existing HTGR plants, appears to make the development of closed-cycle, helium-gas turbines worth pursuing, thereby completely eliminating the steam cycle.

6.1 HEAT REJECTION

All power-producing thermodynamic cycles require the rejection of waste heat, after expansion of the working fluid through the turbine, in order to complete the cycle. This heat can be rejected by means of:

1. Once-through cooling water discharging to natural water bodies such as lakes, rivers, or the ocean.
2. Recirculating cooling water dumping heat to the atmosphere by means of man-made evaporative bodies of water, spray ponds, or evaporative cooling towers.
3. Recirculating cooling fluid dumping heat to the atmosphere by means of dry, air-cooled heat exchangers (dry towers).

Once-through cooling systems are sometimes supplemented by evaporative cooling towers to reduce the temperature of the cooling water before returning it to the water source. Cooling towers (evaporative, dry-heat exchanger, or both in combination) can be designed for either natural draft or forced draft operation.

The selection of a heat rejection method is usually governed by cost. For typical situations, the unit cost of heat rejection systems for steam-electric plants, 600 Mw(e) and larger, varies from 2 to 32 dollars per kilowatt. The cost summary of Jimeson and Adkins* is shown in Table 6-1. Some other sources give tower costs from 25 to 45 percent higher and once-through costs of nearly three-times those indicated in the table.

The lower cost of heat rejection systems for fossil-fueled plants is due to the higher thermal efficiency (less heat rejection per unit of electric production) of the fossil plants compared to the LWR nuclear

*Jimeson, J. M., and Adkins, G. G., "Waste Heat Disposal in Power Plants," Federal Power Commission, Washington, D. C., Cooling Towers, a CEP Technical Manual published by AIChE, 1972.

TABLE 6-1

UNIT COSTS OF HEAT REJECTION SYSTEMS
(Steam-Electric Plants)

System	Investment Cost, \$/kw	
	Fossil	Nuclear
Once-Through	2-3	3-5
Cooling Ponds	4-6	6-9
Evaporative Towers		
Mechanical Draft	5-8	8-11
Natural Draft	6-9	9-13
Dry Towers		
Mechanical Draft	18-20	26-28
Natural Draft	20-24	28-32

plants on which the table is based. For HTGR and LMFBR plants, which have the capability of producing superheated steam comparable to modern fossil-fueled plants, the cost of the heat rejection system would be in the range of that for the fossil plants.

Due to the approximately threefold cost of dry towers over evaporative towers (some sources estimate closer to twofold), dry towers have not been used to any extent for steam-electric plants. The HTGR gas-turbine power plant, HTGR(GT), when developed, could reject heat to a circulating water loop over a temperature range from about 440 F to 105 F. The circulating water rejects its heat in the dry cooling tower over a temperature range from about 340 F to 90 F rather than all at about 140 F which is typical of the steam cycle. This improvement in the driving force for heat transfer in the cooling tower and the higher thermal efficiency of the HTGR(GT) should significantly reduce the heat transfer surface required compared to LWR plants, resulting in dry tower costs for the HTGR(GT) which may be competitive with evaporative towers for the fossil, LMFBR, and HTGR steam systems. The application of large, dry cooling towers to central station power plants would need to be demonstrated to establish cost and reliability of operation before planners could include this system in future plant designs with confidence.

6.2 SYSTEMS DEVELOPMENT

Fossil-fueled power generation systems have been the historic foundation for the growth of the thermal power industry in the United States. The technology of fossil-fired steam generators and their supporting processes and equipment has been developed carefully over many years. Continual improvements have been achieved in combustion efficiency, higher steam pressures and temperatures, cycle efficiency, and effluent cleanup. Modern fossil power systems and system components are available from several large organizations in a well established industry. Approximately four to six years are required from the time of decision to on-line application of a large central station fossil power plant.

The LWR is the first nuclear reactor concept to be developed for central station application. Power systems based on PWR and BWR steam supplies started commercial power production under utility company ownership at about the same time (1960 to 1961). Since commitment for these initial units, utility organizations in the United States have placed orders with the manufacturers for nearly 50 BWR units and 90 PWR units. The first three LWR units (two BWRs, one PWR) in the 1,000 Mw(e) class were scheduled for operation in 1972. Due to lengthening lead times for major components, licensing procedures, and siting problems, the project period for some LWR plants has approached ten years. The BWR steam supply system has undergone several modifications and advancements in over 15 years of development. The latest version of this basic concept is designated the BWR/6 by the General Electric Company, the sole supplier in the United States of this type of light water reactor system. The BWR/6 incorporates a pressure suppression containment configuration and a turbine building layout to achieve a slightly smaller plant volume. The PWR, developed initially for application in the Navy program, has been developed to the larger sizes required for economical central station application. This concept is offered commercially, with some differences in features of the detail design, by Babcock and Wilcox, Combustion Engineering, and Westinghouse.

Nuclear steam power plants based on the HTGR are well along in development and demonstration of economic feasibility. The Peach Bottom Power Station (40 Mw(e)) has operated since 1967 with high availability; and the Fort St. Vrain Station (330 Mw(e)) is scheduled for operation during 1973. Both these stations were developed by Gulf General Atomic, the only supplier of the gas-cooled, nuclear steam system in the United States. Commercial acceptance of this concept,

based on about 15 years of research and development in the United States and Europe, is evidenced by recent letters of intent for six gas-cooled, nuclear steam systems in the range of 700 to 1,200 Mw(e). A special feature of the HTGR being developed in the United States is that it employs the uranium/thorium fuel cycle. Development of this fuel cycle will take advantage of the vast energy resource of the thorium reserves unused by other present reactor concepts.

The HTGR(GT), in which the high temperature, gas-cooled reactor is combined in a direct cycle with a closed-cycle, helium-gas turbine drive for the electric generator, is in the early stages of study by Gulf General Atomic. If an aggressive and highly successful R&D effort is initiated in the very near future, the on-line operation date for an initial HTGR(GT) power plant potentially could be as early as 1985. Although gas turbines have experienced a rapid growth in conventional power plant applications in recent years, much development work remains to extend the technology from these small, open-cycle combustion gas units to units using helium in the size range required for economical base load plants. In addition, the entire primary system will need to be developed to operate in a pressure range 40 percent above that of the HTGR with a steam cycle. Several advantages are expected from the gas turbine plant in comparison to those using the steam cycle. Perhaps the most important advantage is the possibility of developing a more economical, dry-cooling system for heat rejection to the atmosphere, thus providing greater flexibility in site selection by removing the requirement for a major water source.

The LMFBR steam supply system and supporting systems are presently being developed in an intensive AEC sponsored demonstration program oriented toward commercial service of sodium-cooled plants by the early or mid-1980's. This program is based on technology developed over a 20-year period from design and operation of several low power (up to 300 Mw(t)), liquid-metal-cooled reactors built in the United States and Europe. The technical problems which have been solved in the development of sodium-cooled reactors have required the development of an entirely new technology for the liquid sodium. Three industrial organizations, Atomics International, General Electric, and Westinghouse, have developed reference designs for LMFBR demonstration plants in the 300 to 500 Mw(e) range targeted for initial operation by 1978 to 1979. Westinghouse has been selected recently as the nuclear system supplier for the initial demonstration plant. Following successful demonstration of the concept in a commercial environment, one or more designs will be developed in the economically competitive range of 1,000 Mw(e).

6.3 SYSTEMS DESCRIPTION

The systems of all nuclear power plants can be grouped into five major categories. These are:

1. Production systems.
2. Engineered safety features.
3. Auxiliary systems.
4. Radioactive waste and radiation protection.
5. Site and security.

Each of the systems and subsystems is described in detail in Appendix B.

Fossil-fueled plants also have systems in each of these categories, although the engineered safety features are less extensive and less easily identified as separate systems. While the fossil plants do not have radioactive waste and radiation protection systems as required for nuclear plants, they have ash and flue gas cleanup systems.

The differences in the specific systems of the various power plants stem from the:

1. Type of fuel (fossil, nuclear).
2. Properties and characteristics of the primary coolant (water, gas, liquid-metal).
3. Working fluid (steam, gas).
4. Heat rejection method (once-through, ponds, towers).

The selection of these alternatives and the specific arrangement and design of the resulting systems determine the space requirements for the plant and plant site and the visual image obtained by an outside observer of the plant.

6.3.1 Production Systems

The production systems of a thermal-steam, electric plant are those systems and subsystems required to convert thermal energy into

electricity and deliver it to a transmission or distribution grid. These systems consist of:

1. A source of thermal energy (heat source).
2. A means of transferring the energy from the heat source to steam.
3. A steam turbine to drive an electric generator.
4. A steam condenser.
5. Condensate and feedwater pumps and heaters to return the condensate as feedwater to the steam generator.
6. A circulating water system to remove the heat of condensation (waste heat) from the condenser and transport it to the point of discharge into the environment.
7. The electricity producing system including the generator, transformers, switchgear, and transmission lines to an existing grid.
8. An instrumentation and control system required for start-up, steady-state operation, and shutdown of the production systems.

The heat source for a fossil plant is the combustion of fuel in the fire box section of the steam generator. For a 1,100 Mw(e), oil-fired plant, the fuel consumption approaches 60,000 gallons (three tank cars) per hour and larger quantities of air must be delivered to the burners. The steam generating unit contains thousands of pressure tubes and may be over 100 feet high and 20 to 60 feet on a side, depending on plant size.

The heat source for all nuclear plants is the nuclear reactor consisting of fuel elements which must be replaced periodically (9-month to 2-year cycles depending on type). New fuel elements must be brought into the plant, usually by truck, and spent fuel elements, heavily shielded, must be transported by truck or railroad to a fuel reprocessing plant remote from the site.

The core is supported in a heavy-walled, steel pressure vessel which is approximately 44 feet long x 22 feet in diameter, and weighs up to 500 tons for the PWR. The BWR vessel which also acts as the steam generator is about 74 feet high and 24 feet in diameter. The reactor vessel for the LMFBR will be of about the same magnitude. The core of the 1,000 Mw(e) HTGR will be contained in a prestressed, concrete reactor vessel (PCRV) measuring about 90 feet high and 90 feet in diameter. This vessel will also house all other units of the steam supply system.

The major difference in the nuclear systems is in the systems for transferring heat from the core to the steam generator. In the PWR, heat is transported by a pressurized water loop, while in the BWR, the water passing through the core is allowed to boil in the core to produce steam. The HTGR transports heat from the core to the steam generators, which are also located in the PCRV by a pressurized gas loop. The LMFBR will use three redundant heat transfer systems, each consisting of two low pressure, liquid-sodium loops in tandem, to isolate radioactive sodium from the possibility of contact with water. Many components of the steam supply systems for all nuclear types are massive units comparable in size and weight to the reactor vessel.

In the fossil plant, heat is transferred directly to the boiler, superheater, reheater, and economizer by thermal radiation and by the hot combustion gases passing over the tube banks.

Beyond the steam generator, the production systems of all steam-electric plants (fossil and nuclear) are similar, except for the selection of a heat rejection system type which was discussed previously.

The systems with higher thermal efficiency (fossil, HTGR, and LMFBR) require less cooling water flow rate (about 600,000 gpm, depending on thermal efficiency, rather than 800,000 gpm for the LWR), for the same temperature rise across the condenser. Also, the line sizes and equipment sizes for steam generators, turbines, heat exchangers, pumps, and condensers are slightly reduced by the increased efficiency.

6.3.2 Engineered Safety Features

The engineered safety features are a group of systems designed to localize, mitigate, terminate, and control the consequence in the event of the release of fission products from the reactor core. Their purpose is to protect plant personnel and to assure that off-site

consequences are within acceptable limits established by the guidelines of the Code of Federal Regulations.

The major systems in this group are:

1. Containment.
2. Emergency core cooling.
3. Emergency electrical systems.

All large nuclear systems are housed in buildings which serve to contain internal pressures resulting from a loss-of-coolant accident (LOCA). The building normally would be a cylindrical containment vessel with a domed head. The dry concept for the PWR is designed for an internal pressure of 60 psig following the LOCA. The ice condenser concept for the PWR and the water suppression concept for the BWR are added systems which reduce these pressures to 30 psig and 15 psig, respectively, thus reducing vessel wall thicknesses. The HTGR and LMFBR containments are not subject to the larger pressure surges associated with the LOCA in a LWR. Although the size of the containment vessel varies with the reactor type and containment system used, they all present similar visual impacts. Typical dimensions are:

<u>Type</u>	<u>Diameter (feet)</u>	<u>Height (feet)</u>
LWR	138	209
HTGR	130	228
LMFBR	170	240

The HTGR(GT) containment would be somewhat larger in diameter to accommodate the gas-turbine generators inside the containment.

The LWR containment is provided with a spray system, emergency cooling system, and purge exhaust system to maintain the desired temperature, pressure, and contaminant levels in the containment during an accident condition. The HTGR, which is designed to preclude rapid releases into the containment building by retention in the PCRVR, and the LMFBR, which has only low pressure systems within the containment, do not require these containment safety features. These concepts will handle accidental releases to the containment by means of their isolation systems and ventilation purge systems operating through filters and/or scrubbers.

Emergency core cooling (ECC) is provided in the LWR systems by an elaborate set of borated water injection and circulating systems.

Decay heat is removed from the borated water by heat exchangers cooled by the same water source used for the condenser cooling water. Due to inherent characteristics of the HTGR and LMFBR cores and primary cooling fluids, neither of these reactor systems will require a quick-acting ECC system. Shutdown cooling will be provided in the HTGR and LMFBR systems by operation of one or more of the redundant core cooling systems used for power production. In addition, they will have potential for cooling through auxiliary shutdown systems independent of power production systems.

Emergency electrical systems are identical in principle and function for all reactor concepts. All engineered safety features equipment is provided with a minimum of an off-site source and two on-site standby sources of emergency power. The off-site source is the transmission system network furnishing power through reserve auxiliary transformers; standby power is provided by redundant diesel generators and redundant battery stations.

6.3.3 Auxiliary Systems

The same eight auxiliary systems are found in all nuclear plants although the system configurations differ to meet the characteristics of the materials being serviced. In general, the auxiliary systems of the HTGR and LMFBR plants tend to be less extensive and less complex than for the LWR plants. These systems are:

1. Chemical and Volume Control System.
2. Shutdown Cooling System.
3. Fuel Storage Cooling System.
4. Component Cooling Water System.
5. Fluid Sampling and Analysis.
6. Fuel Handling and Storage.
7. Facility Services Systems.
8. Decontamination Processes.

The Chemical and Volume Control System in the LWR plant maintains the reactor coolant water volume, activity level, and chemistry, and provides for filling and testing for boric acid content.

In the HTGR, the Chemical and Volume Control System is replaced by the helium purification system which performs similar functions. The LMFBR has no Chemical and Volume Control System, but the sodium level is maintained by a storage tank connected to the reactor's primary tank.

The function of the Shutdown Cooling System is to reduce and maintain the primary cooling fluid temperature during refueling. In the LWR, this is accomplished by low pressure injection pumps circulating reactor coolant water through shutdown heat exchangers which are cooled by circulating water from the condenser cooling water source. The HTGR uses a combination of the primary coolant system loop and the core auxiliary cooling system. The LMFBR uses a reactor auxiliary system to transfer heat to a heat sink provided by an air-cooled heat exchanger.

The function of the Fuel Storage Cooling System is to remove spent fuel decay heat from the spent fuel storage area. LWR fuel is stored underwater in a large, open top, pool cooled by circulating pool water through a heat exchanger and ion exchange system to maintain purity. HTGR fuel is stored in dry storage wells cooled at the walls by circulating water. LMFBR fuel is stored in a sodium-filled, fuel decay tank from which heat is removed by a heat exchanger.

The Component Cooling Water System of an LWR plant acts as a heat sink for shutdown cooling, emergency cooling, and component cooling during normal operation. It circulates up to 45,000 gpm of water to service approximately twenty heat exchanger, cooler, and pump items. The HTGR's Component Cooling Water System serves similar units and functions. In the LMFBR, the cooling water is confined to those units of the plant not containing sodium. Oil or cryogenic gas is used in other plant units.

The Fluid Sampling and Analysis systems of each plant are matched to the needs of the particular fluids being analyzed.

The Fuel Handling and Storage for each reactor type consists of complex machines, equipment, tools, and procedures for moving fuel elements from the core to the spent fuel storage area and from new fuel storage into the core. These operations are performed underwater in LWR plants; dry in shielded containers for the HTGR; and remotely by a machine operating in an inert atmosphere for the LMFBR. The mechanisms tend to be more complex for the HTGR and LMFBR than for the LWR.

The Facility Services Systems group of systems includes heating, ventilating and air conditioning, turbine plant cooling, fire protection, and compressed air is identical in function and concept for all the nuclear plants except that water-based fire protection systems cannot be used in LMFBR areas containing sodium.

Decontamination is provided for equipment and tools, shipping casks and larger equipment prior to shipping, and personnel. The water environment of the LWR tends to make decontamination more prevalent than for either the HTGR or the LMFBR. In the LMFBR, provision also must be made for sodium removal from equipment and tools, and from major components prior to repair or shipment off-site.

6.3.4 Radioactive Waste

All nuclear reactor systems produce some gaseous, liquid, and solid radioactive waste. Radioactive waste systems provide controlled handling and disposal, minimize station personnel exposure to radiation, and minimize or preclude discharge of radioactive wastes to the surrounding environment. Developments in radwaste technology and management philosophy have reduced discharges to the environment of gaseous and liquid radioactive waste to levels considerably below those permitted by regulatory standards. Proposed regulations call for discharge levels to be "as low as practicable."

Although the details of solid waste management may vary from plant to plant, in general, all radioactive solid wastes are processed, if required; packaged in approved containers (shielded as needed); stored for radioactive decay, and shipped off-site by an AEC licensed disposal contractor. Items to be laundered are processed off-site by an AEC licensed contractor. Solid wastes from a LWR consist of spent ion exchange resins, crud from the primary water system, disposable filter elements, and contaminated paper, plastic, clothing, shoe covers, tools, fittings, and other miscellanea. Graphite reflector elements, in-core instrumentation, control rods, titanium sponge, and various filter absorbers and demineralizer materials are the major solid radioactive wastes from a HTGR. The LMFBR is expected to produce similar solid radioactive waste, but the quantities (about 700 cubic feet per year) from the LMFBR and the HTGR are expected to be somewhat less than for a LWR plant.

LWR plants generate larger volumes (about 600 gallons per hour) of radioactive liquids to be processed than either the HTGR (about 12 gph) or the LMFBR plants. Over 99 percent of the liquid waste is produced as the result of changes in boric acid concentration in the

reactor coolant. This function is not present in the HTGR and the LMFBR plants. Other sources of liquid radioactive waste are drains, sinks, and steam generator blowdown. All radioactive liquids are processed in appropriate systems which include filtration of particulates, oil absorption, ion exchangers to remove ionic fission products, gas strippers to remove fission product gases, and evaporation to reduce volume. The deactivated effluent is recycled to the maximum extent feasible. Excess quantities are disposed of through the circulating water outfall or by tank truck for off-site disposal.

Gaseous radwaste (produced by all reactor types) containing gaseous fission products is processed by hold-up for decay, filtration, absorption, and/or cryogenic separation to produce an effluent stream well below radiation limits for discharge through a stack and dispersion in the atmosphere. The quantity of radioactive gas is quite small (less than 10 cubic feet per hour) and can, therefore, be easily held in storage and processed without unreasonable cost.

6.3.5 Radiation Protection

Radiation protection adds to the space requirement for some areas of the plant to provide for radiation shielding as protection for the plant operating personnel and to prevent undue hazard to the general public during normal operation or in the event of a power plant accident. Systems or areas requiring shielding in a LWR plant are:

1. Nuclear Steam Supply System.
2. Control Room.
3. Radwaste Systems.
4. Chemical and Volume Control System.
5. Sampling System.
6. Spent Fuel Transfer and Storage.

The nuclear steam supply system requires the greatest amount of shielding. Three separate radiation barriers, totalling 13 feet of reinforced concrete, are provided to reduce the radiation level outside the containment building to less than 1 mrem per hour at full power operation. Concrete walls, covers, and removable blocks are used to shield components of the radwaste, chemical and volume control, and sampling systems. Concrete walls and borated water provide shielding

for the spent fuel elements during refueling and storage. Because of the large number of units requiring shielding and the spread-out arrangement of the equipment, more space is occupied by shielding in the LWR than either in the LMFBR or in the HTGR.

The systems of a LMFBR plant requiring radiation shielding are:

1. The reactor core.
2. The primary coolant.
3. Refueling and fuel storage.
4. Primary sodium service systems.
5. Radwaste systems.

The amount of shielding is minimized by placing these systems in a common area. All system components, except refueling, requiring shielding are placed below the operating floor in low leakage compartments or vaults separated by reinforced concrete shielding walls 4 to 6 feet thick. This permits maintenance access to a service system component without shutdown of other components.

All HTGR systems requiring radiation shielding are either contained in the PCRV or are in vaults in the fuel storage building. The space required for shielding is minimized by this compact arrangement. The outside walls of the PCRV are approximately 16 feet thick minimum, and the top and bottom heads are about 18 feet thick.

6.3.6 Site and Security

The site and security features of all nuclear power plants are essentially identical but with variations in detail in accordance with the operating philosophy of the owner and specific site requirements. Typical features which are characteristic of the plant site during normal operation or construction are:

1. Road and railroad access.
2. Parking for plant personnel.
3. Administration building.

4. Shops and warehouses.
5. Security system.
6. Communication systems.
7. Radiological and meteorological monitoring system.
8. Freshwater reservoir.
9. Visitor center.
10. Temporary requirements for construction.
 - a. Parking.
 - b. Equipment and materials laydown.
 - c. Shops and subassembly areas.

Site features of a fossil plant are similar to those of a nuclear plant, but without the requirement for radiological and meteorological monitoring. Visitor centers are not normally provided for fossil plants and will be found less frequently with nuclear plants as they become more common.

Although it is possible to transport turbine generator parts, pressure vessels, steam generators, other major components, and spent fuel shipping casks by special truck, rail transportation is preferred and provided, if feasible.

Transportation requirements for nuclear plants (1,000 Mw(e)) are quite small compared to coal or oil fossil plants as seen from the following comparison of annual shipping requirements.*

	<u>LWR</u>	<u>LMFBR</u>	<u>Fossil</u>
Fresh Fuel (Trucks)	5.3	8.0	-
Spent Fuel (Railcars)	9.3	14.0	-
Low-Level Waste (Trucks)	6.4	3.2	-
Oil (Railcars)	-	-	20,000
Coal (Railcars)	-	-	30,000

* U. S. Atomic Energy Commission, "Environmental Statement, Liquid Metal Fast Breeder Reactor Demonstration Plant," WASH-1509, April, 1972.

Land requirements are also much greater for coal-fired fossil plants as summarized below for 3,000 Mw(e) stations consisting of three 1,000 Mw(e) plants and their associated facilities.*

<u>Heat Source</u>	<u>Acres</u>
Coal (including coal yard and ash disposal)	900 - 1,200
Coal (as above and storage of spent limestone used for SO ₂ removal)	1,050 - 1,600
Oil (including storage)	150 - 350
Gas (including back-up oil storage)	100 - 200
Nuclear (including exclusion area)	200 - 400

* U. S. Atomic Energy Commission, "Environmental Statement, Liquid Metal Fast Breeder Reactor Demonstration Plant," WASH-1509, April, 1972.

7. CONCEPTS EVALUATION

In this section an assessment of each siting concept is made to arrive at a quantitative evaluation and then to a suitability ranking (or acceptability) of each. As a prelude to this discussion, it is well to address some of the philosophical questions surrounding any such evaluation scheme. The first question is whether an attempt should be made at all to perform a quantitative evaluation. Hopefully, a decision is based on quantitative data so that in deciding where to locate a plant, one is forced to assign a value, knowingly or implicitly, to aesthetics, risks, and all the other "nonquantifiables." So the question is not whether to quantify or not to quantify; the question is whether to quantify explicitly or implicitly. Explicitness is desired and an overt numerical evaluation scheme should then be selected. However, such a scheme is a guide, not a replacement for human judgment. Collective human judgment remains particularly desirable.

It is impossible for a panel trying to choose between many sites, siting concepts, and energy sources, while subject to widely different interests and opinions of others, to reach an objective decision without some scheme or formalism for organizing the issues and evaluating the options. Such a scheme at least serves to focus the arguments and reduce them to explicit, numerical terms. Left on the verbal level such arguments could go on forever without much progress toward resolution.

The next question is how to construct a quantitative scheme. The essential steps in any such scheme are:

1. A listing of the alternative courses of action or nonaction.
2. A listing of all the categories of impacts or effects which are pertinent to these actions.
3. A rating of each course of action with respect to each effect category.
4. A combination of all the ratings into a net ranking of the alternative courses of action.

Of these, the first three steps can be essentially factual, although always subject to question as to their correct choice, completeness, or accuracy. Some judgment may be required in Step 3 as a result of a lack

of factual information. In Step 4, weighting values are required to combine individual value judgments. Thus, all the steps may generate controversy. However, in the absence of factual and undisputable data, use of subjective evaluations at a detailed level improves the objectivity of the assessment. The point to be emphasized is that the real benefit of the evaluation comes in identifying and quantifying the major consequences of the proposed actions. The specific choice of weighting factors and reduction for net ranking is valuable, but too much emphasis should not be placed on the numerical values obtained. It is the relative comparison of acceptabilities which is important and, therefore, the results are displayed in a way that makes all of the major impacts of the proposed actions visible.

Details of the evaluation methodology used here are presented in Appendix C.

7.1 EVALUATION FACTORS

In the past it has been common to select sites and siting concepts for fossil-fueled power plants based primarily on least cost, considering land, water availability, and proximity to the load center (low cost for transmission lines). Such judgments were simplified because the primary consideration was cost of each factor. Today, evaluation factors for nuclear power plants also must include feasibility, environmental impact, plant vulnerability, and nuclear safety. Therefore, the evaluation scheme derived in this study includes the above factors to compare concepts.

There are a number of factors needed to arrive at a decision for identifying the best concept at a specific site. It is important to note however that most site-oriented input to such a decision requires a great amount of site investigation, and that is not feasible for the entire state nor meaningful for this study. However, there are many factors which can be considered that are not nearly so site peculiar, but are sufficiently appropriate to allow culling-out of less acceptable concepts. Therefore, factors which are peculiar only to selection of specific sites and not to the relative merits of concepts being evaluated are not included.

A panel of individuals, attempting to represent a cross section of siting interests and concerns, assessed many considerations and placed them into groups by principal factor. First, to place factors into perspective, the panel was polled to determine the relative weighted values to be assigned to each factor. Then a determination was made

of relative weighted values to be assigned to each subfactor in the group. Following are the factors, subfactors, and the mean values of weighted values.

1. Cost Factors (0.287).
 - a. Capital costs.
 - (1) Production plant.
 - (2) Transmission plant.
 - (3) Engineering.
 - (4) Interest during construction.
 - b. Operation and maintenance costs.
 - (1) Fuel.
 - (2) Labor.
 - (3) Material and equipment.
 - c. Taxes, insurance, depreciation, interim equipment replacement.
2. Environmental Impact (0.301).
 - a. Compatibility with existing and planned adjacent land use (0.050).
 - b. Ability to return the site to its natural state at plant retirement (0.033).
 - c. Visual image (0.055).
 - d. Operations impact on physical and biological environment (0.075).
 - e. Construction impact on physical and biological environment (0.015).
 - f. Multiple use of reject heat and facilities (0.033).
 - g. Multiple use of site property (0.040).
3. Feasibility (0.272).
 - a. State of the art (0.119).
 - b. Existence of characteristic sites (0.153).
4. Risk (0.140).
 - a. Plant exposure.
 - b. Safety (environmental exposure).

7.2 EVALUATIONS

7.2.1 Cost

Capital costs were estimated in accordance with the Federal Power Commission electric plant chart of accounts and specific operating and maintenance costs. Capital cost estimates were prepared for each siting concept using a light water reactor system. Cost information for the Rancho Seco plant was used as a basis for estimating costs for all concepts since the data are current with this study. The annual expenditures and forecasts for that plant (operational in 1974) were adjusted to 1972 dollars and then factored up to an 1,100 Mw(e) capacity plant, recognizing economies due to size. Cooling systems, land, reservoirs, and other features of the inland plant were then removed from the estimate and adjustments made to develop a baseline cost for an 1,100 Mw capacity aboveground coastal plant. These adjustments included the addition of intake and discharge condenser cooling lines; a 9,000 hp, 863,000 gpm pumping plant; and the increased efficiency resulting from the low condenser cooling water temperatures. This became the basis for developing costs for the other concepts by adjustments as a function of the differences in plant and site development scope. Engineering costs are included in each account.

Operating and maintenance costs similarly were obtained from forecasts for the Rancho Seco plant upgraded to an 1,100 Mw plant. Adjustments to these costs were made to obtain basic data for the above-ground coastal plant. These were developed by adjusting fuel, labor, material, and maintenance equipment costs.

The aboveground coastal and offshore plant cooling systems are based on use of a closed water loop to the ocean. The difference in elevation between the seawater intake line and aboveground coastal or near sea level offshore plants is small; and, therefore, the required pumps are sized for a relatively small static head. The underwater concepts can utilize differential intake and discharge elevations to reduce pump plant horsepower to a value less than the plants near sea level. However, the aboveground and underground plants which are conceived to be at elevations of about 150 feet above sea level, and which utilize once-through cooling, require a substantially larger pump plant to overcome the static head involved in raising ocean water to the turbine condenser box level. Larger pumps and pump house are assumed for these concepts.

While the size of the pumps does not increase proportionally with the increased horsepower, the operating costs for driving the pump

motor does, and alternative systems are worthy of consideration. The elevated water would have a potential energy available for conversion to pump power to reduce the net power otherwise required. There are a number of potential solutions. One might be to install turbines in discharge lines and couple them to the pump shafts, making provisions for variable speeds. Another solution might be to place a hydroelectric unit into the discharge system and to generate electric power to meet the pump demand. This system would supply a substantial part of the pump electric demand, but due to the loss in efficiency, additional power would be required from the power plant. It was not within the scope of this study to develop a detailed concept for this portion of the plants. However, cost estimates for elevated plants include the cost of a 30,000 hp hydroelectric unit in the discharge line at the pumphouse and the balance of electric power needed at the pump motors, are supplied at a cost of 8 mils/kw-hr.

Adjustments in costs for various siting concepts were made as a function of the differences in scope identified below. Cost breakdown summaries for each concept are presented in Appendix D, Tables D-1 through D-17.

The aboveground coastal plant would be located on undeveloped coastal property perhaps valued at \$5,000 per acre, with a minimum of 150 acres utilized. Also, a sea wall would be required to protect against potential plant inundation from tsunami or storm wave action.

The aboveground inland plant would be located on undeveloped or agricultural property perhaps valued at \$500 per acre, with a minimum of 400 acres used, including space for a large reservoir to hold cooling water supply during brief periods when the normal supply is down.

The aboveground hillside plant would be located inland perhaps as much as 1-1/2 miles and at grade elevations of up to 150 feet. As a consequence, no sea wall is required but the pump plant must be increased to provide greater horsepower for the added head and for line losses. Additionally, the plant will be situated in an area requiring extensive grading and drainage control for storm runoff. Access roads to the plant, the shore-based pumping plant, and the underground distribution lines to the pumping plant located at the shore tend to add capital and maintenance costs. Land in this somewhat remote area may be valued at about \$500 per acre, with about 200 acres required.

The aboveground, low profile plant would be located adjacent to the coastal road and could be situated on property valued at \$5,000 per

acre, with 200 acres required as a minimum. The plant is conceived as being sufficiently above sea level to not require a sea wall. However, the development of the low profile by a large amount of excavation will add capital and site maintenance costs. Also, operation and maintenance of an isolated cooling water pumping plant will increase costs.

The aboveground, floating platform mounted plant in a lagoon includes the cost of the canal from the shore to the plant. It includes costs for towing the plant from another distant location and mooring it in place. Since intake water is drawn from the canal, costs exclude an intake line to the plant; but because the plant may be inland as much as 1/2 mile, the outfall cost is increased. In the construction of the plant, credit is given to the savings in structure fabrication due to the shipyard approach being taken. However, the cost for installation of equipment and piping is increased to account for the greater difficulty in access into various levels of the plant than would be encountered in land-based, non-production line plant approaches. Land values for these types of sites are estimated to be \$5,000 per acre, with a total of about 200 acres required. Operating and maintenance costs would be slightly increased by the water-situated facility.

The underground plant in igneous rock would be located as much as 1-1/2 miles from the shore and perhaps at a base elevation of as much as 150 feet above sea level. The land would be relatively inexpensive because it would be hilly or mountainous and in an undeveloped area. A value of about \$500 per acre for 200 acres is estimated. Exploration costs are greater than for surface plants. A substantial increase in construction costs is contributed by excavation of the facilities. In particular, the large diameter intake and discharge lines over the assumed distance account for over half of all the required excavation. Some savings is achieved in concrete costs since concrete walls, when used, would generally be formed against the rock excavation. Even when the cost for rock bolts and mesh is added, the cost for structural walls in this concept does not exceed that for the aboveground structural system. Air conditioning and underground ventilation systems add capital costs to the facilities. In addition, costs are increased for installation of equipment below grade, since their transport and maneuverability underground would be more constrained than in aboveground installation. Additional costs are incurred for underground transmission lines extending from the underground switchyard to a terminal at the surface and from the termination onto an overhead transmission line structure assumed to be suitable in the remote area. Pumping plant costs are also increased to provide greater horsepower for pumping the water to the 150-foot elevation

and the distance from shore. Construction time is increased over above-ground plants by as much as 2 years; and, therefore, the interest on money during this period adds to the capital cost. Costs are increased by the maintenance of the added length of cooling water lines and the additional ventilation plant required when below ground. Operating costs are also increased by the added ventilation plant.

The cost of an underground installation in sedimentary rock is similar in many respects to that of the plant in igneous rock. Although exploration costs may be slightly higher, it is anticipated that a proven site will not contain weak or water-bearing strata, and that the rock is sufficiently strong to preclude the need for support. On that basis, excavation costs should be about the same as those for igneous rock, with some increased costs incurred for greater rock bolting and rock anchoring often necessary in media of this type.

An underground plant in unconsolidated materials at a beach location has about the same excavation volume as the other underground concepts assuming near vertical faces can be obtained for the excavation. The unit cost for excavation is much less, provided the ground is prepared for excavation. However, significant additional costs are incurred for ground freezing or other methods which will enable surface excavation techniques to be used. An increase in structural strength, required by the buildings located in a saturated soil condition, result in greater costs. Vertical transport systems, air conditioning and ventilation required underground, and the installation of equipment through vertical transport modes all contribute additional costs. Site values for property at low elevations are estimated at \$5,000 per acre, for a total of 200 acres. The construction period for this concept is about 9 years, due to ground preparation, and thus results in greater interest costs than the other concepts during construction. Maintenance and operating costs are increased over other underground concepts by the need for underground dewatering during plant operation.

The cut-and-cover underground plant located in poorly cemented materials is similar in many respects to the plant in unconsolidated beach materials. However, there is much less ground preparation cost and less expenditure for concrete for this dryer site. In this concept, costs are accrued for access tunnels instead of vertical transport systems. Using these tunnels for equipment installation results in installation costs that are similar to those for the underground rock site. Costs are incurred for maintaining the elevated fill, grading, and drainage systems in this concept. Also, the pumping station cost is increased similar to that for the other plants located at grade elevations about 150 feet above sea level and about 1-1/2 miles inland.

The underground plant located in a faulted medium incurs building costs similar to those for an aboveground coastal plant. Unlike the other rock concepts, the rock faces cannot be used as the outer wall form to provide cost savings. Further, additional costs are incurred for the greater volume of excavation than is required in the other rock concepts due to the rattle spaces required. Aside from increased foundation costs to provide bases for resisting potential ground displacements, the other costs are similar to the facilities in rock media.

The offshore floating plant in shallow water is a facility similar to the plant floating in a lagoon. There are some savings from the elimination of the channel and the shortening of the cooling water outfall line. However, a significant cost increase results from the breakwater which is assumed to be in 44 feet of water, and for the underwater power transmission line which is assumed to extend 1 mile to shore. Also, a transmission line terminal station would be required at the shore if the balance of transmission system is an overhead line. Operating and maintenance costs are increased over shore-based plants in a number of ways. Water transportation is required to transport people and supplies to the plant. A small docking and loading crew with minimal boat maintenance capability will be necessary at the plant. Some added handling equipment will be needed at the dock. Communications equipment and crew are included, as well as added maintenance of structure surfaces which are exposed to the saltwater environment.

The offshore plant floating in deep water has plant costs similar to the shallow water concept. The breakwater savings is significant, but the added hull cost and mooring system cost tend to offset some of these savings. Operating and maintenance costs are essentially the same as for the plant in shallow water.

The seabed concept includes a costly superstructure to the water surface and a costly watertight pressure hull. Vertical access, ventilation systems, vent shafts, and elevator systems add costs to the plant. Towing, lowering, and placement costs for this concept are higher than for the other offshore plants. Some savings accrue from shorter intake and outfall lines, but these are offset by additional expenses for increased pressure in the in-plant portions of the cooling water system, bottom preparation, anchoring on the bottom, a communications system, and a water transportation system. Operating and maintenance costs are similar to those for the floating plants, with potential increases in labor unit costs due to the environment and access, and some minor savings in the maintenance of structure surfaces.

Costs for the undersea concept build up from the underground plants located in rock. Substantial additional costs are incurred for extensive exploration costs needed to prove the suitability of geology in this offshore location. Costs are also increased to provide for initial grouting and sealing of jointed areas to insure against water seepage and inundation. The 7 miles of access tunnel also add cost and tend to offset savings from shorter intake and outfall lines. Mechanical ventilation costs are increased to provide for added ventilation ducts and booster fans in the access tunnels. Other increases accrue from the added difficulty in transporting plant equipment into the facility and the possible need to transload equipment onto special vehicles at the portal. Further, interest during construction is greatest in this concept since the construction schedule is longest. Operating and maintenance costs are increased to account for the added ventilation plant power and the crew to operate it.

The artificial island utilizes facilities similar to the aboveground coastal plant. However, costs are added for the large land fill required and its dewatering for construction of facilities. Breakwater protection is added on the seaward side. Similar to most of the other offshore plants, an underwater transmission line and a water transportation system, as well as docking facilities at the plant, are needed. Operating and maintenance costs are similar to the aboveground coastal plant, with addition of boat fuel and maintenance, and the associated crews.

An aboveground plant situated on a natural offshore island has facilities very similar to those of the typical aboveground coastal plant. Basic costs are increased to provide for the lost construction efficiency in having to transload and transport materials and manpower to the offshore location. Costs are added for docking facilities, helicopter landing pad, greater living quarters, and the 23-mile transmission lines to the mainland. Operating and maintenance costs are similar to the other offshore concepts.

The tuned sphere has greater capital costs associated with the structure than the plant floating in deep water, largely due to the uniqueness of the shape and size of the structure and superstructure. However, costs are not included for the potential research and development necessary to prove that the concept is viable. Maintenance costs are similar to those of the floating plant in shallow water.

Relative acceptability as a function of cost is determined on the basis of bus bar costs. In addition to construction costs, capital costs include 5 percent interest during construction. Expenditures during

construction are assumed to be made in accordance with the construction schedules shown in Tables D-18 through D-24 of Appendix D. Depending on concept, the construction period extends from 6 to 9 years. A fixed rate charge was applied to each cost to cover sinking fund, interest, taxes, insurance, and interim equipment replacement. Rates of 12, 15, and 18 percent per annum respectively were applied to determine if changes in fixed rate charge affect the ranking of concepts. The annual charge was combined with annual operating costs to determine bus bar costs. Estimated bus bar costs were computed on the basis of 1,100 Mw net electric output at 80 percent of available annual operating hours.

Tables D-25, D-26, and D-27 summarize the bus bar costs and establish the ranking of concepts for each of the fixed rate charges noted above. It can be seen that changes in fixed rate charge have little impact in changing the ranking of the concepts as a function of cost. The acceptability of each concept as a function of costs was determined as discussed in Appendix C. Recognizing that low cost is good, Table D-28 reflects the computed acceptability as a function of cost, using a fixed rate charge of 15 percent.

7.2.2 Environment Impact

7.2.2.1 Land Use. This subfactor is pertinent on the basis that concepts are less acceptable if they tend to inhibit the potential use of land or water in adjacent unrestricted zones from purposes for which the area might be well or uniquely suited. The alternative uses considered for the adjacent areas are listed below.

1. Agricultural.
2. Recreational.
3. Transportation Systems.
4. Industrial.
5. Commercial.
6. Residential.

The distance to the adjacent area is assumed to be 1 to 2 miles from the plant boundary or, in the case of an offshore plant, from the boundary of the shore-end transmission line terminal facilities. (In this way, offshore concepts having less shore use are credited with less

interference than onshore concepts.) If a particular use of the adjacent land is reasonable for the type of location at which the concept would be sited, then a portion of the weighted value of that use is assigned, depending on an estimate of the degree of preemption. Normalizing and computations of acceptability were performed as noted in Appendix C.

In Appendix D, Table D-29 indicates the weighted value, or relative significance, of the considerations and the quantified impacts for each concept. A low impact value results in higher acceptability.

The rationale for estimating concept impact is presented below.

7.2.2.1.1 Agricultural. The aboveground inland concept is assigned the highest impact due to its designated location closer to rural areas where agricultural activities are usually located; and, conversely, all offshore concepts are rated the lowest since they are several miles from the coast. Underground concepts in rugged terrain and the coastal, hillside, and low profile concepts have low impact since the rugged, hilly areas would most likely be unsuitable for farming. The floating lagoon and underground beach concepts are given a nominal impact since they are located in low, flat lands which might be suitable for some type of farming activities.

7.2.2.1.2 Recreational. The aboveground coastal concept was penalized most since it is located directly on the coastline which may be in prime recreational zones. The lowest impact values were assigned to five offshore concepts; natural island and undersea receiving the lowest and slightly higher values given to three deepwater concepts - floating deep, seabed, and tuned sphere. The natural island is considered too remote to be readily accessible to the public; however, it might preempt the use of a relatively small coastal zone due to substation requirements as would all the offshore concepts. Similarly, the undersea concept would have a minimal impact and only since the access tunnel emerges on the mainland. The deepwater offshore concepts have slightly higher impact than the island and undersea concepts due to the ocean area preempted. The offshore floating shallow and artificial island concepts have a still higher impact, since they occupy more surface area and would be closer to shore than the deepwater sites. The four underground concepts in rugged terrain and the aboveground low profile plant have a nominal rating due primarily to the coastal pump house, and due to the exclusion of relatively rugged land areas which might be utilized by backpackers, hikers, or horseback riders. The floating lagoon and underground unconsolidated concepts were penalized a little more since they are both assumed to be located

closer to a low level beach area that is likely to be more in demand for recreational uses than the other areas. In addition, the low lands in these last two concepts are characteristic of slough areas in California which are natural habitats of some wildlife and game. The aboveground inland concept is penalized a little less than average due to the rural classification of the area. The aboveground hillside plant is penalized slightly more than the underground coastal concepts which are in similar terrain since more acreage is involved.

7.2.2.1.3 Transportation Systems. All concepts were estimated to have the same impact value in preempting the use of adjacent zones for transportation systems. Offshore concepts were considered to be on an equivalent basis with the mainland plants since ocean shipping lanes would be used to transport personnel, fuel, equipment, supplies, and radwaste materials in the same way that highways will be used onshore.

7.2.2.1.4 Industrial. The four underground concepts in rugged terrain are estimated to have no applicability to this subfactor due to the fact that the terrain and remote locations would be unattractive to most industries. The aboveground coastal concept was penalized the most, although on a minimal basis, since it occupies ocean front property which might affect industries which are adjacent to the ocean in some areas. (These concepts were only slightly penalized since it was assumed that most industries would have a difficult time in securing ocean front property.) The aboveground inland concept also was only slightly penalized since it was assumed to be in a rural area. The aboveground hillside and low profile plants were penalized less than the coastal aboveground concept since they probably would be located further in from the beach in a hilly terrain not likely to be used for industrial applications. The floating lagoon and underground beach concepts also are assigned a small impact value since they are inland from the beach. All offshore concepts were penalized only slightly because of their limited use of coastal land where industry might locate.

7.2.2.1.5 Commerical and Residential. All the offshore concepts; the four rugged terrain, underground concepts; and the aboveground hillside and low profile plants were assigned the same low impact value, reflecting a minimal requirement for shoreline facilities (substation or pump house) where residential and commercial areas would most likely be located. The aboveground coastal concept was estimated to have the largest impact since it is located directly on ocean front property which is often developed for residential purposes. The floating lagoon and underground beach concepts were penalized slightly less than the coastal plant since they would be located further in from the beach. The aboveground inland concept is penalized less due to its location in an isolated rural area, not particularly used for developments of this type.

7.2.2.2 Land Restoration. As the plant nears the end of its useful life, it might receive major modification, or a newer type of power generation facility might be constructed on-site to replace or augment the existing system. However, in the event that the nuclear power plant must be decommissioned to make the site available for other uses, the effort required to completely dismantle the facility and restore the area to its original condition, within reason, would be quite extensive. Therefore, this subfactor assesses the relative significance of restoration required for each concept by judging the magnitude of effort involved, which diminishes in value when considered on a present worth basis. As part of this assessment, it is assumed that there will be no major nuclear accident or release of radioactive materials beyond the capability of the engineered safeguard systems.

Initially, radwaste materials, contaminated items, and salvageable equipment would be removed from all plants as part of the restoration scope of work. For aboveground plants, all surface structures would be razed both at the plant and coastal areas (e. g., pump houses, substations). Access roads and surface grading would remain as built. For underground plants, vents, elevator head houses, and any other surface structures would be removed, penetrations sealed, and reservoirs drained and back-filled. Underground cavities would not be filled. For offshore (and lagoon) floating plants, mooring lines would be removed and the facility would be towed to an existing salvage yard. For the seabed concept, structures would be razed down to the vessel deck. The breakwater in the offshore floating shallow concept and the artificial island would remain intact. All underwater items, such as the seabed plant, transmission, and cooling water lines would remain in place where they are sufficiently deep so as not to be hazardous, or retrieved if their salvage value warranted it.

The tasks described above are itemized as "considerations" in Table D-30 located in Appendix D. These are checked where appropriate for each concept. Weighted values are noted in the table, and the acceptability determined. Note that low impact results in higher acceptability.

The aboveground inland concept appears to require the most effort due to demolition of the cooling towers and was therefore assigned a weighted value of 1.0, simulating greatest cost penalty. The aboveground coastal, hillside, and low profile concepts were penalized slightly less with the artificial island and natural island plants somewhere between, due to the necessity of conducting offshore operations. The floating lagoon plant requires the least effort, and offshore floating shallow, deep, and tuned sphere concepts were estimated to require slightly

more effort since they would be more remote. The seabed concept was penalized more since a superstructure had to be removed in deep water. The four hilly underground concepts were penalized slightly above the average due to the number of tasks involved, and the underground plant in unconsolidated sediments was penalized slightly higher since there would be more surface structures to raze. The undersea concept was penalized a little less since there is only one surface structure (substation) to raze and only one tunnel to seal.

7.2.2.3 Visual Image. In many cases, facilities can be designed to blend in with the surrounding environment thereby lessening their prominence. In some extreme instances, however, no amount of architectural treatment can conceal the element. Examples include containment buildings and natural draft cooling towers located on flat terrain. Furthermore, aesthetic acceptability cannot be definitely established on the basis of general criteria. Firm, well defined ground rules cannot identify adequately the standards of the observer population. Therefore, rather than attempt to determine aesthetic acceptability values, the visual image of plant facilities as seen by an observer on a nearby heavily travelled highway was selected as a measure of merit. This approach has some relationship to aesthetic acceptability since facilities which are out of sight of the observer have no adverse aesthetic impact. Conversely, as more facilities of a concept are revealed to any given random observer population, the visual impact increases, and the more likely that the aesthetic acceptability value will be subject to criticism.

For purposes of this analysis, the projected visual image for all concepts was calculated in geometric proportion to the actual plant frontal area and the plant distance from the observer. These values and resultant acceptabilities are shown in Table D-31. It is to be noted that low impact results in higher acceptability.

By definition, the aboveground hillside and undersea concepts are located out of sight. Also, a coastal type plant on a natural island would not be visible from the mainland, approximately 23 miles away. These three concepts would have no visual impact and therefore were assigned a minimum value (less than any other calculated areas) and became most acceptable for this factor. The aboveground coastal concept is least acceptable since it was assumed to be viewed from a coastal highway as near as 800 feet away. Although the real profile area of the aboveground inland plant is the largest (due to the natural draft cooling towers), the nearest highway from its rural location was assumed as 2 miles, thereby considerably lowering the visual image area. The aboveground low profile and floating lagoon concepts were assumed to be partially

hidden by foothills within 1,000 feet of a highway. Surface ventilation structures for the four underground hilly concepts were assumed to be visible from a coastal highway at a distance of 7,000 feet; whereas surface vents and elevator head houses were assumed visible in the underground plant in unconsolidated sediments at a distance of 1,000 feet. The off-shore floating shallow and artificial island were assumed to be a minimum of 1 mile from the coastal highway, whereas the three remaining deepwater concepts were at a maximum of 3 miles offshore.

7.2.2.4 Physical Effects. During operation, the nature of the plant combined with the type of environment in which it normally would be located will most likely disturb some of the neighboring biological community. These impacts will vary for each concept and there are a number of considerations. As shown in Table D-32, it was possible to assign relative importance to each consideration and to evaluate acceptability of each siting concept as related to the group. Low impacts result in higher acceptability. The rationale follows.

7.2.2.4.1 Biota Intake. All concepts which take cooling water from the ocean will entrap fish and plant life in the lines and on the intake system screens. Also, smaller fish, larvae, and other organisms will pass through the screens and through the condenser with resultant destruction of some of these biota. As seen in Table D-32, the highest value was therefore assigned to eight of these shore intake concepts. The severity of this impact was reduced for two offshore plants, floating shallow and artificial island and the natural island concept, since water is generally deeper near the plant than the onshore concepts and biota per unit volume of water are assumed greater in shallow areas close to the mainland. A still smaller value was assigned to this effect for the four deepwater concepts. The floating lagoon plant is given the lowest impact rating of the coastal onshore concepts since it would draw water from the inland portion of a 1/2-mile canal, and it was assumed that canal traffic and additional protective screens would tend to reduce the intake of biota. The aboveground inland plant is indicated as having the least impact since only makeup water (about 2 percent of the total cooling water flow) is taken from the water source. Further, there probably would be less biota in a freshwater system than might be found in a seawater system.

7.2.2.4.2 Marine Life-Thermal Effects. Coastal plants which discharge heated water into the ocean will employ expensive outfall lines and diffuser systems to minimize adverse thermal impacts on the existing biological community. Values for all nine onshore/coastal concepts were therefore estimated to be low for this impact. Since marine life at

the coast is more adaptable to temperature changes than life further offshore in deeper waters, offshore shallow water concepts and deepwater concepts were assigned higher impact values. The natural island concept was penalized more than the coastal concept but less than the deepwater sites. The inland plant is evaluated as having the least impact.

7.2.2.4.3 Terrestrial Life - Thermal Effects. Plants which utilize cooling towers reject to the atmosphere, concentrating the heat in a relatively smaller area over the tower. By tower sizing, the impact of introducing large amounts of heated water vapor into the local terrestrial environment can be minimized. However, bird life in the area may be somewhat disturbed; and, therefore, the aboveground inland concept is penalized slightly for this effect whereas all other concepts were not.

7.2.2.4.4 Biological Interference by Plant Presence. The plant may interfere with the indigenous biological community merely by its presence. Remote land-based plants may disturb various types of wildlife in the area; and, therefore, four of the aboveground concepts were assigned average impact values. The floating lagoon concept impacts less due to its compactness. Underground plants were given a lesser penalty because, although the restricted zone is enclosed by fencing, there are relatively few surface penetrations (ventilation structures, elevator head houses) that would constitute interferences. The impact of the offshore floating deep and tuned sphere concept were considered to be minimal and were, therefore, rated lowest. The offshore floating shallow and artificial island concepts were penalized more since they are located in shallower water where the likelihood of impacting marine life is perhaps more than the deepwater plants. The impact of the natural island plant was also higher due to the possibility of more wildlife being affected on a confined island than at a mainland location. Due to introduction of the large seabed structure into the marine environment, this concept was considered to have maximum impact. However, realizing that some of the effects may be favorable, considering the possibility that certain species of fish may be attracted to subsurface structures, a number less than the maximum value was assigned. Since the only surface penetration in the undersea concept is a tunnel entrance, it was given minimal impact.

7.2.2.4.5 Rainout. As previously stated, cooling towers introduce large amounts of heat and water vapor into concentrated areas. The aboveground inland concept was therefore assigned a maximum impact value and all other concepts are not affected.

7.2.2.5 Construction Impact. During the construction period, the labor force and the materials and equipment required to construct the facilities will impact on the community in a number of ways. Table D-33

reflects the acceptability assessment, including the relative weights of each of the factors considered. Note that low impact results in higher acceptability. The rationale is presented below.

7.2.2.5.1 Traffic. The large construction force (peak about 1,500) will be interfering with the adjacent highway traffic on a multishift basis. In addition to nuisance, there will be a potential hazard when vehicles move on and off the highway that provides access to the plant site. The underground plant at an unconsolidated sediment (beach) site was assigned the highest impact due to the extensive excavation requirements and contemplated operations attendant with the excavation technique. Most of the other coastal aboveground and underground concepts and the undersea concept were rated as having slightly less impact. The above-ground inland plant has less impact since it is assumed to be in reasonable proximity to a heavily travelled highway. The floating lagoon plant impact was less since only the canal and mooring facilities are constructed locally. Except for the undersea concept, offshore concepts have low impacts since onshore highway traffic would only be affected by support and logistic activities at the coastline for substation construction. In addition, the nearest existing port facilities would most likely be utilized for the bulk of the traffic and major pieces of equipment, thereby minimizing the impact on the coast highway.

7.2.2.5.2 Aesthetics. With the exception of the aboveground hillside concept which is concealed from the highway, construction activities at the plant site will be visible from the coastal highway for several years. As discussed previously under the visual image subfactor, the aesthetic acceptability value can be related to plant visibility from a nearby highway. Using the same approach during construction, the underground beach concept was assigned the greatest impact value for the same reason described above for traffic. The impact of the aboveground coastal concept was rated next since it would have slightly less excavation. The aboveground low profile plant has somewhat less impact since it is partly hidden from view, and the inland concept because the towers will be visible miles from a highway, and the floating lagoon was given a lower value since most of the impact results from the canal. The remaining four underground concepts were assigned medium impacts since most of the activities are hidden from view in underground caverns. In the case of offshore concepts which require minimal coastline activity, the artificial island concept is rated low and as having slightly more impact than the floating shallow concept since the former involves construction of a total facility and the latter mostly requires breakwater construction. The two offshore floating deep plants and the seabed concepts have less impact since only coastal operations are involved until the plants are towed in place, moored, and transmission lines connected. Since the undersea and natural island plants are out of sight from the coast highway, they, therefore, have the least impact.

7.2.2.5.3 Noise. This consideration is pertinent to the extent that any nearby communities, recreation areas, or highways might be within earshot of construction operations. The underground beach concept was given the most severe rating due to the nature of excavation and construction required and the close proximity to the coastal road. The aboveground coastal and low profile concepts were rated less since the operations are less complex. The inland plant also has a nominal penalty since it is several miles from the main highway but perhaps close enough to rural communities to cause some interference. The floating lagoon has less impact since construction of the canal is the major local effort. The hillside plant has less impact due to its secluded location away from the coast highway in the hills. The remaining four underground concepts were rated a minimal value due to their remote location and the fact that most of the construction activities will be underground. All seven offshore concepts have the least impact.

7.2.2.5.4 Labor Force Support. Concepts which might be located near small communities because of the remote nature of the siting environment will have much greater impact on whatever communities may exist during the construction period than those concepts located near larger communities. For example, where the environment is remote, as could be the case for some underground plant sites, it may not be feasible for the construction work force to commute to their normal residence, and it is likely that the nearby communities will be called on to support that work force. Offshore concepts which would not require the larger level of construction force, or where the work force would normally be transported to docks located close to larger communities, would have much less impact and would be more acceptable. For purposes of this analysis, it was necessary to characterize typical locations for some concepts along the California coast. For example, locating the four rugged terrain underground plants, the aboveground hillside plant, and the undersea plant on (or just off) the hilly central coastal range, resulted in high applicability values of 0.8; i. e., they would most likely rely on smaller communities for support during the construction period. The aboveground coastal and low profile plants were penalized less since they were assumed to be a little closer to larger communities, which tend toward lowlands. The aboveground inland plant was penalized about the same since it may rely on some smaller adjacent communities for support. The underground beach and floating lagoon concepts were assumed to be in close proximity to San Diego and were therefore penalized still less since a local labor supply would be available. The six remaining offshore concepts were penalized least because of the minimum impact resulting from minimum on-site construction.

7.2.2.5.5 Impact on Biota. During construction, activities in the area often will be much greater than during the operational period. The

habitat of the biota will be disturbed more on the natural island since it would most likely be closer to a naturally confined wilderness than coastal or inland sites and is therefore penalized most. All five aboveground concepts have slightly less impact. The underground beach concept is in an area similar to the floating lagoon plant and is given a similar impact. The four remaining underground concepts impact less since most of the construction activities will be in the caverns. The offshore concepts impose much less disturbance for a period than onshore plants. Therefore, the floating shallow and artificial island concepts are assigned less impact and the three deepwater concepts are assigned a minimal value. The undersea concept is considered to have almost no impact on the biota.

7.2.2.6 Multiple Uses of Heat and Plant. The practicality of multiple uses of reject heat from a nuclear power plant is dependent not only on the demand for these uses but also on the resultant impact on plant efficiency, i. e., conversion of thermal energy into electricity. Suggestions have been made to utilize "reject heat" in desalination, sewage treatment, or central heating applications. However, the discharge cooling water temperature is normally less than 90°F and is therefore of little value to these processes which require considerably higher temperatures. Furthermore, if the cooling water temperature is raised to useful levels, perhaps by decreasing flow, then the turbines will be subjected to greater back pressures which would result in a proportional loss in power plant efficiency. This is a penalty for providing the higher water temperature. Additional heat would have to be made available from the steam cycle and thereby directly increase electrical production costs attributable to the added process. An exception to this may be the HTGR using a gas turbine with plant system discharge temperatures over a range approaching 340°F. This possibility for a combined power and desalination plant is discussed by Sager and Krase.*

Other potential applications for low level reject heat that have been cited include aquaculture (the value of this has been questioned by some biologists), water sport activities, and irrigation if freshwater cooling systems are involved.

A potential application of the plant facilities is use as a shelter from attack and fallout, although its value is dependent on reasonable proximity to population and the hazard one associates with the possibility of a strike on the facility.

*Sager, P. H., and J. M. Krase, "Combined Nuclear Gas Turbine Power and Desalination Plant," June 20, 1972, Gulf-GA-A12142, Proceedings of 7th Intersociety Energy Conversion Engineering Conference, San Diego, California, September 25-29, 1972.

Since these potential applications have been discussed in the literature, their value was measured for the various siting concepts, recognizing the limitations described above. The relative value of each consideration and the evaluation for acceptability is presented in Table D-34 in Appendix D. The rationale for the evaluation is given below, noting that in this case large impacts result in higher acceptability.

7.2.2.6.1 Aquaculture. The aboveground coastal, low profile, floating lagoon, underground beach, and natural island concepts all were evaluated based on a location in Southern California where the warmer waters are compatible with a wide variety of marine life and proximity to the ocean environment normally might be expected. These concepts were assigned a maximum value. The aboveground hillside and four underground plants were rated less since they were assumed to be located on the hilly central California Coastal Range which has colder, rougher water conditions, but which still may be adaptable to some marine species. The six remaining offshore concepts were given no credit since it was considered highly unlikely that costly platforms would be provided to carry on this activity in these isolated locations. The aboveground inland concept was also rated low because of its distance from the ocean.

7.2.2.6.2 Water Sports. The floating lagoon and aboveground inland concepts were the only two considered applicable since they each normally incorporate a large body of enclosed water. The lagoon concept was assigned a maximum value since more applications are possible than for the inland concept which is rated slightly less (See Section 7.2.2.7.) All other concepts were given no value.

7.2.2.6.3 Irrigation. The aboveground inland plant is the only concept which is applicable since it uses freshwater as coolant. Since the value of this water will be dependent upon the quality and quantity discharged, and also the availability of other sources adjacent to the plant, a value less than maximum was assigned to this concept. All other concepts were assigned a minimum value.

7.2.2.6.4 Population Shelter. The five underground plants and the undersea facility are the only concepts that might be reasonably considered for emergency shelters. A maximum was therefore assigned to these, and all other concepts were given no credit.

7.2.2.7 Multiple Uses of Site Property. The coastal and inland plants are located in areas which might also be considered for various other uses. Recreational activities perhaps constitute the greatest number by virtue of their relatively low cost to the general public. Furthermore, in some

cases, facilities could be provided during construction in unrestricted zones adjacent to the plant at relatively little additional cost to improve the natural environment and facilitate access from the nearby highway. Seven recreational activities were considered, and their impacts are described below. Table D-35 reflects their relative weighted values and assessments of acceptability. High impacts have greater acceptability. The activity weights are in proportion to values presented in the California cost/benefit procedure indicating recreational activity values. The offshore concepts were given a minimum value for all activities (except water skiing which received no credit) since the primary plant is miles away from the coastline and a relatively small amount of coastline is involved near the shore substation. Rationale follows.

7.2.2.7.1 Bathing. The inland plant was assigned a maximum impact of 1.0 because of a large reservoir constructed on-site for the storage of standby and emergency cooling water supply. Similarly, the floating lagoon has a high impact because of the suitability of developing swimming areas off the canal in addition to areas at the beach. The aboveground coastal and low profile concepts and the underground beach facility have slightly less impact since they are not actually creating any new areas but would perhaps facilitate access to the beach either next to the plant or at a coastal pump house. The aboveground hillside and four other underground concepts were assumed to be in the hilly zones and were therefore assigned a lower impact since the beach next to a coastal pump house in this area is less attractive to the general public.

7.2.2.7.2 Picnicking. The aboveground inland and floating lagoon concepts were assigned a maximum impact since picnic areas are particularly suitable next to the reservoir and along the canal respectively. Following the same reasoning described above under bathing, a slightly less impact was assigned to the aboveground coastal and low profile plants and the underground plant at an unconsolidated sediment site near the beach. Still less value is placed on the aboveground hillside and four other underground concepts.

7.2.2.7.3 Camping. The aboveground inland and floating lagoon concepts were assigned a maximum value since camping facilities adjacent to the reservoir and canal are very suitable. All other concepts were valued less since they do not create new attractions but merely improve the accessibility for providing camping facilities.

7.2.2.7.4 Fishing. The aboveground inland and floating lagoon concepts were again assigned a maximum value since this activity is particularly suitable to the reservoir and canal. Following the same reasoning described for bathing, lesser values were assigned to the aboveground coastal and low

profile plants and the underground beach concept. The aboveground hillside and four other underground concepts were valued as having the least impact on encouraging fishing activities.

7.2.2.7.5 Boating. The aboveground inland and floating lagoon concepts were assigned a maximum value since this activity again is most suitable to the reservoir and canal. Installation of equivalent boating facilities on the coast (beyond an access road and ramp) would require a relatively larger level of effort during construction for all other concepts. Therefore, the impact values were downrated for the aboveground coastal and low profile and for the underground beach concepts, and still less for the aboveground hillside and four other underground plants.

7.2.2.7.6 Enjoyment and Use of Wildlife. Provision of access back into rugged central coastal areas typified by the terrain around the aboveground hillside and four underground plants in hilly terrain is the basis for assigning a high impact value to these five concepts. Similarly, the floating lagoon and underground beach concepts were assigned a high impact because slough areas, which are natural habitats of some wildlife and game, are typically found at low elevations. The remaining three concepts, aboveground coastal, inland, and low profile plants were valued less since less wildlife was assumed to be indigenous to these areas.

7.2.2.7.7 Water Skiing. This activity is most suitable to specific areas developed off the canal required for the floating lagoon facility. Therefore, this concept was assigned the highest impact value. With regard to the inland plant, the size of the reservoir and frequency of alternate uses would determine whether an area can be set aside for water skiing. Therefore, a lesser value was assigned to indicate its potential suitability and also to recognize that this activity might be subject to limitations in this concept. Provision of coastal facilities to make all other concepts suitable for this activity would involve a relatively larger level of effort during construction; therefore, these concepts have little value.

7.2.3 Feasibility

Two subfactors contribute to the significance of feasibility. The first consideration is the availability of technology today as required by any of the concepts. This might be evidenced by similar nuclear power plants or other type facilities that exist or are in design, construction, or development stages. Those concepts requiring the most research and development effort to be feasible by 1990 are considered to be least feasible and ultimately have the lowest acceptability. The second consideration is that for concepts to be feasible there must be a sufficient quantity of potentially suitable sites.

7.2.3.1 Technology. An evaluation of the state of the art in technology can be applied to four main elements of the plant. They are plant structure, production system, transmission system, and the method of construction. The weighted value of each consideration is shown in Table D-36. Some of the technologies are within the present state of the art as evidenced by the existence of similar plants or systems, plants under construction or in various lesser stages of development. Therefore, in assessing feasibility reflected in Table D-36, maximum value is given if the element presently exists and functions. Lesser values are assigned in descending order if they are not beyond construction or design phases, conceptual design or development stages, or the research phase. Recognition is given to increased feasibility when similar elements exist in other applications. Therefore, high values reflect greatest acceptability.

7.2.3.1.1 Structure. The aboveground plants on land and on a natural island were all rated high because of the existence of other plants with similar structure requirements. The plant located on an artificial island is similarly feasible, but there are some special foundation design considerations when located in the island fill. The Bolsa Island project was in the design stage when cancelled and is justification for the relatively high value for this concept. Also, the floating platform concepts are currently in the design stage, with similar facilities previously designed and constructed for other applications justifying its high value.

The underground concepts excavated in rock onshore and undersea are given lower ratings because, although a number of underground facilities exist with roof spans of over 80 feet and heights similar to those required here, spans of 130 to 145 feet currently are unprecedented for permanent facilities. Also, there may be some question about the ability to seal off severe water intrusions; however, vehicular tunnels have been built successfully in similar environments. The underground facility in poorly cemented materials is similar to facilities which have been designed as cut and cover concepts for underground installations but not to this magnitude. However, the design for this condition does not appear to present unsolvable problems.

The offshore floating plant in deep water is not unique in hull concept since the shape, size, and capacity are compatible with existing hull designs. The required mooring system is not particularly unique; similar ones are in use to moor oil tankers. Considering the hull constructed of concrete, the feasibility is reduced since concrete vessels of this size have been proposed but have no record of successful utilization.

The underground concept at the beach and/or saturated soils extends to some degree the state of the art for large facilities 200 feet or more in depth in a saturated media with maximum assurance of constructability and watertightness for long term use. Therefore, it has been assigned less feasibility.

The seabed concept and tuned sphere incorporate large concrete vessels which do not exist today in applications of these magnitudes and shapes. They therefore have been assigned the least feasibility.

7.2.3.1.2 Production System. The nuclear steam supply and electrical energy conversion systems will be basically the same for all concepts; any differences will be due to constraints encountered in areas such as packaging, platform motion, and isolation requirements. Therefore, the land-based plants are judged to be the most feasible; and the other concepts which reflect a need to modify existing designs of the systems so that they would be responsive to motions have been assigned slightly lower values.

7.2.3.1.3 Transmission System. Four aboveground concepts utilize existing applications of transmission lines at the plant and were therefore assigned maximum feasibility. The underground and undersea concepts will utilize underground or enclosed type transmission lines at the plant and in the tunnels. Additional development for large capacity lines of this type is underway, except faulted rock conditions are not being considered. Since indications are that the systems will be available when required, slightly lower values were assigned to these concepts. Also, offshore plants located within a few miles from shore are given a slightly lower value since lower capacity, underwater high voltage lines are now operative and a number of these circuits can make up the needed capacity today. The natural island transmission line is rated as less feasible because there is no precedence for submarine lines 23 miles long for long term use and this could present a design problem. Also, the transmission line required for the faulted concept may have unique design problems associated with umbilical flexibility needed for potential displacements.

7.2.3.1.4 Construction Method. The aboveground land-based plants received the maximum feasibility ratings since similar plants have been built. Floating platforms of smaller size in structural steel have been built in shipyards in the past and many vessels have been towed to other locations. The floating lagoon, floating shallow, and floating deep concepts have been rated slightly lower because of the tow requirements, reflecting some concern of feasibility in tow.

The underground and undersea concepts in rock or poorly cemented materials represent construction which has been accomplished previously in many respects. The magnitude of the project warrants the slightly lower value of feasibility. The same is true of the artificial island concept where the land fill in open water, which is perhaps 40 feet deep, represents a major earthwork task.

The underground concept in unconsolidated, saturated materials at a beach site will present a formidable task in the preparation for excavation. If ground freeze techniques are used, they are unprecedented in projects of this size. Furthermore, other methods relying on dewatering may not be entirely feasible. However, some feasibility is recognized since these techniques have been successfully utilized in smaller projects.

The seabed concept is rated lower in feasibility because it presents uniqueness in shipyard construction techniques for the large, concrete vessel. Also, the tow, the lowering process, and the task for bottom preparation present questions of feasibility. Similarly, the tuned sphere requires unprecedented concrete construction. Further, towing would be unique because of the size and mass distribution of the vessel. Therefore, these two concepts have been rated the lowest.

7.2.3.2 Potential Sites. There are a number of constraints in seeking potential sites for each of the concepts studied. In some cases, the environmental characteristic acts as a constraint unique to the siting concept. Geology is an example of this in the underground concepts. In other cases, the environmental characteristic, by regulation, may be a constraint on all concepts. For example, proximity to population centers of 25,000 or more is at the present time a constraint in site acceptability for all concepts. The Atomic Energy Commission has not yet licensed a plant where that distance is less than about 5 miles. Still, other environmental characteristics affect the acceptability of a site, but in many cases, precautions taken in the design may be all that is necessary to minimize or eliminate the impact of the plant on the environment. Certainly, in some cases, potential sites identified in this study might prove to be unacceptable when a detailed site investigation is performed.

In assessing feasibility of a concept, it is necessary to consider the extent to which sites conducive to the concept can be identified. The greater the number of potential sites, the greater the potential use of the concept and, therefore, the greater the feasibility. The availability of suitable environments is not included in this evaluation since that will be dependent on ownership, interventions, time, and many other factors. However, a reasonable measure of merit is the mileage of suitable coastline which might be made available for each concept.

In some cases, there are many more miles of suitable site characteristics than needed to meet planning requirements. There are upper limits of availability beyond which added coastal mileage does not proportionately increase the feasibility and, therefore, some other modifying expression is needed. Assuming that twenty-five sites might be required by 1990, with each site requiring as much as 2 miles of coastline (for six 1,100 Mw(e) units), concept feasibility should diminish very rapidly if less than 100 miles of coastal environment acceptable to the concept is identified. Figure D-1 in Appendix D presents a reasonable approach to weighting the value of existing coastal miles and was used to convert mileage for this factor. The values were then used in developing Table D-37 where higher values lead to greater acceptability.

The approach taken in assessing the miles of potentially suitable sites that may be available was to constrain each site on the following basis:

1. No closer than 5 miles to centers of 25,000 population.
2. No site in zones of known active faults (except for the underground concept defined in this medium).
3. Offshore geology parallels onshore characteristics.
4. Present land use as National or State forests, or as other government owned and used land, does not preclude the potential availability of land.

Additional constraints were then placed on each site to determine the linear miles of potentially suitable sites for each concept. The locations of the sites were presented on Plate 3-8.

The aboveground coastal plant site would be at low elevations and may be situated on a coastal plain or beach, or on a low terrace adjacent to the ocean. With these characteristics, condenser cooling water pumping facilities are minimized, as are friction losses resulting from longer intake lines to the condensers. There are a total of about 144 miles of these sites.

The aboveground inland plant would be located on a plain and may be in a high or low desert environment. Cooling water in large quantities will be necessary for the wet cooling tower system. The required quantities might be made available in a number of ways. Development of new conveyance systems from areas of water resources are possible or water rights might be reallocated to areas where power

plants might be located at considerably less cost for conveyance. The availability of inland sites assumes that such water can be provided to these plant sites at some cost and thus eliminate water availability as a siting constraint. To compare the linear miles of coastal sites with inland areas, it was necessary to convert the inland area for this concept to equivalent coastal miles. This was accomplished by dividing the gross characteristic inland area by 1-1/2 miles which is the assumed coastal zone width. This resulted in having about 20,000 equivalent coastal miles available for the inland concept.

The aboveground hillside plant site would be situated at base elevations varying up to perhaps a 200-foot elevation but surrounded by hills having elevations at least 250 to 300 feet higher so that the plant is hidden from view at a coastal highway. There are about 408 coastal miles of this environment.

The aboveground low profile plant would be situated on the side of the coastal road with elevations lower than the road. There are about 119 coastal miles of these characteristic sites.

The floating plant in a lagoon requires a site with very low elevation to minimize the excavation required to develop a sea level canal or inlet. The identification of sites was based on having sufficient distance from the shore to allow consideration of a marina development or construction of a coastal road on the shore side of the plant. There are about 115 coastal miles of these sites.

The underground plant in massive igneous rock would be in a site characterized by the required geology and also in hilly terrain suitable for lateral access to the plant. There are only about 6 miles of coastline having the defined characteristics.

The underground plant in massive sedimentary rock would also be in a site characterized by the required geology and hilly terrain to permit tunnel access to the facility in lieu of shaft access. There are about 96 coastal miles of these sites.

The underground plant in unconsolidated materials would be at a beach location. Coastal sites having these characteristics and meeting the constraints initially identified in this section constitute about 69 miles of coastline.

The underground plant located in nonmassive or poorly cemented materials would be sited in hilly terrain conducive to cut and fill operations. However, these locations need not completely hide the

plant from the coastal road. There are about 265 miles of coastline having the appropriate characteristics.

Sites potentially suitable for underground plants located in massive rock formations, but where they are likely to be subjected to small ground displacements, are difficult to identify without a great deal of investigation and study. However, such sites would be less in number than those which are located in the zones generally identified as having major seismic intensity and faults. The quantity of coastal sites for this concept would not exceed 29 miles.

The offshore floating platform mounted plant requires sites with water depths at least 40 feet. As depths increase, the breakwater cost rises sharply and, therefore, depths much greater than 40 feet are not particularly desirable. The same logic applies to the artificial island concept. The ocean bed drops off rapidly in almost all of the coastal locations. Sites in the range of 40 to 60 feet of water depth at 2-1/2 to 3 miles from the shore amount to only 7 miles of the coastline. If constrained to greater distances from the shore, additional sites are virtually nonexistent. If not constrained by a minimum offshore distance of 3 miles and considering sites about 1 mile from the shore, there are about 580 miles of coastal waters with the appropriate depth. This latter value is used in the evaluations.

The locations for offshore floating deep plants increase in number as a minimum water depth is no longer a constraint. Elimination of zones adjacent to populated areas or shallow water locations still provides a potential of 855 miles of coastal sites. This amount would be appropriate to both the floating deep and tuned sphere concepts.

The offshore seabed concept would be located in 250 to 300 feet of water within the 3-mile limit. Greater depths are available, but that would result in greater costs for the facility than estimated in this study. There are about 135 miles of coastline with these depths offshore 3 miles.

The undersea concept would be located in massive rock formations offshore. It is desirable to locate the facility within the 3-mile limit. The access tunnel should be of sufficient length to permit a gradient suitable for vehicular traffic into the facility, possibly on rail, and therefore might have to be as long as 6 or 7 miles. However, this length can be provided by aligning the tunnel parallel or askew with the shore before turning to a position 3 miles offshore. Assuming that offshore geology at the 3-mile distance is similar to adjacent shore conditions, the suitable coastal zone would not exceed the sum of massive igneous and sedimentary rock locations, or about 102 miles. Greater accuracy in the availability of suitable geology offshore is beyond the scope of this project.

The interest in locating at an offshore natural island would be to retain an aboveground coastal plant concept away from mainland inhabitants. Therefore, site characteristics at the island would be similar to a beach or low terrace site of the aboveground coastal plant. Ignoring the seismic constraints which likely exist in the Channel Islands, there are only about 2 miles of low terrace available, and they are on Santa Cruz Island.

7.2.4 Risk

In assessing the merits of any proposed nuclear power plant, a plant site, or a siting concept, it is apparent that a great deal of attention is given to determining the design basis of the project; that is, establishing assumed wind loadings, storm conditions, wave heights, earthquake motions, and many other conditions. The design considers all credible conditions to assure that the plant will operate safely in its environment. In some cases the safety in question may be nuclear related and in some cases it may be safety of facilities, equipment, and people from nonnuclear hazards. Most natural or man-caused events which jeopardize nuclear safety are the same events which result in nonnuclear hazards.

Plants licensed today are designed to operate safely under all natural and manmade events which might reasonably occur in the life of the plant. Such events are criteria for the operating basis of design. Other events which are judged to occur much less frequently, but still constituting credible events, form the criteria for the safe shutdown basis of design. Under this latter criteria the nuclear and safety components are to be capable of safely shutting down the plant during the occurrence of the event. These plant components are defined by the AEC as Category I systems. It is envisioned that during these events portions other than Category I systems might be damaged and, if so, that would not jeopardize safe shutdown of the plant. Finally, other events have such a low probability of occurrence that they are not considered in the design of the plant.

Design and construction of nuclear power plant facilities are accomplished with the intent of incorporating into the plant the strength and safeguard systems to satisfactorily resist the hazardous events. Many elements of the completed plant serve to attenuate or eliminate adverse effects. The design bases to meet the AEC licensing requirements for the safe shutdown of a nuclear reactor are site dependent and can be determined only after a detailed site investigation has been made.

One method of measuring inherent vulnerability of various concepts might be to identify the cost of providing and maintaining safety related features or increased material strength which protect against natural phenomena or predictable hazardous events. However, most often it is not possible to isolate the cost of the features and strengths designed into the facility to a specific event, particularly when a system serves more than one type of event. Therefore, another approach is necessary for this evaluation of the relative acceptability of siting concepts.

Risk can be defined as the product of the penalty or damage resulting from the occurrence of an event and the frequency in occurrence of the event. Thus, if an infrequent event occurs and results in severe damage, less risk may be present than from an event which causes less damage on a more frequent basis.

The assessment of risk for the various siting concepts consists of:

1. Identification of the major natural and man-made events which present a hazard to the operation of a nuclear power plant.
2. Assignment of an occurrence frequency factor for each event.
3. Assessment of the damage and potential repair or replacement cost resulting from each event occurring for each siting concept.
4. Determination of risk for each siting concept by summing the products of damage and frequency for all events acting on the concept.

7.2.4.1 Events. The natural and man-made events which might have different consequences, depending on the siting concept, and which were considered for the risk assessment of concepts are:

1. Severe storms and floods.
2. Great earthquakes.
3. Major landslides.

4. Tsunamis, severe tides, and wave action.
5. Collision of large ships with the site facilities or other transport accidents.
6. Missiles such as aircraft and rockets accidentally striking the site.*
7. Missiles carrying warheads (excluding nuclear) targeted for the plant site.*
8. Sabotage by foreign agents or deranged citizens.*
9. Major fires not caused by other events considered.
10. Accidents occurring during transport of spent fuel or radioactive waste outside the plant.

In all cases, the events considered were assumed to be of greater severity and less frequently occurring than those used as the operational design basis for the plant. In no case is it assumed that the safe shutdown design basis is exceeded.

7.2.4.2 Frequency. Data related to the frequency of occurrence of natural and man-made events of concern to the safety of nuclear power plants are at best difficult to develop. Furthermore, existing data are of uncertain meaning in regard to the siting situations considered in this evaluation. Nevertheless, since the frequency of occurrence is a major factor in the assessment of risk, an attempt was made to develop a reasonable order-of-magnitude frequency value for each of the events considered. It is recognized that the frequency of any event will vary from one specific site to another. Except for siting situations in which the event is not applicable, no attempt was made to take specific sites into consideration; the frequency of occurrence of each of the events considered in this evaluation are general and apply only to large regions where concepts might apply.

Due to the cost of site investigation and the cost of complying with AEC design requirements for the safe shutdown of nuclear plants, areas that have a high probability of hazardous events occurring are expected to be eliminated by the site selection process and AEC siting

*Precaution for acts of war are not a design requirement for AEC license.

requirements. Thus the frequencies used in this study are high for specific sites and are at best only applicable for a gross assessment of siting concepts.

California experiences a tornado on the average of about one per year. The approximate average frequency for any specific 100 acre site can be obtained by dividing the occurrence rate by the ratio of 100 acres to the total area of the State (150,000 square miles) or about 10^{-6} . If severe floods are assumed to occur much more frequently, say at about 10^{-4} , the frequency for both events occurring is 10^{-4} events per year for a given facility area. This is probably high for the severity of storms and floods assumed.

The selection of the design basis earthquake for safe shutdown is based on ground motion intensities attributable from the most credible earthquakes, considering all recorded history as well as in-depth geologic and seismologic investigations of faulting, tectonic structure and other features. Operating basis earthquakes are usually selected as being the largest which can be expected over a period which is 1 to 3 times the life of the plant, or say 50-100 years. AEC criteria* requires that the operating basis earthquake be at least one-half the intensity of the safe shutdown earthquake. Housner** notes that in very general terms this can be approximated to an increase in Richter magnitude of 1.0 such that the intensity of a 6.0 magnitude is twice that of a 5.0 magnitude earthquake. Allen, et al *** present earthquake curves relating change in magnitude with change in recurrence of earthquakes, and indicates that an increase in magnitude of 1.0 roughly corresponds to a ten-fold decrease in recurrence rate. Accordingly, the references indicate that if the recurrence rate of an operating basis earthquake is say 100 years, then the recurrence rate of a safe shutdown earthquake (twice the intensity of the operating basis earthquake) is about 1,000 years, or 10^{-3} . That value is used in this study as the frequency of earthquake forces required to produce the damage estimated.

*10CFR100 Appendix A.

**Housner, G. W., "Strong Ground Motion (Chapter 4), Design Spectrum (Chapter 5)," Earthquake Engineering (R. L. Weigel, Ed.), Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1970.

***Allen, C. R., P. St. Armand, C. F. Richter, and J. M. Nordquist, "Relationship Between Seismicity and Geologic Structures in the Southern California Region," Bulletin of the Seismological Society of America, Vol. 55, No. 4, August, 1965.

The major cause of landslides is excessive groundwater resulting from severe rainstorms; additional landslides may be initiated by earthquakes. It can be assumed that sites which are susceptible to landslides are avoided. Sites having topography which suggest the possibility for slides, but for which no history of slides is indicated, can be designed to avoid adverse drainage which might contribute to slide tendencies. Eliminating all adverse conditions relative to potential slides, including a magnitude of storm sufficient to cause a slide, a frequency of occurrence of 10^{-4} is assumed.

The occurrence and magnitude of severe waves and tides on the California coast varies considerably with the specific location, with excessive waves (over 40 feet) much more likely to occur at northerly latitudes such as at Monterey or at exposed locations like Santa Cruz Island than at Point Mugu, Bolsa, or San Onofre. Based on data and extrapolations presented by Okrent,* a frequency of 10^{-5} appears reasonable for the occurrence of waves exceeding the operating design basis wave (frequency 10^{-2}) by more than, say, 30 percent.

It has been reported* that the probability of collision of a large vessel with a floating nuclear power plant off the California coast may be as large as 10^{-3} per year.

Otway** gives a value of 4.3×10^{-8} as the frequency per person per year of an individual on the ground being killed by a falling aircraft. This represents the probability of a falling plane striking a given site and the probability that a person is at the site. Since the probability of a reactor being at the site is much less than that of a person, a frequency of 8×10^{-8} appears to be a high value and makes adequate allowance for all other types of accidental missiles.

If it is assumed that a targeted missile carries a nuclear warhead, it implies a nuclear war is in progress. In this event, the hazard from the nuclear warheads is much greater than that from a nuclear power plant being struck by a warhead. Therefore, this situation is not relevant to an assessment of relative risk of siting concepts. Chemical explosives are assumed in the assessment of targeted missiles. The frequency of a targeted missile or barrage of targeted missiles striking a nuclear power plant is the product of the probability of being at war in which the United States is under attack, the probability of the defense

*Okrent, D., et al, "Offshore Siting Study," University of California, Los Angeles, Unpublished, 1972.

**Otway, H. J., "The Application of Risk Allocation to Reactor Siting and Design," University of California, Los Alamos, New Mexico, June, 1970, LA-4316.

system allowing a missile to penetrate, and the probability that the missile is targeted for a nuclear power plant in California. No data are available for these complex interdependent probabilities, but it seems that the product would be quite low. A frequency of 10^{-6} was assumed for this evaluation.

A well planned and executed act of sabotage, excluding targeted missiles, could have serious consequences if the emergency core cooling supply for a light water reactor were destroyed simultaneously with all other methods of core cooling. The probability of an act of sabotage being attempted, the attempt made at a particular plant, and the success of the sabotage effort of a major magnitude during peacetime appears remote. Since access would be more difficult than from the air, a frequency of 10^{-7} per year is assumed since no data are available for this event.

Fires resulting from other events considered are accounted for in the estimate of damage for the event. The frequency of fires, beyond the capability of the fire protection system to extinguish, starting internally or resulting from fuel truck or vessel fires in the vicinity is assumed to be of the order of 10^{-6} per year.

A recent analysis* gives a spent fuel transport accident rate of 0.03 accidents per year resulting in some radioactive release in California by 1990 when forty 1,000 Mw(e) nuclear plants are projected in that study to be in use. This is equivalent to a transport accident frequency of 7.5×10^{-4} per year per plant. This value is used as the frequency for all transportation accidents which might release radioactivity, including transport of radioactive waste.

7.2.4.3 Seismic Considerations. In California, the assurance of nuclear safety incorporates an assurance against major consequences resulting from seismic ground motions. It is particularly significant, therefore, to discuss the seismic events and the expectation of effects on the siting concepts. Seismic considerations include:

1. Ground shaking.
2. Landslides.
3. Liquefaction and loose soils.
4. Faulting and ground rupture.
5. Tectonic uplift or subsidence.

*Yadigaroglu, G., Reinking, A. G., and Schrock, V. E., "Spent Fuel Transportation Risks," Nuclear News, November, 1972.

6. Tsunamis and seiches.

7. Troughing.

The vibrations in the soil or water medium in contact with a structure excites the structure into motions that, in general, differ from the vibrations in the medium. Sometimes the vibrations precipitate failure of land masses causing slides along weak planes. Further, these structural motions impart motions to equipment located within the structure different from motions of the structure and the medium. This situation is a complicated dynamics problem that often demands the utmost sophistication in its solution for nuclear facilities.

The accelerations applied to the structures by the ground shaking are mainly a function of the site properties of the foundation materials. It is also recognized that ground shaking intensity is related to other factors such as the distance to the causative fault, mechanism, and path.

In general, it can be said that ground shaking intensity in soils exceeds that in rock; for most structures, such as containment buildings, the response when a structure is founded on soil exceeds the response when a structure is founded on rock. Rock and rock-like materials, therefore, are the preferred foundation materials for supporting nuclear power plant structures.

The characteristic motions of containments under earthquake excitation consist of horizontal translation and rocking resulting from the horizontal component of ground motion and vertical translation due to the vertical components of the ground motion. The response to the horizontal component of ground motion may differ markedly from the input ground motion itself. However, the vertical response may more closely resemble the vertical component of ground motion. These characteristic motions apply to all surface structures.

Liquefaction is the phenomenon whereby saturated granular soils which are otherwise competent are loosened by seismic vibrations and thereby lose strength, acting as a fluid. The effect on walls adjacent to soils is to increase lateral soil bearing pressures on the structure, and the values are maximized in the presence of groundwater as might be expected in some of the locations typical for the siting concepts being considered. Since liquefaction destroys the strength of foundation-supporting soils, materials subject to the phenomena are to be avoided for these purposes.

Faulting and ground rupture were discussed in Section 5 when presenting the underground concept in rock at a location where faults might be anticipated.

Tsunamis were discussed in Section 3. "Troughing" refers to the formation of a trough in the water surface, with water pouring in from both sides. Such a phenomenon was observed in the Chilean earthquakes of 1960.*

The aboveground, land-based concepts, including the artificial and natural island concepts, will be subjected to the ground motions previously described, so long as areas sensitive to fault displacements are avoided. In hillside and low profile concepts, additional concern for potential landslides in the slope regions is appropriate. In the artificial island concept, liquefaction of the fill material bearing on underground walls and flow from under foundations is a concern in plant design.

In underground concepts where the structures are in direct contact with the surrounding material, seismic accelerations will be applied to all exterior surfaces. Confinement by the medium puts significant restraints on the response of the structure, forcing the structural vibrations to closely match those of the medium. The well defined rocking mode that is often the primary feature of the response in aboveground containments is suppressed. When the roof and walls are isolated from the cavity walls, the response resembles that of an aboveground structure.

The attenuation of the ground motion with increasing depth is subject to some controversy. Proof of such attenuation adequate to meet the requirements for nuclear power plant licensing may be difficult to achieve in view of the limited measurements experience and documentation. Underground earthquake motions recently have been reviewed.**

Relative ground motion intensities vary with the medium. Computed free field ground motions based on a given base rock ground motion intensity generally show minimum intensity at sites in massive igneous rock and maximum intensity at sites in unconsolidated sediments. In general, the motions will be greater in massive sedimentary rock than in massive igneous rock but less than in unconsolidated sediments.

*Hellmuth, Sievers, Villegas, and Barros, "The Seismic Seawave of May 22, 1960, along the Chilean Coast," Bulletin of Seismological Society of America, Vol. 53, No. 6, December, 1963.

**Leeds, D. J., "The Underground Seismic Environment," Proceedings from Rapid Excavation and Tunnelling Conference, ASCE, Chicago, 1972.

The water table assumed in the unconsolidated soils configurations tends to increase the intensity of the ground motion. In this concept, safeguards against liquefaction and against differential displacements may be required. The configuration in poorly cemented materials is very similar to the configuration in unconsolidated soils. However, the location above the water table is more favorable in reducing the intensity of seismic loading.

The underground configuration in moderately faulted rock features a "rattle space" isolating the side walls and roof from the surrounding rock. As indicated earlier, the isolation makes response to ground shaking similar to that of an aboveground system.

Floating concepts receive seismic inputs primarily through the water. The impulses are hydrodynamic since the inability of water to transmit shear forces precludes transmission of horizontal impulses from a horizontal bottom surface. However, submerged surfaces, inclined or vertical, such as breakwaters or cliffs, can induce horizontal impulses whose effects might have to be considered. Also, mooring lines which are relatively stiff through initial tension can transmit horizontal forces if the anchor point has been displaced. Some low frequency seismic waves might also be transmitted.

Seismic considerations for the seabed configuration are similar to those for aboveground concepts, except that response would be modified to some extent by the presence of the water. Amplification of the ground motion and possibility of settlement might require consideration if the facility is located on soft sediment. Special problems similar to those of offshore platforms may be associated with the surface platform and its tubular supports that extend down to the submerged vessel.

Seismic effects applicable to a platform-mounted nuclear power plant, moored in shallow water in a lagoon or surrounded by a breakwater include ground shaking, faulting, seiche, and possibly troughing. Movements of the ground and breakwater result from both ground shaking and faulting, the latter hypothesized as being limited to a single cycle motion. These movements, whatever their source, cause motion in the water, consisting of one or more impulses, and may produce oscillations associated with free vibrations of the water. Typically, the oscillations have very long periods and persist long after the impulsive motions have ceased. The long period oscillations consist of horizontal and vertical translation and rotation of water particles associated primarily with tilting of the free surface.

The response of water in the lagoon affected by seismic-initiated ground shaking depends primarily upon the characteristics of the ground shaking and whether it is horizontal or vertical. In the absence of an enclosing structure, the horizontal shaking produces essentially zero response of the water mass because water is incapable of transmitting shearing forces. However, the horizontal shaking induced in the breakwater or lagoon sides transmits horizontal acceleration to the water and sets it in motion.

The vertical shaking imparts accelerations to the water directly from the bottom of the lagoon. Purely vertical ground motion does not cause long period vertical oscillations. Theoretically, vertical shaking can induce horizontal accelerations and hydrodynamic pressures in the water. However, for several reasons, computed values are considered to be unrealistically high.*

The response of the water mass affected by fault displacement depends primarily on the magnitude and velocity of the displacement, its direction (vertical or horizontal), and location of the rupture plane relative to the lagoon. When the rupture plane is outside the lagoon, the response of the water in the lagoon due to the faulting displacement is that resulting from a single cycle movement. When the rupture plane is inside the lagoon, all relative displacements due to faulting, regardless of direction, will cause local relative motions of the breakwater, in turn generating motions of the water in the lagoon. A relative purely horizontal displacement in the lagoon bottom in the absence of the breakwater will not generate water motions because of the zero shear transmissibility of water. A relative vertical displacement, creating a vertical step in the lagoon bottom, would cause a vertical impulsive motion of the water; a temporary horizontal flow from the high part to the low part; and long period oscillations. Peak response of the water due to faulting may or may not coincide with the peak response due to shaking, depending on the phasing between the shaking and faulting movements.

The barge will respond dynamically to the various transient motions that have been described. The response can be severe. The peak transient hydrodynamic pressure due to horizontal shaking that acts on a solid vertical face of a structure such as a dam is approximately equal to the hydrostatic pressure times the peak horizontal acceleration in g's.

*Newmark and Rosenblueth "Fundamentals of Earthquake Engineering." Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1971.

Face slopes in the range of 25 degrees to 45 degrees lead to reduced pressures - about 23 percent to 41 percent as great as the pressure on a vertical face. It is expected that the peak horizontal input acceleration acting on the barge due to water-transmitted impulsive motions, assuming a breakwater slope in the range indicated, would be attenuated in a similar way, and would be substantially less than that of the free field ground motion.

Vertical motion transmitted to the barge would be similar to the vertical free field ground motion in intensity and duration. Assuming that the peak free field vertical ground acceleration has roughly the same magnitude as the peak free field horizontal acceleration, it is to be expected that the effect of vertical ground acceleration would be more severe than the effect of horizontal ground acceleration because the vertical impulsive pressures act on the entire bottom area of the barge, whereas the horizontal impulsive pressures act on the much smaller submerged area of the vertical side of the barge. The effect of horizontal ground acceleration is further attenuated if the inside face of the breakwater is sloped. Short period vertical accelerations transmitted by the barge would be significant in their effect on Class I equipment items that typically have natural frequencies in the short period range. The high frequency response to vertical ground shaking can be attenuated using open bottomed air chambers located at the bottom of the barge.

The long period oscillations can cause rolling, pitching, and translation of the barge of large amplitude. This is true regardless of whether the source mechanism is shaking or faulting, separately or in combination. These motions may be significant in barge-mounted fluid containers wherein the fluid has a free surface, leading to a "sloshing" mode of response.

It is assumed that to accommodate tidal movements, the mooring cables would have to be fairly slack. Consequently, cable forces at the upper end, arising from shaking movements of the ground at the anchor, would be small. However, mooring cables might be affected by large amplitude motions of the anchor point caused by faulting.

The precise behavior of a floating nuclear power plant under the various earthquake phenomena cannot be accurately predicted. However, for most of these phenomena, conservative upper bounds of response can probably be determined that would still be within the limits of technical feasibility.

For a given intensity of horizontal ground shaking, the response of barge-mounted Class I equipment is probably less severe than the response of identical equipment in a land-based facility, with the possible exception of features such as filled tanks which are responsive to long period motions. The effect of vertical ground shaking on Class I equipment is expected to be quite similar, whether barge-mounted or land-based. A sizeable advantage in reduced response of barge-mounted equipment relative to land-based equipment would require use of a barge equipped with an effective attenuating system. Faulting effects would be changed in nature from those associated with a land-based facility, and would probably be generally less severe.

7.2.4.4 Assessment. The assessment of the consequence of an event was made by visualizing the severity of the event and then making a gross estimate of the damage which might result from the action of the event on each of the siting concepts. Damage was expressed in millions of dollars for:

1. Physical damage to the plant facilities in terms of cost to repair.
2. Cost to the owner due to plant outage at \$4 million per month off-line.
3. Death or injury to plant personnel and off-site personnel at \$300,000 per death and \$30,000 per average injury.
4. Damage to the land of at least \$5,000 per acre (depending on location) if the area is made unsuitable for future normal use.
5. Damage to the sea estimated on an overall gross basis.

The total damage estimate for the event acting on the siting concept was obtained by summing the estimate of damage to each of the above items.

The risk associated with an event acting on a concept is the product of the total damage estimate and the frequency or likelihood of occurrence of the event. The total risk associated with a concept is the sum of the risks for each event acting on that concept.

Low risks indicate greater acceptability; Table D-38 in Appendix D indicates the acceptability for risk of each concept.

It can be observed that:

1. Earthquake risk is the predominant contributor for all land-based concepts and offshore concepts subject to earthquakes. (Risk values generally between 74,000 and 678,000.)
2. For most concepts subject to ship collision, this event is the predominant contributor to risk or is comparable with the earthquake event (risk values between 58,000 and 300,000).
3. Storms and floods, and landslides make intermediate contributions to risk. (Risk values less than 21,000.)
4. The accidental missile event, targeted missile, sabotage, tsunamis and tides, transportation accidents, and fire events make minor contributions to the risk for all concepts. (Risk values less than 1,500.)

The earthquake and ship collision risks are predominant due to the major damage which could be inflicted on the physical plant, the resulting prolonged plant outage, and the relatively high frequency of occurrence used for the events. The frequencies used in the evaluation for these events are 10^{-3} per year compared to values of the order to 10^{-7} and 10^{-8} for some of the other events. Other events with frequencies in the range of 10^{-4} to 10^{-5} (storms and floods, 10^{-4} ; tsunamis and tides, 10^{-5} ; transportation accident, 7.5×10^{-4}) are judged to result in much less damage than that from earthquakes or ship collision, and hence the risk is much less for these events.

The damage estimate, in all cases, is dominated by damage to the physical facilities and the resulting outage penalty. With plant values in the range of \$300 million to over \$500 million and an outage penalty in the range of \$4 million per month, major plant destruction resulting in plant outage up to 6 years would generate damage estimates up to \$800 million. To approach this damage level from damage to people or the environment would require either:

1. 2,700 deaths at \$300,000 each,
2. 27,000 injuries at \$30,000 each,
3. 160,000 acres of land removed from use at \$5,000 per acre,

Present practice* uses much less severe (although acknowledged to be conservative) assumptions in assessing public risk from reactor accidents. These include release to the reactor building of approximately 15 percent of the gross fission-product inventory with subsequent leakage into the atmosphere at a rate of about 0.1 percent per day. These release values together with an exclusion area for reactor siting lead to estimates of damage to the public and the environment much less than that estimated for damage to the facility owner (damage to the physical plant and plant outage).

It can be observed for LWR plants that, in general, due to the predominance of the risk from earthquake and ship collision, the aboveground concepts, including the floating plant in a lagoon, have the least risk (values to about 130,000) the underground concepts have intermediate risk (values to 160,000, except for the faulted concept), and the concepts subject to ship collision have the greatest risk (values to 710,000).

The lagoon concept has the least overall risk due to a reduction in the risk from earthquake and elimination of the risk from ship collision. Risks from storms and floods, landslides, and severe tides also appear to be minimized.

The hillside, inland, low profile, and coastal concepts are very similar in configuration resulting in risk within a narrow value band, almost twice the value for the lagoon concept. The coastal concept has slightly higher risk due to the more populated area and higher land values and the assumed damage to them.

The natural island concept is almost identical in configuration to the coastal concept with the addition of undersea transmission cables. The cost of the transmission cables and cost increases for offshore construction cause the estimated capital cost for the natural island concept to be about 25 percent higher than for the coastal concept. This increased capital cost is reflected in an increased damage estimate even though the estimated damage to population and environment is decreased. This places the risk value for the natural island concept in the range for the underground concepts rather than with the other aboveground concepts.

*Otway, H. J., "The Application of Risk Allocation to Reactor Siting and Design," University of California, Los Alamos, New Mexico, June, 1970, LA-4316.

The underground concepts include, in order of increasing risk, plants constructed in the following ground conditions:

1. Unconsolidated ground requiring soil freezing for excavation from the surface.
2. Poorly cemented ground requiring cut-and-cover construction methods.
3. Massive igneous rock.
4. Massive sedimentary rock.
5. Faulted igneous or sedimentary rock.
6. Undersea in massive igneous or sedimentary rock.

The underseabed and faulted rock concepts are judged to have the greatest risk (more than twice as great as other underground concepts) of all concepts not subject to ship collision. This is due in the undersea case, to the possibility of an earthquake opening a fissure resulting in flooding of the entire plant complex. In the faulted rock case, it is due to the higher frequency value assumed. For all other events, the undersea concept has average or better than average risk.

The floating deep and seabed concepts located in the ocean are judged to have the greatest risk due to the high probability and severe consequence of ship collision.

The seabed concept with its sea-surface platform and structure which connects the platform to the subsurface vessel, appears to maximize the hazard. It is potentially subject to severe damage from earthquakes and ship collision. It requires two transport modes (water and land) for transfer of spent fuel and radioactive waste. Landslides would not create a hazard assuming the site is on a relatively flat seabed.

The breakwater and artificial island concepts are similar in that they are founded to some extent on the ocean floor and both are subject to damage by earthquake and ship collision. The damage from ship collision is judged to be essentially the same for the two concepts but considerably less than for the shiphull, tuned sphere, or seabed concepts. The only significant difference in the risk values for the breakwater and

artificial island concepts is due to the estimate of earthquake damage for the artificial island being about twice that for the breakwater since the floating platform within the breakwater should reduce the damage to the plant components.

The tuned sphere concept is a vessel or hull modified to improve stability and seaworthiness in a moored mode of operation. Both this concept and the shiphull concept have minimum risk from earthquakes since only the moorings could be subject to earthquake damage. It is visualized that complete loss of mooring does not occur and no plant outage is necessary during repair of damage to the mooring. The tuned sphere is judged to have less risk than the shiphull due to less storm damage and better resistance to ship collision. The ship collision damage to the physical facility for the tuned sphere is estimated to be only 60 percent of that for the shiphull.

Ship collision, which dominates the risk evaluation for those concepts subject to this event, carries a frequency factor of the order of 10^{-3} while most other events considered in the risk evaluation were assigned frequencies in the range of 10^{-4} to 10^{-8} . Since the occurrence of man-made events is controllable to some degree, it should be possible to reduce significantly the frequency of ship collision by control of traffic patterns, early warning systems, or other means. To examine the impact of improvement in frequency of ship collision on the relative risk of the siting concepts, risk values were recalculated for the breakwater, artificial island, tuned sphere, shiphull, and seabed concepts assuming frequency factors of 5×10^{-5} and 5×10^{-6} . For a 10-fold reduction in frequency of ship collision, the tuned sphere and shiphull obtain low risk values; the breakwater concept obtains similar overall risk value as the aboveground land based concepts; the artificial island obtains values like the underground concepts; and the faulted rock and seabed concepts retain the highest risk values of all the concepts.

7.3 ACCEPTABILITY

The results of the siting concept evaluations are presented in visual display for easier analysis to determine the more acceptable concepts. Figures 7-1 through 7-17 are graphical presentations of the acceptabilities. Each of the four evaluation factor groups are indicated, as well as the appropriate subfactors. Since acceptability is the summation of the individual products of weighted value (bar width) of each factor or subfactor and the relative rating (bar height) assigned to each, the total acceptability of each siting concept is represented by the total area in the bars. The total area, or acceptability, also is numerically summarized by factor on each figure.

FIGURE 7-1
ACCEPTABILITY
ABOVEGROUND COASTAL

FIGURE 7-2
ACCEPTABILITY
ABOVEGROUND - INLAND

Evaluation Factors
 (See Table 7-1 for Legend)

FIGURE 7-3
ACCEPTABILITY
ABOVEGROUND - HILLSIDE

Evaluation Factors
(See Table 7-1 for Legend)

FIGURE 7-4
ACCEPTABILITY
ABOVEGROUND - LOW PROFILE

FIGURE 7-5
ACCEPTABILITY
ABOVEGROUND - FLOATING LAGOON

FIGURE 7-6
ACCEPTABILITY
UNDERGROUND - MASSIVE IGNEOUS ROCK

FIGURE 7-7

ACCEPTABILITY

UNDERGROUND - MASSIVE SEDIMENTARY ROCK

FIGURE 7-8

ACCEPTABILITY
UNDERGROUND - UNCONSOLIDATED MATERIALS, BEACH

FIGURE 7-9

ACCEPTABILITY
UNDERGROUND - NONMASSIVE, POORLY CEMENTED MATERIALS

FIGURE 7-10

ACCEPTABILITY
UNDERGROUND - MASSIVE ROCK FAULTED

FIGURE 7-11

ACCEPTABILITY
OFFSHORE - FLOATING SHALLOW

FIGURE 7-12
ACCEPTABILITY
OFFSHORE - FLOATING DEEP

FIGURE 7-13

ACCEPTABILITY
OFFSHORE - SEABED

Σ Acceptability

A_C 0.192

A_{EI} 0.173

A_F 0.169

A_R 0.015

0.549

(See Table 7-1 for Legend)

FIGURE 7-14

ACCEPTABILITY
OFFSHORE - UNDERSEA

FIGURE 7-15
ACCEPTABILITY
OFFSHORE - ARTIFICIAL ISLAND

FIGURE 7-16

ACCEPTABILITY
OFFSHORE - NATURAL ISLAND

FIGURE 7-17

ACCEPTABILITY
OFFSHORE - TUNED SPHERE

TABLE 7-1

EVALUATION FACTORS LEGEND

<u>Evaluation Factor</u>	<u>Weighted Value</u>
1. Cost	0.287
2. Environmental Impact	0.301
a. Land Use	0.050
b. Land Restoration	0.033
c. Visual Image	0.055
d. Physical Effects	0.075
e. Construction Impact	0.015
f. Multiple Uses - Heat, Plant	0.033
g. Multiple Uses - Site	0.040
3. Feasibility	0.272
a. Technology	0.119
b. Potential Sites	0.153
4. Risk	0.140

Table 7-2 indicates the total acceptability of the siting concepts in ranked order. A first look at ranking acceptability indicates that the inland plant has the greatest acceptability and that the other above-ground concepts, i. e., lagoon, hillside, low profile, and coastal plants, have greater overall acceptability than the remaining concepts. The offshore floating deep plant is next and represents the most favorable offshore concept. The underground plant in poorly cemented materials appears to be the most acceptable of the underground concepts.

Although subject to seismic risk, the inland plant is reasonably higher in overall acceptability from a combination of low cost, low environmental impact, and greater feasibility when compared to other concepts. The hillside plant has good acceptability due to low cost, average risk, environmental impact and technical feasibility, but somewhat fewer potential sites are available than for the inland plant. Still fewer potential sites are available for the aboveground coastal and low profile plants. The floating plant in an onshore lagoon has good acceptability considering risk, principally due to its lower seismic risk and the elimination of ship collision which confronts most of the offshore concepts.

The underground concepts generally have lower acceptability than the aboveground plants from a cost standpoint, with the concept in unconsolidated sediments at a beach site being the least acceptable. The concepts in poorly cemented materials and in sedimentary rock have greater feasibility due to the existence of more potentially suitable sites, and this contributes to their greater acceptability than the other underground concepts.

Of the offshore concepts, the artificial island and floating platforms in shallow and deep water are more acceptable. The contributing factor appears to be feasibility as compared with the other offshore concepts. The artificial island and shallow floating platform are closer to the shore than the others. If they are constrained to a 3-mile limit, then their feasibility drops for lack of potential sites in California.

The least acceptable of the offshore concepts is the seabed version, mostly because of the high seismic and ship collision risk and the low technical feasibility.

The merit of these acceptability interpretations can be further analyzed by assessing acceptability as a function of the individual evaluation factors. Acceptability is measured against cost, environmental impact, feasibility, and risk. Assessments are also made

TABLE 7-2

CONCEPT TOTAL ACCEPTABILITY VALUES

Concept Number	Title	Acceptability Values
2	Aboveground-Inland	0.779
5	Aboveground-Floating Lagoon	0.761
3	Aboveground-Hillside	0.756
4	Aboveground-Low Profile	0.674
1	Aboveground-Coastal	0.657
12	Offshore-Floating, Deep	0.649
9	Underground-Nonmassive, Poorly Cemented Materials	0.642
15	Offshore-Artificial Island	0.637
11	Offshore-Floating, Shallow	0.636
17	Offshore-Tuned Sphere	0.617
7	Underground-Massive Sedimentary Rock	0.603
16	Offshore-Natural Island	0.581
14	Offshore-Undersea	0.549
6	Underground-Massive Igneous Rock	0.540
8	Underground-Unconsolidated Materials, Beach	0.522
13	Offshore-Seabed	0.502
10	Underground-Massive Rock, Faulted	0.494

against the measurable subfactors (visual image, and miles of potential coastal sites). It can be said that concepts which appear more acceptable in all of these plots will be more acceptable on an overall basis regardless of weighted values given to each of the evaluation factors.

7.3.1 Cost Evaluation

The total acceptability value for each concept is reduced by the value of cost acceptability and plotted versus cost acceptability. Increasing acceptability is denoted by increasing values along both axes; therefore, the more favorable zone of acceptability appears in the upper right hand portion of the plot. Furthermore, the more favorable concepts with respect to the isolated factor (cost) shown on the abscissa will appear on the right side of the distribution.

Figure 7-18 indicates that all five aboveground concepts which are highest in overall acceptability appear in the most favored zone when viewed on a cost basis. The aboveground hillside concept appears to be the most favorable of these. The cut-and-cover underground concept in poorly cemented materials and the artificial island concept appear to be the most acceptable of the others when viewed as a function of cost. Low environmental impact and risk are responsible for high acceptability of the floating lagoon concept.

The underground concepts in massive igneous or sedimentary have costs about 16 percent higher than the aboveground coastal concept.

7.3.2 Environmental Evaluation

As shown in Figure 7-19, three of the aboveground plants appear in the most favorable acceptability zone when viewed in respect to the environmental considerations given in this study. The floating plant in a lagoon is most acceptable, and the inland and hillside concepts are also rated relatively high.

The underground plants in rock and poorly cemented materials are about the same in environmental acceptability value.

Of the offshore concepts, the undersea and natural island concepts have high environmental acceptability simply because they have low visual image, least interference with land use, and low physical

FIGURE 7-18

COST EVALUATION

7-67

FIGURE 7-19

ENVIRONMENTAL IMPACT EVALUATION

and construction impacts. However, it is seen that their acceptability in the other factors is low and, therefore, they appear less acceptable on the plot.

7.3.3 Feasibility Evaluation

The aboveground plants appear in the most favorable zone as seen in Figure 7-20. The inland plant is most feasible due to its advanced state of the art and, in particular, the large number of potentially suitable sites. The artificial island, aboveground hillside, and floating deep and shallow concepts also show high feasibility, but only on the assumption that the offshore shallow water concepts can be located about 1 mile from shore. The three offshore concepts are not particularly acceptable when viewed in light of the other three evaluation factors, whereas the inland and hillside concepts are much more favorable in this respect.

The tuned sphere, underground poorly cemented, aboveground coastal and low profile concepts have fairly good feasibility due to the potential availability of many sites in some cases and existence of technology in other cases. However, the former two are low in acceptability when considering the other evaluation factors.

The concepts which appear to be the least feasible and have relatively low acceptability when considering the other factors are the underground concepts in unconsolidated beach material or in faulted rock both due to technical state of the art and a limited number of potential sites; and the seabed concept, due to the state of the art in its development.

7.3.4 Risk Evaluation

The plot in Figure 7-21 clearly indicates the high acceptability (low risk) of the floating lagoon concept onshore. Seismic effects and ship collision are the two largest contributing events toward risk evaluation. The floating plant in a lagoon is removed from ship traffic. Also, preliminary study indicates a reduced seismic impact may be available when using this concept. A lower feasibility rating accounts for the reduction in the balance of acceptability; however, this is largely due to a somewhat limited number of potential sites. The other aboveground plants are next, all having about the same level of risk. They are followed by the underground plants, particularly in sedimentary rock and in poorly cemented materials, and the natural island concept. The offshore plants (tuned sphere, floating deep, and seabed) show the highest

FIGURE 7-20

FEASIBILITY EVALUATION

7-70

FIGURE 7-21

RISK EVALUATION

risk. The reasons for these relative positions are that the seismic and ship collision risks are highest. Since risk was associated with damage and plant value, the less costly plant concepts show less risk and higher acceptability.

7.3.5 Visual Image Evaluation

It is possible that visual image may some day become one of the principal issues in siting power plants. Facilities with the least image from publicly traveled roads would be more acceptable. The impact on acceptability is seen in Figure 7-22. Obviously, the concepts which are not visible attain the highest ratings. These are the aboveground hillside, undersea, and the natural island concepts. Of these, only the hillside concept has good acceptability in the other factors. The other aboveground concepts have very low acceptability in this regard, and the offshore and underground concepts are somewhat better, in that order. Most of these plants have some features such as stacks, entrances, access roads, or onshore terminals which do not completely hide the presence of the plant and this accounts for the low acceptability of most concepts. However, the underground plants are better than most in this regard.

Due to the method used in deriving visual image acceptability values, large mathematical differences appear for all concepts and are not discernible on a plot to the same scale as the factors described above. Therefore, the data in Figure 7-22 are on a semilog plot, with visual image acceptability values on the log axis.

7.3.6 Potential Sites Evaluation

Figure 7-23 indicates the acceptability of concepts with respect to the number of potential sites which may be available. Those which rank highest are the inland and deepwater floating concepts. Also, provided that close-in locations would be permitted, the artificial island and offshore floating platform in shallow water have a high acceptability with respect to sites. The aboveground hillside and underground in a cut-and-cover mode also have a reasonably large number of potential sites available.

Of those concepts having a large number of sites, the aboveground hillside and inland concepts have the highest acceptability in the other factors evaluated.

FIGURE 7-22

CONCEPT ACCEPTABILITY (LESS VISUAL IMAGE) VERSUS VISUAL IMAGE ACCEPTABILITY

FIGURE 7-23

POTENTIAL SITES EVALUATION

7.4 ALTERNATIVE SYSTEMS

7.4.1 Power Systems

The evaluation of relative acceptability of siting concepts has been made assuming the utilization of a light water reactor (PWR or BWR) power system in each of the siting concepts. There are, however, other power systems which can be used or are being developed. These include a liquid metal fast breeder reactor (LMFBR), the high temperature gas-cooled reactor (HTGR), a conventional fossil fueled (coal, gas or oil) boiler, a conventional gas turbine, and a combined cycle fossil fueled system.

Most of these systems contain features which utilize different design principles and therefore exhibit different operational characteristics. It is desirable to judge the effect, if any, that alternatives might have on conclusions relative to power plant siting and siting concepts. Therefore, each of the siting concepts was additionally evaluated with two of the nuclear power systems, the LMFBR and HTGR systems. The fossil fueled plants were briefly considered in this same regard, but their design and effluent characteristics are so different from the nuclear plants, and their environmental impacts so dependant on specific sites and emission control systems, that direct comparisons between siting concepts having nuclear systems and those with fossil fueled systems would not be particularly informative.

With the limitations of cost estimate accuracy from only preliminary plant definition and the limited or non-existent operating experience of the HTGR and LMFBR power systems, an analysis was made of these systems similar to the evaluations made using an LWR. The conclusion is that these alternative power systems appear to have little effect on the feasibility or ranking of most of the siting concepts. Acceptability graphs and ranking table are similar to those presented in Section 7.3 and therefore are not included.

7.4.2 Inland Plant Cooling Systems

The evaluation of relative acceptability based on cost, environmental impact, feasibility and risk places the aboveground-inland concept (Table 7-2) in the position of greatest overall acceptability assuming that adequate water for condenser cooling can be provided to the plant site. An approach to eliminate the need for large quantities of cooling water is under study by the utility and plant supplier industries. In this approach, air-cooled dry towers (either natural or forced draft) would be substituted for the wet evaporative towers presently used.

Special tower designs using a combination of wet and dry sections are also being developed. Although both dry and combination towers have been used in commercial installations, their application has been for fossil fueled plants in sizes much smaller than the 1,000 Mw(e) plants considered here.

Air cooled towers condense the steam at a slightly higher temperature and pressure than that achieved by the evaporative towers. This is due to the fact that the limiting temperature of the dry tower is the dry-bulb temperature of the air rather than the lower wet-bulb temperature which limits the evaporative towers. The increased condenser temperature reduces the cycle efficiency of the plant resulting in increased plant size to maintain the same net electric output. In addition to increased plant cost due to increased plant size, the dry cooling towers are significantly more costly than wet towers because tower dimensions approximately 20 to 25 percent greater are required for equivalent capacity. Larger tower size (wet or dry) is required for LWR plants than for fossil fueled plants due to the lesser efficiency of the LWR (about 33 percent versus 39 percent).

Another prospect for reducing the significance of water availability for plant sites, is the use of a closed cycle gas turbine with the high temperature gas cooled reactor. This hardware system, the HTGR(GT), is in an early stage of study and would eliminate the steam cycle from the plant. The gas turbine would reject waste heat over a temperature range at an average temperature considerably higher than that of the steam condensed by a dry tower. The higher reject temperature would therefore permit the use of smaller dry towers than required for a steam cycle with the same reject heat requirements. In addition, the HTGR(GT) is predicted to have a higher efficiency than the LWR with evaporative cooling (36 percent versus 33 percent), thus further reducing the tower size.

To view these concepts, which offer a potential solution to the inland siting water problem, in relation to the others previously evaluated, the LWR, the fossil fueled plant and the HTGR(GT), all with dry cooling towers and sited aboveground in an inland environment were evaluated against the same acceptability factors previously used. In general, factors such as land use and restoration, construction impact, and miles of suitable land type do not affect the acceptability of these concepts in comparison to the inland LWR with wet cooling tower since these factors are independent of the power plant system. Although data were not developed to the same level of detail as for the other concepts and hence are not included in Appendix D, graphs summarizing the

relative rating based on each factor and the relative acceptability of each of these concepts are presented in Figures 7-24, 7-25, and 7-26.

7.4.3 Inland/LWR (Dry Cooling Tower)

The effect of using dry cooling towers rather than evaporative cooling towers for an inland plant is to increase the capital cost for cooling towers by about 20 million dollars. The capital cost for the production system also increases to compensate for the added thermal output required to maintain the same electric output due to the decreased thermal efficiency resulting from the higher heat rejection temperature and higher back pressure on the turbine. The operating cost (primarily fuel cost) is also increased by the decreased efficiency. The net effect on cost is an increase over an inland plant using a wet cooling system of about 0.68 mils/kw-hr, or about 7.3 percent for a 15 percent fixed rate charge.

The visual image presented by the dry cooling tower system is larger than that for the evaporative system due to the requirement for more heat transfer surface. However, other environmental impact factors tend to overcome this. Dry cooling eliminates possible steam clouds and rainout exhibited by wet towers. Also, the vast reduction in water resource consumption obtained when using a dry tower is of considerable significance.

Technical feasibility is somewhat less for the dry system due to less worldwide experience with this system than with evaporative systems for large central power stations.

The increased capital cost of the plant is reflected in increased risk resulting from potential increased damage from storm and flood, earthquake, and missiles.

Compared with the most acceptable concept, the acceptability is reduced about 6 percent due to increased cost and higher risk. The impact of a dry cooling tower would be even more pronounced when considered for any of the other concepts in which once-through cooling was used. However, the reduction in acceptability may be overridden by other considerations when siting this concept in areas where large volumes of cooling water cannot be provided economically.

Evaporative or dry cooling towers used with any of the underground siting concepts would penalize the visual image factor if the towers were placed aboveground. It would increase the cost significantly to provide space underground and to transport air through the towers.

FIGURE 7-24

ACCEPTABILITY
ABOVEGROUND - INLAND, LWR, DRY TOWER

FIGURE 7-25

ACCEPTABILITY
ABOVEGROUND - INLAND, FOSSIL FUELED, DRY TOWER

FIGURE 7-26

ACCEPTABILITY
ABOVEGROUND - INLAND, HTGR (GT) DRY TOWER

7.4.4 Inland/Fossil Fuel (Dry Cooling Tower)

The net effect on total cost (capital plus operating) with a fixed rate charge of 15 percent is that the inland fossil fuel plant with dry tower is about 9 percent more costly than the inland LWR plant using evaporative tower cooling even though the capital cost for the fossil plant is considerably less than that of the LWR plant.

The visual image presented by an oil fired fossil plant would be somewhat less acceptable than the LWR plant due to storage tanks for the fuel and large flue gas stacks. Storage of coal (about 15 acres to height of 40 feet) would present an equally unattractive visual image. A gas fired plant might present a more acceptable image but no better than the nuclear plant.

The physical effect of the fossil fueled plant is more severe than for the LWR due to the more deleterious effect of effluent gas on people and plant life during normal operation.

The technical feasibility of the fossil fueled plants at inland sites is well established except for the uncertainty regarding the large dry cooling towers, thus the acceptability based on feasibility is judged to be the same as for the LWR with dry tower.

When considering risk, the damage value for the fossil fuel plant is less than for the LWR plant due to the lower capital cost, even with greater vulnerability to the more destructive events. The large flue ducts, large stacks, and massive steam generator, superheater, and heat recovery equipment are components subject to severe damage by earthquake or missiles. Injury to plant personnel could result from steam line rupture or steam generator explosion, but no injury to off-site personnel or land is visualized. In addition, a shorter period of outage would be expected following plant damage since no operating license, comparable to that for a nuclear plant, is required.

The net effect of these considerations on overall acceptability is a reduction of about 9 percent compared to the inland LWR plant with wet tower. About the same reduction in acceptability would be expected if the fossil plant were substituted for the LWR in any of the other aboveground siting concepts. For underground concepts the differential would be expected to be somewhat greater since underground fuel storage would need to be provided and large air ducts and flue gas ducts would be essential.

7.4.5 Inland/HTGR(GT), (Dry Cooling Tower)

The HTGR(GT) power system will use high temperature gas (helium) as the primary coolant for the reactor. The gas coolant, direct cycle gas turbine, ceramic fuel elements, and graphite moderator allow the thermal cycle to operate in a higher temperature range than that of the LWR, while obtaining better retention of fission products within the fuel elements. The other major distinguishing characteristic of the HTGR(GT) power plant will be the use of a massive prestressed concrete reactor vessel (PCRv) to contain the entire thermal system including the gas turbines. This compact, unitized approach should provide improved protection against damage from earthquakes and missiles.

The high temperature gas cooled reactor system with gas turbine and dry cooling tower is in the early stages of study, thus there are uncertainties regarding cost. However, very preliminary analysis indicates that the costs will be about the same as those of the LWR. In comparison to the LWR with a dry tower, the HTGR(GT) should realize cost reduction due to the elimination of the steam system, elimination of the water support systems, reduced size of the dry cooling tower, and reduced overall plant size. On the other hand the cost of the gas turbine and increased costs of the thermal system due to a slightly higher temperature and a 40 percent increase in pressure should offset these cost reductions resulting in a total bus bar cost for the HTGR(GT) about equal to that for the LWR with dry cooling tower.

The environmental impact of the HTGR(GT) is about the same as for the LWR, recognizing some reduction in the HTGR(GT) impact due to a lower visual image for the dry tower.

The technical feasibility of the HTGR(GT) is less certain than that of the LWR since no operating experience with large HTGR plants has been accumulated and much system development remains to be done for the higher pressure reactor system and for closed cycle gas turbines of the size required.

The inland plant using a high temperature gas cooled reactor with a gas turbine appears to offer lower risk than the LWR system because of less facilities involved, thus less vulnerability to facility damage from natural or man made events. The elimination of water and steam systems will result in a smaller turbine generator building, or perhaps in eliminating it. Also the more efficient dry cooling tower for this high temperature system would result in a smaller size cooling tower structure.

The HTGR(GT) is judged to have a reduction of about 8 percent in overall acceptability compared to the LWR with wet tower in an inland siting concept. Due to inherent characteristics of the HTGR(GT) plant, about the same reduction in acceptability would be expected for the HTGR(GT) when substituted for the LWR in any of the other above-ground concepts.

The assessment of acceptability of nuclear alternatives to the LWR system for each of the siting concepts has essentially no effect on the ranking of siting concepts. When considering the application of dry cooling towers for inland plants, to lessen the importance of large volumes of water as a siting parameter, there appears to be a slight penalty for substituting an LWR/dry tower, fossil fueled/dry tower or the potential HTGR(GT)/dry tower concepts. However, the penalties are so small that each can be considered viable alternatives to the LWR/wet tower inland concept and, therefore, viable alternatives to the aboveground coastal plant.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

8.1.1 Sites

There are a large number of coastal sites in California with diverse characteristics that are compatible with concepts which have been suggested in this study as alternatives to aboveground plants located near the ocean front. The physical features include beaches, plains, hills, and rugged terrain which is typical of the coastal ranges that extend from the Oregon Border to Point Conception. Over 60 percent of the coastal zone is comprised of hilly to mountainous terrain. This accounts for a general lack of development in the coastal zone north of Santa Barbara with the exception of populated areas in relatively level zones near Eureka, San Francisco, Santa Cruz, Monterey, and San Luis Obispo. The most extensive coastal development in the State is found south of Santa Barbara where topography is generally less severe.

Geologic materials include relatively small amounts of massive igneous rock and more massive sedimentary rock which potentially could be mined out without extensive support required during construction. However, most of the coastal materials are nonmassive, fractured heterogeneous material which, if mined, would not be self-supporting.

The seismic activity in California is high with a great deal of the coastal zone located near active faults. These coastal locations are subject to ground displacements or sufficiently high ground motion intensities that increase the licensing problems under present AEC regulations; design solutions, in these cases, would be costly or impractical to provide the required assurance of nuclear safety.

Following identification of potential coastal sites having low seismic activity, and which are a sufficient distance from high density population centers, there are a number of additional constraints which may further limit site suitability. These include parks, education and research centers, as well as the impacts on sensitive biota in adjacent terrestrial and marine environments. While it is possible to eliminate those sites where these constraints are most important, it may be best to eliminate first the zones of high seismic activity and high density population, then assess the potential for designing the plant to minimize any adverse effects on the other environmental characteristics.

Coastal regions where potential sites appear to be suitable for alternative siting concepts can be categorized first by topography (beach or low terrace, hilly or rugged or lagoon); then by geology (massive igneous or sedimentary rock, unconsolidated beach material, nonmassive or poorly cemented materials, faulted massive rock); and for offshore locations, by shallow water and deep water. Regions with such characteristics were shown on Plate 3-8. There are limited massive igneous rock regions. Areas of low terrain at sufficient distances from high density population centers with an acceptable seismic activity level are also limited. Further, offshore zones 3 miles from shore with depths of 40 to 60 feet essentially are nonexistent. To a limited degree, shallow water sites could be developed as lagoons onshore. The most abundant siting regions in California appear to be available for plants located inland, in deep water, in shallow water close to shore, in hillside areas, and in nonmassive, poorly cemented materials (underground) in that order.

The inland regions of California represent the largest area for potential plant sites. Sites for large, central station power plants within the present state of the art must have available large quantities of water for steam-turbine, condenser cooling. However, since there are several potential methods for supplying this water, most of them requiring major water development or reallocation programs, inland sites not presently having water can be considered.

Inland regions which are relatively flat generally can be considered as more economical for plant construction purposes than would be mountainous or relatively inaccessible regions. The regions can be limited by eliminating areas which are generally defined as having high seismic intensity or major ground subsidence. Additional areas of high population and major parks, reservations and monuments further reduce potential zones although detailed site investigations may reveal some areas which could be suitable. Plate 4-1 indicates these eliminated areas and indicates the remaining regions where there should be a higher probability for finding suitable plant sites.

8.1.2 Transmissions

When considering the high voltage transmission lines which will carry power from the generating plant to load centers, it may be necessary to consider underground and underwater lines. Both types are in use today in systems of low capacity and with shorter runs than may be required by the siting concepts or by restrictions placed on their use. Currently, there are a number of research and development programs directed toward increasing line capacity so that the number

of transmission circuits that would otherwise be required would be reduced with little or no additional cost. Two of these techniques which are being advanced are a compressed-gas insulated system, and superconducting or resistive cryogenic systems.

8.1.3 Siting Concepts

There are many siting concepts which seem well suited to location in California. These can be grouped as follows:

1. Aboveground - Coastal, inland (backfeed power to coastal zone), hillside, low profile, floating platform in lagoon.
2. Underground - Massive igneous rock, massive sedimentary rock, unconsolidated beach materials, nonmassive and poorly cemented materials, faulted massive rock.
3. Offshore - Floating platform in shallow water, floating platform in deep water, seabed, undersea, artificial island, natural island, tuned sphere.

Each of these has advantages and disadvantages which can be evaluated on a common, relative basis according to cost, environmental impact, feasibility, and risk factors. Evaluation of 17 concepts on a relative basis according to these four factors indicates that the aboveground plants generally rank highest; and of these, the inland plant, the floating platform in an onshore lagoon, and the hillside concept rank high in that order. The underground concept with cut-and-cover installation in nonmassive, poorly cemented materials appears to be the more acceptable of the underground concepts. With regard to offshore siting, the floating concept in deep water appears most acceptable only if a risk of a ship collision can be tolerated. The floating platform in shallow water and the artificial island concepts are reasonably acceptable assuming that they can be located 1 mile from shore. Concepts which appear to be least acceptable from an overall view are the seabed and underground concepts in unconsolidated beach materials or faulted rock zones.

Comparing the concepts in terms of each evaluation factor leads to similar conclusions. From a cost standpoint, the inland plant, hillside, and floating lagoon concepts rank high. Less cost is observed for the aboveground coastal and low profile concepts, but they are less acceptable than the other aboveground facilities for the remaining factors.

The bus bar cost for an inland plant is about 9 percent over the coastal concept; and for the hillside plant located within 1-1/2 miles of the coast, it is about 4 percent greater than the coastal concept. Costs for the underground concept in poorly cemented materials (cut-and-cover) are about the same as for the concepts in massive igneous or sedimentary rock, but is clearly more acceptable overall; bus bar costs for these are all about 16 percent higher than the coastal plant (20 percent higher based on capital investment). The most costly concepts are the underground plant at a beach site and the undersea location.

From an environmental consideration, the floating platform in a lagoon has the highest relative rating, with the inland and hillside concepts also ranking high. Although the undersea and natural island concepts are favorable with respect to environmental impact, they are low in acceptability based on the other three factors. In the final analysis, conclusions with respect to this factor are subject to detailed on-site assessments of specific conditions. Environmental impact treated in this study only considered general site constraints which might be particularly pertinent.

The inland and hillside aboveground concepts rank highest in technical feasibility simply because similar plants are now functional and a large number of potential sites exist, since both of these factors contribute to feasibility evaluation in this study. The floating plants in shallow and deep water and the plant on an artificial island also rank high, but largely due to an abundance of potential sites. The number of shallow water sites, however, is dependent on being able to locate the plant 1 mile from shore. Underground plants and other offshore concepts are less feasible due to the lack of experience and the necessity for further development.

With respect to the risk evaluation factor, seismic activity and ship collisions present the greatest threat to the siting concepts. Since the floating platform in a lagoon tends to minimize effects from both events, it is highly acceptable on a risk basis. The other four aboveground concepts are next highest, with the underground and offshore groups the least acceptable, respectively.

If visual image is a key evaluation factor, the natural island, undersea, and hillside facilities are the highest ranked, and the latter concept ranks high in the other three factors as well.

8.1.4 Alternative Systems

When considering alternative nuclear power systems to the light water reactor such as the high temperature gas-cooled reactor

with a steam cycle, or the liquid metal fast breeder reactor, there is no apparent affect on the relative ranking of the concepts described above. It is also likely that the evaluation against each factor is proportional to concepts using the light water reactor power system.

When considering fossil-fueled plants as an alternative to the light water reactor systems, the large exhaust stacks and fuel storage requirements are either not feasible for incorporation in many of the siting concepts considered, or they would require additional conceptual definition beyond the scope of this study. The same is true of various cooling systems. However, variations in the inland concept may be practical to consider. Since the inland plant concept appears to be one of the more acceptable concepts in the baseline studies, but may present a water availability problem, variations of an inland plant using a dry tower were considered. Mechanical draft towers could be used in the dry concept, but since a natural draft, wet tower was assumed when evaluating the other concepts, the natural draft system was also assumed for the evaluation of the concepts using a dry tower.

An evaluation was made of dry cooling towers applied to an inland plant concept using a LWR system with a low-sulphur content, a fossil-fueled steam supply system, and a high temperature gas reactor with a gas turbine. The latter is now being studied and has not yet reached the development stage. The results of the evaluation indicate that for the factors considered (cost, environmental impact, feasibility, and risk), all three concepts have acceptability similar to an inland plant using a wet cooling tower and, therefore, also are viable alternatives to the coastal plant. The evaluation did not consider the potential, adverse atmospheric and terrestrial effects resulting from the use of the fossil-fueled plants, nor did it quantify the potential savings in water resources provided by all three approaches. However, the latter would tend to increase the acceptability of these solutions.

8.1.5 Summary

In summary, it can be concluded that:

1. The inland siting concept ranks highest in overall acceptability and would utilize land of greatest abundance in California. The concept consistently ranks high in acceptability when compared with other concepts against only cost, environmental impact, feasibility, or risk individually. Not fully investigated is the availability of

water for inland plants, but the potential use of dry cooling towers may reduce that constraint. The other concepts which also rank high are coastal zone aboveground plants located in a hillside environment and the floating platform-mounted plant in a lagoon environment at the shore. The California coast has a predominance of hilly areas potentially suitable for the hillside concept. Significantly fewer sites exist for the lagoon concept. The lagoon concept is particularly dependent on the existence of sites having low topographic features as well as acceptable environmental impact, both site dependent. The existence of such sites must be more fully investigated to prove the high acceptability ranking of this concept.

2. Underground concepts are not competitive with the acceptability of aboveground plants; but if they are preferred for aesthetics or for any of the other factors studied, the underground concept appearing most favorable is one located in a cut-and-cover situation in nonmassive or poorly cemented materials. This is mainly due to the larger number of potential sites in this media.
3. Offshore concepts are not competitive with the acceptability of aboveground plants. However, some concepts are more acceptable than underground concepts. The floating plant in a vessel located in deep water is more acceptable than the other offshore concepts because of the length of coastline where deep water exists and its lower cost. However, this is predicated on accepting the risk of a ship collision. If avoidance of a ship collision cannot be assured, the floating platform in a breakwater or the plant on an artificial island are more acceptable solutions. For these concepts, the plant must be located in shallow water as close as one mile to shore, since an insufficient number of shallow water sites exist at greater distances.

8.2 RECOMMENDATIONS

As a result of the study and the conclusions noted above, a number of specific recommendations are made. Action toward these recommendations might best be implemented by Federal or State Governments; by the utility companies most directly concerned; or in some cases, by the nuclear steam supply system manufacturers. No specific directions are given nor intended.

8.2.1 Sites and Planning

8.2.1.1 Inland Plant Plan. Recognizing the advantages in siting power plants inland, but noting the limited supply of cooling water in many inland areas of California, develop a plan designating regions which may be suitable for such plants. Modify the State water resource and transmission plan to include make-up water for evaporative cooling systems used in conjunction with power plants.

1. Study the potential development of plant locations near present aqueduct systems which presently supply large quantities of water for irrigation purposes. Consider the potential for rerouting irrigation water into once-through cooling systems in some plants to be located upstream of irrigation areas. Discharge water would be cooled by evaporation while flowing to the downstream irrigation systems. (Increased evaporation of this water will result from higher water temperatures in the aqueduct.)
2. Consider the alternative of developing new water sources and water transmission systems to regions where power plants potentially might be located.
3. Consider a combination of these approaches to satisfy the development time frame.
4. Consider the potential location of inland plant sites at existing hydro projects which contained dammed reservoirs, and which have too low a power generation capacity, or are inefficient as compared with current power generation plants. These reservoirs could serve to feed make-up water to evaporative cooling systems, or might be sufficiently large enough to constitute an evaporative lake.

8.2.1.2 Water Allocation Study. Review existing water rights and allocations from the California Water Plan. Assess the utilization of this water and the potential for reassigning rights for power plant cooling purposes, if shown to be in the best overall interests of the State.

8.2.1.3 Seismic Intensity Maps. A principal factor in seeking nuclear power plant sites in California is the avoidance of areas with high seismic risk. The magnitude of seismic activity at any location is based on the seismic history of the area under consideration and of adjacent areas. Fault maps exist and general plots show contours of seismic intensity. However, a study should be accomplished in which, based on known faults and historic seismic intensities in coastal and relatively flat inland areas, predicted intensities are determined and microzonation grid maps are prepared to indicate these values as an aid in plant siting.

8.2.1.4 Hillside Topographic Study. Aboveground coastal hillside locations appear acceptable for power plant sites. These sites generally are located on the inland side of the coastal road, and it is desirable to validate the existence of suitable topography in greater detail than was possible in this study. Such investigations may tend to increase or decrease the potential availability of suitable sites.

8.2.1.5 Lagoon Topographic Study. If it can be ascertained that floating platforms in an onshore lagoon would be publicly acceptable, then conduct a detailed investigation to determine the existence of suitable topography in low population zones to increase the accuracy of the limited investigation made in this study.

8.2.2 Siting Concepts

8.2.2.1 Hillside Concept Study. Validate cost estimates and other factors for the hillside plant by preparing a concept study based on a potentially acceptable site.

8.2.2.2 Preferred Underground Concepts. Incentives may be generated for locating plants underground because of factors not considered in this study. In this case, concepts which should be given greater consideration are those underground in nonmassive, poorly cemented materials or in massive, sedimentary rock since more coastal sites with these materials exist in California than the other materials studied. The problems which may be associated with mining in a sedimentary rock and the development of a detailed quality design concept appear greater than in the cut-and-cover approach in poorly cemented materials. Therefore, investigate the potential problems which might be encountered in excavating and supporting massive sedimentary rock in California and thereby validate the cost estimates, feasibility, and risks used in this study.

8.2.2.3 Seismic Evaluation of Floating Platform in Lagoon. One of the principal advantages anticipated in the use of a floating platform supported plant in a lagoon is the lower seismic risk. Detailed studies in this regard are lacking to determine the reality of this assumption. Perform a conceptual seismic analysis of a floating plant, moored in an enclosed shallow water environment to determine the impact of seismic activity on the floating body.

8.2.2.4 Floating Plant Fabrication Facilities. One of the constraints in considering floating platform-mounted plants is the question of providing fabrication facilities on the west coast, or the practicality of towing plants here from the east coast. Therefore, investigate the practicality of supplying such plants to the west coast.

8.2.3 Dry Cooling Systems

8.2.3.1 Dry Cooling Towers. The use of dry cooling towers for inland plants where water is not readily available appears to be a reasonable alternative to wet towers, considering cost and environmental impact. However, demonstration is needed to establish feasibility in the sizes required for large central station plants. Since this concept represents a means of reducing the requirement for large quantities of water as a constraint in siting inland plants, demonstration projects requiring smaller units should be initiated and then project sizes increased on subsequent larger plants so that feasibility can be established.

8.2.3.2 HTGR Development with Gas Turbine and Dry Cooling Systems. The application of high temperature gas cooled reactor system with a gas turbine provides an opportunity for reducing the strain on a limited water supply which often is characteristic of inland sites. The high temperature heat discharged from this system has a greater differential with the environment and thereby provides a greater efficiency and more economical dry cooling tower system than is afforded by the thermal transfer from closed loop steam systems. Efforts to develop the gas turbine and dry tower peculiar to the HTGR system should be encouraged.

8.2.4 Risk Assessments

Risk evaluations made for this study are dependent on the frequency of occurrence of the postulated natural or man-made events which cause the risk. Data on the frequency of these events are inadequate. Existing data are of uncertain meaning in regard to

evaluating siting concepts and even less data are available for evaluating specific sites. Refinements in risk assessments may affect ranking of concepts. It is recommended that a more detailed risk analysis be performed on the most favorable siting concepts from each of the three basic groups: aboveground, underground, and offshore. The analysis should include a detailed investigation of frequency of occurrence of events and potential mitigation systems.