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A Critical Evaluation of the Nonradiological Environmental Technical Specifications

Vol. 4 San Onofre Nuclear Generating Station Unit 1

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**Prepared for the U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
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ENERGY DIVISION

A CRITICAL EVALUATION OF THE NONRADIOLOGICAL
ENVIRONMENTAL TECHNICAL SPECIFICATIONS

VOLUME 4

SAN ONOFRE NUCLEAR GENERATING STATION UNIT 1

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FOREWORD

Under the sponsorship of the Office of Nuclear Regulatory Research of the U.S. Nuclear Regulatory Commission, Argonne National Laboratory, Battelle Northwest Laboratory, and Oak Ridge National Laboratory have collaborated in conducting a one-year study on the evaluation of the nonradiological environmental monitoring programs and Technical Specifications requirements at various operating nuclear power plants. As a result of this work, a series of reports is being prepared by the three laboratories. The titles of these reports are given below.

Argonne National Laboratory

The following reports were prepared by Argonne National Laboratory scientists:

<u>Report Title</u>	<u>Report Number</u>
An Evaluation of Environmental Data Relating to the Kewaunee Nuclear Power Plant Site	ANL/EIS-1
An Evaluation of Environmental Data Relating to the Quad Cities Nuclear Power Station	ANL/EIS-2
An Evaluation of Environmental Data Relating to the Duane Arnold Energy Center	ANL/EIS-3
An Evaluation of Environmental Data Relating to the Three Mile Island Site	ANL/EIS-4
An Evaluation of Environmental Data Relating to the Zion Nuclear Power Plant	ANL/EIS-5
An Evaluation of Environmental Data Relating to the Prairie Island Site	ANL/EIS-6
An Evaluation of Environmental Data Relating to the Nine Mile Point - 1	ANL/EIS-7
An Evaluation of Environmental Data Conclusions and Recommendations for Nonradiological Environmental Monitoring	ANL/EIS-8

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Battelle Northwest Laboratory

The following reports were prepared by Battelle Northwest Laboratory scientists:

<u>Report Title</u>	<u>Report Number</u>
Evaluation of Monticello Nuclear Power Plant Environmental Impact Prediction, Based on Monitoring Program	BNWL-1250
Evaluation of Haddam Neck (Connecticut Yankee) Nuclear Power Plant Environmental Impact Prediction, Based on Monitoring Program	BNWL-1251
Evaluation of Millstone Nuclear Power Plant, Unit 1, Environmental Impact Prediction, Based on Monitoring Program	BNWL-1252
Evaluation of Three Nuclear Power Plants, Environmental Prediction, Based on Monitoring Program. A Summary Report	BNWL-1253

Oak Ridge National Laboratory

The following reports were prepared by Oak Ridge National Laboratory scientists:

<u>Report Title</u>	<u>Report Number</u>
A Critical Evaluation of the Nonradiological Environmental Technical Specifications: Conclusions and Recommendations	ORNL/NUREG/TM-69
A Critical Evaluation of the Nonradiological Environmental Technical Specifications: Surry Power Plant Units 1 and 2	ORNL/NUREG/TM-70
A Critical Evaluation of the Nonradiological Environmental Technical Specifications: Peach Bottom Atomic Power Station Units 2 and 3	ORNL/NUREG/TM-71
A Critical Evaluation of the Nonradiological Environmental Technical Specifications: San Onofre Nuclear Generating Station Unit 1	ORNL/NUREG/TM-72

ABSTRACT

A comprehensive study of the data collected as part of the environmental Technical Specifications program for Unit 1 of the San Onofre Nuclear Generating Station (SONGS 1) was conducted for the Office of Nuclear Regulatory Research of the U.S. Nuclear Regulatory Commission. The program included an analysis of the hydrothermal and ecological monitoring data collected during 1975.

The hydrothermal analysis includes a discussion of models used in plume predictions prior to plant operation and an evaluation of the present hydrothermal monitoring program. The primary methods used for hydrothermal monitoring are bimonthly boat surveys, quarterly aerial infrared thermal scannings, and two fixed-thermograph stations. Review of the currently existing program reveals that it is responsive to the Technical Specifications requirements.

The ecological evaluation was directed toward reviewing the strengths and weaknesses of the various sampling programs designed to monitor the planktonic, benthic, and nektonic communities inhabiting the inshore coastal area in the vicinity of San Onofre. Recommendations are presented for the ecological monitoring program for Units 2 and 3, which are to be operational within the next five years. Evaluation of the monitoring data suggests that the frequency of sampling of all trophic levels is presently inadequate and that additional useful information could be derived by the extension of monitoring into offshore areas that will receive thermal effluents from Units 2 and 3.

Recommendations are made for both the hydrothermal and ecological monitoring programs. Hydrothermal monitoring would be improved (1) if vertical temperature data were acquired from a moving boat equipped with a thermistor rake, rather than using bathythermograph (BT) profiles at fixed stations, (2) if bimonthly infrared temperature mapping were conducted using advanced dual-reference imaging systems with computer enhancement of the outputs, and (3) if the present thermograph network were expanded. Ecological monitoring programs could be improved by increasing sampling frequency for all trophic groups, by using consistent reporting formats, by eliminating the intertidal survey, and by expanding the number of sampling stations to cover offshore areas that will be receiving thermal discharges from Units 2 and 3. Potential impacts of the operation of SONGS 1 on the environment were not assessed because of the sparse monitoring data collected during the preoperational period and the fact that only one complete year of operating data was collected as part of the Technical Specifications program. Additional data collected during periods when all three units at the SONGS site are operating at full capacity will be quite useful and will allow an assessment of the potential ecological impact of the San Onofre facility under conditions of maximum plant-induced perturbations.

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I. PLANT DESIGN AND CHARACTERISTICS

San Onofre Nuclear Generating Station (SONGS) is owned jointly by Southern California Edison Company (SCE) and San Diego Gas and Electric Company (SDG&E).^{1,2} SCE operates the facility. The architect-engineer for Unit 1 was Bechtel Corporation; Units 2 and 3 are presently under construction (1977). Unit 1 consists of a single pressurized-water reactor (PWR) with a core thermal power of 1347 MW(t) and a net electrical output (maximum dependable capacity) of 430 MW(e). At full power operation, Unit 1 rejects 917 MW(t) to the environment.

The heat is rejected by once-through cooling. As indicated in Fig. 4.1, cooling water is withdrawn from the Pacific Ocean through a submerged offshore intake and flows through a buried intake pipe to an onshore screenwell. Pumps then force the water through the main condensers into a buried discharge pipe leading to a vertically oriented submerged discharge port. At full power operation, the design cooling water flow rate is 780.5 cfs, which corresponds to a temperature rise across the condenser of 18.3°F. Although continuous records of intake and discharge temperatures are not routinely reported, special measurements have indicated that these conditions are not always realized in practice.³ For example, measurements made by Pacific Northwest Laboratories⁴ from November 13 through 15, 1972, a period of normal operation, indicated that the actual flow rate was 650 cfs and that the actual temperature rise was 22°F. The reason for this reduced flow rate is not known with certainty, but it may be that some condenser tubes are permanently plugged. A monthly average temperature rise of 22°F was also reported for October 1975 (see Sect. IV.A.2.b).

The intake structure is similar to the discharge structure (see Fig. 4.1), except that the intake is fitted with a velocity cap in order to ensure that water flows horizontally into the structure. This is believed to enhance the ability of fish to avoid entrapment. The intake structure is located 3160 ft offshore where the depth below mean lower low water (MLLW) is 27 ft. The lower lip of the intake structure is 10.5 ft above the bottom, and the underside of the 1-ft-thick velocity cap is 4 ft above the lower lip. Therefore, the minimum submergence of the intake is 11.5 ft. At the measured flow rate of 650 cfs, the horizontal velocity across the lip of the intake is 2.2 fps. The water then flows toward shore at a velocity of about 5.7 fps through a 12-ft-diam intake pipe. This process takes about 9 min.

On shore, the water empties into the screenwell forebay where the velocity drops to about 1.7 fps. The water passes through bar racks and conventional traveling screens to two parallel 390-cfs designed capacity pumps and then to the condenser. From the condenser, the heated water flows 2560 ft offshore to the discharge structure through a 12-ft-diam pipe. The total travel time from intake to discharge is about 20.5 min.

ORNL DWG 76-19699

Fig. 4.1. San Onofre - San Onofre Unit 1 intake/discharge system.
 Source: D. S. Trent, H. P. Foote, and J. R. Eliason, *Determination of the Near Field Excess Temperature Distribution for the San Onofre Nuclear Generating Station Cooling Water Discharge Units 2 and 3*, Battelle-Pacific Northwest Laboratories (August 1, 1974).

The vertical discharge port is located where the bottom depth is 22.5 ft MLLW, and its lip extends upward to a depth of 11.5 ft MLLW. The horizontal cross section of the vertical port has a rounded rectangular shape with an area of about 280 ft². If the velocity profile were flat, the discharge velocity would be 2.3 fps. However, a comparison of surface temperatures observed above the port with theoretical predictions indicates that the discharge structure may act as an unsteady mixing chamber, as shown in Fig. 4.2. The vertical momentum of the discharged water causes a 6- to 12-in. bulge in the ocean surface above the port. This unsteady phenomenon is referred to as a "boil" or "bubble."

ORNL DWG 76-19700

UNIT 1 CROSS-SECTION

Fig. 4.2. San Onofre - Possible instantaneous discharge flow for San Onofre Unit 1 illustrating mixing chamber effect. Source: D. S. Trent, H. P. Foote, and J. R. Eliason, *Determination of the Near Field Excess Temperature Distribution for the San Onofre Nuclear Generating Station Cooling Water Discharge Units 2 and 3*, Battelle-Pacific Northwest Laboratories (August 1, 1974).

Incrustation of the intake and discharge pipes by hard-shelled marine organisms is such that large reductions in flow area can result. This incrustation problem is controlled by a program of heat treatments conducted every five to six weeks; these treatments kill the organisms and flush them from the system. The high temperatures needed to accomplish this goal are achieved by reducing the net flow of cooling water. In a typical heat treatment, net electrical output is reduced to about 360 MW(e), but the net flow of cooling water is dropped to 196 cfs — about 25% of the normal design flow. These changes result in a net condenser temperature rise of about 58°F. In order to treat the intake pipe with heat, the direction of flow is reversed using internal gates so that water is withdrawn from the ocean through the normal discharge port and discharged through the normal intake structure. After 2 hr of heat treatment, the flow direction is returned to normal and the discharge pipe is subjected to high temperatures for 2 hr. The entire time between the inception of heat treatment and the return to normal operation is about 8 hr. This method has been very effective in controlling incrustation.

II. PLANT SITE CHARACTERISTICS¹⁻⁴

A. LOCATION

The San Onofre Nuclear Generating Station is located in California about 60 miles downcoast from Los Angeles and about 50 miles upcoast from San Diego. As shown in Fig. 4.3, the nearest city is San Clemente, about 2.5 miles upcoast. The closest downcoast municipality, Oceanside, is about 12 miles away. The site extends for about 4500 ft along the coast and is separated from the ocean by a public beach. The entire site is part of the Camp Pendleton Marine base.

B. OCEANOGRAPHY

As shown in Fig. 4.4, the sea bottom near the site is quite regular, with a shallow slope and depth contours which parallel the shoreline. The bottom material consists of sand interspersed with areas of cobble and boulders.

The movement of the ocean near the site may be conceptualized as the product of large-scale ocean circulations, winds, and tides, all subject to the geometric constraints of bathymetry and shoreline. The major circulation pattern in the north Pacific Ocean is a huge clockwise gyre whose eastern limb forms the California Current. The California Current is a 400-mile-wide band that flows southward along the California coast. During the months of November through January, the California Current is displaced farther away from the coast, and the northward flowing Davidson Current is observed off San Onofre. Each of these currents is retarded by the shallow coastal zone, and the resulting shear leads to the formation of large eddies, which break away and influence local coastal circulations.

The influence of wind in the coastal zone is generally confined to the upper few feet of water and depends on wind speed, duration, fetch, and the degree of stratification present. During periods of strong stratification, the motion of the surface layers tends to be decoupled from that of the deeper water, and the influence of wind is significant. When stratification is weak, wind-induced currents tend to be less important. Nevertheless, wind-induced surface currents are often strong enough to mask tidal influences at San Onofre. Drogue measurements have shown that surface and subsurface currents often flow in different directions. Wind-induced currents are thought to be strongest in the afternoon as a result of prevailing sea breezes.

The most important influence on the San Onofre current pattern is usually the tide. The San Onofre tide is of the mixed semidiurnal type in which two unequal high tides and two unequal low tides occur every 25 hr. In a 17-year period, the average high tide level was +4.5 ft MLLW and the average mean tide level was +2.7 ft MLLW. The maximum tidal excursion in this period was 8.8 ft. Because of the constraint imposed by the

Fig. 4.3. San Onofre - Vicinity within the 50-mile radius of the San Onofre Nuclear Generating Station. Source: Directorate of Licensing, U.S. Atomic Energy Commission, *Final Environmental Statement - San Onofre Nuclear Generating Station Unit 1*, Docket No. STN 50-206 (October 1973), Fig. 2.1.

Fig. 4.4. San Onofre - Bathymetry (MLLW), environmental surveillance zones (bold letters), and hydrographic sampling stations off SONGS Unit 1. Source: Lockheed Marine Biology Laboratory, San Onofre Nuclear Generating Station Unit 1, Semiannual Operating Report, Environmental Technical Specifications, Sections 3.1 and 4.0, prepared for Southern California Edison Company, (July through December 1975), Fig. 11-1.

shoreline, tidal currents tend to be primarily oscillatory parallel to the shore. Flood tide currents tend to flow upcoast and onshore, while ebb tide currents tend to flow downcoast and offshore. Currents in excess of 1 knot are rarely observed in the San Onofre area.

The most authoritative study of natural temperature variations in the San Onofre area is that of Koh and List.⁵ Rather than use the sporadic measurements of temperature obtained at the site prior to plant operation, their study is based on temperatures measured daily at 8:00 AM from 1966 through 1970 at Balboa, San Clemente, Oceanside, and La Jolla. The measurements were made at the end of the local piers using identically calibrated bucket thermometers. The probable error of measurement was estimated to be $\pm 0.09^\circ\text{F}$. The data were separated by digital filtering into three components:

$$T = T_L + T_M + T_H .$$

T_L is the low-frequency component obtained by averaging over two months; it portrays the seasonal variations.

T_M is a middle frequency component obtained by averaging $T - T_L$ over one week; thus, it portrays variations having periods of from one week to two months.

T_H is the residual, which contains daily to weekly fluctuations.

The results of this analysis for the San Clemente data are presented in Fig. 4.5 where the T_L , T_M , and T_H curves are displaced by 20°C , 10°C , and 30°C respectively. Temperatures range from about 55 to 72°F . The low-frequency component demonstrates a convincing seasonal trend with a global maximum during the summer and a local maximum during the January through February period. The annual range of T_L is about 13°F . The T_L curves of the various stations were highly correlated. The correlation coefficient for San Clemente and Oceanside was 0.99.

The midfrequency component, T_M , was also found to be highly correlated (0.89 between San Clemente and Oceanside), with a maximum at zero time lag. This indicates that the spatial scale of the mechanisms responsible for T_M variations exceeds the distance between stations. The amplitude of the T_M oscillations is about $\pm 3^\circ\text{F}$.

The high-frequency component, T_H , has a low correlation between stations (0.28 between San Clemente and Oceanside), indicating that localized mechanisms account for these variations. T_H has an approximately Gaussian distribution with a standard deviation that exhibits seasonal variations. These fluctuations are highest in summer and smallest during the winter peak in T_L . At San Clemente, the standard deviation for June through September was 1.3°F and the standard deviation for October through May was 0.7°F .

6-4

Fig. 4.5. San Onofre - Daily temperatures and decompositions into various frequency bands at San Clemente. Source: R. C. Y. Koh and E. J. List, Report to Southern California Edison Company on Further Analysis Related to Thermal Discharges at San Onofre Nuclear Generating Station, September 30, 1974, Fig. 3.2.

The strong correlation found for T_L and T_M between San Clemente and Oceanside suggests that these data adequately represent temperature variations averaged over one week or longer at San Onofre. More rapid fluctuations at San Onofre do not appear to be deterministically predictable on the basis of data from the other locations, but the statistical properties are probably similar. Data from rapid response thermographs at other southern California locations indicate that fluctuations of 3.6°F may occur in 5 or 10 min. In fact, measurements in 30 to 60 ft of water off La Jolla show 9°F fluctuations in 5 sec during the summer. Typical natural diurnal variations at San Onofre should be about 1 to 2°F in winter and 2 to 4°F in summer, with smaller variations expected on cloudy days.

Near-surface temperature measurements made from moving boats indicate that temperature variations of 2°F in horizontal distances of 1 mile are not uncommon off the southern California coast. Measurements at the San Onofre site prior to operation show that, during the winter months, the waters are approximately isothermal but that a mean stratification of 0.3°F/ft exists during the summer.

Because there are no significant freshwater outfalls in the vicinity, the salinity at San Onofre shows little spatial variation. The typical annual range of salinity is from about 33.3 to 33.7 ppt, with the minimum in winter and the maximum in summer.

Turbidity in the San Onofre area is primarily due to the suspension of bottom material in the surf zone. Outside of the surf zone, turbidity generally decreases as distance from shore increases. Typical depths of Secchi Disc visibility range from 2 to 5 m. The vertical variation of turbidity is often quite complex, with layers of clear and turbid water interleaved.

C. METEOROLOGY

San Onofre enjoys a mediterranean climate characterized by short mild winters and warm dry summers. Long-term temperature records reveal an average July maximum temperature of 72°F and an average February minimum of 42°F. The normal daily temperature range is about 40 to 60°F in winter and 60 to 72°F in summer. The highest measured temperature was 108°F and the coldest temperature measured was 25°F. The average annual rainfall is about 12 in., which occurs chiefly in winter. Measurable precipitation occurs on about 40 days/year, and dry spells of eight months duration are not uncommon.

Wind patterns near the coast are strongly influenced by topography and diurnal heating. The typical diurnal wind pattern consists of onshore winds during the afternoon and offshore breezes at night. The mean wind speed at the site is about 7 mph, and the predominant wind direction is from the north and west.

III. OPERATING HISTORY⁶⁻⁹

The Construction Permit for SONGS Unit 1 was issued in March 1964. About 463,000 yd³ of San Mateo sand, excavated during construction, was placed on the beach just south of the plant between June 1964 and September 1967. This sand was dispersed by natural wave erosion. Offshore construction of the cooling system conduits took place from December 1964 to April 1966. The first reported flow through the cooling system was in December 1966.

Initial criticality was achieved in June 1967, and the plant entered commercial service in December 1967. The reactor suffered a forced outage from March 1968 to September 1968. Since that time, SONGS 1 has established a remarkable reliability record. Table 4.1 shows that consistently high power plant capacity factors (PCFs) have been achieved since 1968, including four years above 80%. Table 4.2 gives monthly PCFs for 1975. Note that the monthly PCFs for the second half of 1975 were never lower than 97%. The relatively low values in March and April reflect the annual refueling outage, which extended from March 14 to April 23, 1975. It may be concluded that, due to this high PCF, the results of monitoring programs conducted during this time should reflect changes caused by power plant operation.

The information on PCFs was obtained from various reports^{7,8} but not from the Semiannual Operating Reports (SORs).⁹ The SORs contain a useful narrative of plant operations but do not provide much quantitative data on heat rejection rates. Beginning with SOR-12 (January through June 1973), a graph of daily core thermal power [MW(t) or percent rated] is included. The SORs do not provide any data on circulating water flow or condenser temperature rise.

Table 4.1 San Onofre – Annual power plant capacity factor (PCF) for SONGS Unit 1

Year	PCF (%)
1967	21
1968	34
1969	69
1970	81
1971	88
1972	85
1973	60
1974	84
1975	86

Source: Energy Research and Development Administration, *Operating History of U.S. Nuclear Reactors 1974*, ERDA-29-74 (1974).

Source: U.S. Nuclear Regulatory Commission, *Operating Plants Status Reports*, NUREG-75/020-1 (January 1975) through NUREG-75/020-12 (December 1975).

Table 4.2. San Onofre – Monthly power plant capacity factors (PCFs) during 1975 for SONGS Unit 1

Month	PCF (%)
January	98.5
February	98.9
March	42.6
April	19.8
May	96.5
June	80.5
July	99.8
August	99.1
September	100.6
October	97.6
November	99.8
December	100.0
Average	86.1

Source: U.S. Nuclear Regulatory Commission, *Operating Plants Status Reports*, NUREG-75/020-1 (January 1975) through NUREG-75/020-12 (December 1975).

IV. CONFIRMATORY ASSESSMENT

A. HYDROTHERMAL MONITORING

1. Predicted hydrothermal impacts

When SONGS 1 began operation, the art of hydrothermal prediction was in a relatively primitive stage, and interest in thermal pollution problems was less intense than at the present. In keeping with the then prevailing levels of ability and interest, no preoperational thermal plume predictions were published for SONGS 1. In recent years, the situation has changed, and considerable resources have been expended in developing models to predict the combined plume of San Onofre Units 1, 2, and 3. Each modeling effort has included attempts to model Unit 1 alone in order to verify the approach being used by comparison with measurements. As a result, SONGS 1 offers an opportunity to compare several different analytical and experimental approaches to hydrothermal prediction. There have been three modeling studies, each funded by the utility, whose results have been published.^{4,10-14} The earliest study was performed by Intersea Research Corporation (IRC), the second by Pacific Northwest Laboratories (PNL), and the most recent by the W. M. Keck Laboratory of Hydraulics and Water Resources of the California Institute of Technology (Caltech). The comparison of each of these studies with Unit 1 field data will be discussed, but it should be remembered that all were performed in order to predict the combined plume of Units 1, 2, and 3.

a. Intersea Research Corporation model¹⁰

Adamo, Horner, and Rupp of IRC developed an analytical model based on solving the convective diffusion or energy equation in the far field. Neither the continuity nor momentum equations were solved. The model was based on the superposition of a series of puffs of heated water which were convected by a spatially uniform time-varying velocity and allowed to diffuse radially and vertically according to empirical laws. Heat transfer to the atmosphere was also allowed. The puffs were assumed to be axisymmetric and to have Gaussian temperature distributions radially and vertically. The initial size of the puffs was empirically determined, and the maximum temperature was varied to simulate changing plant power levels. However, the IRC investigators were apparently unaware of the deviation from the circulating-water-design flow rate described in Sect. I. Heated water carried past the shoreline was reflected back into the study area.

In order to determine the empirical portions of the model, IRC conducted a special intensive monitoring program. Continuous-current meter records of six weeks duration at four locations and five months at another location were acquired. Continuous surface and bottom temperatures at one location were measured from May 14 through 17, 1972. Eleven infrared

radiation thermometry overflights were flown from May 15 through 17, 1972, to determine sea-surface temperature. The aircraft in these flights was positioned electronically, and coverage extended 20,000 ft offshore. During the same time period, a continuous dye-release experiment was conducted. Dye concentrations at two depths and near-surface temperature were recorded for 50 hr by an electronically positioned moving boat. Vertical profiles of dye and temperature (obtained using an electronic bathythermograph) were obtained at 67 locations. An additional 34 vertical temperature profiles were obtained using a mechanical (bellows-type) bathythermograph. During January and February 1972, seven series of drogue tracking experiments were run to obtain information on the current field. A portion of these data, presented in Ref. 10, was used to construct the IRC model.

In the simulations discussed here, the velocity field measured by a fixed recording current meter (located 1000 ft south of the outfall, 21 ft above the bottom in 30 ft of water) was used. This velocity was assumed to be constant both horizontally and vertically throughout the study area. Predicted tidal elevations were also used as input, and ambient temperature was assumed constant. The model calculations began at 0100 Pacific Daylight Time (PDT) on May 14, 1972, and Figs. 4.6 (a and b) and 4.7 (a and b) compare the results with surface temperature maps obtained by airborne infrared thermometry at 1400 PDT May 15 and 0900 PDT May 16. In the former case, the agreement is very poor, with the measurement showing no central region of heated water and with the maximum temperature being overpredicted by a factor of 4. The latter case shows much better agreement. Such a range of agreement is typical of models having a large empirical component. With simplifications such as a uniform current and ambient temperature, agreement in individual realizations is a matter of chance. A comparison of areas within specified isotherms averaged over a day might have yielded better results, but such a comparison was not attempted.

b. Pacific Northwest Laboratories study⁴

The study conducted by PNL included field measurements, two physical models, and a near- and intermediate-field numerical model. The field studies during normal plant operation were conducted from November 13 to 15, 1972, and those during heat treatment were made on November 19, 1972. Two boats were used to measure wind speed, wind direction, air temperature, relative humidity, surface temperature, vertical temperature profiles, and dye concentrations. Currents were measured continuously at two depths at one location and were also studied using drogues and dye releases from the boats and through the discharge port. Most importantly, maps of surface temperature distribution were obtained using PNL's sophisticated airborne thermal imaging system. This system provides a nearly instantaneous thermal image of the water surface with a spatial resolution of about 7 ft and an accuracy of better than 1°F with the available ground truth. Figure 4.8 shows a high resolution image of the outfall area at 1425 PDT, November 13, 1972. This image

Fig. 4.6a. San Onofre - Sea surface excess temperature isotherms (°F) measured by Intersea Research Corporation from 1353 to 1414 PDT, May 15, 1972. Source: L. C. Adamo, P. L. Horrer, and S. M. Rupp, *Thermal Model Development and Initial Simulations of SONGS Units 2 and 3. Phase I Report*, Intersea Research Corporation, La Jolla, California (revised August 1972).

Fig. 4.6b. San Onofre - Sea surface excess temperature isotherms (°F) predicted by Intersea Research Corporation model for 1400 PDT, May 15, 1972. Source: L. C. Adamo, P. L. Horrer, and S. M. Rupp, *Thermal Model Development and Initial Simulations for SONGS Units 2 and 3. Phase I Report*, Intersea Research Corporation, La Jolla, California (revised August 1972).

Fig. 4.7a. San Onofre - Sea surface excess temperature isotherms ($^{\circ}\text{F}$) measured by Intersea Research Corporation from 0842 to 0857 PDT, May 16, 1972. Source: L. C. Adamo, P. L. Horrer, and S. M. Rupp, *Thermal Model Development and Initial Simulations of SONGS Units 2 and 3. Phase I Report*, Intersea Research Corporation, La Jolla, California (revised August 1972).

Fig. 4.7b. San Onofre - Sea surface excess temperature isotherms ($^{\circ}\text{F}$) predicted by Intersea Research Corporation model for 0900 PDT, May 16, 1972. Source: L. C. Adamo, P. L. Horrer, and S. M. Rupp, *Thermal Model Development and Initial Simulations of SONGS Units 2 and 3. Phase I Report*, Intersea Research Corporation, La Jolla, California (revised August 1972).

Fig. 4.8. San Onofre — Thermal map of San Onofre Unit 1 obtained by PNL airborne thermal imaging system during normal operation at 1425 PDT, November 13, 1972. Temperatures range from 62°F to 76°F. Area of individual elements is 46.77 ft². Distance between tick marks along edge of figure is 100 ft. Outfall is near center of figure. Dark circles and numbers indicate position of boat at various times. Source: D. S. Trent, H. P. Foose, and J. R. Eliason, *Determination of the Near Field Excess Temperature Distribution for the San Onofre Nuclear Generating Station Cooling Water Discharge Units 2 and 3*, Battelle-Pacific Northwest Laboratories (August 1, 1974).

was obtained at higher low water when currents were at a minimum. The chaotic nonaxisymmetric nature of the thermal field is evident.

The first PNL physical model was an undistorted model of the outfall on a flat ocean bottom. The model-to-prototype length ratio was 1:200. The model depth was 1.5 in., and the tests were conducted in an 8-ft-diam cylindrical tank. By maintaining the same temperature rise in the model as was observed in the PNL field studies (22°F), Froude number similarity was achieved. As a consequence, exit Reynolds numbers in the model were far smaller than in the prototype (4×10^6). Tests with prototype equivalent flows of 650 cfs and 195 cfs were conducted. The model exit Reynolds number in the former case was 1512, and a realistic-looking turbulent jet was observed; in the latter case, the Reynolds number of 454 produced an unrealistic laminar plume. Surface temperature distributions were measured using an AGA Thermo Vision system, but only qualitative photographs were reported. Local subsurface measurements using a thermistor probe were made, but the size of the bead resulted in temperatures averaged over a 4-ft depth in the prototype. Flow patterns were observed using dye tracers. There was no provision for simulating ambient current.

Pacific Northwest Laboratory's second physical model was an undistorted model of both intake and discharge on a flat ocean bottom. The model-to-prototype length ratio was 1:46. Tests were conducted in an irregularly shaped concrete pond having a primary rectangular section measuring 150 ft by 250 ft. The water depth was 6.5 in. Tests performed with the model inoperative indicated that, although the pond temperature varied by 28°F in 24 hr, the pond temperature varied spatially by less than 2°F at any instant. Neither the intake nor the discharge structure was perfectly simulated in this model. In simulating the discharge structure, it was impossible to model the buried discharge plenum; therefore, a perforated plate was inserted inside the riser to produce a uniform discharge velocity profile. By using a temperature rise of about 22°F, Froude number equality was achieved. The exit Reynolds number of 13,850 was high enough to produce a turbulent jet.

The test simulated a prototype flow of 650 cfs for 2.25 prototype days under stagnant conditions, a worst-case type situation. Background temperatures were monitored at both ends of the pond, and the intake and discharge temperatures were measured using thermistors. The discharge temperature was manually controlled to be $23^\circ\text{F} \pm 1^\circ\text{F}$ above background. Temperatures were measured every hour at five depths (every 5 prototypic feet) and every 50 ft out to a prototypic radius of 300 ft. These measurements were made by thermistor probe and represent prototype temperatures averaged over a 1-ft depth. There is no indication as to how many radials were traversed. Only one set of these data was reported.

The PNL numerical model is a near- and intermediate-field finite difference model for a vertical circular buoyant jet into an initially stagnant ambient of finite depth. The model is based on a stream function-vorticity formulation of the time-averaged Boussinesq equations of continuity, momentum, and buoyancy. The mean flow is assumed to be

steady and axisymmetric precluding the treatment of ambient cross currents. Turbulence is assumed to act differently in the vertical and radial directions and is accounted for by separate zero-order models for the zone of established flow, the zone of flow establishment, the zone of lateral surface spreading, and the circulating ambient zone. The bottom and port side are taken as nonslip surfaces, and the exit velocity is assumed to have a flat power-law profile. The water surface is treated as an adiabatic rigid free-slip lid. Streamlines are assumed to have a constant slope at the large radius vertical boundary.

The resulting computer code, known as SYMJET, was verified by comparison with existing similarity solutions and well-accepted laboratory data for deep plumes and jets. These comparisons established the validity and versatility of SYMJET.

Figure 4.9 compares the predictions of the 1:46 scale physical model and SYMJET to excess surface temperatures measured along a radius from the Unit 1 outfall at 1425 PDT on November 13, 1972. The field temperatures were obtained from the data displayed in Fig. 4.8 by averaging over azimuthal angle. Presumably, the physical model data were similarly averaged. SYMJET predicts a centerline surface temperature of 21°F, and the physical model predicts 20°F, whereas field measurements show a maximum of only 17°F. Trent, Foote, and Eliason attribute the lower surface temperature rise of the prototype to an unsteady separated flow in the discharge plenum, as illustrated in Fig. 4.2.⁴ This explanation is apparently reasonable because there seems to be no other common deficiency in the numerical and physical models. The more rapid drop in temperature exhibited by the field data and the physical model data was attributed to the mixing action of the turbulent boil. SYMJET cannot account for this phenomenon because it postulates a horizontal sea surface. Similar discrepancies were found in other comparisons of SYMJET to field data. In summary, a more precise undistorted physical model might have duplicated the Unit 1 behavior, but SYMJET, for all its sophistication, excluded the most important physical processes. Nevertheless, it is difficult to see any other way this unexpected physical behavior could have been discovered. Soon after the PNL study was completed, the utility changed the Units 2 and 3 design from a vertical port diffuser to an inclined port diffuser. This rendered further development of SYMJET irrelevant to Units 2 and 3, and no further reports were issued.

c. Caltech model¹¹⁻¹⁴

The Caltech modeling work was based on the use of laboratory scale models and, like the IRC and PNL efforts, was directed mainly toward predicting the combined plumes of Units 1, 2, and 3. The experiments in which the Units 2 and 3 diffusers were simulated were conducted using distorted models with vertical scale ratios of 1:200 and horizontal scale ratios of 1:800. Additional tests were conducted using an undistorted 1:100 model to simulate the behavior of Unit 1 alone; only the latter tests are discussed here.

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Fig. 4.9. San Onofre — Comparison of predicted and observed ΔT vs average radial distance for San Onofre Unit 1 discharge at 1425 PDT, November 13, 1972. Source: D. S. Trent, H. P. Foote, and J. R. Eliason, *Determination of the Near Field Excess Temperature Distribution for the San Onofre Nuclear Generating Station Cooling Water Discharge Units 2 and 3*, Battelle-Pacific Northwest Laboratories (August 1, 1974).

The Unit 1 tests were conducted with an undistorted length scale ratio of 1:100 in a basin with horizontal dimensions of 20 by 36 ft. The placement of the Unit 1 intake and discharge ports is illustrated in Fig. 4.10. The region simulated in the basin extends from 1800 ft offshore to 3800 ft offshore and from 1300 ft upcoast to 2300 ft downcoast of the Unit 1 discharge. Scale models of the intake and discharge structures were placed in the basin and partially covered by a constant-slope sand bottom. Downcoast currents were simulated by flow manifolds at the upcoast and downcoast ends of the basin. These manifolds were manually adjusted to provide a downcoast current with time and with a constant magnitude in the offshore direction. Ambient stratification was not simulated. Froude number equality was maintained, and a flow rate of 700 cfs at a temperature rise of 20°F was simulated. One minute of model time was equivalent to 10 min of prototype time.

MODEL SCALE = 100:1

Fig. 4.10. San Onofre - Layout of Caltech test basin for modeling Unit 1 plume. Units 2 and 3 intakes were inoperative during the Unit 1 tests. Source: R. C. Y. Koh, *Hydraulic Tests of Thermal Dispersion for Unit 1 of the San Onofre Nuclear Power Plant*, Progress Report No. 6, Tech. Memo. No. 73-7, W. M. Keck Laboratory of Hydraulics and Water Resources, California Institute of Technology, Pasadena, California (July 31, 1973).

A total of 11 runs was made to study the Unit 1 plume. The duration of the runs was limited by the finite size of the basin or the time for heated water to travel to the upcoast manifold. The main object of the first six runs was flow visualization at different ambient velocities. The heated effluent was dyed, and photographs of the plume were obtained. A single thermistor probe was also used to survey the temperature field.

In the remaining five runs, quantitative data were obtained for cross currents of 0 to 0.5 knot by means of an array of 112 fixed thermistors. The thermistor array covered only the part of the basin shown in Fig. 4.11, corresponding to a rectangle extending 1350 ft offshore and 1100 ft along the coast. As a result, only a small part of the far-field plume was measured. The thermistors were apparently¹¹ mounted at a prototype depth of 1.6 ft below the surface; due to the 1.5-mm bead size of the thermistors, recorded temperatures averaged over a depth of about 0.5 ft in the prototype. The thermistor readings were zeroed at the start of each run, and temperatures were digitally recorded in 1 or 2 sec every few minutes. These readings were computer processed to provide contours of constant percentage of discharge excess temperature. Figure 4.12 shows the contours after 2 hr (prototype time) with no ambient current. Figure 4.13 presents results after 2 hr (prototype time) with a downcoast current of 0.27 knot (prototype). In all cases studied, there was a strong tendency for the plume to drift onshore. This tendency has been observed in Unit 1 field measurements and was attributed to the internal hydraulics of the discharge. The separated jet is believed to "bounce" off the offshore wall of the port and be reflected toward shore. On the other hand, there was little temperature decrease immediately above the port. This is in contrast with field observations and suggests that the model discharge Reynolds number was too small. Considerable dilution was found to occur within 100 ft (prototype) of the model discharge, and this was attributed to an internal hydraulic jump. This mechanism has not been observed in the field. At the higher cross-flow velocities, a pronounced bifurcation of the thermal plume became apparent. This has been observed in the field, but not as frequently as these tests would suggest. Vertical temperature profiles obtained in the lab indicated that the warm surface layer had a depth of 5 to 10 ft (prototype) near the discharge and 10 to 15 ft several hundred feet away.

Comparison with field measurements was attempted only for the 0.27-knot (prototype) case. Figure 4.11 compares this case with surface temperatures measured by PNL using airborne infrared imaging at 1036 PDT, November 15, 1972. The current during this flight was 0.27 knot directed upcoast. In spite of uncertainty about the actual value of the discharge excess temperature in the field, the agreement is good. The leading edge of the plume, the bifurcation, and the tendency to drift toward shore are all reproduced. The depth of the heated water is also in agreement. Nevertheless, agreement in a single case cannot be interpreted as validation for a model of an environment with the complexity of San Onofre.

Fig. 4.11. San Onofre - Comparison of Caltech laboratory prediction and PNL field data for surface temperatures at 1036 PDT, November 15, 1972. Source: R. C. Y. Koh, *Hydraulic Tests of Thermal Dispersion for Unit 1 of the San Onofre Nuclear Power Plant*, Progress Report No. 6, Tech. Memo. No. 73-7, W. M. Keck Laboratory of Hydraulics and Water Resources, California Institute of Technology, Pasadena, California (July 31, 1973).

In a further series of tests, recirculation of the Unit 1 effluent into the Unit 1 intake was measured. The plume-induced temperature increase at the Unit 1 intake was predicted to be less than 1°F under all conditions studied.

Fig. 4.12. San Onofre - Caltech surface temperature map with zero ambient current 2 hr (prototype time) after start of discharge. Contours show constant percentages of discharge ΔT . Intervals are 5% up to 20% (heavy line) and 10% thereafter. Intake is indicated by Q. Hash marks show 100-ft (prototype) intervals. Source: R. C. Y. Koh, *Hydraulic Tests of Thermal Dispersion for Unit 1 of the San Onofre Nuclear Power Plant*, Progress Report No. 6, Tech. Memo. No. 73-7, W. M. Keck Laboratory of Hydraulics and Water Resources, California Institute of Technology, Pasadena, California (July 31, 1973).

Fig. 4.13. San Onofre - Caltech surface temperature map with 0.27-knot (prototype) ambient current 2 hr (prototype time) after start of discharge. Interpretation same as Fig. 4.12. Source: R. C. Y. Koh, *Hydraulic Tests of Thermal Dispersion for Unit 1 of the San Onofre Nuclear Power Plant, Progress Report No. 6, Tech. Memo. No. 73-7*, W. M. Keck Laboratory of Hydraulics and Water Resources, California Institute of Technology, Pasadena, California (July 31, 1973).

2. Observed hydrothermal impacts

a. History of hydrothermal monitoring at San Onofre

Hydrothermal monitoring at the San Onofre site began in July 1963, ten months before the start of construction for Unit 1. The monitoring program was conducted by Marine Advisers, Inc., until July 1971.^{6,15-17} At that time, responsibility for the program was assumed by Intersea Research Corporation, the corporate successor to the studies group of Marine Advisers.¹⁸⁻²¹ Since January 1974, Lockheed Aircraft Service Company has conducted the monitoring program.²²⁻²⁷

Beginning in May 1964, oceanographic survey cruises have been conducted in daylight approximately every other month. The parameters measured during these cruises are temperature, current, salinity, turbidity, bottom sediment, suspended sediment, dissolved oxygen (DO), pH, and coliform bacteria. Because the monitoring program has undergone a gradual evolution, the methods of temperature and current measurement used prior to 1974 will be reviewed in this section.

Before plant operation, temperatures were measured at 32 fixed stations located in a grid pattern off the San Onofre site. These 32 are among those marked in Fig. 4.4. At each station, temperatures in the upper few inches of water were measured by bucket thermometer. The bucket thermometer consists of a mercury-in-glass thermometer mounted inside of a small clear cylinder (about 1-in. diam and 4-in. deep). In addition, continuous vertical temperature profiles were obtained by means of a bathythermograph (BT). This device consists of a temperature sensor which is lowered to the bottom. The time required to sample the 32 stations was about 4 to 5 hr. After the plant began operation, additional stations were added near the outfall and far from the region of the plume. This increased the amount of time needed for sampling the fixed stations.

Beginning in August 1969, infrared radiation thermometry was used to provide a more complete picture of the surface thermal plume. These measurements were generally made at the time of the boat cruises because bucket thermometer readings were needed as ground truth. The surface temperature along a path 20- to 35-ft wide was recorded on a strip chart in the aircraft. The aircraft usually flew at 500 to 700 ft along fixed paths. The total time required to scan a plume was about 1 hr, and three flights were usually made each day. Surface isotherm maps, which were contoured by hand, were prepared by plotting temperatures at intervals along the flight path.

During 1974, the Intersea Research surveys were replaced by temperature measurements from a moving boat. In this technique, ten thermistors were mounted on a vertical rake at depths ranging from 0.5 to 15 ft. Each thermistor was sampled every 2 sec as the boat traversed a fixed path, and the readings were recorded on magnetic tape. Somewhat less than 2 hr was required to traverse the path at a speed of about 5 knots. This method was discontinued, and the Intersea Research program was reinstated in 1975.

Currents were measured during boat surveys by means of drogues. At first, both tethered and free drogues were used, but the tethered drogues were discontinued during 1967. The free drogues were released at points along the intake-discharge line and were tracked optically. Both surface and subsurface drogues were used. The drogues were useful in explaining plume configurations and often had the salutary effect of forcing attention on the complexity of the current field. More complete current data were obtained using six fixed recording current meters during 1972.²⁸ These data were studied by Koh and List,⁵ but further analysis appears feasible.

Summaries of the results of the pre-Technical Specifications monitoring program are contained in Refs. 3 and 6.

b. Environmental Technical Specifications (ETS) monitoring program

Hydrothermal monitoring at San Onofre was first required by the U.S. Atomic Energy Commission in November 1974. The Environmental Technical Specifications (ETS)²⁹ issued at that time required evolutionary changes in the existing program, which was being conducted for the California Regional Water Quality Control Board, San Diego Region. During the first half of 1975, both programs continued and separate reports^{25,26} were issued. Since that time, the California requirements have been changed to be identical to those imposed by ETS, and only ETS reports are now issued.

Section 3.1.1.1.a.5, "Thermal Measurements," has the objective of providing temperature data for defining the thermal plume. This section requires bimonthly measurements of vertical profiles of temperature at 34 fixed stations. Thirty stations are to be selected (from among those shown in Fig. 4.4) at the discretion of the survey crew, subject to the requirement that there be at least one in each zone. The additional four stations are located beyond the boundaries of the map, one upcoast and three downcoast. Water temperatures are to be measured bimonthly at four fixed intertidal stations in order to estimate shoreline heating due to the plume. Aerial infrared measurements of sea surface temperature are required once each quarter. These are to coincide with the bimonthly surveys, if possible. Finally, temperatures near the surface, mid-depth, and bottom are to be recorded every 0.5 hr at two locations, one about 2000 ft and the other about 22,000 ft downcoast from the discharge and both in 30 ft of water.

The utility is required to report each vertical temperature profile and its time of measurement. Surface temperature maps are to be prepared from these data and from the aerial infrared measurements. There are no requirements for monitoring currents or for reporting weather or sea state.

Section 3.1.1.a(6), "Comparison of Intake and Discharge Temperatures with Ambient Temperatures," has as its objectives the determination of

the temperature rise of the discharged water over ambient water and the estimation of the extent to which heated water is recirculated back into the intake of the circulating water system. The requirements of Sect. 3.1.1.a(6) involve the comparison every 2 hr of temperatures measured by thermocouples in the intake and discharge conduits behind the tsunami wall with the surface temperature 22,000 ft downcoast.

In 1975, vertical temperature profiles and intertidal temperatures were measured during the oceanographic cruises of February 24, April 29, July 1, September 4, and November 6. Aerial infrared mapping was conducted on February 24, July 1, September 11, and November 6. Essentially continuous temperature measurements at the designated stations were obtained starting in June. The results were reported in two Semiannual Operating Reports^{25,26} and one Annual Analysis Report.²⁷ Except for the fact that five rather than six oceanographic cruises were conducted, compliance with the spirit and letter of these sections of the ETS appears to have been remarkably complete.

A more specific idea of the ETS monitoring program can be obtained by focusing attention on a typical survey date. July 1, 1975, has been selected because the bimonthly oceanographic boat cruise and the quarterly aerial infrared survey coincided. This was also the last survey in which separate measurements were made for the California Regional Water Quality Control Board's Marine Environmental Monitoring (MEM) program.

Vertical temperature profiles were obtained from the 48-ft Research Vessel (R/V) Sea Quest using an electronic bathythermograph (BT). The sensor contained a pressure transducer for measuring depth and a thermistor for measuring temperature. The sensor was lowered to the bottom by a power winch at 1 to 2 fps and was raised at a similar rate. The down and up profiles were recorded on an x-y plotter, and a single smoothed profile was reported. The thermistor had a time constant of 4 ms, and the overall system accuracy was estimated to be $\pm 0.5^{\circ}\text{F}$. The 34 vertical temperature profiles presented in the ETS report²⁶ are a subset of the 41 profiles reported in the MEM document.²⁵ The time required to measure the 34 ETS profiles was about 10 hr.

Figure 4.14 shows isotherms developed from the vertical profiles at the B-line stations. These stations are on a line perpendicular to the discharge conduit about 2000 ft offshore. The presence of a strong vertical stratification typical of the summer is clear. The down bending of the isotherms near the discharge is due to the addition of heat by the outfall. Further interpretation of this plot is not justified because it is neither an instantaneous nor a time-average temperature cross section. The data used to draw Fig. 4.14 were measured during an 8.5-hr interval.

Caution should also be exercised in comparing vertical profiles made at the same station on different dates. Unless the time at which the profiles were recorded is similar, diurnal variations could lead to misleading conclusions.

Fig. 4.14. San Onofre - Temperature cross section from B-line station vertical temperature profiles on July 1, 1975. The vertical scale is exaggerated by a factor of 200. Source: Lockheed Aircraft Service Company, *San Onofre Nuclear Generating Station Unit 1, Semiannual Operating Report, Environmental Technical Specifications Sections 3.1 and 4.0, November 1974-July 1976* (undated).

Figure 4.15 is an isotherm map prepared from the surface temperatures of the BT profiles. Note that, in preparing this figure, data from all MEM stations were used. When only the ETS stations were used, the isotherm configuration was considerably different. This suggests that the density of ETS profiling stations is too low to justify the preparation of such plots. An even more serious objection to the preparation of surface isotherm maps from the vertical profile data is the long duration of the sampling period. This is made particularly clear by comparison with the isotherm maps generated by aerial infrared thermometry.

Three mapping flights were made using a Cessna 172 single-engine aircraft. The plane flew at an altitude of 700 ft at a speed of 70 knots along a series of straight lines marked by fixed weather balloons and other landmarks. A Barnes Engineering Company Precision Radiation Thermometer (PRT-5) was mounted with a fixed nadir viewing angle so that 9.5 to 11.5 micron radiation from a 35-ft-wide swath of sea surface was detected and recorded on a strip chart. The PRT-5 has a single internal reference and a specified absolute accuracy of $\pm 0.9^{\circ}\text{F}$. Groundtruth was obtained by flying over the surface vessel while the sea-surface temperature was measured by bucket thermometer. This temperature was radioed to the aircraft and noted on the strip chart. The time needed to complete an infrared scan of the area is about 1 hr.

Figures 4.16, 4.17, and 4.18 show the surface isotherm maps obtained from 0925 to 1005, 1220 to 1255, and 1530 to 1615 PDT on July 1, 1975. Each map was obtained during the boat survey. The solid lines are the hand-drawn isotherms and the dashed lines show the flight paths of the aircraft. The most obvious conclusion obtained from these figures is that the appearance of the plume changed drastically during the day. None of the IRC maps looks like any other, and none of them looks like the surface map derived from the BT measurements (Fig. 4.15). When a plume changes totally in appearance in the space of a few hours (as Figs. 4.16 and 4.17 demonstrate), a map drawn from data taken over a 10-hr period will be seriously misleading. For this reason, surface maps prepared from BT profiles do not accurately represent the discharge conditions.

It should be noted that the plant operating data contained in the ETS report are not sufficient to rule out variations in plant operation as a cause for variations in the plume. A remark in the MEM report does indicate that no variations occurred on July 1, 1975. To avoid such ambiguity, each ETS report could contain hourly information on heat rejection rate, intake temperature, and discharge temperature beginning at least 48 hr before the start of the survey and continuing to the end of the survey.

In order to calculate areas within given excess temperature isotherms and the distances to these isotherms in the IRC isotherm maps, ambient temperatures must be determined. In most cases, these choices have been correctly made from the available data. The ambient temperature for Fig. 4.17 was chosen to be 66°F . This means that the area within the

Fig. 4.15. San Onofre - Sea surface isotherm map developed from surface readings of BT vertical profiles on July 1, 1975. Source: Lockheed Aircraft Service Company, San Onofre Nuclear Generating Station Unit 1, Semiannual Operating Report, Environmental Technical Specifications Sections 3.1 and 4.0, November 1974-July 1975 (undated).

Fig. 4.16. San Onofre - Sea surface isotherm map developed from aerial infrared thermometry flight 1, 0925 to 1005 PDT, July 1, 1975. Source: Lockheed Aircraft Service Company, San Onofre Nuclear Generating Station Unit 1, Semiannual Operating Report, Environmental Technical Specifications Sections 3.1 and 4.0, November 1974-July 1975 (undated).

Fig. 4.17. San Onofre - Sea surface isotherm map developed from aerial infrared thermometry flight 2, 1220 to 1255 PDT, July 1, 1975. Source: Lockheed Aircraft Service Company, *San Onofre Nuclear Generating Station Unit 1, Semiannual Operating Report, Environmental Technical Specifications Sections 3.1 and 4.0, November 1974-July 1975 (undated).*

Fig. 4.18. San Onofre - Sea surface isotherm map developed from aerial infrared thermometry flight 3, 1530 to 1615 PDT, July 1, 1975. Source: Lockheed Aircraft Service Company, San Onofre Nuclear Generating Station Unit 1, Semiannual Operating Report, Environmental Technical Specifications Sections 3.1 and 4.0, November 1974-July 1975 (undated).

1°F elevated temperature (67°F) isotherm is 22 acres and the area within the 4°F elevated temperature (70°F) isotherm is 8.8 acres. The maximum distances to these isotherms are 1700 ft and 700 ft respectively. These values are extremely sensitive to the choice of ambient temperature. For this reason, it must be remembered that what appears to be ambient temperature water in a tidal system may contain heat rejected during the previous half-tidal cycle. There seems to be no simple way around this difficulty.

A rather unusual feature of Fig. 4.17 is the existence of a cool ring of 65 to 67°F water surrounding the outfall. This water is cooler than the water above the discharge and the water farther away. This phenomenon, which has been observed several times at San Onofre, has been attributed to the entrainment of cooler bottom water by the upward jet of the discharge. This mechanism would seem to be possible only for brief periods of time; otherwise, a cold plume would be observed.

One distinct problem is the lack of any weather, sea-state, or current information. Without some idea of the current pattern, the interpretation of the isotherm maps is very speculative. Fortunately, the MEM report for July 1, 1975, contains some of these data. The weather was calm and the sea state was low during the entire cruise. Figure 4.19 shows the tracks of three drogues launched along the extended intake axis between 1000 and 1121 PDT. The drogues drifted down and oncoast at about 0.2 knots. Figure 4.19 also shows that the tidal elevation rose about 3 ft during the course of the survey. Even though these data are not very detailed, they aid enormously in the interpretation of the thermal data. Weather and current data of at least this level of completeness should be taken in connection with oceanographic surveys.

Temperatures were measured at five intertidal stations in the surf zone using a bucket thermometer between 1510 and 1607 PDT. The temperatures ranged from 68.4 to 69.0°F. Although midday and evening IRC isotherm maps and current measurements suggest an onshore drift of heated water, the intertidal temperatures are higher than any found offshore during this time period. Consequently, it is uncertain whether these elevated intertidal temperatures are due to the plume or to natural shoreline processes. Because the intertidal measurements have never yielded conclusive data on this question, a more sophisticated program of measurements appears to be needed to determine the effect of the plume at the shoreline.

The program of continuous temperature monitoring reached operational status on June 1, 1975. Buoys were placed 2000 ft downcoast of the intake (station C2S) and 22,000 ft downcoast of the intake (station C22S). The depth at each station is 30 ft MLLW, and the buoys are moored in a manner that allows them to follow variations in the height of the sea surface caused by waves and tides of up to 16 ft. The temperature sensors are mounted at depths of 2 ft, 15 ft, and 24 ft below the surface, and the temperatures they measure are referred to as surface, mid-depth, and bottom temperature. A sophisticated thermistor-radiotelemetry system was under development but did not become operational during 1975.

Fig. 4.19. San Onofre - Drogue tracks observed between 1000 to 1121 PDT only, July 1, 1975.
Source: Lockheed Aircraft Service Company, *San Onofre Nuclear Generating Station Marine Environmental Monitoring Report*, January-June 1975 (May 1976).

Data were obtained using a backup system consisting of Peabody-Ryan Model F-45 Waterproof Thermographs. These are liquid expansion thermographs which record temperatures on a clock-driven pressure-sensitive strip chart. The Peabody Ryan thermographs are accurate to $\pm 1^\circ\text{F}$ in temperature and $\pm 2\%$ in time. Assuming that the timing mechanism was reset when the operation of the thermographs was checked every two weeks, a maximum time error of ± 6.7 hr could have occurred. In accordance with Technical Specification 2.1.1, intake and discharge temperatures are measured by thermocouples mounted in the intake and discharge conduits behind the tsunami wall. These thermocouples are accurate to $\pm 0.5^\circ\text{F}$ and are continuously monitored and recorded in the reactor control room.

Data from all these sensors were digitized at 2-hr intervals and are presented in Figs. 4.20, 4.21, and 4.22. These time series all show a warming trend through July followed by a long-term cooling trend for the rest of the year. Cooling trends of about one week duration are seen in all series during late July, early August, and late August. Similar cooling trends were observed at San Clemente and La Jolla. These have been tentatively attributed to the passage of large eddies of cooler water separated from the California Current. Spikes in the intake and discharge temperature time series are due to heat treatment or switching from dual- to single-pump operation. Some intake conduit heat treatments were not resolved by the 2-hr digitizing period. Spikes in the temperature series at C2S and C22S have not been explained. Another unexplained feature of these time series is that, at both C2S and C22S, the temperature variance at mid-depth exceeds that at the surface. This is visually evident in Fig. 4.21.

Monthly averages of temperatures at the discharge, the intake, and the ambient station (as defined in Technical Specification 1.14) are presented in Table 4.3. During the months of July through December when the plant capacity factor (PCF) never fell below 97% (see Table 4.2), the average condenser temperature rise was 20.8°F with an uncertainty of $\pm 1^\circ\text{F}$. This is in excess of the design temperature rise of 18.3°F and is supported by the 22°F rise measured by Pacific Northwest Laboratories in 1972 (see Sect. I). The monthly average difference between intake and ambient is always within the $\pm 1.5^\circ\text{F}$ combined uncertainty of the two measurements. If the choice of ambient were suitable, this would indicate that recirculation was negligible. Technical Specification 1.14 defines ambient temperature as the temperature measured in the upper 2 ft of the water column at station C22S. As described in Sect. I, the intake structure withdraws water horizontally through an opening that extends from 12.5-ft to 16.5-ft MLLW in water whose depth is 27-ft MLLW. Therefore, if the plant were not operating, the surface temperature at station C22S would usually exceed the intake level temperature due to natural stratification. This would be especially true during summer. With the plant operating, there is the further possibility that the buoyant thermal plume may preferentially increase near-surface temperatures. Consequently, the comparison of the near-surface temperature at station C22S with the intake temperature will not reliably indicate recirculation. Ambient temperature would be defined better by mid-depth at station C22S.

Fig. 4.20. San Onofre - Temperature-time series for surface, mid-depth, and bottom at station C2S from June through December 1975. Source: Lockheed Aircraft Service Company, *San Onofre Nuclear Generating Station Unit 1, Annual Analysis Report, Environmental Technical Specifications Sections 3.1 and 4.0, January through December 1975* (August 1976).

Fig. 4.21. San Onofre - Temperature-time series for surface, mid-depth, and bottom at station C22S from June through December 1975. Source: Lockheed Aircraft Service Company, *San Onofre Nuclear Generating Station Unit 1, Annual Analysis Report, Environmental Technical Specifications Sections 3.1 and 4.0, January through December 1975 (August 1976).*

Fig. 4.22. San Onofre - Temperature-time series measured in SONGS 1 intake and discharge conduits from June through December 1975. Source: Lockheed Aircraft Service Company, San Onofre Nuclear Generating Station Unit 1, *Annual Analysis Report, Environmental Technical Specifications Sections 3.1 and 4.0, January through December 1975* (August 1976).

Table 4.3. San Onofre - Monthly averages of continuous temperature records (°F) at San Onofre

Month	Discharge temperature	Intake temperature	Discharge - intake	Ambient ^a temperature	Intake - ambient
June	79.2	63.3	15.9	62.6	+0.7
July	87.8	68.0	19.8	68.2	-0.2
August	83.8	63.7	20.1	64.8	-1.1
September	86.7	65.5	21.2	66.0	-0.5
October	86.2	64.2	22.0	64.9	-0.6
November	81.3	60.1	21.2	60.4	-0.3
December	78.8	58.3	20.5	57.0	+1.3

^aStation C22S, 2-ft depth.

Source: Lockheed Aircraft Service Company, *San Onofre Nuclear Generating Station Unit 1, Annual Analysis Report, Environmental Technical Specifications Sections 3.1 and 4.0, January through December 1975* (August 1976).

All of the continuous temperature time series were subjected to spectral analysis. In each case, diurnal (24 hr) and tidal (12.4 hr) peaks were found. Cross spectra for ten pairs of time series indicated that events with periods of less than 12 hr were poorly correlated between stations. This finding may have been significantly influenced by the temporal inaccuracy of the thermographs. Comparing these results with those of Koh and List,⁵ it appears that the scale of oceanographic processes responsible for temperature variations with periods between two and seven days exceeds 22,000 ft but is less than the 15 miles between Oceanside and San Clemente. Additional data will be needed to define these processes.

Our analysis suggests that additional study of the difference in thermal stratification at stations C2S and C22S may provide new information about the variation in the depth of the San Onofre plume. Such knowledge would aid in predicting recirculation.

B. ECOLOGICAL EVALUATION

1. Thermal effects

The present ecological monitoring programs at San Onofre have evolved from programs initiated in 1963 to study the offshore marine ecology in the vicinity of San Onofre 1. These studies were conducted in compliance with specifications set forth by the California Regional Water Quality Control Board (San Diego). Southern California Edison has employed the following consultants since 1963 to conduct the ecological surveys off San Onofre: Marine Advisers, Incorporated (1963 through 1971); Intersea Research Corporation (1972 and 1973); and Lockheed Aircraft Service Company, Department of Marine Biology (1974 to the present).

San Onofre 1 became commercially operational in January 1968; the Technical Specifications were established in December 1974. From 1964 until the initiation of the Technical Specifications program, the methods of sampling and analysis of data were variable from year to year for many of the ecological groups surveyed. From 1964 through 1974, phytoplankton and zooplankton were monitored at five locations, three discharge stations and two control stations. The discharge stations were located on a line at various distances seaward of the discharge structure. Phytoplankton samples were collected in quart jars, concentrated 50 times, and enumerated. Zooplankton were sampled at the surface (0 to 2 m) with a 0.5-m-diam net with 363- μ m mesh (#2 mesh). Intertidal surveys were conducted at six stations employing meter-square quadrats along transects. At each transect, sand was removed, washed through screens, and organisms enumerated. On cobble habitats, encrusting organisms were recorded as percent areal coverage, and individuals were counted. The benthic dive surveys were conducted by random meter-square quadrats, circular and reconnaissance swim techniques, and sediment cores.

During this pre-Technical Specification period of monitoring (1963 through 1974), planktonic, benthic, and intertidal samples were taken one to three times a year (Table 4.4). Monitoring was generally conducted in the winter and summer, periods when maximum impacts could potentially occur. During this period, sampling for plankton, benthos, and intertidal organisms were not always conducted during the same month each year. For example, there was a benthic sample collected in May 1970, September 1971, September 1972, October 1973, and October 1974. Data collected during these years are not conducive to any statistical analysis that could be performed to detect potential power plant impacts or temporal trends in population dynamics. No realistic comparisons of preoperational and operational data can be made for the following reasons: (1) ecological surveys prior to 1974 were conducted only one to three times per year, (2) sampling was not consistent among years, and (3) sampling stations and methods were different during the pre-Technical Specifications and Technical Specifications periods (after November 1974). An in-depth description and comprehensive evaluation of the inadequacies of the pre-Technical Specifications ecological monitoring programs (1964 through 1974) at the San Onofre site were made by Hedgepeth.³⁰ The ORNL staff concurs with Hedgepeth's conclusion that no meaningful comparison of preoperational and operational ecological data can be made.

The ORNL evaluation of the Technical Specifications at San Onofre for 1975 has been performed within the following framework. Bimonthly monitoring of most biota at the site did not begin until May 1975; therefore, only four sampling periods were available for analysis under the scope of this program. Due to the small number of samples collected and lack of preoperational data, we concluded that insufficient data were available to determine, through appropriate statistical analysis, whether an impact had occurred. Thus the scope of this evaluation was

Table 4.4. San Onofre - Frequency of monitoring of ecological parameters from 1963 through 1975

	1963	1964	1965	1966	1967	1968 ^a	1969	1970	1971	1972	1973	1974	1975
January			I ^b	I					I				
February			P ^c	P	B ^d	B	P	I,P					I
March			B	B		P	B	B	I,B,P	P			
April			I			I	I	I		I	P,I,B	P,I,B	B
May		I,B,P			I			B					P
June			I		I	B			I	I			I
July			I,P		I	I	I	I		I		I	P,B
August			B	B		P	B	P		P	P,I	P	
September		I,B			B	B			B,P	B			P
October	I,B		I	I,P	P	I		I,P	I		I,B	B	I,B
November					I							I	P
December													I

^aUnit 1 became operational January 1968.

^bI = Intertidal surveys.

^cP = Phytoplankton and zooplankton surveys.

^dB = Benthic surveys.

directed toward a critique of the present Technical Specifications monitoring program because of the unique physical and ecological characteristics of this coastal marine facility and the ongoing construction of Units 2 and 3. We believe that consideration of the future operation of Units 2 and 3 is necessary within the context of this evaluation. When SONGS Units 1, 2, and 3 are operational, Unit 1 will account for only 17% of the water usage and thermal discharge volume; thus, it is important to consider operation of all three units at the site in assessment of environmental impacts.

Unit 1 presently produces 430 MW power and uses 350,000 gpm of sea water for cooling. Each of the future Units 2 and 3 will produce 1140 MW of power and utilize 830,000 gpm of sea water.³¹ In Fig. 4.23, a cross section of the depth profile offshore San Onofre is presented. The intake port for SONGS 1 is located 3200 ft offshore in 30 ft of water, while the single (point source) discharge port is located 2600 ft offshore (Fig. 4.24). The separate intake ports for Units 2 and 3 are located 3500 ft offshore in approximately 30 ft of water; however, the condenser heat from both units is discharged along two 2500-ft-long diffusers located from 3500 to 6000 ft offshore and from 6000 to 8500 ft offshore respectively. In Fig. 4.25, a cross section design of the diffuser port to be used is shown. From the view in Fig. 4.24 of the dispersion of thermal effluents from the SONGS facility at variable depths and at various distances offshore, it appears that the present monitoring design, which exclusively samples all biota along the 9-m isobath, could be improved. The sampling program suggestions will be based on sampling at both inshore and offshore areas where water depths range from 9 to 15 m. This range

Fig. 4.23. San Onofre - Offshore profile through intake and discharge. Source: Southern California Edison Company and San Diego Gas and Electric Company, *Thermal Effect Study, Final Summary Report, San Onofre Generating Station Units 2 and 3*, prepared by Quality Analysts and Marine Biological Consultants, Inc., September 1973.

Fig. 4.24. San Onofre - Undersea conduits and diffusers. Source: U.S. Atomic Energy Commission, *Final Environmental Statement - San Onofre Nuclear Generating Station Units 2 and 3*, Docket Nos. STN 50-361 and 50-362, March 1973.

Fig. 4.25. San Onofre - Typical diffuser port block. The nozzles will be oriented at a vertical angle of 20° above the horizontal and are aligned to direct the discharge offshore alternately at angles of 25° to the right and 25° to the left of the diffuser section centerline. Source: R. A. DeLaParra, "The Coastal Environment and a Nuclear Power Plant," presented at the Fifteenth Coastal Engineering Conference, Honolulu, Hawaii, July 11-17, 1976.

encompasses depths associated with both the inshore point source discharge of Unit 1 and the offshore discharge conduits of Units 2 and 3. The utility has designated zones 0A, 1A, 2A, 3A, and 4A as inshore areas and zones 0B, 1B, 2B, 3B, and 4B as offshore areas, although sampling is presently not being conducted in the offshore areas. Zone 6 could be similarly subdivided to areas 6A and 6B (Fig. 4.26). A more detailed description of the suggested sampling program is discussed in Sect. IV.B. of this volume.

2. Assessment of monitoring methods

a. Phytoplankton

Phytoplankton were collected bimonthly during 1975, but only from May through November. Samples were collected at seven stations (Fig. 4.27); two stations located in Zones 0A, 1A, and 2A, and one station located in Zone 6. Replicate sampling was conducted twice each year. Stations were spaced at increasing distances upcoast and downcoast from the SONGS 1 intake-discharge line. All stations were located along the 9-m depth contour to permit correlation of plankton data with physical and biological data that were collected at similar depths.

Phytoplankton samples were collected at two discrete depths (1 m and 8 m) at each station during daylight hours (0900 to 1500 hr) using a Lockheed-designed plankton pump system. Whole-water samples were collected at the pump discharge, and each 470-ml sample was preserved in 1% Lugol's solution until taxonomic analysis could be performed in the laboratory. All species observed were identified, and results were expressed as percentage of total number of cells present. Unfortunately, species were not enumerated, but major phytoplankton groups were reported.

Chlorophyll a

Coinciding with phytoplankton samples, a separate 470-ml sample of water was collected at both depths (1 m and 8 m) and was stored in a dark coldbox. At the laboratory, three 100-ml aliquots from each chlorophyll sample were filtered using a Millipore filtration apparatus (Whatman GF C glass fiber filters). These filters were refrigerated and stored in the dark until analysis could be performed on a Turner model 111 fluorometer. For chlorophyll a and phaeopigments, data were reported as milligrams per cubic meter. In the applicant's *Annual Analysis Report - 1975*,²⁷ phytoplankton sampling data were not reported quantitatively as the total numbers of cells per unit volume nor as the total number of cells per each major genera; rather, phytoplankton were reported as percent relative abundance to the total. Because of this, variations in the temporal variation in the phytoplankton population cannot be observed. Sorensen's quotient of similarity was the major statistical test employed to analyze similarity in species composition of the phytoplankton. The only graphic representation of seasonal changes in the primary producers

Fig. 4.26. San Onofre - Ecological surveillance zones showing discharge structures from Units 1, 2, and 3. Source: modified from Southern California Edison Company, *San Onofre Nuclear Generating Station Unit 1, Semiannual Operating Reports*, No. 1 (November 1974 through July 1975) and No. 2 (July through December 1975).

Fig. 4.27. San Onofre - Ecological surveillance zones for SONGS 1 showing present and possible locations for plankton, benthos, nekton, and intertidal stations. Source: modified from Southern California Edison Company, *San Onofre Nuclear Generating Station Unit 1, Semi-annual Operating Reports*, No. 1 (November 1974 through July 1975) and No. 2 (July through December 1975).

was constructed for chlorophyll a and the phaeopigment data (Figs. 4.28 and 4.29). The data presentation enables one to compare all station samples collected at a particular sampling date; however, it does not facilitate comparison of changes in the control area and the discharge area over a yearly cycle. Because variations between stations are usually considerable, it would be helpful to group the data from stations into control and thermally stressed area responses as was performed for the Surry data (see Vol. 2, Sect. IV.B). Consideration should be given to presenting the SONGS data in this manner for both the total phytoplankton cell densities and the concentrations of plant pigments. For the chlorophyll a and phaeopigment data, three-way ANOVA's and Tukey's multiple comparison tests were used by the applicant to examine difference in plant pigment concentrations between sampling periods, depths, and stations.

b. Zooplankton

Zooplankton were collected bimonthly during 1975, but only from May through November (May, July, September, and November) to coincide with phytoplankton sampling. Samples were collected at the same seven sampling stations (Fig. 4.27) (in zones 0A, 1A, 2A, and 6) that were used for phytoplankton collections. Replicate samples were collected twice each year. Stations were spaced at increasing distances upcoast and downcoast from SONGS 1 intake-discharge line. All stations were located along the 9-m depth contour to permit correlation of plankton data with other physical and biological data that were collected at similar depths.

Zooplankton samples were collected during daylight hours (0900 to 1500 hr) using a Lockheed-designed plankton pump system. Two discrete zooplankton strata (surface to 5 m and 5 to 10 m) were collected using 202- μ m mesh (#8 mesh) Nitex netting to determine daytime vertical distribution of zooplankters. Integrated samples were obtained for each of the two strata by lowering the intake funnel of the pump at 1-m interval steps. One cubic meter of water was sampled at each meter step, yielding a 5 m³ sample for each strata. Samples were preserved in 4% buffered formalin until identification could be performed. Stemple pipette subsamples of either 2- or 5-ml volumes were used for identification and enumeration of zooplankton, depending on the concentration of organisms per sample. Four subsamples were processed and returned to the sample after counting. The percentage of each taxon in each whole sample was also computed.

The zooplankton monitoring data were reported quantitatively as concentrations per cubic meter. Like the chlorophyll a data, the only graphic representation of the zooplankton data (Fig. 4.30) compared concentrations at all seven stations at each sampling period, rather than determining seasonal changes between control and thermally stressed areas, as was performed at both Surry (Vol. 2, Sect. IV.B) and Peach Bottom (Vol. 3, Sect. IV.B). Consideration should be given to presenting the

Fig. 4.28. San Onofre - Chlorophyll *a* concentrations from 1975 surveys. Open circles and triangles indicate values from the upper and lower strata respectively. The relative distances of the plankton stations from SONGS 1 are shown. A solid triangle indicates the position of SONGS 1. A vertical bar connects the July replicates. Source: Southern California Edison Company, *San Onofre Nuclear Generating Station Unit 1, Annual Analysis Report, Environmental Technical Specifications Sections 3.1 and 4.0*, prepared by Lockheed Marine Biology Laboratory, January through December 1975.

Fig. 4.29. San Onofre — Phaeopigment concentrations from 1975 surveys. Open circles and triangles indicate values from the upper and lower strata respectively. The relative distances of the plankton stations from SONGS 1 are shown. A solid triangle indicates the position of SONGS 1. A vertical bar connects the July replicates. Source: Southern California Edison Company, *San Onofre Nuclear Generating Station Unit 1, Annual Analysis Report, Environmental Technical Specifications Sections 3.1 and 4.0*, prepared by Lockheed Marine Biology Laboratory, January through December 1975.

Fig. 4.30. San Onofre - Zooplankton concentrations from 1975 surveys. Open circles and triangles indicate values from the upper and lower strata respectively. The relative distances of the plankton stations from SONGS 1 are shown. A solid triangle indicates the position of SONGS 1. A vertical bar connects the July replicates. Source: Southern California Edison Company, *San Onofre Nuclear Generating Station Unit 1, Annual Analysis Report, Environmental Technical Specifications Sections 3.1 and 4.0*, prepared by Lockheed Marine Biology Laboratory, January through December 1975.

SONGS zooplankton data in this manner. In the applicant's *Annual Analysis Report - 1975*,²⁷ zooplankton sampling data were analyzed by comparing the number of individuals and number of taxa collected at various sampling periods, depths, and stations using three-way ANOVA's and Tukey's multiple comparison tests. Shannon-Wiener species diversity values were computed, and similarities in species composition were examined by Sorenson's quotient of similarity.

In addition to analyzing the results of the phytoplankton and zooplankton density data separately, consideration should be given to correlating the predator-prey relationships of these two populations, as was performed on the Surry data (Vol. 2, Sect. IV.B). This comparison can only be performed if phytoplankton and zooplankton are collected at the same time and over the same water strata (depth profiles).

c. Benthos

(i) Epibenthos

The benthic monitoring program at SONGS was designed to monitor potential changes in sublittoral fauna through epibenthic, kelp bed, and settling plate studies and potential changes in the littoral fauna through intertidal studies. Before epibenthic sampling began, a preliminary diver reconnaissance survey was initiated (February 1975) to locate substrate suitable for the establishment of 11 permanent benthic stations in areas of comparable physical habitats. Four stations were established in Zone 0A, four in Zone 6, and one each in San Onofre kelp (Zone 2B), San Mateo kelp (Zone 3A), and Barn kelp (Zone 6) beds (Fig. 4.31). When possible, stations were located at the same depths and on similar substrate types in each area. Each station was permanently marked by a buoy. A permanent band transect (10 m by 1 m) was established at each benthic station using reinforcing bar stakes driven into the substrate at 2-m intervals along each side of the transect.

Epibenthic macrobiota were sampled quarterly in subtidal cobble and kelp bed areas, with nondestructive sampling techniques at the permanently marked benthic stations. Diver-biologists, using a series of lines, divided the transect at each station into ten 1-m² quadrats (Fig. 4.27). In-situ identification and enumeration of epibenthos observed within each quadrat and estimates of percent areal coverage of colonial and encrusting species were recorded on underwater slates. Some species were recorded only as percent areal coverage (primarily encrusting forms), some species as total numbers of individuals (i.e., molluscs, arthropods, polychaetes, etc.); however, some species were reported in both sets of units, which created serious problems in analysis of the data because no correlation can be drawn between percent coverage and numbers of individuals. The problem associated with reporting data in two separate units has been corrected in the 1976 sampling program, and each taxon is reported in only one set of predetermined units. In addition to the in-situ identification and enumeration, photographs of all quadrats were made for future reference.

Fig. 4.31. San Onofre — Typical configuration of a 1- by 10-m band transect established at fixed benthic stations in the vicinity of SONGS 1. Quadrat 1 is marked with a small float. Source: Southern California Edison Company, *San Onofre Nuclear Generating Station Unit 1, Semiannual Operating Reports*, No. 1 (November 1974 through July 1975) and No. 2 (July through December 1975).

Results of the epibenthic surveys were analyzed²⁷ by the applicant as numbers of individuals and numbers of taxa at each station using a two-way ANOVA coupled with Tukey's multiple comparison tests and using a species diversity using a Shannon-Wiener Index. Similarity of species composition between stations was examined with Sorenson's quotient of similarity and a stepwise discriminant analysis was performed to determine interstation differences in the species distribution. All analyses were performed so that the percent coverage data and enumerated species data were examined separately. This was appropriate because of the problem associated with reporting the epibenthic data in the two different units. The effects of substrate type (i.e., cobble and sand composition) were also evaluated for their effects on the species distribution. As with other portions of the monitoring program, no definitive conclusions can be made in assessing whether an impact has occurred due to the infrequency of sampling and the lack of preoperational data.

(ii) Settling plates

The settling plate monitoring program was designed to supplement information collected in the benthic diving surveys. Settling plate racks were installed near two benthic stations in both Zones OA and 6. Replicate plates from each station were removed sequentially at 3, 6, 9, and 12 month intervals from the date of installation, the first plates being collected in 1975 during August (three months immersion) and November (six months immersion). Raw data were not available at the time of our analysis; however, statistical analysis of this data was performed and is presented in the applicant's *Annual Analysis Report - 1975*.²⁷ The methods and materials used in the settling plate programs are described, and the importance of this sampling to the overall benthic monitoring program is discussed.

The settling plates were constructed of transite, a highly effective substrate for collecting fouling organisms.^{32,33} The plates were mounted horizontally because invertebrate larvae settle in greater numbers on substrates in this position.^{32,34,35} Settling plate racks (Fig. 4.32) were designed to hold an array of ten plates. Each array (2.4 m by 1.2 m) was supported 1 m off the bottom. Transite plates (20.5 by 30.5 by 1.3 cm) were spaced approximately 15 cm apart along the array. To guard against vandalism or loss due to natural causes, two racks were placed at each station.

Two replicate plates were removed at random from each station and returned to the laboratory for analysis. A photographic record of each plate was made for future reference. Results were to be reported as numbers of individuals per species, diversity index values, and an estimate of plate biomass recorded as wet weight. Data comparisons were made within and between replicates, between discharge and control areas, and between seasons.

In the applicant's *Annual Analysis Report - 1975*,²⁷ the settling plate results were not analyzed as intensively as other benthic data; however,

Fig. 4.32. San Onofre — Configuration of benthic settling plate racks installed near benthic stations 3-4 in Zone OA and station 5 in Zone 6. Source: Southern California Edison Company, *San Onofre Nuclear Generating Station Unit 1, Semiannual Operating Reports*, No. 1 (November 1974 through July 1975) and No. 2 (July through December 1975).

this occurred because only the three-month and six-month samples were available. More detailed analysis is to be presented later. The dominant attached epibiota were identified and enumerated individually, and encrusting forms were reported as percent of areal coverage. Biomass determination which were to have been performed on the settling plate organisms were not performed; however, size range was determined where appropriate. Biomass determinations could have been used as an alternative to the size measurement for evaluating changes in the fouling community. Nauman and Cory,³⁶ studying a power plant at Chalk Point, Maryland, reported three differences in the fouling plates collected at the intake as compared to the discharge. First, species composition was generally similar to both locations. Secondly, a higher production occurred at the discharge during all months, even though fewer species were present at the discharge (biomass measured as dry weight at the discharge was nearly three times greater than intake). Thirdly, differences in species, biomass production, and total number of individuals appear to be temperature dependent with other factors exerting minor influence. For the fouling study at San Onofre, determination of the length frequencies of the major biota may be a comparable method for monitoring changes in the fouling plate community than using biomass determinations.

(iii) Intertidal survey

A preliminary survey of the intertidal area in the vicinity of SONGS 1 was conducted to locate areas suitable for the specified monitoring. Five permanent intertidal stations were established based on similar substrate and habitat types, extent of the thermal field, similarity in flora and fauna, and where possible, proximity to previously established intertidal stations that were formed during past preTechnical Specification surveys in the San Onofre area. Two stations are located down-coast of SONGS 1, while three stations (including a control) are located upcoast (Fig. 4.27). Based on previously collected thermal data, four stations were located within the thermal influence on SONGS 1 (stations 2, 3, 4, and 5) and one station (station 1) served as a control, as defined by the 1°F isotherm.

A permanent origin marker was installed at each station, and ecological zones were designated at each station in accordance with the generalized scheme of intertidal zonation recognized by Ricketts et al.³⁷ This zonation is based on established elevations, areal extent of cobble beds, biotic composition, and annual tidal height data. After the ecological zones were defined and permanently marked, three equidistantly spaced 1/4-m² quadrats were permanently established in Zone 4 (Fig. 4.33). Quadrats were located along a line 15 m in length, paralleling the shore and perpendicular to a line drawn through the zone markers. Each quadrat was permanently marked with a 2.5-cm-diam pipe and three lengths of reinforcing bar.

Intertidal biota were surveyed once each calendar quarter (February, June, October, and December) at five permanently marked stations. All

Fig. 4.33. San Onofre - Configuration of a typical intertidal station at SONGS 1. Dashed line defines the 2-m-wide band transect. Source: Southern California Edison Company, *San Onofre Nuclear Generating Station Unit 1, Semiannual Operating Reports*, No. 1 (November 1974 through July 1975) and No. 2 (July through December 1975).

field work was conducted during daylight hours and during low tides of at least 0.6 ft MLLW. Observations of all recent and obvious unnatural occurrences (i.e., holes left by clam diggers) that may have affected biota within the zone were recorded. Two types of nondestructive sampling techniques were employed to survey the dominant macroscopic epibiota at each station. These included general qualitative observations along a band transect through the station's ecological zones and a quantitative assessment of three permanently fixed $1/4\text{-m}^2$ quadrats. For the latter sampling method, a $1/4\text{-m}^2$ frame (subdivided into 25 equal sections) was placed over each fixed quadrat. All exposed macroscopic epibiota were identified to the lowest possible taxon and enumerated; estimates of percent areal coverage of encrusting species were recorded. Unfortunately, in the 1975 monitoring reports, some species were reported both in units of percent areal coverage and as total numbers of individuals, creating serious problems in analyzing the data; however, this problem has been resolved by standardizing the reporting units for each species. In addition to the in-situ identification and enumeration of organisms, 35-mm color photographs were taken of each quadrat for future reference.

The utility analyzed the intertidal sampling data similar to the methods employed in epibenthic data by using a two-way ANOVA coupled with a Tukey's multiple comparison test; species diversity was assessed using a Shannon-Wiener Index.²⁷ The percent coverage and enumerated species data were analyzed separately. In addition, Sorensen's quotient of similarity and stepwise discriminant analysis was employed. As with the kelp bed data, the trophic structure of the intertidal community was compared among stations by identifying the primary producers, suspension feeders, scavengers, grazers, and predators. However, because of the frequency of sampling and the problems associated with anthropogenic disturbance in the intertidal quadrats, no definitive conclusions can be made based on the data collected.

d. Kelp bed benthic stations

At the kelp bed benthic stations (Fig. 4.27), San Onofre kelp, Barn kelp, and San Mateo kelp, the following parameters were recorded: (1) numbers of stripes on individual kelp plants counted 2 m above the bottom, (2) general condition of the kelp plants, (3) kelp growth (number of new fronds), and (4) number and species of kelp grazers (i.e., sea urchins) present.

The statistical analyses employed on the kelp bed data were identical to those used for the epibenthic data.²⁷ In addition, the trophic structure of each of the three kelp beds was compared by identifying and enumerating the primary producers, suspension feeders, scavengers, grazers, and predators. The effect of substrate type was also evaluated with respect to predominance of various species at a sampling station. The lack of adequate data precludes drawing a definitive conclusion as to the impact of SONGS 1 on the kelp community.

e. Fish

A preliminary nekton survey was conducted in order to: (1) determine the set duration and vertical position of the gill nets in the water column that would yield the most effective catch and (2) establish six nekton stations (three in Zone OA near the discharge and three in Zone 6 in the control area). Experimental monofilament gill nets were set in the following manner: (1) on both the surface and bottom, (2) over various substrate types (i.e., cobble and sand) as determined by divers, and (3) for durations from 2 to 18 hr. Results of 21 preliminary sets indicated that:

- (a) nets set over cobble substrate yielded more species in greater numbers than those set over sand for the same period;
- (b) longer sets (18 hr) yielded both the greatest number of species and greatest number of individuals;
- (c) surface and bottom nets tended to catch different species.

Consequently, in order to obtain a maximum amount of information for comparison of control and discharge areas, it was determined that both surface and bottom nets would be set in each zone over the cobble substrate for a period of 24 hr.

In the final sampling program (1975), nekton were collected on a quarterly basis (March, June, September, and December) at the 9-m depth contour (Fig. 4.27). Within each zone, nets were set on the bottom at two stations and on the surface at a third station. Marinovich experimental monofilament gill nets (45 m by 1.8 m) containing six 7.6-m panels of 22-, 25-, 38-, 46-, 53-, and 76-cm bar mesh were used. Thus, different panels collected different size fishes.

Nets were oriented perpendicular to the coastline, were checked by divers to ensure a proper set, and were recovered approximately 24 hr after setting. Fish collected were identified and enumerated; the standard length (teleosts), total length (sharks), or disc width (rays) of all individuals of each species were recorded. All fish were visually inspected for external parasites, diseases (fin erosion), and anomalies. A subsample, consisting of a maximum of ten individuals of each resident fish species, was randomly selected for sex determination.

In the *Annual Analysis Report - 1975*,²⁷ the nekton were the most completely analyzed trophic group at the SONGS site. Both quantitative and qualitative methods of analysis were employed to evaluate differences between nekton captured in the control as compared to the discharge area. In addition to use of ANOVA, Sorensen's quotient of similarity and stepwise discriminant analysis of fish catches were performed. Length frequencies of all fish captured were reported. The evaluation of length-frequency data should have been correlated with age-class distributions for the major species of fish identified in the sampling

program. Age-class distributions of the major species should be compared between the control and discharge areas to determine if there is a differential preference of specific age groups to the thermal plume area. If differential preference for the discharge area is occurring for a specific species age class, possible reasons for this should be studied (i.e., thermal preference and food availability).

Also, the age-class distributions of fish captured in the regular nekton surveys should be compared to the age-class distributions of impinged fish to determine whether differential impingement of a specific age-class group is occurring for various species. If impingement is preferentially affecting younger age groups, the possible implications of this to the structure and dynamics of the offshore fish populations should be examined.

f. Kelp beds

Aerial infrared photographs were taken of the San Mateo, San Onofre, and Barn kelp beds in March, July, September, and December 1975 to monitor qualitative changes in the canopy extent and configuration and to determine the number of small beds comprising each of the three major beds.

Several factors had to be considered in comparing photographs, including sea state, stage of the tide, time of day, and altitude of the plane above the water. The ORNL staff did not analyze this information; however, the utility reported in the July through December 1975 semiannual report²² that no significant differences in the extent of the kelp bed areas were observed. Considering the qualitative nature of this sampling technique, no future analysis was performed. It should be added, however, that coupled with hydrothermal plume maps and in-situ examination of the kelp beds, this method does provide a different perspective by monitoring canopy extent.

3. Consideration of SONGS 2 and 3 in the ecological monitoring program

The present monitoring area at the San Onofre site encompasses 11 zones (Fig. 4.27) covering approximately 11 sq miles of the Pacific Ocean. All of the present monitoring stations are located at the 9-m isobath in Zones 0A, 1A, 2A, 3A, 4A, and 6. The main disadvantage of the present zone system is that samples are collected only in the inshore areas; however, with the completion of Units 2 and 3, offshore monitoring will be necessary as the majority of the thermal effluent from Units 2 and 3 will be discharged from 0.7 to 1.6 miles offshore. An expansion in the monitoring program to include the offshore areas would increase the sampling field to approximately 22 sq miles and may create a long lag period between sample collection at the various stations. Particularly for the zooplankton that migrate diurnally in the water column, a long lag period in sampling may result in misinterpretation of the data. To

ensure that sampling is conducted with the shortest lag time among those stations in the discharge and control that will be compared statistically, all inshore stations might be sampled one day and the corresponding stations offshore sampled on the following day. Within any month, only two days might then be required for sampling.

Of paramount importance is the need to begin the sampling program for Units 2 and 3 at least one to two years before these units become commercially operational, which is projected for 1981 and 1983 respectively.

a. Phytoplankton

Phytoplankton monitoring data could be improved for the purpose of assessing temporal and spatial variations in the population dynamics of the primary producers. Information of this nature is needed in order to adequately evaluate potential perturbations on the phytoplankton communities due to plant operation.

The following suggestions for sampling programs are presented:

1. Phytoplankton could be collected at both inshore and offshore stations in both control and discharge areas similar to those shown in Fig. 4.27.
2. Sampling could be performed at monthly intervals for a period of not less than one year using whole water collection techniques (associated with the Lockheed plankton pump); however, samples should be collected over the same strata as the zooplankton (surface to 5 m and 5 to 10 m) for the inshore areas and for the offshore areas (surface to 5 m, 5 to 10 m, and 10 to 15 m). These depth comparisons of phytoplankton densities will increase the accuracy of assessing the potential effects of entrainment for the three units.
3. Phytoplankton genera could be identified and enumerated at all depths and stations. Resulting data should be reported as total cell number per volume, and the total cell number per volume for each genus.
4. Chlorophyll *a* samples could be collected to coincide with the phytoplankton cell counts at each station and each depth for a period of not less than one year.

b. Zooplankton

Zooplankton monitoring data could be improved for the purpose of assessing temporal and spatial variations in the population dynamics of this group. Information of this nature is needed in order to adequately evaluate the potential perturbations on the zooplankton community due to power plant operations.

1. Zooplankton could be collected monthly at the same stations (Fig. 4.27), depths, and at the same time as phytoplankton so that comparisons can be made between these two trophic groups. Often, changes in concentrations of the primary producers will result in corresponding but time lagged changes in the herbivorous zooplankton.
2. Sampling could be performed over several integrated strata (e.g., surface to 5 m, 5 to 10 m, and 10 to 15 m where applicable) so that concentrations of zooplankton can be compared to phytoplankton assemblages collected in the same strata of the water column. The present procedure of phytoplankton sampling at discrete depths (1 and 8 m) does not allow for direct comparisons of these two trophic groups.
3. Predominant zooplankton genera could be identified (where possible) and enumerated at all depths and stations. Resulting data should be expressed as total organisms per volume and total number of organisms per volume for each predominant genus or taxon.
4. An attempt could be made to collect zooplankton at all stations at the same time of day. As mentioned earlier, if this cannot be done for all stations on the same day without a lengthy lag period, then sampling might best be conducted at all inshore stations on one day and at all offshore stations on the following day. Accurate records as to the time of collection should be made because time of day and season of the year influence distribution and composition of zooplankton in the water column.
5. At least once during each season, zooplankton samples could be collected at regular intervals (at least every 4 hr) for a period of 24 hr at both a discharge and a control station to evaluate changes in zooplankton resulting from vertical migration. Samples could be collected at the same integrated depths used in the monthly sampling program. Knowledge of diurnal variations of densities in the water column will aid in the predictions of entrainment mortalities as a result of plant operations.

c. Benthos

A large portion of the benthic monitoring program at San Onofre involves the use of nondestructive sampling techniques within various quadrats for the epibenthic and intertidal surveys. This type of sampling is unique and is made possible by the relatively good underwater visibility in this area. The lack of visibility would make application of this method impossible in many other aquatic systems. Although benthic biomass cannot be estimated, the staff feels this nondestructive sampling method is both appropriate and applicable at SONGS 1. Benthic monitoring data could be improved for the purpose of assessing temporal changes in the benthic communities in the vicinity of SONGS.

1. Epibenthic sampling could be performed at both inshore and offshore stations in the control and discharge areas as shown in Fig. 4.34.

Fig. 4.34. San Onofre -- Ecological surveillance zones for SONGS 1 showing locations of present and possible benthic sampling stations. Source: modified from Southern California Edison Company, *San Onofre Nuclear Generating Station Unit 1, Semiannual Operating Reports*, No. 1 (November 1974 through July 1975) and No. 2 (July through December 1975).

An equal number of stations in Zones A and B in the discharge can be compared to comparable stations in the control area.

2. Sampling frequency for epibenthos, including the kelp bed stations, could be increased to monthly intervals. If four additional stations are added offshore in both the control and discharge areas, random sampling of five out of ten of the 1 m² quadrat at each of the 10 m² transects might be initiated instead of sampling all ten of the 1 m² quadrats consistently.
3. Emphasis in the epibenthic and kelp bed monitoring programs could be directed toward identifying and enumerating only the predominant genera (taxon) comprising the majority of the benthic population (i.e., dominant groups that make up about 95% of the total).
4. The kelp bed community has been previously shown to be sensitive to the thermal increases in temperature and may provide a good indicator for assessing changes in the environment when coupled with hydrothermal plume maps and in-situ studies of trophic structure of the beds. A well integrated monitoring program for this community can provide essential information.
5. The settling plate study, unlike the epibenthic and kelp bed monitoring programs (conducted by in-situ diver biologists), allows for removal of biological material to the laboratory for determination of species diversity and size range measurements. The utility's use of replicate plates will provide a more detailed picture of natural variation in this benthic community.²⁷
6. The intertidal benthic data may not provide information that reflects plant operational effects because:
 - (a) The intertidal area is subjected to a high degree of natural variation in temperature under natural tidal and seasonal cycles. Most organisms in the intertidal zone are eurythermal and can adapt to broad temperature changes.
 - (b) Anthropogenic perturbations in the intertidal cobble areas (by clam diggers) have eliminated these stations as a valuable source of information in assessing the impacts of SONGS on the littoral fauna. Seasonal changes in abundance of the little neck clam, *Protothaca staminea*, collected at these disturbed quadrats cannot be attributed to power plant operations because decreases in density may be a result of human harvesting. In addition, movement of the substrate cobble by clam diggers tends to be injurious to the habitat of other intertidal organisms.
 - (c) In the *Final Environmental Statement - San Onofre Nuclear Generating Station Units 2 and 3*,³¹ the following predictions of the effects of plant operation are given:

"The littoral fauna could be exposed to increased water temperatures caused by heated effluents from San Onofre Units 2 and 3. Only an occasional increase of 1 to 2°F will occur inshore as a result of thermal effluents from

Units 2 and 3 (Sect. 3.3). However, even a 4°F increase — equal to California's thermal-limitation policy (Sect. 3.3.9) — is judged to be insignificant. Increased temperatures in the littoral will vary with weather and with tide conditions. Under such conditions, no significant effect on the benthic biota would be anticipated because similar temperature changes could occur under natural conditions."

Generic-type short-term thermal studies on intertidal organisms can provide useful data. Such laboratory studies may be able to indicate whether thermal additions of the magnitude induced by the operation of the SONGS Units 1, 2, and 3 would affect dominant intertidal species. Many of these types of thermal tolerance studies are in progress at other facilities operated by Southern California Edison (see Sect. V.B.1). Also, one could examine the feasibility of a one-year study conducted in the field to determine during which three-month period the greatest settling of fouling organisms occurs. For this study, settling plates could be placed out from January through March (three-months immersion) with new plates replacing these being installed every three months. Growth occurring during the winter, spring, summer, and fall could then be observed.

d. Fish

The utility has spent an extensive period of time in designing the present fish monitoring program with respect to selection of stations over appropriate substrates (cobble bottom), the duration of the net setting period, and the location in the water column; however, the fish catch in the surface nets is usually poor. During the entire 1975 nekton survey, in both control and discharge areas, only 334 fish were collected in the surface nets, while 2882 were collected in the bottom nets (Tables 4.5 and 4.6). This sample size is inadequate, particularly with respect to examining age-class structure of the dominant species. The utility, for reasons of poor sampling efficiency of the nets and insufficient sample size, decided to eliminate the surface nets from the 1976 surveys and redirected their effort to more intensively monitor bottom fishes. This modification is justified; however, if sampling could be conducted at monthly intervals at all stations, the temporal variations in fish species and relative abundance of fish populations in the area could be better determined. Based on our analysis, additional areas for sampling are suggested in Fig. 4.35 and correspond to possible plankton and benthic sampling stations in offshore control and discharge areas.

A preliminary evaluation of the nekton data for the bottom set gill nets indicates that less than nine species generally comprise 75% or more of the bottom dwelling fish population. These species represent two major families, Sciaenidae and Embiotocidae. The nine species are presented in Table 4.7. More intensive offshore sampling may reveal that offshore collections are dominated similarly by these species, and data on age class and size distributions could be collected so that potential shifts

Table 4.5. San Onofre — Total number and percent of major species of bottom fish collected in the discharge area of SONGS 1 during 1975

Discharge	March	June	September	December	1975
<i>Sciaenidae</i>					
Queenfish (R) ^a	221 (53.0)	185 (28.9)	61 (28.5)	107 (17.9)	574 (30.7)
White croaker (T) ^b	63 (15.1)	24 (3.7)	33 (15.4)	180 (30.1)	300 (16.0)
Spotfin croaker (T)		245 (38.2)	11 (5.1)		269 (14.4)
Black croaker (R)		54 (8.4)			95 (5.1)
White seabass (T)		45 (7.0)			71 (3.8)
<i>Embiotocidae</i>					
Walleye surfperch (R)	26 (6.2)	33 (5.2)	77 (36.0)	103 (17.3)	239 (12.8)
White surfperch (R)	15 (3.6)			88 (14.7)	110 (5.9)
Black surfperch (R)	31 (7.4)			40 (6.7)	74 (4.0)
Pile surfperch (R)					
Total (major species)	356 (85.3)	586 (91.4)	182 (85.1)	518 (86.7)	1732 (92.6)
Total number of fish	417	641	214	598	1870
Total number of species	20	23	17	20	

^a(R) = resident species.

^b(T) = transient species.

Table 4.6. San Onofre — Total number and percent of major species of bottom fish collected in the control area of SONGS 1 during 1975

Control	March	June	September	December	1975
<i>Sciaenidae</i>					
Queenfish (R) ^a	31 (12.3)	55 (26.4)	83 (21.7)	9 (5.3)	178 (17.6)
White croaker (T) ^b	17 (6.7)	21 (10.1)	32 (8.4)	15 (8.9)	85 (8.4)
Spotfin croaker (T)		24 (11.5)	156 (40.7)		181 (17.9)
Black croaker (R)	30 (11.9)			20 (11.9)	60 (5.9)
White seabass (T)					
<i>Embiotocidae</i>					
Walleye surfperch (R)	13 (5.1)	58 (27.9)	45 (11.8)		117 (11.6)
White surfperch (R)	61 (24.1)		19 (5.0)	73 (43.5)	154 (15.2)
Black surfperch (R)	19 (7.5)	10 (4.8)			39 (3.9)
Pile surfperch (R)	25 (9.9)	8 (3.9)			42 (4.2)
Total (major species)	196 (77.5)	176 (84.5)	335 (87.5)	117 (69.6)	856 (84.6)
Total number of fish	253	383	208	168	1012
Total number of species	24	23	19	19	

^a(R) = resident species.

^b(T) = transient species.

Fig. 4.35. San Onofre -- Ecological surveillance zones for SONGS 1 showing locations of present and possible nekton sampling stations. Source: modified from Southern California Edison Company, *San Onofre Nuclear Generating Station Unit 1, Semiannual Operating Reports*, No. 1 (November 1974 through July 1975) and No. 2 (July through December 1975).

Table 4.7. San Onofre -- Major species of fish collected in the bottom nets at SONGS 1

Common name	Scientific name
<i>Sciaenidae</i>	
Queenfish	<i>Seriphus politus</i>
White croaker	<i>Genyonemus lineatus</i>
Spotfin croaker	<i>Roncador stearnsii</i>
Black croaker	<i>Cheilotrema saturnum</i>
White seabass	<i>Cynoscion nobilis</i>
<i>Embiotocidae</i>	
Walleye surfperch	<i>Hyperprosopon argenteum</i>
White surfperch	<i>Phanerodon furcatus</i>
Black surfperch	<i>Embiotoca jacksoni</i>
Pile surfperch	<i>Damalichthy vacca</i>

in the age structure of dominant species in the population may be detected. Intensive monitoring for changes in dominant species inhabiting the site and correlating migration patterns of the transient species with periods of their appearance in the SONGS area are items for consideration.

e. Kelp beds

Aerial infrared surveys, which monitor the extent of the three major kelp beds in the area, are useful. In-situ observations are made of the condition of the kelp plants at the San Onofre kelp (discharge) and at the San Mateo kelp (control) and Barn kelp beds. While kelp beds in this part of southern California were once extensive, natural periods of warming during 1957 through 1959 resulted in major reductions in this community. The hydrothermal monitoring program to monitor the plume movements in this area will provide accurate documentation from which thermal effects on kelp beds can be estimated. This is particularly important in light of the additions of Units 2 and 3 in the near future.

4. Impingement

Impingement at SONGS was monitored for both periods of normal operation and during heat treatment periods. From November 27, 1974, until December 31, 1975, seventy-six 24-hr samples were taken during periods of normal plant operation. Fish impinged during heat treatments primarily represent fish entrapped inside the screen well since the last heat treatment process. Only impingement data from the heat treatments were presented in the semiannual reports. These data are reported as

total numbers, percent of the total numbers, total weight, and sex distribution of each species impinged during all heat treatments for each six months. Raw data on impingement occurring during normal operation were supplied by the utility. For each 24-hr sample, the total number and total weight of each species were recorded. Average fish impingement loss during a 24-hr period was 86 lb during 1975.

However, these types of impingement data are generally not amenable to ecological and statistical analysis for the following reasons.

1. Only total number and total weight of each species are given; therefore, the size distributions (lengths and age classes) of the fishes being impinged are not known. It would be helpful to know whether certain age classes (such as the young-of-the-year) are more vulnerable to impingement and cropped selectively from the population.
2. In order to identify and assess the physical factors of the environment that contribute to impingement, various physical measurements (such as temperature and turbidity at the intake, wind conditions, and tidal state) are needed on the day the impingement sample is collected. Intake design may have the largest influence on the magnitude of impingement, but the influence of both physical and biological variables on impingement need to be evaluated.

The type of impingement data collected and reported could be improved in order to better assess the effects of plant operations on the fish populations in the San Onofre area. During the periods when impingement samples are made, operating conditions at the site should be accurately recorded. The following parameters deserve consideration: number of pumps operating, number of units at the site that are operational, temperature and turbidity at the intake, tidal stage, and wind conditions. The impingement data is most useful if reported as the total number of fish impinged at each sampling period, the total number of individuals of each species impinged, and the total body length of all impinged individuals recorded by species. Length-frequency data for representative samples of each species should be reported for each sampling period. Using the length-frequency data, age-class determinations for all predominant species impinged could be made. Age distributions of impinged fish could be compared with the age distributions of populations caught in the nekton sampling programs to determine if certain age-class fish are differentially impinged. Possible implications of this to offshore fish populations might be evaluated. Because migratory species are prevalent in the San Onofre area, it is important that the type of data described above be collected for a period of approximately one year. If impingement impacts are deemed minimal in light of the unique fish-return system of Units 2 and 3 (Fig. 4.36), impingement sampling could then be significantly reduced.

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Fig. 4.36. San Onofre -- San Onofre screen well concept. Source: R. A. De La Parra, "The Coastal Environment and a Nuclear Power Plant," presented at the Fifteenth Coastal Engineering Conference, Honolulu, Hawaii, July 11-17, 1976.

5. Entrainment

In order to avoid the possibility of redundant studies, the utility is presently developing a plankton entrainment study plan to comply with both the Technical Specifications requirements and 316(b). No data were available at the time this report was written. Results of entrainment studies will be presented in later operating reports.

C. CHEMICAL EFFECTS

Heavy metal samples were collected quarterly at SONGS in both the receiving water (by Van Doren bottles) and in the bottom sediments (by divers using nonmetallic cores). Collected samples were analyzed for copper, chromium, nickel, and iron. Copper, nickel, and chromium are expected to be the most significant contaminants and are discharged at concentrations of 1.6 ppb, 0.2 ppb, and 2.0 ppb respectively.

Chlorine was monitored bimonthly at discharge and control stations, and concentrations averaged 0.1 ppm at the discharge. Some replicate sampling was performed. Chlorine was used infrequently because heat treatment was the primary method employed to control growth of fouling organisms. Units 2 and 3 will employ Amertap and heat treatments to control fouling of the condensers and conduits.

D. AVIAN MORTALITY

1. Cooling towers

Condenser waste heat will be discharged indirectly into the Pacific Ocean; therefore, avian mortality due to cooling towers is not applicable.

2. Transmission lines

Only a distance of 1437 ft of new additional transmission lines is needed at San Onofre to connect the plant to existing transmission lines. No monitoring data on bird populations are presented in the Technical Specifications reports.

E. SALT DRIFT

Condenser waste water is discharged directly into the Pacific Ocean; therefore, salt drift problems are not applicable.

F. HERBICIDES

No mention is made of herbicide use by the applicant for vegetation management of transmission rights-of-way. The only new transmission line construction required for Unit 1 is a distance of 1437 ft.

V. FINAL ASSESSMENT OF SAN ONOFRE TECHNICAL SPECIFICATIONS

A. HYDROTHERMAL

Based on a review of environmental Technical Specifications hydrothermal monitoring, the staff has made the following conclusions.

1. The condenser temperature rise was observed to exceed the original design value much of the time, and it has reached at least 22°F on occasion during normal fullpower operation.
2. It is suggested that hourly values of the plant heat rejection rate, circulating water flow rate, intake temperature, and discharge temperature be recorded and be made available on magnetic tape. It is further suggested that tables of the daily average values of these parameters be included in the monitoring reports.
3. SONGS 1 has operated at consistently high power plant capacity factor; therefore, most of the monitoring should reflect changes, if any, due to the power plant operation.
4. The 1975 hydrothermal monitoring program provided excellent results as required by the Technical Specifications.
5. SONGS 1 outfall structure produces higher-than-expected dilutions, possibly because it acts as a mixing chamber.
6. Of the three studies conducted to predict the SONGS 1 plume, the most recent study, the Caltech physical model, most accurately reproduced the single realization of the plume.
7. The SONGS 1 plume may change configuration in a few hours. For this reason, vertical cross sections and surface isotherm maps prepared from the existing bathythermograph (BT) profiles can be misleading.
8. Even if the plume underwent no temporal changes, the density of BT is sufficiently low to make the plotting of accurate surface isotherm maps difficult.
9. The staff suggests that using BT data to produce vertical cross sections and surface isotherm maps is of limited value here, and it could be discontinued.
10. The staff further suggests that more meaningful vertical temperature data could be acquired from a moving boat with a thermistor rake, as was done for the MEM program in 1974,^{23,29} rather than using BT profiler at fixed stations.
11. To properly interpret the plume measurements, information on the weather, sea state, currents, and plant operating level is needed for the time that the plume data are being obtained.
12. It would be extremely helpful if hourly data were obtained on the plant heat rejection rate, intake temperature, discharge temperature,

weather parameters, and sea state for the period beginning 48 hr before the start of the hydrothermal monitoring and ending at the end of the survey. Some current observations consisting of at least a series of drogue tracks made during the same period would also be very helpful.

13. The staff suggests that the airborne surveys be conducted bimonthly, rather than quarterly.
14. The program of infrared temperature monitoring could be improved by using a more advanced dual-reference imaging system with computer enhancement of the output.
15. A special study to explain the cool ring phenomenon at the circulating water discharge would be of much interest.
16. The intertidal measurements are not of sufficient detail to determine the degree of shoreline impingement of the plume. The staff suggests that a new method to determine this degree of impingement be devised to replace the present intertidal monitoring. Airborne thermal imaging during the power ascension phase following a refueling shutdown or dye-release technique may be suitable for this purpose.
17. The choice of the appropriate ambient temperature is difficult and crucial when evaluating areas under the isotherms.
18. The fact that the temperature variance at mid-depth exceeds the surface value at stations C2S and C22S cannot be explained. Therefore, the use of the surface temperature at station C22S as an ambient temperature for comparison with the intake temperature can be misleading because the intake location is well below the surface.
19. The staff analysis indicates that the definition of the ambient temperature in Technical Specification 1.14 is more accurately represented by the mid-depth temperature at station C22S. The 1975 recirculation study could be repeated using the newly defined ambient temperature.
20. The staff suggests that additional studies of the vertical stratification at stations C2S and C22S be undertaken to help predict the recirculation.
21. The spikes in the temperature time series at stations C2S and C22S remain unexplained. Better temporal accuracy in the continuous temperature measurements is needed for the cross-spectral analysis to be meaningfully performed.
22. The thermographs limit the validity of the spectral analysis of the data. The staff suggests that consideration be given to expanding the present thermograph network to provide a more statistically significant body of thermal data for the San Onofre plume.

B. ECOLOGICAL

1. Summary and conclusions

An adequate assessment of the environmental impact of the SONGS 1 facility cannot be made because only one year of operational data was available, data were not collected frequently enough (quarterly or bimonthly), and no meaningful preoperational data were available. Sampling frequency appears to be the major inadequacy of the present monitoring program. Appropriate changes in sampling are noted and might be considered for the purpose of providing data that are more amenable to statistical analysis and thus will improve our capability of detecting potential impacts. Attention might be directed toward designing a more intensive program to be in effect for at least one to two years prior to the operation of Units 2 and 3 and for a specific contracted time period (i.e., three to five years) after commencement of commercial operation of Units 2 and 3. This contracted period should include a period of not less than one year when all three units are operating at optimal commercial capacity. In this way, hydrothermal and ecological sampling could be coordinated during a period of minimal (Unit 1 only) and maximal (Units 1, 2, and 3) thermal discharge into the coastal marine system. If, after monitoring intensively for three to five years, an analysis of resulting data suggests that no detrimental effects on the biota are occurring, monitoring frequency should be reduced and specific sampling programs could be appropriately phased out of the Technical Specifications requirements. Monitoring program design should be directed toward answering relevant ecological questions as adequately as possible within the limits imposed by the ecosystem under study. The staff fully recognizes the vastness and complexities associated with sampling in an open ocean environment as opposed to sampling in a more restricted aquatic system.

The utility should be acknowledged for publication of an analysis of the Technical Specifications monitoring data collected for 1975.²⁷ This report is a good example of what is needed to fully document and understand the results of the Technical Specification program for a particular plant. While no definitive conclusions as to power-plant-induced perturbations can be made for Unit 1 based on the absence of preoperational data and only one year of operational data, at least a start has been made toward evaluation of potential ecological changes at the site. In addition, there is still adequate time to begin sampling offshore stations not presently affected by the thermal discharge from Unit 1 for at least one to two years before operation of Units 2 and 3 begins, which can be considered preoperational years for Units 2 and 3. Collection of preoperational data for Units 2 and 3 would also improve the monitoring program of Unit 1. The staff recommends that the utility continue to statistically evaluate additional years of monitoring data. In addition to the review of monitoring data collected at the site, the utility should be acknowledged for its support of special in-house generic-type

studies directed toward addressing ecological questions associated with power plant operations at coastal marine sites. During the ORNL site visit to SONGS, the staff was shown three on-going projects related to various ecological aspects of operating power facilities in the marine environment. These types of studies, which are discussed below, are directed toward several specific areas of environmental concern and should be encouraged by the NRC.

a. Thermal tolerance of fouling organisms

In these experiments, three different temperatures and three different exposure periods were being assessed for their effectiveness in killing fouling organisms. (SONGS 1 uses heat treatment as a major means of controlling fouling organisms, rather than exclusively using regular chlorination additions to reduce condenser fouling.) Units 2 and 3 will employ heat treatments and Amertap to control fouling.

b. Velocity cap design as related to impingement of fishes

In these experiments, various velocity cap designs and water velocities were being evaluated to compare rates of impingement based on physical parameters as well as various biological characteristics (swim speed, behavioral characteristics) of the impinged species. For the latter work, underwater video tape cameras were mounted at the intake structure of an operational plant to observe fish behavior.

c. Thermal growth studies

In these tests, the effects of various gradients of heated effluents on growth, survival, and reproduction were measured for several marine organisms over extensive time periods. These types of laboratory investigations may provide basic data to help explain, in part, responses of various ecological compartments that were measured in the field. They provide information which may eliminate or reduce the need for maintaining intensive sampling programs for the entire lifetime of the facility. Often, controlled laboratory experiments can provide corroboration of results obtained in the field, which may suggest that no detrimental environmental impact is occurring as a result of power-plant-induced perturbations.

2. Validation and comparison of Technical Specifications

In Table 4.8, a summary is presented of the predictions of impact at the San Onofre site made in the Final Environmental Statement. Adequate monitoring data were not available to validate these predictions. A comparison of the required Technical Specifications monitoring has also been made with the applicant's actual program (Table 4.9).

In summary, our evaluation of the present monitoring programs at SONGS 1 indicates insufficient information was obtained to allow the ORNL staff to determine if perturbations due to power plant operations are occurring to the marine ecosystem in the plant vicinity. We have made suggestions that could be useful in improving the design of the monitoring programs. Data collected under these suggested monitoring programs would be more amenable to statistical analysis and, therefore, would improve our capability of detecting and evaluating potential perturbations on the marine ecosystem due to operation of San Onofre Nuclear Generating Station Units 1, 2, and 3.

Table 4.8. San Onofre -- Impacts predicted in FES

Predicted impacts
Phytoplankton
1. The principal source of impact on phytoplankton will be from: <ul style="list-style-type: none"> (a) increased temperature, (b) chemical exposure (i.e., chlorine), (c) thermal shock during entrainment in summer.
2. A possible localized change in species composition at discharge may occur.
3. No adverse effect on the Barn or San Mateo kelp bed is expected.
Zooplankton
4. The primary impact on zooplankton will be from entrainment thermal shock. Little mortality is predicted for those organisms exposed only to the plume.
5. Mortality of 28.4% predicted for entrained organisms ^a
6. No overall detrimental effect to ocean zooplankton community is expected.
7. Most resident benthic organisms will not be exposed to a ΔT greater than 4°F.
8. Larvae of benthic organisms may be entrained; however, because of the high reproductive potential of these organisms, no widespread effect is predicted.
Fish
9. No cold shock kills are expected.

^aEntrainment: 18 to 23°F ΔT is expected to increase mortality in ichthyoplankton, phytoplankton, zooplankton, and benthic larvae.

Table 4.9. San Onofre - Comparison of utility monitoring programs with Technical Specifications requirements

Technical Specifications requirement	Utility program	Comments
A. Phytoplankton		
1. Seven stations sampled bimonthly near surface and bottom	Yes	First sample was not taken until May 1975
2. Plankton composition and numbers of organisms per unit volume compared at discharge and control area	Phytoplankton were not quantitatively enumerated	Each species recorded as percent of total, no enumeration
B. Zooplankton		
1. Seven stations sampled bimonthly near surface and bottom	Yes	First sample in May 1975
2. Composition and number compared between discharge and control	Yes	
C. Benthos (dive surveys)		
1. Benthic monitoring quarterly at four discharge stations, four control stations, and three help beds	Yes	
2. Stations surveyed using 10X or band transects	Yes	
3. Flora and fauna recorded as percent cover or numerical count	Yes	
4. Aerial infrared photos of help beds taken quarterly	(Yes)	Not taken in July 1975
D. Settling plates		
* Settling plates (replicates) were to be removed after 3, 6, 9, and 12 months immersion at one control and one discharge station	Yes	Only 3- and 6-month plates removed to date
2. Plates (3, 6, 9, and 12 month) removed sequentially each year and analyzed for species diversity and composition	3- and 6-month plates presently being analyzed	Data will be reported in 1976
E. Intertidal		
1. Five cobble intertidal transects per quarter	Yes	
2. Transects established at each station at 2 m wide band through ecological zones, three 1/2 m ² fixed quadrants at each station	Yes	
3. All macroscopic forms counted and/or recorded as percent cover	Yes	
F. Entrainment		
1. Entrainment studies on plankton and ichthyoplankton	(Yes)	A special plankton entrainment mortality study is under way to comply with 318(b) and the Tech Specs and will be presented in the third semiannual operations report
2. Density and species composition for zooplankton and ichthyoplankton		
3. Determine mortalities due to chlorination, mechanical, and thermal effects		
4. Detailed description of entrainment study program to be presented in first semiannual report		
G. Impingement		
1. During each heat treatment, the weight, size, condition, and sex of each species recorded	Yes	
2. Monitoring during normal operations consists of continuous collections for at least 25 hr/week for three weeks after heat treatment and at least 24 hr periods two weeks before the next heat treatment	Yes	Special study, data not reported in semiannual reports
3. Total weight and number by species recorded	Yes	
H. Chlorine		
1. Chlorine concentrations and demand monitored bimonthly for two years at six stations during plant operations	Yes	Special study

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