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TECHNICAL REPORT
TO THE
CALIFORNIA COASTAL COMMISSION

O. Water Quality Compliance

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1. INTRODUCTION

The San Onofre Nuclear Generating Station (SONGS) permit to operate, issued by the California Coastal Commission to San Diego Gas & Electric and Southern California Edison, includes permit condition, B.1.b, that requires the Marine Review Committee (MRC) to "measure the effect of San Onofre Units 2 and 3 on the marine environment, with emphasis on (a) the effects of the new units ... and (b) compliance with the regulatory requirements of State and Federal water quality agencies" (Permit No. 183-73; issued February 20, 1974). The purpose of this report is to relate the findings of the MRC to the various water quality regulations under which Units 2 and 3 now operate.

Federal and State water quality regulations that apply to SONGS are outlined in Section 2 of this report. Included is a review of the Federal Water Pollution Control Act, the California Ocean Plan and the State Thermal Plan, the National Pollution Discharge Elimination System Permits (NPDES) for Units 2 and 3, and other State water quality regulations imposed by the California Department of Fish and Game and the California Coastal Commission. We also determine which of these regulations can be addressed by data collected by MRC contractors.

In Section 3 of this report MRC findings pertaining to water quality are summarized and are applied to the relevant regulations to evaluate compliance. In the last section, we compare the MRC findings with those of the NPDES compliance studies. When the findings based on MRC data and the results of the NPDES monitoring studies disagree, we discuss the reasons for the differences.

2. APPLICABLE REGULATIONS

A number of agencies have jurisdiction over marine water quality issues in the State of California. The Federal agency with jurisdiction is the Environmental Protection Agency (EPA). The EPA reviews a state's water quality control plan and approves the plan if it conforms to federal regulations; once the plan is approved, the state agency developing the plan becomes the regulatory authority. The agency empowered with this authority in California is the State Water Resources Control Board (State Board), with separate Regional Water Quality Control Boards (Regional Boards) to conduct the permit review and preparation process for the State Board. The San Diego Regional Board has the responsibility for writing and administering the permits for SONGS.

The State Board has prepared various water quality control plans, such as the Ocean Plan and the Thermal Plan, for the State. These plans are used to develop NPDES permits for the regulation of ocean waste discharges. Water quality regulations of two other State agencies discussed below, the Department of Fish and Game, and the Coastal Commission, are more general than those of the State Board.

The State Board and San Diego Regional Board have primary responsibility for determining if SONGS is in compliance with the NPDES permit conditions. Regulatory agencies such as the Department of Fish and Game and the Coastal Commission report violations of their own policies to the Regional Board and act through the Regional Board to correct violations or effect changes in the NPDES permits for SONGS. Project-specific monitoring data and any other relevant information available to the Regional Board can be used by the Board to modify the

NPDES permit. Revisions can occur periodically, as relevant data become available, or as part of the five-year review period for each NPDES permit.

2.1 Federal Regulations

The Federal Government adopted the "Water Pollution Control Act" (Clean Water Act) to provide the regulations and mandates for discharge of thermal and other effluents. The Clean Water Act applies to all discharges in Federal and State waters. It includes a provision that allows states to develop their own water quality control plans with regulations that are at least as stringent as the Federal act. State plans may include regulations that are not in the Clean Water Act and may omit regulations that are in the act. Once the State plans are adopted, the State regulations supersede the Federal ones. However, regulations in the Clean Water Act that are omitted from State plans still apply to discharges within the State and are used by the Regional Boards to write NPDES permits.

2.2 State of California Regulations

The State Water Resources Control Board (State Board) of the State of California has been empowered to develop standards for all discharges within State of California jurisdiction. Several Regional Water Quality Control Boards (Regional Boards) of the State Board have been established to implement the water quality regulations developed by the State and to prepare NPDES permits, as authorized through the Environmental Protection Agency. The San Diego Regional Board has prepared the NPDES permits for SONGS Units 2 and 3.

When NPDES permits are prepared for proposed discharges, the Regional Board considers all applicable State and Federal water quality criteria, regulations and laws. From these, and based on the specific design and description of the proposed discharge, the Regional Board prepares the NPDES permit. NPDES permits contain the regulations under which each discharge must operate, including the monitoring requirements and programs that will be necessary to determine if the discharger is in compliance with the provisions of the permit. Draft permits are published and considered by the Regional Board at a public hearing. Permits must be renewed every five years; SONGS Units 2 and 3 NPDES permits will be renewed in 1990.

Since the Ocean Plan and the Thermal Plan contain the water quality regulations adopted by the State of California for offshore discharges, we summarize them briefly. By design, the NPDES permit contains the water quality information most applicable to a proposed discharge; accordingly, we provide a more detailed description of the NPDES permits for SONGS Units 2 and 3.

2.2.1 Thermal Plan

Thermal discharges are regulated under the "Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California" (Thermal Plan). The Thermal Plan is used by the staff of the Regional Board, to prepare NPDES water quality permits for dischargers of effluent that is proposed to be above ambient temperature of the receiving water (i.e. the parcel of water into which the discharge flows).

The intent of the Thermal Plan is to establish basic standards and requirements for waste heat discharges such as that from SONGS. The Thermal Plan contains regulations for all fresh, brackish and marine waters in the State. Only regulations applying to coastal ocean waters are used by the Regional Board to write the NPDES permits for SONGS. The applicable restrictions from the Thermal Plan include:

3.b.2 Elevated temperature wastes shall be discharged a sufficient distance from areas of special biological significance to assure the maintenance of natural temperatures in these areas. (The Regional Board will determine what areas will be afforded special protection as areas of special biological significance.)

3.b.3 The maximum temperature of thermal waste discharges shall not exceed the natural temperature of receiving waters by more than 20^{o} F.

3.b.4 The discharge of elevated temperature wastes shall not result in increases in the natural water temperature exceeding 4^{o} F at (a) the shoreline, (b) the surface of any ocean substrate, or (c) the ocean surface beyond 1,000 feet from the discharge system.

The Thermal Plan allows for exemptions (variances) to these standards provided the applicant can demonstrate to the Regional Board that adequate protection to balanced indigenous populations can be maintained. The plan also prohibits cumulative effects of thermal discharges from exceeding the limitations outlines above.

2.2.2 Ocean Plan

The State Board has also adopted the "Water Quality Control Plan for Ocean Waters of California" (Ocean Plan). The Ocean Plan, revised in September 1988, is intended to establish criteria for effluent discharge in coastal waters of California to protect "the quality of the ocean waters for use and enjoyment by the people of the State". To this end, the plan establishes water quality objectives for receiving waters that include bacteriological, physical, chemical, and biological characteristics, and radioactivity. These water quality objectives are all incorporated into the receiving water limitations in the NPDES permits for SONGS Units 2 and 3, and will be outlined in detail later (i.e. Table 3).

Compliance with these objectives is determined from samples collected at stations within the waste field of the discharge, but outside the zone of initial dilution. (Initial dilution is defined in the Ocean Plan as rapid and irreversible turbulent mixing of waste water with ocean water, completed when diluting wastewater ceases to rise in the water column and first begins to spread horizontally. The Regional Board could not establish the distance that the zone of initial dilution (ZID) extends beyond the diffusers for Units 2 and 3 at SONGS. We assume the zone of initial dilution does not extend beyond the 1000 ft limit set for the regulation governing increased surface temperatures.)

A number of the limitations in the ocean plan prohibit the degradation of marine biota. The Ocean Plan requires that degradation will be "determined by comparison of the waste field and reference site(s) for characteristics such as species diversity, population density, contamination, growth anomalies, debility, or supplanting of normal species by undesirable plant and animal species". Any significant differences in demersal fish, benthic invertebrates or attached algae shall be considered degradation and other groups may be evaluated where benthic species are not affected or are not the only ones affected.

To achieve the water quality objectives, the Ocean Plan outlines a number of requirements for the management of waste discharge to the ocean. The first is that "waste management systems that discharge to the ocean must be designed and operated in a manner that will maintain the indigenous marine life and a healthy and diverse marine community". Other requirements prohibit substances in the discharge that would (1) form sediments that would degrade benthic communities, (2) accumulate to toxic levels in sediments, or (3) significantly decrease the natural light to benthic communities or other marine life.

The plan also provides a method for calculating limits for concentrations of toxic substances in the discharge water so that receiving water limitations are not exceeded. The computation takes into account the concentration to be met at the completion of initial dilution (Table B, Ocean Plan 1988), the background seawater concentration (Table C, Ocean Plan 1988), and the rate of initial dilution of discharged water.

2.2.3 NPDES Permit

The Regional Board of San Diego has prepared separate NPDES permits for SONGS Unit 2 and Unit 3. Both of the permits have gone through several revisions since their original version and include the requirements the Regional Board staff considered to be important and relevant to proposed discharges from SONGS. Permits for Units 2 and 3 are virtually identical; the only differences concern volumes of discharges.

The NPDES permits prohibit discharge to the ocean of high level radioactive wastes, polychlorinated biphenyl compounds, municipal and industrial sludge, and untreated wastes. Total residual chlorine may not be discharged from any unit for more than two hours per day, unless there is demonstrated need for control of macroinvertebrates. The other regulations in the NPDES permits can be divided into 2 groups, those that refer to the effluent and those that refer to characteristics of the receiving water.

2.2.3.1 Discharge Limitations

There are numerous regulations for discharged water; some are general, others specific. The general limitations are usually related to the overall condition of the marine environment and the marine biota. These regulations include the following:

> B.5. "SONGS ... waste management systems that discharge to the ocean shall be designed and operated in a manner that will maintain the indigenous marine life and a healthy diverse marine community."

> B.7. "The location of the waste discharge ... shall assure that: ... (b) natural water quality conditions are not altered in areas designated as being of special biological interest; (c) maximum protection is provided to the marine environment."

> B.8. "SONGS ... discharge of elevated temperature wastes to the Pacific Ocean shall comply with limitations necessary to assure protection of beneficial uses and designated areas of special biological significance."

Additional limitations are general in that the regulated substances are not clearly defined. For example, SONGS discharge should not contain any substances that (1) "form sediments which degrade benthic communities or other aquatic life", (2) are "toxic to marine life due to increases in concentrations in marine waters or sediments", or (3) "significantly decrease the natural light of benthic communities and other marine life".

More specifically, the pH of the discharge must remain between 6.0 and 9.0 at all times, and during normal operations the daily average of the difference between discharge water and intake water must not exceed 20° F. There is also a series of specific limitations on the levels of total suspended solids and grease and oil, and concentrations of toxic chemicals in the discharge. These are summarized in Tables 1 and 2, respectively. The toxic chemical limitations are calculated using the method outlined in the Ocean Plan (see above). The initial dilution factor for SONGS is about 10 times the total volume rate of discharged flow (Finding 51 of the NPDES permit for Unit 3).

The NPDES permits include a variance to allow thermal discharge in excess of the Thermal Plan restriction of 20° F above intake water during heat treatments to remove fouling organisms. A series of parameters outlined in the permits are used to determine the timing and duration of heat treatments.

2.2.3.2 Receiving Water Limitations

The receiving water limitations provide considerations for cumulative effects of discharge. They are derived from the water quality objectives in the California Ocean Plan. The limitations apply to thermal, bacteriological, physical, chemical and biological characteristics of the receiving water. All limitations except those for bacteriological characteristics are summarized in Table 3. The bacteriological characteristics include limitations in concentrations of coliform organisms in waters within 1,000 ft. from the shore, in kelp beds, and in areas where shellfish may be harvested for human consumption.

Many of the physical, chemical and biological regulations prohibit the degradation of marine biota. The NPDES permits require that degradation be determined by "analysis of the effects of the discharge on species diversity, population density, contamination, growth anomalies, debility, or supplanting of normal species by undesirable plant and animal species" (p. 41, NPDES permit for Unit 3).

Toxic chemicals in sediments are mentioned under Chemical Characteristics in Table 3. Limitations for toxic materials in ocean water outside the zone of initial dilution are in Table 4. They are taken directly from Table B in the California Ocean Plan. The Ocean Plan was updated in 1988, after the last revision of the NPDES permits, and includes more stringent limitations for Cadmium, Copper, Lead, Mercury and Nickel, and a less stringent limitation for Silver than required in the NPDES permits (Table 5). These new limitations will undoubtedly be included in the 1990 revision of the permits.

2.2.3.3 Monitoring Program

The NPDES permits require extensive monitoring programs to assess SONGS ability to comply with water quality requirements imposed in the permit. The basic monitoring requirements of the NPDES permits include:

1. Fish entrainment monitoring;
2. Cooling water intake monitoring;
3. Combined discharge (out plant) monitoring;
4. In-plant waste stream monitoring;
5. Fish handling system monitoring;
6. Receiving water monitoring.

Monitoring requirements will be discussed in more detail in the last section of this report. Monthly and annual reports summarizing the monitoring results are required as part of the monitoring effort. The monitoring reports are submitted to the San Diego Regional Board and used to determine if SONGS is in compliance with permit conditions.

2.2.4 California Department of Fish and Game

There are several regulations that have been adopted by the California Department of Fish and Game that pertain to discharges in coastal marine waters. These regulations are much more general than those adopted by the State Board and generally address types of discharges that are prohibited and restricted; they do not establish criteria or standards for water chemistry or physical characteristics.

2.2.4.1 Fish & Game Code 5650

Fish and Game Code Section 5650 makes it unlawful for anyone to pollute waters of the State of California, by prohibiting discharge of any substances deleterious to fish, plant or bird life. The regulation states:

> "It is unlawful to deposit in, permit to pass into, or place where it can pass into the waters of this State any of the following: ...
>
> (f) Any substance or material deleterious to fish, plant life, or bird life."

The Department of Fish and Game is the agency that determines when damage to fish, plants or birds has occurred. There is further guidance given in the regulations that states any substance is deleterious if, "because of its nature or quantity, it has a harmful effect on fish, plant life, or bird life when it is deposited into the waters of the State." The regulation is one that allows flexibility to the Department to protect natural habitats and species from water pollution while also providing the mechanism for criminal prosecution of chronic or acute polluters.

2.2.4.2 Fish and Game Code 5651

Fish and Game Code 5651 establishes the process for correcting a continuing or chronic pollution offense that may be a violation under Fish and Game Code

5650. In Section 5651, the Department is required to report the violating condition to the appropriate Regional Board, in this case San Diego, and must cooperate and act through the Regional Board to correct the water quality violation.

2.2.4.3 Fish and Game Code 12015 and 12016

Section 12015 of the Fish and Game Code, particularly subsection (b), requires a polluter to clean up and remove substances placed in State waters that are detrimental to fish, plant, bird or animal life. If the polluter does not remove the substance, then it must pay for the State to remove the substance.

Another section of the Fish and Game regulations, 12016, requires a polluter to cleanup and restore any habitats or communities that are damaged. However, this section explicitly states that the requirement in Section 12016 does not apply to materials that are permitted to be discharged. SONGS would appear to be a permitted discharge through the Regional Water Quality Control Board and its NPDES permits, and thus is not appropriately considered under Section 12016.

2.2.5 California Coastal Act

The California Coastal Act, implemented through the California Coastal Commission, also establishes water quality and discharge parameters for discharges within State coastal waters. Coastal Act Policy 30231 states that :

> "The biological productivity and the quality of coastal waters, streams wetlands, estuaries and lakes appropriate to maintain optimum populations of marine organisms and for the protection of human health shall be maintained and, where feasible, restored through, among other means, minimizing adverse effects of waste water discharges and entrainment, controlling runoff, preventing depletion of groundwater supplies and substantial interference with surface water flow, encouraging waste water reclamation, maintaining natural vegetation buffer areas that protect riparian

habitats, and minimizing alteration of natural streams."

It appears that this policy envisions that waste discharges into the ocean shall not adversely affect the biological productivity or quality of coastal habitats of any area where discharges occur. Discharges from SONGS diffusers must comply with this policy; therefore, should any degradation of biological productivity occur, SONGS would be violating this Coastal Act policy pertaining to water quality. Determination of adverse effect to the marine community would be made by the Coastal Commission.

2.3 MRC Findings Relevant to Water Quality Regulations

MRC contractors did not sample the effluent from SONGS Units 2 and 3. Thus, there are no MRC findings that relate directly to limitations for discharge water in the NPDES permits.

MRC does have data that relate to the receiving water regulations reviewed above. The primary effort of the MRC studies was focused on effects on the marine biota as a result of SONGS operation. Kelp, kelp bed invertebrates, benthic, midwater and kelp bed fish, mysids, sand crabs and the soft benthos community were studied. The findings of these studies are directly relevant to regulations that require the maintenance of indigenous marine life and prohibit the degradation of marine communities including vertebrates, invertebrates and plants.

Physical and chemical monitoring programs were carried out in support of the studies of the marine biota. Findings from the monitoring of irradiance are relevant to regulations that prohibit the reduction of natural light outside the zone of initial dilution. Extensive temperature records were compiled during monitoring and relate to the thermal limitation regarding the elevation of ocean temperatures near the surface beyond 1000 ft from the discharge, and at the surface of ocean substrates.

The physical and chemical monitoring program included studies of sediment characteristics and deposition in the area near SONGS. A separate program addressed the accumulation of cohesive sediments in kelp bed areas and studied the characteristics of the sediments. The findings of these programs may be relevant to regulations that prohibit changes in the rate of deposition or characteristics of inert solids or increases in the concentrations of organic materials in ocean sediments that result in the degradation of benthic communities.

MRC contractors have collected data on concentrations of heavy metals in sand crabs, mussels and marine sediments both near and far from SONGS. Findings based on these data relate to the discharge requirement that levels of toxic substances in the discharge should not result in increases in concentrations in marine waters or sediments to levels that would be toxic to marine life. Similarly, there is a receiving water regulation that stipulates that the concentration of toxic substances in marine sediments can not increase to levels that would degrade indigenous biota.

3. RESULTS OF MRC STUDIES THAT RELATE TO WATER QUALITY REGULATIONS

3.1 Introduction

Results reported here are taken primarily from the Interim and Final Technical Reports. We have studied the reports, extracted results that pertain directly to water quality regulations, and drawn preliminary conclusions about SONGS' compliance with the regulations. The conclusions are provisional because they reflect the current status of the Final Technical Reports, many of which are in draft form.

There are no MRC data that relate directly to discharge limitations because MRC contractors did not sample the effluent at SONGS. The results of studies supported by the MRC do pertain to some of the water quality regulations for receiving water in the NPDES permits for SONGS Units 2 and 3. The MRC has data that relate to receiving water limitations for temperature, irradiance, sediments, metals and marine biota. Results suggest that SONGS is not in compliance with regulations for irradiance and marine biota (Table 6). The determination of compliance for sediments depends on the results of an ongoing study.

We first summarize the sampling design used by MRC contractors to determine if a SONGS effect occurred, and then discuss the results of the relevant studies and how they relate to the regulations.

3.2 Sampling design

Water quality regulations that apply to the receiving waters near SONGS, such as those that prohibit the degradation of the marine biota and the reduction of natural light, require that effects be assessed by comparison of characteristics of receiving waters (i.e. Impact sites near SONGS) and reference sites (i.e. Control sites unaffected by SONGS). Physical and chemical characteristics of ocean waters and the abundance of marine organisms are highly variable in space and time. This presents a problem when comparing samples from receiving water and reference sites because differences in biological or physical characteristics measured at any point in time will reflect natural spatial and temporal variation as well as effects of SONGS, if effects occur.

The sampling method used most often by the MRC and its contractors to separate power-plant effects from natural variation unrelated to SONGS was the Before-After/Impact-Control Pairs (BACIP) design. Samples were taken a number of times at both Control and Impact sites, Before and After SONGS' Units 2 and 3 began operations. Samples collected at Control and Impact sites were taken as close as possible in time and the difference between the paired samples was calculated. To test for a SONGS effect, the average difference in the Before period was compared with the average difference in the After period.

The reasoning behind this design is outlined in detail in Interim Technical Report 2, and we discuss it only briefly here. Measuring the difference between the Control and Impact sites (1) recognizes that characteristics such as irradiance and the abundance of kelp will naturally differ between sites, and (2) has the added advantage of subtracting out long-term temporal fluctuations (e.g. seasonal effects) that tend to be similar at the two sites. Short-term, local fluctuations will affect the two areas differently, but the average of the differences between the areas should reflect a relatively constant difference between the sites in the Before and After period. If there is a difference in the average difference between Control and Impact sites in the Before and After periods, the difference must be attributed to a factor that has a localized long-term effect at one site and not the other.

An important assumption in the BACIP design is that the only long-term local effect that would cause a change in the difference between the Impact and Control is the onset of operations at SONGS' Units 2 and 3. Other naturally-induced changes are possible and their occurrence could falsely implicate SONGS or mistakenly exonerate it. It seems, however, that persistent, natural changes whose effects differ at Control and Impact sites, and coincide with the onset of SONGS operation, are either unlikely, or will be recognized if they occur.

Three critical assumptions of the BACIP analysis are (1) that in the Before period, differences are additive (i.e. the difference is the same when abundances are small and large), (2) differences are not serially correlated (i.e. differences close together in time are not correlated), and (3) there is no trend in the differences (i.e. differences do not steadily increase or decline over time). Additivity can frequently be corrected by transforming the raw data. If the data set is large (at least 50 sample times) short-term autocorrelation can be treated by using autoregressive procedures and doing a modified BACIP test (see Interim Technical Report 2 for details).

3.3 Results

3.3.1 Temperature

The effect of the operation of SONGS Units 2 and 3 on the temperature of the receiving water is regulated in section D.1.a. of the NPDES permits which states:

> "Elevated temperature wastes shall not result in increases in the natural water temperature exceeding 4°F at (a) the shoreline, (b) the surface of any ocean substrate, or (c) the ocean surface beyond 1,000 feet from the discharge system. The surface temperature limitation shall be maintained at least 50 percent of the duration of any complete tidal cycle."

MRC contractors collected temperature data at the ocean bottom at a number of sites near SONGS and at a station in the San Mateo Kelp bed. Since the bottom is the "surface" of an "ocean substrate", we can apply these data to the temperature limitation. The station at SOK which is closest to, but beyond, the 1,000 ft temperature boundary, and has sufficient data for a BACIP test is SOKU (500 m south of the diffusers for Units 2 and 3) The 45 ft SOKU station (SOKU45) was used for the BACIP analysis because the control station, SMK45, is 45 feet deep.

Although the results of the BACIP analysis comparing SMK and SOKU can not be used because the data violated the assumption of additivity ($P_A=0.0032$, where P_A is the probability that the Before data were additive), the differences in temperature at the SMK and SOK stations in the Before and After periods was small. In the Before period temperature was, on average, 0.1°C lower at SOKU45 than at SMK45, and in the After period it was 0.07°C lower at SOKU45. Thus the temperature 500 m south of SONGS' diffusers increased only 0.03°C after Units 2 and 3 began operating. This is well below the 2.2°C (4°F) restriction.

Similar results were obtained in a comparison of SOKU and SOKD stations, where SOKD is used as the Control station. The BACIP analysis for SOKU45 and SOKD45 was not statistically significant ($P=0.76$ for the BACIP analysis, $P_A=0.59$ for additivity using log-transformed data). The BACIP analysis was not used for the inshore stations (SOKU35 and SOKD35) because the data were not additive, but the average increase in temperature at SOKU35 compared to SOKD35 was only 0.45°C, which is well within the limitation.

Surface temperature data were rarely collected, but temperature 3 m below the surface (near-surface temperature) was monitored on a regular basis at two stations on opposite sides and equidistant from SONGS' diffusers. These data were used in a Plume-Model analysis (Final Technical Report L) to compare the temperature of water in the plume with water outside the plume (ambient). The model classified a station as being in or out of the plume based on the recent history of local currents measured at the stations. Currents may have a natural effect on temperature, but taking the difference between the plume and ambient temperature removes this effect if it is the same at both stations. Any difference between the stations will be a SONGS' effect unless natural currents affect the stations differently; this is unlikely since the stations are close together.

The NPDES permit regulation states that the temperature at the surface can not exceed 2.2°C for more than 50% of any tidal cycle. Since a tidal cycle lasts approximately 12 hrs, temperature can not exceed the limitation for more than 6 hrs within the cycle. Results of the Plume-Model analysis show that near-surface temperature never exceeded 2.2°C for stretches of 6 out of 12 hours.

3.3.2. Irradiance

The effect of SONGS' operation on natural light levels in receiving waters is regulated in section D.1.c.3. of the NPDES permits for Units 2 and 3 which states that the "transmittance of natural light shall not be significantly reduced at any point outside the initial dilution zone". A significant reduction is defined as a difference which is statistically significant at the $p=0.05$ level. The California Ocean Plan, from which the NPDES permit regulation is derived, states that the reduction of natural light may be determined by measuring light transmissivity or total irradiance (see the Appendix of the Ocean Plan).

Irradiance was used in MRC's studies to measure light intensity in the water column. Downward planar irradiance represents photons available for photosynthesis and is measured as Einsteins/m^2/unit time. I_z, irradiance at depth z, is a function of surface irradiance, I_o, and the log of the negative extinction coefficient, -K, times the depth, z ($I_z = I_o e^{-kz}$). I_o is the same for Control and Impact sites near San Onofre, averaged over time because, they are within a few kilometers of one another.

The physical and chemical monitoring program carried out by MRC contractors included monitoring irradiance levels each hour, on the bottom and 2 m above the bottom, at 3 sites in the San Onofre kelp bed (SOKU45, SOKD45, SOKD35) 500 to 1300 m south of the discharge diffusers, and at a control site in the San Mateo kelp bed (SMK45). Stations were kept clear of kelp at all times, and the bottom depth was either 10.7m (35) or 13.7m (45). Separate BACIP analyses were done on data from the bottom and at 2 m. For each depth, data from the three Impact stations in the San Onofre kelp bed, were combined by averaging the mean daily irradiance from the sites.

Irradiance limitations apply outside the zone of initial dilution which is operationally defined as the area where rapid and irreversible turbulent mixing of waste water with ocean water occurs. The actual extent of the zone in meters is not strictly defined for SONGS, but it seems reasonable to conclude that it does not extend beyond the boundary where the temperature of receiving waters must not exceed ambient (natural) water temperature by more than 2.2°C; this boundary is 330 m from the diffusers. Thus, the three SOK sites which are at least 500 m from the discharge, are outside the zone of initial dilution.

The discharge plume is comprised of the effluent discharged from the diffusers and entrained water; the volume of water entrained is about 10 times the volume discharged. Local currents affect the direction of flow of the discharge plume so that the plume extends downcoast (southeast) over San Onofre kelp bed during some periods and upcoast (northwest) away from the kelp bed during others. The Impact stations were downcoast of SONGS. Since the effect of SONGS on irradiance depends on whether or not the stations are in the discharge plume, the position of the plume was taken into account in the analyses. Four BACIP analyses were done for each depth. Two separate analyses were done for days when the current flowed either downcoast or upcoast for all 9 daylight hours; the other two analyses included days when the current moved either north or south for 5 of the 9 daylight hours.

When the plume from SONGS Units 2 and 3 extended south over the San Onofre kelp bed, irradiance at the bottom at the SOK stations was significantly reduced compared to the reference station at SMK (downcurrent analyses in Table

X); the average reduction at SOK was about 0.5 E/m^2/day (a reduction of about 40%, Final Technical Report K). The difference between SOK and SMK sites 2 m above the bottom was not statistically significant but the trend also indicated a reduction in irradiance at SOK. (Results were not highly additive, i.e. $p_A < .80$, and are therefore less reliable.) When currents moved upcoast there was no statistically significant difference between SOK and SMK, but there was a tendency for irradiance to increase at SOK (upcurrent analyses in Table 7) perhaps because clearer water from offshore was drawn in to replace water that was pushed offshore and upcoast by SONGS' discharge.

These results suggest that the operation of SONGS Units 2 and 3 resulted in a significant reduction in irradiance in the receiving waters near the bottom outside the zone of initial dilution when currents moved to the south. If the trend for increased irradiance at SOK when the current flows north is taken into account, the average reduction in irradiance at the SOK stations relative to SMK, was -0.21 E/m^2/day which is a 17% decrease in average irradiance at the bottom in SOK. These results suggest that SONGS is not in compliance with the receiving water regulation that prohibits a statistically significant reduction in natural light outside the zone of initial dilution.

3.3.3. Sediments

There are two limitations in the NPDES permits for SONGS' Units 2 and 3 that pertain to sediments in the receiving water. Section D.1.c.2. states that the rate of deposition of inert solids in ocean sediments should not be changed in a way that would degrade benthic communities, and Section D.1.d.5. states that organic materials in sediments should not increase to levels that degrade marine life.

This section will be written when the sediment report is completed.

3.3.4. Metals

The NPDES permits outline specific limitations for concentrations of toxic substances (primarily metals) in SONGS' effluent (Table 1) and the receiving waters surrounding SONGS (Tables 4 and 5). MRC's contractors did not measure the concentration of metals in either discharge or receiving waters and thus we can not address these specific regulations directly. There are however two additional regulations that apply to toxic substances that we can address. Section B.4.c. of the NPDES permits for SONGS Units 2 and 3 states that the discharge should not contain substances that accumulate in water or sediments to levels that are toxic to marine life, and Section D.1.d.4. states that the concentrations of substances listed in the Ocean Plan (reproduced in Table 4) should not be increased to levels that would degrade indigenous biota. While the MRC did not conduct a long-term field monitoring program to assess the effect of emissions of toxic substances, some short-term studies of concentrations of metals in marine organisms and sediments were conducted and can be applied to these regulations.

3.3.4.1. Mussel studies

MRC sponsored one study in 1976-1977, when only Unit 1 was operational, and a second in 1986, when all 3 Units were operating, which assessed the concentrations of metals in the bay mussel, *Mytilus edulis*, outplanted at varying distances from SONGS. In the earlier study, bags of mussels were outplanted at 25, 50, 1,600 and 12,800 m downcoast from the outfall of Unit 1, during two periods, one when SONGS was "on" and the other when it was "off". In 1986, mussels were outplanted in six areas that ranged from 5 km north to 5 km south of the SONGS diffusers. Spatial patterns in metal concentrations were analyzed by regression against distance from the outfall or diffusers. (Detailed descriptions of the methods and analyses are given in Kastendiek et al. 1981 and Final Technical Report E.)

Mussel tissues were tested for concentrations of cadmium, chromium, copper, iron, manganese, nickle, lead and zinc. In the 1976-77 study, concentrations of six of the metals (exceptions were Cd and Zn) were significantly higher in the "off" period when water flow from Unit 1 was about one-half the flow during the "on" period (Tables 8 and 9). Concentrations of chromium, iron and manganese declined significantly or nearly significantly with increasing distance from the outfall (Table 9) suggesting that there is a source for these metals at or upcoast of SONGS. SONGS can not be identified as the source because concentrations of metals were not measured upcoast from the outfall. There were no significant trends with distance for the other metals. Growth rate of mussels was significantly and negatively related to the concentration of copper in tissues, and was not significant for the other metals (Table 10).

In the 1986 outplant study, concentrations of metals were generally highest 4.5 km north of SONGS, in the southern end SMK (SMKD), and declined with increasing distance downcoast (Table 11). These results suggest that there is a source of metals, particularly Mn, Fe, Cr and Pb upcoast of SONGS. Although there was a tendency for the concentration of cadmium to increase near SONGS' diffusers, it was not statistically significant.

Growth rate of mussels was lowest near SONGS (Table 11). There was a significant correlation between growth rate and the concentration of cadmium

(Table 12), but it is confounded by the increase in seston flux near the diffusers which may affect growth by interfering with mussel feeding (Kastendiek et al. 1981). Growth rate was not related to the concentration of Cu as it was in the previous study, suggesting that the previous relationship was spurious.

3.3.4.2. Sand crabs

Metal concentrations were measured in the tissues of sand crabs collected from numerous sites along the coast north and south of SONGS. (Details of methods and analyses are presented in Final Technical Report A). The original report of the results of surveys in 1982 (Wenner 1982) suggested that concentrations of some metals were highest near SONGS, but subsequent re-analysis of the data showed that the pattern occurred for manganese only (Final Technical Report A). This conclusion was supported by surveys in July and August 1983. Although concentrations of manganese near SONGS were the highest within the local region, they were not particularly high compared to concentrations found at other sites within 30 km of SONGS. Also, there is no known source of manganese at SONGS (Final Technical Report A).

3.3.4.3. Beach sediments

Beach sediments were collected from numerous sites both north and south of SONGS in conjunction with the sand crab surveys in July and August 1983. Concentrations of eight metals were measured in the sediments. In general, metal concentrations in sediments near SONGS were low relative to other beaches (Tables 13 and 14). Local maxima for manganese in July and August, and iron and lead in August occurred 1.5 km north of SONGS, but concentrations were much lower 0.4 km north and 1.5 km south of SONGS.

Overall, analyses of beach sediments, and tissues of mussels and sand crabs provide no clear evidence that SONGS has modified metal concentrations in the nearby region. Also, there is no compelling evidence that metals released from SONGS have adversely affected the marine biota. Thus there is no evidence to suggest that SONGS is in violation of limitations that regulate metals.

3.3.5 Marine biota

The effects of SONGS on the marine biota, including algae, invertebrates and fish, are covered in two broad regulations in the NPDES permits. Section B.5. in the discharge limitations states that the waste management systems at SONGS that discharge to the ocean "shall be designed and operated in a manner that will maintain the indigenous marine life and a healthy and diverse marine community". Section D.1.e.1. in the receiving water limitations states that "marine communities, including vertebrate, invertebrate, and plant species, shall not be degraded", where degradation is determined by analysis of SONGS' effects on "population density, species diversity, contamination, growth anomalies, debility, or supplanting of normal species by undesirable plant and animal species" (footnote reference 15 to the NPDES permit for Unit 3).

Studies sponsored by the MRC have focussed on the effects of SONGS on the abundance of populations of giant kelp (*Macrocystis pyrifera*), kelp bed invertebrates and fish, midwater and bottom fish, plankton, hypoplanktonic mysids, and invertebrates associated with the soft benthos. In most cases, effects were determined by comparing population densities at Impact stations near SONGS and

Control stations away from SONGS using the BACIP procedures. Effects are summarized in Table 15. There was no evidence for statistically significant declines in populations of plankton (Interim Technical Report 4), hypoplanktonic mysids (Final Technical Report G), bottom fish (Interim Technical Report 3), and invertebrates in the soft benthos (Final Technical Report I). In fact, hypoplanktonic mysids and invertebrates and fish associated with the soft benthos, generally increased near SONGS relative to Control sites. There was evidence for declines in populations of giant kelp, kelp bed invertebrates and fish, and midwater fish; they will be discussed in detail below.

Ichthyoplankton, juvenile and adult fish, zooplankton, phytoplankton and mysids were killed when they were drawn into the power plant with the cooling water. These entrainment losses are not regulated by the California Ocean Plan, the NPDES permits or the California Fish and Game regulations, which deal only with the effects of discharged water. The California Coastal Act does comment on entrainment losses, and we will discuss this below.

3.3.5.1. Giant kelp

There was a significant decline in the kelp population in the San Onofre kelp bed relative to the San Mateo kelp bed after SONGS Units 2 and 3 began operations. Evidence for the decline in kelp comes from sampling natural populations at both sites, experimental manipulations and transplants in the field, and studies of causal mechanisms (see Final Technical Report K for details).

Data from down-looking sonar surveys over large areas within SOK and SMK show declines in the areal extent and density of giant kelp in SOK relative to

SMK (Table 16a and b). Results were significant for SOK as a whole and for areas with moderate to high kelp densities (i.e. more than 4 plants/100m^2) (Table 16a). SOK lost about 60% of the area that would have had kelp if SOK had changed in the same way as SMK (Final Technical Report K). Declines in kelp density were statistically significant at SOKU45 and SOKD45 relative to SMK (Table 16b).

Kelp plants were surveyed at least quarterly on permanent transects beginning in 1978 at SOK and in 1981 at SMK, and continuing through 1986 at both sites. Individual plants were marked and followed through time (see Final Technical Report K for more detail). At SOKU35, SOKU45 and SOKD45 the density of adult plants had declined 50 to 90 % in the After period relative to the density at SMK (Tables 17 and 18). The relative decline in SOK was due to a relative reduction in recruitment at SOK rather than an increase in mortality of adult plants. Very little recruitment of blade stage and juvenile kelp was observed in SOK in the After period, while substantial recruitment occurred in SMK (Final Technical Report K). Results of a repeated measures BACIP analysis were statistically significant for all SOK stations combined and indicate that recruitment declined at least 75% in SOK compared to SMK (Tables 17 and 18). Separate analyses for inshore and offshore SOK stations show the decline in recruitment at the inshore stations relative to SMK was statistically significant, while the decline at the offshore stations was not (Table 17 and 18).

Evidence suggests that the reduction in recruitment in SOK is not the result of limited availability of gametophytes, but rather reflects low densities of microscopic sporophytes at SOK relative to SMK (Final Technical Report K). The effect of the physical environment on sporophyte production was examined using a multiple regression model on data collected from a series of sporophyte outplants into sites in SOK and SMK. Results indicate that the production of sporophytes is negatively related to high levels of seston flux and high temperatures, and positively related to irradiance. Results of a 1986 experiment where cobbles with microscopic sporophytes were transplanted to SOK and SMK indicate that sporophyte survival was significantly lower at the SOK stations nearest the diffusers (SOKU35 and SOKU45) than at SMK. Survival was negatively correlated with seston flux and positively correlated with irradiance in the experiment (Final Technical Report K). In another analysis, sporophyte mortality in an extensive series of outplant experiments was related to the position of the outplant station relative to the plume from SONGS diffusers; mortality rates increased with the proportion of time a station was classified as being in the plume (Final Technical Report K).

The results relating sporophyte production and mortality to physical characteristics of the habitat suggest that there is a strong link between irradiance and seston flux, and recruitment success. Irradiance was significantly lower at SOK relative to SMK (BACIP results discussed above). Seston flux was also measured at stations in SOK (SOKU45 and SOKD45) and at SMK. Results of a BACIP analysis comparing seston flux at the bottom at the SOK and SMK stations was not statistically significant, but suggest that seston flux increased at SOKU45 in the After period (Table 19). The time series in the Before period is much longer for SOKU45 and SOKD45 than for SMK. The BACIP result for the comparison of SOKU45 and SOKD45 was significant and showed that there was a 45% increase in seston flux in the After period at SOKU45 (Table 20). The decrease in irradiance and increase in seston flux near the SONGS' diffusers suggests that these factors contribute to the reduction in sporophyte production and survival near SONGS.

3.3.5.2. Kelp bed invertebrates

The density of snails in the San Onofre kelp bed has declined significantly since SONGS Units 2 and 3 began operations. Kelp bed invertebrates were sampled at two Impact stations in SOK (SOKU and SOKD) and at a Control station in SMK. All stations were about 14 m deep, on cobble substrate at least 10 m from the nearest sand plain, and were initially under a kelp canopy. At each station, invertebrates were counted within permanent 1 m^2 quadrats positioned at 10 m intervals along four 40 m transects that radiated from a central point (see Final Technical Report F for details).

A modified BACIP analysis was used to compare the Control station and both Impact stations simultaneously. In this "repeated measures" analysis, a significant main effect of period means that on average (i.e. across both Impact stations) there was a SONGS' effect. A significant interaction between period and station indicates that the magnitude of the effect was different at the two stations. For many analyses, there were only two surveys in the Before period and tests of the assumptions underlying the BACIP test were not done.

Gastropod mollusks as a group declined more than 70% at stations in SOK relative to SMK in the After period (Table 21). The relative decline was the result of decreases in mean snail density at the two SOK stations and an increase in density at SMK (Final Technical Report F). Thirteen species or groups of species of snails were examined individually. All except *Calliostoma* declined in abundance at both SOK stations relative to SMK and in all but 3 cases, declines were more than 50% (Table 21). *Calliostoma* declined at SOKU but increased at SOKD. For 9 species, percent declines compared to SMK were greater at the Impact station closer to the diffusers (SOKU) than at the far station (SOKD).

Statistical analyses were possible for 8 of the 13 species, although assumption tests were not possible for six of them. Data for the other species violated at least one of the assumptions and so "repeated measures" BACIP tests were not done. The decline in density in the After period, averaged over the two Impact sites relative to SMK, was statistically significant for *Conus califonica*, *Kelletia kelletii* and *Ophiodermella inermis* ("period" effect in Table 21). There was a significant decline in the density of *Calliostoma* spp. and *Maxwellia gemma* at the impact station near the diffusers (SOKU) relative to the station far from the diffusers (SOKD) ("period-by-station" interaction effect in Table 21).

Patches of fine, cohesive sediments (see sediments above) first appeared in the permanent quadrats in October 1985. By December 1986, sediments of this type were present in more than 90% of the SOKU quadrats. A BACIP analysis of quadrats with and without sediments at the SOKU station, showed that snails, sea urchins, sea stars and sessile invertebrates as a group all declined in quadrats with sediments present; the declines were statistically significant for the latter 3 groups (Table 22).

The inability to test assumptions for many of the BACIP analyses and the violation of assumptions in a number of other cases, allows the possibility that declines in density at the Impact stations are simply continuations of trends that were independent of SONGS effects. Evidence strongly suggests however that declines were related to SONGS operation. For at least 3 species which declined, *Conus califonica*, *Kelletia kelletii* and *Mitra idae*, there were no significant trends in the data. Also, declines in density were generally greater at the Impact station near

SONGS than at the far station. Finally, there are two plausible mechanisms that could cause declines in benthic invertebrates: (1) increased seston flux near SONGS (see above), and (2) an increase in the cover of cohesive sediments near SONGS. The density of some species declined sharply near the end of the After period when cohesive sediments became increasingly abundant (Final Technical Report F).

3.3.5.3. Kelp bed fish

The density of a number of species of kelp bed fish declined significantly near the bottom after SONGS' Units 2 and 3 began operations. The density of fish that occur in the kelp canopy (more than 1.5 m off the bottom) increased, but this apparent increase may be confounded by the reduction in the area of the kelp bed in the After period.

Fish were counted along transects (3m wide x 1.5 m high x 75 m long) on the bottom, and sampled in the canopy with "cinetransects" which were filmed and then viewed and analyzed. Surveys were conducted in the fall of 1980, 1981, 1985 and 1986 in two regions in the San Onofre kelp bed (SOKU and SOKD) and in the San Mateo kelp bed. (Details of methods and analyses are in Final Technical Report J.) A two factor analysis of variance with period (Before = 1980 and 1981 and After = 1985 and 1986) and location (SOKU, SOKD, SMK) as factors, was used to test for changes in fish density among sampling stations. A significant period-by-location interaction indicates that densities changed in the After period at SOK relative to SMK.

Four species of fish in the canopy had significant period-by-location interactions, indicating a SONGS' effect (Table 23). The densities of three of them increased in SOK relative to SMK (Final Technical Report J). The relative increase in senorita was the result of increases in SOK and declines in SMK in the After period. The relative increase in halfmoon was caused by a large decline in SMK while SOK densities remained about the same. Kelp perch declined at all sites in the After period, but less at SOKD which resulted in an increase in density in SOK relative to SMK. One species, giant kelp, decreased in SOK compared to SMK. The relative decline was the result of smaller increases in SOK than in SMK.

Period-by-location interactions were significant for five species of bottom fish (Table 23). Senorita increased in SOK relative to SMK in the After period. The relative increase in SOK reflected actual increases in SOK and a decrease in density in SMK. Densities of the other four species declined in SOK compared to SMK in the After period. Rainbow seaperch and sheephead declined at all sites but decreases were larger in SOK. Barred sand bass increased at SOKD, but declined at SOKU to produce an overall relative decline when compared to the increase in SMK. Finally, the relative decline of black perch in SOK reflected actual declines at SOKU and SOKD coupled with an increase in SMK (Final Technical Report J).

Changes in the density of fish in SOK relative to SMK were based on samples in areas which had kelp in both the Before and After periods. Changes in the abundance of fish must take into account changes in the area of the kelp bed as well as changes in density. An index of fish abundance in areas with and without (less than 4 plants/100m^2) kelp in the Before and After periods in the two kelp beds was related to the total area with and without kelp in the beds to estimate the relative abundance of fish (see Final Technical Report J for details).

There was a relative decrease (about 65%) in abundance of bottom fish at

SOK relative to SMK, as expected from declines in both fish density and kelp area in the After period. The relative decline in the abundance of canopy fish was smaller. Abundance of canopy fish in SMK and SOK both fell in the After period, but the decline was slightly greater in SOK; abundance in SOK decreased about 8% relative to SMK (Final Technical Report J). This suggests that the increase in density of canopy fish in areas with kelp in SOK in the After period was the result of fish aggregating in areas where kelp remained.

3.3.5.4. Midwater fish

There is strong evidence that 2 species of midwater fish, queenfish and white croaker, declined in numbers near SONGS in the After period. Midwater fish were sampled at night with a lampara seine which stretched from the surface to the bottom. Samples were taken at three stations, less than 1 km (Near-Impact), 1.5-3 km (Far-Impact), and 18-19 km (Control) downcoast of SONGS' diffusers, at two depths, shallow (5-10 ft m) and deep (11-16 m). Samples were taken frequently in the Before (1979-1982) and After (1984-1986) periods. (Details of methods and analyses are given in Interim Technical Report 3.)

BACIP comparisons were done for 11 species of fish at 4 Impact stations (near-shallow, near-deep, far-shallow and far-deep) for a total of 44 tests. Overall there were 19 declines in abundance at Impact stations relative to Controls, 8 increases and 6 cases when the direction of change could not be determined (Table 24). Many of these changes were either not statistically significant or there were problems with the interpretation of the results because data were scarce (lots of zeros) and highly variable. Results for queenfish, white croaker and silversides were significant at one or more Impact stations (Table 24).

The abundance of queenfish was significantly lower at both the near- and far-shallow and the far-deep Impact sites relative to Control sites; decreases ranged from about 35-70%. Declines occurred in both adult and juvenile stages of queenfish (Interim Technical Report 3). White croaker declined about 40-60% at the shallow Impact sites. In contrast, silversides increased in abundance at the far-shallow Impact site (Table 24), primarily because there was a large decline in abundance at the Control site in the After period (Interim Technical Report 3).

3.3.5.5. Summary

The NPDES permits do not give a precise definition of degradation, but state that it can be determined by analysis of the effect of the discharge on population density. The California Ocean Plan states that degradation occurs if there are statistically significant differences in fish, benthic invertebrates or attached algae. Results for giant kelp, kelp bed fish and snails, and midwater fish indicate that statistically significant declines in abundance did occur after SONGS' Units 2 and 3 began operations. This suggests that SONGS is not in compliance with regulations governing effects on marine biota.

3.3.6. Entrainment losses

Regulations in the NPDES permits, the California Ocean Plan and the Department of Fish and Game Code pertain to effects of discharges into the ocean; they do not regulate losses incurred when organisms are drawn into the plant with the intake water. The California Coastal Act does refer to entrainment losses in Section 30231 which states:

> " The biological productivity and quality of coastal waters ... shall be maintained and, where feasible, restored through, among other

means, minimizing adverse effects of waste water discharges and entrainment, ...".

Plankton, mysids, ichthyoplankton, and adult and juvenile fish are entrained and die when they are trapped on screens or as the cooling water heats up. An estimated 1200 MT of plankton (Interim Technical Report 4) and $6.5x10^9$ mysids (Final Technical Report G) are lost annually, although there is no evidence that losses significantly reduced local abundances. Ichthyoplankton losses ($5x10^9$ larvae/yr) reduce recruitment to adult populations of some species of fish in the California bight. Estimated losses from reductions in recruitment for queenfish, white croaker and giant kelpfish are in excess of 5% of the bight-wide population (Final Technical Report D). About 15 MT of juvenile and adult fish are captured on screens in the plant (Final Technical Report C). Losses of queenfish and white croaker are relatively high and may contribute to their decline in abundance in the midwater habitat near SONGS.

Possible techniques to minimize entrainment losses at SONGS are discussed and recommended in the technical report on mitigation (Final Technical Report H).

4. COMPARISON OF NPDES COMPLIANCE STUDIES AND MRC FINDINGS

4.1 Introduction

The NPDES permits for Units 2 and 3 require that Southern California Edison (SCE) monitor the physical and biological characteristics of the marine environment near SONGS and at reference sites to determine if SONGS is in compliance with the water quality regulations imposed in the permits. Each July, SCE submits a report to the San Diego Regional Water Quality Board that describes the results that describes the results of studies conducted in the previous calendar year.

SONGS Unit 2 became fully operational in August 1983 and Unit 3 began operations in April 1984. In the report on 1984 data (SCE 1985) and all subsequent annual reports (SCE 1986, 1987, 1988), SCE concluded that the operation of SONGS Units 2 and 3 had no significant adverse effects on the marine communities and resources of the San Onofre area. This implies that SONGS was in compliance with the receiving water regulations. In contrast, results of MRC studies outlined in the previous section of this report suggest that SONGS is not in compliance with regulations for turbidity and marine biota (Table 6).

There are three general reasons that conclusions drawn from the NPDES monitoring studies and the MRC studies were different: (1) SCE did not monitor the affected populations, (2) the sampling methods were different, and (3) the analytical approaches used to determine if adverse effects occurred were different.

We first outline the monitoring studies required by the NPDES permits for Units 2 and 3, then discuss the different approaches used by SCE and MRC contractors to determine if SONGS was in compliance with water quality regulations, and finally discuss the reasons for differences in compliance determinations for particular regulations.

4.2 NPDES Monitoring Program

Studies of the physical and biological characteristics of the receiving waters around SONGS began in 1964 with the Marine Environment Monitoring program (MEM) which continued through 1974. Monitoring programs required by NPDES permits for Units 2 and 3 began in 1976 (Table 25). Additional studies for the Construction Monitoring Program (CMP), the Preoperational Monitoring Program (PMP) and the Interim Program were conducted between 1976 and 1984 (Table 25). The operational monitoring program outlined in the current NPDES permit began in 1984.

The NPDES permits for Units 2 and 3 require that water temperature, turbidity, benthic fish, kelp populations and substrate composition within kelp beds are monitored regularly during the year in the area near SONGS and at reference sites (Table 26). Other special studies of light transmission, chlorine, metals, and dissolved oxygen and hydrogen concentrations must be conducted for shorter periods of times.

4.3 Determination of Compliance

The determination of compliance with the water quality regulations for turbidity and marine organisms requires statistical comparisons of characteristics at impact and control sites. The regulation for turbidity in receiving water states that the transmittance of natural light shall not be significantly reduced outside the zone of initial dilution. A significant reduction is defined as a difference that is statistically significant at the $p=.05$ level. Light levels in the impact area (outside the zone of initial dilution) must be compared to levels in a control area that is not affected by SONGS to determine if a significant reduction has occurred. The receiving water regulation that governs marine biota prohibits the degradation of vertebrate, invertebrate and plant species. The California Ocean Plan defines degradation as a statistically significant difference in population density or other biological characteristics at the impact and control sites.

The monitoring program for receiving water outlined in the NPDES permits Units 2 and 3 does not include explicit guidelines for data analysis. Rather, it states that the methods used for analyses shall be the same as those described in previous annual monitoring reports submitted by SCE to the Regional Board (e.g. SCE 1980, 1981, 1982, 1983, 1984). The general approach used in SCE reports was descriptive. Analyses focused on describing the temporal and spatial variability in physical and biological characteristics at sites close to SONGS and at reference sites. The purpose of many analyses was to relate changes in physical properties of ocean waters and the abundance of animals and algae to natural events such storms, changes in benthic substrates, and the warming trend associated with El Nino. Comparisons between impact and reference sites were generally limited to descriptions of similarities or differences in the temporal patterns and magnitude of changes in characteristics at the sites. There were few statistical comparisons of differences between sites. Based primarily on these descriptive comparisons, SCE has maintained that SONGS is in compliance with water quality regulations because "fluctuations in biological communities and resources following natural events ... were greater in magnitude than any effects attributed to the generating station" (SCE 1988, p. RS-1).

In contrast, MRC contractors used statistical comparisons to detect differences between impact and control sites. The method used most often in MRC studies was the BACIP design. The reasoning behind this design recognizes that physical characteristics of ocean waters and the abundance of marine organisms are highly variable in time and space, and that differences between impact and control sites measured at any point in time will reflect natural spatial and temporal variability as well as effects of SONGS. The BACIP design and analytical procedures accounted for natural variation so that statistically significant differences could be attributed to the effect of SONGS with reasonable confidence. BACIP analyses required that impact and control sites were sampled both before and after SONGS Units 2 and 3 became operational. (The design is outlined in detail in Section 3 above and in Interim Technical Report 2.)

Conclusions about the effects of SONGS on the marine environment reported in NPDES monitoring reports were, with few exceptions, based on descriptive comparisons of spatial and temporal patterns at impact and reference sites, while MRC results relied on statistical comparisons, particularly the BACIP approach. We have more confidence in the conclusions based on statistical comparisons of impact and reference sites because the statistical approach is less subjective and is more likely to detect effects, if they occur. It will be extremely difficult to detect SONGS' effects, when they occur, using descriptive comparisons because effects will almost always be masked by the large, natural spatial and temporal variability in physical characteristics and abundances of organisms in the marine environment. With appropriate statistical analyses, such as the BACIP design, persistent effects caused by the power plant may be detected, even when large natural fluctuations occur.

4.4 Reasons for differences in compliance determination

4.4.1 Turbidity

Results of the MRC study detected a significant reduction in irradiance at the bottom in SOK compared to a reference station in SMK. This suggests that SONGS was not in compliance with the receiving water regulation that prohibits a significant reduction in natural light outside the zone of initial dilution. As a result of the NPDES monitoring study, SCE concluded that SONGS is in compliance with this regulation. The results of the two studies differ because sampling design and analytical approaches were different.

The reduction in irradiance detected in the MRC study was the result of an increase in turbidity downcurrent from the diffusers for Units 2 and 3. Turbidity was increased when inshore water was taken into the plant and bottom water was entrained in the discharge plume. The position of the plume with respect to impact sampling stations was determined from current direction and was taken into account in the analyses. Samples were taken at three impact stations in SOK and one control station in SMK. (Details are given in the previous section.) Irradiance and currents were monitored each hour for at least 175 days before SONGS Units 2 and 3 were operational (mid 1981 to April 1983) and for more than 1,000 days after operations began (May 1983 to December 1986). A BACIP analysis was used to test for a SONGS effect.

SCE has monitored turbidity in the San Onofre region since 1964. Two types of studies were conducted, (1) aerial photography, and (2) depth profiles of light transmittance measured with a transmissometer. Aerial photographs of the region extending 16 km north of SONGS and 6 km south were taken quarterly from 1975 to 1977, bimonthly from 1977 to 1981, and from 13 to 4 times a year since 1983 (Table 27). SCE used these photographs to compare turbidity between San Onofre and a reference site at Dana Point. Comparisons were necessarily descriptive (SCE 1981, 1982, 1984, 1985, 1986, 1987, 1988) and can not be used to determine if the discharge plume caused a reduction of light levels close to the bottom near SONGS.

Light transmittance was measured from 1964 through mid-1981 under various monitoring programs (Table 27). Sampling was suspended in 1982 and resumed in 1985. Samples were taken on 4 to 6 days in most years and more frequently for a special study in 1980 (Table 27). The position of the discharge plume was not considered in the analyses.

In most years comparisons of light transmittance among sites was descriptive. The only statistical treatment of the data was described in the 1985 annual report (SCE 1986). In 1985, samples were collected on 7 dates at up to 23 stations in the San Onofre region. The difference between light transmittance at sites near the Unit 1 intake (within 3,075 m) and far from the intake (more than 3,075 m) was not statistically significant (SCE 1986). This comparison illustrates the problem with tests based on data collected over a short time after SONGS Units 2 and 3 became fully operational. The results of this comparison can not be used to determine if the discharge plume has affected light transmittance near SONGS because the relationship between transmittance in the two areas in the period before the units were operational is not known. For example, if transmissivity was higher in the area near SONGS than in the far area in the Before period, and was the same in both areas in the After period, then the turbid discharge plume may have reduced light levels near SONGS.

4.4.2 Marine biota

Results of MRC studies have found significant reductions in local populations of midwater fish near SONGS, and fish, invertebrates and kelp in SOK compared to reference sites. These effects indicate that SONGS was not in compliance with the NPDES receiving water regulation that prohibits the degradation of vertebrates, invertebrates and plants. In contrast, results of NPDES monitoring studies did not show reductions in these populations that were linked to the power plant and concluded that SONGS was in compliance.

4.4.2.1 Midwater fish

Results of BACIP analyses of data collected by MRC contractors detected declines in local populations of several species of midwater fish after SONGS Units 2 and 3 began operating. Queenfish and white croaker were the two most abundant species affected. Comparisons between impact and control sites were based on about 40 to 60 samples in the Before period (September 1979 to June 1982) and 30 samples in the After period (April 1984 to August 1986). Samples were collected with a lampara net.

There have been no NPDES monitoring studies for midwater fish since SONGS Units 2 and 3 began operating because the NPDES permits do not require them. Midwater fish were sampled with gill nets from 1975 to 1982 (Table 25), but only benthic fish have been sampled since then.

4.4.2.2 Giant kelp

The results of MRC studies found that the giant kelp population at SOK was reduced by 60% relative to the reference station at SMK, after SONGS Units 2 and 3 began operations. In contrast, the results of studies in the NPDES monitoring program found no evidence that SONGS had an adverse effect on kelp. The difference in the conclusions of the two studies arises from differences in approaches to detecting SONGS effects on kelp and differences in types of analyses used.

The approach of the MRC study was to determine whether there was a change in the difference between impact and control stations coincident with the onset of operations at SONGS Units 2 and 3, and to investigate the mechanisms responsible for the change. Kelp populations were sampled, by divers, along permanent benthic transects, and with down-looking and side-scan SONAR. Benthic transects were sampled 4 times per year from 1978 through 1986 at SOK, and from 1981 through 1986 at SMK. A BACIP analysis was used to test for a SONGS effect.

Down-looking SONAR was used to assess the density of adult kelp plants over large areas in SOK and SMK. SONAR surveys were conducted by Ecosystems Management Associates (Eco-M) about every 6 months beginning in February, 1982. The results of the down-looking SONAR surveys and detailed substrate maps produced from side-scan SONAR were used to estimate the density of kelp on hard substrate at SOK and SMK, and to determine areas where kelp density exceeded specified thresholds (e.g. 4 plants per $100m^2$).

There were too few SONAR surveys in the Before period to use a BACIP analysis to test for a SONGS effect. Instead, the difference between the area of kelp at SOK and SMK on each survey was regressed against time. A significant, negative regression indicated that kelp at SOK declined through time with respect to SMK. This is consistent with a SONGS effect that "accumulated" through time, but the results must be viewed with caution because kelp abundances might have begun diverging before SONGS Units 2 and 3 began operations.

The results of the surveys indicated that the reduction in the relative density of adult kelp plants in SOK was caused by a reduction in the production of new plants, relative to SMK. Few young plants were produced at SOK in the After period. Various laboratory and field experiments were conducted to determine the mechanisms that produced the reductions in kelp at SOK. Field experiments were done to investigate the survival and growth of new recruits and juvenile plants. Between 1977 and 1986, microscopic stages were "outplanted at SOK and SMK and their development was follower. Juveniles plants were also outplanted at SOK and SMK, and survivorship and growth were measured over 6 weeks. In 1986, microscopic stages from SMK were transplanted to SOK and SMK to monitor survival. The effects of physical factors such as light and nutrients on the performance of microscopic stages were tested in the laboratory.

Results of the experiments indicated that the reduction in kelp at SOK was caused by the suppression of microscopic stages. Although kelp spores settled at SOK, either the microscopic sexual stage did not produce sporophytes, or the sporophytes failed to survive to the visual stage, or both. Other experiments indicated that small visible plants survived poorly at SOK compared to SMK. Evidence suggests that the reduction of light levels and the increase in seston flux near the bottom associated with the discharge plume, were the main factors affecting the survival and growth of the microscopic stages.

Results of kelp surveys did detect a decline in kelp abundance at SOK relative to SMK in the After period, but those results alone are not compelling evidence for a SONGS effect given the large natural temporal and spatial variability in kelp populations. The results of experiments that demonstrate a mechanism by which SONGS affected kelp at SOK clearly strengthens the claim that the reductions are a result of the operation of SONGS Units 2 and 3.

Giant kelp populations in the San Onofre region have been monitored by SCE contractors since 1975 under various programs (Table 28). Juvenile, subadult and adult kelp plants have been counted 4 times per year at 6 permanent stations at SOK since 1980 (Tables 28 and 29) and at 2 stations in SMK since 1981 (SCE 1987).

The main focus of these studies has been to describe the spatial and temporal variability of kelp within SOK and to relate the changes in kelp to changes in physical factors, particularly the composition of the bottom. Results of the surveys at SMK were first reported in the 1986 annual report to the Regional Boars (SCE 1987), but the graphs of mean density through time for SMK show that stations have been sampled since mid-1981. Comparisons of kelp abundance at SOK and SMK have been descriptive; no statistical tests have been presented. The conclusion reached in these studies is that densities are highly variable, and that the changes caused by natural phenomena are much greater that any effects caused by the operation of the power plant.

Maps of the kelp beds at SOK, SMK and Barn Kelp have been included in the annual monitoring since 1982. The maps are derived from the down-looking and side-scan SONAR surveys conducted by Eco-M since 1982. (These are the same surveys described above in the MRC studies of kelp.) The focus of the SCE study was to describe the temporal changes in the distribution of kelp patches of various densities in relation to the composition of the bottom substrate at the 3 kelp beds. Comparisons between SOK, SMK and Barn Kelp were qualitative; no statistical tests were done.

4.4.2.3 Kelp-bed invertebrates

The results of MRC studies found a reduction in the densities of some kelp-bed invertebrates in SOK relative to SMK in the period after SONGS Units 2 and 3 began operations. Kelp-bed invertebrates are not included in the NPDES monitoring program, but SCE contractors have counted urchins and sea stars at the fixed and random stations sampled for kelp at SOK and SMK (Table 29). In addition, a special study of changes in density of kelp-bed invertebrates at SOK and reference sites was discussed in the 1985 annual report to the Regional Board (Patton 1986). The studies by SCE contractors found no evidence that SONGS has had an effect on densities of kelp-bed invertebrates. Difference in the results of MRC and SCE studies occur because (1) surveys were taken at different times with respect to the onset of full operations at Units 2 and 3, (2) different impact and control sites were surveyed, and (3) methods used to compare impact and control sites differed.

In the MRC studies kelp-bed invertebrates were surveyed at near (500 m downcoast of diffusers for Units 2 and 3) and far (1300 m downcoast of diffusers) impact stations at SOK, and at a reference site at SMK. Eleven surveys were done at 2 to 4 month intervals from October 1980 to April 1983, before Unit 2 became fully operational. Sampling was suspended in the interim period and resumed in October 1984, after Unit 3 became fully operational. A modified BACIP analysis (repeated measures analysis, details are in Final Technical Report F) was used to test for a SONGS effect. The densities of 13 species of snails, declined at SOK relative to SMK in the After period. Reductions in density were statistically significant for *Conus californicus*, *Kelletia kelletii* and *Ophiodermella inermis*. The densities of two other groups of snails, *Maxwellia gemma* and *Calliostoma* spp. declined significantly at the near impact site compared to the far one.

Sea stars and urchins were counted in the surveys for kelp and subtidal cobble at 6 stations in SOK from 1978 to the present (Table 28) and at 2 stations in SMK from at least 1981 (first reported in SCE 1987). Results focused on a discussion of the spatial and temporal variability within SOK. Comparisons between SOK and SMK were included only in the last two annual reports (SCE 1987, 1988), and consisted of descriptions of general changes in mean density at the two kelp beds. There were no statistical comparisons of invertebrate densities between SOK and SMK.

A special study that compared changes in the density of kelp-bed invertebrates throughout the southern California bight was discussed in the 1985 annual compliance report to the Regional Board (Patton 1986). The main purpose of the study was to determine the effects of severe storms in 1983-84 on benthic invertebrates. Changes in the density of invertebrates at SOK and 3 reference sites, SMK, Batiquitos Kelp and Barn Kelp, were compared to assess the impact of SONGS on SOK.

Surveys of invertebrates were divided into 3 periods with respect to the storms: "pre-storm" surveys in 1979 and 1980, "post-storm" surveys in 1983 and 1984, and "recovery" surveys in 1985. Flow rates from Units 2 and 3 were similar in 1983 through 1985 (Final Technical Report F) so that the "post-storm" and "recovery" periods would both be in the After period in a BACIP analysis.

For statistical analyses, benthic invertebrates were grouped by their tolerance to environmental conditions. For example, current-intolerant species were usually found in habitats with low current velocity. The following steps were taken to calculate an index of the total abundance of organisms in each "tolerance group" for each survey: (1) densities were standardized by dividing the density in a survey by the maximum density of that species found in any survey, (2) standardized densities were transformed (arcsine x transformation) and (3) transformed values were summed over all species in the "tolerance group".

Either a Friedman test or a two-factor analysis of variance was used to test for differences in the index of abundance between sites and periods. A significant site-by-period interaction was used to determine if the index of abundance was different at different sites through time. A significant period-by-time interaction was not necessarily a useful indicator of a SONGS effect at SOK. The analysis tested for differences between reference site, as well as differences between SOK and reference sites. A significant site-by-period interaction could have resulted from differences in the changes in abundance of organisms between reference sites only.

Results of the study found that reference sites sometimes changed in opposite directions with respect to SOK (Patton 1985). This casts doubt on the appropriateness of the reference sites as controls for determining a SONGS effect, since it appears that some factor affected the sites differently. The choice of an appropriate control site should be based on the similarity of important environmental factors at the control and impact sites, so that naturally-induced changes are similar at all sites. Batiquitos Kelp, Barn Kelp and SMK were chosen as reference sites for SOK in the SCE study because they were all "low-relief" sites. (At low-relief sites, the mean elevation above a flat bottom of sand or sand mixed with rock, is less than 0.5 m [Patton 1986]). This assumes that relief is more important than other environmental factors that vary among the sites. In the MRC study, SMK was chosen as the reference site because it was close to SOK, the substrate at both site was composed of boulders, cobble and sand (Final Technical Report F), and kelp was present at both sites throughout the study. The substrate at Barn Kelp was mostly a flat, consolidated reef and kelp was lost from the site at the beginning of the study.

In the SCE study, species were categorized by their tolerance to environmental factors, but they may not respond to environmental changes induced by SONGS in the same way. Combining species into groups may mask changes in the abundance of individual species at SOK compared to reference sites. If species respond differently, a decline in one species may be cancelled by an increase in another species when abundance indices are summed. Since abundance is standardized by dividing the density in a sample by the maximum density in all samples, rare species and abundant species have the same importance. An increase in a rare species could cancel a decline in an abundant one.

A second comparison of kelp-bed invertebrates samples in the SCE study focused on changes in the assemblage of species as a whole. The density of a species in a sample was transformed by the square root, standardized by the mean transformed density, and used to calculate the "biological distance" between sites (Patton 1986). "Biological distance" is an estimate of the relative similarity of assemblages in different samples.

Statistical tests were done on pairs of means to determine if temporal changes in the "biological distances" between sites were significant (Patton 1986). In comparisons of SOK and SMK, and SOK and Batiquitos Kelp, the differences between assemblages in the "pre-storm" (Before) and "recovery" (After) periods were significant; however, the difference between SOK and Barn Kelp was not significant. Once again this raises the question of what is an appropriate reference site for SOK (see discussion above).

Comparing differences in assemblages between sites has problems similar to the comparison of "tolerance-groups" in the previous analysis; a change in one species may be cancelled by a change in the opposite direction in another species. So the effect of SONGS on populations may not be detected.

4.4.2.4 Kelp-bed fish

MRC studies detected a large decline in the abundance of fish living near the bottom at SOK relative to SMK after SONGS began operations. The decline in species that live in the kelp canopy was much smaller. The decline in the relative abundance of fish at SOK was the result of a decrease in density and a reduction in the area covered by kelp. In contrast, an SCE-sponsored study concluded that the density of fish on hard substrates near SONGS increased in the After period. The abundance of fish in SOK relative to SMK was not estimated in the SCE study. The difference in the results of the studies arises from differences in the species selected for discussion, the location of sampling stations, and the analytical approach.

In the MRC study, fish were sampled at SOK and SMK in the fall of 1980 and 1981 (Before period) and the fall of 1985 and 1986 (After period). Several transects were sampled by divers at two locations in SOK and one in SMK each fall. A two-factor analysis of variance was used to test for changes in the density of fish among sampling locations and periods; a significant period-by-location interaction indicated a SONGS' effect.

Kelp density varied within the kelp beds and fish density varied with kelp density. The relative change in the abundance of fish at SOK and SMK was estimated from (1) the densities of fish in areas "with" (at least 4 plants per 100 m^2) and "without" (fewer than 4 plants per 100m^2) kelp, and (2) the area of the kelp bed "with" kelp and "without" kelp in the Before and After periods (see previous section for details).

Kelp-bed fish were not sampled regularly in the NPDES monitoring program (Table 26), but the effect of SONGS on species of fish associated with reefs and kelp beds was discussed in a special study in the 1986 annual report (Patton 1987). The study focused on the physical condition of fish sampled along the diffuser lines and the relationship between fish density and factor such as discharge flow rate and heat treatments. There was a brief discussion of differences in the abundance of fish in 1982-83 compared to 1986 at two impact sites, the diffusers and SOK, and four reference sites, SMK, Batiquitos Kelp, Barn Kelp and Mohawk Reef (Figure 7-11 in Patton 1983). Density was the number of fish counted in a 350 m^2 area. There were no statistical tests of differences in abundance between sites and years.

Three of the benthic species that declined in the MRC study, rainbow seaperch, sheephead and blackperch, were not discussed in the SCE study. The SCE study detected large increases in the abundance of total fish, senorita, rock wrasse, and kelp bass in the After period at the diffusers, an area that was not sampled in the MRC study. Results for senorita, kelp bass and rock wrasse at SOK and SMK were similar in both studies; senorita increased at SOK relative to SMK and there was no detectable effect of SONGS on kelp bass or rock wrasse.

5. RECOMMENDATIONS

In the process of determining why the results of NPDES monitoring studies and MRC studies differed, we formulated a set of suggestions for changes in the NPDES monitoring program for receiving water. The intent of these recommendations is to focus the monitoring studies on the physical and biological characteristics that will most likely be affected by coastal power plants like SONGS and to increase the likelihood that studies will detect effects, if they occur. We include suggestions for additional studies for marine organisms and physical characteristics, and changes in sampling design and analytical procedures used to determine if the power plant is in compliance with water quality regulations (Table 30). These recommendations are for the NPDES permits for SONGS, but may apply to other discharges in coastal marine environments.

5.1 Irradiance

The survival and growth of marine plants can be limited by the amount of light they receive; if light levels are too low, plants can not produce the energy needed to meet metabolic demands. The California Ocean Plan states that reduction of natural light may be determined by measuring light transmissivity or irradiance. We suggest that irradiance is better than transmissivity for detecting reductions in natural light because irradiance is a more direct measure of the light available to plants for photosynthesis.

The instrument used to measure transmissivity shines a beam of light on a detector. As the light travels to the detector, some is absorbed by water and particles, and some is scattered (Reitzel et al. 1985). Transmissivity is a measure of the percentage of the beam of light that reaches the detector. Absorbed light is lost, but scattered light may be used by plants. Transmissivity is not a good estimate of the light available to plants for photosynthesis because scattered light is not measured.

Downward planar irradiance was used to measure natural light at depth in MRC studies. The meter used to measure irradiance has a detector that is aimed upwards, towards the surface. The detector measures all light that travels directly downwards from the surface (i.e. is not scattered) and also measures scattered light that strikes it at an angle. So only absorbed light is not measures. The detector counts photon in the photosynthetic band and is a direct measure of the light used by plants (Reitzel et al. 1985, Technical Report L).

Results of SCE and MRC studies show that natural light levels are highly variable. Light must be measured frequently to detect effects, if they occur. In MRC studies irradiance was measured continuously at impact and control stations. Currents were measured continuously also at the same stations so that the position of the discharge plume could be included in the analysis. We suggest that the NPDES monitoring program for SONGS be amended to replace the quarterly transmissivity samples with continuous measurements of irradiance and currents. We also suggest that future sampling stations include the stations used in MRC studies so that data collected at these sites in the Before period can be used in BACIP analyses.

5.2 Midwater fish

Results of MRC studies detected a large reduction in local populations of midwater fish, while benthic fish increased in abundance. The NPDES permits require that only benthic fish are monitored. Effluents from sources that discharge industrial and sewage wastes to the ocean will tend to affect benthic fish, but the impact of a coastal power plant may be greater for midwater fish which are lost in the cooling water intakes. We suggest that populations of midwater fish should be monitored near coastal power plants with ocean intakes for cooling water.

5.3 Kelp forest biota

Kelp forests are productive habitats that support a diverse group of algae, fish and invertebrates (Foster and Schiel 1985). Kelp studies are included in the NPDES monitoring program, but studies of fish and invertebrates in kelp forests are not required (although SCE contractors did sample fish periodically and counted sea stars and urchins in kelp transects). MRC studies detected reductions in the abundance of fish and snails, as well as kelp. We recommend that NPDES monitoring studies of kelp forests include regular samples of fish and large macroinvertebrates, in addition to kelp.

5.4 Sampling design and analyses

The California Ocean Plan and NPDES permits for SONGS state that compliance with many of the receiving water regulations should be determined by statistical tests of differences for physical (e.g. mean irradiance) and biological (e.g. mean abundance of kelp) characteristics at impact and reference sites. The permits do not discuss the statistical approach that should be used. We suggest that the NPDES permits include more specific guidelines for the sampling design and statistical procedures that should be used for compliance monitoring.

SCE generally relies on descriptions of the temporal and spatial patterns (e.g. changes in mean abundance over time at impact and reference sites) to determine if there is a SONGS effect, and rarely uses statistical comparisons. It will be extremely difficult to detect SONGS effects, if they occur, using descriptive comparisons because it will be difficult to separate effects from the large, natural spatial and temporal variability in the marine environment. MRC has used the BACIP design to test for SONGS effects (Interim Technical Report 2) and we suggest that the NPDES permits adopt this type of approach whenever possible. SONGS effects, when they occur, can often be detected with the BACIP design, even when temporal and spatial variability is large.

The BACIP design can be used only if the same impact and control stations were sampled both before and after the power plant began operating. Stations must be sampled many times in both the Before and After period to account for short-term temporal variability and to identify persistent temporal patterns in changes between the impact and control stations, if they occur.

There may be ongoing NPDES studies at SONGS that can use the BACIP design. For example, kelp densities have been monitored at five stations at SOK downcoast of the diffusers, and control two stations in SMK since 1981; a BACIP analysis may be appropriate for these data. However, it may be difficult to meet the BACIP requirements for other studies, because few samples were taken in the Before period. In some cases, such as midwater fish, MRC samples in the Before period could be used if the MRC impact and control stations are sampled in the future.

If there are no (or few) samples in the Before period, but many samples in the After period, an alternative to BACIP is to test for a trend in the difference between impact and control stations through time (Technical Report K). A significant regression of the difference between the impact and the controls station for each survey, against time, may indicate that an effect had "accumulated" through time. This test must be used with caution because a trend may be a continuation of a pattern that had begun before Units 2 and 3 began operating; in this case, the effect might not be caused by SONGS.

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7. TABLES

Table 1
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NPDES permit limitations for pollutants discharged from SONGS Unit 3. 6-Month median and Daily Maximum refer to the combined discharge from all Unit 3 in-plant waste sources. Instantaneous maximum refers to the combined discharge from Unit 3 to the Pacific Ocean. tu = toxicity units.

PARAMETER	UNITS	6-MONTH MEDIAN	DAILY MAXIMUM	INSTANTANEOUS MAXIMUM
Toxicity concentration	tu	0.55	--	--
Total residual chlorine	ıg/l	--	200	200
	lbs/day	--	192	192
Hydrazine	ıg/l	--	--	340
	lbs/day	--	--	3953
Arsenic	ıg/l	--	--	850
	lbs/day	675	3744	9883
Cadmium*	ıg/l	--	--	330
	lbs/day	384	1535	3837
Chromium (Hexavalent)	ıg/l	--	--	220
	lbs/day	256	1023	2558
Copper*	ıg/l	--	--	530
	lbs/day	407	2325	6162
Lead*	ıg/l	--	--	880
	lbs/day	1023	4093	10232
Mercury*	ıg/l	--	--	14.8
	lbs/day	11	65	172
Nickel*	ıg/l	--	--	2200
	lbs/day	2558	10232	25579
Silver*	ıg/l	--	--	47.9
	lbs/day	39	212	557
Zinc	ıg/l	--	--	2120
	lbs/day	1628	9302	24649

Table 1
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PARAMETER	UNITS	6-MONTH MEDIAN	DAILY MAXIMUM	INSTANTANEOUS MAXIMUM
Cyanide	ig/l	--	--	550
	lbs/day	640	2558	6395
Ammonia	ig/l	--	--	66000
(Express as Nitrogen)	lbs/day	76750	306952	767379
Phenolic	ig/l	--	--	3300
compounds	lbs/day	3838	15348	38369
Chlorinated	ig/l	--	--	110
Phenolics	lbs/day	128	512	1279
Aldrin and	ig/l	--	--	0.066
Dieldrin	lbs/day	0.26	0.51	0.77
Chlordane	ig/l	--	--	0.099
and related compounds	lbs/day	0.38	0.77	1.15
DDT and	ig/l	--	--	0.033
derivatives	lbs/day	0.14	0.26	0.38
Endrin	ig/l	--	--	0.066
	lbs/day	0.26	0.51	0.77
HCH	ig/l	--	--	0.132
	lbs/day	0.51	1.0	1.5
Toxaphene	ig/l	--	--	0.231
	lbs/day	0.9	1.7	2.69
Radioactivity	Not to exceed limits specified in Title 17, Chapter 5, Subchapter 4, Group 3, Article 3, Section 30269 of the California Administrative Code.			

* limits will change when regulations are brought into line with 1988 revison of the California Ocean Plan (see Table 5).

Table 2

NPDES permit limitations for discharge levels of total suspended solids and grease and oil from sources within SONGS Unit 3. These wastes are discharged into the cooling water flow.

SOURCE	UNITS	MONTHLY AVERAGE	DAILY MAXIMUM	INSTANTANEOUS MAXIMUM
Total Suspended Solids				
1. flush hydrotest storage tank draindown	mg/l lbs/day	30 550	100 1835	100 1835
2. condenser hotwell overboard	mg/l lbs/day	30 1801	100 6005	100 6005
3. steam generator blowdown	mg/l lbs/day	30 180	100 601	100 601
4. blowdown processing system demineralizer regenerants	mg/l lbs/day	30 18	100 60	100 60
5. full flow condensate polish demineralizer	mg/l lbs/day	30 61	100 204	100 204
6. radwaste system	mg/l lbs/day	30 5	100 17	100 17
7. building sumps	mg/l lbs/day	30 72	100 240	100 240
8. intake structure sumps	mg/l lbs/day	30 28	100 93	100 93
Grease and Oil				
1. flush hydrotest storage tank draindown	mg/l lbs/day	15 275	20 367	20 367
2. condenser hotwell overboard	mg/l lbs/day	15 901	20 1201	20 1201
3. steam generator blowdown	mg/l lbs/day	15 90	20 120	20 120
4. blowdown processing system demineralizer regenerants	mg/l lbs/day	15 9	20 12	20 12
5. full flow condensate polish demineralizer	mg/l lbs/day	15 31	20 41	20 41
6. radwaste system	mg/l lbs/day	15 2.5	20 3.3	20 3.3
7. building sumps	mg/l lbs/day	15 36	20 48	20 48
8. intake structure sumps	mg/l lbs/day	15 14	20 19	20 19

Table 3

NPDES permit limitations for receiving water at SONGS. Reductions or increases listed are with reference to levels in natural waters and are determined by comparisons with reference sites. The following are prohibited.

A. <u>Thermal Characteristics</u>

1) increases in natural water temperature in excess of $4^{o}F$ at (a) the shoreline, (b) the surface of any ocean substrate, or (c) the ocean surface beyond. The latter limitation is in effect for at least 50% of the duration of any complete tidal cycle.

B. <u>Physical Characteristics</u>

1) visible floating particulates and grease and oil

2) esthetically undesirable discoloration of the ocean surface

3) a statistically significant reduction in transmittance of light outside the initial dilution zone

4) a change in the rate of deposition and character of inert solids in ocean sediments that would result in the degradation of benthic communities

C. <u>Chemical Characteristics</u>

1) reduction of more than 10% in the dissolved O2 concentration as a result of discharge of oxygen

2) a change in pH of more than 0.2 units

3) a statistically significant increase in sulfide ion concentration

4) concentrations of toxic substance (a list of substances is in Table 4) in marine sediments that would degrade indigenous biota

5) concentrations of organic materials in sediments that would degrade marine life

6) nutrient materials that would cause objectionable aquatic growths or degrade biota

D. <u>Biological Characteristics</u>

1) degradation of marine communities including vertebrate, invertebrate and plant species

2) altering the natural taste, odor and color of fish, shellfish, and other marine resources used for human consumption

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Table 4

NPDES permit limitations for toxic materials in receiving waters at SONGS. These limitations are not to be exceeded in ocean waters upon completion of initial dilution. tu = toxicity units.

PARAMETER	UNITS	6-MONTH MEDIAN	DAILY MAXIMUM	INSTANTANEOUS MAXIMUM
Toxicity concentration	tu	0.05	--	--
Arsenic	ιg/l	8	32	80
Cadmium	ιg/l	3	12	30
Chromium (Hexavalent)	ιg/l	2	8	20
Copper	ιg/l	5	20	50
Lead	ιg/l	8	32	80
Mercury	ιg/l	0.14	0.56	1.4
Nickel	ιg/l	20	80	200
Silver	ιg/l	0.45	1.8	4.5
Zinc	ιg/l	20	80	200
Cyanide	ιg/l	5	20	50
Ammonia (Express as Nitrogen)	ιg/l	600	2400	6000
Phenolic compounds (non-chlorinated)	ιg/l	30	120	300
Chlorinated Phenolics	ιg/l	1	4	10
Aldrin and Dieldrin	ιg/l	0.002	0.004	0.006
Chlordane and related compounds	ιg/l	0.003	0.006	0.009
DDT and derivatives	ιg/l	0.001	0.002	0.003
Endrin	ιg/l	0.002	0.004	0.006
HCH	ιg/l	0.004	0.008	0.012
PCBs	ιg/l	0.003	0.006	0.009
Toxaphene	ιg/l	0.007	0.014	0.021
Radioactivity	Not to exceed limits specified in Title 17, Chapter 5, Subchapter 4, Group 3, Article 3, Section 30269 of the California Administrative Code.			

Table 5

Updated limitations for toxic materials in the 1988 revision of the California Ocean Plan.

PARAMETER	UNITS	6-MONTH MEDIAN	DAILY MAXIMUM	INSTANTANEOUS MAXIMUM
Cadmium	ιg/l	1	4	10
Copper	ιg/l	3	12	30
Lead	ιg/l	2	8	20
Mercury	ιg/l	0.04	0.16	0.4
Nickel	ιg/l	5	20	50
Silver	ιg/l	0.7	2.8	7

Table 6. Summary of SONGS' compliance with water quality regulations for Units 2 and 3. Conclusions are drawn from results in Final Technical Reports and are preliminary.

RECEIVING WATER CHARACTERISTIC	EVIDENCE NON-COMPLIANCE
Transmittance of natural light (Irradiance)	YES
Temperature	NO
Sediments	*
Toxic substances (Metals)	NO
Marine Biota	YES

* Depends on the results of an ongoing study.

Table 7. Results of BACIP analyses for irradiance (I). Results are shown for periods when the impact stations were upcurrent or downcurrent for 9 of 9 hrs and 5 of 9 hrs. Height is distance (m) above the bottom. Mean **I** (1 S.D.) is the SONGS effect on irradiance (measured in Einsteins/m^2/day). P is the significance for the SONGS effect. P_A is the probability that the Before data-set was additive; results with P_A less than 0.80 are more or less unreliable. (from Final Technical Report L)

	HEIGHT	SONGS EFFECT MEAN I (1 S.D.)	P	P_A
DOWNCURRENT				
9hr/9	0	-0.60 (0.23)	0.01	0.98
5hr/9	0	-0.46 (0.21)	0.03	0.86
9hr/9	2	-0.39 (0.32)	0.22	0.50
5hr/9	2	-0.43 (0.29)	0.14	0.20
UPCURRENT				
9hr/9	0	+0.51 (0.32)	0.11	0.97
5hr/9	0	+0.02 (0.26)	0.93	0.31
9hr/9	2	not additive		
5hr/9	2	+0.41 (0.42)	0.93	0.82

Table 8. Biological variables and metal concentrations (lg/g dry wt.) for 1976-1977 MRC mussel outplant. "On" and "Off" designate different time periods for the outplants. Flow volume from Unit 1 was 0.9 x 10^6 during "off" period and 1.6 x 106 m^3/d during "on" period. (from Final Technical Report E).

Station (Distance downcoast of Unit 1 discharge)	Growth rate ($mm\ d^{-1}$) On	Growth rate ($mm\ d^{-1}$) Off	Cd On	Cd Off	Cr On	Cr Off	Cu On	Cu Off	Fe On	Fe Off	Mn On	Mn Off	Ni On	Ni Off	Pb On	Pb Off	Zn On	Zn Off
25 m	0.11	0.11	2.40	2.31	0.62	1.33	6.1	12.0	392	1100	7.8	13.4	0.94	1.71	0.88	2.26	85	126
50 m	0.10	0.09	2.99	1.72	0.66	1.58	7.0	13.2	430	988	8.3	15.6	1.39	2.00	1.20	1.94	109	116
1600 m	0.12	0.15	2.34	1.60	0.33	1.34	5.1	8.4	149	785	4.8	12.4	0.90	2.05	0.93	1.46	78	103
12800 m	0.13	0.11	3.15	1.74	0.36	0.66	5.8	10.1	148	134	5.7	8.2	1.06	1.36	1.13	1.41	92	96

Table 9. Summary of results of ANCOVA for metal concentrations during 1976-1977 MRC mussel outplants. Distance was the coviariate and Period ("on" or "off") was the class variable. Distance x Period represents a test for homogeneity of slopes for the independent variable Distance during the two periods. Entries in the table are F values (d.f. = 1,7 in all cases). * indicates $p < 0.05$, t indicates $p < 0.10$. (from Final Technical Report E)

DEPENDENT VARIABLE	SOURCE		
	DISTANCE	PERIOD	DISTANCE X PERIOD
Cd	0.14	4.57^{t}	1.02
Cr	7.44^{t}	19.90*	0.63
Cu	0.35	13.04*	0.05
Fe	19.86*	13.76*	3.64
Mn	4.83^{t}	15.15*	0.75
Ni	1.29	13.90*	0.99
Pb	0.42	16.77*	2.01
Zn	0.74	4.54	0.70

Table 10. Summary of ANCOVA results for growth rate during the 1976-1977 MRC mussel outplants. Metal concentration was the covariate (separate analyses for each metal: Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn) and Period was the class variable. Preliminary analyses indicated that slopes were homogeneous across periods. Entries in the table are F values. * indicates $p < 0.05$. (from Final Technical Report E).

Covariate (Metal)	----------- Source ----------	
	Metal Concentration	Period
Cd	0.02	<0.01
Cr	0.46	0.49
Cu	12.70*	11.08*
Fe	0.34	0.32
Mn	1.23	1.10
Ni	0.01	0.04
Pb	0.86	0.82
Zn	1.27	0.87

Table 11. Mean (± 1 S.E.) of growth rate and metal concentrations [lg/g dry wt.] for 1986 MRC mussel outplant. Solid lines connect means that are not significantly different. Dotted lines are used to jump stations when a group of means that are not significantly different from one another are separated from one another by a station that differs from at least one of the group. Stations are arranged in order from upcoast to downcoast. (from Final Technical Report E)

STATIONS	GROWTH RATE (mm d^{-1})	CD	CR	CU	FE	MN	PB	ZN
SMKU (~5 km upcoast)	0.13±0.002	3.4±0.16	0.96±0.07	6.54±0.31	346±74	11.8±0.58	1.08±0.13	129.3±17.5
SMKD (~4 km upcoast)	0.13±0.007	3.6±0.30	1.59±0.03	6.45±0.26	841±22	18.0±1.05	1.40±0.16	114.3±3.5
SOKN (<0.5 km upcoast)	0.13±0.006	3.4±0.16	1.52±0.19	6.22±0.22	739±121	16.0±0.70	1.11±0.11	120±4.0
DIFF (Diffusers of Units 2 & 3)	0.10±0.004	4.6±0.27	1.36±0.09	5.94±0.17	657±61	14.4±0.72	0.89±0.04	127±3.2
SOKU (~0.5 km downcoast)	0.11±0.0003	4.6±0.41	1.30±0.05	6.04±0.19	582±27	12.7±0.60	0.81±0.27	132±21.0
PAR (~5 km downcoast)	0.13±0.003	4.0±0.31	0.89±0.03	5.24±0.05	289±19	9.1±0.56	0.60±0.01	112±6.7

Table 12. Coefficients of determination (r2) of growth rate versus metal concentrations for 1986 MRC mussel outplant. In all cases, d. f. = 15. ** indicates $p < 0.01$. (from Final Technical Report E)

METAL	GROWTH RATE
Cd	0.46**
Cr	0.004
Cu	0.07
Fe	0.006
Mn	0.005
Pb	0.05
Zn	0.02

Table 13. Metal concentration (lg/g dry wt.) in sediments for all beaches during the July 1983 MRC study. (from Technical Report E)

DISTANCE FROM SONGS (KM)	CD	CR	CU	FE	MN	NI	PB	ZN
NORTH								
115	0.0223	0.302	0.308	104	5.15	0.462	1.58	2.93
100	0.0128	0.428	0.197	124	2.403	0.677	1.52	3.02
79 (Cabrillo Beach)	0.363	2.27	2.38	943	34.6	1.18	3.32	13.8
15.5	0.0208	0.109	0.277	104	9.42	0.623	0.261	1.39
12	0.0158	0.130	0.184	98.1	5.57	0.440	0.197	1.36
6.5	0.006	0.172	0.101	82.4	4.08	0.699	0.373	1.61
1.5	0.0105	0.153	0.173	84.3	6.43	0.559	1.21	1.39
0.4	0.00725	0.116	0.169	79.4	4.61	0.490	0.251	1.13
SOUTH								
1.5	0.00675	0.085	0.125	52.0	2.52	0.487	0.183	1.20
6.5	0.006	0.193	0.132	56.4	4.56	0.497	0.183	1.14
12	0.00350	0.167	0.130	46.6	2.85	0.603	0.1003	1.13
18	0.00575	0.188	0.0985	86.8	2.94	0.648	0.216	1.33
25 (Oceanside)	0.00500	0.186	0.149	118	5.50	0.609	0.242	1.43
45	0.00325	0.192	0.101	68.9	1.67	0.632	0.471	1.44
65 (La Jolla)	0.00500	0.340	0.173	50.4	1.89	0.614	0.944	1.54

Table 14. Metal concentration (lg/g dry wt.) in sediments for all beaches during the August 1983 MRC study. (from Final Technical Report E)

DISTANCE FROM SONGS (KM)	CD	CR	CU	FE	MN	NI	PB	ZN
NORTH								
450	0.006	0.357	0.0713	107	2.03	0.718	0.113	1.44
115	0.0095	0.339	0.208	99.4	4.83	0.586	1.50	2.75
100	0.0120	0.582	0.231	165	3.39	0.336	1.48	3.50
79 (Cabrillo Beach)	0.338	2.46	0.606	1144	30.8	1.36	4.81	14.1
15.5	0.0215	0.0703	0.227	93.7	9.27	0.606	0.242	1.34
12	0.0138	0.051	0.199	72.9	5.56	0.513	0.203	1.10
6.5	0.0070	0.0938	0.133	88.5	2.58	0.507	0.271	1.52
1.5	0.0075	0.0590	0.187	340	4.52	0.519	0.848	1.19
0.4	0.00375	0.0523	0.112	53.5	3.11	0.466	0.208	1.12
SOUTH								
1.5	0.00425	0.116	0.138	59.3	2.30	0.517	0.197	1.11
6.5	0.0053	0.0593	0.115	38.8	2.69	0.483	0.136	1.02
12	0.0060	0.0985	0.122	45.6	2.54	0.538	0.145	1.81
18	0.00625	0.166	0.0913	47.6	2.76	0.454	0.150	1.22
25 (Oceanside)	0.00675	0.178	0.138	114	4.49	0.557	0.246	1.43
45	0.00725	0.183	0.106	57.9	1.76	0.604	0.358	1.35
65 (La Jolla)	0.00573	0.177	0.093	80.0	2.60	0.694	0.491	1.78

Table 15. Summary of effects of SONGS' Units 2 and 3 on the marine biota in the receiving water near SONGS, and entrainment losses. Estimated effects are taken from Final Technical Reports and are preliminary.

GROUP	ESTIMATED EFFECT
RECEIVING WATER	
Giant kelp	40% decline in area of kelp bed (83 ha)
Kelp bed invertebrates	20-80% decline in gastropod density
Kelp bed fish	approximate 60% decline in bottom fish
Midwater fish	decline in density of some species
Bottom fish	increase in density of some species
Soft benthos invertebrates	increase in density of some species
Mysids	increase in density
Plankton	no measurable effect
ENTRAINMENT LOSSES	
Plankton	1200 MT/yr lost
Mysids	6.5×10^{9} mysids/yr lost
Ichthyoplankton	5×10^{9} larvae/yr lost
Juvenile and adult fish	1.27×10^{6} fish/yr (15 MT) lost

Table 16. (A) Tests of trends in deltas (Impact - SMK) of areas exceeding threshold kelp densities. Data were not transformed. (B) Trends of deltas (Impact - SMK) for kelp density. Data were log transformed. Area and density were estimated by downlooking SONAR. (from Final Technical Report K)

(A) AREA

TYPE OF AREA	IMPACT	SLOPE	R^2	P
Area with kelp present	SOK	-454	0.71	0.0012
	SOKU45	-382	0.82	0.0001
	SOKU35	-362	0.84	0.0001
	SOKD45	-381	0.80	0.0002
	SOKD35	-375	0.81	0.0002
Area with kelp density exceeding 4/100 m^2	SOK	-338	0.68	0.0018
	SOKU45	-226	0.63	0.0037
	SOKU35	-216	0.64	0.0032
	SOKD45	-229	0.64	0.0033
	SOKD35	-232	0.69	0.0016
Area with kelp density exceeding 16/100 m^2	SOK	-46	0.43	0.03
	SOKU45	-25	0.07	0.44
	SOKU35	-28	0.09	0.37
	SOKD45	-24	0.06	0.45
	SOKD35	-25	0.08	0.40

(B) DENSITY

IMPACT AREA	SLOPE	R^2	P
SOK	-0.0001	0.34	0.06
SOKU45	-0.003	0.70	0.0013
SOKD45	-0.002	0.44	0.03
SOKU35	-0.0002	0.006	0.82
SOKD35	-0.0007	0.06	0.46

Table 17. BACIP tests on adult kelp on transects at SOKU35. SMK was used as the Control. Transformations were chosen to induce additivity. Density transformation is log(x); recruitment transformation is log(x+0.00314). Power is 100 x the probability of detecting a 50% change at the impact site testing at the 0.05 level. Tests of serial correlations could not be done for recruitment rate, because there were only three Before observations. (from Technical Report K)

VARIABLE	MEAN VALUES				% CHANGE	POWER (%)	P
	BEFORE		AFTER				
	CONTROL	IMPACT	CONTROL	IMPACT			
Density	0.137	0.052	0.179	0.006	-91.5	32.5	<0.0001
	(n = 4)		(n = 14)				
Recrutiment	0.052	0.010	0.078	0.001	-78.4	5.6	0.295
	(n = 3)		(n = 8)				

Table 18. Results of repeated-measures BACI analysis for adult kelp on transects.Estimated percent changes in the SOKU45 (near impact) and SOKD45 (far impact) quadrants relative to the values in the control kelp forest, SMK, and the results of repeated measures analyses. Data were log transformed before analysis. (from Final Technical Report K)

	% CHANGE		PERIOD		PERIOD X LOCATION		POWER (%)	POWER (%)
	SOKU45	SOKD45	F(DF)	P	F(DF)	P	MAIN	PERIOD X LOCATION
Density	-44.9	-55.4	7.95(18)	0.011	3.64(18)	0.073	47.6	99.9
Recruitment	-83.9	-89.7	2.23(13)	0.159	0.41(13)	0.534	7.7	25.8
Mortality	-4.3	-19.0	0.47(17)	0.502	0.34(17)	0.566	38.8	29.0

Table 19. BACIP tests on setson flux (bottom data collected during gametophyte outplants), comparing the near (SOKU45) and far (SOKD45) impact sites with SMK. The station differences were significantly correlated for both comparisons and thus reported p-values are lower than they would be. Time series models were not fit because of the limited Before data. Daily seston flux values were log (x + 0.53) transformed. (from Final Technical Report K)

COMPARISON (CONTROL VS IMPACT)	MEAN VALUES BEFORE CONTROL	BEFORE IMPACT	AFTER CONTROL	AFTER IMPACT	P	POWER (%)	% CHANGE
SMK45 vs SOKU45	2.37	6.69	2.93	11.16	0.077	93.1	35.5
	(n = 14)		(n = 21)				
SMK45 vs SOKD45	2.37	7.86	2.93	7.47	0.21	96.1	-20.3
	(n = 14)		(n = 21)				

Table 20. BACIP tests on seston flux (bottom data collected during gametophyte outplants) using an AR(1) time series model to correct for serial correlations (Preliminary analysis with an AR(3) model produced similar results and indicated that higher order correlations were not present). Only the SOKU45 (Impact) versus SOKD45 (Control) comparison is tested using a time series model, because too few data were available to use this method with comparisons with SMK. Daily seston flux was log (x + 0.53) transformed to induce additivity. Power to detect a 50% change at the impact sites was estimated assuming uncorrelated errors and this is somewhat inflated. (from Final Technical Report K)

Mean Values				P	Power (%)	% Change
Before		After				
Control (SOKD)	Impact (SOKU)	Control (SOKD)	Impact (SOKU)			
7.62	7.65	7.47	11.16	0.001	~100%	45.8
(n = 31)		(n = 21)				

Table 21. Results of repeated measures BACI analyses for benthic invertebrates. Estimated percent changes at SOKU (near impact) and SOKD (far impact) stations relative to the SMK (control) station, and the results of repeated measures analysis. NR (no result) indicates all densities were zero at the test stations. -- indicates repeated measures test not done due to additivity, trends in the deltas, serial correlation or no result. ^{U} indicates that the assumption tests could not be done. (from Final Technical Report F)

SPECIES	% CHANGE SOKU	% CHANGE SOKD	PERIOD P	PERIOD X STATION P	POWER(%) PERIOD X STATION
Snails	-84.0^{U}	-73.2^{U}	0.02	0.12	7.6
Astrea undosa	-85.5	-68.2	--	--	--
Calliosotma spp.	-58.9^{U}	19.1^{U}	0.33	0.02	5.1
Conus californicus	-90.8	81.0	0.0001	0.06	50.1
Crassispira semiinflata	-82.0	-60.1	--	--	--
Cypraea spadicea	-85.5	-55.9	--	--	--
Kelletia kelletii	-63.5	-51.8	0.003	0.096	98.0
Mitra idae	-70.5	-35.0	0.24	0.087	28.9
Nassarius spp.	-36.3^{U}	(NR)	--	--	--
Ophiodermella inermis	-32.3^{U}	-68.6^{U}	0.01	0.095	42.5
Tegula aureotincta	-93.2^{U}	(NR)	--	--	--
Maxwellia gemma	-88.9^{U}	-61.1^{U}	0.08	0.04	20.6
Murexiella santarosana	-86.3^{U}	-62.8^{U}	0.10	0.35	9.1
Pteropurpura festiva	-84.2^{U}	-73.6^{U}	0.13	0.32	5.3

Table 22. Summary of BACI tests in effects of cohesive sediments on kelp bed invertebrates. Tests compare densities Before and After the influx of cohesive sediments on impacted relative to unimpacted quadrats in SOKU. (from Final Technical Report F)

GROUP	%CHANGE	P
Snails	-12.7	0.32
Non-muricid snails	-6.4	0.67
Muricid snails	-20.7	0.19
Sea urchins	-36.0	0.001
Sea stars	-56.4	0.02
Sessile invertebrates	-41.6	0.002

Table 23. Mean density of kelp bed fish (A) in the canopy and (B) near the bottom in the Before (1980, 1981) and After (1985, 1986) periods at SMK, SOKU, and SOKD. Density is no./1,000 m^3. P is significance level for the period x location interaction for the 2-factor ANOVA comparing mean fish density among locations. (from Final Technical Report J).

SPECIES	SMK		SOKU		SOKD		P FOR INTERACTION TERM OF ANOVA
	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
(A) Canopy							
Kelp perch	32.3	3.7	10.7	0.9	8.2	1.7	0.003
Senorita	21.5	18.3	14.3	39.3	14.5	35.3	<0.01
Halfmoon	4.2	1.2	2.9	5.3	1.8	3.1	0.01
Giant kelpfish	0.1	0.45	0.05	0.13	0.03	0.25	0.01
(B) Bottom							
Barred sand bass	0.4	1.4	2.2	2.0	1.8	3.7	<0.01
Black perch	1.4	1.9	3.9	0.8	11.4	4.2	0.04
Rainbow perch	0.29	0.20	0.27	0.26	1.6	0.44	0.04
Senorita	11.5	5.4	3.4	10.7	3.0	6.0	<0.01
California sheephead	2.6	0.9	7.4	1.3	7.4	0.8	<0.01

Table 24. BACI analyses of midwater fish. Impact stations are NS = near-shallow, FS = far-shallow, ND = near-deep and FD = far-deep. Impact sites were compared with shallow and deep Control sites. (d) indicates a decline in abundance relative to the Control, (i) indicates an increase in abundance, and (-) indicates that the direction of change could not be determined. The % catch is averaged over all locations and periods. ** = $P<0.05$, * = $0.05<P<0.1$, and ^{p} indicates a significant but problematic result (see text). (from Interim Technical Report 3)

TAXON	% CATCH	CHANGE IN ABUNDANCE			
		NS	FS	ND	FD
Northern anchovy	62.8	i	d	i	i
Queenfish	16.0	d^{**}	d^{*}	d	d^{**}
Silversides	5.0	d	i^{**}	d	d
Pacific mackerel	3.7	i^{p}	d	d^{p}	d^{p}
Pacific butterfish	3.1	-	-	i	-
White croaker	2.8	d^{**}	d^{*}	i	i
Jack mackerel	2.2	d	d^{p}	d^{p}	d^{p}
Pacific barracuda	0.5	d^{p}	d^{p}	d	d
Salema	0.4	d	d	d	d
Walleye seaperch	0.2	d	-	-	-
White seaperch	0.1	d	d	d	d

Table 25. Monitoring programs conducted by Southern California Edison from 1964 to 1987

Program and studies	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Marine Environmental Monitoring (MEM) turbidty benthic invertebrates	—	—												
Environmental Technical Specifications (ETS) & National Pollutant Discharge Elimination System (NPDES) turbidity kelp benthic invertebrates midwater fish (gill nets)	—	—	—	—	—	—	—	—	—					
Sand Disposal Study (SDS) kelp benthic invertebrates	—	—	—											
Construction Monitoring Program (CMP) sediments kelp			—	—	—	—					—	—	—	—
Preoperational Monitoring Program (PMP) turbidity kelp benthic invertebrates midwater fish (gill nets)					—	—	—							
316(b) Program entrainment: larval, juvenile, adult fish					—	—	—	—	—	—	—	—	—	
Interim Studies - NPDES turbidity kelp benthic invertebrates							—	—	—	—	—			
Operational Program - NPDES turbidity kelp benthic invertebrates											—	—	—	—

Table 26. Summary of studies in the NPDES monitoring program for receiving water. From Table 1 in the NPDES permit (No. CA0108181) for SONGS Unit 3.

STUDY	STATIONS	FREQUENCY	SAMPLE METHOD
REGULAR MONITORING			
Continuous temperature	2 at SONGS 1 at Don Light	hourly	remote
Benthic fish	San Mateo Point San Onofre Don Light	bimonthly	otter trawl
Kelp mapping	San Onofre Kelp San Mateo Kelp Barn Kelp	semi-annual	sonar
Kelp density	5 in SOK main bed 1 in SOK north bed	tri-annual	divers
SPECIAL STUDIES			
Kelp bed aerial survey	general San Diego region	annual	photography
Surface temp-erature maps	near Units 2 and 3 diffusers	semi-annual (min 1 yr)	infrared mapping
Temperature profiles	19 at San Onofre 1 at San Mateo Pt. 3 at Don Light	quarterly	grab
Transmissometer profiles	same as temperature profiles	quarterly	grab
Water quality, pH and DO	3 at San Onofre 1 at Don Light	quarterly (min 1 yr)	grab
Chlorine	7 at SONGS intakes and difussers 1 at Don Light	tri-annual (min 1 yr)	grab
Metals	5 at San Onofre 1 at Don Light	tri-annual	grab

Table 27. Turbidity studies in the San Onofre region conducted by SCE. Light transmittance measurements were collected from the surface to the bottom. Letter codes for monitoring studies are explained in Table 25. (Updated from Table 2B-1 in SCE 1982).

MONITORING PROGRAM	SAMPLE METHOD	YEARS	FREQUENCY
MEM	light transmittance	1964-1975	bimonthly
ETS & NPDES	light transmittance	1975-1981	bimonthly
	aerial photography	1975-1977 1977-1981	quarterly bimonthly
PMP	light transmittance	1978-1980	bimonthly
Special PMP study	light transmittance	1980	22 weekly surveys
	aerial photography	1980	22 weekly surveys
NPDES interim study	aerial photography	1980-1981 1983	bimonthly 13 times
NPDES opera-ational study	light transmittance	1985-1987	quarterly
	aerial photography	1984-1987	at least quarterly

Table 28. Quantitative studies kelp and invertebrates on subtidal, hard substrates. Letter codes for monitoring programs are explained in Table 25. (From Table 4-1 in SCE 1988.)

MONITORING PROGRAM	TOTAL NO. OF SURVEYS	NO. OF SAMPLES / YEAR	NO. OF STATIONS	NO. OF SAMPLING AREAS / STATION
ETS (1975-1981)	25	4	11	10 fixed
CMP (1976-1980)	15	4	2	10 fixed
PMP (mid-1978 to mid-1980)	8	4	10	1 fixed 4 random
Interim Kelp Program (IKP) (1980-1984)	10	3	6	3-6 fixed 12 random
NPDES				
(mid-1981)	1	1	11	10 fixed
(mid-1981 - 1984)	11	3	6	3-6 fixed 12 random
Operational Program (1984 to present)	12	3	6	3-6 fixed 12 random

Table 29. Kelp and invertebrate species sampled at permanent stations in SOK and SMK by SCE contractors. Life stage is determined by length of plant for kelp. Length is measured from the top of the holdfast to the meristem of *Pterogophora* and to the meristem of the longest frond of *Macrocyctis*. (From Table 5-2, SCE 1984.)

Species	Life Stage
KELP	
Laminaria farlowii	adult (> 15 cm)
Macrocystis pyrifera	juvenile (15-40 cm) subadult (41 cm - 2 m) adult (>2 m)
Pterogophora californica	subadult (<30 cm) adult (≥30 cm)
Laminoid, (too small to be identified)	<15 cm
INVERTEBRATES	
Lytechinus anamesus	all stages
Strongylocentrotus spp.	all stages
Patiria miniata	all stages
Pisaster spp.	all stages

Table 30. Recommended additions to the NPDES monitoring program for SONGS Units 2 and 3.

STUDY	RECOMMENDATION
Turbidity	1. measure irradiance instead of transmissivity 2. measure currents at the "irradiance" stations 3. sample continuously
Marine Biota	1. survey midwater fish 2. survey macroinvertebrates and fish in kelp beds, as well as kelp
Sampling design and analyses	1. impact and control sites should be compared using statistical analyses 2. utilize a Before-After, Impact-Control design