6.2.1.6 Kelp beds

The three kelp beds, San Mateo, San Onofre, and Barn, located near SONGS (Fig. 6.1) are being studied. A brief outline of the scope of effort at the three kelp beds is as follows:

1. Three benthic stations are located in and about the San Onofre kelp bed and one each at Barn kelp and San Mateo kelp. Stations are quantitatively assessed quarterly.

2. Kelp canopies and rock substrate are mapped for areal extent on a quarterly basis.

3. Water nutrient analysis for ammonia, nitrates, nitrites, and phosphate are taken monthly at all three beds. Water samples are taken from the surface and bottom from within each bed and offshore of each bed. An additional offshore station serves as a monitoring area for upwelling.

4. Kelp tissue analysis for nutrient content is conducted on a monthly basis at all three kelp beds. Each leaf is analyzed for nitrogen content.

5. An assessment of the health of the kelp plants in the three beds is made on a quarterly basis. Parameters assessed include: success of juvenile recruitment, density of kelp plants, amount of encrusting organisms and grazing by herbivores and abundance of senile and diseased plants.

6. Aerial infra-red photographs of the three kelp bed canopies will be taken on a monthly basis.

6.2.2 Water quality monitoring program

The preoperational water quality monitoring program is an expansion of the existing program required by the Environmental Technical Specifications for SONGS 1. This program is designed to establish baseline characteristics of selected oceanographic parameters for comparison with data obtained during the operation of SONGS. This comparison will allow determination of the extent to which SONGS operation alters water quality. Those parameters identified in the FES-CP and in this document which might be altered include: pH, temperature, turbidity, certain heavy metals, and dissolved oxygen.

Sea water temperature-depth profiles are measured bimonthly at stations in the area of the Units 2 and 3 diffusers and at a reference station outside of the area of predicted thermal influence. Stations are as follows: two within each of zones 1B, 2B, 1C, OC, 2C, and 6, six stations within zone OB (Fig. 6.1). Additionally, sea water temperatures are continuously monitored near the surface, at mid-depth, and near the bottom at a permanent station in zone OB. Temperatures from each depth are recorded hourly. The accuracy of the system is ±0.5 degrees centigrade, ±30 minutes per month.

Turbidity is monitored bimonthly at two stations within each of zones 1B, 2B, 1C, OC, 2C, and 6, and at six stations within zone OB (Fig. 6.1). The pH is monitored bimonthly at four sampling stations — one in each of zones OB, 1B, 2B, and 6. Dissolved oxygen is measured bimonthly at four stations — one in each of zones OB, 1B, 2B, and 6.

Mid-depth ocean water samples and grab samples of ocean bottom sediments are collected quarterly in the area of the Units 2 and 3 diffusers and an appropriate control area for analysis of heavy metals. One station in each of zones 1B, 2B, OB, and 6 is sampled. Samples will be analyzed for chromium, iron, and titanium. Copper will not be monitored as the applicant has indicated that SONGS 2 and 3 will have titanium condenser tubing.

The staff considers this program adequate with the following additions: (1) the water quality data should be collected within a two-day period at maximum to permit station-by-station comparisons and the investigation of possible cause and effect relationships, and (2) all control samples should be collected from an area predicted to be unaffected by any discharge effect.

6.2.3 Terrestrial monitoring program

The baseline terrestrial environmental monitoring program for the FES-CP was very nominal. As a condition of the construction permit, the applicant expanded its terrestrial monitoring program to establish an adequate preoperational baseline by which the operational effects of SONGS 2 and 3 may be judged. Biological data were collected seasonally in order to document changes in the biotic communities over a one-year time span. Methods utilized included

small mammal trapping; bird censusing; observations of reptiles, amphibians, and large mammals; plant species lists; and vegetation analyses using the line intercept and quadrat methods. Results of this expanded monitoring program are presented in Sect. 2.5.1.

The applicant has proposed and is currently monitoring areas of cut and fill associated with construction of the plant and transmission lines to detect areas of erosion (ER, Appendix 6A, Special Studies I). Visual inspections are conducted and documented biweekly; any erosion resulting from the applicant's construction activities will receive appropriate corrective action.

6.2.4 Radiological monitoring program

Radiological environmental monitoring programs are established to provide data on measurable levels of radiation and radioactive materials in the site environs. Appendix I to 10 CFR Part 50 requires that the relationship between quantities of radioactive material released in effluents during normal operation, including anticipated operational occurrences, and resultant radioactive doses to individuals from principal pathways of exposure be evaluated. Monitoring programs are conducted to verify the effectiveness of in-plant controls used for reducing the release of radioactive materials and to provide public reassurance that undetected radioactivity will not build up in the environment. A surveillance program is established to identify changes in the use of unrestricted areas to provide a basis for modifications of the monitoring programs.

The preoperational phase of the monitoring program provides for the measurement of background levels and their variations along the anticipated important pathways in the area surrounding the plant; the training of personnel; and the evaluation of procedures, equipment, and techniques.

This is discussed in greater detail in NRC Regulatory Guide 4.1, Rev. 1, "Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants," and the Radiological Assessment Branch Technical Position, August 1977, "Standard Technical Specification for Radiological Environmental Monitoring Program."

The applicant has proposed a radiological environmental monitoring program to meet the objectives discussed above. The applicant's proposed preoperational radiological environmental monitoring program is presented in Sect. 6.1.5 of the applicant's Environmental Report.

The applicant proposes to initiate parts of the program two years prior to operation of the facility, with the remaining portions beginning either six months or one year prior to operation.

The staff concludes that the radiological preoperational monitoring program proposed by the applicant is acceptable.

6.2.5 Onsite meteorological monitoring program[1,2,3]

The original onsite meteorological program began in late 1964 with wind measurements at the top of a 19.5-m (64-ft) mast. In December 1970, the current meteorological monitoring program began with the installation of a 36.6-m (120-ft) tower atop the coastal bluff about 100 m (330 ft) west-northwest from the Unit 1 containment and 420 m (1380 ft) west-northwest of the Unit 2 containment. In October 1975 the tower was extended to a height of about 43 m (140 ft). Table 6.1 describes the kinds of measurements and their elevations on the tower between 1970 and the present.

Southern California Edison Company also conducted an onshore tracer test program at the San Onofre site. Among the objectives of the program were (1) to evaluate the appropriateness of using data measured on the existing site meteorological tower located on the coastal bluff for making dispersion estimates for onshore flows, and (2) to characterize dispersion representative of meteorological conditions during routine plant releases. NUS-1927[3] describes the test program and data.

On the basis of our analysis of the test data, we conclude that the wind and vertical temperature data measured on the San Onofre onsite (bluff) tower are acceptable for use in calculating atmospheric dispersion estimates for the site vicinity using the staff's model, described in Sect. 2.4.4.

Table 6.1. SONGS onsite meteorological instrumentation

Period	Measured parameter	Elevation above ground: Meters	Feet
December 1970–January 1973	Wind direction, speed and standard deviation	36.6	120
	Dry bulb vertical temperature gradient	36.6–6.1	120–20
January 1973–October 1975	Wind direction and speed	10, 36.6	33, 120
	Wind direction standard deviation	36.6	120
	Dry bulb temperature[a]	6.1	20
	Wet bulb temperature[b]	6.1	20
	Dry bulb vertical gradient	36.6–6.1	120–20
October 1975–present	Wind direction and speed	10, 20,[c] 40	33, 66, 131
	Wind direction standard deviation	10	33
	Dry bulb temperature	10	33,
	Dry bulb vertical gradient	40–10[d]	131–33
		36.6–6.1[c]	120–20

[a] Installed January 1974.
[b] Installed January 1974, removed January 1975.
[c] Temporary.
[d] Two sets of instruments.

6.3 OPERATIONAL MONITORING PROGRAMS

6.3.1 Aquatic biological monitoring program

The aquatic biological operational monitoring program will contain sampling programs which are extensions of the baseline and preoperational programs so that analyses can readily be made of the changes, if any, that occur in the aquatic environment due to plant operation. Thus, the ichthyoplankton study now being conducted and the required kelp preoperational program should be continued during operation of the facility until such time as it is possible to state credibly that no significant impacts result from the facility.

The new fish return system (Sect. 3.2.2) is expected to be about 90% effective according to laboratory models (ER, p. 5.1-20). Precise figures on its effectiveness will not be available until it is operated in conjunction with the heat dissipation system. The staff recommends that the applicant include a program for optimizing the effectiveness of the fish return system. This should include consideration of the delayed mortality of the fish successfully diverted by the fish return system by holding them for 48 to 96 hours before returning them to the ocean.

Consideration of deletion of the intertidal sampling program from the operational monitoring program for SONGS 2 and 3 is discussed in Sect. 6.2.1.5.

6.3.2 Water quality monitoring program

The water quality operational monitoring program is a continuation of the existing preoperational water quality monitoring program (Sect. 6.2.2). This continuity will allow for confirmatory monitoring to assess any possible changes to water quality due to operation of San Onofre Units 2 and 3.

The NRC and the California Regional Water Quality Control Board, San Diego Region (CRWQCB) have worked in a cooperative manner in order to develop the preoperational monitoring program for SONGS 2 and 3. NRC and CRWQCB have agreed to continue to work together to establish an operational phase NPDES permit which will incorporate the aquatic concerns from each regulatory group.

6.3.3 Terrestrial monitoring program

The applicant does not have an operational terrestrial monitoring program. The staff does not recommend any operational monitoring of floral or faunal species because no significant

effects have been identified between the operation of SONGS 2 & 3 and the terrestrial environment. The California Coastal Commission, however, requires the applicant to protect the bluffs 0.5 km (0.31 mile) south of the plant site for the duration of the site easement (expiration date, May 1, 2023) (ER, Appendix 12B).

6.3.4 Radiological monitoring program

The operational offsite radiological monitoring program is conducted to measure radiation levels and radioactivity in the plant environs. It assists and provides backup support to the detailed effluent monitoring (as recommended in NRC Regulatory Guide 1.21, "Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Release of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water Cooled Nuclear Power Plants") which is needed to evaluate individual and population exposures and to verify projected or anticipated radioactivity concentrations.

The applicant plans essentially to continued the proposed preoperational program during the operating period. However, refinements may be made in the program to reflect changes in land use or preoperational monitoring experience.

6.3.5 Meteorological monitoring program

The applicant plans to continue the program begun for the construction permit evaluation. The onsite meteorological tower provides data in accordance with the recommendations of Regulatory Guide 1.23, "Onsite Meteorological Programs." Furthermore, operating technical specifications require meteorological monitoring as a condition of operation.

6.4 RELATED ENVIRONMENTAL RESOURCE DATA

6.4.1 Thermal exception studies

As a condition of the exception to the State Thermal Plan granted by the California Regional Water Quality Control Board, San Diego, the applicants are required to perform studies to determine the optimum mode of heat treatment to control fouling organisms while minimizing adverse effects on marine life and to permit the Regional Board to set precise limits on the frequency, degree, and duration of heat treatment. These studies were submitted to the State Water Resources Control Board on January 31, 1979. On December 18, 1980, the Board determined that the studies fulfilled the conditions set earlier and further determined that the heat treatment operating conditions proposed by the applicant will assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife within the meaning of Section 316(a) of the Clean Water Act.

6.4.2 Marine Review Committee studies

The California Coastal Commission specified in the Coastal Zone Permit issued in 1974 for SONGS 2 and 3 that an extensive study be conducted at San Onofre. The study program is funded by the utility and is being administered by a three-member Marine Review Committee (MRC) appointed by the Coastal Commission. The intent of the program is to provide an independent assessment of the marine environment and a prediction of the potential impact of SONGS 2 and 3. The MRC has identified the following areas for study: physical, oceanographic, and ecological monitoring and modeling; plankton — far field effects and entrainment; fish populations, impingement, and diversion; and benthic communities, intertidal zone organisms, and kelp beds.

MRC has conducted studies at SONGS 2 and 3 in some of the above mentioned areas since August 1976. In November 1980 the MRC issued a report containing its recommendations, predictions, and rationale. The conclusions of the MRC are essentially consistent with those of the staff as described in Section 5 of this statement. Although noting uncertainties, the MRC has concluded that it does not predict at this time that substantial adverse effects on the marine environment are likely to occur from the operations of the SONGS cooling system. Accordingly, the report recommends no design changes but does recommend continued monitoring of the aquatic community to ensure that there is no serious ecological damage, especially to the kelp beds, as a result of plant operation. (See Appendix E for the options and recommendations of the Marine Review Committee.)

6.5 CONCLUSIONS

The preoperational and operational monitoring programs as described above give adequate attention to impacts discussed in this environmental impact statement.

REFERENCES

These documents are available for inspection and copying for a fee in the NRC Public Document room 1717 H Street, N.W., Washington, D.C. 20555

1. Southern California Edison Company, "San Onofre Nuclear Generating Station Units 2 and 3, Environmental Report - Operating License Stage," Docket No. 50-361/362, 1977.

2. Southern California Edison Company, "San Onofre Generating Station Units 2 and 3, Final Safety Analysis Report," Docket No. 50-361/362, 1977.

3. M. Septoff, A. E. Mitchell, and L. H. Teuscher, "Final Report of the Onshore Tracer Tests Conducted December 1976 through March 1977 at the San Onofre Nuclear Generating Station," Report NUS-1927, NUS Corporation, Rockville, Md., 1977.

7. ENVIRONMENTAL IMPACT OF POSTULATED ACCIDENTS

7.1 PLANT ACCIDENTS

The staff has considered the potential radiological impacts on the environment of possible accidents at the San Onofre Nuclear Generating Station Units 2 and 3 in accordance with a Statement of Interim Policy published by the Nuclear Regulatory Commission on June 13, 1980.[1] The following discussion reflects these considerations and conclusions.

The first section deals with general characteristics of nuclear power plant accidents including a brief summary of safety measures to minimize the probability of their occurrence and to mitigate their consequences if they should occur. Also described are the important properties of radioactive materials and the pathways by which they could be transported to become environmental hazards. Potential adverse health effects and impacts on society associated with actions to avoid such health effects are also identified.

Next, actual experience with nuclear power plant accidents and their observed health effects and other societal impacts are then described. This is followed by a summary review of safety features of the San Onofre Units 2 and 3 facilities and of the site that act to mitigate the consequences of accidents.

The results of calculations of the potential consequences of accidents that have been postulated in the design basis are then given. Also described are the results of calculations for the San Onofre site using probabilistic methods to estimate the possible impacts and the risks associated with severe accident sequences of exceedingly low probability of occurrence.

7.1.1 General characteristics of accidents

The term accident, as used in this section, refers to any unintentional event not addressed in Section 5.5 that results in a release of radioactive materials into the environment. The predominant focus, therefore, is on events that can lead to releases substantially in excess of permissible limits for normal operation. Such limits are specified in the Commission's regulations at 10 CFR Part 20 and 10 CFR Part 50, Appendix I.

There are several features which combine to reduce the risk associated with accidents at nuclear power plants. Safety features in the design, construction, and operation comprising the first line of defense are to a very large extent devoted to the prevention of the release of these radioactive materials from their normal places of confinement within the plant. There are also a number of additional lines of defenses that are designed to mitigate the consequences of failures in the first line. Descriptions of these features for the San Onofre Units 2 and 3 plant may be found in the applicant's Final Safety Analysis Report,[2] and in the staff's Safety Evaluation Report.[3] The most important mitigative features are described in Section 7.1.3.1 below.

These safety features are designed taking into consideration the specific locations of radioactive materials within the plant, their amounts, their nuclear, physical, and chemical properties, and their relative tendency to be transported into and for creating biological hazards in the environment.

7.1.1.1 Fission product characteristics

By far the largest inventory of radioactive material in a nuclear power plant is produced as a byproduct of the fission process and is located in the uranium oxide fuel pellets in the form of fission products. These pellets are contained in the fuel rods which make up the fuel assemblies. During periodic refueling shutdowns, the assemblies containing these fuel pellets are transferred to a spent fuel storage pool so that the second largest inventory of radioactive material is located in this storage area. Much smaller inventories of radioactive materials are also normally present in the water that circulates in the primary coolant system and in the systems used to process gaseous and liquid radioactive wastes in the plant.

These radioactive materials exist in a variety of physical and chemical forms. Their potential for dispersion into the environment is dependent not only on mechanical forces that might physically transport them, but also upon their inherent properties, particularly their volatility. The majority of these materials exist as nonvolatile solids over a wide range of temperatures. Some, however, are relatively volatile solids and a few are gaseous in nature. These characteristics have a significant bearing upon the assessment of the environmental radiological impact of accidents.

The gaseous materials include radioactive forms of the chemcially inert noble gases krypton and xenon. These have the highest potential for release into the atmosphere. If a reactor accident were to occur involving degradation of the fuel cladding, the release of substantial quantities of these radioactive gases from the fuel is a virtual certainty. Such accidents are very low frequency but credible events (see Section 7.1.2). It is for this reason that the safety analysis of each nuclear power plant analyzes a hypothetical design basis accident that postulates the release of the entire contained inventory of radioactive noble gases from the fuel into the containment structure. If further released to the environment as a possible result of failure of safety features, the hazard to individuals from these noble gases would arise predominantly through the external gamma radiation from the airborne plume. The reactor containment structure is designed to minimize this type of release.

Radioactive forms of iodine are formed in substantial quantities in the fuel by the fission process and in some chemical forms may be quite volatile. For this reason, they have traditionally been regarded as having a relatively high potential for release from the fuel. The chemical forms in which the fission product radioiodines are found are generally solid materials at room temperature, however, so that they have a strong tendency to condense (or "plate out") upon cooler surfaces. In addition, most of the iodine compounds are quite soluble in, or chemically reactive with, water. Although these properties do not inhibit the release of radioiodines from degraded fuel, they do act to mitigate the release from containment structures that have large internal surface areas and that contain large quantities of water as a result of an accident. The same properties affect the behavior of radioiodines that may "escape" into the atmosphere. Thus, if rainfall occurs during a release, or if there is moisture on exposed surfaces, e.g., dew, the radioiodines will show a strong tendency to be absorbed by the moisture. Because of radioiodine's relatively high solubility and distinct radiological hazard, its potential for release to the atmosphere has also been reduced by the use of special containment spray systems. If released to the environment, the principal radiological hazard associated with the radioiodines is ingestion into the human body and subsequent concentration in the thyroid gland.

Other radioactive materials formed during the operation of a nuclear power plant have lower volatilities and therefore, by comparison with the noble gases and iodine, a much smaller tendency to escape from degraded fuel unless the temperature of the fuel becomes quite high. By the same token, such materials, if they escape by volatilization from the fuel, tend to condense quite rapidly to solid form again when transported to a lower temperature region and/or dissolve in water when present. The former mechanism can have the result of producing some solid particles of sufficiently small size to be carried some distance by a moving stream of gas or air. If such particulate materials are dispersed into the atmosphere as a result of failure of the containment barrier, they will tend to be carried downwind and deposit on surface features by gravitational settling or by precipitation (fallout), where they will become "contamination" hazards in the environment.

All of these radioactive materials exhibit the property of radioactive decay with characteristic half-lives ranging from fractions of a second to many days or years (see Table 7.1). Many of them decay through a sequence or chain of decay processes and all eventually become stable (nonradioactive) materials. The radiation emitted during these decay processes is the reason that they are hazardous materials.

7.1.1.2 Exposure pathways

The radiation exposure (hazard) to individuals is determined by their proximity to the radioactive material, the duration of exposure, and factors that act to shield the individual from the radiation. Pathways for the transport of radiation and radioactive materials that lead to radiation exposure hazards to humans are generally the same for accidental as for "normal" releases. These are depicted in Section 5, Figure 5.17. There are two additional possible pathways that could be significant for accident releases that are not shown in Figure 5.17. One of these is the fallout onto open bodies of water of radioactivity initially carried in the air. The second would be unique to an accident that results in temperatures inside the reactor core sufficiently high to cause melting and subsequent penetration of the basemat underlying the reactor by the molten core debris. This creates the potential for the release of radioactive material into the hydrosphere through contact with ground water. These pathways may lead to external exposure to radiation, and to internal exposures if radioactivity is inhaled, or ingested from contaminated food or water.

Table 7.1 Activity of Radionuclides in a San Onofre Reactor Core at 3560 MWt

Group/Radionuclide	Radioactive Inventory (millions of curies)	Half-life (days)
A. NOBLE GASES		
Krypton-85	0.63	3,950
Krypton-85m	27	0.183
Krypton-87	52	0.0528
Krypton-88	76	0.117
Xenon-133	190	5.28
Xenon-135	38	0.384
B. IODINES		
Iodine-131	95	8.05
Iodine-132	130	0.0958
Iodine-133	190	0.875
Iodine-134	210	0.0366
Iodine-135	170	0.280
C. ALKALI METALS		
Rubidium-86	0.029	18.7
Cesium-134	8.3	750
Cesium-136	3.3	13.0
Cesium-137	5.2	11,000
D. TELLURIUM-ANTIMONY		
Tellurium-127	0.029	18.7
Tellurium-127m	1.2	109
Tellurium-129	34	0.048
Tellurium-129m	5.9	34.0
Tellurium-131m	14	1.25
Tellurium-132	130	3.25
Antimony-127	6.8	3.88
Antimony-129	37	0.179
E. AKALINE EARTHS		
Strontium-89	100	52.1
Strontium-90	4.1	11,030
Strontium-91	120	0.403
Barium-140	180	12.8
F. COBALT AND NOBLE METALS		
Cobalt-58	0.87	71.0
Cobalt-60	0.32	1,920
Molybdenum-99	180	2.8
Technetium-99m	160	0.25
Ruthenium-103	120	39.5
Ruthenium-105	80	0.185
Ruthenium-106	28	366
Rhodium-105	55	1.50
G. RARE EARTHS, REFRACTORY OXIDES AND TRANSURANICS		
Yttrium-99	4.3	2.67
Yttrium-91	130	59.0
Zirconium-95	170	65.2
Zirconium-97	170	0.71
Niobium-95	170	35.0
Lanthanum-140	180	1.67
Cerium-141	170	32.3
Cerium-143	150	1.38
Cerium-144	95	284

Table 7.1 (Continued)

Group/Radionuclide	Radioactive Inventory (millions of curies)	Half-life (days)
G. RARE EARTHS, REFRACTORY OXIDES AND TRANSURANICS (Continued)		
Praseodymium-143	150	13.7
Neodymium-147	67	11.1
Neptunium-239	1800	2.35
Plutonium-238	0.063	32,500
Plutonium-239	0.023	8.9×10^6
Plutonium-240	0.023	2.4×10^6
Plutonium-241	3.8	5,350
Americium-241	0.0019	1.5×10^5
Curium-242	0.56	163
Curium-244	0.026	6,630

NOTE: The above grouping of radionuclides corresponds to that in Table 7.3.

It is characteristic of these pathways that during the transport of radioactive material by wind or by water, the material tends to spread and disperse, like a plume of smoke from a smokestack, becoming less concentrated in larger volumes of air or water. The result of these natural processes is to lessen the intensity of exposure to individuals downwind or downstream of the point of release, but they also tend to increase the number who may be exposed. For a release into the atmosphere, the degree to which dispersion reduces the concentration in the plume at any downwind point is governed by the turbulence characteristics of the atmosphere which vary considerably with time and from place to place. This fact, taken in conjunction with the variability of wind direction and the presence or absence of precipitation, means that accident consequences are very much dependent upon the weather conditions existing at the time.

7.1.1.3 Health effects

The cause and effect relationships between radiation exposure and adverse health effects are quite complex[4] but they have been more exhaustively studied than any other environmental contaminant.

Whole-body radiation exposure resulting in a dose greater than about 10 rem for a few persons and about 25 rem for nearly all people over a short period of time (hours) is necessary before any physiological effects to an individual are clinically detectable. Doses about to 10 to 20 times larger than the latter dose, also received over a relatively short period of time (hours to a few days), can be expected to cause some fatal injuries. At the severe, but extremely low probability end of the accident spectrum, exposures of these magnitudes are theoretically possible for persons in the close proximity of such accidents if measures are not or cannot be taken to provide protection, e.g., by sheltering or evacuation.

Lower levels of exposures may also constitute a health risk, but the ability to define a direct cause and effect relationship between any given health effect and a known exposure to radiation is difficult given the backdrop of the many other possible reasons why a particular effect is observed in a specific individual. For this reason, it is necessary to assess such effects on a statistical basis. Such effects include cancer and genetic changes in future generations after exposure of a prospective parent. Cancer in the exposed population may begin to develop only after a lapse of 2 to 15 years (latent period) from the time of exposure and then continue over a period of about 30 years (plateau period). However, in the case of exposure of fetuses (in utero), cancer may begin to develop at birth (no latent period) and end at age 10 (i.e., the plateau period is 10 years). The health consequences model currently being used is based on the 1972 BEIR Report of the National Academy of Sciences.[5]

Most authorities are in agreement that a reasonable and probably conservative estimate of the statistical relationship between low levels of radiation exposure to a large number of people is within the range of about 10 to 500 potential cancer deaths (although zero

is not excluded by the data) per million man-rem. The range comes from the latest NAS BEIR III Report (1980)[6] which also indicates a probable value of about 150. This value is virtually identical to the value of about 140 used in the current NRC health effects models. In addition, approximately 220 genetic changes per million person-rem would be projected by BEIR III over succeeding generations. That also compares well with the value of about 260 per million man-rem currently used by the NRC staff.

7.1.1.4 Health effects avoidance

Radiation hazards in the environment tend to disappear by the natural process of radioactive decay. Where the decay process is a slow one, however, and where the material becomes relatively fixed in its location as an environmental contaminant (e.g., in soil), the hazard can continue to exist for a relatively long period of time--months, years, or even decades. Thus, a possible consequential environmental societal impact of severe accidents is the avoidance of the health hazard rather than the health hazard itself, by restrictions on the use of the contaminated property or contaminated foodstuffs, milk, and drinking water. The potential economic impacts that this can cause are discussed below.

7.1.2 Accident experience and observed impacts

The evidence of accident frequency and impacts in the past is a useful indicator of future probabilities and impacts. As of mid-1980, there were 69 commercial nuclear power reactor units licensed for operation in the United States at 48 sites with power generating capacities ranging from 50 to 1130 megawatts electric (MWe). (The San Onofre Units 2 and 3 are designed for 1140 MWe each.) The combined experience with these units represents approximately 500 reactor years of operation over an elapsed time of about 20 years. Accidents have occurred at several of these facilities.[7] Some of these have resulted in releases of radioactive material to the environment, ranging from very small fractions of a curie to a few million curies. None is known to have caused any radiation injury or fatality to any member of the public, nor any significant individual or collective public radiation exposure, nor any significant contamination of the environment. This experience base is not large enough to permit a reliable quantitative statistical inference. It does, however, suggest that significant environmental impacts due to accidents are very unlikely to occur over time periods of a few decades.

Melting or severe degradation of reactor fuel has occurred in only one of these 69 operating units, during the accident at Three Mile Island - Unit 2 (TMI-2) on March 28, 1979. In addition to the release of a few million curies of xenon-133, it has been estimated that approximately 15 curies of radioiodine was also released to the environment at TMI-2.[8] This amount represents an extremely minute fraction of the total radioiodine inventory present in the reactor at the time of the accident. No other radioactive fission products were released in measurable quantity.

It has been estimated that the maximum cumulative offsite radiation dose to an individual was less than 100 millirem.[8,9] The total population exposure has been estimated to be in the range from about 1000 to 3000 man-rem. This exposure could produce between none and one additional fatal cancer over the lifetime of the population. The same population receives each year from natural background radiation about 240,000 man-rem and approximately a half-million cancers are expected to develop in this group over its lifetime,[8,9] primarily from causes other than radiation. Trace quantities (barely above the limit of detectability) of radioiodine were found in a few samples of milk produced in the area. No other food or water supplies were impacted.

Accidents at nuclear power plants have also caused occupational injuries and a few fatalities but none attributed to radiation exposure. Individual worker exposures have ranged up to about 4 rems as a direct consequence of accidents, but the collective worker exposure levels (man-rem) are a small fraction of the exposures experienced during normal routine operations that average about 500 man-rem per reactor year.

Accidents have also occurred at other nuclear reactor facilities in the United States and in other countries.[7] Due to inherent differences in design, construction, operation, and purpose of most of these other facilities, their accident record has only indirect relevance to current nuclear power plants. Melting of reactor fuel occurred in at least seven of these accidents, including the one in 1966 at the Enrico Fermi Atomic Power Plant Unit 1. This was a sodium-cooled fast breeder demonstration reactor designed to generate 61 MWe. The damages were repaired and the reactor reached full power four years following the accident. It operated successfully and completed its mission in 1973. This accident did not release any radioactivity to the environment.

A reactor accident in 1957 at Windscale, England released a significant quantity of radioiodine, approximately 20,000 curies, to the environment. This reactor, which was not operated to generate electricity, used air rather than water to cool the uranium fuel. During a special operation to heat the large amount of graphite in this reactor, the fuel overheated and radioiodine and noble gases were released directly to the atmosphere from a 123-m (405-ft) stack. Milk produced in a 512-km^2 (200-mi^2) area around the facility was impounded for up to 44 days. This kind of accident cannot occur in a reactor like San Onofre, however, because of its water-cooled design.

7.1.3 Mitigation of accident consequences

The Nuclear Regulatory Commission is conducting a safety evaluation of the application to operate San Onofre Units 2 and 3. Although this evaluation will contain more detailed information on plant design, the principal design features are presented in the following section.

7.1.3.1 Design features

San Onofre Units 2 and 3 are essentially identical units. Each contains features designed to prevent accidental release of radioactive fission products from the fuel and to lessen the consequences should such a release occur. Many of the design and operating specifications of these features are derived from the analysis of postulated events known as design basis accidents. These accident preventive and mitigative features are collectively referred to as engineered safety features (ESF). The possibilities or probabilities of failure of these systems are incorporated in the assessments discussed in section 7.1.4.

Each steel-lined concrete containment building is a passive mitigating system which is designed to minimize accidental radioactivity releases to the environment. Safety injection systems are incorporated to provide cooling water to the reactor core during an accident to prevent or minimize fuel damage. The containment atmosphere cooling system provides heat removal capability inside the containment following steam release accidents and helps to prevent containment failure due to overpressure. Similarly, the containment spray system is designed to spray cool water into the containment atmosphere. The spray water also contains an additive (sodium hydroxide) which will chemically react with any airborne radioiodine to remove it from the containment atmosphere and prevent its release to the environment.

The mechanical systems mentioned above are supplied with emergency power from onsite diesel generators in the event that normal offsite station power is interrupted.

The fuel handling area of each unit is located in a fuel building, a low leakage structure with a safety-grade ventilation system for accident mitigation. The safety-grade ventilation system is an internal recirculation system and contains both charcoal and high efficiency particulate filters. If radioactivity were to be released into the building, it would be drawn through the ventilation system, and radioactive iodine and particulate fission products would be removed from the flow stream, reducing the concentration within the building and hence the amount that might leak to the atmosphere.

There are features of each unit that are necessary for its power generation function that can also play a role in mitigating certain accident consequences. For example, the main condenser, although not classified as an ESF, can act to mitigate the consequences of accidents involving leakage from the primary to the secondary side of the steam generators (such as steam generator-tube ruptures).

If normal offsite power is maintained, the ability of the plant to send contaminated steam to the condenser instead of releasing it through the safety valves or atmospheric dump valves can significantly reduce the amount of radioactivity released to the environment. In this case, the fission product removal capability of the normally operating off-gas treatment system would come into play.

Much more extensive discussions of the safety features and characteristics of San Onofre Units 2 and 3 may be found in the applicant's Final Safety Analysis Report.[2] The staff evaluation of these features is addressed in the Safety Evaluation Report. In addition, the implementation of the lessons learned from the TMI-2 accident, in the form of improvements in design and procedures, and operator training, will significantly reduce the likelihood of a degraded core accident which could result in large releases of fission products to the containment. Specifically, the applicant will be required to meet those TMI-related requirements specified in NUREG-0737. As noted in Section 7.1.4.7, no credit has been taken for these actions and improvements in discussing the radiological risk of accidents in this supplement.

7.1.3.2 Site features

In the process of considering the suitability of the site of San Onofre Units 2 and 3, pursuant to NRC's Reactor Site Criteria in 10 CFR Part 100, consideration was given to certain factors that tend to minimize the risk and the potential impact of accidents. First, the site has an exclusion area as required in 10 CFR Part 100. The exclusion area of the (33.8 hectare (83.6-acre)) site has a minimum exclusion distance of (1968 ft) 600 meters from the containment centerlines to the closest site boundary. The applicant's authority to control all activities within the exclusion area was acquired by a grant of easement from the United States of America made by the Secretary of the Navy. The exclusion area is traversed by old U.S. Highway 101, the San Diego Freeway (Interstate 5), and the Atchison, Topeka and Santa Fe Railroad. The exclusion area on the ocean side extends over a narrow strip of beach and into the Pacific Ocean.

The applicant's control of the landward portion of the exclusion area extends to the mean high tide line but does not include the strip of beach lying between high and low tide that is occasionally uncovered. This strip of "tidal beach" is owned by the State of California and is used primarily as a passageway for individuals walking along the beach. The applicant's lack of control of this strip of tidal beach has been adjudicated in a Commission proceeding (see ALAB-432) and has been determined to be de minimis on the basis of its occasional use, together with the high probability that any radiation exposure to individuals in this zone will be within the guideline values of 10 CFR Part 100 in the event of an emergency.

Activities within the exclusion area which are unrelated to plant operation include a gas pipeline, railroad traffic, through traffic on the San Diego Freeway, and local recreational traffic on old U.S. Highway 101. Recreational activities in the plant vicinity include swimming, camping, and surfing. Recreational activities, such as sunbathing or picnicking, are discouraged within the landward portion of the exclusion area (the area landward of the contour of mean high tide). The seaward portion of the exclusion area (the area seaward of the contour of mean high tide) may be occupied by small numbers of people for passageway transit between the public beach areas upcoast and downcoast from the plant. Additional small numbers of people may be anticipated to occasionally be in the water within the exclusion area.

Transient access to an approximate 2.02-hectare (5-acre) at the southwest corner of the site for the purposes of viewing the scenic bluffs and barrancas will be on an unimproved walkway. The applicant has estimated that at any one time a maximum of 100 persons will be in the walkway and a 2.02-hectare (5-acre) viewing area, and on the beach and water below the mean high tide. The improved walkway affords landward passage between the two beach areas.

In case of a radiological emergency, the applicants have made arrangements with agencies of the State and local governments to control all traffic on the railroad, roadways, and waterways.

Second, beyond and surrounding the exclusion area is a low population zone (LPZ), also required by Part 100. This is a circular area of 3.14 km (1.95 mi) outer radius. Within this zone the applicant must assure that there is reasonable probability that appropriate measures could be taken on behalf of the residents in the event of a serious accident.

The San Onofre State Beach northwest and southwest of the San Onofre exclusion areas represents a public waterfront recreation area within an 8-km (5-mi) radius of the plant. The beach south of the nuclear facility is used for swimming, hiking, and vehicle parking. The 1036 m (3,400-ft) stretch of beach north of the site is used primarily for surfing.

The largest communities in the vicinity of the site are San Clemente, located about 4.8 km (3 mi) away, which had a 1976 estimated population of 23,000, and the U.S. Marine Corp base Camp Pendleton, with a total estimated population of about 33,000. The Marine Corp base consists of several population clusters or camps located at distances from 2.4 km to 19.31 km (1.5 mi to 12 mi) away.

The applicant has estimated a peak transient population in major tourist and recreational activities along Interstate 5 in a 16-km (10-mi) radius of the plant to be 56,600 persons. This occurs during the summer months and is due to persons engaged in water sport recreation on the Pacific Ocean beach and coastal waters.

The Mexican border lies about 121 km (75 mi) from San Onofre, toward the southeast. The cities of Tijuana, Mexicali, and Ensenada are within 241 km (150 mi) of the site.

The safety evaluation of the San Onofre site has also included a review of potential external hazards, i.e., activities offsite that might adversely affect the operation of the plant and cause an accident. This review encompassed nearby industrial, transportation, and military facilities that might create explosive, missile, toxic gas, or similar hazards. The staff concluded at the construction permit stage that the hazards from the nearby military facility are negligibly small. However, the hazards from the nearby interstate highway, the railroad right of way, and natural gas pipelines, are still under review by the staff. Reevaluation of these hazards has been requested by the staff, and the results will be reported in a supplement to the staff's Safety Evaluation Report. It is anticipated that the review will show that either the risks are acceptably small or may be acceptably small.

7.1.3.3 Emergency preparedness

Emergency preparedness plans including protective action measures for the San Onofre facility and environs are in an advanced, but not yet fully completed stage. In accordance with the provisions of 10 CFR Section 50.47, effective November 3, 1980, no operating license will be issued to the applicant unless a finding is made by the NRC that the state of onsite and offsite emergency preparedness provides reasonable assurance that adequate protective measures can and will be taken in the event of a radiological emergency. Among the standards that must be met by these plans are provisions for two Emergency Planning Zones (EPZ). A plume exposure pathway EPZ of about 16 km (10 mi) in radius and an ingestion exposure pathway EPZ of about 80 km (50 mi) in radius are required. Other standards include appropriate ranges of protective actions for each of these zones, provisions for dissemination to the public of basic emergency planning information, provisions for rapid notification of the public during a serious reactor emergency, and methods, systems, and equipment for assessing and monitoring actual or potential offsite consequences in the EPZs of a radiological emergency condition.

NRC findings will be based upon a review of the Federal Emergency Management Agency (FEMA) findings and determinations as to whether State and local government emergency plans are adequate and capable of being implemented, and on the NRC assessment as to whether the applicant's onsite plans are adequate and capable of being implemented. NRC staff findings will be reported in a supplement to the staff's Safety Evaluation Report. Although the presence of adequate and tested emergency plans cannot prevent the occurrence of an accident, it is the judgment of the staff that they can and will substantially mitigate the consequences to the public if one should occur.

7.1.4 Accident risk and impact assessment

7.1.4.1 Design basis accidents

As a means of assuring that certain features of the San Onofre Units 2 and 3 plants meet acceptable design and performance criteria, both the applicant and the staff have analyzed the potential consequences of a number of postulated accidents. Some of these could lead to significant releases of radioactive materials to the environment, and calculations have been performed to estimate the potential radiological consequences to persons offsite. For each postulated initiating event, the potential radiological consequences cover a considerable range of values depending upon the particular course taken by the accident and the conditions, including wind direction and weather, prevalent during the accident.

In the safety analysis of the San Onofre Units 2 and 3 plants, three categories of accidents have been considered. These categories are based upon their probability of occurrence and include (a) incidents of moderate frequency, i.e., events that can reasonably be expected to occur during any year of operation, (b) infrequent accidents, i.e., events that might occur once during the lifetime of the plant, and (c) limiting faults, i.e., accidents not expected to occur but that have the potential for significant releases of radioactivity. The radiological consequences of incidents in the first category, also called anticipated operational occurrences, are discussed in Section 5. Initiating events postulated in the second and third categories for the San Onofre Units 2 and 3 are shown in Table 7.2. These are collectively designated design basis accidents in that specific design and operating features as described above in Section 7.1.3.1 are provided to limit their potential radiological consequences. Approximate radiation doses that might be received by a person at the nearest site boundary (600 meters from the plant) are also shown in the table, along with a characterization of the time duration of the releases.

Table 7.2 Approximate Radiation Doses from Design Basis Accidents, Conservative Calculational Model

	Duration of Release	Dose (rem at 600 m[1]) Whole Body	Thyroid
Infrequent Accidents:			
Waste Gas Tank Failure	< 2 hr	< 3	< 30
Steam Generator Tube[2] Rupture	< 2 hr	< 3	2
Fuel Handling Accident	< 2 hr	7	40
Limiting Faults:			
Main Steam Line Break	< 2 hr	6	10
Control Rod Ejection	hrs-days	< 6	60
Large-Break LOCA	hrs-days	3	100

[1]The nearest site boundary.
[2]See NUREG-0651[6] for descriptions of three steam generator tube rupture accidents that have occurred in the United States.

The calculational model used is a conservative one in that it is expected to provide a reasonable estimate of the potential upper bound for individual exposures. The results are used to implement the provisions of 10 CFR 100 and to establish performance requirements for certain engineered safety features. The conservative assumptions used in these analyses include: (1) large (upper bound) amounts of radioactive material released by the initiating event, (2) single failures in important equipment, including operating the engineered safety features in a degraded mode,* (3) very adverse meteorological conditions, and (4) no reduction in exposure due to possible protective actions.

The results of these calculations show that, for these events, the limiting whole-body exposures are not expected to exceed 7 rem. They also show that radioiodine releases have the potential for offsite exposures ranging up to about 100 rem to the thyroid. For such an exposure to occur, an individual would have to be located at a point on the site boundary where the radioiodine concentration in the plume has its highest value and inhale at a breathing rate characteristic of a person jogging, for a period of two hours. The health risk to an individual receiving such a thyroid exposure is the potential appearance of benign or malignant thyroid nodules in about 4 out of 100 cases, and the development of a fatal cancer in about 2 out of 1000 cases.

The realistically expected consequences, were one of these initiating events actually to occur, would be very substantially less. Therefore, the risk is judged to be extremely small for these design basis accidents. The subject of risk is more fully discussed in Section 7.1.4.6 below.

7.1.4.2 Probabilistic assessment of severe accidents

In this and the following three sections, there is a discussion of the probabilities and consequences of accidents of greater severity than the design basis accidents identified in the previous section. As a class, they are considered less likely to occur, but their consequences could be more severe, both for the plant itself and for the environment. These severe accidents, heretofore frequently called Class 9 accidents, can be distinguished from design basis accidents in two primary respects: they involve substantial physical deterioration of the fuel in the reactor core, including overheating to the point of melting, and they involve deterioration of the capability of the containment structure to perform its intended function of limiting the release of radioactive materials to the environment.

*The containment structure, however, is assumed to prevent leakage in excess of that which can be demonstrated by testing, as provided in 10 CFR Section 100.11(a).

The assessment methodology employed is that described in the Reactor Safety Study (RSS) which was published in 1975.[10*] The San Onofre Units 2 and 3 are Combustion Engineering-designed pressurized water reactors (PWR) having similar design and operating characteristics to the Surry Unit 1 facility used in the RSS as a prototype for PWRs. This assessment has used as its starting point, therefore, the same set of accident sequences that were found in the RSS to be dominant contributors to risk in the prototype PWR. The same set of nine release categories, designated PWR 1 through 9, have also been used to represent the spectrum of severe accident releases that are hypothesized for the San Onofre Units 2 and 3. Characteristics of these categories are shown in Table 7.3. Sequences initiated by natural phenomena such as tornadoes, floods, or seismic events and those that could be initiated by deliberate acts of sabotage are not included in these events sequences. The radiological consequences of such events would not be different in kind from those which have been treated. Moreover, it is the staff's judgment, based upon design requirements of 10 CFR Part 50, Appendix A, relating to effects of natural phenomena, and safeguards requirements of 10 CFR Part 73, that these events do not contribute significantly to risk. The facts upon which the staff based its Safe Shutdown Earthquake and its conclusions regarding the effects of natural phenomena on the plant are given in the Safety Evaluation Report.

A calculated probability per reactor year associated with each release category is also shown in the second column in Table 7.3. These probabilities are the result of a detailed engineering analysis of the prototype PWR in the Reactor Safety Study. There are substantial uncertainties in these probabilities. This is due, in part, to difficulties associated with the quantification of human error and to inadequacies in the data base on failure rates of individual plant components that were used to calculate the probabilities[11] (see Section 7.1.4.7 below). Also, the detailed engineering analysis represents a plant designed by a different nuclear steam supply system designer (CE versus Westinghouse) with different detailed designs. The probability of accident sequences from the Surry plant were used to give a perspective of the societal risk at San Onofre Units 2 and 3 because, although the probabilities of particular accident sequences may be substantially different, the overall effect of all sequences taken together is likely to be within the uncertainties. Except as indicated in the footnotes in Table 7.3, the staff has no present basis for judging whether the probabilities may be too high or too low. The error band for the probabilities of some of the event sequences could be as great as a factor of 100. The event sequences in categories PWR 1-7 lead to partial or complete melting of the reactor core while those in the last two categories do not involve melting of the core. In release categories 1 to 3, the event sequences include containment failure by steam explosion, hydrogen burning, or overpressure. In release categories 6 and 7, the dominant containment failure mode is by melt-through of the containment base mat. The other release categories contain event sequences in which the systems intended to isolate the containment fail to act properly.

The magnitudes (curies) of radioactivity releases for each category are obtained by multiplying the release fractions shown in Table 7.3 by the amounts that would be present in the core at the time of the hypothetical accident. These are shown in Table 7.1 for a San Onofre plant at a core thermal power level of 3560 megawatts.

The potential radiological consequences of these releases have been calculated by the consequence model used in the RSS[12] and adapted to apply to a specific site. The essential elements are shown in schematic form in Figure 7.1. Environmental parameters specific to the San Onofre site have been used and include the following:

(1) Meteorological data for the site representing a full year of consecutive hourly measurements and seasonal variations.

(2) Projected population in the United States and Mexico for the year 2000 extending throughout regions of 80 and 560 km (50 and 350 mi) radius from the site.

(3) The habitable land fraction within the 560-km (350-mi) radius.

(4) Land use statistics, on a state-wide basis, including farm land values, farm product values including dairy production, and growing season information, for the State of California and each surrounding State within the 560-km (350-mi) region.

(5) Land use statistics for Mexico on a country-wide basis. Farm land values, growing season information, and comparison between agriculture and dairy products are based on comparison with U.S. values for nearby States. Farm product values are based on Mexico-average Gross National Product and "agriculture" percentage.

*Because this report has been the subject of considerable controversy, a discussion of the uncertainties surrounding it is provided in Section 7.1.4-7.

Table 7.3

Summary of Atmospheric Release Categories Representing Hypothetical Accidents in a PWR

Release Category	Probability (reactor-yr^{-1})	Fraction of Core Inventory Released[a]						
		Xe-Kr	I	Cs-Rb	Te-Sb	Ba-Sr	Ru[b]	La[c]
PWR 1	5.1×10^{-8}[d]	0.9	0.7	0.4	0.4	0.05	0.4	3×10^{-3}
PWR 2	7×10^{-6}	0.9	0.7	0.5	0.3	0.06	0.02	4×10^{-3}
PWR 3	2.3×10^{-6}	0.8	0.2	0.2	0.3	0.02	0.03	3×10^{-3}
PWR 4	2.1×10^{-11}	0.6	0.09	0.04	0.03	5×10^{-3}	3×10^{-3}	4×10^{-4}
PWR 5	5×10^{-8}	0.3	0.03	9×10^{-3}	5×10^{-3}	1×10^{-3}	6×10^{-4}	7×10^{-5}
PWR 6	6×10^{-7}	0.3	3×10^{-3}	8×10^{-4}	1×10^{-3}	9×10^{-5}	7×10^{-5}	1×10^{-5}
PWR 7	4×10^{-5}	6×10^{-3}	4×10^{-5}	1×10^{-5}	2×10^{-5}	1×10^{-6}	1×10^{-6}	2×10^{-7}
PWR 8	4×10^{-5}	2×10^{-3}	1×10^{-4}	5×10^{-4}	1×10^{-6}	1×10^{-8}	0	0
PWR 9	4×10^{-4}	3×10^{-6}	1×10^{-7}	6×10^{-7}	1×10^{-9}	1×10^{-11}	0	0

(a) Background on the isotope groups and release mechanisms is presented in Appendix VII, WASH-1400 (Ref. 9).

(b) Includes Ru, Rh, Co, Mo, Tc.

(c) Includes, Y, La, Zr, Nb, Ce, Pr, Nd, Np, Pu, Am, Cm.

(d) Current understanding of the phenomenon of containment failure by steam explosion embodied in this release category indicates the probability should be lower than stated.

NOTE: Refer to Section 7.1.4.6 for a discussion of uncertainties in risk estimates.

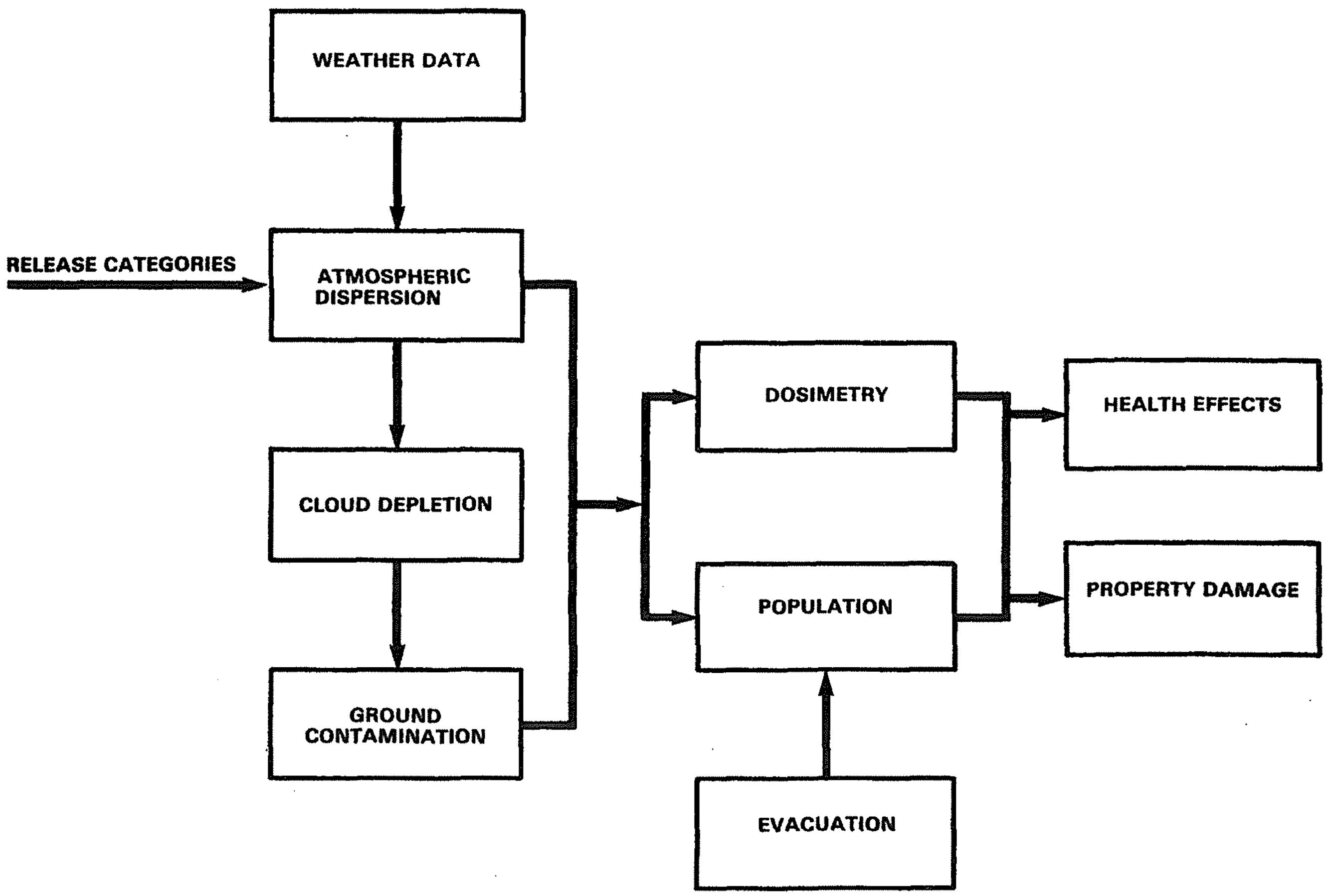

Figure 7.1 Schematic outline of consequence model

To obtain a probability distribution of consequences the calculations are performed assuming the occurrence of each accident release sequence at each of 91 different "start" times throughout a one-year period. Each calculation utilizes the site specific hourly meteorological data and seasonal information for the time period following each "start" time. The consequence model also contains provisions for incorporating the consequence reduction benefits of evacuation and other protective actions. Early evacuation of people would considerably reduce the exposure from the radioactive cloud and the contaminated ground in the wake of the cloud passage. The evacuation model used (see Appendix F) has been revised from that used in the RSS for better site-specific application. The quantitative characteristics of the evacuation model used for the San Onofre site are best estimate values made by the staff and based upon evacuation time estimates prepared by the applicant. Actual evacuation effectiveness could be greater or less than that characterized but would not be expected to be much less, even under adverse conditions.

The other protective actions include: (a) either complete denial of use (interdiction), or permitting use only at a sufficiently later time after appropriate decontamination of food stuffs such as crops and milk, (b) decontamination of severely contaminated environment (land and property) when it is considered to be economically feasible to lower the levels of contamination to protective action guide (PAG) levels, and (c) denial of use (interdiction) of severely contaminated land and property for varying periods of time until the contamination levels reduce to such values by radioactive decay and weathering so that land and property can be economically decontaminated as in (b) above. These actions would reduce the radiological exposure to the people from immediate and/or subsequent use of or living in the contaminated environment.

Early evaucation and other protective actions as mentioned above are considered as essential sequels to serious nuclear reactor accidents involving significant release of radioactivity to the atmosphere. Therefore, the results shown for San Onofre reactor include the benefits of these protective actions.

There are also uncertainties in the estimates of consequences, and the error bounds may be as large as they are for the probabilities. It is the judgment of the staff, however, that it is more likely that the calculated results are overestimates of consequences rather than underestimates.

The results of the calculations using this consequence model are radiological doses to individuals and to populations, health effects that might result from these exposures, costs of implementing protective actions, and costs associated with property damage by radioactive contamination.

7.1.4.3 Dose and health impacts of atmospheric releases

The results of the calculations of dose and health impacts performed for the San Onofre facility and site are presented in the form of probability distributions in Figures 7.2 through 7.5 and are included in the impact Summary Table 7.4. All of the nine release categories shown in Table 7.3 contribute to the results, the consequences from each being weighted by its associated probability.

Figure 7.2 shows the probability distribution for the number of persons who might receive whole body doses equal to or greater than 200 rem and 25 rem, and thyroid doses equal to or greater than 300 rem from early exposure,* all on a per-reactor-year basis. The 200 rem whole body dose figure corresponds approximately to a threshold value for which hospitalization would be indicated for the treatment of radiation injury. The 25 rem whole body (which has been identified earlier as the lower limit for clinically obervable physiological effects in nearly all people) and 300 rem thyroid figures correspond to the Commission's guidelines values for reactor siting in 10 CFR Part 100.

The figure shows in the left-hand portion that there is less than 1 chance in 100,000 per year (i.e. 10^{-5}) that one or more persons may receive doses equal to or greater than any of the doses specified. The fact that the three curves run almost parallel in horizontal lines initially shows that if one person were to receive such doses, the chances are about the same that several tens to hundreds would be so exposed. The chances of larger numbers of persons being exposed at those levels are seen to be considerably smaller. For example, the chances are about 1 in 100,000,000 (i.e. 10^{-8}) that 100,000 or more people might receive doses of 200 rem or greater. A majority of the exposures reflected in this figure would be expected to occur to persons within a 80-km (50-mi) radius of the plant. Virtually all would occur with a 160-km (100-mi) radius.

*The containment structure, however, is assumed to prevent leakage in excess of that which can be demonstrated by testing, as provided in 10 CFR Section 100.11(a).

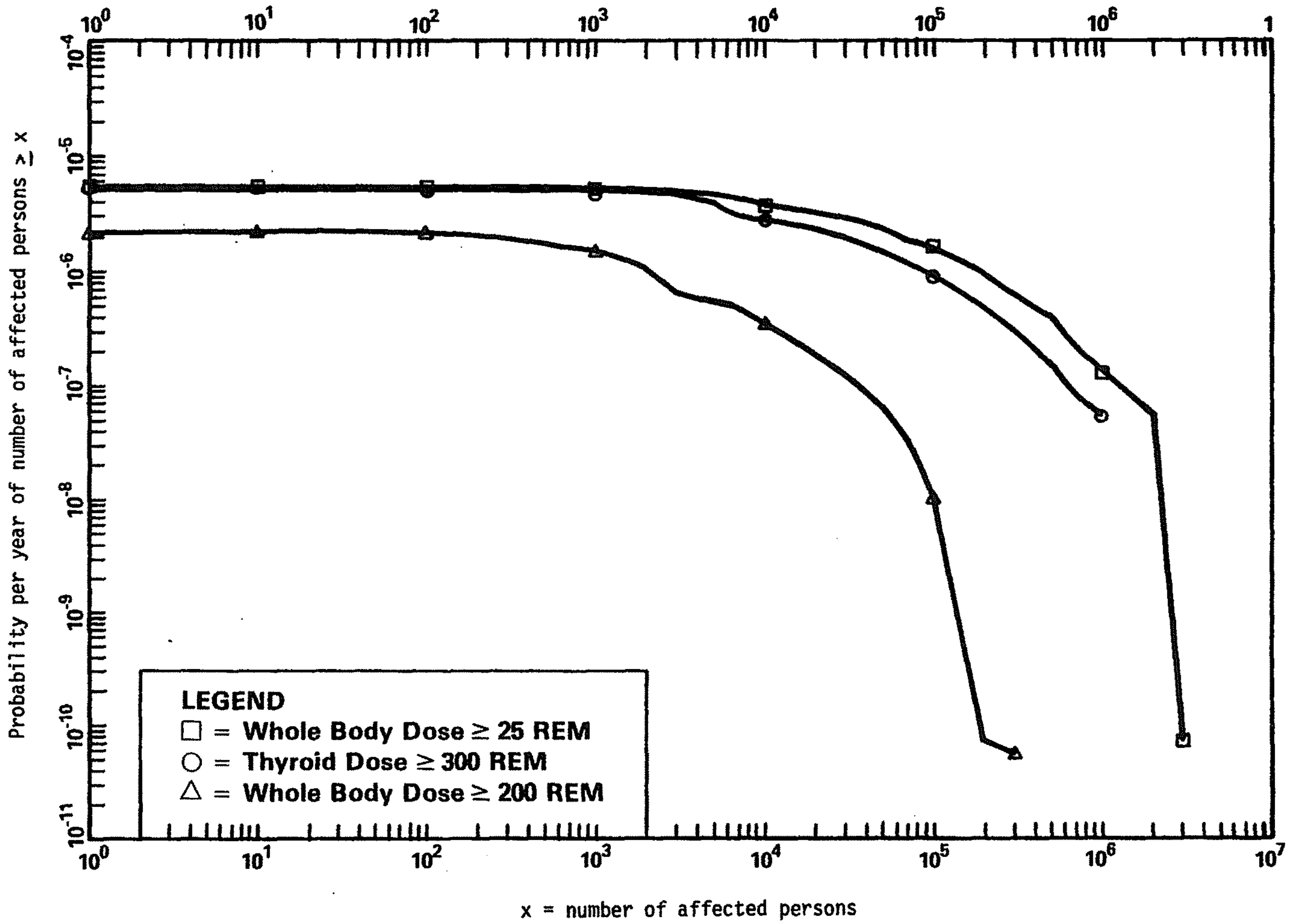

Figure 7.2 Probability distribution of individual dose impacts
(See Section 7.1.4.6 for a discussion of uncertainties in risk estimates.)

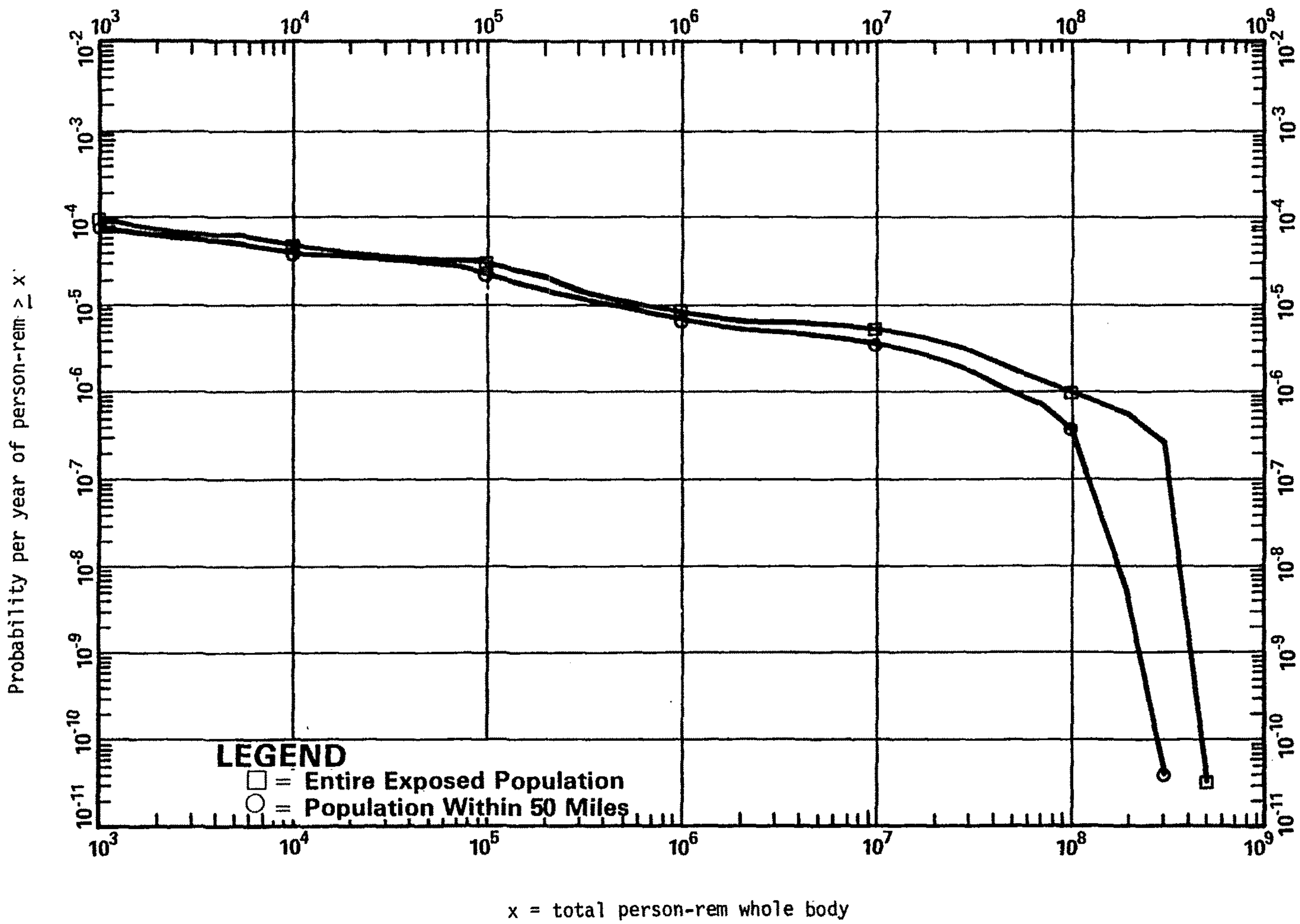

Figure 7.3 Probability distribution of population exposures. (See Section 7.1.4.6 for discussion of uncertainties in risk estimates.) (To convert miles to kilometers, multiply by 1.6.)

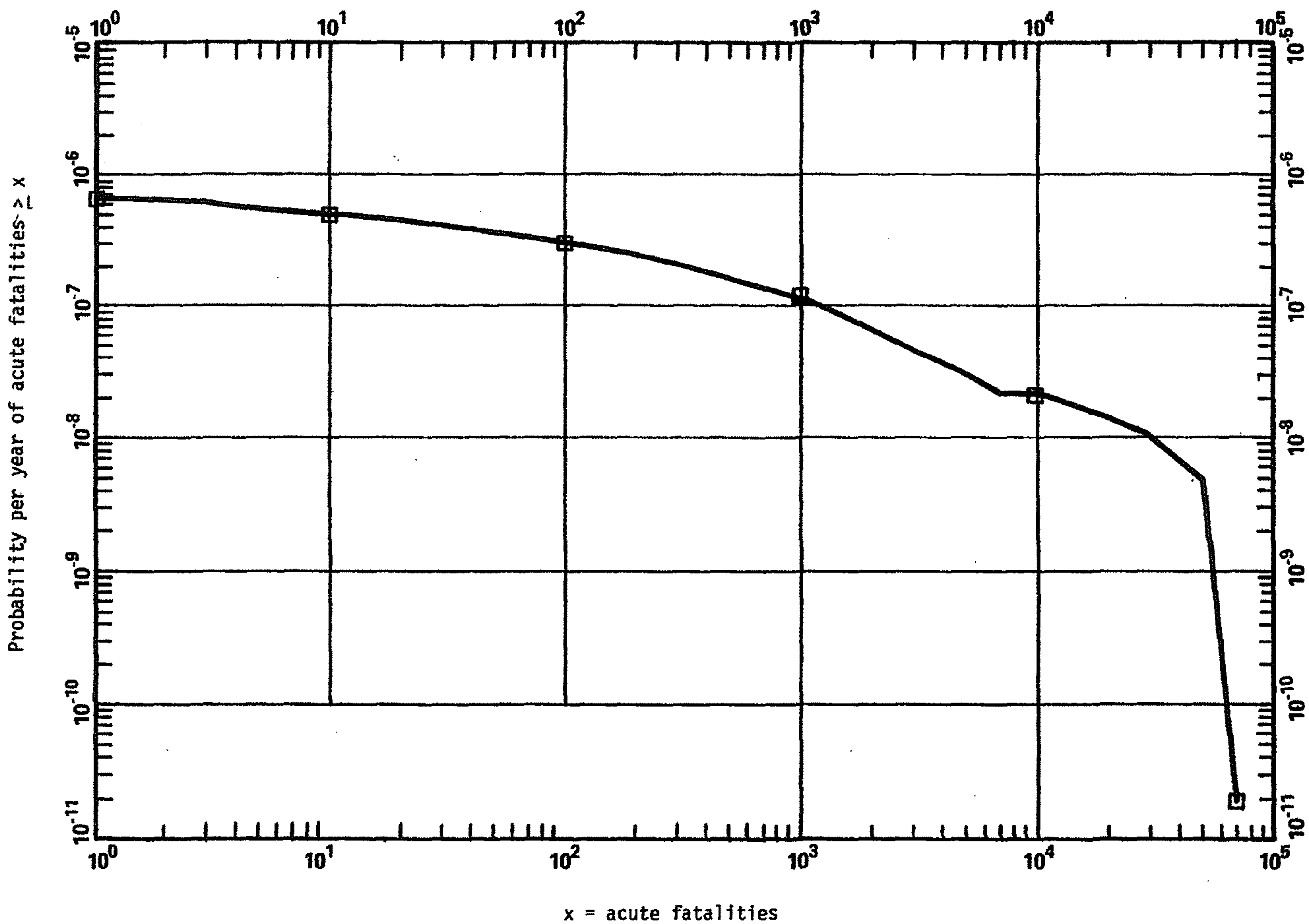

Figure 7.4 Probability distribution of acute fatalities. (See Section 7.1.4.6 for discussion of uncertainties in risk estimates.)

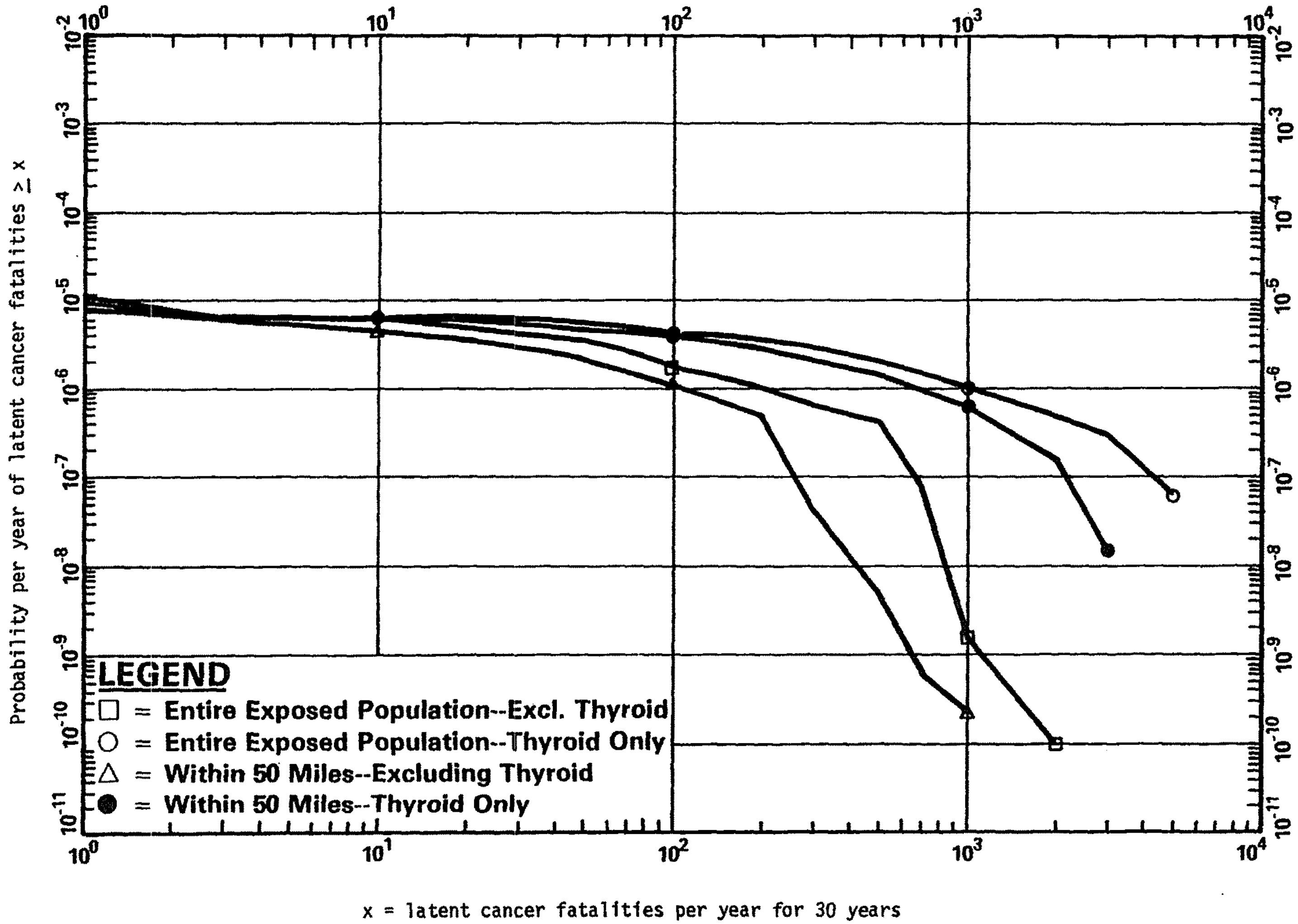

Figure 7.5 Probability distribution of cancer fatalities. (See Section 7.1.4.6 for discussion of uncertainties in risk estimates.) (To convert miles to kilometers, multiply by 1.6.)

Table 7.4 Summary of Environmental Impacts and Probabilities

Probability of impact per year	Persons exposed over 200 rem	Persons exposed over 25 rem	Acute fatalities	Population exposure, millions of man-rem 80 km/total	Latent* cancers, 80 km/total	Cost of offsite mitigating actions, $ millions
10^{-4}	< 1	< 1	< 1	< 0.001	< 60	< 0.001
10^{-5}	< 1	< 1	< 1	0.4/0.6	< 60	12
5×10^{-6}	< 1	160	< 1	2/10	1,400/2,500	400
10^{-6}	2,000	190,000	< 1	45/100	23,000/36,000	5,000
10^{-7}	31,000	1,100,000	1,100	110/300	71,000/143,000	15,000
10^{-8}	100,000	2,000,000	30,000	170/340	12,000/24,000	35,000
Related Figure	7.2	7.2	7.4	7.3	7.5	7.6

*Genetic effects would be approximately twice the number of latent cancers. Thirty times the values shown in the Figure 7.5 are shown in this column reflecting the 30-year period over which they might occur.

NOTE: Refer to Section 7.1.4.6 for a discussion of uncertainties in risk estimates.

Figure 7.3 shows the probability distribution for the total population exposure in person-rem, i.e., the probability per reactor-year that the total population exposure will equal or exceed the values given. A substantial fraction of the population exposure would occur within 80 km (50 mi) but the more severe releases (PWR 1-6) would result in exposure to persons beyond the 80-km (50-mi) range as shown.

For perspective, population doses shown in Figure 7.3 may be compared with the annual average dose to the population within 80 km (50 mi) of the San Onofre site due to natural background radiation of 700,000 man-rem, and to the anticipated annual population dose to the general public from normal station operation of 460 man-rem (excluding plant workers) (Section 5, Table 5.3 and 5.5).

Figure 7.4 shows the probability distribution for acute fatalities, representing radiation injuries that would produce fatalities within about one year after exposure. Virtually all of the acute fatalities would be expected to occur within a 64-km (40-mi) radius. The results of the calculations shown in this figure and in Table 7.4 reflect the effect of evacuation within the 16-km (10-mi) plume exposure pathway EPZ only. For the very low probability accidents having the potential for causing radiation exposure above the threshold for acute fatality at distances beyond 16 km (10 mi), it would be realistic to expect that authorities would evacuate persons at all distances at which such exposures might occur. Acute fatality consequences would therefore reasonably be expected to be very much less than the numbers shown.

Figure 7.5 represents the statistical relationship between population exposure and the induction of fatal cancers that might appear over a period of many years following exposure. The impacts on the total population and the population within 80 km (50 mi) are shown separately. Further, the fatal, latent cancers have been subdivided into those attributable to exposures of the thyroid and all other organs.

7.1.4.4 Economic and societal impacts

As noted in Section 7.1.1, the various measures for avoidance of adverse health effects including those due to residual radioactive contamination in the environment are possible consequential impacts of severe accidents. Calculations of the probabilities and magnitudes of such impacts for the San Onofre facility and environs have also been made. Unlike the radiation exposure and adverse health effect impacts discussed above, impacts associated with adverse health effects avoidance are more readily transformed into economic impacts.

The results are shown as the probability distribution for costs of offsite mitigating actions in Figure 7.6 and are included in the impact Summary Table 7.4. The factors contributing to these estimated costs include the following:

- Evacuation costs
- Value of crops contaminated and condemned
- Value of milk contaminated and condemned
- Costs of decontamination of property where practical
- Indirect costs due to loss of use of property and incomes derived therefrom.

The last named costs would derive from the necessity for interdiction to prevent the use of property until it is either free of contamination or can be economically decontaminated.

Figure 7.6 shows that at the extreme end of the accident spectrum these costs could exceed tens of billions of dollars but that the probability that this would occur is exceedingly small, less than one chance in a hundred million per year.

Additional economic impacts that can be monetized include costs of decontamination of the facility itself and the costs of replacement power. Probability distributions for these impacts have not been calculated, but they are included in the discussion of risk considerations in Section 7.1.4.6 below.

7.1.4.5 Releases to groundwater

A pathway for public radiation exposure and environmental contamination that could be associated with severe reactor accidents was identified in Section 7.1.1.2 above. Consideration has been given to the potential environmental impact of this pathway for the San Onofre plant. The principal contributors to the risk are the core melt accidents associated with the PWR-1 through 7 release categories. The penetration of the basemat of the

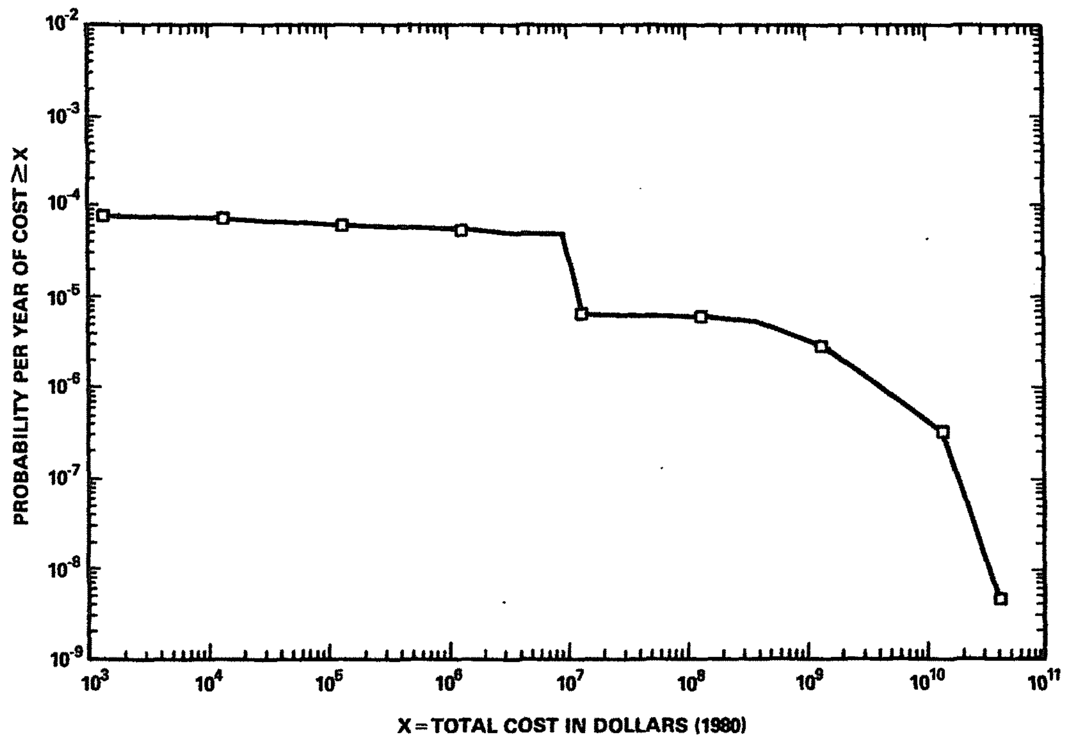

Figure 7.6 Probability distribution of cost of offsite mitigative measures

containment building can release molten core debris to the strata beneath the plant. Soluble radionuclides in this debris can be leached and transported with groundwater to downgradient domestic wells used for drinking or to surface water bodies used for drinking water, aquatic food and recreation. In pressurized water reactors, such as the San Onofre unit, there is an additional opportunity for groundwater contamination due to the release of contaminated sump water to the ground through a breach in the containment.

An analysis of the potential consequences of a liquid pathway release of radioactivity for generic sites was presented in the "Liquid Pathway Generic Study" (LPGS).[13] The LPGS compared the risk of accidents involving the liquid pathway (drinking water, irrigation, aquatic food, swimming and shoreline usage) for four conventional, generic land-based nuclear plants and a floating nuclear plant, for which the nuclear reactors would be mounted on a barge and moored in a water body. Parameters for the land-based sites were chosen to represent averages for a wide range of real sites and are thus "typical," but represented no real site in particular.

The discussion in this section is an analysis to determine whether or not the San Onofre site liquid pathway consequences would be unique when compared to land-based sites considered in the LPGS. The method consists of a direct scaling of the LPGS population doses based on the relative values of key parameters characterizing the LPGS "ocean" site and the San Onofre site. The parameters which were evaluated included amounts of radioactive materials entering the ground, groundwater travel time, sorption on geological media, surface water transport, aquatic food consumption, and shoreline usage.

Doses to individuals and populations were calculated in the LPGS without consideration of interdiction methods such as isolating the contaminated groundwater or denying use of the water. In the event of surface water contamination, commercial and sports fishing, as well as many other water-related activities would be restricted. The consequences would therefore be largely economic or social, rather than radiological. In any event, the individual and population doses for the liquid pathway range from fractions to very small fractions of those that can arise from the airborne pathways.

The San Onofre reactors are situated above the San Mateo Formation, which is about 274-m (876.8-ft) thick and consists of medium to coarse-grained sandstone.[2] Groundwater at the site occurs between elevation 0 and 1.5 m (4.8 ft) Mean Low-Low Water, under water table conditions. The basemat of the reactors would be beneath the water table.

The groundwater gradient is clearly toward the ocean. There are no wells between the site and the ocean, so no groundwater users could be affected by an accidental contamination from the plant. There is virtually no possibility of a reversal of the groundwater gradient due to heavy pumping inland, particularly because such a reversal would at the same time cause an unacceptable intrusion of saltwater into the aquifer. Therefore, liquid radioactivity released from a core melt accident could only cause contamination by being transported through the groundwater and subsequently released to the Pacific Ocean.

The staff's most conservative estimate of the groundwater travel time would be 215 days. For groundwater travel times of this magnitude, it is clear that the most important radionuclide contributors to the liquid pathway population dose would be Sr-90 and Cs-137. Conservative values of the retardation factors, which reflect the effects of sorption of the radionuclides on geologic materials, were estimated on media similar to the granular materials under the site[14] to be 31 for Sr-90 and 2204 for Cs-137. The mean transport time from the reactor building to the Pacific Ocean is therefore conservatively estimated to be about 16 years for Sr-90 and 1080 years for Cs-137. When these travel times are compared to 5.7 years for Sr-90 and 51 years for Cs-137 in the LPGS land-based ocean site case, the relatively larger travel times for the San Onofre site would allow a smaller portion of the radioactivity to enter the surface water. This reduces the Sr-90 release to about 78% of the LPGS value. Virtually all of the Cs-137 would have decayed before reaching surface water.

Contaminants released from the shoreline would disperse in the oceanic turbulence. The LPGS made no distinction between the turbulence which would be found in the east, gulf, or west coasts of the United States. The only assumption which can be made without site-specific data is that the mixing at the San Onofre and LPGS sites are similar.

The two major liquid pathway exposure pathways for an ocean site are aquatic food consumption and direct shoreline exposure.

The commercial and recreational finfish harvest for a rectangular block 80 km along shore and stretching 40 km offshore has been estimated by the staff from data provided in the

Environmental Report[15] to be about 13.1×10^6 kg. For comparison, the same size block using the LPGS ocean site fish catch densities would yield 5.8×10^6 kg of finfish.

Approximately 62% of population dose due to finfish consumption calculated in the LPGS was due to Cs-137 and approximately 38% was due to Sr-90. The only significant radionuclide which could reach the ocean in the San Onofre case would be Sr-90. The staff has conservatively estimated that the uninterdicted population dose in the San Onofre case would be about 69% of the LPGS land-based ocean case population dose for seafood consumption.

Nearly all of the direct shoreline exposure in the LPGS ocean-based site case was determined to emanate from Cs-137. Since virtually all of the Cs-137 would decay before reaching the ocean, the shoreline direct exposure can be eliminated from further consideration.

The San Onofre liquid pathway contribution to population dose has, therefore, been demonstrated to be smaller than that predicted for the LPGS land-based ocean site, which represents a "typical" ocean site. Thus, the San Onofre site is not unique in its liquid pathway contribution to risk.

There are measures which could be taken to minimize the impact of the liquid pathway. The staff estimated that the minimum groundwater travel time from the San Onofre site to the Pacific Ocean would be hundreds of days. In addition, the holdup of important radionuclides would provide additional time to utilize engineering measures such as slurry walls and well-point dewatering to isolate the radioactive contaminants at the source.

7.1.4.6 Risk considerations

The foregoing discussions have dealt with both the frequency (or likelihood of occurrence) of accidents and their impacts (or consequences). Since the ranges of both factors are quite broad, it is useful to combine them to obtain average measures of environmental risk. Such averages can be particularly instructive as an aid to the comparison of radiological risks associated with accident releases and with normal operational releases.

A common way in which this combination of factors is used to estimate risk is to multiply the probabilities by the consequences. The resultant risk is then expressed as a number of consequences expected per unit of time. Such a quantification of risk does not at all mean that there is universal agreement that people's attitudes about risk, or what constitutes an acceptable risk, can or should be governed solely by such a measure. At best, it can be a contributing factor to a risk judgment, but not necessarily a decisive factor.

In Table 7.5 are shown average values of risk associated with population dose, acute fatalities, latent fatalities, and costs for evacuation and other protective actions. These average values are obtained by summing the probabilities multiplied by the consequences over the entire range of the distributions. Since the probabilities are on a per-year basis, the averages shown are also on a per-year basis.

Table 7.5 Annual Average Values of Environmental Risks Due to Accidents

Population exposure	
man-rem within 80 km	170
man-rem total	380
Acute fatalities	
permanent residents	0.001
beach visitors	0.00002
Latent cancer fatalities	
all organs excluding thyroid	0.022
thyroid only	0.011
Cost of protective actions and decontamination	$19,000

NOTE: See Section 7.1.4.6 for discussions of uncertainties in risk estimates.

The population exposure risk due to accidents may be compared with that for normal operational releases. These are shown in Section 5, Tables 5.3 and 5.5, for San Onofre Units 2 and 3 operating concurrently. The radiological dose to the population from normal operational releases may result in:

(1) late somatic effects in the form of fatal and nonfatal cancer in various body organs--following age and organ-specific latency periods--of the exposed population, and

(2) fatal and nonfatal genetic disorders in the future generations of the exposed population.

Because of the randomness of these effects, calculations of these effects are made from the population dose (man-rem). Absolute risk estimators of 140 deaths from expression of latent cancer in various body organs per 10^6 total-body man-rem in the exposed population and 260 cases of all forms of genetic disorders per 10^6 total-body man-rem in the future generations of the exposed population were derived from the 1972 BEIR report.[5] This derivation assumes a linear and nonthreshold dose-effect relationship at all sublethal dose levels. Using these risk estimators and 228 man-rem as the annual population dose (Table 5.5, adjusted for one reactor), the staff calculated that there may occur 0.03 cancer deaths in the exposed population and 0.06 genetic disorders in all future generatons of the exposed population from each year of operation of one reactor.

The comparison of 0.03 cancer deaths given above with about the same value for latent cancer deaths from Table 7.1.4-5 shows that the accident risks are comparable to those for normal operational releases.

There are no acute fatality nor economic risks associated with protective actions and decontamination for normal releases; therefore, these risks are unique for accidents. For perspective and understanding of the meaning of the acute fatality risk of 0.001 per year, however, the staff notes that to a good approximation the population at risk is that within about 16 km (10 mi) of the plant, about 92,000 persons in the year 2000. Accidental fatalities per year for a population of this size, based upon overall averages for the United States, are approximately 20 for motor vehicle accidents, 7 from falls, 3 from drowning, 3 from burns, and 1 from firearms (ref. 5, p. 577).

As a separate item under acute fatalities in Table 7.5 is an entry of 0.00002 for "Beach visitors." As discussed in Section 7.1.3.2, the beaches near the site are heavily used for recreation. The average number of visitors has been estimated, based on seasonal and daily variation. The effects on the visitors are tallied separately because in actuality they are likely to be permanent residents from other nearby locations.

Figure 7.7 shows the calculated risk expressed as whole-body dose to an individual from early exposure as a function of the distance from the plant within the plume exposure pathway EPZ. The values are on a per-reactor-year basis and all accident sequences and release categories in Table 7.3 contributed to the dose, weighted by their associated probabilities. Calculated risk to an individual living within the plume exposure pathway EPZ of San Onofre of acute death due to potential accidents in the reactor is shown in Figure 7.8 as curves of constant risk per year to an individual as a function of distance due to potential reactor accidents. Figure 7.9 shows the same type of isopleths for death from latent cancer. Directional variation of these curves reflect the variation in the average fraction of the year the wind would be blowing into different directions from the plant. For comparison the following risk of fatality per year to an individual living in the U.S. may be noted (ref. 4, p. 577); automobile accident 2.2×10^{-4}, falls 7.7×10^{-5}, drowning 3.1×10^{-5}, burning 2.9×10^{-5}, and firearms 1.2×10^{-5}.

The economic risk associated with protective actions and decontamination could be compared with property damage costs associated with alternative energy generation technologies. The use of fossil fuels, coal or oil, for example, would emit substantial quantities of sulfur dioxide and nitrogen oxides into the atmosphere, and, among other things, lead to environmental and ecological damage through the phenomenon of acid rain (Ref. 4, 559-560). This effect has not, however, been sufficiently quantified to draw a useful comparison at this time.

There are other economic impacts and risks that can be monetized that are not included in the cost calculations discussed in Section 7.1.4.4. These are accident impacts on the facility itself that result in added costs to the public, i.e., ratepayers, taxpayers, and/or shareholders. These are costs associated with decontamination of the facility itself and costs for replacement power.

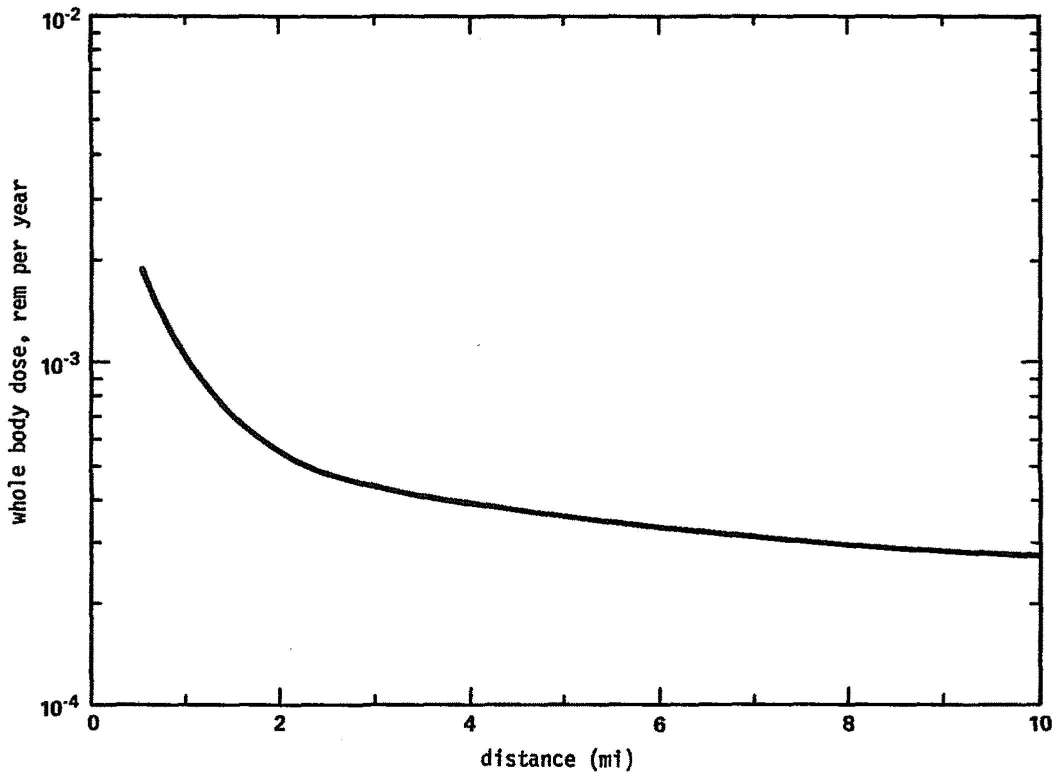

Figure 7.7 Individual risk of dose as a function of distance. (To convert mi to km, multiply by 1.6.)

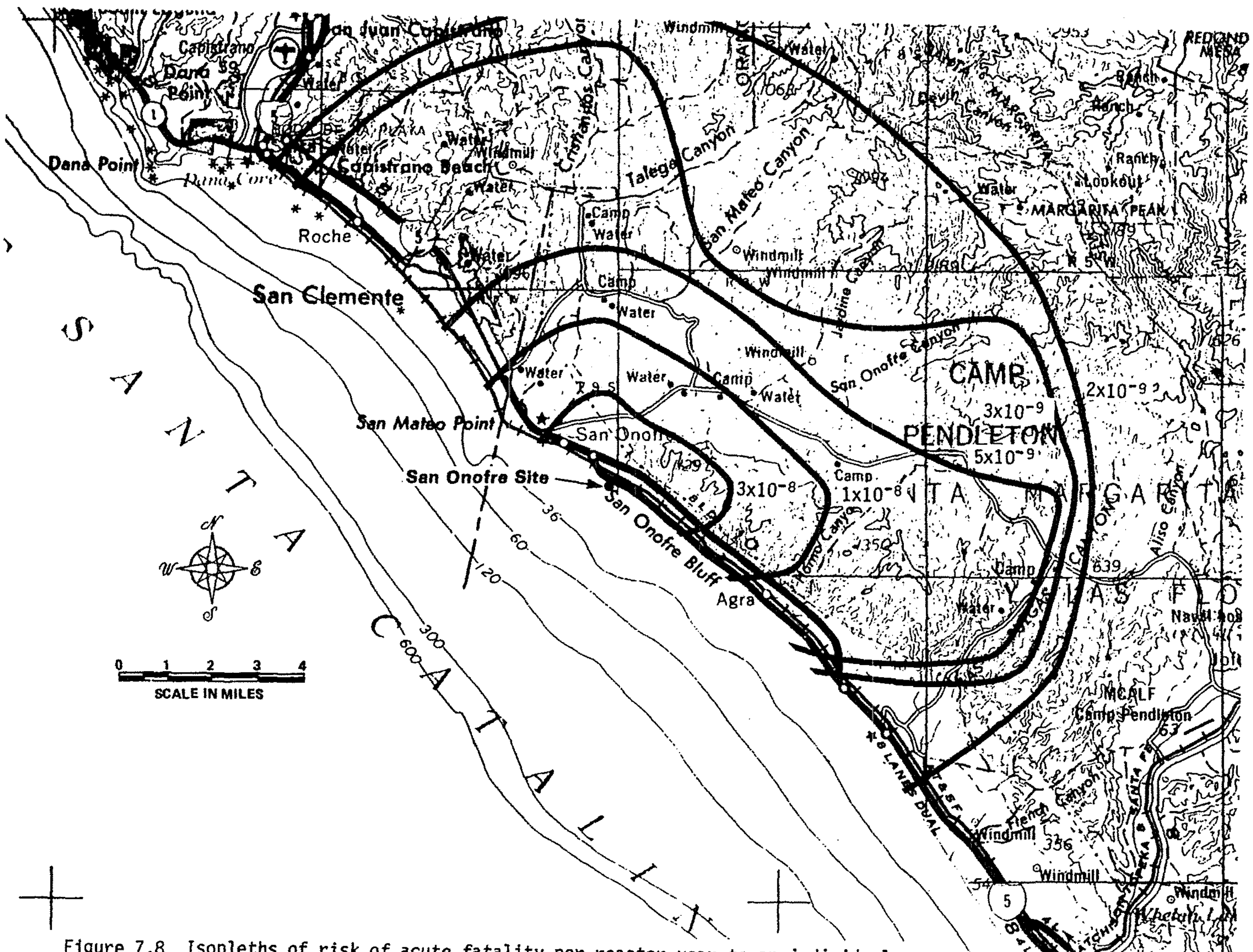

Figure 7.8 Isopleths of risk of acute fatality per reactor year to an individual. (See Section 7.1.4.6 for a discussion of uncertainties in risks estimates.) (To convert miles to kilometers, multiply by 1.6.)

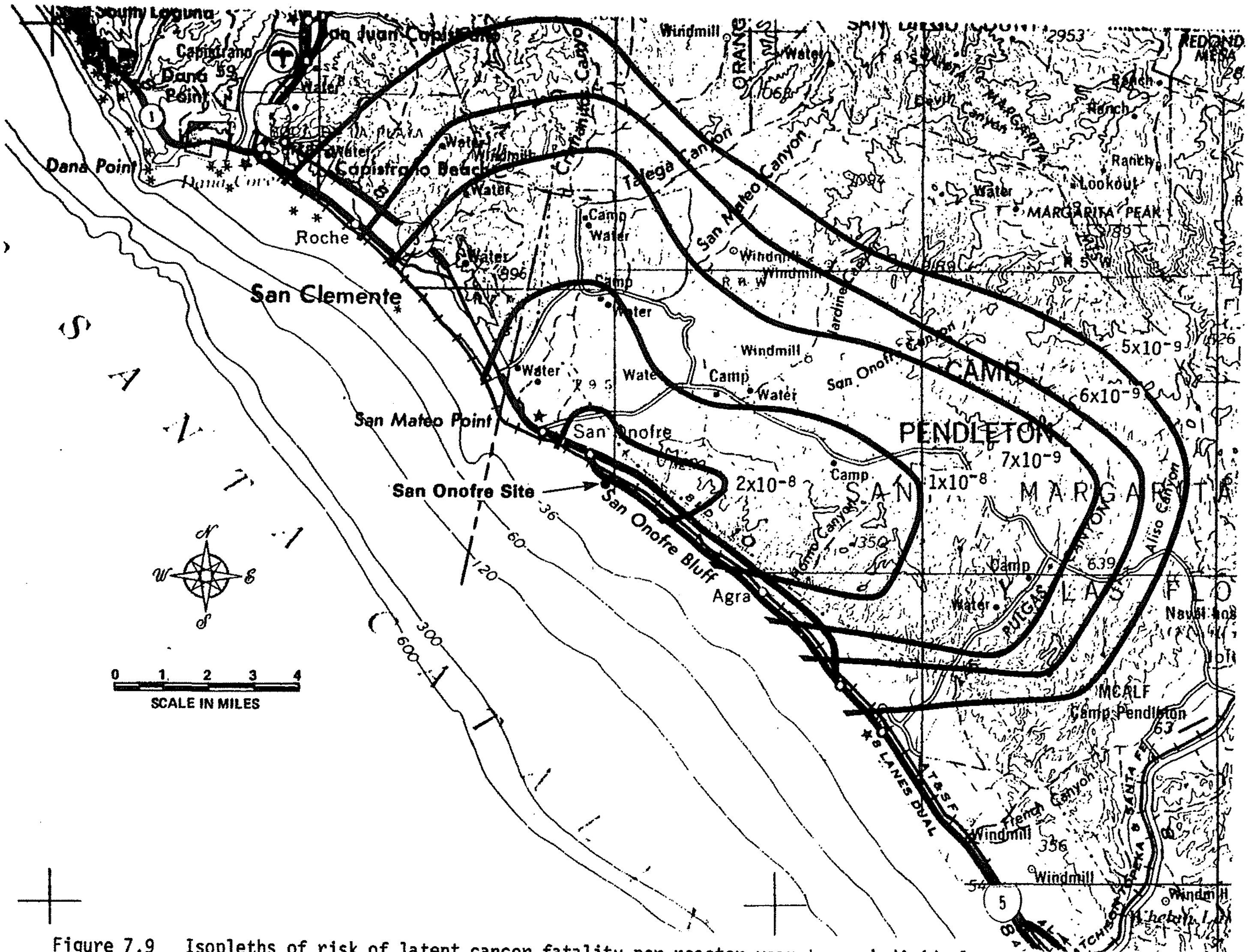

Figure 7.9 Isopleths of risk of latent cancer fatality per reactor year to an individual. (See Section 7.1.4.6 for a discussion of uncertainties in risks estimate.) (To convert miles to kilometers, multiply by 1.6.)

No detailed methodology has been developed for estimating the contribution to economic risk associated with cleanup and decontamination of a nuclear power plant that has undergone a serious accident toward either a decommissioning or a resumption of operation. Experience with such costs is currently being accumulated as a result of the Three Mile Island accident. It is already clear, however, that such costs can approach or even exceed the original capital cost of such a facility. As an illustration of the possible contribution to the economic risk, if the probability of an accident serious enough to require extensive cleanup and decontamination is taken as the sum of the nine categories in Table 7.3, i.e., about 5 chances in 10,000 per year, and if the "average" decontamination cost for these nine categories is assumed to be one billion dollars, then the estimated economic risk would be about $500,000 per year.

Other costs, besides damage to or loss of the facility, result from accidents. The major additional costs are replacement power and replacement of the capacity. These costs are affected by the point in the lifetime of the plant at which an accident might occur. The present worth cost is highest for an accident occurring at the beginning of the plant operating life and decreases over the plant life. It is assumed for these calculations that one unit of San Onofre 2 or 3 is permanently lost and replaced by new capacity after eight years and the undamaged unit is shut down for three years before restart. For illustrative purposes, the costs and economic risk have been estimated for a "worst case" situation for the approximately 2200-megawatt (electric) San Onofre Units 2 and 3 complex by postulating a total loss of one of the units in the first year of a projected 30-year operating life. Net replacement power cost of 45 mills/kWh is assumed (nearly all fossil units in southern California are oil-fired). Using a 60% capacity factor, the annual cost of replacement power would be $520 million for the two units in 1980 dollars. The additional capital costs as a result of having to construct a new facility are $60 million per year, again in 1980 dollars.

If the probability of sustaining a total loss of the original facility is taken as the probability of the occurrence of a core melt accident (approximately by the sum of probabilities for the categories PWR-1 through 7 in Table 7.3, i.e., about 5 chances in 100,000 per year), then the average contribution to economic risk that would result from a loss early in the operating life of a San Onofre unit is about $29,000 for each of the first three years until the undamaged plant is returned to service, then $16,000 per year until the damaged unit is replaced, and $3000 per year additional capital costs for the assumed remaining 22 years of plant service.

7.1.4.7 Uncertainties

The foregoing probabilistic and risk assessment discussion has been based upon the methodology presented in the Reactor Safety Study (RSS),[10] which was published in 1975.

In July 1977, the NRC organized an Independent Risk Assessment Review Group to (1) clarify the achievements and limitations of the Reactor Safety Study Group, (2) assess the peer comments thereon and the responses to the comments, (3) study the current state of such risk assessment methodology, and (4) recommend to the Commission how and whether such methodology can be used in the regulatory and licensing process. The results of this study were issued September 1978.[11] This report, called the Lewis Report, contains several findings and recommendations concerning the RSS. Some of the more significant findings are summarized below.

(1) A number of sources of both conservatism and nonconservatism in the probability calculations in RSS were found, which were very difficult to balance. The Review Group was unable to determine whether the overall probability of a core melt given in the RSS was high or low, but they did conclude that the error bands were understated.

(2) The methodology, which was an important advance over earlier methodologies that had been applied to reactor risk, was sound.

(3) It is very difficult to follow the detailed thread of calculations through the RSS. In particular, the Executive Summary is a poor description of the contents of the report, should not be used as such, and has lent itself to misuse in the discussion of reactor risk.

On January 19, 1979, the Commission issued a statement of policy concerning the RSS and the Review Group Report. The Commission accepted the findings of the Review Group.

The accident at Three Mile Island occurred in March 1979 at a time when the accumulated experience record was about 400 reactor years. It is of interest to note that this was within the range of frequencies estimated by the RSS for an accident of this severity (ref. 4, p. 533). It should also be noted that the Three Mile Island accident has resulted in a very comprehensive evaluation of reactor accidents like that one, by a significant number of investigative groups both within NRC and outside of it. Actions to improve the safety of nuclear power plants have come out of these investigations, including those from the President's Commission on the Accident at Three Mile Island, and NRC staff investigations and task forces. A comprehensive "NRC Action Plan Developed as a Result of the TMI-2 Accident," NUREG-0660, Vol. I, May 1980 collects the various recommendations of these groups and describes them under the subject areas of: Operational Safety; Siting and Design; Emergency Preparedness and Radiation Effects; Practices and Procedures; and NRC Policy, Organization and Management. The action plan presents a sequence of actions, some already taken, that will result in a gradually increasing improvement in safety as individual actions are completed. The San Onofre plant is receiving and will receive the benefit of these actions on the schedule indicated in NUREG-0660. The improvement in safety from these actions has not been quantified, however, and the radiological risk of accidents discussed in this chapter does not reflect these improvements.

7.1.5 Conclusions

The foregoing sections consider the potential environmental impacts from accidents at the San Onofre facility. These have covered a broad spectrum of possible accidental releases of radioactive materials into the environment by atmospheric and groundwater pathways. Included in the considerations are postulated design basis accidents and more severe accident sequences that lead to a severely damaged reactor core or core melt.

The environmental impacts that have been considered include potential radiation exposures to individuals and to the population as a whole, the risk of near- and long-term adverse health effects that such exposures could entail, and the potential economic and societal consequences of accidental contamination of the environment. These impacts could be severe, but the likelihood of their occurrence is judged to be small. This conclusion is based on (a) the fact that considerable experience has been gained with the operation of similar facilities without significant degradation of the environment; and (b) a probabilistic assessment of the risk based upon the methodology developed in the Reactor Safety Study. The overall assessment of environmental risk of accidents, assuming protective action, shows that it is roughly comparable to the risk for normal operational releases although accidents have a potential for acute fatalities and economic costs that cannot arise from normal operations. The risk of acute fatalities from potential accidents at the site are small in comparison with the risk of acute fatalities from other human activities in a comparably-sized population.

The staff has concluded that there are no special or unique features about the San Onofre site and environs that would warrant special or additional engineered safety features for the San Onofre plants.

REFERENCES

1. Statement of Interim Policy, "Nuclear Power Plant Accident Considerations Under the National Environmental Policy Act of 1969," 45 Federal Register 40101-40104, June 13, 1980.*

2. "Final Safety Analysis Report (FSAR), San Onofre Nuclear Generating Station Units 2 and 3, Docket Numbers 50-361 and 50-362," Southern California Edison Company and San Diego Gas and Electric Company, December 1, 1976, as amended.*

3. "Safety Evaluation Report related to the operation of San Onofre Nuclear Generating Station, Units 2 and 3 Docket Numbers 50-361 and 50-362," NUREG-0712, February 1981, as supplemented.**

4. "Energy in Transition 1985 - 2010," Final Report of the Committee on Nuclear and Alternative Energy Systems (CONAES), Chapter 9, pp. 517-534, National Research Council, 1979 (available in public technical libraries) (also C.E. Land, Science 209, 1197, September 12, 1980).

5. "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," Advisory Committee on the Biological Effects of Ionizing Radiations (BEIR), National Academy of Sciences/National Research Council November 1972.***

6. "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," Committee on the Biological Effects of Ionizing Radiations (BEIR), National Academy of Sciences/National Research Council, July 1980.***

7. H.W. Bertini and others, "Descriptions of Selected Accidents that Have Occurred at Nuclear Reactor Facilities," Nuclear Safety Information Center, Oak Ridge National Laboratory, ORNL/NSIC-176, April 1980;*** also, "Evaluation of Steam Generator Tube Rupture Accidents," L.B. Marsh, USNRC Report NUREG-0651, March 1980.**

8. "Three Mile Island - A Report to the Commissioners and the Public," Vol. I, Mitchell Rogovin, Director, Nuclear Regulatory Commission Special Inquiry Group, January 1980, Summary Section 9.*

9. "Report of the President's Commission on the Accident at Three Mile Island," October 1979, Commission Findings B, Health Effects.*

10. "Reactor Safety Study," WASH-1400, USNRC Report NUREG-75/014, October 1975.**

11. H. W. Lewis and others, "Risk Assessment Review Group Report to the U.S. Nuclear Regulatory Commission," NUREG-CR-0400, September 1978.**

12. "Overview of the Reactor Safety Study Consequences Model," USNRC Report NUREG-0340, October 1977.**

13. "Liquid Pathway Generic Study," USNRC Report NUREG-0440, February 1978.**

14. Dana Isherwood, "Preliminary Report on Retardation Factors and Radionuclides Migration," Lawrence Livermore Laboratories, UCID-A3.44, August 5, 1977 (available in public technical libaries).

15. San Onofre Nuclear Generating Station Units 2 and 3, Applicant's Environmental Report, Operating License Stage, Volume 2, November 1976.*

*Available for inspection and copying for a fee in the NRC Public Document Room, 1717 H St. N. W., Washington, DC 20555.
**Available from the NRC/GPO Sales Program, Washington, D. C. 20555 and the National Technical Information Service, Springfield, VA, 22161.
***Available from NTIS only.

8. NEED FOR THE STATION

8.1 RESUME

The ownership of Units 2 and 3 of the San Onofre Nuclear Generating Station is divided among Southern California Edison Company (SCE), 76.55%; San Diego Gas & Electric Company (SDG&E) 20%; the City of Riverdale, California, 1.79%; and the City of Anaheim, California, 1.66%. This section presents an analysis of the need for the station based on the energy demands of the applicant's service areas, the potential for production cost savings, and the potential for increasing the reliability of the applicant's systems.

8.2 APPLICANT'S SERVICE AREAS AND REGIONAL RELATIONSHIPS

8.2.1 Applicant's service areas

Southern California Edison Company's service area extends over a 15-county area of southern and central California, covering about 130,000 km^2 (50,000 mi^2) and containing a population in excess of 7.5 million. In 1978, SCE served 2.95 million customers, over 88% of which were residential. San Diego Gas & Electric Company supplies electricity to about 700,000 customers in San Diego County and in portions of Orange and Imperial counties. The boundaries of the service area enclose a 10,630-km^2 (4105-mi^2) area. The cities of Anaheim and Riverside serve their respective municipalities. A map of the applicant's service area is presented in Figure 8.1.

8.2.2 Regional relationships

SCE and SDG&E are members of the Western Systems Coordinating Council (WSCC) and the California Power Pool (CPP). The WSCC is the regional reliability council for the interconnected power network that serves the states west of the Rockies and parts of British Columbia. Established in 1967, the WSCC's primary function is to facilitate coordinated planning among its member systems and to provide technical support. In relation to these duties, the WSCC compiles load and resource data for the region, performs reliability studies, and recommends minimum reserve criteria. The California Power Pool, whose members are Pacific Gas & Electric Company (PG&E), SCE, and SDG&E, was formed in 1964 to provide for the continuous interconnected operation of the member utilities' power supply systems. This interconnected operation allows the utilities to make more efficient, and therefore more economical use of their generation resources and increases the overall reliability of electric service.

8.3 BENEFITS OF STATION OPERATION

8.3.1 Minimization of production costs

To minimize energy production costs, it is necessary to use the most economical mix of generation resources. The impact of the operation of SONGS 2 & 3 on the applicant's total cost of generation will be a major factor in determining the desirability of such operation. In assessing this impact, it is important to note that the fixed costs of each facility, such as the sunken capital investment and the fixed portion of the operating and maintenance costs, are irrelevant to the choice of which generation resources will be used to meet a given load, precisely because these costs are fixed and will not vary with an altered mode of system operation.

To assess the impact of station operation on the applicant's overall production costs, the staff first reviewed the latest production costs reported by the applicants for their electric generation stations. These data, presented in Tables 8.1 and 8.2, show that all oil/gas- and oil-fired facilities that are listed as base and/or intermediate units had production costs ranging from \$29.2 to \$56.7 per MWh, whereas Unit 1 of the San Onofre Nuclear Generating Station had a production cost of \$9.0/MWhr. In determining how the additional units of the San Onofre Station would compare with these figures, the staff estimated the 1983 fuel cost for these units to be \$10.8/MWhr.[1] Because SCE's and SDG&E's installed capacity is predominately oil- and oil/gas-fired, the staff concludes

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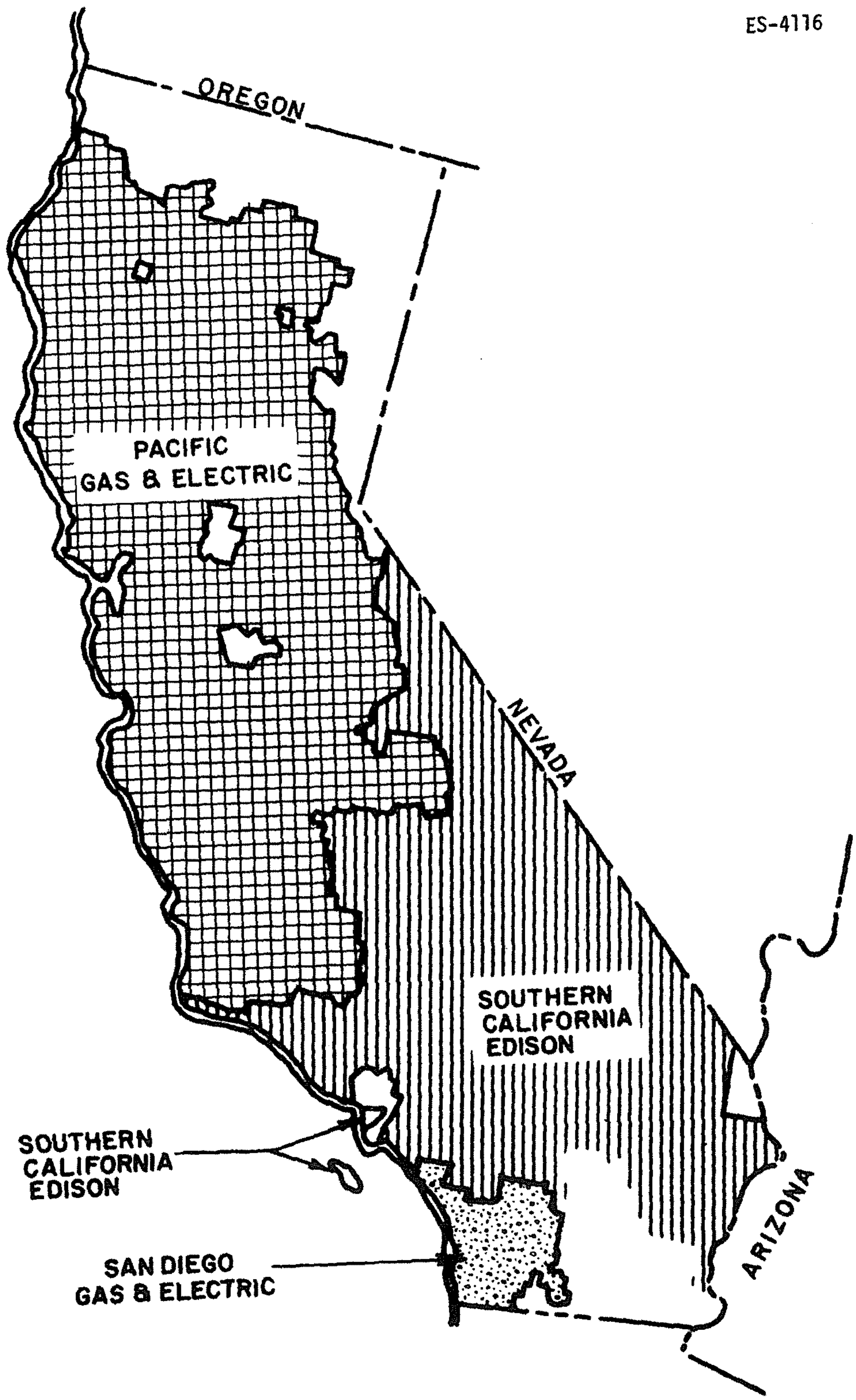

Fig. 8.1. Service areas of the member utilities of the California Power Pool. Source: ER, p. S.2-193.