Diablo Canyon License Renewal Feasibility Study Environmental Report

Technical Data Report

HEAT SHOCK

Revision 0
2008

TABLE OF CONTENTS

1. Background

The NRC made impacts on fish and shellfish resources resulting from heat shock a Category 2 issue because of continuing concerns about thermal discharge effects and the possible need to modify thermal discharges in the future in response to changing environmental conditions (NRC 1996). Information to be ascertained includes (1) Type of cooling system (whether once-through or cooling pond), and (2) Evidence of a Clean Water Act (CWA) Section 316(a) variance or equivalent State documentation.

Diablo Canyon Power Plant (DCPP) has a once-through heat dissipation system that withdraws from and discharges to the Pacific Ocean. The general design and operational parameters of the cooling system are provided in the DCPP License Renewal Application Environmental Report (Environmental Report) Section 3.1.2. This technical data report provides further detail of cooling system operations with regard to ecological impacts of the thermal discharge, and incorporates descriptions of physical and numerical modeling of the discharge plume in the receiving water.

Marine resources in the vicinity of the discharge have been studied since the mid-1960s when the area was first considered as a power plant site. The early studies were conducted to provide baseline inventories of marine resources, and to evaluate the potential effects of the planned thermal discharge. Predictive studies were also conducted before plant start-up to identify the potential environmental effects of full scale commercial operations. Studies have continued through plant operations during the initial license period to evaluate the predictive work, and to document the actual effects of the discharge. A complete listing of published reports resulting from studies associated with the DCPP thermal discharge is provided as **Attachment 1**.

2. Clean Water Act (CWA) Section 401 Certification

Environmental Report Section 4.2 describes DCPP's current CWA Section 401 Certification status.

3. Consultations with Regulatory Agencies

The following discussion presents an overview of consultations with regulatory and resource agencies on the issue of heat shock resulting from the DCPP once-through cooling system thermal discharge. Regulatory action on the discharge can be separated into:

a) The period prior to power plant operation and plant licensing, which involved the preparation and submittal of a Final Environmental Statement (FES) as part of the NRC licensing process (described in the next sub-section).

b) Compliance with regulatory provisions for thermal discharges.

Following licensing of the power plant, the regulatory activity was primarily focused on demonstrating thermal discharge compliance requirements with Section 316(a) of the Federal Clean Water Act (CWA). Elevated temperature discharges are regulated in the State of California through water quality objectives established by the State Water Resources Control Board (SWRCB or State Board) in the Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California (Thermal Plan or Plan). The Plan defines the thermal discharge at Diablo Canyon as an existing coastal discharge. The DCPP thermal discharge is therefore subject to a narrative standard, which requires the limits imposed on the discharge be sufficient to "assure protection of the beneficial uses" of the receiving water. However, the Plan does not provide guidance on how to make a protection of beneficial uses determination regarding a thermal discharge temperature limit. At the federal level, Section 303(g) of the Clean Water Act (CWA) requires that any state water quality standard for heat be consistent with the standard set forth in Section 316 of the CWA. Section 316(a) authorizes the establishment of an alternative limit for heat where a discharger can show that the alternative limit will assure protection of a "balanced indigenous population of fish, shellfish, and wildlife in and on the water body to which the discharge is made."

The Thermal Plan requires existing dischargers, such as DCPP, to conduct a study to define the effect of the discharge on beneficial uses and to identify power plant design and operating changes if the discharge is not in compliance with the Plan. Additionally, all thermal discharges must be monitored to determine compliance with requirements specified in the power plant's National Pollutant Discharge Elimination System (NPDES) permit issued by the State Board or appropriate Regional Water Quality Control Board (RWQCB). Thermal discharges that are deemed significant by the State or Regional Board shall be required to implement expanded monitoring programs (either continuous or periodic) to determine whether the limits provide "adequate protection to beneficial uses (including the protection and propagation of a balanced indigenous community of fish, shellfish, and wildlife, in and on the body of water into which the discharge is made)."

<u>NRC Licensing</u>

The NRC examines the potential environmental impacts of a nuclear power plant prior to issuing construction or operating permits as required under the NEPA. This environmental assessment includes a review of the effects of the proposed plant's thermal discharge and is referred to as an Environmental Statement. DCPP's Final Environmental Statement (FES) was completed by the Atomic Energy Commission (AEC 1973), the NRC's predecessor. This was done in May 1973 and an Addendum was completed in 1976 (NRC 1976). The FES, prepared by AEC staff, was based on environmental reports submitted by PG&E (PG&E 1972), as well as additional materials from government agencies and other organizations. The purpose of the FES was to evaluate the potential for environmental impacts to air, land, water, and the human community from the construction and operation of DCPP.

The FES and Addendum reviewed and analyzed the available information on the predicted environmental effects that might be caused by a DCPP thermal discharge at a projected normal temperature elevation of approximately 19 degrees Fahrenheit (°F). Overall, the FES found that there would be a shift in benthic organisms and fishes as a result of the replacement of cold-water species with narrow temperature tolerance ranges and an increase in species able to tolerate a wide range of temperatures, especially in the area near the discharge where the plume contacts the bottom (estimated to be approximately 10 acres) prior to lifting to the surface as it moves offshore. This resulted in a prediction that an increased number of warm-water-tolerant forms, indigenous to the general area, would occupy the habitat exposed to the plume. The area exposed to the plume would also experience a reduction of as much as 10-20 acres of bull kelp and a reduction in the kelp canopy within the 4°F isotherm. There was also the prediction that losses of red and black abalone may occur as a result of reductions in algal food species in more than half of the intertidal and subtidal zones in Diablo Cove. However, due to a subsequent increase in the sea otter population that had significant impacts on the existing abalone population, the Addendum (NRC 1976) predicted additional declines in abalone, due to the thermal plume, would be small. No fish losses were expected as a result of the discharge but there would be attraction to, and avoidance of, the plume by juvenile and adult fishes. The Addendum indicated that the effects of the thermal plume outside Diablo Cove, the immediate receiving water body, would be minimal.

After weighing the environmental, economic, technical, and other aspects against the environmental costs, and considering available alternatives, the AEC staff concluded in the FES that construction permits should be continued. The staff reached the same conclusion in the Addendum and recommended that the operating license be granted.

<u>Federal and State CWA Compliance</u>

Details on consultations relative to compliance with provisions of the Federal CWA pertaining to thermal discharges through the regulatory authority in California administered by the Central Coast Regional Water Quality Control Board (Regional Board or CCRWQCB) are described below.

Pre-Operational Permits and Assessments

Provisions of the Federal CWA pertaining to thermal discharges are regulated through the NPDES permit system administered in California through the SWRCB and nine RWQCBs. The first permit issued to DCPP from the CCRWQCB predates the current CWA, as well as the State Thermal Plan. DCPP was issued a Waste Discharge Requirement (WDR) permit in October 1969 (CCRWQCB 1969). The overall objective of this initial WDR was "to protect public health, to protect beneficial uses made of the receiving waters and adjacent shorelines from unreasonable impairment and to prevent nuisance conditions from occurring." The WDR did not include any numeric thermal limits, but required that the temperature of the discharge "not cause undesirable ecological change or deleterious effects upon aquatic plant and animal life." The permit included a definition of the term 'undesirable ecological change' from the California Department of Fish and Game (CDF&G). The definition included the following criteria: (1) for any point in the receiving water, including the areas within Diablo Cove, there shall be no acute toxicity to the marine biota due to the waste discharge; and (2) for the ocean waters beyond Diablo Cove, this discharge should not either directly or indirectly cause undesirable ecological changes or deleterious effects upon the marine environment.

The CCRWQCB issued the first NPDES permit for the DCPP in October 1974 (CCRWQCB 1974, Order No. 74-41). Although this Order made no explicit changes to DCPP's thermal limits, stating that the discharge requirements established in the 1969 WDR remained in effect, the Order did state that the California Thermal Plan and federal requirements established under Section 316 of the CWA apply to the discharge. Provision B.4 of the Order required DCPP to prepare a request for a thermal variance under Section 316(a) of the CWA, if necessary, by October 1975.

To meet the requirements in Provision B.4 of Order No. 74-41, PG&E submitted a study plan to the CCRWQCB in December 1975 (PG&E 1975). The Diablo Canyon 316(a) Demonstration Study Plan described the studies that would be conducted to verify that a thermal discharge prohibition was more stringent than necessary to meet the federal variance standard of assuring "protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the Pacific Ocean" and that an alternative thermal limit would be sufficient. The 316(a) demonstration was designed to use field data to determine the potential effect of the plant's thermal discharge on twenty-one representative, important species (RIS) selected for the study by the CCRWQCB staff and the CDF&G (**Table 1**). Laboratory tests, physical model tests, and mathematical models were to be used to supplement the field data as necessary to provide a comprehensive, integrated analysis of the effect of the plant's thermal discharge. The data were eventually to be used to determine compliance with applicable physical and biological guidelines relative to mixing zone characterization.

The CCRWQCB issued DCPP a new NPDES permit in 1976 (CCRWQCB 1976). At this time, the EPA technology-based regulations were still in place. Therefore, Order No. 76-11 included a prohibition on the discharge of heat after July 1, 1981, unless PG&E made a demonstration that the prohibition, or other heat-related limitations were more stringent than necessary to meet the federal variance standard. The Order also noted that PG&E had submitted a study plan for a demonstration program under the requirements of Section 316(a) in December 1975. Thus, the marine studies at DCPP initially assumed that a federal variance from the 1974 technology-based limit would be necessary and the CCRWQCB permit reflected this fact. Additionally, the Order contained heat-related limits that were in effect until July 1981. These limits established a maximum discharge temperature increase of 25°F, and required the maximum increase to be no more than 22°F for 12 hours in a calendar day and 24 hours in a calendar week. During heat treatments, the maximum increase allowed was 50°F, and the permit required the operation of the pumps of the unit not being treated, in order to minimize the absolute temperature increase in the receiving water.

The CCRWQCB issued Order No. 82-24 (CCRWQCB 1982) in January 1982 after extensive public hearings. This Order included a prohibition on thermal discharges with exceptions until July 1, 1982 or until the CCRWQCB had the opportunity to reconsider the prohibition in light of a technical report required to be submitted by PG&E. The technical report was to describe alternative plans to reduce the heat and volume of the proposed cooling water discharge. The report was to contain further information on the anticipated and possible thermal and volume effects of the discharge on the beneficial uses of the ocean. This requirement resulted in the submittal of two reports to the CCRWQCB in 1982: (1) Assessment of Alternatives to the Existing Cooling Water System (Alternatives Report) (PG&E 1982a); and (2) Thermal Discharge Assessment Report (TDAR) (PG&E 1982b).

The Alternatives Report presented an evaluation of alternatives to reduce the heat and volume of the cooling water discharge. The report identified several alternatives for retrofitting the plant's cooling water system to reduce the quantity of heat discharged into Diablo Cove. The costs of the retrofits were estimated to range from 1.6 to 3.1 billion dollars (in 1982 dollars) over the 30-year life expectancy of the plant. These costs were shown to be far in excess of the environmental benefits expected from the retrofits.

The TDAR found that an increase in the abundance and distribution of warmer water species would be expected in areas where the temperature was constantly at 64°F or greater. During normal plant operation, the 64°F isotherm was expected to encompass the entire surface area of Diablo Cove and approximately 50 percent of the cove's bottom area. Many of the predictions in the report were based on the results of extensive laboratory studies on the thermal tolerance of the RIS species (PG&E 1982c). The primary changes predicted included:

- areas dominated by bull kelp and tree kelp may, after exposure to the thermal plume, become dominated by kelp species more tolerant of warm water, such as giant kelp;
- in the immediate vicinity of the discharge, a new community may form, dominated by thermally tolerant filter feeders, such as sea anemones, barnacles, hydroids, and mussels;
- few changes were expected in the intertidal community;
- greater changes were expected in the less thermally tolerant subtidal community; and
- the majority of the changes would occur in the south portion of Diablo Cove.

Upon review of these reports and from testimony at additional public hearings, the CCRWQCB amended Order No. 82-24 in June 1982. The amendment (Order No. 82-

54) deleted the prohibition on heat and established a maximum discharge temperature increase of 20°F, and also added limitations on the daily volume of the discharge, including the cross condenser delta T°. Both the original Order No. 82-24 and the amendment were appealed to the SWRCB on a variety of grounds by a number of petitioners, including PG&E. The appeals included a contention by some petitioners that the thermal limits were 'excessive'.

In March 1983, the SWRCB issued its decision upholding the thermal 20°F limit (SWRCB 1983). The decision found that "normal two unit operation and heat treatment will significantly alter the quality of waters in Diablo Cove" and concluded that "this alteration of water quality is not unreasonable." The SWRCB based this conclusion on several factors. First, the Porter-Cologne Act allows for the balancing of interests, and recognizes that water quality can be changed to some degree without unreasonably affecting the beneficial uses. Second, the SWRCB has an explicit policy preference for the siting of power plants on the coast. Third, they stated that the CDF&G had been involved in the marine studies at the DCPP for over ten years (Burge and Schultz 1973, Gotshall et al. 1984, 1986) and from testimony provided at the public hearings recognized that changes from power plant operation were likely and that the predicted changes were acceptable. Fourth, Diablo Cove is not a state designated Area of Special Biological Significance. Therefore, some change in water quality was acceptable. Fifth, under the Thermal Plan, a new power plant can be allowed a 20°F limit and the State Board noted that an existing discharge such as Diablo Canyon would presumably be subject to a less stringent requirement. Finally, the limit was found to be not excessive when compared to other coastal power plants, both in California and at other locations outside the state. For all of these reasons, the SWRCB found that the proposed limit was reasonable based on the predicted impacts. They also required PG&E to conduct Thermal Effects Monitoring Program (TEMP) studies as an extension of the work summarized in the TDAR, to provide ongoing data on thermal impacts.

The CCRWQCB modified Order No. 82-54 to conform with the SWRCB decision, and issued a new amended order in April 1983. This Order maintained the thermal limit of a maximum discharge temperature increase of 20°F (except during heat treatments) and also required PG&E to submit within 36 months of commercial operation the results of its TEMP study. The Order also included a requirement that during heat treatment of Unit 1, Unit 2 circulating pumps must be run at full capacity with no commercial load (heat output) and established a maximum discharge water temperature of 100°F during heat treatments. PG&E was also required, prior to commercial operation of Unit 2, to evaluate ways to reduce the maximum temperature increase during heat treatments to 50°F.

Operational Permits and Assessments

Commercial operation of Unit 1 began in May 1985. In August 1985, the CCRWQCB issued the plant a new NPDES Permit (Order No. 85-101 CCRWQCB 1985). This Order raised the discharge temperature increase limit to a daily average of 22°F. The increase from 20°F was based on additional operational information, which indicated the temperature during transient conditions, such as load rejection, steam dump, generator trip, and the operation of engineered safety features, could exceed 20°F and might reach 22°F. During heat treatments, the daily average temperature increase was set at 25°F, with a maximum of 50°F for one hour during a 24-hour period of treatment. Additionally, PG&E was required to provide results of the Thermal Effects Monitoring Program (TEMP) studies to the CCRWQCB by May 1988 to provide the CCRWQCB further information on whether the existing temperature limits were sufficient to protect beneficial uses (marine habitat).

As required by Order No. 85-101, PG&E submitted a report on the TEMP studies to the CCRWQCB in April 1988 (PG&E 1988). This report included nine years of pre-operational data and approximately 30 months of operating data (18 months of two-unit operation). The overall conclusion of the report was that communities in Diablo Cove were still changing and that the protection of the beneficial uses of the cove was demonstrated by the continued presence of marine algal, invertebrate, and fish species whose composition, abundance, and distribution, though different than those previously found at the site, were representative of natural marine habitat.

The CCRWQCB staff reviewed the report and notified PG&E in April 1989 that the TEMP program was "appropriately designed and conducted in a satisfactory manner," but that it was "not conducted long enough to determine the steady state environment in and around Diablo Cove for the life of Diablo Canyon Power Plant." Subsequently, the Executive Officer established a multi-agency workgroup, comprised of CCRWQCB, CDF&G staff, and PG&E and its consultants. In addition to providing guidance, the workgroup was to develop recommended monitoring requirements, which would allow the CCRWQCB to determine whether beneficial uses were protected. The workgroup met throughout 1989 and early 1990, discussing a variety of data collection and analysis methodologies that would be incorporated into the TEMP study.

The renewal of the permit in 1990 (CCRWQCB 1990, Order No. 90-09) required PG&E to continue the TEMP studies, maintained the maximum discharge temperature increase of 22°F (daily average), and maintained the limits for heat treatments.

Beginning in 1994, after nine years of commercial operation, CCRWQCB staff and PG&E began discussing the possibility of bringing the thermal effects studies to closure and preparing a comprehensive final assessment of the existing limits. PG&E submitted a draft proposal for a reduced monitoring program that was reviewed by CCRWQCB and CDF&G staff. Based on the review, changes were made to address their concerns. In February 1995, the CCRWQCB voted to modify the existing monitoring program by requiring PG&E to prepare a comprehensive assessment of the thermal effects data collected and to implement the new monitoring program developed by PG&E, CDF&G, and CCRWQCB staff, referred to as the Ecological Monitoring Program.

In addition to recommending the modification of the Monitoring and Reporting Program of Order No. 90-09, CCRWQCB staff also recommended the establishment of a multi-agency workgroup to advise on the development of the comprehensive thermal effects assessment and the hiring of an independent consultant to coordinate the technical aspects of the workgroup process. The workgroup decided that the comprehensive assessment should be formatted into two separate volumes or chapters: (1) an analysis of the data collected over the last twenty years, and (2) an assessment of whether the existing thermal limits are adequate to protect beneficial uses. The first volume of the report, the 1997 Analysis Report (Tenera 1997) was submitted to the CCRWQCB in 1997 and the second volume was submitted in 1998 (Tenera 1998a).

The review of the 1997 Analysis Report by the CCRWQCB staff and their consultants resulted in a request for additional studies and reports on surfgrass, thermal effects on surface kelps and in Fields Cove (Tenera 1998b, 1999a, 2000), and additional detailed assessments of the thermal effects on the marine environment that had occurred in the years following the submittal of the 1997 Analysis Report (Tenera 1998c, 1999a).

From their review of the additional data, the CCRWQCB staff concluded that adverse water quality impacts exceeded the impacts predicted in the 1982 TDAR (PG&E 1982b) and this constituted a violation of various receiving water limitations in PG&E's 1990 NPDES permit. The CCRWQCB staff contended that the thermal effects exceeded those anticipated by the State and Regional Boards when the plant was permitted and did not protect beneficial uses as required by the Thermal Plan. PG&E disagreed with the staff's position and contended that a balanced indigenous community of fish, shellfish and plants has persisted in Diablo Cove and beyond and that beneficial uses were therefore protected. In March 2000, the CCRWQCB conducted a hearing to determine whether PG&E violated its 1990 NPDES permit and whether to issue a Cease and Desist Order. After the testimony period at the hearing, the CCRWQCB continued the hearing for the presentation of closing statements and Board deliberation.

The Cease and Desist Order hearing was never completed when discussions between the CCRWQCB staff and PG&E resulted in a tentative resolution that included alternative approaches to protect beneficial uses. The effects of the thermal discharge were addressed in a tentative settlement through the permanent preservation of coastal habitat, including the same type of intertidal and shallow subtidal habitat affected by the thermal discharge. The components of the tentative settlement are presented in Section 7 of this report.

Based on the discussions between the CCRWQCB staff and PG&E, a draft NPDES permit was prepared for consideration at a CCRWQCB July 2003 hearing (CCRWQCB

2003a). In preparation for the hearing, PG&E prepared, at the request of the CCRWQCB staff, an additional report in 2002 on the thermal discharge effects that had occurred since 1995 (Tenera 2002). The results showed that since 1995, there had been minor additional biological changes in Diablo Cove, and no additional biological changes in Field's Cove. The minor additional changes in Diablo Cove were within the areas previously established as being impacted. Based on their review of the thermal effects and the CCRWQCB staff concluded that any design or operational changes to reduce thermal discharge impacts would either be ineffective or infeasible. Therefore, an alternative approach to the protection of beneficial uses based on the settlement agreement was justified (CCRWQCB 2003b). The draft NPDES Permit incorporated the settlement agreement by reference and grant of conservation easement approved by the CCRWQCB. This was done at a CCRWQCB March 23, 2003 meeting. The settlement agreement was designed to address impacts caused by the thermal discharge, but also impacts resulting from entrainment of larval fishes and crabs by the cooling water intake system.

Testimony submitted by the Technical Workgroup (TWG) members (Raimondi 2003) and provided at the hearing was not supportive of the settlement agreement. As a result, the draft NPDES permit was not adopted, based on testimony and discussions among the CCRWQCB members at the July 10, 2003 hearing. The effects from the thermal discharge were less of an issue than the potential effects of the cooling water intake system, specifically entrainment. While the settlement agreement included components that directly compensated for the effects of the thermal discharge, testimony was provided that the settlement did not compensate for the potential effects of entrainment. Although PG&E disagreed with the testimony from the TWG and presented their own testimony that the thermal discharge did not affect the maintenance of a "balanced indigenous community" in the receiving water, the CCRWQCB closed the hearing except for further consideration of specific issues, including mitigation options for addressing the effects of both the intake and discharge. The CCRWQCB directed staff and the TWG to consider additional mitigation options and related issues, including:

1. Marine Protected Areas (marine reserves)
2. The uncertainty regarding impacts and mitigation measures
3. Performance monitoring for any mitigation projects
4. Thermal effects mitigation projects
5. A reduced thermal effects monitoring program

The report on mitigation options was prepared and submitted by the independent scientists on the TWG (Raimondi et al. 2005) and presented at the CCRWQCB meeting on September 9, 2005. PG&E submitted responses on the mitigation options report (PG&E 2005) that primarily focused on the incompatibility of the recommendations with the EPA draft 316(b) Rule for existing power plants (Phase II facilities).

Thermal Effects Monitoring and Predictive Reports

PG&E has submitted annual reports on the TEMP studies to the CCRWQCB since 1983. The reports present the results from the previous year using a variety of tabular and graphical analyses. These reports documented natural changes to the marine environment before power plant operation and provided an on-going assessment of changes following plant start-up. There were several years when annual reports were not submitted when more comprehensive reports were requested by the CCRWQCB and TWG. **Attachment 1** was compiled to demonstrate the breadth and scope of marine environmental studies conducted in the Diablo Canyon area. Since 1967, over 100 reports have been submitted to the CCRWQCB and other regulatory agencies, such as the U.S. EPA, NRC and CDF&G. Additionally, studies were also conducted directly by CDF&G. The studies include not only TEMP-related monitoring, but predictive studies, baseline pre-operation studies, plume modeling and environmental assessments required by the NRC.

4. Fish and Shellfish Resources Susceptible to Heat Shock.

The fish and shellfish resources in the vicinity of the plant that are susceptible to heat shock are described in Environmental Report Section 2.2.1. The Marine Ecology Section of the Environmental Report includes lists of the species identified during the extensive monitoring program of the marine environment that began in 1976, and which continued through the initial license period to present. The monitoring (originally referred to as the Thermal Effects Monitoring Program – TEMP) is currently conducted under the heading of the Receiving Water Monitoring Program (RWMP). The purpose of the RWMP is to monitor changes in the marine environment that may be occurring as a result of the DCPP thermal discharge. The components of the RWMP are presented in **Table 2**, and are described in more detail in the monitoring reports that are submitted annually to the CCRWQCB (**Attachment 1**). More extensive analyses of the RWMP data have also been completed and submitted to the CCRWQCB (PG&E 1988, Tenera 1997, 1998c, 1999b, 2002). The most current comprehensive data summary was presented in an analysis report that summarized changes in the marine environment through mid-year of 2002 (Tenera 2002). Changes in the marine environment resulting from the thermal discharge are summarized in Section 6 of this report. An updated comprehensive assessment of the monitoring program data is currently in preparation and will be completed in 2010. The in-progress report will include an analysis of data collected through 2008.

The distribution and value of commercial and sport fisheries in the vicinity of DCPP are provided in Environmental Report Section 2.2.1, which includes lists of the commercial and recreational fishery species and summaries of the commercial catch from the local ports during power plant operation. Thermal effects monitoring results on these species can be found in the summaries presented in previous reports (PG&E 1988; Tenera 1997, 1998a, 1999a, 2002). Many of these species have been recorded in the DCPP monitoring studies. Also, several of the species were included as RIS in the original

316(a) Demonstration Plan (**Table 1**) and were the focus of extensive field and laboratory studies (PG&E 1982c). A summary of the changes in fishery species resulting from the thermal discharge is provided in Section 6 of this report.

The marine environment in Diablo Cove, where the thermal discharge is located, is similar to areas north and south of the power plant not affected by the thermal discharge, or which are less affected. The same habitat types and species found in Diablo Cove are also found in these areas. There are no unique habitats, spawning areas, nursery grounds, or feeding areas in Diablo Cove that are not also found in areas directly north and south of the cove. Although a few species, such as salmon and the grey whale, migrate along the coast offshore from the DCPP, the shoreline discharge reduces any potential for impacts on migrating species, since the plume only occurs as a thin surface layer of warm water once it reaches the nearshore areas outside Diablo Cove.

Inside Diablo Cove, the thermal discharge contacts intertidal and subtidal rocky reef habitat that supports numerous species of algae, invertebrates, and fishes, including species of kelp on the subtidal reefs. There are species of kelp that grow along the bottom that form a subsurface canopy, and other species such as the giant and bull kelps that form a canopy on the surface. The combined surface and subsurface canopies provide important structural habitat for invertebrates and fishes, especially small juvenile and newly recruited first-year fishes. Another important habitat is surfgrass that can be abundant in areas with substrate dominated by sand. Kelp and surfgrass occur in Diablo Cove and also in the nearshore areas surrounding the DCPP.

Monitoring previously included extensive studies on black abalone that occurs primarily in the intertidal and red abalone that occurs in the lower intertidal and subtidal out to depths of 60 ft. There were abundant abalone populations in Diablo Cove documented in the early studies prior to the spread of the southern sea otter (*Enhydra lutris*) into the area (Gotshall et al. 1984, 1986). Following initial declines in both red and black abalone abundances in 1974-75 that were attributed to sea otter predation (Gotshall et al. 1984, 1986), abundances in Diablo Cove remained relatively stable, although variable from 1975-1982. Results of surveys from 1984 through 1988 showed no obvious trends in abundances, and red abalone remained in Diablo Cove in similar abundances before and after power plant start-up (Tenera 1997).

The abundance of black abalone in Diablo Cove and surrounding areas has been monitored periodically since 1966 when studies were conducted by the California Department of Fish and Game (Burge and Schultz 1973). Data from the TEMP and RWMP monitoring showed a healthy population of black abalone existed in Diablo Cove through 1987 after the power plant began operating. In 1988, however, their numbers began to decline as a result of withering syndrome (WS) disease, which was first described from the southern California Channel Islands in 1986 (Tissot 1988, Haaker et al. 1992). WS was observed in other shoreline areas near Diablo Cove by early 1990. Black abalone populations have since declined throughout central and southern

California from WS disease (Altstatt et al. 1996). The pathogen that causes WS is apparently present in healthy abalone populations (Gardner et al. 1995), and symptoms are exacerbated by environmental factors including elevated temperature (Steinbeck et al. 1992). The decline has resulted in black abalone being proposed for listing under the federal Endangered Species Act (Federal Register Vol. 73, No. 8, January 11, 2008).

5. Description of Cooling System and Thermal Discharge Plume

The DCPP once-through cooling water system is described in detail in Environmental Report Section 3.1.2. The following discussion provides a summary description of the cooling system relevant to the thermal discharge, and provides a detailed description of the thermal plume from various modeling and monitoring studies. The information in this section is also included in the Chapter 1 Analysis Report (Tenera 1997).

Cooling System Description

The discharge system consists of two parallel conduits (one for each unit) that are combined immediately before the point of shoreline discharge into Diablo Cove. Within the discharge structure, cut-outs in the center wall that separate the two conduits allow mixing when flows from both units are unequal, but are of less importance when the flows from each unit are equivalent. The velocity of the effluent at the point of discharge into Diablo Cove is relatively high due to the momentum created by the water cascading downward through the discharge conduits to the shoreline.

The first warm water discharges occurred intermittently in 1984 with start-up testing of Unit 1. Commercial operation of Unit 1 began in May 1985, and Unit 2 in March 1986. The power plant has operated at high capacity factors throughout the initial license period. Therefore, the thermal discharge has been relatively consistent. Design cooling water flows have only been reduced during periodic refueling outages (staggered for Unit 1 and Unit 2), planned system maintenance curtailments between refueling outages, and unplanned forced outages (**Figure 1**).

Seawater temperatures have, and are continuing, to be measured at the cooling system intake and discharge. Temperatures are also measured at a number of locations inside Diablo Cove and in surrounding areas not contacted by the power plant thermal discharge as part of the RWMP (**Table 2**). The ambient seawater temperatures in the vicinity of the DCPP vary from a low of approximately 50°F in winter to less than 60°F in summer. Periodically, ambient seawater temperatures become warmer, especially during Pacific Ocean El Niño events. These have occurred in 1987, 1990, 1992–1993, 1995, and 1997. The temperatures at the point of discharge track the seasonal changes in ambient with a delta T° that varies from 10°F to 20°F depending upon plant operations.

Thermal Plume Modeling

DCPP thermal plume characteristics were extensively studied using a physical hydraulic 1:75" scale model of the discharge and surrounding coastline (Babcock et al. 1987, Ryan et al. 1986, 1987a, 1987b, Weigel et al. 1975, 1976). A mathematical model was also used to describe the near- and far-field characteristics of the thermal plume (Tu et al. 1986, Tu 1989, Tu and Trent 1989). The following description of the thermal plume is a summary of the above reports, and includes the extensive field studies used to verify the physical and numerical models.

The DCPP discharge has momentum from its 85-ft drop in elevation to the shoreline and from there buoyancy from it's increased temperature. The thermal discharge plume, when entering the receiving water, pushes aside ambient water at a constant velocity expanding both laterally and vertically. In the shallow areas in front of the discharge the mean velocities and temperature levels decrease with distance from the discharge point, due to mixing with ambient water.

The rate of mixing in the receiving water depends on many factors, such as the shear stress between the plume and ambient water. Lateral mixing is limited, due to the semi-enclosed bay of Diablo Cove. Shallow areas of the cove limit vertical mixing. At some point along the plume's trajectory, the momentum is diluted to the extent that the upward force of buoyancy becomes dominant. At this point the plume will detach (or 'lift-off') from the bottom and become a surface phenomenon. The surface plume is subject to buoyant spreading that is an essential process in dissipating waste heat to the atmosphere. In general, the plume can be categorized into two regions in which different physical processes occur; (1) the near-field in Diablo Cove where the plume's inertia is the dominant force, and (2) the far-field beyond the cove where the buoyancy force dominates. Environmental factors such as winds, tides, waves and ambient current interact with each other and the plume dynamics resulting in various configurations of the DCPP thermal plume.

The immediate receiving water area in Diablo Cove is shallow with a typical water depth of less than approximately 10-ft MLLW over a distance of 450-ft from the outfall. The topography directly in front of the discharge consists of shallow water rock ridges at oblique angles to the plume's trajectory. These bottom features modify the direction and momentum of the discharge plume depending on tide level. During low tides, the rock ridges deflect the discharge plume northward towards Diablo Rock, resulting in a portion of the plume exiting Diablo Cove north of Diablo Rock (**Figure 2**). The north channel of the cove is shallower than the south channel. This, in combination with prevailing northwesterly winds and currents, slows any warm water exiting through the north channel of Diablo Cove. In contrast, during high tide the plume tends to pass over the near-field ridges without changing its direction and the plume exits Diablo Cove south of Diablo Rock (**Figure 3**). The topography in the area of the south channel is irregular, consisting of wash rocks originating from depths of up to 60-ft. The momentum of the discharge plume causes it to entrain cold bottom water and create a subsurface countercurrent into Diablo Cove through the south channel where the smooth topography of the bottom allows uninterrupted current flows into the cove. Thermal dilution, from cross flow of ambient water into the immediate discharge area, is influenced by the volume and velocity of the discharge flow into Diablo Cove. The greatest depth of the thermal plume in Diablo Cove varies between -16 and -36 feet MLLW. Maximum plume depths coincide with extreme low tides, high wave action, and strong winds. Minimum plume depths coincide with extreme high tides, low wave action, and calm winds. The plume is also affected by Diablo Rock, a small island at the mouth of the cove that obstructs the discharge plume. As the plume bifurcates around Diablo Rock, the plume downwells on the inshore side of the rock, and deeper ambient water upwells on the offshore side (**Figure 4**). Warm water eddies and countercurrents occur at the plume's boundary areas. As discharge velocities decrease, thermal buoyancy becomes dominant and causes the plume to lift-off the bottom to become a surface layer of warm water as it exits Diablo Cove.

In the offshore area, the shape and size of the plume are affected by winds and currents. T he winds and currents can vary rapidly in strength and direction, producing highly dynamic offshore plume dispersion patterns. Prevailing winds and currents from the northwest can deflect the offshore plume southward, or winds and currents from the south can move the offshore plume northward, and under certain situations towards Lion Rock and into Field's Cove.

Field studies of the thermal plume were done in 1984 during start-up testing of Unit 1, in 1985 during the start-up of Unit 2 (Leighton et al. 1986), during thermal verification studies in June 1986, and during NPDES plume surveys from 1986 to 1990. The results were analyzed as isotherms of excess plume temperature above ambient that were measured or simulated under a variety of oceanographic and power plant operating conditions. Comprehensive analyses of the behavior of the DCPP discharge plume are discussed with respect to various environmental factors in the near-field and far-field in Leighton et al. (1986) and Tu et al. (1986). Plume component descriptions include the surface and depth distribution of excess temperature, temperature dilution and decay, plume trajectories, velocity, currents, plume isotherms-buoyant spreading extent, and the geographic locations of shoreline and bottom detachment of the plume. Several other studies were done to estimate the dilution factor for the thermal discharge plume, which are described in Leighton (1988).

One of the studies used aerial infrared (IR) data to present excess surface temperatures as varying colored pixels. The tests used the plant's intake temperatures as the ambient values to compute excess temperatures. Seawater at the intake is withdrawn from a depth of -16 to -33 feet MLLW, and can be lower in temperature than surface water. The IR data of surface temperatures show that the intake temperature was approximately 2°F cooler than surface temperatures measured offshore using a towed bathythermograph (Leighton 1988). Therefore, the isotherms presented in **Figures 2** and **3** represent natural heating and the effect of the discharge plume (Leighton 1988). Data for two tests were collected while the plant was operating at 100 percent power for

Unit 1 and 70 percent power for Unit 2. Test TV-7 (**Figure 2**) was done on June 11, 1986 under mid-tide conditions and shows that, although warm water at the surface was diverted out the north channel, the central plume jet (warmest temperatures) was directed towards the south channel of the cove. The aerial IR representations of the plume only portray temperatures from a thin layer of surface water. They do not portray the three-dimensional dynamics of the plume that result from changes in its mass and momentum, as depicted in **Figure 4**. Test TV-9 (**Figure 3**) was done on June 12, 1986 at low tide and shows the central plume jet shifted towards the north. This test was also done in the morning under low wind conditions, which allowed the plume to spread out past Field's Cove towards Lion Rock to the north. The figure also depicts the effect of solar insolation that warms shallow shoreline areas during the day. The two surface plumes (**Figures 2** and **3**) represent summer conditions. Plume characteristics can be different under other seasonal conditions.

Plume data were also obtained using a towed electronic bathythermograph unit near the water's surface (<1 ft depth) combined with a microwave navigation system for positioning. Sea surface temperature profiles from 40 of the surveys from December 1985 through April 1990 were compiled into composite profiles to determine the extent of the plume under a variety of environmental and power plant conditions. The composite figures (**Figures 5** and **6**) present the frequency of occurrence for the 2°F and 4°F isotherms. Each frequency contour represents an envelope collectively derived from all plume measurements and does not represent the plume extent at any single time. Although, the composite figure shows the 2°F surface isotherm extending approximately 2 miles upcoast and 2 miles downcoast from DCPP, a condition that would never occur at the same time, the distance offshore ranged between 0.5-1.0 miles during 41-60% of the surveys. Tu et al. (1986) found that, in general, the surface area of the offshore plume (seaward of Diablo Rock) was largest (1500-2000 acres) when the tide level was ebbing towards mean sea level (+3 ft MLLW), and smallest (500-700 acres) during low tide conditions. During high tide conditions the plume covered an area of about 700-1200 acres.

Temperatures were and continue to be recorded at intertidal (+2 ft MLLW) and shallow subtidal (-10 and -15 ft MLLW) stations in Diablo Cove, Field's Cove, South Diablo Point, and at control stations as part of the RWMP (**Table 2**). The data from the temperature monitoring are reported each year as part of the RWMP program, and have been analyzed in more detail in Tenera (1997, 1998c, 1999b, 2002). The findings show that while the seawater temperatures at the point of discharge average from 10°F to 20°F above ambient depending upon plant operations, the temperatures in the receiving water tend to be considerably less due to mixing of the plume. The average delta T° values for various stations monitored as part of the RWMP are shown in **Figure 7**. The average delta T° for intertidal stations along the shoreline in north Diablo Cove has averaged approximately 6°F above ambient, while the average delta T° has been slightly less in south Diablo Cove. Temperature increases in Field's Cove to the north have averaged less than 2°F above ambient. The same general pattern holds for the subtidal stations. However, a station at the base of Diablo Rock (NDC-6), which is no longer included in the RWMP) has had the highest subtidal temperature recordings, due to the downwelling of the plume when it hits Diablo Rock.

6. Description of Biological Effects of Cooling System Discharge

The biological effects of the cooling system discharge have been extensively studied and documented both in RWMP annual reports to the CCRWQCB and in more detailed reports that included statistical analyses of the changes (PG&E 1988, Tenera 1997, 1998c, 1999b, 2002). The most current comprehensive data summary was presented in an analysis report that summarized changes in the marine environment through mid-year of 2002 (Tenera 2002). An updated comprehensive assessment of the monitoring program data is currently in preparation and will be completed in 2010. The report expands the second operational period (OpPeriod-2) data set from 1995-2002 to 1995-2008. Preliminary conclusions from the in-progress project are not substantially different from those in the earlier comprehensive assessment.

The Chapter 1 Analysis Report (Tenera 1997) included detailed statistical analyses of the changes in many of the over 800 taxa (species and species groups) identified during the RWMP studies. The statistical methods used in the analyses were the subject of an article in a peer-reviewed scientific journal (Steinbeck et al. 2005). Analyses were done to identify the most abundant taxa, and these were the taxa statistically analyzed for changes due to the thermal discharge. Many of the other taxa were observed infrequently, and therefore any discharge effects on them could not be statistically analyzed. The ability to detect changes statistically in the more commonly-occurring taxa was very high, due to the long periods of study before and during power plant operation. **Table 3** summarizes the results for the statistical analyses for the taxa analyzed from the different field tasks.

The spatial extent of the effects on biological communities from the thermal discharge varied depending on the species or habitat examined. In the intertidal zone, effects were observed throughout Diablo Cove, and extended north into Fields Cove, south onto South Diablo Point, and along the inshore side of Diablo Rock, a total shoreline distance of approximately 2.3 miles. The magnitude of the effects observed at the two areas outside Diablo Cove (South Diablo Point and Fields Cove) was much less than the effects within Diablo Cove. Intertidal areas further to the north and south had reduced frequency of plume contact, and therefore diminishing biological effects. Impacts were not evident at Seal Haulout located 0.4 miles to the south of Diablo Cove or at the North Control sites, located 1.4 miles north of Diablo Cove. Within the subtidal benthic habitat, most effects of the discharge were limited to the shallow (<22 ft) portions of Diablo Cove, a bottom area of approximately 20 acres.

In the surface waters the extent of the plume can be considerably greater, depending on wind and tide. The only surface-dwelling organisms included in the monitoring were the kelps that have surface canopies. The only noticeable effect was upon bull kelp *Nereocystis luetkeana*. Evidence of this effect, the withering of surface blades, was mapped by diver surveys, cliff-top observations, and boat surveys. During an unusually warm water period during the fall of 1987 combined with elevated temperatures from the discharge plume, the total area of bull kelp affected was 104.6 acres. Observations of bull kelp were made each year, and after 1987 the extent of effects were typically confined to an area of approximately 56 acres.

The timing and spatial extent of thermal discharge-related effects varied among taxa. Fish generally responded quickly to thermal changes in Diablo Cove by moving to preferred temperature regimes. Subsequent changes in fish abundances involved differences in recruitment success and species interactions within thermally contacted areas.

The timing of the declines in some of the abundant intertidal and subtidal perennial algal taxa was relatively consistent among stations in the thermal discharge area, whereas increases in limpets, sea urchin grazers, barnacles, and ephemeral algae were more variable over space and time. This variation was undoubtedly due to physical and biological factors that affected species occurrences, including habitat dissimilarities and spatial and temporal variation in local temperature regimes. Although variation can be expected in most natural populations, the TEMP studies have shown that the nature and magnitude of changes within impacted areas exceeded those in control areas.

The Chapter 1 Analysis Report (Tenera 1997) concluded that the DCPP thermal discharge had effects on many species within Diablo Cove and nearby areas, which resulted in communities that were still undergoing change. The community found within Diablo Cove now includes a number of species that are more commonly found in warmer waters further south, but remain uncommon along the coast outside Diablo Cove. In contrast, other species that remain common along the coast north and south of the power plant are now infrequent or absent within Diablo Cove. In the intertidal, algal cover has decreased while invertebrate abundance has increased. Bull kelp abundance has declined to level where it is largely absent in Diablo Cove. Effects of increased temperatures from the discharge have also resulted in changes in species composition and abundance of the seabed understory algae and invertebrates. In 1990, giant kelp in Diablo Cove increased, and canopy shading effects from giant kelp resulted in further changes in the understory in Diablo Cove. Numbers of fish taxa have increased in subtidal areas within Diablo Cove since power plant start-up.

In preparation for hearings in 2003 to consider modification and renewal of the DCPP NPDES permit, the CCRWQCB staff requested that PG&E prepare a report on the biological changes that may have occurred since 1995, the last data included in the Chapter 1 Analysis Report (Tenera 1997). The report (Tenera 2002) was similar to the Chapter 1 Analysis Report in using a statistical model to detect changes that had occurred since 1995. The report was prepared to describe any effects of the discharge that may have taken longer to manifest or were not detected in the previous report. The effects of the discharge were assessed by comparing data from three time periods: (1) a 'PreOp Period' before power plant start-up (January 1978 to December 1984), (2) 'OpPeriod-1' an eight year period after power plant start-up (1987 through April 1995), and (3) 'OpPeriod-2' a seven-year period of operation following OpPeriod-1 (May 1995 through June 2002). The comparisons between OpPeriod-1 and OpPeriod-2 formed the basis for categorizing the continuing effects of the DCPP discharge into the three general responses:

1. New discharge effects - species with no statistically significant effects in OpPeriod-1, but with significant differences between OpPeriod-1 and OpPeriod-2.
2. Continuing discharge effects - species with statistically significant effects in OpPeriod-1 and varying effects in OpPeriod-2.
3. No significant effects - species with no detectable effects in either period.

The initial effects of the DCPP discharge during OpPeriod-1 were described in the Chapter 1 Analysis Report (Tenera 1997). While 'new' discharge effects included both increases or decreases in OpPeriod-2, 'continuing' discharge effects included the three following categories of change:

1. Species that increased or decreased in OpPeriod-1 and continued increasing or decreasing in OpPeriod-2.
2. Species that increased or decreased in OpPeriod-1, and no changes were detected between OpPeriod-1 and OpPeriod-2.
3. Species with increases or decreases in OpPeriod-2 that offset or reversed changes previously detected in OpPeriod-1.

The relative abundances of most intertidal algae, invertebrates and fishes were unchanged between OpPeriod-1 and OpPeriod-2 at stations in Diablo Cove, Field's Cove and the two control areas. However, other species continued to increase or decrease over time in response to the cooling water discharge. Continued changes were expected based on the results from the Chapter 1 Analysis Report, and are typical of biological assemblages that are acclimating to disturbances. South Diablo Point was the one intertidal area sampled where new and continuing effects were most evident during OpPeriod-2. This was because the area had low or intermittent levels of exposure to the discharge plume, and changes to the biological community there occurred more slowly and over a longer time period than in Diablo Cove. Effects at South Diablo Point in OpPeriod-2 included statistically significant reductions of iridescent seaweed (*Mazzaella flaccida*), which is usually very common along the outer rocky shores and was abundant on South Diablo Point. Other effects included increases in mussels (*Mytilus californianus*) and purple sea urchins (*Strongylocentrotus purpuratus*).

Although few new effects of the discharge on Diablo Cove subtidal algal communities were detected in OpPeriod-2, there were continued changes in surface canopy and subcanopy kelps that affected associated algae, invertebrates and fishes. Giant kelp (*Macrocystis pyrifera*) increased throughout the cove during OpPeriod-2. Increased shading effects from the kelp canopy and grazing pressure from increased abundances of sea urchins (*Strongylocentrotus* spp.) caused a reduction in the foliose red algae that grow on rocks beneath the kelp canopy. Subcanopy tree kelps, that had decreased in OpPeriod-1 at the shallower -10 feet MLLW depth stations, declined in OpPeriod-2 at the deeper stations. These changes in kelp and understory algal communities contributed to some of the new and continuing effects detected in subtidal invertebrates. For example, reductions in understory algal cover probably facilitated the increased settlement of sand tube worms (*Phragmatopoma californica*) at the shallow stations. The overall abundance of fishes in Diablo Cove did not change in OpPeriod-2 after an initial increase in OpPeriod-1, although the increased abundances of some midwater fishes may have been associated with the algal canopy changes in Diablo Cove. There were no observed effects of the discharge on algae, invertebrates, or fishes at the -10 feet MLLW subtidal station in Field's Cove.

7. Mitigation Measures for Reducing Adverse Effects of Cooling System Discharge

The results of the 2002 Report (Tenera 2002) showing; "that since 1995, there have been minor additional biological changes in Diablo Cove and no additional biological changes in Field's Cove. The minor additional changes in Diablo Cove were within the areas previously recognized as being impacted", was one of the reasons that the CCRWQCB staff recommended adoption of the DCPP NPDES permit by the Regional Board in the July 2003 hearing. As part of the preparation for the hearing, the staff also evaluated design and operational changes that could be used to reduce thermal discharge impacts, but determined that any changes would either be ineffective or infeasible. Board staff also recognized that the primary issue of disagreement between the CCRWQCB and PG&E with respect to thermal effects was the incremental increase in the spatial area of impacts between the predicted area presented in the Thermal Discharge Assessment Report (PG&E 1982b) and the actual larger impact area that had been detected. The staff recognized that some degradation of marine habitat was allowed based on the 1982 NPDES Permit (CCRWQCB 1982). From this, CCRWQCB staff and PG&E agreed upon another approach to protect beneficial uses that focused on permanent preservation of coastal habitat, including the same type of intertidal and shallow subtidal habitat affected by the thermal discharge.

To resolve the issue of the incremental thermal effects above predicted impacts, (*and also resolve issues regarding entrainment larval losses from cooling water intake system operation*), the CCRWQCB staff and PG&E negotiated a settlement based primarily on marine habitat conservation. The CCRWQCB and PG&E announced a tentative agreement in June 2000, following submittal of the entrainment study results and the evidentiary hearing regarding thermal effects. The general terms of this settlement were presented in 2000 when the Regional Board considered written and oral public comments and directed legal counsel to negotiate a consent judgment and conservation easement incorporating the basic settlement terms.

At a March 2003 meeting, the CCRWQCB considered public comments and approved the draft consent judgment to form a conservation easement negotiated with legal counsel. The agreement was intended to resolve all issues regarding the thermal discharge for DCPP over its operating life (*and also resolve any issues regarding entrainment/impingement over the power plant operating life*). This was subject to compliance with thermal effluent limitations, and included the following components:

1. PG&E would grant a conservation easement to preserve forever specified land between Fields Cove and Coon Creek comprising 2,013 acres of watershed draining to approximately 5.7 miles of coastline.
2. PG&E would fund a $200,000 endowment to fund the Land Conservancy of SLO for easement stewardship costs.
3. PG&E would provide $4.05 million for projects to directly improve permanent preservation, restoration, enhancement, monitoring and research of marine life, habitat and water quality in coastal waters of San Luis Obispo County, California or on projects in coastal waters outside San Luis Obispo County to preserve, protect, restore, monitor or research marine life relating to the effects of the DCPP's cooling water system.
4. PG&E would make its laboratory facilities available for ten years for marine research to educational organizations and for fisheries related activities, providing $100,000 in initial operating money, as well as up to $5,000 annually for water and electricity during this period.
5. PG&E would contribute $350,000 to the California Department of Fish and Game for its abalone restoration project.
6. DCPP receiving water monitoring would be changed to consist of participating in the Central Coast Ambient Monitoring Program ($150,000 per year over the next ten years).

As discussed in Section 3 of this report, the draft NPDES permit that incorporated the settlement agreement was not adopted at the July 10, 2003 hearing. The settlement agreement included components that directly compensated for the effects of the thermal discharge, but testimony was provided that the settlement did not fully compensate for the potential effects of intake entrainment. As a result, the Regional Board directed staff and their consultants of the Technical Workgroup (TWG) to consider additional mitigation options that would more directly compensate for cooling water intake system entrainment effects. The CCRWQCB consultants of the TWG prepared a report on additional mitigation options that was presented at the CCRWQCB meeting on September 9, 2005 (Raimondi et al. 2005). The options in the report primarily focused on addressing the effects of entrainment. While the intent of the original settlement agreement was to provide compensation for the environmental effects of both the thermal discharge and cooling water intake system operations, the major points of disagreement between the CCRWQCB staff and PG&E focused on entrainment, delaying any resolution of the outstanding thermal discharge effects issue, and issuance of a modified NPDES permit. Further delays to the resolution of outstanding issues regarding the environmental effects of the DCPP once-through cooling system are anticipated due to uncertainty of California State and Federal EPA regulations involving implementation of 316(b) Phase II Rules for existing facilities (facilities with cooling system source water withdrawal volumes of 50 million gallons per day [mgd] or greater).

8. Conclusions – Impacts on Fish and Shellfish Resources Resulting From Heat Shock (Thermal Discharge) During a Period of Extended Operation

The physical characteristics and biological effects of the DCPP thermal discharge have been extensively studied beginning in the mid-1960s when the area was first considered as a power plant site, as documented by the extensive list of published reports **(Attachment 1)**. During plant operations in the initial license period, actual effects of the thermal discharge were found to be only slightly greater in spatial extent than predicted, but are largely confined to the shoreline and shallow areas of Diablo Cove. The most recent detailed analysis of the effects of the thermal discharge (Tenera 2002) showed that the nature and spatial extent of the effects have not increased since the previous assessment detailing changes through 1995 (Tenera 1997). In general, pre-operational assessments have been confirmed by actual plant operations, and thermal discharge impacts are not significantly changing overtime as a result of continued plant operations.

Continued monitoring of the marine environment influenced by the power plant discharge is anticipated to support previous conclusions regarding thermal impacts. Once-through cooling system thermal effects are not significantly changing or increasing, and protection of the beneficial uses of the receiving water will continue in a period of extended operation.

Therefore, heat shock (thermal discharge) impacts to fish and shellfish resources from operation of the once-through cooling system during the period of extended operation, relative to the determinations of thermal discharge impacts during the initial operating license period, are projected to be SMALL.

TABLE 1

REPRESENTATIVE IMPORTANT SPECIES (RIS) LIST FROM DIABLO CANYON POWER PLANT 316(a) DEMONSTRATION STUDY PLAN

Habitat-Formers	Shellfish and Invertebrates		Fishes
<u>**Intertidal Habitat**</u> **Un-named red seaweed** (*Chondracanthus canaliculatus*, formerly *Gigartina canaliculata*) **Hollow-branched seaweed** (*Gastroclonium subarticulatum*, formerly *G. coulteri*) **Iridescent seaweed** (*Mazzella flaccida*, formerly *Iridaea flaccida*) **Feather-boa kelp** (*Egregia menziesii*) <u>**Subtidal Habitat**</u> **Oar-blade kelp** (*Laminaria dentigera*) **Bull kelp** (*Nereocystis luetkeana*) **Tree kelp** (*Pterygophora californica*)	<u>**Intertidal Habitat**</u> **Aggregating sea anemone** (*Anthopleura elegantissima*) **Black abalone** (*Haliotis cracherodii*) **Ochre starfish** (*Pisaster ochraceus*) <u>**Subtidal Habitat**</u> **Red Abalone** (*Haliotis rufescens*) **Brown turban snail** (*Chlorostoma brunnea*, formerly *Tegula brunnea*) **Red sea urchin** (*Strongylocentrotus franciscanus*)	**Purple sea urchin** (*Strongylocentrotus purpuratus*) **Sun stars** (*Pycnopodia helianthoides*) **Rock crab** (*Cancer antennarius*) **Kelp crab** (*Pugettia producta*)	<u>**Intertidal Habitat**</u> **Rock Prickleback** (*Xiphister mucosus*) <u>**Subtidal Habitat**</u> **Blue rockfish** (*Sebastes mystinus*) **Gopher rockfish** (*Sebastes carnatus*) **Cabezon** (*Scorpaenichthys marmoratus*)

TABLE 2

DCPP RECEIVING WATER MONITORING PROGRAM (RWMP) TASKS, STATIONS, AND FREQUENCY OF SURVEYS

Task and Sampling Frequency	Stations
Temperature Monitoring (continuous measurements every 20 min)	
Intertidal	Fourteen Stations – NC 2, FC 1, FC 2, FC 3, NDC 1, NDC 2, NDC 3, SDC 1, SDC 2, SDC 3, SDP 1, SDP 2, SC 1, and SC 1-V
Subtidal	Nine Stations – NC 1, FC 1, NDC 2, NDC 3, NDC 4, SDC 1, SDC 4, SC 1, and SC 2
Intertidal Horizontal Band Transects (algae, seagrasses, invertebrates, substrate)	
4 surveys per year	Fourteen Stations – NC 1, NC 2, FC 1, FC 2, FC 3, NDC 1, NDC 2, NDC 3, SDC 1, SDC 2, SDC 3, SDP 1, SDP 2, and SC 1
Intertidal Vertical Band Transects (fishes)	
4 surveys per year	Five Stations – NC-1V, FC-1V, NDC-1V, SDC-2V, and SC-1V
Subtidal Benthic Stations (algae, invertebrates, substrate)	
4 surveys per year	Eight Stations – FC 1, NDC 2, NDC 3, NDC 4, SDC 2, SDC 3, SC 1, and SC 2
Subtidal Fish Observations (fishes)	
4 surveys per year	Twelve Stations – FC FO-1, FC FO-2, FC FO-3, NDC FO-1, NDC FO-2, NDC FO-3, SDC FO-1, SDC FO-2, SDC FO-3; SC FO-1, SC FO-2, and SC FO-3
Habitat-Forming Kelp Survey (bull kelp, giant kelp)	
1 survey per year	Diablo Cove

TABLE 3

SUMMARY OF RESULTS OF STATISTICAL ANALYSIS OF CHANGES DUE TO THE THERMAL DISCHARGE IN BIOLOGICAL TAXA GROUPS PRESENTED IN THE 1997 ANALYSIS REPORT (TENERA 1997)

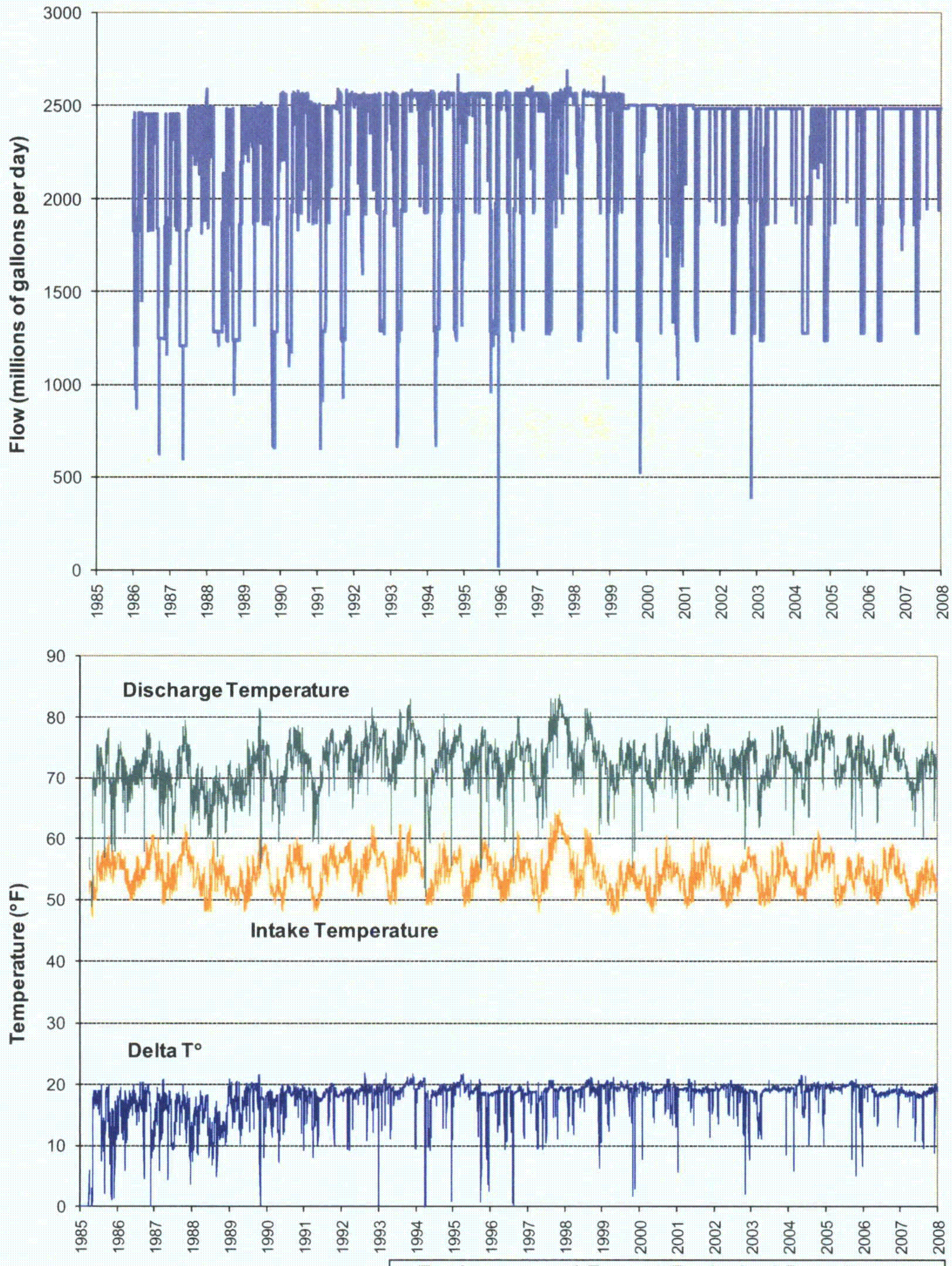
Taxa Groups	Data Sets*	Analyzed	Increases	Decreases	No Change	Not Conclusive
Algae						
Intertidal	119	38	7	26	2	3
Subtidal	109	39	14	11	2	12
Invertebrates						
Intertidal [1]	248	39	16	16	4	3
Intertidal [2]	314	100	22	36	6	36
Subtidal	238	106	28	32	14	32
Fish	96	48	13	12	8	15

* - includes both taxa groups and summary statistics (e.g., number of species, total algal cover)

[1] - invertebrates from intertidal band transect study

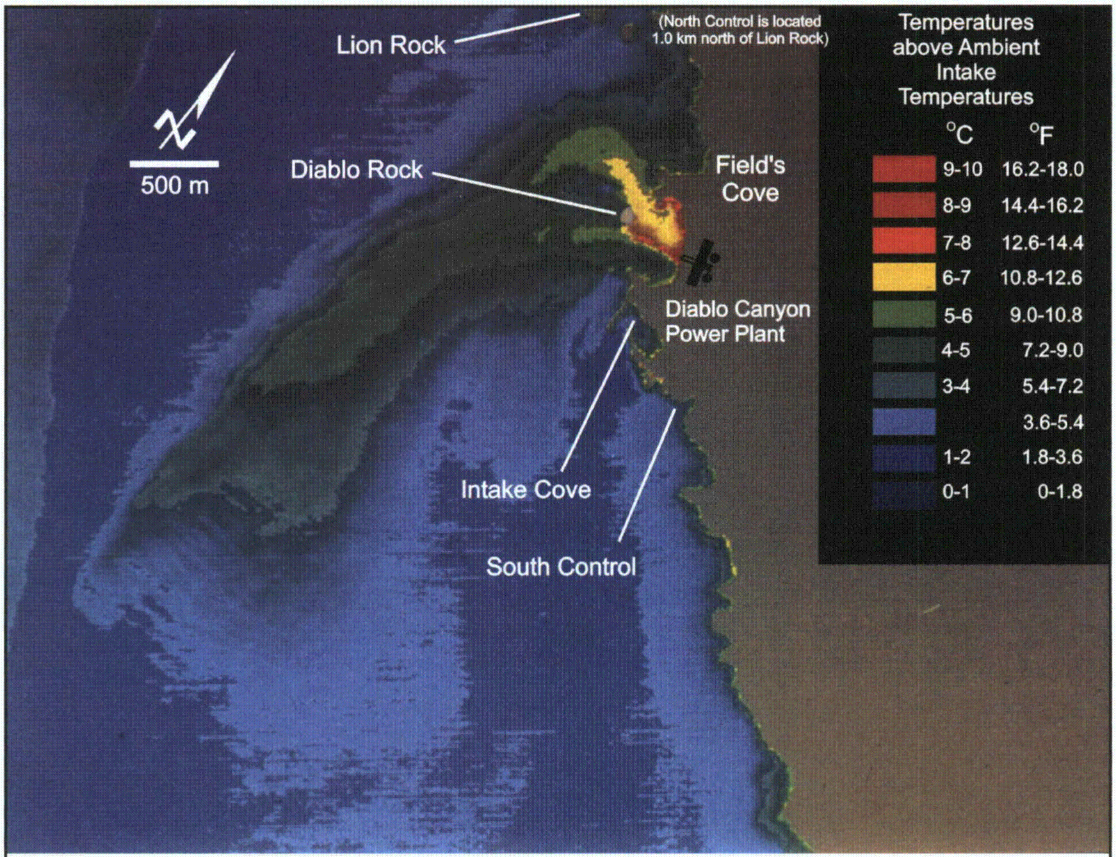
[2] - invertebrates from intertidal algal-faunal study

10. Figures



Environmental Report Technical Data Report
Diablo Canyon Power Plant

Figure 1
Cooling Water Flow, Intake and Discharge Temperatures, and Delta T° Values for the Diablo Canyon Power Plant



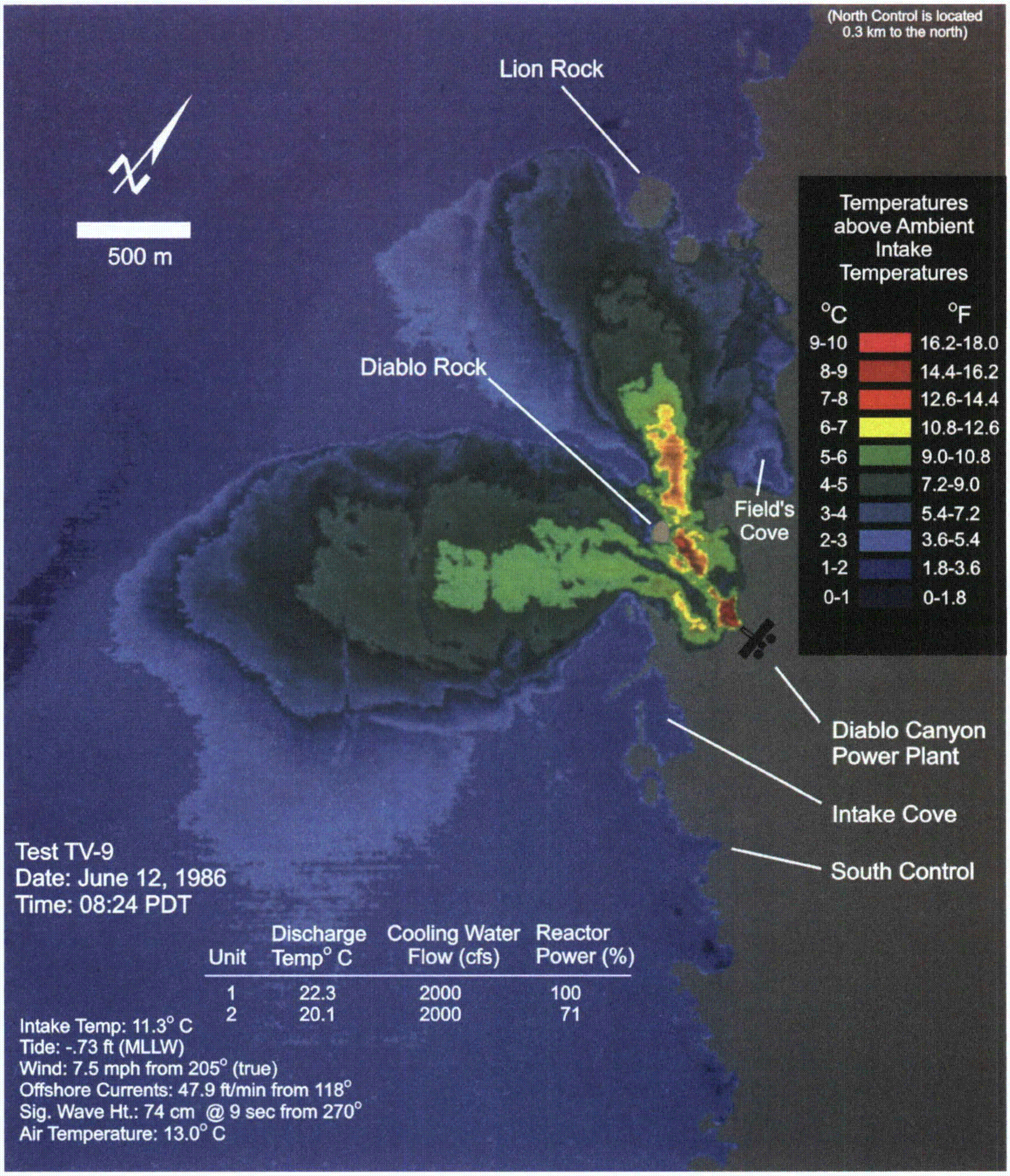
Test TV-7
Date: June 11, 1986
Time: 18:20 PDT

Unit	Discharge Temp° C	Cooling Water Flow (cfs)	Reactor Power (%)
1	21.4	2000	100
2	19.5	2000	70

Intake Temp: 10.9° C
Tide: 2.8 ft (MLLW)
Wind: 17.5 mph from 313° (true)
Offshore Currents: 19.4 ft/min. from 135°
Sig. Wave Ht.: 92 cm @ 11 sec from 270°
Air Temperature: 15.5° C

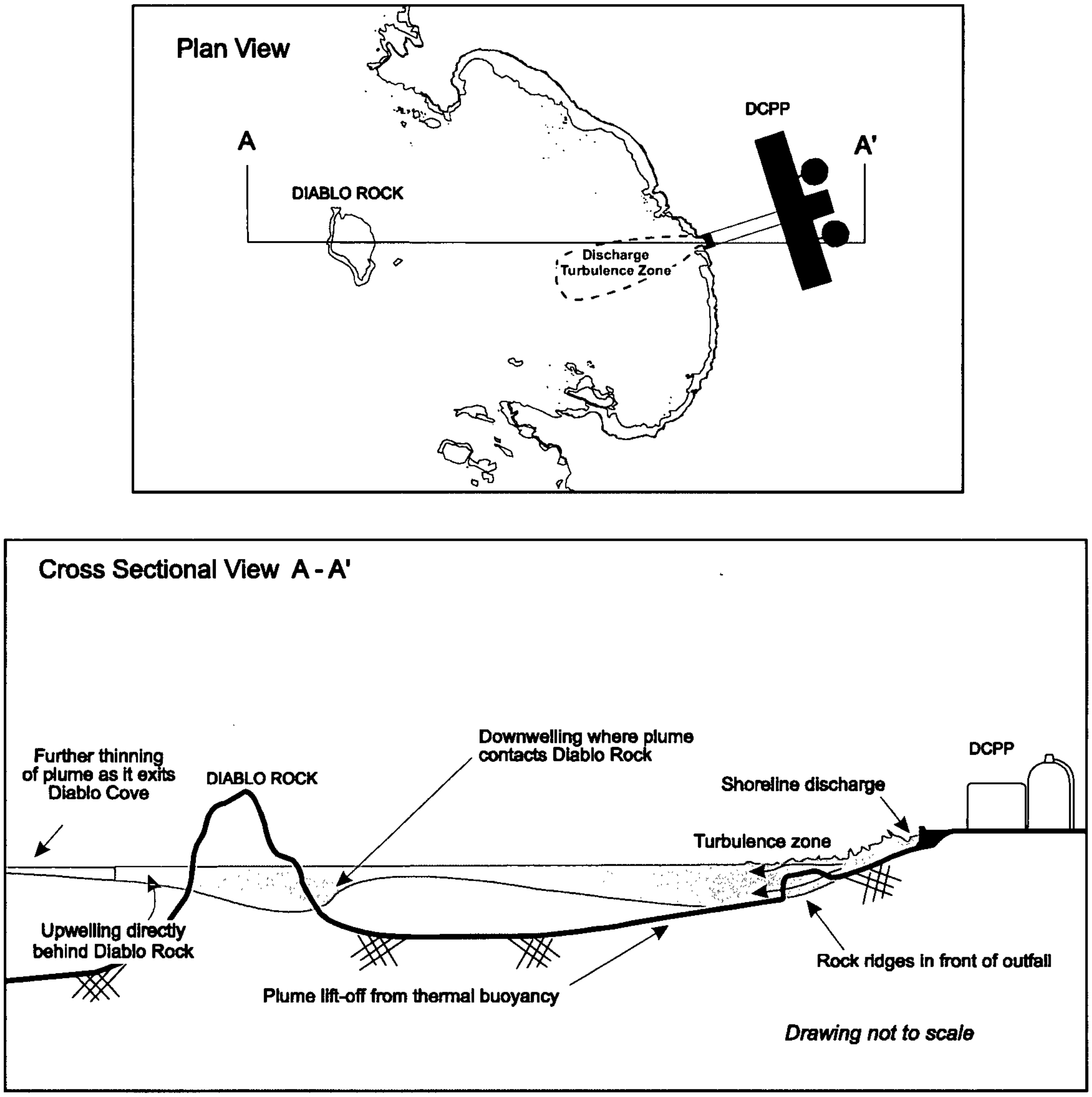
Environmental Report Technical Data Report
Diablo Canyon Power Plant

Figure 2
Surface Infra-Red Aerial Survey of DCPP Thermal Plume on June 11, 1986 During Mid-Level Tide Conditions



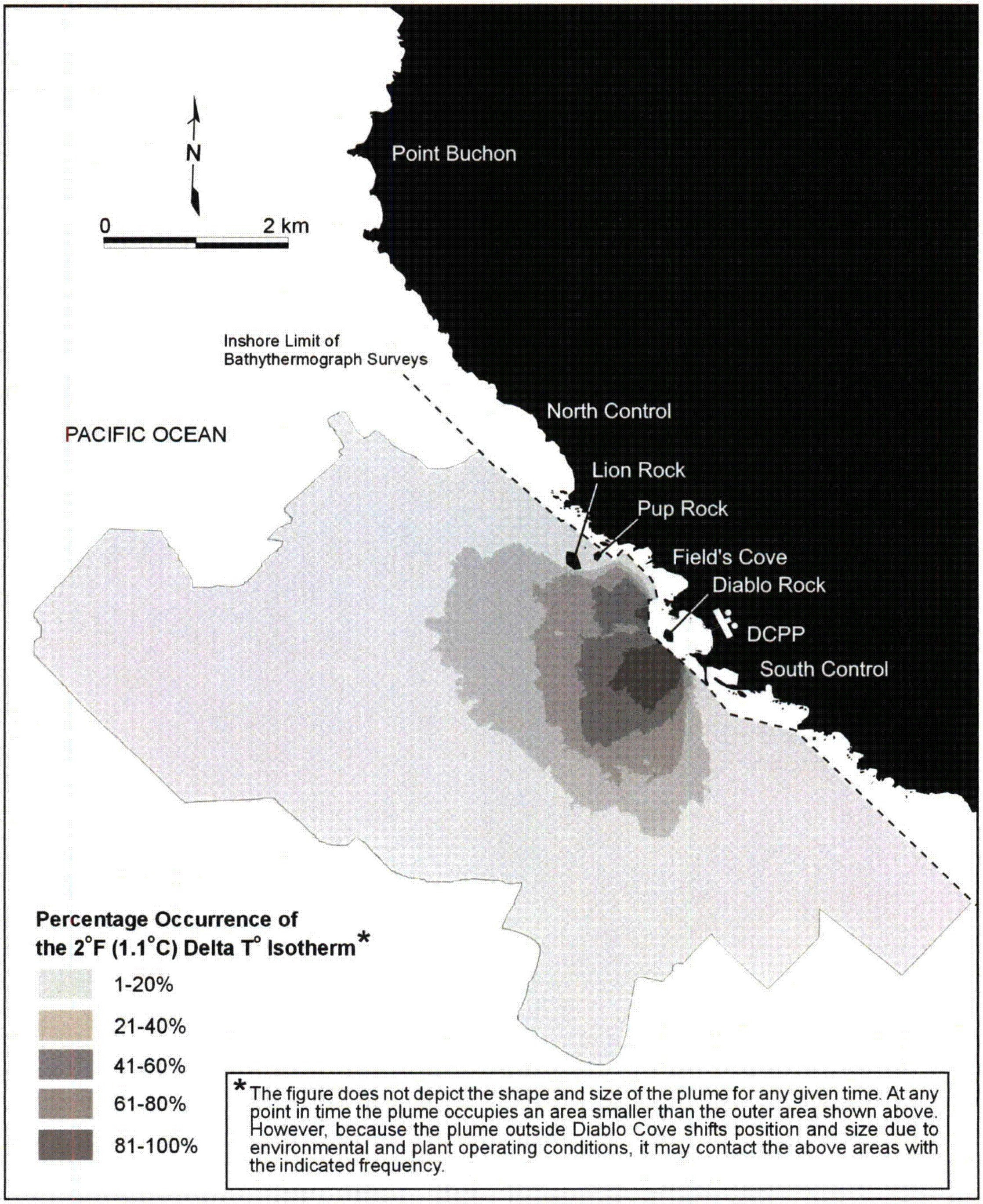
Environmental Report Technical Data Report
Diablo Canyon Power Plant

Figure 3
Surface Infra-Red Aerial Survey of DCPP Thermal Plume on June 12, 1986 During Low Tide Conditions



Environmental Report Technical Data Report
Diablo Canyon Power Plant

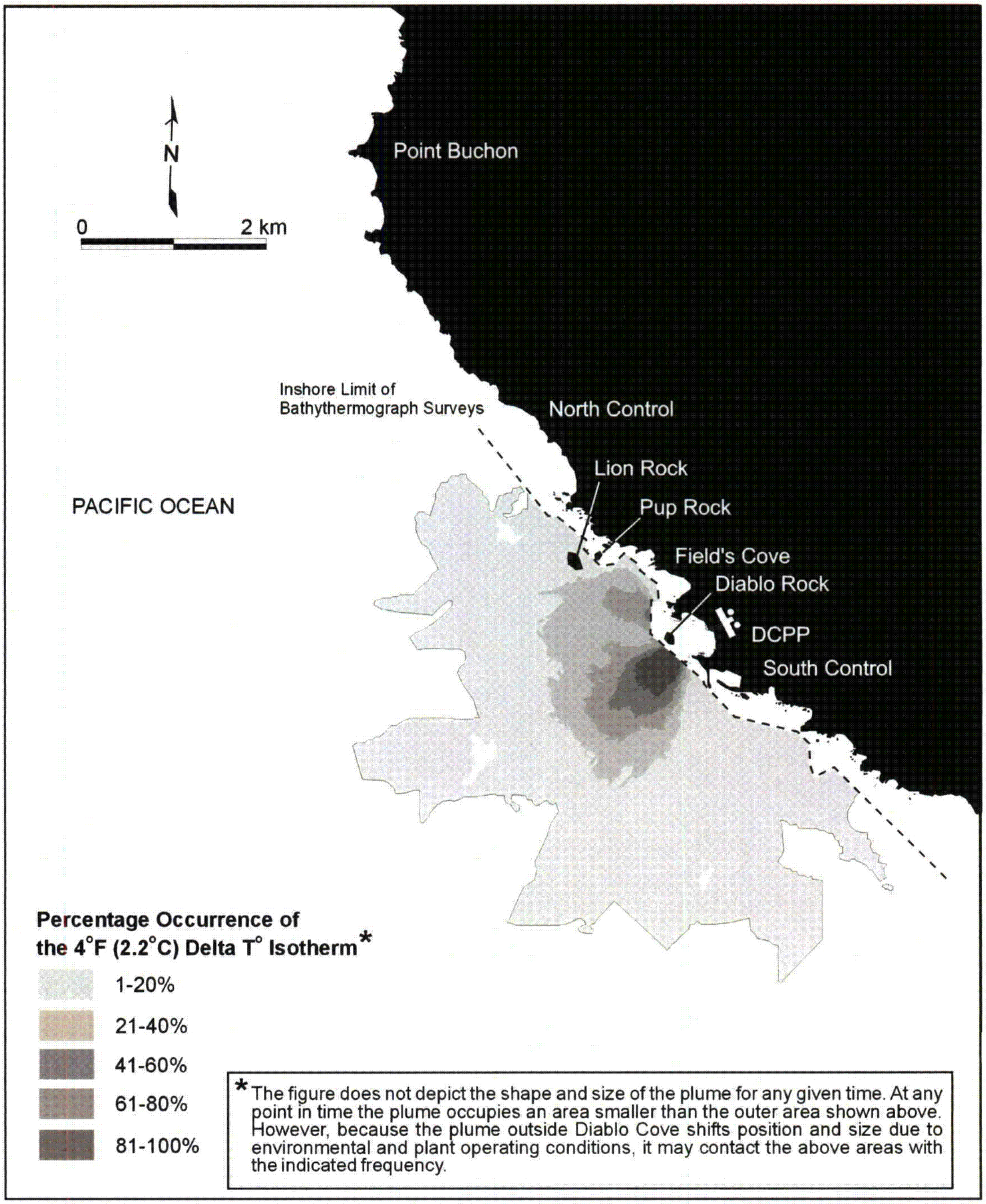
Figure 4
Conceptual Diagram of a Cross-Sectional View of the Diablo Canyon Power Plant Thermal Plume in Diablo Cove



*The figure does not depict the shape and size of the plume for any given time. At any point in time the plume occupies an area smaller than the outer area shown above. However, because the plume outside Diablo Cove shifts position and size due to environmental and plant operating conditions, it may contact the above areas with the indicated frequency.

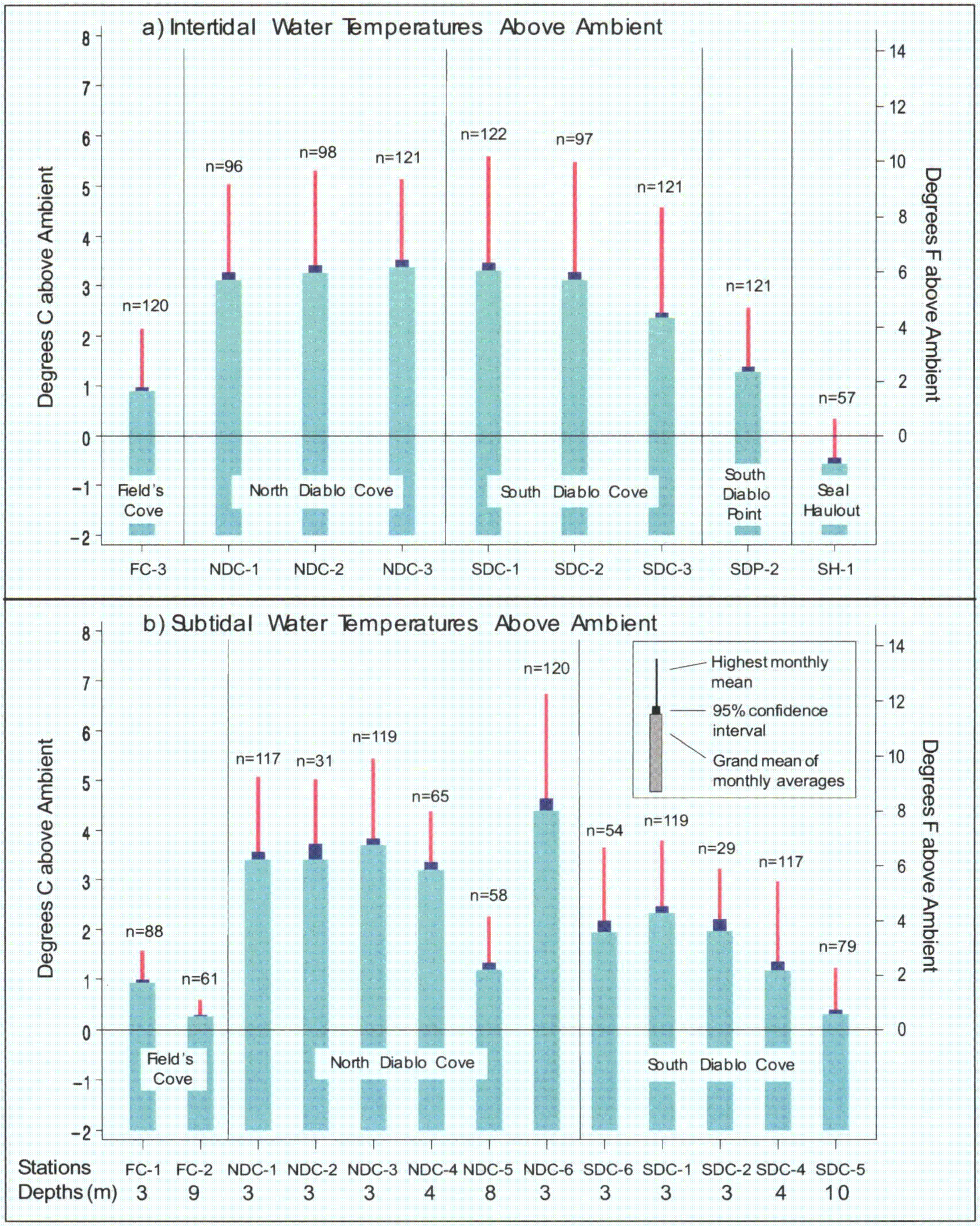
Environmental Report Technical Data Report
Diablo Canyon Power Plant

Figure 5
Percentage Occurrence for 2°F Isotherm for the Diablo Canyon Power Plant Thermal Plume



Environmental Report Technical Data Report
Diablo Canyon Power Plant

Figure 6
Percentage Occurrence for 4°F Isotherm for the Diablo Canyon Power Plant Thermal Plume



Environmental Report Technical Data Report
Diablo Canyon Power Plant

Figure 7
Average Receiving Water Temperatures Above Ambient for a) Intertidal, and b) Subtidal Stations for Period of May 1985 thru June 1995

11. References

1. AEC Directorate of Licensing (AEC). 1973. Final Environmental Statement related to the Nuclear Generating Station Diablo Canyon Units 1 & 2. Docket Nos. 50-275 and 50-323.

2. Altstatt, J. M., R. F. Ambrose, J. M. Engle, P. L. Haaker, K. D. Lafferty, and P. T. Raimondi. 1996. Recent declines of black abalone, Haliotis cracherodii, on the mainland coast of central California. Marine Ecology Progress Series 142:185-192.

3. Babcock, J. D., P. J. Ryan, S. W. Tu, and V. Wyman. 1987. Hydraulic model study quality assurance requirements. Diablo Canyon Power Plant. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420-DC-87.17. May 1987.

4. Burge, R. T. and S. A. Schultz. 1973. The marine environment in the vicinity of Diablo Cove with special reference to abalone and bony fishes. Calif. Dept. Fish Game, Mar. Res. Tech. Rpt. No. 19.

5. Central Coast Regional Water Quality Control Board (CCRWQCB). 1969. Waste Discharge Requirements for Pacific Gas & Electric Co., Diablo Canyon Power Plant, adopted October 17, 1969.

6. Central Coast Regional Water Quality Control Board (CCRWQCB). 1974. Diablo Canyon Power Plant NPDES Permit, CA 0003751; Order No. 74-41, October 1974.

7. Central Coast Regional Water Quality Control Board (CCRWQCB). 1976. Diablo Canyon Power Plant NPDES Permit, CA 0003751; Order No. 76-11, July 1976.

8. Central Coast Regional Water Quality Control Board (CCRWQCB). 1982. Diablo Canyon Power Plant NPDES Permit, CA 0003751; Order No. 82-24, January 1982.

9. Central Coast Regional Water Quality Control Board (CCRWQCB). 1985. Diablo Canyon Power Plant NPDES Permit, CA 0003751; Order No. 85-101, August 1985.

10. Central Coast Regional Water Quality Control Board (CCRWQCB). 1990. Diablo Canyon Power Plant NPDES Permit, CA 0003751; Order No. 90-09, May 1990.

11. Central Coast Regional Water Quality Control Board (CCRWQCB). 2003a. Draft Permit for Diablo Canyon Power Plant NPDES Permit, CA 0003751; Order No. RB3-2003-0009, July 2003.

12. Central Coast Regional Water Quality Control Board (CCRWQCB). 2003b. Staff Testimony for Regular Meeting of July 10, 2003 Pacific Gas and Electric Company's (PG&E's) Diablo Canyon Power Plant Renewal of NPDES Permit. Prepared on June 6, 2003.

13. Gardner, G. R., J. C. Harshbarger, J. L. Lake, T. K. Sawyer, K. L. Price, M. D. Stephenson, P. L. Haaker, and H. A. Togstad. 1995. Association of prokaryotes with symptomatic appearance of withering syndrome in black abalone *Haliotis cracherodii*. Journal of Invertebrate Pathology 66:111-120.

14. Gotshall, D. W., L. L. Laurent, S. L. Owen, J. Grant, and P. Law. 1984. A quantitative ecological study of selected nearshore marine plants and animals at the Diablo Canyon Power Plant site: a pre-operational baseline: 1973-1978. Calif. Dept. Fish Game, Mar. Res. Tech. Rep. No. 48.

15. Gotshall D. W., J. R. R. Ally, D. L. Vaughn, B. B. Hatfield, and P. Law. 1986. Pre-operational baseline studies of selected nearshore marine biota at the Diablo Canyon Power Plant site: 1979-1982. Calif. Dept. Fish Game, Mar. Res. Tech. Rep. No. 50.

16. Haaker, P. L., D. O. Parker, H. Togstad, D. V. Richards, G. E. Davis, and C. S. Friedman. 1992. Mass mortality and withering syndrome in black abalone, Haliotis cracherodii, in California. In: S.A. Shepherd, M.J. Tegner, and S.A. Guzman del Proo (eds.). Abalone of the world: biology, fisheries and culture. Blackwell Scientific Publications Ltd., Oxford. p. 214-224.

17. Leighton, J. P., S. W. Tu, A. A. Petroccitto and L. K. Eastman. 1986. Characterization of receiving water temperatures during power ascension testing of Unit 1, Diablo Canyon Power Plant. Department of Engineering Research, Report No. 420-85.748, Pacific Gas and Electric Company, San Ramon, CA.

18. Leighton, J. P. 1988. Estimation of the dilution factor for the Diablo Canyon Power Plant thermal discharge plume. Technical and Ecological Services, Report No. 028.282-88.2, Pacific Gas and Electric Company, San Ramon, CA.

19. NRC Office of Nuclear Reactor Regulation (NRC). 1976. Addendum to the Final Environmental Statement for the Operation of the Diablo Canyon Nuclear Plant Units 1 and 2. Docket Nos. 50-275 and 50-323.

20. Pacific Gas & Electric Co. (PG&E). 1972. Environmental Report, Units 1 and 2 Diablo Canyon, Environmental Report Supplement No. 2. San Francisco, CA.

21. Pacific Gas & Electric Co. (PG&E). 1975. 316(a) Demonstration Work Plan, Pacific Gas and Electric Company, Diablo Canyon Power Plant. Prepared by TERA Corp., Berkeley, CA. for Pacific Gas & Electric Co., San Francisco, CA.

22. Pacific Gas & Electric Co. (PG&E). 1982a. Diablo Canyon Power Plant. Assessment of alternatives to the existing cooling water system. Pacific Gas & Electric Co., San Francisco, CA.

23. Pacific Gas & Electric Co. (PG&E). 1982b. Diablo Canyon Power Plant. Thermal discharge assessment. Prepared by TERA Corp., Berkeley, CA for Pacific Gas & Electric Co., San Francisco, CA.

24. Pacific Gas & Electric Co. (PG&E). 1982c. Compendium of Thermal Effects Laboratory Studies Volumes 1, 2, and 3. Diablo Canyon Power Plant. Prepared by TERA Corp., Berkeley, CA for Pacific Gas & Electric Co., San Francisco, CA.

25. Pacific Gas & Electric Co. (PG&E). 1988. Thermal Effects Monitoring Program: Final Report. Pacific Gas and Electric Company, San Francisco, CA.

26. Pacific Gas & Electric Co. (PG&E). 2005. PG&E Comments on Independent Scientists' Draft Recommendations. PG&E Letter DCL-2005-527. Pacific Gas & Electric Co., San Francisco, CA.

27. Raimondi, P. 2003. Cooling Water System Findings Regarding Clean Water Act Section 316(b) Diablo Canyon Power Plant NPDES Permit Order RB3-2003-0009. Testimony submitted to CCRWQCB for July 10, 2003 CCRWQCB hearing.

28. Raimondi, P., G. Cailliet, and M. Foster. 2005. Diablo Canyon Power Plant Independent Scientist's Recommendations to the Regional Board Regarding Mitigation for Cooling Water Impacts. Submitted to CCRWQCB.

29. Ryan, P. J., S. W. Tu, J. P. Leighton, and R. L. Wiegel. 1986. Hydraulic model verification tests for unit 1 Diablo Canyon Power Plant. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420-86.557. November 1986.

30. Ryan, P. J., N. Ismail, R. C. H. Lou, S. W. Tu, and R. L. Wiegel. 1987a. Hydraulic model verification tests for units 1 and 2 Diablo Canyon Power Plant. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420-DC-87.15. April. 1987.

31. Ryan, P. J., N. Ismail, R. C. H. Lou, S. W. Tu, and R. L. Wiegel. 1987b. Hydraulic model verification tests for Units 1 and 2, Diablo Canyon Power Plant. Tech. Rpt. HEL 27-17, HEL, UCB.

32. California State Water Resources Control Board (SWRCB). 1983. Order No. 83-1, March 17, 1983

33. Steinbeck, J. R., J. M. Groff, C. S. Friedman, T. McDowell, and R. P. Hedrick. 1992. Investigations into a mortality among populations of the central California black abalone. In: S.A. Shepherd, M.J. Tegner, and S.A. Guzman del Proo (eds.). Abalone of the world: biology, fisheries and culture. Blackwell Scientific Publications Ltd., Oxford. p. 203-213.

34. Steinbeck, J. R., D. R. Schiel, and M. S. Foster. 2005. Detecting long-term change in complex communities: a case study from the rocky intertidal zone. Ecological Applications 15:1813-1832.

35. Tenera Inc. (Tenera). 1997. Diablo Canyon Power Plant Thermal Effects Monitoring Program Analysis Report. Chapter 1. Changes in the marine environment resulting from the Diablo Canyon Power Plant thermal discharge. Prepared for Pacific Gas and Electric Company, San Francisco, CA.

36. Tenera Inc. (Tenera). 1998a. Diablo Canyon Power Plant Thermal Effects Monitoring Program Analysis Report. Chapter 2 - Assessment of Thermal Effects. Prepared for Pacific Gas & Electric, San Francisco, CA.

37. Tenera Inc. (Tenera). 1998b. Surfgrass (*Phyllospadix*) in the Vicinity of the Diablo Canyon Power Plant Discharge. E7-225.4. Prepared for Pacific Gas and Electric Company, San Francisco, CA.

38. Tenera Inc. (Tenera). 1998c. Diablo Canyon Power Plant. Receiving Water Monitoring Program. 1995-1997 Progress Report. Prepared for Pacific Gas and Electric Company, San Francisco, CA.

39. Tenera Inc. (Tenera). 1999a. Effects of the DCPP discharge on surface canopy kelps as determined by analysis of aerial photographs. Prepared for Pacific Gas and Electric Company, San Francisco, CA.

40. Tenera Inc. (Tenera). 1999b. Diablo Canyon Power Plant Receiving Water Monitoring Program: 1995-1998 Progress Report. Prepared for Pacific Gas & Electric Company, San Francisco, CA.

41. Tenera Environmental, Inc. (Tenera). 2000. Diablo Canyon Power Plant Receiving Water Monitoring Program Effects of Water Temperature on the Distribution and Abundance of Intertidal Organisms in Field's Cove. Prepared for Pacific Gas & Electric Company, San Francisco, CA.

42. Tenera Environmental, Inc. (Tenera). 2002. Diablo Canyon Power Plant Receiving Water Monitoring Program: 1995 - 2002 Analysis Report. Prepared for Pacific Gas & Electric Company, San Francisco, CA.

43. Tissot, B. N. 1988. Mass mortality of black abalone in southern California. American Zoologist 28:69 (abstract).

44. Tu, S. W. 1989. Numerical model simulation of Diablo Canyon Power Plant far-field thermal plume. Pacific Gas and Electric Company, San Ramon, CA. Report 420-DC-89.441. August 1989.

45. Tu, S. W. and D. S. Trent. 1989. Verification of Diablo Canyon Power Plant far-field thermal plume numerical model. Pacific Gas and Electric Company, San Ramon, CA. Report 420-DC-89.303. August 1989.

46. Tu, S. W., J. P. Leighton, C. O. White, and C. C. Hsu. 1986. Surface buoyant jet characteristics of the thermal discharge plume at Diablo Canyon Power Plant. A field study of power ascention testing of unit 2 and full load operation of unit 1. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420-86.475. November 1986.

47. Wiegel, R. L., V. W. Harms, B. Safaie, R. P. Della, and C. B. Leidersdorf. 1975. A preliminary report on model study of cooling water system of Pacific Gas and Electric Company Power Plant located at Diablo Canyon, California. Hydraulic Engineering Lab., University of California at Berkeley; also PG&E docket no. 50-275-02 and 50-323-02, Supplement no. 7.

48. Wiegel, R. L., V. W. Harms, B. Safaie, J. D. Cumming, R. P. Della, C. B. Leidersdorf, and C. Young. 1976. Report on model study of cooling water system of Pacific Gas and Electric Company Nuclear Power Plant at Diablo Canyon, California. Report no. HEL 27-2, Hydraulic Engineering Lab., University of California at Berkeley, California.

Reports are arranged by subject or conducting organization. Status reports of some studies were prepared on a quarterly basis, with the results compiled in final or annual reports. The list of status reports is too exhaustive for this Appendix. However, some status reports are presented as individual chapters in the series of PG&E reports titled Environmental Investigations at Diablo Canyon (Section A.11). Also, some individual reports that are in sections preceding Section A.11 are included as chapters in Environmental Investigations at Diablo Canyon.

Thermal Effects Monitoring Program Reports

Thermal Effects Monitoring Program (TEMP) reports consist of a series of reports that describe results of one program whose name changed several times over the course of study. The TEMP studies consist of intertidal and subtidal algal, invertebrate, fish, water temperature, and underwater light transmittance for various locations near the power plant. Synonymous names of the TEMP are 316(a) demonstration, Marine Environmental Monitoring Program (MEMP), Ecological Monitoring Program (EMP), and Receiving Water Monitoring Program (RWMP). Changes in the scope-of-work resulted in the various program name changes, as well as the reports differing in content. The program name most commonly used to refer to the collective studies is the TEMP. The principal conducting organization is Tenera Environmental Services, San Francisco, CA (formerly TERA Corp.) who developed the original study elements of the program. All reports below were submitted to the Regional Water Quality Control Board, as part of the plant's NPDES permit and requests from the Board. The reports are listed in chronological order.

Lockheed Marine Biology Laboratory. 1976. Diablo Canyon Study Report: Field Biological Studies, Nine-Month Report to Kaiser Engineers, Inc. October 1976.

PG&E. 1978. Pacific Gas and Electric Company 316(a) Demonstration Program Field Biology Preoperational Phase Database Summary, Vols. 1 and 2. Prepared by Lockheed Center for Marine Research, Carlsbad, CA. for Kaiser Engineers, Inc. April 1978.

PG&E. 1978. Diablo Canyon Power Plant 316(a) Demonstration. Nine-Month Progress Report. Prepared by TERA Corp., Berkeley, CA. May 1978.

PG&E. 1979. Diablo Canyon Power Plant 316(a) demonstration. Nine-Month Progress Report. Prepared by TERA Corp., Berkeley, CA. February 1979.

PG&E. 1983. Thermal Effects Monitoring Program. 1982 Annual Report. Diablo Canyon Power Plant. Pacific Gas and Electric Company, San Francisco, CA. Prepared by TERA Corp., Berkeley, CA. January 1983.

PG&E. 1984. Thermal Effects Monitoring Program. 1983 Annual Report. Diablo Canyon Power Plant. Pacific Gas and Electric Company, San Francisco, CA. Prepared by TERA Corp., Berkeley, CA. January 1984.

PG&E. 1985. Thermal Effects Monitoring Program. 1984 Annual Report. Diablo Canyon Power Plant. Pacific Gas and Electric Company, San Francisco, CA. Prepared by TERA Corp., Berkeley, CA. March 1985.

PG&E. 1986. Thermal Effects Monitoring Program. 1985 Annual Report. Diablo Canyon Power Plant. Pacific Gas and Electric Company, San Francisco, CA. Prepared by TERA Corp., Berkeley, CA. April 1986.

PG&E. 1987. Thermal Effects Monitoring Program. 1986 Annual Report. Diablo Canyon Power Plant. Pacific Gas and Electric Company, San Francisco, CA. DCL-87-087. Prepared by TERA Corp., Berkeley, CA. May 1987.

PG&E. 1988. Thermal Effects Monitoring Program. Final Report. Pacific Gas and Electric Company, San Francisco, CA.

PG&E. 1989. Diablo Canyon Power Plant. Marine Environmental Monitoring Program. 1988 Annual Report. Pacific Gas and Electric Company, San Francisco, CA. DCl-89-119. April 1989.

PG&E. 1990. Thermal Effects Monitoring Program. 1989 Annual Report. Diablo Canyon Power Plant, Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, Berkeley, CA. DCL-90-111. April 1990.

PG&E. 1991. Thermal Effects Monitoring Program. 1990 Annual Report. Diablo Canyon Power Plant, Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, Berkeley, CA. DCL-91-069. March 1991.

PG&E. 1992. Thermal Effects Monitoring Program. 1991 Annual Report. Diablo Canyon Power Plant, Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, Berkeley, CA. DCL-92-070. March 1992.

PG&E. 1993. Thermal Effects Monitoring Program. 1992Annual Report. Diablo Canyon Power Plant, Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, Berkeley, CA. DCL-93-067. March 1993.

PG&E. 1994. Thermal Effects Monitoring Program. 1993 Annual Report. Diablo Canyon Power Plant, Pacific Gas and Electric Company, San Francisco, CA. DCL-94-062. Prepared by Tenera Environmental Services, Berkeley, CA. March 1994. Addendum, DCL-94-081.

PG&E. 1995. Thermal Effects Monitoring Program. 1994 Annual Report. Diablo Canyon Power Plant, Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, Berkeley, CA. DCL-95-062. March 1995.

PG&E. 1996. Ecological Monitoring Program. Summer/Fall 1995 Status Report. Diablo Canyon Power Plant. Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, San Francisco, CA. February 1996.

PG&E. 1996. Ecological Monitoring Program. Status Report. Winter 1995 and Spring 1996 surveys. Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, San Francisco, CA. July 1996.

PG&E. 1997. Receiving Water Monitoring Program. 1996 Semi-annual Status Report. Diablo Canyon Power Plant. Pacific Gas and Electric Company, San Francisco, CA. Prepared by Tenera Environmental Services, San Francisco, CA. February 1997.

Tenera, Inc. (Tenera). 1997. Diablo Canyon Power Plant Thermal Effects Monitoring Program Analysis Report. Chapter 1. Changes in the marine environment resulting from the Diablo Canyon Power Plant thermal discharge. Prepared for Pacific Gas and Electric Company, San Francisco, CA.

Tenera, Inc. (Tenera). 1998. Diablo Canyon Power Plant. Receiving Water Monitoring Program. 1998 Winter-Spring Report. Prepared for Pacific Gas and Electric Company, San Francisco, CA. July 1998.

Tenera, Inc. (Tenera). 1998. Diablo Canyon Power Plant. Receiving Water Monitoring Program. 1995-1997 Progress Report. Prepared for Pacific Gas and Electric Company, San Francisco, CA.

Tenera Inc. (Tenera). 1998. Surfgrass (*Phyllospadix*) in the Vicinity of the Diablo Canyon Power Plant Discharge. E7-225.4. Prepared for Pacific Gas and Electric Company, San Francisco, CA.

Tenera Inc. (Tenera). 1998. Diablo Canyon Power Plant Thermal Effects Monitoring Program Analysis Report. Chapter 2 - Assessment of Thermal Effects. Prepared for Pacific Gas & Electric Company, San Francisco, CA.

Tenera Inc. (Tenera). 1999. Effects of the DCPP discharge on surface canopy kelps as determined by analysis of aerial photographs. Prepared for Pacific Gas & Electric Company, San Francisco, CA.

Tenera Inc. (Tenera). 1999. Diablo Canyon Power Plant Receiving Water Monitoring Program: 1995-1998 Progress Report. Prepared for Pacific Gas & Electric Company, San Francisco, CA.

Tenera Environmental (Tenera). 2000. Diablo Canyon Power Plant Receiving Water Monitoring Program: 1999 Annual Report. Prepared for Pacific Gas & Electric Company, San Francisco, CA.

Tenera Environmental, Inc. (Tenera). 2000. Diablo Canyon Power Plant Receiving Water Monitoring Program Effects of Water Temperature on the Distribution and Abundance of Intertidal Organisms in Field's Cove. Prepared for Pacific Gas & Electric Company, San Francisco, CA.

Tenera Environmental (Tenera). 2001. Diablo Canyon Power Plant Receiving Water Monitoring Program: 2000 Annual Report. Prepared for Pacific Gas & Electric Company, San Francisco, CA.

Tenera Environmental (Tenera). 2002. Diablo Canyon Power Plant Receiving Water Monitoring Program: 2001 Annual Report. Prepared for Pacific Gas & Electric.

Tenera Environmental, Inc. (Tenera). 2002. Diablo Canyon Power Plant Receiving Water Monitoring Program: 1995 - 2002 Analysis Report. Prepared for Pacific Gas & Electric Company, San Francisco, CA.

Tenera Environmental (Tenera). 2003. Diablo Canyon Power Plant Receiving Water Monitoring Program: 2002 Annual Report. Prepared for Pacific Gas and Electric Company, San Francisco, CA.

Tenera Environmental (Tenera). 2004. Diablo Canyon Power Plant NPDES Receiving Water Monitoring Program: 2003 Annual Report. Prepared for Pacific Gas and Electric Company, San Francisco, CA.

Tenera Environmental (Tenera). 2005. Diablo Canyon Power Plant NPDES Receiving Water Monitoring Program: 2004 Annual Report. Prepared for Pacific Gas and Electric Company, San Francisco, CA.

Tenera Environmental (Tenera). 2006. Diablo Canyon Power Plant NPDES Receiving Water Monitoring Program: 2005 Annual Report. Prepared for Pacific Gas and Electric Company, San Francisco, CA.

Tenera Environmental (Tenera). 2007. Diablo Canyon Power Plant NPDES Receiving Water Monitoring Program: 2006 Annual Report. Prepared for Pacific Gas and Electric Company, San Francisco, CA.

Tenera Environmental (Tenera). 2008. Diablo Canyon Power Plant NPDES Receiving Water Monitoring Program: 2007 Annual Report. Prepared for Pacific Gas and Electric Company, San Francisco, CA.

Predictive Analyses and Evaluation Reports

The reports in this category were prepared by various organizations and are listed in chronological order.

PG&E. 1971. Environmental report, units 1 and 2, Diablo Canyon site. AEC dockets 50-275, 50-323. July 1971; PG&E, environmental report supplement no. 2 (1972).

North, W.J. and E. Anderson. 1973. Anticipated biological effects from heated effluents at Diablo Cove. Dept. Eng. Res., Pacific Gas and Electric Company, San Francisco, CA. May 1973.

United States Atomic Energy Commission Directorate of Licensing. 1973. Final Environmental Statement related to the nuclear generating station Diablo Canyon units 1 & 2, May 1973 (docket nos. 50-275 and 50-323); NRC Office of Nuclear Reactor Regulation, addendum to the final environmental statement for the operation of the Diablo Canyon Nuclear Plant units 1 and 2 (May 1976) (docket nos. 50-275 and 50-323).

Brown, C.A., R.A. Molina, G.A. Jacoby, and P.M. Maroney. 1974. Effluent control systems. Diablo Canyon Nuclear Power Plant. Preliminary study based on EPA's proposed effluent limitation guidelines and standards of March 4, 1974. Kaiser Engineers. Prepared for Pacific Gas and Electric Company. July 1974.

PG&E. 1982. Diablo Canyon Power Plant. Thermal discharge assessment. Prepared by TERA Corp., Berkeley, CA for Pacific Gas & Electric Co., San Francisco, CA.

PG&E. 1982. Diablo Canyon Power Plant. Assessment of alternatives to the existing cooling water system. Pacific Gas & Electric Co., San Francisco, CA.

PG&E. 1985. Environmental evaluation of heat treatment thermal discharges. Diablo Canyon Power Plant. Prepared by TERA Corp., Berkeley, CA. July 1985.

Wheeler J. North Studies

Dr. Wheeler J. North and associate staff conducted studies on intertidal and subtidal algae and invertebrates at DCPP. Their studies spanned 20 years, but extended only two years into the power plant operation study period. Periodic status reports of the monitoring studies appear in the Environmental Investigations at Diablo Canyon reports prepared by PG&E and submitted to the Regional Water Quality Control Board (see Section A.11). The monitoring results that spanned the 20-year study were compiled in North, et al. (1989). North and Anderson (1973) also published a report titled "Anticipated Biological Effects from Heated Effluents at Diablo Cove", which appears above in Section A-2.

North, W.J. 1969. An evaluation of the marine flora and fauna in the vicinity of Diablo Cove, California. Marine Advisors, La Jolla, CA. p. 1097-1128.

North, W.J. and E. Anderson. 1973. Anticipated biological effects from heated effluents at Diablo Cove. Dept. Eng. Res., Pacific Gas and Electric Company, San Francisco, CA.

North, W.J., E.K. Anderson, and F.A. Chapman. 1989. Wheeler J. North ecological studies at Diablo Canyon Power Plant. Final Report, 1967-1987. Pacific Gas and Electric Company, San Francisco, CA.

Fish and Game Reports

The earliest investigations at DCPP were conducted by the California State Department of Fish and Game (Ebert, 1966). Since then, Fish and Game conducted monitoring studies of intertidal and subtidal biota based from a DCPP on-site office and laboratory facility, but the studies ended before power plant start-up. Quarterly results from the monitoring studies were periodically included as chapters, compiled by PG&E in the Environmental Investigations at Diablo Canyon reports (Section A.11). All Environmental Investigations at Diablo Canyon reports were submitted to the Regional Water Quality Control Board. Results from the entire duration of the Fish and Game monitoring studies were reported in two comprehensive Fish and Game reports (Gotshall, et al., 1984, 1986). Martin, et al. (1977) reported on a suspected copper toxicity incident following a pre-start-up testing procedure of the DCPP cooling water system. The state mussel watch program for trace metal monitoring at DCPP remains ongoing (see Martin, et al., 1985, for example report). The reports are listed in chronological order.

Ebert, E.E. 1966. An evaluation of marine resources in the Diablo Canyon area, May 2-4, 1966. MRO Ref. No. 66-10. Calif. Dept. Fish Game, Special Study.

Burge, R.T. and S.A. Schultz. 1973. The marine environment in the vicinity of Diablo Cove with special reference to abalone and bony fishes. Calif. Dept. Fish Game, Mar. Res. Tech. Rpt. No. 19.

Martin, M.M., D. Stephenson, and J.H. Martin. 1977. Copper toxicity experiments in relation to abalone deaths observed in a power plant's cooling waters. Calif. Dept. Fish Game 63:95-100.

Gotshall, D.W., L.L. Laurent, S.L. Owen, J. Grant, and P. Law. 1984. A quantitative ecological study of selected nearshore marine plants and animals at the Diablo Canyon Power Plant site: a pre-operational baseline: 1973-1978. Calif. Dept. Fish Game, Mar. Res. Tech. Rep. No. 48.

Martin, M., M. Stephenson, D. Smith, J. Linfield, G. Ichikawa, J. Goetzel, J. Bennett, S. Eastman, and M. Manera. 1985. Diablo Canyon Nuclear Power Plant outfall monitoring report. State Mussel Watch Progr. Prelimin. Data Rpt. 1984-1985. Calif. Dept. Fish Game. 19 pp.

Gotshall D.W., J.R.R. Ally, D.L. Vaughn, B.B. Hatfield, and P. Law. 1986. Pre-operational baseline studies of selected nearshore marine biota at the Diablo Canyon Power Plant site: 1979-1982. Calif. Dept. Fish Game, Mar. Res. Tech. Rep. No. 50.

DCPP Thermal Effects Laboratory Reports

Laboratory thermal tolerance studies for over 30 marine species of algae, invertebrates, and fish were conducted by Tenera Environmental Services (previously TERA Corp.).

The studies encompassed a range of heat tolerance and temperature preference/avoidance experiments, and included numerous status reports on the findings, as well as on procedure methods and quality assurance. The methods and results from the entire set of laboratory experiments are reported in three volumes of the Compendium of thermal effects laboratory studies. The data were integrated with thermal plume modeling results to identify which species may be at risk to the thermal discharge, and types of changes that may occur during power plant operation. This assessment of predicted thermal effects is presented in the report titled Thermal Discharge Assessment Report (see Section A-2).

PG&E. 1979. Diablo Canyon Power Plant 316(a) demonstration. Nine month progress report. Prepared by TERA Corp., Berkeley, CA. February 1979.

PG&E. 1979. Diablo Canyon Power Plant 316(a) demonstration. Nine month progress report. Prepared by TERA Corp., Berkeley, CA. November 1979.

PG&E. 1980. Diablo Canyon Power Plant 316(a) demonstration. Nine month progress report. Prepared by TERA Corp., Berkeley, CA. August 1980.

PG&E. 1982. Compendium of Thermal Effects Laboratory Studies Volumes 1, 2, and 3. Diablo Canyon Power Plant. Prepared by TERA Corp., Berkeley, CA for Pacific Gas & Electric Co., San Francisco, CA.

Plume Modeling and Oceanographic Reports

Thermal plume modeling and oceanographic studies were conducted under the management of PG&E's Department of Engineering Research (name changed to Technological and Ecological Services). Bathythermograph surveys were conducted to map the extent of surface plume isotherms, as part of the plant's NPDES. The surveys were conducted bi-monthly from August 1986 to April 1990. Results from the surveys were submitted in quarterly and annual influent/effluent monitoring reports to the Regional Water Quality Control Board. Aerial infra-red photographs of the surface thermal plume were conducted for thermal verification of the physical model and the far-field numerical model, as part of an NRC requirement. Results from the aerial infra-red surveys were also used to verify dilution factor and bathythermograph studies of the plume. The reports are listed alphabetically by principal author. Several reports not listed in this section appear in Section A.11, Environmental Investigations at Diablo Canyon (e.g. reports authored by C.O. White in 1985).

Babcock, J.D., P.J. Ryan, S.W. Tu, and V. Wyman. 1987. Hydraulic model study quality assurance requirements. Diablo Canyon Power Plant. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420-DC-87.17. May 1987.

Borgman, L.E. 1982. Extremal analysis of wave hindcasts for the Diablo Canyon area, California made by Mr. R. Rea Strange III. Oceanweather, Inc. Prepared for Omar J. Lillevang, Whittier, CA. December 1982. 130 pp. and appendices.

Borgman, L.E. 1982. Extremal analysis of wave hindcasts for the Diablo Canyon area, California made by Dr. Don Resio. A companion report to Extremal analysis of wave hindcasts for the Diablo Canyon area, California made by Mr. R. Rea Strange III.: Oceanweather, Inc. Prepared for Omar J. Lillevang, Whittier, CA. December 1982. 142 pp.

Findikaki, I.T. 1986. Documentation and user's manual of the software for the statistical analysis and comparative evaluation of field and hydraulic model temperature data in the vicinity of the Diablo Canyon thermal outfall. Submitted to Bechtel Inc., San Francisco, CA. Prepared for Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. February 1986.

Findikaki, I.T. 1986. Statistical analysis and comparative evaluation of field and hydraulic model water temperature data in the vicinity of the Diablo Canyon thermal outfall. Submitted to Bechtel Inc., San Francisco, CA. Prepared for Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. February 1986.

Leighton, J.P. 1988. Comparison of the effects of heat treatment and full load operation on receiving water temperatures. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420-DC-87.760. January 1988.

Leighton, J.P. 1988. Estimation of the dilution factor for the Diablo Canyon Power Plant thermal discharge plume. Technical and Ecological Services, Report No. 028.282-88.2, Pacific Gas and Electric Company, Technical and Ecological Services, San Ramon, CA. February 1988.

Leighton, J.P., C.O. White, and S.W. Tu. 1990. Far-field statification of a buoyant jet. pp 137-144 *in* Huatong, W., W. Jingyong, and D. Hua (eds.), Physics of shallow seas. China Ocean Press, Beijing, China.

Leighton, J. P., S. W. Tu, A. A. Petroccitto and L. K. Eastman. 1986. Characterization of receiving water temperatures during power ascension testing of Unit 1, Diablo Canyon Power Plant. Department of Engineering Research, Report No. 420-85.748, Pacific Gas and Electric Company, San Ramon, CA.

Leighton, J. P. 1988. Estimation of the dilution factor for the Diablo Canyon Power Plant thermal discharge plume. Technical and Ecological Services, Report No. 028.282-88.2, Pacific Gas and Electric Company, San Ramon, CA.

Meek, R.P. 1988. Diablo Canyon continuous current measurements, July 1986 through June, 1987. Prepared by Robert P. Meek, ECOMAR, Inc., Goleta, CA.

Resio, D.T. 1982. Report on wave climatology for Diablo Canyon, California. Oceanweather, Inc. June 1982. 97 pp.

Ryan, P.J. S.W. Tu, J.P. Leighton, and R.L. Wiegel. 1986. Hydraulic model verification tests for unit 1 Diablo Canyon Power Plant. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420-86.557. November 1986.

Ryan, P. J., N. Ismail, R. C. H. Lou, S. W. Tu, and R. L. Wiegel. 1987a. Hydraulic model verification tests for units 1 and 2 Diablo Canyon Power Plant. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420-DC-87.15. April. 1987.

Ryan, P.J., N. Ismail, R.C.H. Lou, S.W. Tu, and R.L. Wiegel. 1987. Hydraulic model verification tests for Units 1 and 2, Diablo Canyon Power Plant. Tech. Rpt. HEL 27-17, HEL, UCB.

Ryan, P.J., R. Kloepper, N. Ismail, S.W. Tu, and R.L. Wiegel. 1987. Hydraulic model tests for heat treatment conditions at Diablo Canyon Power Plant. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420-DC-87.16. April 1987.

Safaie, B. 1986. Study of nearshore current in the vicinity of Diablo Canyon, California. Prepared for Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. June 1986.

Strange, R.R.III. 1982. A hindcast of severe storm waves at Diablo Canyon, California. Pacific Weather Analysis. Prepared for O.J. Lillevang. 43 pp.

Tu, S. 1990. Diablo Canyon Power Plant offshore thermal plume numerical model study, a video report. Pacific Gas and Electric Company, Technical and Ecological Services, San Ramon, CA. February 1986.

Tu, S.W. 1989. Numerical model simulation of Diablo Canyon Power Plant far-field thermal plume. Pacific Gas and Electric Company, San Ramon, CA. Report 420-DC-89.441. August 1989.

Tu, S. W. and D. S. Trent. 1989. Verification of Diablo Canyon Power Plant far-field thermal plume numerical model. Pacific Gas and Electric Company, San Ramon, CA. Report 420-DC-89.303. August 1989.

Tu, S. W., J. P. Leighton, C. O. White, and C. C. Hsu. 1986. Surface buoyant jet characteristics of the thermal discharge plume at Diablo Canyon Power Plant. A field study of power ascention testing of unit 2 and full load operation of unit 1. Pacific Gas and Electric Company, Dept. Engr. Research, San Ramon, CA. Report 420-86.475. November 1986.

Wiegel, R.L. and M.J. Doyle. 1987. Cooling by ocean water: model/field comparison. Shore and Beach. July-October 1987. pp. 38-53.

Wiegel, R. L., V. W. Harms, B. Safaie, R. P. Della, and C. B. Leidersdorf. 1975. A preliminary report on model study of cooling water system of Pacific Gas and Electric Company Power Plant located at Diablo Canyon, California. Hydraulic Engineering Lab., University of California at Berkeley; also PG&E docket no. 50-275-02 and 50-323-02, Supplement no. 7.

Wiegel, R. L., V. W. Harms, B. Safaie, J. D. Cumming, R. P. Della, C. B. Leidersdorf, and C. Young. 1976. Report on model study of cooling water system of Pacific Gas and Electric Company Nuclear Power Plant at Diablo Canyon, California. Report no. HEL 27-2, Hydraulic Engineering Lab., University of California at Berkeley, California.

Other Individual Reports and Publications

A number of other reports were prepared from data sets and observations of the field and laboratory studies at DCPP as supportive documents for marine environmental assessments and for broader scientific distribution. Reports are listed alphabetically by principal author.

Abbott, I.A. and W.J. North. 1971. Temperature influences on floral composition in California coastal waters. pp. 72-79 *in* K. Nisizawa (ed.), Proc. 7the Int. Seaweed Symp. Wiley Interscience, New York.

Behrens, D.W. 1976. Toxicity of concentrated seafoam generated at Diablo Canyon Nuclear Power Plant *in* PG&E-DER Report 7846.6-76.

Benech, S.V. 1978. Observations of the sea otter, *Enhydra lutris,* population between Coon and Rattlesnake Creeks, January-December 1978. Ecomar, Inc. No. VII-3-78.

Benech, S.V. 1995. Observations of the sea otter, *Enhydra lutris,* population between Point Buchon and Rattlesnake Creek, San Luis Obispo, California, January through December 1994. Benech Biological and Associates, Ventura, CA.

Blecha, J.B., J.R. Steinbeck, and D.C. Sommerville. 1992. Aspects of the biology of black abalone, *Haliotis cracherodii*, near Diablo Canyon, central California. pp. 225-236 *in* S.A. Shepherd, J.J. Tegner, and S.A. Guzman del Proo (eds.), Abalone of the world: biology, fisheries and culture. Blackwell Scientific Publications Ltd., Oxford.

Bowker, R.C. 1980. Community structure analysis. The Diablo Canyon intertidal red algae - eel grass community. A report prepared from a Master's Thesis. California State Polytechnic University. June 1980.

Carroll, J.C. 1982. Seasonal abundance, size composition, and growth of rock crab, *Cancer antennarius* Stimpson, off central California. J. Crust. Biol. 2(4):549-561.

Danner, E.M, T.C. Wilson, and R.E. Schlotterbeck. 1994. Comparison of rockfish recruitment of nearshore artificial and natural reefs off the coast of central California. Bull. Mar. Sci. 55:333-343.

Hines, A., S. Anderson, and M. Brisbin. 1980. Heat tolerance in the black abalone, *Haliotis cracherodii* Leach, 1814: effects of temperature fluctuation and acclimation. Veliger 23:113-118.

PG&E 1976. Foam control at Diablo Canyon. Report to the California Regional Water Quality Control Board, Central Coast Region. January 15, 1976. 17 pp. Appendices.

PG&E. 1972. Environmental Report, Units 1 and 2 Diablo Canyon, Environmental Report Supplement No. 2. San Francisco, CA.

PG&E. 1976. Foam control at Diablo Canyon. Pacific Gas and Electric Company. Report to the California Regional Water Quality Control Board, Central Coast Region. January 1976.

PG&E. 1985. South Diablo Cove algal observations. Diablo Canyon Power Plant. Pacific Gas and Electric Company, Dept. Engr. Res., San Ramon, CA. Report 411-85.199. December 1984.

PG&E. 1992. Acute toxicity assessment of foam from the discharge of Diablo Canyon Power Plant. PG&E NOS-ODES Report 420-92.22.

Setran, A.C. and D.W. Behrens. 1993. Transitional ecological requirements for early juveniles of two sympatric stichaeid fishes, *Cebidichthys violaceus* and *Xiphister mucosus*. Envir. Biol. Fishes 37:381-395.

Steinbeck, J.R. 1986. A numerical analysis of intertidal algal community structure in Diablo Cove, California. Master's Thesis. California Polytechnic State University, San Luis Obispo.

Steinbeck, J.R., J.M. Groff, C.S. Friedman, T. McDowell, and R.P. Hedrick. 1992. Investigations into a mortality among populations of the central California black abalone. *In*: S.A. Shepherd, M.J. Tegner, and S.A. Guzman del Proo (eds.). Abalone of the world: biology, fisheries and culture. Blackwell Scientific Publications Ltd., Oxford. p. 203-213.

Steinbeck, J. R., D. R. Schiel, and M. S. Foster. 2005. Detecting long-term change in complex communities: a case study from the rocky intertidal zone. Ecological Applications 15:1813-1832.

TERA Corp. 1981. Life history and ecology of 21 central California nearshore marine species. Prepared for Pacific Gas and Electric Company. 204 pp.

Wyman. V.L. 1979. Diablo Canyon Foam Study, 1976-1977. Pacific Gas and Electric Company, Dept. Engr. Research. Report 411-78.72.

Environmental Investigations at Diablo Canyon ("Green Reports"):

Environmental Investigations at Diablo Canyon is a series of 18 reports produced by PG&E's Department of Engineering Research (dept. name later changed to Technical and Ecological Services). Each report contains chapters compiled by PG&E that describe results from the various DCPP marine field and laboratory studies conducted at DCPP by PG&E, its consultants, and the California Dept. of Fish and Game. These include Fish and Game quarterly reports, Wheeler J. North intertidal and subtidal observations; gray whale, sea otter, and peregrin falcon surveys; laboratory toxicity studies; partyboat fisheries monitoring; and plume modeling and monitoring results. The reports also include some tasks and studies unrelated to NPDES monitoring and assessment, such as power plant biofouling and artificial reef studies and effects of construction and breakwater repairs. The reports span studies and tasks that began in 1969, but the series of reports ended in 1987. Each report is bound in a green cover. Hence, the reports have often been referred to as the "green reports". All reports were submitted to the Regional Water Quality Control Board, as well as donated to various university libraries throughout California. The reports are listed below in chronological order by year and volume with chapters listed sequentially within each report.

1972 Report

Adams, J.R. 1972. Introduction. Chapter I *in* Adams, J.R. (ed.), Marine environmental investigations at the Diablo Canyon Units 1 and 2 nuclear power plant site, 1969-1971. PG&E, Dept. Engr. Res. July 1972.

Doyle, M.J., Jr. 1972. Physical investigations. Chapter II *in* Adams, J.R. (ed.), Marine environmental investigations at the Diablo Canyon Units 1 and 2 nuclear power plant site, 1969-1971. PG&E, Dept. Engr. Res. July 1972.

North, Dr. W.J. 1972. Marine ecology. Chapter III *in* Adams, J.R. (ed.), Marine environmental investigations at the Diablo Canyon Units 1 and 2 nuclear power plant site, 1969-1971. PG&E, Dept. Engr. Res. July 1972.

Waters, B.F. 1972. Abalone transplants. Chapter IV *in* Adams, J.R. (ed.), Marine environmental investigations at the Diablo Canyon Units 1 and 2 nuclear power plant site, 1969-1971. PG&E, Dept. Engr. Res. July 1972.

Warrick, J.W. 1972. Radiological collections. Chapter V *in* Adams, J.R. (ed.), Marine environmental investigations at the Diablo Canyon Units 1 and 2 nuclear power plant site, 1969-1971. PG&E, Dept. Engr. Res. July 1972.

Warrick, J.W. 1972. Biological Studies by California State Polytechnic College. Chapter VI *in* Adams, J.R. (ed.), Marine environmental investigations at the Diablo Canyon Units 1 and 2 nuclear power plant site, 1969-1971. PG&E, Dept. Engr. Res. July 1972.

CDF&G. 1972. Diablo Canyon ecological survey. Chapter VII *in* Adams, J.R. (ed.), Marine environmental investigations at the Diablo Canyon Units 1 and 2 nuclear power plant site, 1969-1971. PG&E, Dept. Engr. Res. July 1972.

North, Dr. W.J. and J.R. Adams. 1974. Studies planned for 1972. Chapter VIII *in* Adams, J.R. (ed.), Marine environmental investigations at the Diablo Canyon Units 1 and 2 nuclear power plant site, 1969-1971. PG&E, Dept. Engr. Res. July 1972.

1974 Report

Adams, J.R. 1974. Introduction. Chapter I *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Doyle, M.J., Jr. 1974. Physical Oceanography. Chapter II *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

North, W.J., E.K. Anderson, and F.A. Chapman. 1974. Summary report on marine ecological studies. Chapter III *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Warrick, J.W. 1974. Bull Kelp Studies. Chapter IV *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Icanberry, J.W. and J.R. Adams. 1974. Zooplankton Studies. Chapter V *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Adams, J.R. and D.G. Price. 1974. Thermal shock tolerances of larval red abalone (*Haliotis rufescens*). Chapter VI *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Adams, J.R. 1974. Thermal tolerance of adult red abalone. Chapter VII *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Hurley, J.F. 1974. Abalone: An annotated bibliography. Chapter VIII *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Fairbrother, K. 1974. Diablo Canyon breakwater studies. Chapter IX *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Colson, E.W. 1974. Marine mammal investigation. Chapter X *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Warrick, J.W. 1974. Intake cofferdam investigations. Chapter XI *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Serpa, D.P. 1974. Off-site radiological monitoring program. Chapter XII *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Serpa, D.P. and S.G. Sharp. 1974. Diablo Canyon concentration factors study. Chapter XIII *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Serpa, D.P. and S.G. Sharp. 1974. Morro Bay trace metals analysis. Chapter XIV *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Colson, E.W. and R.S. Osterling. 1974. Terrestrial ecological studies. Chapter XV *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

CDF&G. 1974. California Department of Fish and Game contract studies. Chapter XVI *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

Adams, J.R., W.J. North, and M.J. Doyle, Jr. 1974. Studies planned for the future. Chapter XVII *in* Adams, J.R. and J.F. Hurley (eds.), Environmental investigations at Diablo Canyon, 1972-1973. PG&E, Dept. Engr. Res. May 1974.

1975 Report

Adams, J.R. 1975. Introduction. Chapter I *in* Adams, J.R. and B.J. Anderson (eds.), Environmental investigations at Diablo Canyon, 1974. PG&E, Dept. Engr. Res. July 1975.

Warrick, J.W., S.G. Sharp, and S.J. Friedrich. 1975. Chemical, biological, and corrosion investigations related to the testing of the Diablo Canyon Unit 1 cooling water system. Chapter II *in* Adams, J.R. and B.J. Anderson (eds.), Environmental investigations at Diablo Canyon, 1974. PG&E, Dept. Engr. Res. July 1975.

Warrick, J.W. and J.R. Adams. 1975. Intake and discharge cofferdam investigations. Chapter III *in* Adams, J.R. and B.J. Anderson (eds.), Environmental investigations at Diablo Canyon, 1974. PG&E, Dept. Engr. Res. July 1975.

Doyle, M.J., Jr. 1975. Physical Oceanography. Chapter IV *in* Adams, J.R. and B.J. Anderson (eds.), Environmental investigations at Diablo Canyon, 1974. PG&E, Dept. Engr. Res. July 1975.

Warrick, J.W. 1975. Benthic temperature study. Chapter V *in* Adams, J.R. and B.J. Anderson (eds.), Environmental investigations at Diablo Canyon, 1974. PG&E, Dept. Engr. Res. July 1975.

North, W.J., E.K. Anderson, and F.A. Chapman. 1975. Marine ecological transect studies. Chapter VI *in* Adams, J.R. and B.J. Anderson (eds.), Environmental investigations at Diablo Canyon, 1974. PG&E, Dept. Engr. Res. July 1975.

Icanberry, J.W. and J.W. Warrick. 1975. Larval fish, phytoplankton, and zooplankton studies. Chapter VII *in* Adams, J.R. and B.J. Anderson (eds.), Environmental investigations at Diablo Canyon, 1974. PG&E, Dept. Engr. Res. July 1975.

Colson, E.W. 1975. Marine mammal investigations. Chapter VIII *in* Adams, J.R. and B.J. Anderson (eds.), Environmental investigations at Diablo Canyon, 1974. PG&E, Dept. Engr. Res. July 1975.

Colson, E.W. 1975. Terrestrial ecological studies. Chapter IX *in* Adams, J.R. and B.J. Anderson (eds.), Environmental investigations at Diablo Canyon, 1974. PG&E, Dept. Engr. Res. July 1975.

Lorenz, R.W. and D.P. Serpa. 1975. Off-site radiological monitoring program. Chapter X *in* Adams, J.R. and B.J. Anderson (eds.), Environmental investigations at Diablo Canyon, 1974. PG&E, Dept. Engr. Res. July 1975.

CDF&G. 1975. California Department of Fish and Game contract studies. Chapter XI *in* Adams, J.R. and B.J. Anderson (eds.), Environmental investigations at Diablo Canyon, 1974. PG&E, Dept. Engr. Res. July 1975.

Adams, J.R. and M.J. Doyle, Jr. 1975. Studies planned for 1975. Chapter XII *in* Adams, J.R. and B.J. Anderson (eds.), Environmental investigations at Diablo Canyon, 1974. PG&E, Dept. Engr. Res. July 1975.

1978 Report

Banuet-Hutton, E.A. 1978. Suspended solids sampling at Diablo Canyon Power Plant. Chapter I *in* Warrick, J.W., E.A. Banuet-Hutton, and L.R. Friedman (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume II. PG&E, Dept. Engr. Res. October 1978.

Icanberry, J.W. and J.W. Warrick. 1978. Seasonal distribution of plankton in the nearshore marine environment of Diablo Canyon Nuclear Power Plant. Chapter II *in* Warrick, J.W., E.A. Banuet-Hutton, and L.R. Friedman (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume II. PG&E, Dept. Engr. Res. October 1978.

Icanberry, J.W. and J.W. Warrick. 1978. Seasonal distribution of larval fish and fish eggs in the nearshore marine environment of Diablo Canyon Nuclear Power Plant. Chapter III *in* Warrick, J.W., E.A. Banuet-Hutton, and L.R. Friedman (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume II. PG&E, Dept. Engr. Res. October 1978.

Icanberry, J.W. 1978. Delayed mortality of entrained copepods at Morro Bay Power Plant. Chapter IV *in* Warrick, J.W., E.A. Banuet-Hutton, and L.R. Friedman (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume II. PG&E, Dept. Engr. Res. October 1978.

Behrens, D.W. and B.C. Larsson. 1978. Effects of intermittent chlorination of selected invertebrate species indigenous to Diablo Cove. Chapter V *in* Warrick, J.W., E.A. Banuet-Hutton, and L.R. Friedman (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume II. PG&E, Dept. Engr. Res. October 1978.

Wilson, T.C. 1978. The effect of chlorine residuals on the blue rockfish (*Sebastes mystinus*), the rock prickleback (*Xyphister mucosus*), and the copepod (*Calanus pacificus*). Chapter VI *in* Warrick, J.W., E.A. Banuet-Hutton, and L.R. Friedman (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume II. PG&E, Dept. Engr. Res. October 1978.

Warrick, J.W. 1978. Investigations of the thermal tolerance of bull kelp, *Nereocystis luetkeana* (Mertens) P and R. Chapter VII *in* Warrick, J.W., E.A. Banuet-Hutton, and L.R. Friedman (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume II. PG&E, Dept. Engr. Res. October 1978.

Benech, S.V. and E.W. Colson. 1978. Size and distribution of the California sea otter population in the vicinity of Diablo Canyon Nuclear Power Plant, October 1973 - December 1975. Chapter VIII *in* Warrick, J.W., E.A. Banuet-Hutton, and L.R. Friedman (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume II. PG&E, Dept. Engr. Res. October 1978.

Behrens, D.W. 1978. Environmental monitoring and animal transplanting during breakwater repair work at Diablo Canyon Nuclear Power Plant. Chapter IX *in* Warrick, J.W., E.A. Banuet-Hutton, and L.R. Friedman (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume II. PG&E, Dept. Engr. Res. October 1978.

CDF&G. 1978. California Department of Fish and Game contract studies. Chapter X *in* Warrick, J.W., E.A. Banuet-Hutton, and L.R. Friedman (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume II. PG&E, Dept. Engr. Res. October 1978.

Behrens, D.W. and T.C. Wilson. 1978. Toxicity studies of chemical antifoaming agents at Diablo Canyon. Chapter XI *in* Warrick, J.W., E.A. Banuet-Hutton, and L.R. Friedman (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume II. PG&E, Dept. Engr. Res. October 1978.

1979 Report

Doyle, M.J. Jr. 1979. Physical oceanography. Chapter I *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

Gosink, J. and R.L. Wiegel. 1979. Nearshore currents in the vicinity of Diablo Canyon, California, 1972 - 1976. Chapter II *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

Orvosh, W.T. 1979. Diablo Canyon oceanographic densities, 1972 - 1977, review and comment. Chapter III *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

Banuet-Hutton, E.A. 1979. Oceanographic stations, 1975 - 1977. Chapter IV *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

Holmbeck, T.M. and J.W. Warrick. 1979. Review of surface water temperatures, 1967 - 1975. Chapter V *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

Warrick, J.W. 1979. Analysis of subtidal water temperatures in the vicinity of Diablo Cove. Chapter VI *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

Wyman, V.L. 1979. Diablo Canyon foam study, 1977. Chapter VII *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

Stephan, J.A. 1979. Analysis of aerial photographs to determine the aerial extent of kelp beds near the Diablo Canyon Power Plant. Chapter VIII *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

Behrens, D.W. 1979. Toxicity studies at Diablo Canyon. Chapter IX *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

Behrens, D.W. and B.C. Larsson. 1979. Impingement of fishes and macroinvertebrates at Diablo Canyon Nuclear Power Plant. Chapter X *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

Wilson, T.C. and D.W. Behrens. 1979. Ecological studies of the Diablo Canyon Nuclear Power Plant intake cove. Chapter XI *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

Benech, S.V. 1979. Size, distribution, and behavior of the California sea otter population in the vicinity of Diablo Canyon Nuclear Power Plant, 1976. Chapter XII *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

Benech, S.V. 1979. Size, distribution, and behavior of the California sea otter population in the vicinity of Diablo Canyon Nuclear Power Plant, 1977. Chapter XII *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

North, Dr. W.J., E.K. Anderson, and F.A. Chapman. 1979. Marine ecological transect studies. Chapter XIII *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

Lorenz, R.W. 1979. Radiological monitoring program. Chapter XIV *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

CDF&G. 1979. California Department of Fish and Game contract studies. Chapter XV *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

Behrens, D.W. 1979. NPDES monitoring program. Chapter XVI *in* Warrick, J.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1975-1977, Volume I. PG&E, Dept. Engr. Res. July 1979.

June 1981 Report

Banuet-Hutton, E.A. 1981. Oceanographic stations. Chapter I *in* Behrens, D.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1978. PG&E, Dept. Engr. Res. June 1981.

Safaie, B. 1981. Mixing of horizontal buoyant surface jet over sloping bottom. Chapter II *in* Behrens, D.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1978. PG&E, Dept. Engr. Res. June 1981.

Volker, W., Harmes, and R.L. Wiegel. 1981. Dye vector flow visualization, cooling water model. Chapter III *in* Behrens, D.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1978. PG&E, Dept. Engr. Res. June 1981.

Mayer, Dr. D.L., Dr. P.A. Lebednik, and P.J. Selak. 1981. 316(a) demonstration studies at Diablo Canyon Nuclear Power Plant. Chapter IV *in* Behrens, D.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1978. PG&E, Dept. Engr. Res. June 1981.

Wilson, T.C. 1981. Zooplankton entrainment mortality resulting from mechanical stress at the Diablo Canyon Nuclear Power Plant. Chapter V *in* Behrens, D.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1978. PG&E, Dept. Engr. Res. June 1981.

Behrens, D.W. 1981. NPDES monitoring program and toxicity studies at Diablo Canyon. Chapter VI *in* Behrens, D.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1978. PG&E, Dept. Engr. Res. June 1981.

Benech, S.V. 1981. Observations of the sea otter *Enhydra lutris* population between Coon and Rattlesnake Creeks. Chapter VII *in* Behrens, D.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1978. PG&E, Dept. Engr. Res. June 1981.

North, Dr. W.J., E.K. Anderson, and F.A. Chapman. 1981. W.J. North marine ecological transect studies. Chapter VIII *in* Behrens, D.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1978. PG&E, Dept. Engr. Res. June 1981.

Szalinski, P.A. 1981. Off-site radiological monitoring program. Chapter IX *in* Behrens, D.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1978. PG&E, Dept. Engr. Res. June 1981.

Gotshall, D.W., L.L. Laurent, F.E. Wendell, and J.J. Grant. 1981. Diablo Canyon Power Plant site ecological study annual report - July 1, 1976 - June 30, 1977; and Quarterly report no. 16- April 1, 1977 - June 30, 1977. Chapter X *in* Behrens, D.W. and E.A. Banuet-Hutton (eds.), Environmental investigations at Diablo Canyon, 1978. PG&E, Dept. Engr. Res. June 1981.

<u>December 1981 Report</u>

White, C.W. 1981. Oceanographic studies. Chapter I *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1979. PG&E, Dept. Engr. Res. December 1981.

Meek, Dr. R.P. 1981. Diablo Canyon continuous current measurements, June 1978 - December 1979. Chapter II *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1979. PG&E, Dept. Engr. Res. . December 1981.

Lebednik, Dr. P.A., Dr. D.L. Mayer, and P.J. Selak. 1981. Diablo Canyon Nuclear Power Plant 316(a) demonstration studies - annual report 1979. Chapter III *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1979. PG&E, Dept. Engr. Res. . December 1981.

Pimentel, Dr. R.A. 1981. Community structure emphasizing intertidal fishes in the vicinity of Diablo Cove. Chapter IV *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1979. PG&E, Dept. Engr. Res. . December 1981.

Wilson, T.C. 1981. The effect of chlorine produced oxidents and temperature on the blue rockfish, *Sebastes mystinus*. Chapter V *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1979. PG&E, Dept. Engr. Res. . December 1981.

Wiley, S.W. 1981. The effects of chlorine residuals on *Sebastes mystinus*. Chapter VI *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1979. PG&E, Dept. Engr. Res. . December 1981.

Behrens, D.W. 1981. NPDES monitoring program and toxicity studies at Diablo Canyon. Chapter VII *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1979. PG&E, Dept. Engr. Res. . December 1981.

Benech, S.V. 1981. Observations of the sea otter Enhydra lutris population between Coon and Rattlesnake Creeks. Chapter VIII *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1979. PG&E, Dept. Engr. Res. . December 1981.

Chambers, J.R. 1981. Population studies of California sea lions near Diablo Canyon, California. Chapter IX *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1979. PG&E, Dept. Engr. Res. . December 1981.

North, Dr. W.J., E.K. Anderson, and F.A. Chapman. 1981. W.J. North marine ecological transect studies. Chapter X *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1979. PG&E, Dept. Engr. Res. . December 1981.

Szalinski, P.A. 1981. Off-site radiological monitoring program. Chapter XI *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1979. PG&E, Dept. Engr. Res. . December 1981.

Sommerville, D.C. 1981. Rockfish fisheries studies in the vicinity of Diablo Canyon - a status report. Chapter XII *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1979. PG&E, Dept. Engr. Res. . December 1981.

Kelly, J.L. and D.W. Behrens. 1981. Intertidal algal faunal associations study - a progress report. Chapter XIII *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1979. PG&E, Dept. Engr. Res. . December 1981.

March 1982 Report

White, C.O. 1982. Oceanographic station, 1980. Chapter I *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1980. PG&E, Dept. Engr. Res. March, 1982.

Bordreau, R.H. 1982. Analysis of the lee eddy generated by a buoyant surface jet issuing into a crossflow over a sloping bottom: A re-entrainment problem. Chapter II *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1980. PG&E, Dept. Engr. Res. March, 1982.

Ismail-Awadalla, N. 1982. Wave-current interaction. Chapter III *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1980. PG&E, Dept. Engr. Res. March, 1982.

Lebednik, Dr. P.A., Dr. D.L. Mayer, and P.J. Selak. 1982. Diablo Canyon Nuclear Power Plant 316(a) demonstration studies - annual report 1980. Chapter IV *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1980. PG&E, Dept. Engr. Res. March, 1982.

Behrens, D.W. 1982. NPDES monitoring program and toxicity studies at Diablo Canyon - 1980. Chapter V *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1980. PG&E, Dept. Engr. Res. March, 1982.

Benech, S.V. 1982. Observations of the sea otter Enhydra lutris population between Coon and Rattlesnake Creeks, January - December 1980. Chapter VI *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1980. PG&E, Dept. Engr. Res. March, 1982.

Pimentel, Dr. R.A. and R.C. Bowker. 1982. Community structure involving intertidal fish in the vicinity of Diablo Cove: Project Report, Surveys 2 - 8, May 1979 - May 1980. Chapter VII *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1980. PG&E, Dept. Engr. Res. March, 1982.

Bowker, R.C. 1982. Community structure analysis - The Diablo Canyon intertidal red algae/eel grass community. Chapter VIII *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1980. PG&E, Dept. Engr. Res. March, 1982.

Sommerville, D.C. 1982. Fisheries investigations at Diablo Canyon - 1980 progress report. Chapter IX *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1980. PG&E, Dept. Engr. Res. March, 1982.

April 1982 Report

White, C.O. 1982. Oceanographic stations, 1981. Chapter I *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1981. PG&E, Dept. Engr. Res. April, 1982.

Ismail, Nabil M. 1982. Effects of opposing waves on the mixing of a horizontal surface momentum jet. Chapter II *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1981. PG&E, Dept. Engr. Res. April, 1982.

Monopolis, G.M. and R.H. Boudreau. 1982. Current patterns in the intake cove of the PG&E Diablo Canyon Power Plant hydraulic model. Chapter III *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1981. PG&E, Dept. Engr. Res. April, 1982.

Meek, R.P. 1982 Diablo Canyon continuous current measurements, second progress report. Chapter IV *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1981. PG&E, Dept. Engr. Res. April, 1982.

Behrens, D.W. 1982. NPDES monitoring program and toxicity studies at Diablo Canyon - 1981. Chapter V *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1981. PG&E, Dept. Engr. Res. April, 1982.

Warrick, J.W. and D.W. Behrens. 1982. Bibliography of environmental studies at Diablo Canyon. Chapter VI *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1981. PG&E, Dept. Engr. Res. April, 1982.

Benech, S.V. 1982. Observations of the sea otter Enhydra lutris population between Coon and Rattlesnake Creeks, January - December 1981. Chapter VII *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1981. PG&E, Dept. Engr. Res. April, 1982.

Walton, B. 1982. Peregrine falcon observations - 1981. Chapter VIII *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1981. PG&E, Dept. Engr. Res. April, 1982.

Wishard, Dr. L. 1982. A biochemical genetic analysis of *Sebastes carnatus* and *Sebastes chysomelas* from Diablo Canyon, California. Chapter IX *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1981. PG&E, Dept. Engr. Res. April, 1982.

Sommerville, D.C. 1982. Fisheries investigations at Diablo Canyon - 1981. Chapter X *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1981. PG&E, Dept. Engr. Res. April, 1982.

North, Dr. W.J., E.K. Anderson, and F.A. Chapman. 1982. W.J. North marine ecological studies: 1980, 1981. Chapter XI *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1981. PG&E, Dept. Engr. Res. April, 1982.

Laurent, L.L., D.W. Gotshall, S.L. Owen, and D.L. Vaughan. 1982. Diablo Canyon Power Plant site ecological study report: January 1, 1979 - June 30, 1980. Chapter XII *in* Behrens, D.W. (ed.), Environmental investigations at Diablo Canyon, 1981. PG&E, Dept. Engr. Res. April, 1982.

1983 Report

White, C.O. 1983. Oceanographic stations, 1982. Chapter I *in* Behrens, D.W (ed.), Environmental investigations at Diablo Canyon, 1982. PG&E, Dept. Engr. Res. June, 1983.

White, C.O. 1983. Diablo Canyon Power Plant nearshore seawater temperature analysis, 1978 - 1982. Chapter II *in* Behrens, D.W (ed.), Environmental investigations at Diablo Canyon, 1982. PG&E, Dept. Engr. Res. June, 1983.

White, C.O. 1983. Seawater densities in the vicinity of Diablo Canyon Power Plant, 1977 - 1982. Chapter III *in* Behrens, D.W (ed.), Environmental investigations at Diablo Canyon, 1982. PG&E, Dept. Engr. Res. June, 1983.

White, C.O. and E.M. Kenzler. 1983. Diablo Canyon Power Plant dye tracer simulation of heat treatment plume dispersion. Chapter IV *in* Behrens, D.W (ed.), Environmental investigations at Diablo Canyon, 1982. PG&E, Dept. Engr. Res. June, 1983.

Meek, R.P. 1983. Diablo Canyon continuous current measurements, June 1979 - April 1982. Chapter V *in* Behrens, D.W (ed.), Environmental investigations at Diablo Canyon, 1982. PG&E, Dept. Engr. Res. June, 1983.

Kendall, T.R. 1983. A three dimensional study of circulation patterns in Diablo Cove caused by the cooling water discharge and coastal currents: PG&E Diablo Canyon, California Power Plant hydraulic model. Chapter VI *in* Behrens, D.W (ed.), Environmental investigations at Diablo Canyon, 1982. PG&E, Dept. Engr. Res. June, 1983.

Behrens, D.W. 1983. NPDES monitoring program and toxicity studies at Diablo Canyon - 1982. Chapter VII *in* Behrens, D.W (ed.), Environmental investigations at Diablo Canyon, 1982. PG&E, Dept. Engr. Res. June, 1983.

Pimentel, R.A. and R.C. Bowker. 1983. Intertidal community structure analysis: An evaluation of the performance of selected subsets of Diablo Cove intertidal data analyzed by reciprocal averaging. Chapter VIII *in* Behrens, D.W (ed.), Environmental investigations at Diablo Canyon, 1982. PG&E, Dept. Engr. Res. June, 1983.

Tissot, B.N. and J.R. Steinbeck. 1983. A study of microgeographic variation in *Collisella digitalis* in Diablo Cove, California. Chapter IX *in* Behrens, D.W (ed.), Environmental investigations at Diablo Canyon, 1982. PG&E, Dept. Engr. Res. June, 1983.

North, Dr. W.J., E.K. Anderson, and F.A. Chapman. 1983. W.J. North marine ecological transects: 1982. Chapter X *in* Behrens, D.W (ed.), Environmental investigations at Diablo Canyon, 1982. PG&E, Dept. Engr. Res. June, 1983.

Benech, S.V. 1983. Observations of the sea otter Enhydra lutris population between Coon and Rattlesnake Creeks, January - December 1982. Chapter XI *in* Behrens, D.W (ed.), Environmental investigations at Diablo Canyon, 1982. PG&E, Dept. Engr. Res. June, 1983.

Bennett, C., D. Thompson, and B. Walton. 1983. Peregrine falcon observations - 1982. Chapter XII *in* Behrens, D.W (ed.), Environmental investigations at Diablo Canyon, 1982. PG&E, Dept. Engr. Res. June, 1983.

Behrens, D.W. 1983. Observations of the gray whale migration in the vicinity of Diablo Canyon: 1981 - 1982 migration. Chapter XIII *in* Behrens, D.W (ed.), Environmental investigations at Diablo Canyon, 1982. PG&E, Dept. Engr. Res. June, 1983.

Sommerville, D.C. and S.J. Krenn. 1983. Fisheries investigations at Diablo Canyon - 1982. Chapter XIV *in* Behrens, D.W (ed.), Environmental investigations at Diablo Canyon, 1982. PG&E, Dept. Engr. Res. June, 1983.

Wilson, T.C. and S.J. Krenn. 1983. Breakwater repair marine monitoring program - 1982. Chapter XV *in* Behrens, D.W (ed.), Environmental investigations at Diablo Canyon, 1982. PG&E, Dept. Engr. Res. June, 1983.

1984 Report

White, C.O. 1984. Oceanographic stations, 1983. Chapter I *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1983. PG&E, Dept. Engr. Res. March, 1982.

Meek, R.P. 1984. Diablo Canyon continuous current measurements, July 1982 - June 1983. Chapter II *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1983. PG&E, Dept. Engr. Res. March, 1982.

Murdoch, M.A. 1984. Hydraulic model tests performed to check validity of recirculating cooling water model theory. Chapter III *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1983. PG&E, Dept. Engr. Res. March, 1982.

Behrens, D.W. 1984. NPDES monitoring program and toxicity studies at Diablo Canyon - 1983. Chapter IV *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1983. PG&E, Dept. Engr. Res. March, 1982.

Benech, S.V. 1984. Observations of the sea otter Enhydra lutris population between Coon and Rattlesnake Creeks, January - December 1983. Chapter V *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1983. PG&E, Dept. Engr. Res. March, 1982.

Behrens, D.W., D.J. Sommerville, and D.C. Sommerville. 1984. Observations of the gray whale migration in the vicinity of Diablo Canyon: 1982 - 1983 migration. Chapter VI *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1983. PG&E, Dept. Engr. Res. March, 1982.

North, W.J., E.K. Anderson, and F.A. Chapman. 1984. W.J. North marine ecological transect: 1983. Chapter VII *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1983. PG&E, Dept. Engr. Res. March, 1982.

Wilson, T.C. and S.J. Krenn. 1984. Breakwater repair marine monitoring program - 1983. Chapter VIII *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1983. PG&E, Dept. Engr. Res. March, 1982.

Kelly, J.L. 1984. Master species list for biological studies at Diablo Canyon. Chapter IX *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1983. PG&E, Dept. Engr. Res. March, 1982.

Sommerville, D.C. and F.L. Steinert. 1984. Heat treatment optimization studies: annual progress report for 1983. Chapter X *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1983. PG&E, Dept. Engr. Res. March, 1982.

Pimentel, R.A. and R.C. Bowker. 1984. Diablo Canyon intertidal fish study and community structure analysis report for survey 2 through 15. Chapter XI *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1983. PG&E, Dept. Engr. Res. March, 1982.

1985 Report - Volume I

Warrick, J.W. and D.W. Behrens. 1985. Bibliography of reports and presentations on environmental studies at Diablo Canyon. Chapter I *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1984. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December, 1985.

Kelly, J.L., J.W. Warrick, and D.W. Behrens. 1985. Intertidal fish community study at Diablo Canyon Power Plant. Chapter II *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1984. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December, 1985.

Kelly, J.L. 1985. NPDES monitoring program and toxicity studies at Diablo Canyon Power Plant: 1984. Chapter III *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1984. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December, 1985.

Sommerville, D.C., F.L. Steinert, and G.R. McCumber. 1985. Heat treatment optimization studies at the Diablo Canyon Power Plant. Chapter IV *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1984. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December, 1985.

Krenn, S.J. and T.C. Wilson. 1985. Breakwater repair marine monitoring program: 1984. Chapter V *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1984. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December, 1985.

North, W.J., E.K. Anderson, and F.A. Chapman. 1985. W.J. North marine ecological transect: 1984. Chapter VI *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1984. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December, 1985.

Sommerville, D.C. and S.E. Gibbs. 1985. Analysis of the party boat sportfishery in the vicinity of Diablo Canyon, San Luis Obispo County, California. Chapter VII *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1984. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December, 1985.

Benech, S.V. 1985. Observations of the sea otter Enhydra lutris population between Point Buchon and Rattlesnake Creek, San Luis Obispo, California, January - December 1984. Chapter VIII *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1984. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December, 1985.

Behrens, D.W., P.A. Dunn, and D.C. Sommerville. 1985. Observations of the gray whale migration in the vicinity of Diablo Canyon: 1983 - 1984 migration. Chapter IX *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1984. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December, 1985.

1985 Report - Volume II

White, C.O. 1985. Oceanographic studies, 1984. Chapter I *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1984. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December, 1985.

Meek, Dr. R.P. 1985. Diablo Canyon continuous current measurements, July 1983 - June 1984. Chapter II *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1984. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December, 1985.

White, C.O. 1985. Summarization of wave data measured offshore of Diablo Canyon. Chapter III *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1984. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December, 1985.

Ryan, Dr. P.J. and Dr. S.W. Tu. 1985. Diablo Canyon discharge structure hydraulic model crossflow studies. Chapter IV *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1984. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December, 1985.

Ryan, Dr. P.J. and L. Miller. 1985. Diablo Canyon surface heat treatment experiment. Chapter V *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1984. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December, 1985.

Johnson, T.L. 1985. Transient effects and heat buildup in the physical model of the cooling water intake and discharge system of the Pacific Gas and Electric Nuclear Power Plant, Diablo Canyon, California. Chapter VI *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1984. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December, 1985.

Bertolotti, Andrea. 1985. Model study of the thermal plume discharge geometry and zone of bottom contact, temperatures, and water motions within Diablo Cove, Diablo Canyon, California. Chapter VII *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1984. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December, 1985.

1986 Report - Volume I

North, W.J., F.A. Chapman, and E.K. Anderson. 1986. W.J. North marine ecological transect: 1985. Chapter I *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1985. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1986.

Gibbs, S.E. and D.C. Sommerville. 1986. Fisheries investigations at Diablo Canyon - 1985. Chapter II *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1985. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1986.

Sommerville, D.C. 1986. Development of a site specific biofouling control program for the Diablo Canyon Power Plant. Chapter III *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1985. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1986.

Behrens, D.W. and J.L. Kelly. 1986. Space and habitat resource creation in four species of intertidal red algae. Chapter IV *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1985. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1986.

Schlotterbeck, R.E. 1986. Management options for the control of attached and drift macroalgae adjacent to the cooling water intake at Diablo Canyon Power Plant. Chapter V *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1985. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1986.

Krenn, S.J. and T.C. Wilson. 1986. Diablo Canyon artificial reef project - 1985 studies.. Chapter VI *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1985. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1986.

Benech, S.V.. 1986. Observations of the sea otter Enhydra lutris population between Point Buchon and Rattlesnake Creek, San Luis Obispo, California, January - December 1985. Chapter VII *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1985. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1986.

Behrens, D.W. and K.E. Shaffer. 1986. Observations of the gray whale migration in the vicinity of Diablo Canyon: 1984 - 1985 migration. Chapter VIII *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1985. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1986.

Walton, B.J. 1986. Peregrin falcon activity at Diablo Canyon, 1981 - 1985. Chapter IX *in* Behrens, D.W. and C.O. White (eds.), Environmental investigations at Diablo Canyon, 1985. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1986.

1986 Report - Volume II

White, C.O. 1986. Oceanographic studies offshore of Diablo Canyon Power Plant, 1985. Chapter I *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1985. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December 1986.

Meek, Dr. R.P. 1986. Diablo Canyon continuous current measurements, July 1984 - June 1985. Chapter II *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1985. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December 1986.

Safaie, Dr. B.A. 1986. Study of nearshore current, wind, and tide in the vicinity of Diablo Canyon, California. Chapter III *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1985. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December 1986.

White, C.O. 1986. Summarization of wave data measured offshore of Diablo Canyon. Chapter IV *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1985. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December 1986.

White, C.O. and L.L. Day. 1986. Seawater densities in the vicinity of Diablo Canyon Power Plant, 1984 - 1985. Chapter V *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1985. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December 1986.

Leighton, J.P, Dr. S.W. Tu, A.A. Petroccitto, and L.K. Eastman. 1986. Characterization of receiving water temperatures during power ascension testing of Unit 1, Diablo Canyon Power Plant. Chapter VI *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1985. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December 1986.

Porter, B.A. 1986. Model verification study of the thermal plume discharge geometry and temperatures within Diablo Cove. Chapter VII *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1985. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December 1986.

Ryan, Dr. P.J., Dr. S.W. Tu, J.P. Leighton, and Prof. R.L. Wiegel. 1986. Hydraulic model verification test for Unit 1, Diablo Canyon Power Plant. Chapter VIII *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1985. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December 1986.

1987 Report - Volume I

Chapman, F.A., North, W.J., and E.K. Anderson. 1987. W.J. North marine ecological investigations: 1985. Chapter I *in* Behrens, D.W. and White, C.O. (eds.), Environmental investigations at Diablo Canyon, 1986. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1987.

Gibbs, S.E. and D.C. Sommerville. 1987. Diablo Canyon sportfishery monitoring program, progress report for 1986. Chapter II *in* Behrens, D.W. and White, C.O (eds.), Environmental investigations at Diablo Canyon, 1986. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1987.

Graham, J.W., D.B. Innis, D.C. Lees, W.C. Lester, F.L. Steinert, and D.C. Sommerville. 1987. Diablo Canyon Power Plant biofouling control studies and final report for phases I and II. Chapter III *in* Behrens, D.W. and White, C.O. (eds.), Environmental investigations at Diablo Canyon, 1986. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1987.

Steinbeck, J.R. 1987. A numerical analysis of the intertidal algal community of Diablo Cove, California. Chapter IV *in* Behrens, D.W. and White, C.O. (eds.), Environmental investigations at Diablo Canyon, 1986. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1987.

Walton, B.J. 1987. Peregrine falcon activity at Diablo Canyon, 1981 - 1986. Chapter V *in* Behrens, D.W. and White, C.O. (eds.), Environmental investigations at Diablo Canyon, 1986. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1987.

Behrens, D.W. 1987. Observations of the gray whale migration in the vicinity of Diablo Canyon: 1985 - 1986 migration. Chapter VI *in* Behrens, D.W. and White, C.O. (eds.), Environmental investigations at Diablo Canyon, 1986. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1987.

Benech, S.V.. 1987. Observations of the sea otter Enhydra lutris population between Point Buchon and Rattlesnake Creek, San Luis Obispo, California, January - December 1986. Chapter VII *in* Behrens, D.W. and White, C.O. (eds.), Environmental investigations at Diablo Canyon, 1986. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1987.

Krenn, S.J. and S.V. Benech. 1987. Distribution of pinniped haul-out sites in the vicinity of Diablo Canyon Power Plant, July 1973 - June 1986. Chapter VIII *in* Behrens, D.W. and White, C.O. (eds.), Environmental investigations at Diablo Canyon, 1986. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1987.

Krenn, S.J. and T.C. Wilson. 1987. Diablo Canyon artificial reef project - 1985 studies. Chapter IX *in* Behrens, D.W. and White, C.O. (eds.), Environmental investigations at Diablo Canyon, 1986. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1987.

James, D.E., J.R. Steinbeck, E.K. Anderson, and W.J. North. 1987. Use of long-term mean background temperatures to analyze changes and trends in waters off Diablo Canyon. Chapter X *in* Behrens, D.W. and White, C.O. (eds.), Environmental investigations at Diablo Canyon, 1986. Volume I - Marine ecological studies. PG&E, Dept. Engr. Res. December 1987.

1987 Report - Volume II

White, C.O. 1987. Oceanographic studies offshore of Diablo Canyon Power Plant, 1986. Chapter I *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1986. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December 1987.

Meek, Dr. R.P. 1987. Diablo Canyon continuous current measurements, July 1985 - June 1986. Chapter II *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1986. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December 1987.

White, C.O. 1987. Summarization of wave data measured offshore of Diablo Canyon. Chapter III *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1986. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December 1987.

Kenzler, E.M. 1987. Comparison of surface foam in Diablo Cove: cold versus heated jet. Chapter IV *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1986. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December 1987.

Wyman, V.L. 1987. Diablo Canyon intake approach velocity measurements. Chapter V *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1986. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December 1987.

Tu, Dr. S.W., J.P. Leighton, C.O. White, and Dr. C.C. Hsu. 1987. Surface buoyant jet characteristics of the thermal discharge plume. Chapter VI *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1986. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December 1987.

Ryan, Dr. P.J., L.P. Miller, and J. Piritz. 1987. Analysis of surface heat transfer experiments at Diablo Canyon Power Plant. Chapter VII *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1986. Volume II - Oceanographic and environmental engineering studies. PG&E, Dept. Engr. Res. December 1987.

<u>1987 Report - Volume III</u>

Wiegel, Prof. R.L. and M.J. Doyle. 1987. Hydraulic model studies model/prototype comparison 1974-1986. Chapter I *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1986. Volume III - Hydraulic model studies. PG&E, Dept. Engr. Res. December 1987.

Ryan, Dr. P.J., Dr. S.W. Tu, and Prof. R.L. Wiegel. 1987. Hydraulic model verification tests for Units 1 and 2 Diablo Canyon Power Plant. Chapter II *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1986. Volume III - Hydraulic model studies. PG&E, Dept. Engr. Res. December 1987.

Ryan, Dr. P.J., R.G. Kloepper, N. Ismail, Dr. S.W. Tu, and Prof. R.L. Wiegel. 1987. Hydraulic model tests for heat treatment conditions at Diablo Canyon Power Plant. Chapter III *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1986. Volume III - Hydraulic model studies. PG&E, Dept. Engr. Res. December 1987.

Ewing, L.C., K.O. Aiyesimoju, H.A. Basha, S. Eiger, R.G. Kloepper, R.C.H. Lou, N. Ismail, Dr. S.W. Tu, and Wiegel, Prof. R.L. 1987. Hydraulic model tests, Diablo Canyon Power Plant: comparison of 1975/75 and 1986 studies. Chapter IV *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1986. Volume III - Hydraulic model studies. PG&E, Dept. Engr. Res. December 1987.

Kloepper, R.G. 1987. Model study of the heat field and liftoff characteristics of thermal plumes with different densimetric froude numbers. Chapter V *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1986. Volume III - Hydraulic model studies. PG&E, Dept. Engr. Res. December 1987.

Lou, R.C.H. 1987. Field and model study of the dynamic behavior characteristics of the thermal discharge plume at the Diablo Canyon Power Plant. Chapter VI *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1986. Volume III - Hydraulic model studies. PG&E, Dept. Engr. Res. December 1987.

Babcock, J.D., Dr. P.J. Ryan, Dr. S.W. Tu, and V.L. Wyman. 1987. Hydraulic model study quality assurance requirements Diablo Canyon Power Plant. Chapter VII *in* White, C.O. and D.W. Behrens (eds.), Environmental investigations at Diablo Canyon, 1986. Volume III - Hydraulic model studies. PG&E, Dept. Engr. Res. December 1987.