MOSS LANDING POWER PLANT MODERNIZATION PROJECT

EVALUATION OF PROPOSED DISCHARGE SYSTEM WITH RESPECT TO THE THERMAL PLAN

Duke Energy Moss Landing, LLC
Moss Landing, California

Final Report
April 28, 2000

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EXECUTIVE SUMMARY

Duke Energy Moss Landing, LLC is proposing to repower and modernize the existing Moss Landing Power Plant (MLPP) by replacing older steam-turbine generators with combined-cycle combustion turbine generators. The project will utilize the existing seawater intake structure for retired Units 1 through 5 and the existing seawater discharge structure for Units 6 and 7.

Several new studies and evaluations were proposed to address questions regarding entrainment and thermal discharge issues related to the modernization project. A study plan, developed in coordination with the Technical Working Group established under the auspices of the Central Coast Regional Water Quality Control Board (RWQCB) for this project and these studies, was implemented in March, 1999.

Thermal studies and evaluations were designed to obtain current information on the temperature, size, and depth of the dispersed thermal discharge into Monterey Bay under varying tidal and power plant operating conditions. These studies were also designed to estimate the magnitude and extent of thermal differences of the proposed heat loading and flow volume changes. The sampling scheme data were designed to assess the thermal effects that occur in Moss Landing Harbor, Elkhorn Slough, and Monterey Bay, under present and future conditions.

The present study demonstrates that the existing discharge partially complies with the California Thermal Plan (Water Quality Control Plan for Control of Temperature in the coastal and Interstate Waters and Enclosed Bays and Estuaries of California), for new discharges in that the discharge does not exceed 4 °F above natural receiving water temperatures for more than 50 percent of the duration of a tidal cycle at the shoreline, the surface of any ocean substrate, or the ocean surface beyond 1,000 feet from the discharge system. The temperature survey data at stations halfway between the discharge and the beach show elevated temperatures 4-5 °F above receiving water temperatures at the surface during current conditions of highest plant load. These data combined with data from fixed recorder stations at the beach suggest that temperatures at the beach are generally within 4 °F of ambient during worst-case conditions, and well below this value during most of the tidal cycle.

Characterizations of future MLPP thermal plume conditions based upon this study include the following:

- The temperatures in the future thermal plume are not expected to exceed 4° F above natural water temperatures at the shoreline, the surface of any ocean substrate, or the ocean surface beyond 1,000 feet from the discharge for more than 50 percent of the duration of any complete tidal cycle.

- The maximum temperatures of the future thermal plume are not expected to exceed the natural water temperatures by more than 20 °F at any point on the ocean surface based on the vigorous mixing that occurs with surrounding ocean waters at the point of the submerged discharge.

- Under most operating conditions the future power plant will meet the Thermal Plan standard of 20°F Delta-T between the "receiving waters" and the thermal discharge. (Most exceptions will be when only the older Units 6 and 7 are operating or when all Units are operating at or near full power 24 hours per day.)

- The excursion, and therefore effect, of heated water from the future thermal plume on Moss Landing Harbor and Elkhorn Slough temperatures is expected to remain insignificant under future conditions due to the dominance of natural heating and tidal variations in these water bodies. (See pages 53-55 for other conclusions).

Given these results, it is concluded that operation of MLPP with the proposed modifications will comply with the Thermal Plan for new facilities in all aspects with regard to the 4 °F requirement for conditions within the environment of the receiving waters. Because, the maximum temperature of the thermal discharge will exceed the natural temperature of the receiving water by more than 20 °F under the very limited conditions described above, Duke Energy is requesting an exception to the Thermal Plan for this standard. For this reason, as requested by the RWQCB, the report includes an analysis of alternatives and modifications available for achieving full compliance with Thermal Plan requirements.

The analysis included alternatives to the proposed cooling water discharge for the new combined cycle (CC) units at MLPP, modifications to the existing discharge system, and modifications to MLPP operations after installation of the new CC units. Each alternative was evaluated in terms of its effectiveness in achieving the Thermal Plan standards, feasibility of application at the Moss Landing location, secondary impacts including environmental impacts, and the benefits realized in proportion to the economic costs.

The following alternatives were evaluated:

1. A new, separate offshore discharge for once-through cooling water from the new CC units.
2. Mechanical draft cooling towers
3. Natural draft cooling tower
4. Air cooled condensers
5. Increased once-through cooling water pumping rate for the CC units to reduce the temperature of the combined Units 6 and 7 plus CC units discharge
6. Generation curtailment of Units 6 and 7 to limit the maximum 24-hour average cooling water discharge temperature

This review of alternatives for achieving full compliance with the requirements of the Thermal Plan for new facilities concludes that there are no reasonable alternatives for implementation at the proposed MLPP modernization project. The only component of the proposed discharge that results in it being characterized as “new” is the addition of the cooling water from the new CC units, and that component of the discharge will be in full compliance with all requirements of the Thermal Plan. Even with the blending of the discharge water from the existing and proposed units, the discharge will be in compliance with the 4 ºF requirement of the Thermal Plan at all times, and of the 20 ºF requirement much of the time. Also, as has been concluded in the past, and again in this report, the beneficial uses, including a balanced indigenous community of organisms, of the receiving water have been, and will continue to be protected by the existing cooling water discharge structure. Therefore, considering the near full compliance with the Thermal Plan for new discharges, the protection of beneficial uses, and the high capital, operating, environmental, and other societal costs, there are no sound reasons to implement any of the available alternatives.

As part of the overall thermal discharge evaluation, the RWQCB requested an evaluation and comparison of the differences in thermal discharge effects between historical (with and without the operation of Units 1-5) and new operation conditions. Data available from existing reports and confirmatory studies and evaluations presented in this report have provided a set of findings that are useful in assessing the potential biological effects of the modernized MLPP thermal discharge. These support the following conclusions:

- Results of past thermal plume studies at peak power plant loading still provide a solid basis for understanding the distribution and dispersion of discharge surface plumes and an absence of significant thermal effects.

- The plume dispersion figures in this report depict the magnitude and extent of the thermal plumes with respect to available data from both past and recent thermal discharge studies.

- Findings from past marine biological studies of MLPP thermal effects showed no effects on intertidal mudflat, eelgrass, or sandy beach habitats.

- Results from previous extensive studies of the historical Units 1 through 5 discharge in Elkhorn Slough demonstrated an attraction of adult fishes.

- Because the thermal plume from the discharge into Monterey Bay is a surface phenomenon, there is little possibility of thermal effects on the area's subtidal habitats (benthos) deeper than 2-3 meters.

- Studies conducted at peak operating conditions revealed almost no thermal effects, which strongly indicates a lack of potential appreciable harm from the modernization project’s offshore discharge in Monterey Bay, even at 100 percent generating capacity.

- As has been the case in the past, the proposed combined discharge of Units 6 and 7 and the combined-cycle units in Monterey Bay will continue to protect beneficial uses of the receiving water, and will assure the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife in and on the receiving waters.

1.0 INTRODUCTION

1.1 Proposed Project

Duke Energy Moss Landing, LLC is proposing to repower and modernize the existing Moss Landing Power Plant (MLPP) by replacing older steam-turbine generators with combined-cycle combustion turbine generators. The project is located within the existing MLPP site, 12 miles northwest of Salinas, California in Monterey County near the Moss Landing Harbor, in an area that includes industrial facilities, agricultural lands, sparse residences, recreational beaches, and tidal wetlands.

The project involves installation of two 530-megawatt (MW) combined-cycle units with an overall capacity of 1,060 MW, plus installation of four exhaust stacks and removal of eight existing stacks formerly used for Units 1 through 5 (retired from service by Pacific Gas and Electric [PG&E] in 1995). In addition to the new combined-cycle units, the project also includes steam turbine rotor upgrades of existing Units 6 and 7, which will produce an additional 15 MW per unit (a total increase of 30 MW).

The project will utilize the existing seawater intake structure for retired Units 1 through 5 and the existing seawater discharge structure for Units 6 and 7. Cooling water for the new combined-cycle units will be provided using seawater from the existing intake structure for retired Units 1 through 5, which will be modified to incorporate additional features of "best technology available" (BTA) (EPA 1976). The maximum cooling water flow rate is expected to be approximately 250,000 gallons per minute (gpm) for the two new combined-cycle units and 600,000 gpm for Units 6 and 7. The new units will be designed to tie into the existing seawater discharge structures for Units 6 and 7 and thereby avoid using the discharge to Elkhorn Slough that previously served Units 1-5. Under peak power production, the project will result in the discharge of an estimated 850,000 gpm via the existing discharge structures currently used for Units 6 and 7. The design (historic), actual (current) and projected specifications of the cooling water system at MLPP are summarized in Table 1-1. A comparison of average and maximum generating loads, cooling water flow, and heat loads from past and projected operations is provided in Table 1-2.

Table 1-1. Historic, Current, and Projected Specifications of the Cooling Water Systems at MLPP.

	Historic (Design)	Current (Actual)	Projected[1] (AFC Design as Revised)
Units 1 through 5/Combined Cycle Intake			
Intake Flow Rate	381,000 (gpm) 1,441 (m^3/min)	No Cooling Water	250,000 (gpm) 946 (m^3/min)
Approach Velocity @ MLLW	0.7 (fps) 0.2 (mps)		0.5 (fps) 0.2 (mps)
Tunnel Length	350 (ft) 107 (m)		~10 (ft) ~3 (m)
Screens	Vertical Traveling		Inclined Traveling
Units 1 through 5/Combined Cycle Discharge			
Discharge Location	Elkhorn Slough	No Cooling Water	Monterey Bay
Total Design Flow Rate	381,000 (gpm) 1,441 (m^3/min)		250,000 (gpm) 946 (m^3/min)
Maximum Through-Plant Instantaneous Temperature Increase	18-26 (°F) [2] 10.0–14.4 (°C)		20 (°F) 11.1 (°C)
Average Maximum Through-Plant Temperature Increase	20.1 (°F) [3] 11.2 (°C)		20 (°F) 11.1 (°C)
Generating Capacity (MW)	613		1,060
Maximum Discharge Heat Load (Million Btu/min)	63.9		41.7
Units 6 and 7 Intake			
Intake Flow Rate	600,000 (gpm) 2,270 (m^3/min)	532,000 (gpm)[7] 2,013 (m^3/min)	600,000 (gpm) 2,270 (m^3/min)
Approach Velocity	0.8 (fps) 0.24 (mps)	0.7 (fps) 0.21 (mps)	0.8 (fps) 0.24 (mps)
Tunnel Length	~10 (ft) ~3 (m)	~10 (ft) ~3 (m)	~10 (ft) ~3 (m)
Screens	Vertical Traveling	Vertical Traveling	Vertical Traveling
Units 6 and 7/Combined Cycle Discharge			
Discharge Location	Monterey Bay	Monterey Bay	Monterey Bay
Total Flow Rate	600,000 (gpm) 2,270 (m^3/min)	532,000 (gpm) [7] 2,013 (m^3/min)	850,000 (gpm) [4] 3,217 (m^3/min)
Maximum In-Plant Instantaneous Temperature Increase	28 (°F) 15.6 (°C)	~36.2 (°F) [8] ~20.1 (°C)	34 (°F) [9] 18.9 (°C)
Weighted Average Maximum Through-Plant Temperature Increase[5]	Not Applicable	Not Applicable	25.6 (°F) [5] 14.2 (°C)
Total Generating Capacity (MW)	1,500	1,500	2,590
Maximum Discharge Heat Load (Million Btu/min)	140.2	128.7	182.0[6]

(1) Units 1 through 5 intake structure modified to serve the new combined-cycle plant.

(2) Design temperature rise for Units 1 through 3 was 18 °F (10.0 °C) and was 26 °F (14.4 °C) for Units 4 and 5.

(3) Weighted average temperature increase for Units 1 through 5 operating at maximum capacity.

(4) Includes 250,000 gpm (946 m^3/min) flow from new combined-cycle units.

(5) Weighted average temperature increase for upgraded Units 6 and 7 and the new combined-cycle plant, all operating at maximum capacity.

(6) Includes 41.7 Million Btu/min from new combined-cycle units. The historic maximum heat load to the Elkhorn Slough and Monterey Bay environment is reduced from 204.1 Million Btu/min to about 182.0 Million Btu/min (188.3 in the originally proposed Project) with elimination of the direct discharge of cooling water to Elkhorn Slough.

(7) The current condition of the circulating water pumps is degraded due to age. These pumps are rated at 150,000 gpm (568 m^3/min) each for a total of 600,000 gpm (2,270 m^3/min). These pumps will be replaced to restore the rated circulating water flow.

(8) Maximum in-plant instantaneous temperature measured at a condenser outlet. It is not sustained and is also higher than design partially due to reduced cooling flow from degraded pumps.

(9) Maximum in-plant instantaneous temperature measured at a condenser outlet. It is not sustained and is also higher than design. It could occur only when Units 6 and/or 7 are operating, not with the combined-cycle units operating.

Table 1-2. Comparison of MLPP Average and Maximum Cooling Water Flows and Generating Loads.

Averaging Period	Operating Units	Power Generation (MW)	Cooling Water Flow Rate	Heat Load (million Btu/min)
Present Permitted Operations	1 – 7	2,080	1,007,000 gpm 3,812 m^3/min	238.0
9/71 – 8/72[(1)]	1 – 7	1,186	551,000 gpm 2,086 m^3/min	112.3
11/78 – 3/80[(2)]	1 – 7	1,198	784,000 gpm 2,967 m^3/min	113.4
1998 Annual Average[(3)]	6 & 7	597	462,000 gpm 1,749 m^3/min	42.4
Future Average[(4)]	2 new CC units + Upgraded Units 6 & 7	1,566	525,000 gpm[(5)] 1,987 m^3/min	93.6
Future Permitted (Maximum)	2 new CC units + Upgraded Units 6 & 7	2,590	850,000 gpm 3,217 m^3/min	182.0[(6)]

(1) Period of historic thermal, benthic and adult fish studies.

(2) Period of supplemental larval fish and larval invertebrate studies.

(3) Values reported in 1998 NPDES Self Monitoring Report for MLPP, average power generation estimated from capacity factors shown in AFC Table 6.5-2.

(4) Assumes new CC units operate 90 % of the time at 100 % load, and Units 6 and 7 operate 50% of the time at 80% load.

(5) This is an average under the conditions assumed in Footnote 4, not a specific operating mode. Depending on power plant operations, flows could vary from 125,000 (473 m^3/min) to 850,000 gpm (3,217 m^3/min).

(6) This is the maximum heat loading that will exist under future worst-case conditions, as projected in Section 2.4.3.

CC = Combined Cycle

The addition of the new units' cooling water discharge to the existing Units 6 and 7 discharge will lower the maximum temperature, and the average maximum temperature, of the thermal discharge and plume. The maximum temperature of the discharge, as recorded at the surge chambers, with all units operating at full power will be lower by approximately 2.4° F. This temperature reduction will be the result of the blending of 250,000 gpm of new cooling water with a maximum temperature increase of 20° F, with 600,000 gpm from Units 6 and 7 with a maximum temperature increase of 28° F.

1.2 Purpose of This Report

Under the sampling program designs and degree of analyses performed at the time, results of previous thermal and biological studies reported finding no evidence of statistically significant effects of the offshore discharge, with the exception of fishes being attracted to the discharge (PG&E, 1983). With Duke Energy's Moss Landing Power Plant modernization project proposal, several new studies were proposed to address questions regarding entrainment and thermal discharge issues related to the project. A study plan, developed in coordination with the Technical Working Group established under the auspices of the Central Coast Regional Water Quality Control Board (RWQCB) for this project and these studies, was implemented in March 1999.

Thermal discharge field studies, included in the study plan and covered in this report, include: (1) deployment of temperature recorders to provide information on the spatial and temporal nature of the plume; (2) aerial thermal imaging and synoptic boat-based temperature measurements; and (3) a study of the potential for the thermal discharges to interfere with larval fish exchange between Elkhorn Slough/Moss Landing Harbor and Monterey Bay. These studies were initiated in March, 1999.

The purpose of this report is to utilize the results of these thermal studies, in conjunction with other relevant information, to evaluate the Moss Landing Power Plant cooling water discharge system with respect to California Thermal Plan requirements. This is being done in response to a RWQCB letter dated July 21, 1999, requesting that Duke Energy provide a report, "evaluating the Moss Landing power plant discharge system with respect to the Thermal Plan requirements for new facilities."

"The report shall include:

a. An evaluation of whether the discharge systems will comply with the Thermal Plan standards for new facilities. The evaluation may be based on empirical data and plume dispersion modeling.

b. If the discharge system will not comply with the Thermal Plan standards, Duke Energy shall include an analysis of alternatives and modifications available for achieving compliance. The analysis shall include alternatives to the current discharge system, modifications to the existing discharge system, and modifications to power plant operations. The analysis shall include costs of available alternatives and modifications.

c. An evaluation and comparison of the differences in thermal discharge effects between historical (with and without the operation of Units 1-5) and new operation conditions. This evaluation may be based on empirical data and plume dispersion modeling.

This report is submitted in response to that request.

2.0 COMPLIANCE WITH THERMAL PLAN

Thermal studies were designed to obtain current information on the temperature, size, and depth of the dispersed thermal discharge under varying tidal and power plant operating conditions. These studies were also designed to allow for the estimation of the magnitude and extent of thermal differences that might occur when the proposed heat loading and flow volume changes are implemented. The sampling scheme was designed to include data needed to assess the thermal effects, that occur in Moss Landing Harbor, Elkhorn Slough, and Monterey Bay under present and future conditions.

2.1 Background

Previous thermal imaging studies of the discharge from the MLPP were conducted over the period of 1971 through 1972. The results of these studies were summarized by PG&E in a report titled *An Evaluation of the Effect of Cooling Water Discharges on the Beneficial Uses of Receiving Waters at the Moss Landing Power Plant* (PG&E, 1973). During these studies, discharges of cooling water from the power plant were taking place both into Monterey Bay and Elkhorn Slough.

Those studies, which evaluated the combined thermal plumes from the two discharges (Units 1-5 to Elkhorn Slough and Units 6 and 7 to Monterey Bay), did not occur under conditions representative of proposed future conditions, since Duke Energy will not discharge cooling water into Elkhorn Slough with the proposed plant modernization. Stormwater will continue to be discharged through the old Units 1-5 discharge, however, in accordance with the permitted Stormwater Pollution Prevention Control Plan.

PG&E (1973) concluded that "there has been no impact of the operation of Units 6 and 7 on the beneficial uses of Monterey Bay" (page V-2). Since that time, there have been no changes in the operation of Units 6 and 7 cooling system discharge. Furthermore, the existing waste discharge requirements for the MLPP (Order 95-22; NPDES No. CA 0006254) find that the present thermal discharge limitations for the Units 6 and 7 discharge "are adequate to assure protection of the beneficial uses of Monterey Bay."

2.2 Continuous Thermal Plume Monitoring Data

The thermal field monitoring plan for the present study included the placement of constantly recording temperature sensors at the locations shown in Figure 2-1 and described in Table 2-1. Six recorders were deployed in the first week of March 1999 and, based on discussions with the RWQCB and their consultants, 14 more recorders were subsequently deployed. These locations were chosen to obtain information on daily temperature fluctuations in background areas and in areas where heated water might possibly encroach. In most locations, recorders were fixed to a piling or a rock at a depth of 2 or 6 feet below MLLW. In the case of the Navigation Buoy near the discharge (Station ML11) and the floating docks in the Harbor (Stations ML04, ML05, and ML06), the temperature recorders were floating at the surface or 10 feet below the surface as indicated in Table 2-1.

Additional floating recorders were also deployed offshore for 24-hour periods to collect surface water temperatures at three locations during entrainment sampling. (Permanent installations offshore were not utilized due to permitting and logistical constraints.) This procedure resulted in offshore data from at least one 24-hour period per week from November 1998 through June 1999, and every other week from July through October 1999, during the year-long entrainment study, plus continuous recording at the surface and 10-foot depth at the Navigation Buoy near the discharge from March through October 1999. Temperature information from the MLPP Units 6 and 7 intake was also available from May 1999 forward.

The basic data set used in this study—hourly temperature readings from the twenty different temperature recorders around MLPP and from the MLPP Units 6 and 7 intake—are shown in Figures 2-2 – 2-4. These figures provide an overview of the available data. Analyses based on these data are presented below. Three recorder locations were abandoned early on because they were drying out during low tides. Data from these recorders are not used in the statistical calculations below. The raw data plots in Figures 2-2 – 2-4 also provide an overview of typical temperature values, and typical temperature fluctuations, in the area. There are some month-to-month variations present in the data, but most of the variability is due to daily fluctuations that are associated with tidal fluctuations. Simple duration, mean, and variability statistics for each temperature record are provided in Table 2-2.

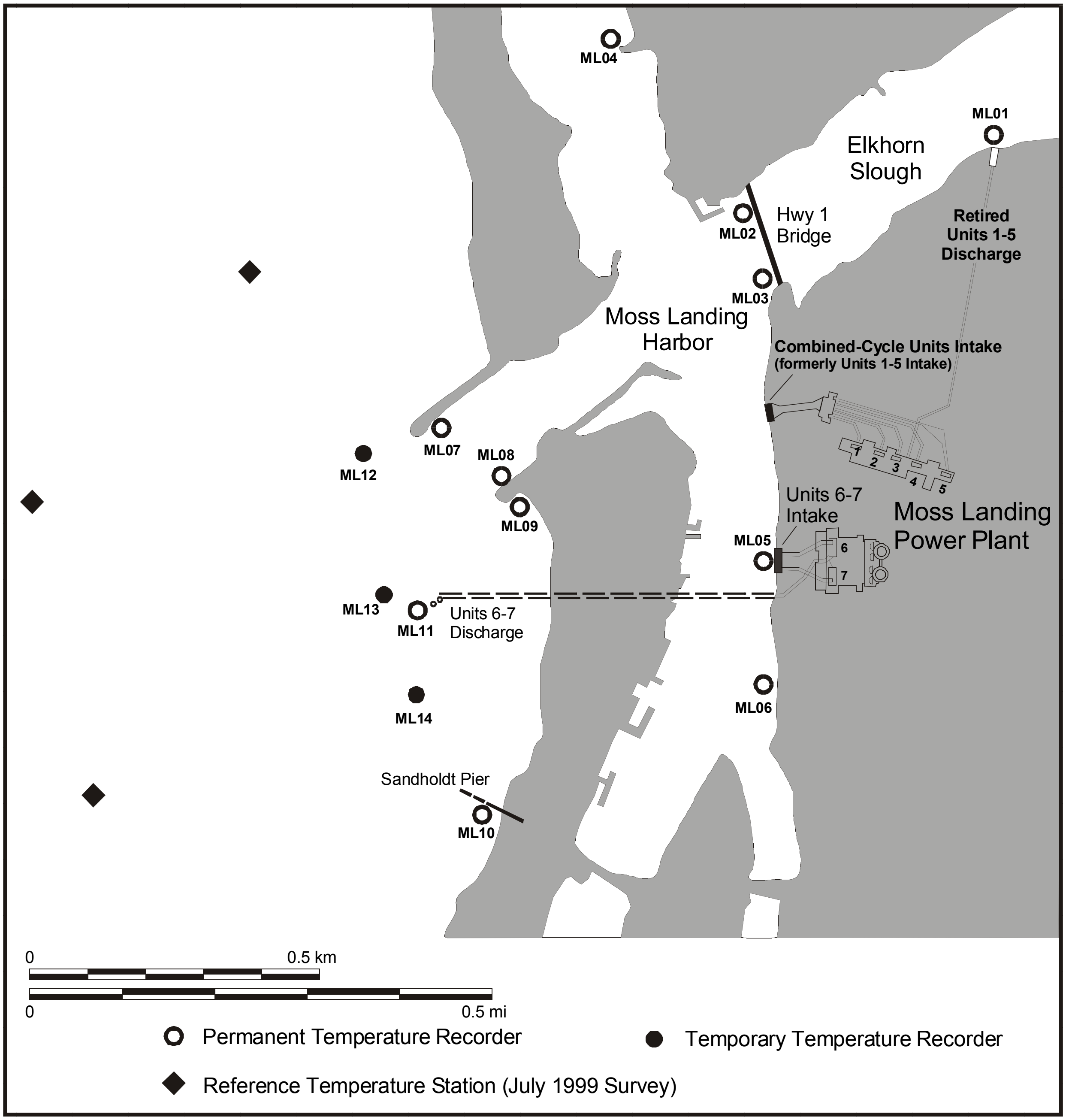


Figure 2-1. Moss Landing Power Plant temperature recorder station locations.

Table 2-1. Moss Landing Power Plant temperature recorder locations.

Station #/Depth	Station Name	Station Description	Lat / Long
ML01/02	1-5 Discharge - 2	MLPP Units 1-5 discharge structure. Approx. depth 2 ft below MLLW.	36°48.675' N / 121°46.761' W
ML01/06	1-5 Discharge - 6	MLPP Units 1-5 discharge structure. Approx. depth 6 ft below MLLW.	36°48.675' N / 121°46.761' W
ML02/02	North Bridge - 2	Piling north end of Highway 1 bridge at mouth of Elkhorn Slough. Approx. depth 2 ft below MLLW.	36°48.606'N / 121°46.083W
ML02/06	North Bridge - 6	Piling north end of Highway 1 bridge at mouth of Elkhorn Slough. Approx. depth 6 ft below MLLW.	36°48.606'N / 121°46.083W
ML02/+2	Middle Bridge +2	Piling at middle of the Highway 1 bridge at the mouth of Elkhorn Slough. Approx. +2 feet above MLLW.	Location abandoned 06/10/99.
ML03/02	South Bridge - 2	Piling south end of Highway 1 bridge at mouth of Elkhorn Slough. Approx. depth 2 ft below MLLW.	36°48.581'N / 121°46.127W
ML03/06	South Bridge - 6	Piling south end of Highway 1 bridge at mouth of Elkhorn Slough. Approx. depth 6 ft below MLLW.	36°48.581'N / 121°46.127W
ML04/00	North Harbor	Southern most tip of mooring dock for Elkhorn Yacht Club. North finger of Moss Landing Harbor. Surface.	36°48.767'N / 121°46.76W
ML05/00	6&7 Intake	South end of floating dock in front of MLPP Units 6&7 intake structure. Surface.	36°48.283'N/ 121°47.067'W
ML05/10	6&7 In-Plant Recorder	Temperature measured inside MLPP from water drawn from Approx. 10 ft below MLLW.	36°48.283'N/ 121°47.067'W
ML06/00	South Harbor	North end of floating dock on east side of the south finger of Moss Landing Harbor. Surface.	36°48.167'N/ 121°47.117'W
ML07/02	North Breakwater - 2	North Breakwater, south/channel side. Approx. depth 2 ft below MLLW.	36°48.428'N / 121°47.423'W
ML07/06	North Breakwater - 6	North Breakwater, south/channel side. Approx. depth 6 ft below MLLW.	36°48.428'N / 121°47.423'W
ML08/+2	South Breakwater +2	South Breakwater, north/channel side. Approx. depth 2 ft feet above MLLW.	Location abandoned 06/03/99.
ML08/02	South Breakwater - 2	South Breakwater, north/channel side. Approx. depth 2 ft below MLLW.	36°48.341'N / 121°47.290'W
ML08/06	South Breakwater - 6	South Breakwater, north/channel side. Approx. depth 6 ft below MLLW.	36°48.341'N / 121°47.290'W
ML09/02	Beach	South Breakwater, south side at junction with Moss Beach. Approx. depth 2 ft below MLLW.	36°48.350'N / 121°47.347'W
ML10/00	Sandholdt Pier 0	Sandholdt Pier piling. Surface.	Location abandoned 06/04/99.
ML10/02	Sandholdt Pier -2	Sandholdt Pier piling, south side. Approx. depth 2 ft below MLLW.	36°48.033'N / 121°47.383'W
ML11/00	Nav. Buoy surface	Navigation buoy at MLPP Units 6&7 discharge. Surface.	36°48.250' N / 121°47.493'W
ML11/10	Nav. Buoy - 10	Navigation buoy at MLPP Units 6&7 discharge. 10 feet below the surface.	36°48.250' N / 121°47.493'W
ML12/00	North Temp. Buoy	North temporary recorder buoy. Surface.	36°48.38' N / 121°47.51' W
ML13/00	Middle Temp Buoy	Middle/Discharge temporary recorder buoy. Surface.	36°48.22' N / 121°47.49' W
ML14/00	South Temp. Buoy	South temporary recorder buoy. Surface.	36°48.18' N / 121°47.51' W

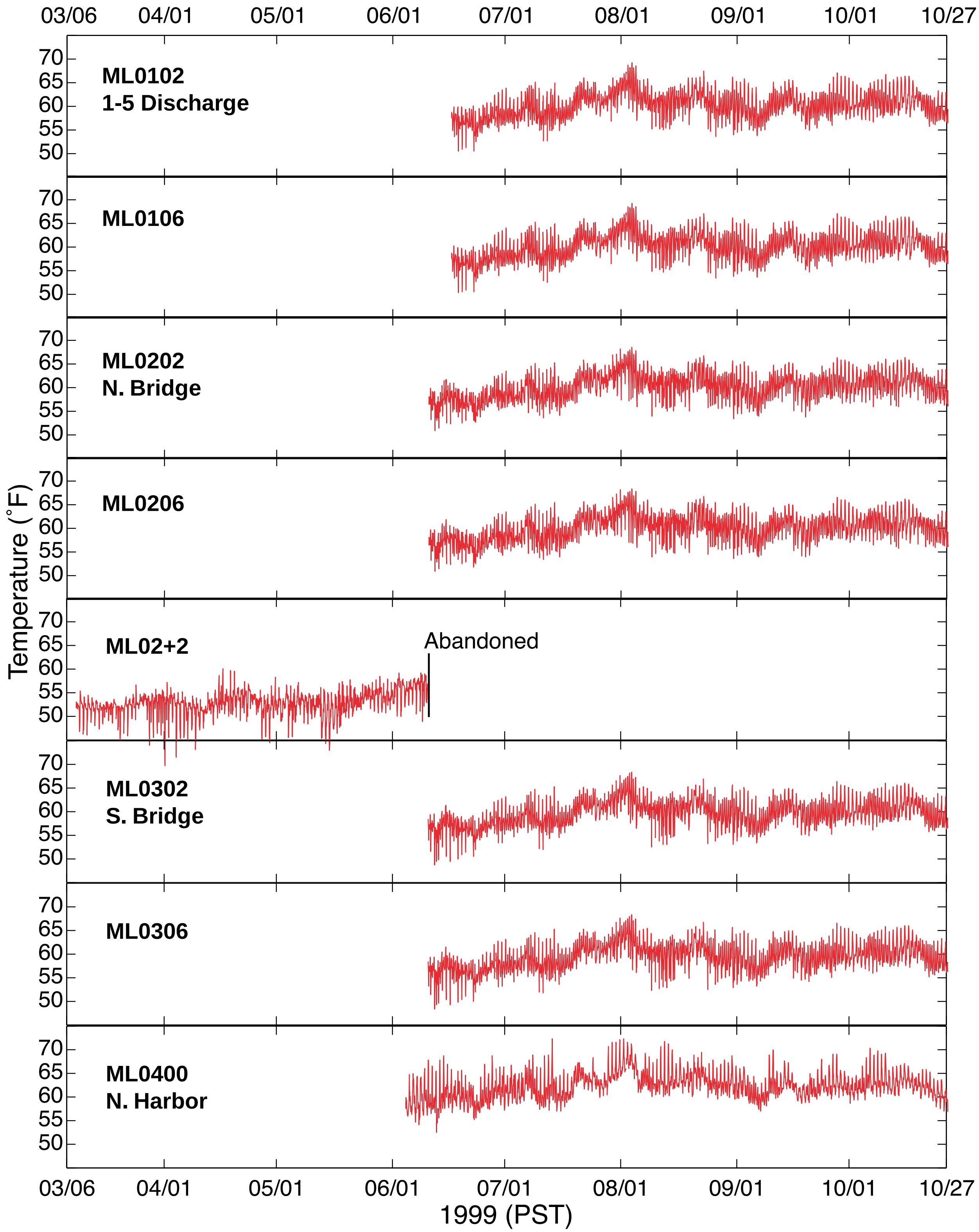


Figure 2-2. Hourly temperature observations from MLPP recording stations, March-October 1999.

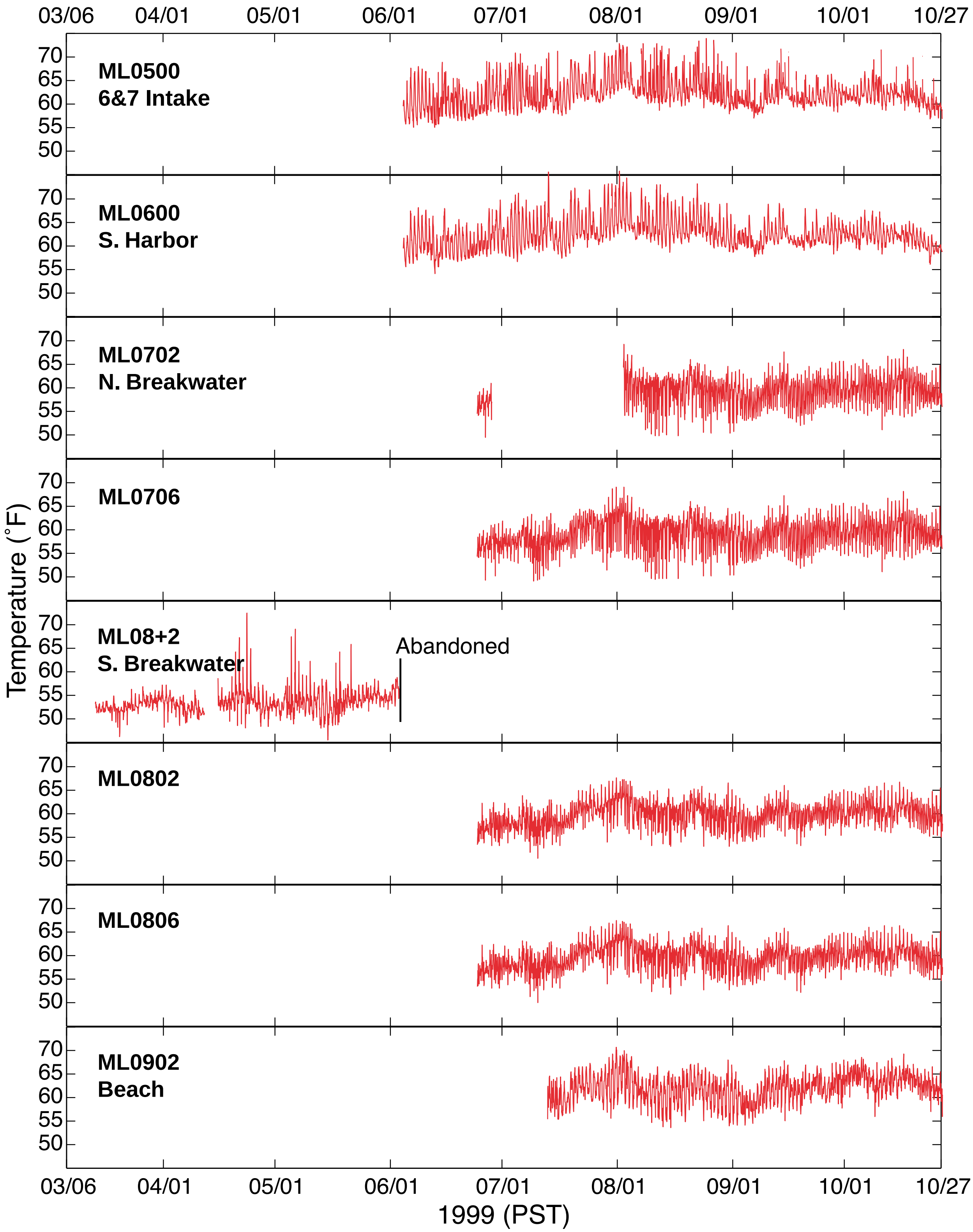


Figure 2-3. Hourly temperature observations from MLPP recording stations, March-October 1999.

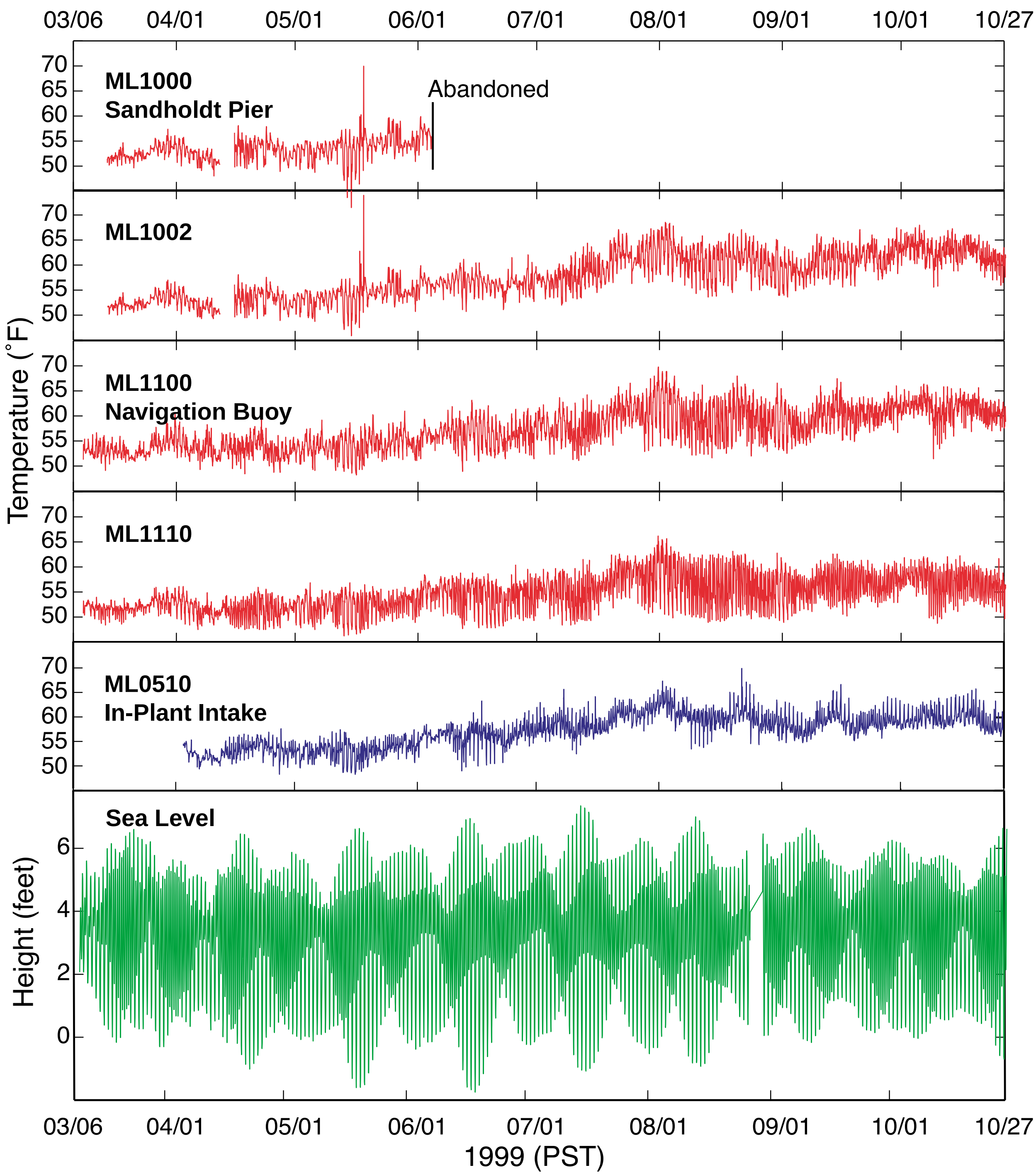


Figure 2-4. Hourly temperature observations from MLPP recording stations, MLPP Units 6 and 7 intake, and sea level at San Francisco (+1 hr), March-October 1999.

Table 2-2. **Temperature record statistics (March-October 1999).**

Station # / Depth	# of Hours	Mean (°F)	Max (°F)	Min (°F)	RMS Variability (°F)
ML01/02	3184	60.3	69.3	50.5	2.7
ML01/06	3184	60.3	69.3	50.4	2.7
ML02/02	3328	60.3	68.5	50.9	2.7
ML02/06	3328	60.1	68.4	50.9	2.7
ML03/02	3330	59.7	68.4	48.7	2.7
ML03/06	3330	59.4	68.4	48.4	2.7
ML04/00	3473	62.4	68.7	52.5	2.9
ML05/00	3446	62.2	68.5	55.0	3.1
ML05/10	4978	57.3	70.2	48.4	3.4
ML06/00	3474	62.6	68.7	54.1	3.1
ML07/02	2155	59.4	69.3	49.5	2.9
ML07/06	2996	59.2	69.1	49.1	2.9
ML08/02	3000	59.9	67.6	50.5	2.5
ML08/06	3000	59.7	67.5	50.0	2.5
ML09/02	2549	62.1	70.7	53.6	2.9
ML10/02	5357	57.7	73.9	45.9	4.3
ML11/00	5586	57.4	69.8	48.2	4.0
ML11/10	5588	54.7	66.2	46.2	3.4

In addition to the recorded temperatures, two other data sources were used in this study: hourly values of sea level and hourly values of the combined thermal output of MLPP Units 6 and 7. Sea level was taken from the San Francisco reporting station because those data were available for the entire study period at the time of this writing. Monterey Bay sea level variations lead San Francisco by, approximately, one hour, which was verified using data from March 1999 when both records were available. The entire San Francisco sea level record is shown in Figure 2-4 simply as an indicator of the available data set; detailed analyses using the data are described below. It is possible to note from the raw data, however, that sea level fluctuations in this area are dominated by semidiurnal (twice daily) highs and lows whose amplitudes are modulated by the spring-neap (fourteen day) tidal cycle.

MLPP thermal load values were used along with sea level values to establish the relative influences of the tidal variations and any possible heating due to the thermal discharge plume. The MLPP load record is not strictly periodic like the sea level record, but it does have a predominantly diurnal (daily) character. (See Figure 2-8, later).

2.3 Aerial Thermal Imaging and Boat Surveys

Aerial imaging of the thermal discharge was conducted using the Pelican aircraft from the Naval Postgraduate School's Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS). The Pelican was equipped with a remotely controlled infrared (IR) imaging camera, which provided real-time images whose brightness was proportional to sea surface temperature. The continuous IR images were recorded on videotape. The real-time imagery was also used to direct a sampling vessel toward different parts of the thermal plume.

During the first week of March 1999, six thermal imaging flights were conducted. Three additional surveys were conducted over the period of 26-27 July 1999. The flights were intended to take place during times when the power plant was operating at maximum or near maximum unit loading comparable to the 1972 study conditions. However, only one unit was in operation during the March surveys. During the July surveys, both units 6 and 7 were in full operation. The timing of the individual flights was chosen to sample a range of tidal conditions, including high, low, rising (incoming), and falling (outgoing). The maximum load plume data from the July surveys should also provide a baseline for projecting plumes under future operating conditions.

During each of the aerial surveys, in-water information was also obtained by temperature sensing equipment on a boat. Temperature data were obtained at various depths and locations from beyond the edges of the plume to the point of discharge. The boat itself was positioned relative to the discharge area by instructions relayed from personnel in the CIRPAS ground station who were viewing the real-time IR video images.

As described below, several different thermal monitoring data sets have been used to verify the conclusions drawn from previous studies, to prepare descriptions of the physical extent of the thermal plume under various oceanographic, meteorological, and power plant operating conditions, and to develop projections of the likely plume configuration under future operating conditions. The data have also been used to evaluate potential thermal effects on biological resources resulting from proposed project operating conditions, as discussed in Section 4.0.

2.4 Thermal Plume Past, Present and Future

This section depicts the present extent of the MLPP discharge thermal plume at the various fixed recorder locations under variable tidal conditions and plant loads. Based on this information and the projected future operating conditions, estimates of the future plume conditions under a worst-case scenario are also provided. Section 2.4.1 gives a depiction of the past thermal plume conditions typical of MLPP operations during the time of the studies conducted in the 1970s. At that time, discharges were made into Elkhorn Slough from Units 1-5 as well as into Monterey Bay from Units 6 and 7. Present conditions with only Units 6 and 7 operating are also representative of the past operating conditions when Units 1-5 were not operating. In Section 2.4.2, the present operating conditions are described in detail based on data from the continuous temperature recorders and from the aerial and boat surveys. The present plumes are provided at various depths under three separate tidal conditions: low tide, mid incoming tide, and high tide. In Section 2.4.3, a future peak load plume is projected for the worst case (full plant load, incoming tide) conditions.

The procedure outlined above relies on direct measurements and empirical relationships to characterize the present and future MLPP discharge thermal plume conditions. This methodology was deemed to be more appropriate than hydrodynamic modeling, which would attempt to characterize the spread and decay of warm water from the discharge using mathematical assumptions about the mixing and spreading rates in the ocean in the vicinity of the discharge. Members of the MLPP Technical Working Group, established under the auspices of the RWQCB, reviewed and provided invaluable input and comments to the study plan and earlier evaluations of the thermal discharge characterization related data. The rationale for using empirical data and mathematical projections of the empirical data rather than mathematical modeling to describe the current and future discharge plume configurations at Moss Landing is summarized by the following points:

- The months-long continuous thermal recorder data provide information on the plume and background temperatures under all combinations of tidal conditions and plant loads and flows. These data provide a good basis for plume projection based on the observed differences in the magnitude and extent of the plume under a range of thermal loads.

- The data collected were found to be remarkably consistent and predictable, showing similar patterns since continuous monitoring was initiated in March, 1999.

- The modeling experts from both coasts that were consulted believe that the behavior of the MLPP discharge structure cannot be accurately simulated by available hydrodynamic models. This is because of the unique configuration of the twin discharges, which creates more nearfield turbulence in shallow water than can be readily simulated and coupled to farfield distribution by the model algorithms. There is no assurance that even an extended original model development effort would appropriately represent this turbulence as it interacts with the already dynamic nearshore surroundings.

2.4.1 Past Thermal Plume

Figures 2-5 and 2-6, developed from 1972 thermal infrared images, show surface water temperatures when all seven units were operating at high load. Figure 2-5 is representative of temperatures under maximum combined effect (low tide) conditions in both the form of color contours from a digitized thermal image and a black and white photograph. Figure 2-6 represents the temperatures on the previous high tide, when it is possible to distinguish the effects from Units 6 and 7 discharging to Monterey Bay.

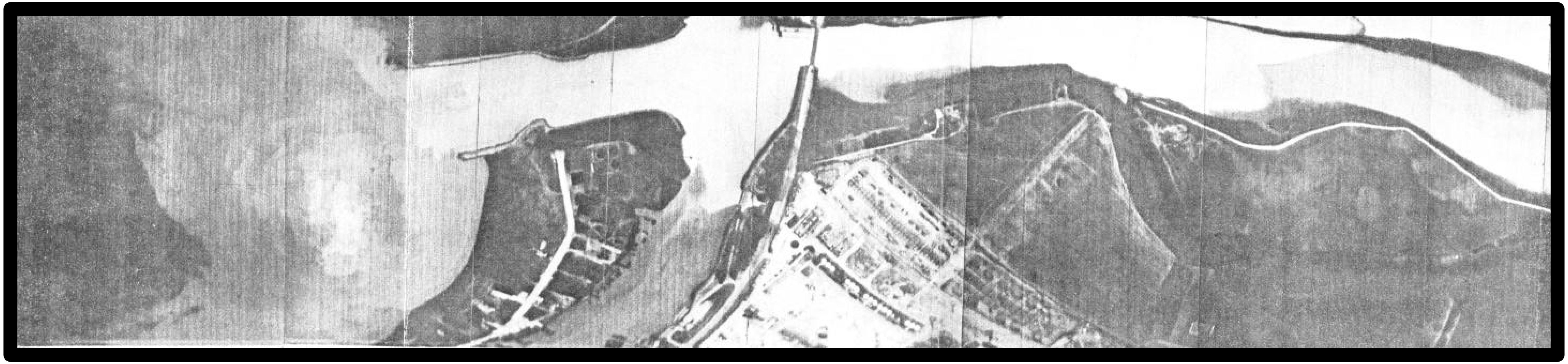
The 1972 thermal images illustrate the following:

- Units 1-5 discharge contributed to maximum surface water temperatures of up to 90 °F in Elkhorn Slough.

- Units 1-5 thermal plume crossed the entire width of the Slough on the illustrated low tide, and extended approximately 1,000 feet downstream at 75–78 °F.

- Units 1-5 thermal plume exited the Harbor on the illustrated low tide at about 66-69 °F, about 9 °F above the Monterey Bay ambient of 57-60 °F. As it mixed with the Bay water, it spread north and south in the nearshore at 63-66 °F, merging with discharged water in the same temperature range from the Units 6 and 7 discharges. This is particularly evident in the black and white photographic portion of Figure 2-5, where the

FIGURE 2-5. EXAMPLE OF HISTORIC MAXIMUM MLPP THERMAL IMPACT ON RECEIVING WATERS.



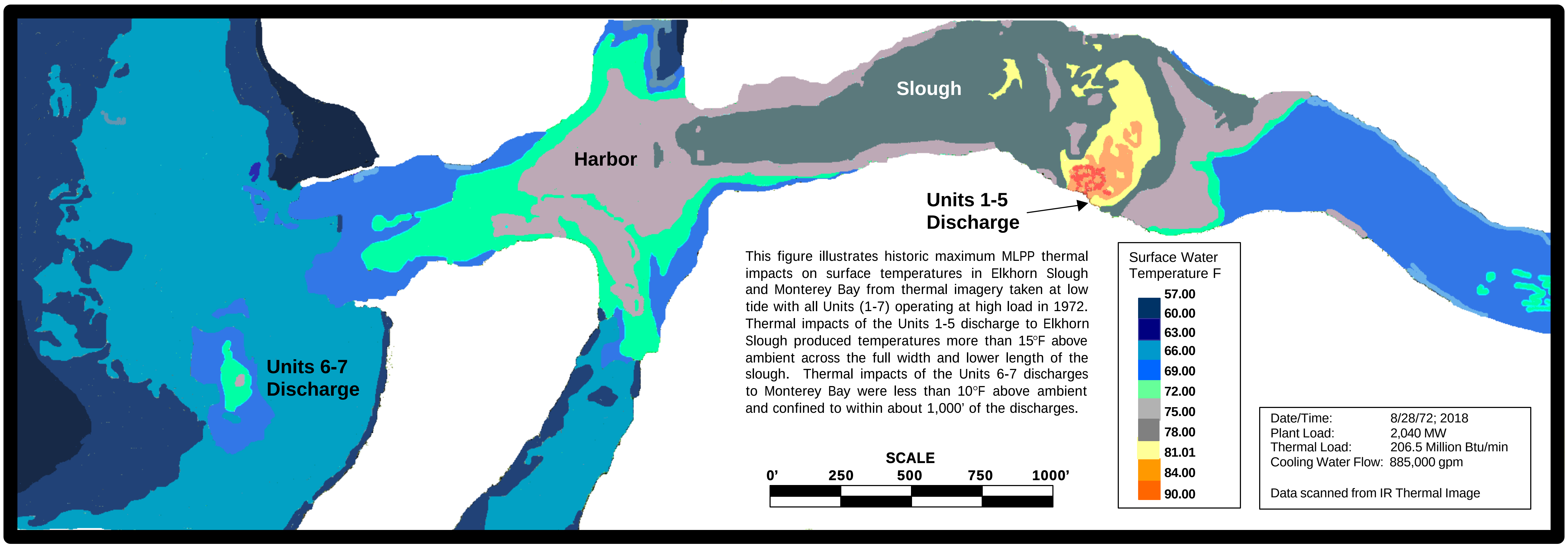
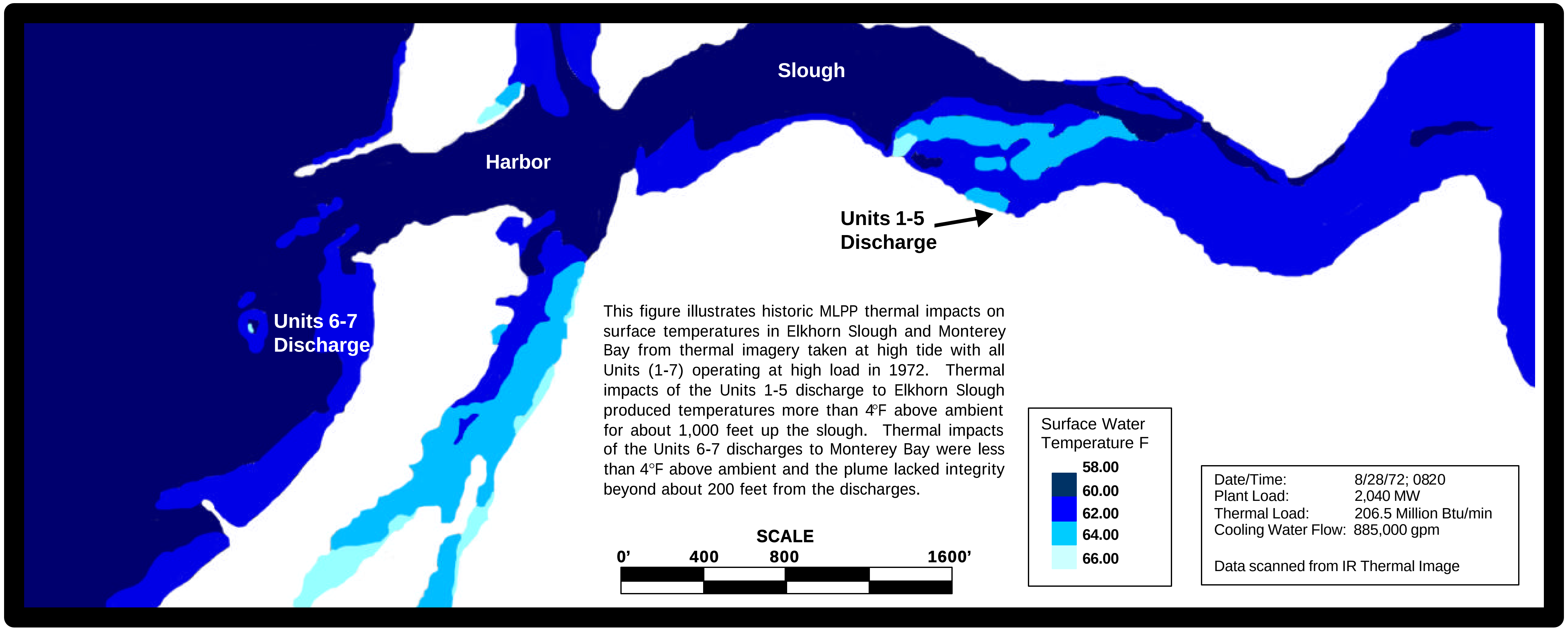


FIGURE 2-6. EXAMPLE OF HISTORIC HIGH TIDE MLPP THERMAL IMPACT ON RECEIVING WATERS.



spread of the Slough plume can be distinguished in some areas from the eastern edge of the plume from the Units 6 and 7 discharges.

- Units 6 and 7 thermal plume appears to be distinguishable to the west of the discharges on the illustrated low tide in Figure 2-5, mixing to Bay ambient within about 600 feet due west of the discharges. The signature north and south of the discharge is apparent at about 6-9 °F above ambient up to about 250 feet in each of those directions.

- Units 6 and 7 thermal plume is readily distinguishable on the illustrated high tide in Figure 2-6, losing integrity and mixing to Bay ambient within 300 feet of the discharge in all directions. Separate from this signature, water about 2 °F above ambient is also apparent along the shoreline east of the discharge. This may be related in part to earlier thermal loads from some or all of the operating units.

2.4.2 Current Thermal Plume

In this subsection, thermal data collected between March and October 1999 are used to characterize the strength and variability of the thermal plume under variable operating conditions. The present-day operating conditions shown here are also representative of the past conditions when Units 1-5 were not operating. Under full plant loads, measurements of the present-day plume are provided at various depths under three separate tidal conditions: low tide, mid incoming tide, and high tide. As outlined in Sections 2.2 and 2.3 above, the MLPP thermal data consists of five basic data sets:

1. *In situ* temperature data for March through October, 1999 from continuous recorders at the locations listed and illustrated in Figure 2-1 and Table 2-1, respectively. In addition to this, short-term (24-hour) temperature records exist from three temporary recording stations (ML12, ML13, and ML14) occupied during several larval survey periods as part of the entrainment source water sampling program.

2. Hourly sea level time series for March through October 1999.

3. Hourly records of MLPP load for March through October 1999.

4. CTD (Conductivity, Temperature, Depth) and GPS (position) measurements around the MLPP discharge made in conjunction with real-time aerial surveys on six occasions during 1-3 March 1999 and on three occasions during 26-27 July 1999. During these surveys, the boat was in constant communication with operators at the ground station at the Marina airport who directed the sampling relative to the thermal plume visible in the real-time IR images.

5. Continuous IR video imagery from the aerial surveys conducted in March and July 1999.

Statistical measurements are provided from the entire data set, but three shorter periods are given particular emphasis: 2-6 July 1999, which includes data from periods of high, medium and minimal plant operations, 25-28 July 1999, which includes periods of high plant operation coincident with boat and aerial surveys, and 21-24 October 1999, which includes an anomalous period with constant high-load conditions. Detailed presentations are not included in this report from the March 1999 surveys because they occurred during periods of relatively low MLPP load.

The long-term temperature recording stations shown in Figure 2-1 are located in three distinct geographic regimes: the open ocean around the discharge, Moss Landing Harbor, and Elkhorn Slough. The statistical analyses performed suggest that these are also three distinct temperature regimes in terms of their correlation with tides or MLPP load. Temperature fluctuations at some stations are more highly correlated with sea level fluctuations than with MLPP load, while the opposite is true for other locations.

The detailed temperature variations at several of the recording stations are shown for the periods of 2-6 July 1999, 25-28 July 1999, and 21-24 October 1999 along with sea level and MLPP load, in Figure 2-7, Figure 2-8, and Figure 2-9, respectively. At all locations, tidal exchange exerts a strong influence on temperature. Water temperatures rise on the falling tide as warm inland water from the shallow reaches of Elkhorn Slough replaces water in the portion of Elkhorn Slough closest to the ocean, as well as water in Moss Landing Harbor and water just offshore of the Harbor entrance along the open-ocean shoreline. This process is essentially the same as illustrated in the 1972 low tide thermal image (Figure 2-5), except that the magnitude of change

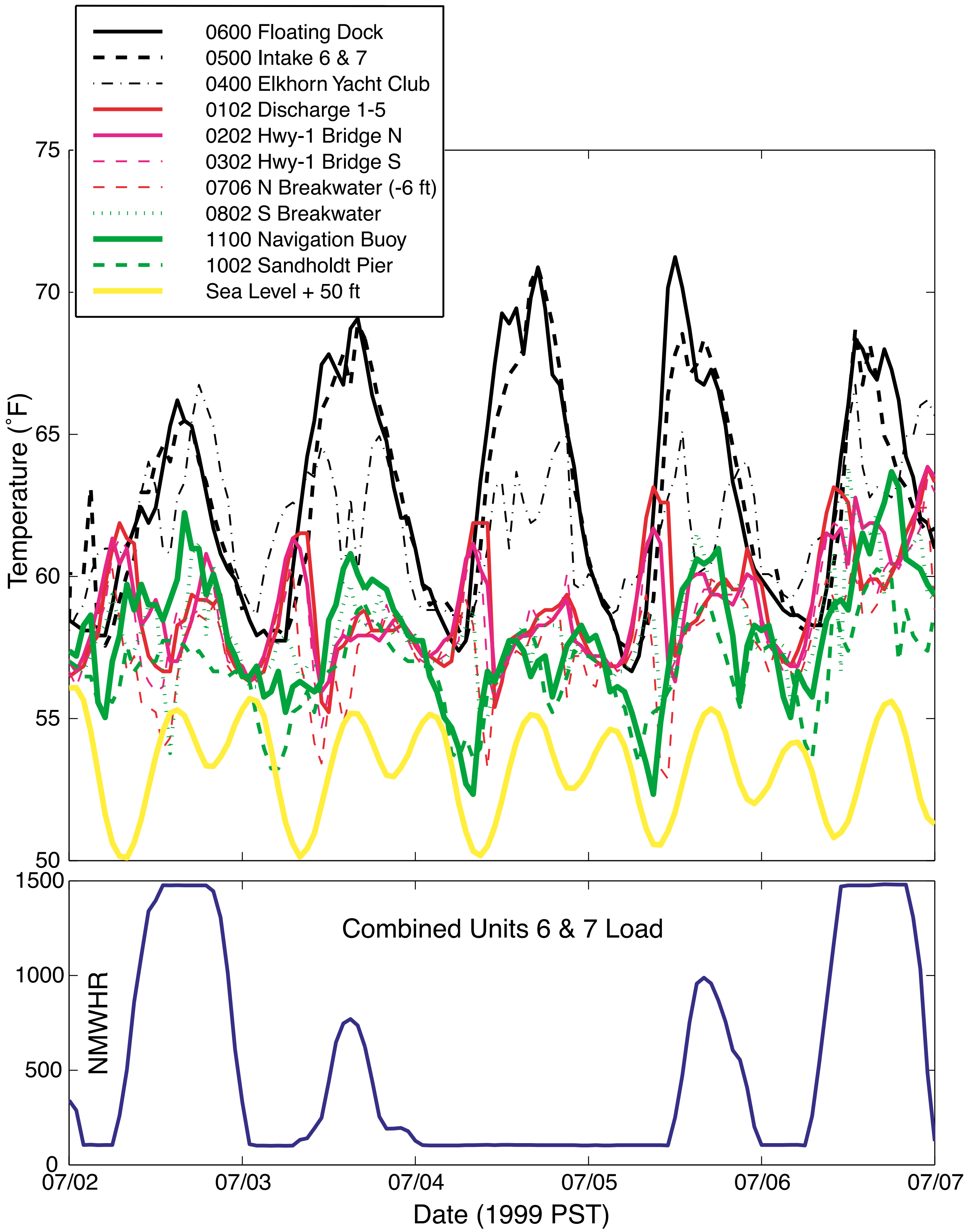


Figure 2-7. Temperature, sea level, and MLPP load time series during a period covering high, medium, and minimal plant loads.

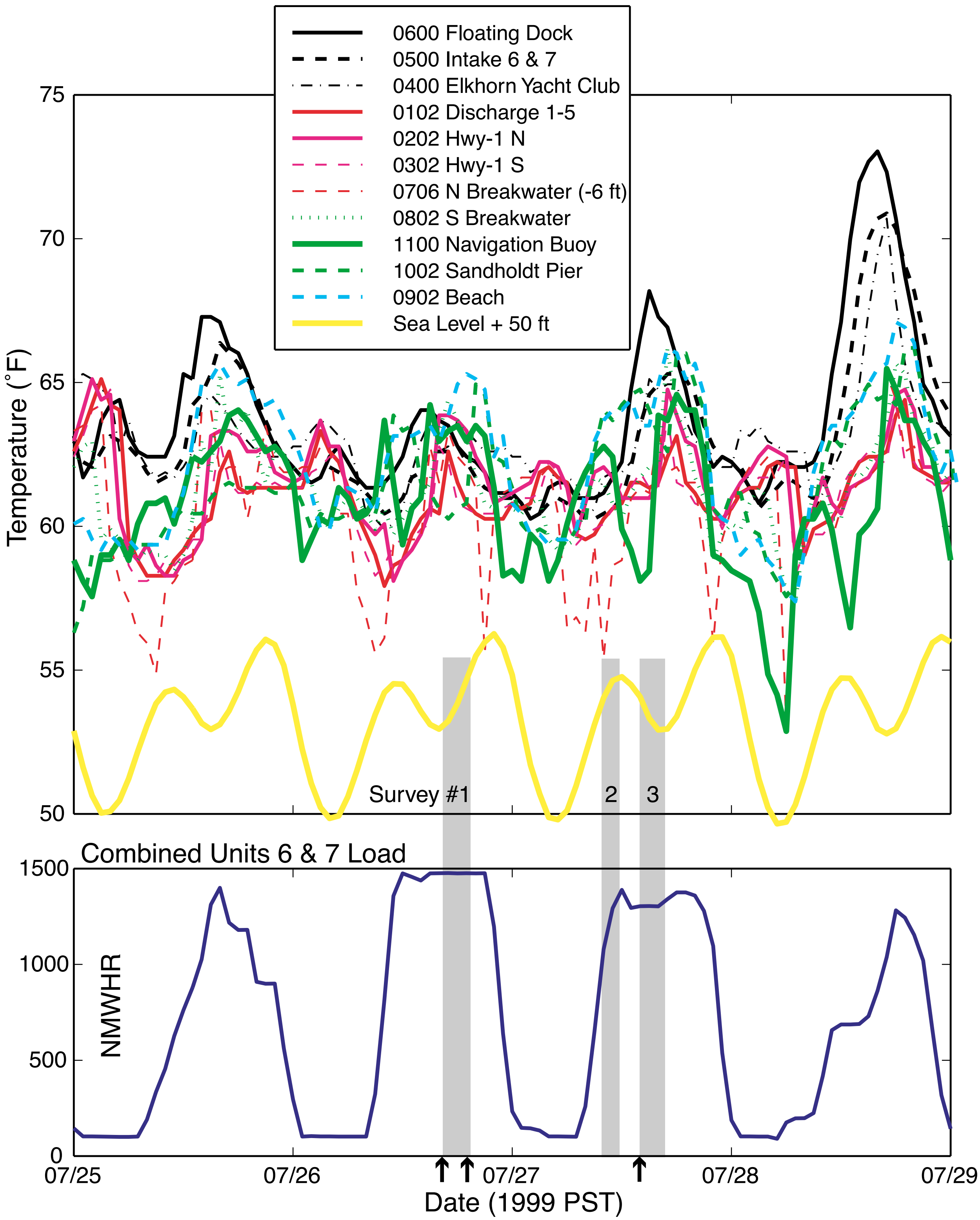


Figure 2-8. Temperature, sea level, and MLPP load time series during a period covering the boat and aerial surveys (shaded). Arrows denote times of offshore reference profiles.

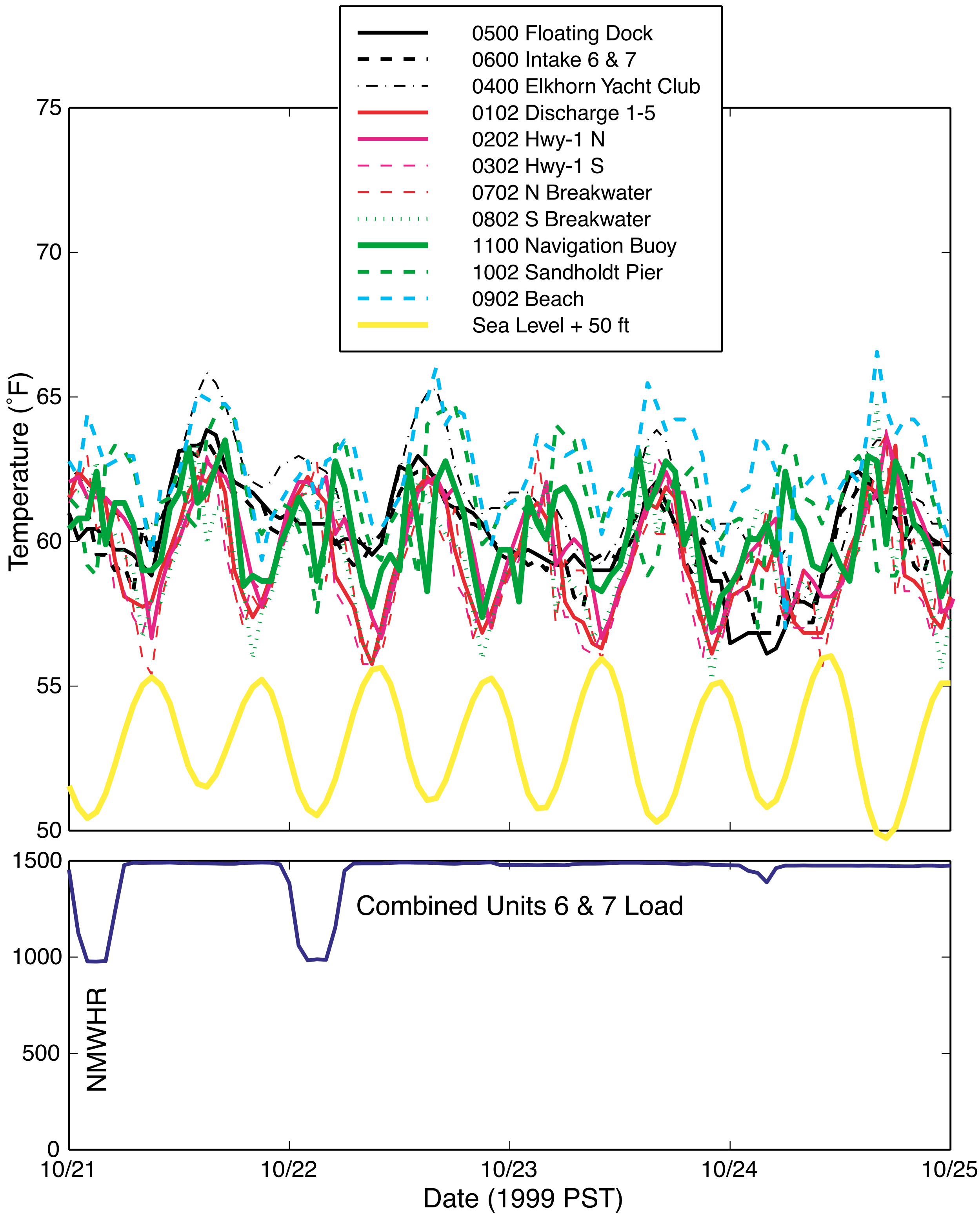


Figure 2-9. Temperature, sea level, and MLPP load time series during a period of maximum tidal range and high MLPP load.

is less in the absence of the Units 1-5 thermal load. See, for example, on Figure 2-7 that Slough stations (ML01, ML02, and ML03) increased 5-7 °F to 62-63 °F late each morning on the extreme low tide, regardless of the levels of MLPP operation. The effect was similar but less on the "half-low" tide each evening with temperatures at these locations reaching 58-61°F. The same pattern is evident at slightly higher ambient temperatures during the 25-28 July period illustrated in Figure 2-8, although the extreme low tides occurred earlier in the day at about 6 AM, when plant operations were minimal.

Harbor temperatures, independent of plant operating loads, rise on the extreme falling tide each morning to about 65-70 °F, depending on location, during the illustrated July periods. The shallower Harbor stations maintained these higher temperatures until cooled by the rising tide in the evening. Figures 2-7 and 2-8 also illustrate how the outer stations in Monterey Bay, including the Navigation Buoy near the discharge (ML11) and the Sandholdt Pier (ML10), rise 2-4 °F when reached by exiting inland water on the morning extreme falling tides, regardless of the levels of plant operations. For periods of 2 to 4 hours on rising tides, the effect of the Units 6 and 7 thermal discharge can be observed at the recorder locations within about 1,000 feet of the discharge. This effect is most evident at the surface recorder on the Navigation Buoy less than 150 feet offshore from the discharge, where the effect occurs as about a peak 4-6 °F rise (see the early afternoons of 2, 3, and 6 July on Figure 2-7, and each day in the 25-28 July period on Figure 2-8).

The time series presented in Figures 2-7, 2-8, and 2-9 have been grouped by color to help illustrate the different types of variability observed in the records. The black data represent the three floating stations in Moss Landing Harbor (ML04, ML05, and ML06), whereas the red and magenta data represent Elkhorn Slough at the Units 1-5 discharge (ML01), the Highway 1 bridge (ML02 and ML03), and the North Breakwater station (ML07). Temperature variations in this later grouping appear to be most directly connected to the sea level variations. The fact that the North Breakwater station is more similar to the Highway 1 bridge stations and the Elkhorn Slough station in July than it is to the South Breakwater station is consistent with a horizontal flow separation in the navigation channel. Water moves in and out of Elkhorn Slough under the Highway 1 bridge and along the northern side of the navigation channel. This type of pattern was seen repeatedly in the aerial survey data from March and July 1999. Temperature variations at the South Breakwater station (ML08) in July are most similar to those at the outer stations, including the Navigation Buoy (ML11), Sandholdt Pier (ML10), and the Beach (ML09). Data from these stations are colored green or cyan. The situation in October differs, somewhat, from that in July in that temperature at all of the stations varies more uniformly with the strong sea level fluctuations during that time frame. The situation in October differs from that in July in that temperatures at all of the stations vary more uniformly with the strong sea level fluctuations during that time frame. The warmest temperatures in the October records are at the Sandholdt Pier and beach stations.

Finally, the time series data in Figure 2-7, 2-8, and 2-9 point out an effect on the data related to the method used to secure individual temperature recorders. That is, data from the floating recorders have the least amount of semidiurnal (twice-daily) variability and the most amount of diurnal (daily) variability. Conversely, data from the fixed-height recorders in the Harbor contain a lot of semidiurnal variability, which is consistent with measurements at shallower (warmer) depths during low tide periods versus measurements at deeper (cooler) depths during high tide periods. The daily variations seen in the data from the floating recorders is consistent with solar heating producing maximum surface temperatures in the afternoon.
Correlations based on the entire hourly temperature time series for each recording station were computed to verify that the relationships seen in the shorter time periods in Figures 2-7, 2-8, and 2-9 are representative of the more general relationships between temperature and sea level and temperature and MLPP load. The statistical results support the inferences made from the shorter time periods in that temperatures in Elkhorn Slough and Moss Landing Harbor are more highly correlated with sea level than with MLPP load, while the opposite is true for stations near the discharge location.

The long-term correlations between the temperature at all of the stations and San Francisco sea level record (adjusted by one hour to approximate conditions in Monterey Bay) are shown in Table 2-3. Correlations were also included for all of the temperature records against MLPP load from the combined output of Units 6 and 7. Data are presented for both the maximum correlation at zero time lag and the overall maximum correlation for time lags up to ±7 hours. Among the most obvious results are that temperatures in Elkhorn Slough, including stations at the Highway 1 bridge, exhibit high correlation with sea level and relatively low correlation with

Table 2-3. MLPP Thermal Data Correlations

	Temperature vs. Units 6 & 7 Load				Temperature vs. Sea Level			
Station # /Depth	# of Hours	Zero Lag Corr.	Max Corr.	Max Lag (hr)	# of Hours	Zero Lag Corr.	Max Corr.	Max Lag (hr)
01/02	3184	0.06	0.17	-7	3110	-0.56	-0.56	0
01/06	3184	0.05	0.18	-7	3110	-0.56	-0.56	0
02/02	3328	0.16	0.22	-6	3254	-0.44	0.45	-7
02/06	3328	0.14	0.22	-6	3254	-0.44	0.45	-7
03/02	3330	0.15	0.22	-5	3256	-0.46	0.46	-6
03/06	3330	0.15	0.22	-5	3256	-0.45	0.45	-6
04/00	3473	0.30	0.32	-2	3399	-0.28	0.39	6
05/00	3446	0.27	0.30	-2	3373	0.09	0.16	4
06/00	3474	0.38	0.38	1	3400	0.11	0.26	4
07/02	2155	0.20	0.26	-3	2081	-0.48	0.50	-6
07/06	2996	0.19	0.25	-4	2922	-0.43	0.47	-6
08/02	3000	0.29	0.30	-1	2926	-0.31	0.34	-7
08/06	3000	0.27	0.28	-1	2926	-0.31	0.34	-7
09/02	2549	0.63	0.63	-1	2475	0.03	0.27	3
10/02	5357	0.65	0.66	-1	5283	0.17	0.19	1
11/00	5586	0.67	0.67	-1	5512	0.14	0.19	2
11/10	5588	0.39	0.46	-4	5514	0.18	0.28	2

MLPP load. At zero lag, the correlation with sea level is negative, indicating that colder ocean water tends to flood into Elkhorn Slough at high tide. Also clear is that the ocean stations surrounding the discharge (stations ML09, ML10, and ML11) exhibit very high correlation with MLPP load and weak correlation with sea level. In between, within Moss Landing Harbor and breakwater, both sets of correlations are relatively weak. This latter result may be due to the fact that all three stations within Moss Landing Harbor were floating recorders, which exhibit the minimum tide-induced temperature variations because they move up and down with sea level.

The long-term correlation statistics presented in Table 2-3 are complemented by results from the short-term aircraft- and boat-based surveys conducted in March and July 1999. In a unique application of technology, real-time IR data from a ground-controlled camera turret on the CIRPAS Pelican aircraft was relayed via cellular telephone to the survey boat operating in the vicinity of the MLPP discharge plume. The boat collected GPS position information along with temperature and depth information from a CTD suspended on a boom alongside the vessel. GPS locations (way points) were recorded at irregular intervals during the surveys. For times when the CTD data are not accompanied by a GPS reading the location was approximated by linearly interpolating the boat position based on its closest previous and future known locations. The assumption is that the boat was traveling in a straight line while it was collecting water temperature data between GPS readings. In most cases the GPS readings were only a few minutes apart and this approximation should work. However, both because of the non-continuous nature of the GPS data and the fact that the instrument was not a differential GPS unit, the position accuracy for the CTD data is likely to be on the order of 100 ft.

The July survey time periods relative to both sea level and MLPP load are shown in Figure 2-8. The three surveys sampled flood, high, and low tide conditions. All surveys were conducted during high MLPP load conditions, although conditions were very low immediately prior to Survey #2. During the survey periods, the Pelican aircraft circled MLPP at an elevation between 1,000-2,000 feet while the operator at the ground station kept the camera pointed at the vicinity of the discharge. Obvious warm-water plumes are visible in the IR imagery, although there is a complicated interaction between the water originating in Elkhorn Slough and the warm water from the MLPP discharge as suggested by the earlier images from the 1972 thermal study, and by the statistical analyses performed on the temperature time series. IR snapshots from each of the July survey periods are presented here to provide a large-scale context for the plume distributions.

A sample IR image from Survey #1 on 26 July 1999, including the discharge plume and the survey vessel, is shown in Figure 2-10. During this incoming tide period, warm water is seen extending to the surf zone inshore of the discharge and along shore to the north and south of the channel breakwaters. The offshore edge of the plume is sharper than the inshore edge suggesting that a preexisting warm surface layer is being pushed onshore by the incoming tidal current. The shape of the warm billows emanating from the discharge suggest along shore flow toward the north.

The survey vessel is visible in Figure 2-10 as a small cold spot near the center of the image. The trail of the boat is also visible as a cold streak leading back into the channel. The real-time IR video dramatically shows this phenomenon at several times during the surveys where the motion of the boat mixes cold water up to the surface from below the warm plume. This suggests that

Figure 2-10. Sample IR image from Survey #1 on 26 July 1999 at 19:19 PDT (27 July at 02:19 GMT) showing warm water from the MLPP discharge plume (lightest shades). The view is looking north. The survey boat is visible in the center of the image along with its cold-water wake (dark lines) emanating from the channel. The wake of another boat that passed through sometime earlier is also visible. Temperature values are estimated from survey data of Figures 2-13 and 2-16.

the depth of the plume is no more than a few feet thick. A second cold streak is visible in Figure 2-10 from a boat that exited the harbor (and the frame) prior to the time of the image. These cold streaks are observed to persist for much, if not all, of the hour-long survey periods, and could lead to problems interpreting the surface temperature data recorded by the survey vessel for cases where the vessel returned to the same location during the survey. However, the anomalies that occurred due to the boat track have been accounted for in the methodology presented in Figures 2-13 to 2-15.

A sample IR image during the high-tide period of Survey #2 is shown in Figure 2-11. The nature of the warm surface plume in this image is changed significantly from that of Survey #1 some sixteen hours before. The temperatures overall are not as warm. There is a tongue of cool water that extends nearly to Sandholdt Pier on the southern side of the discharge. On the northern side of the discharge there is an even sharper edge to the plume between the discharge and the South Breakwater. In other parts of the video sequence, it is clear that this edge wraps around the breakwater and that the southern edge of the largest plume feature extends directly offshore from the North Breakwater.

A sample IR image during the low-tide period of Survey #3 is shown in Figure 2-12. Surface temperatures during this period are warmer than during the high-tide period of Survey #2 just six hours before. In the interim warm water has, presumably, flooded out of Elkhorn Slough with the falling tide. There is a remnant of the tongue of cool water between the discharge and the beach that was seen during Survey #2, although warm water from the direction of the discharge appears to be extending over the cool tongue in the direction of the beach. The IR images from Survey #3 also show a clear separation within the navigation channel with warmer water on the southern side and cooler water along the northern breakwater.

Data from the survey boat have been used to complement the surface patterns seen in the IR imagery. Frequent lowering of the CTD by the survey boat also provided information about the vertical extent of the discharge plume. Surface temperature data collected by the survey boat during the three July surveys are shown in Figures 2-13, 2-14, and 2-15. In these presentations, instantaneous temperatures from the CTD suspended just below the water line are shown as colored symbols plotted at the locations estimated from the boat's GPS way points. The

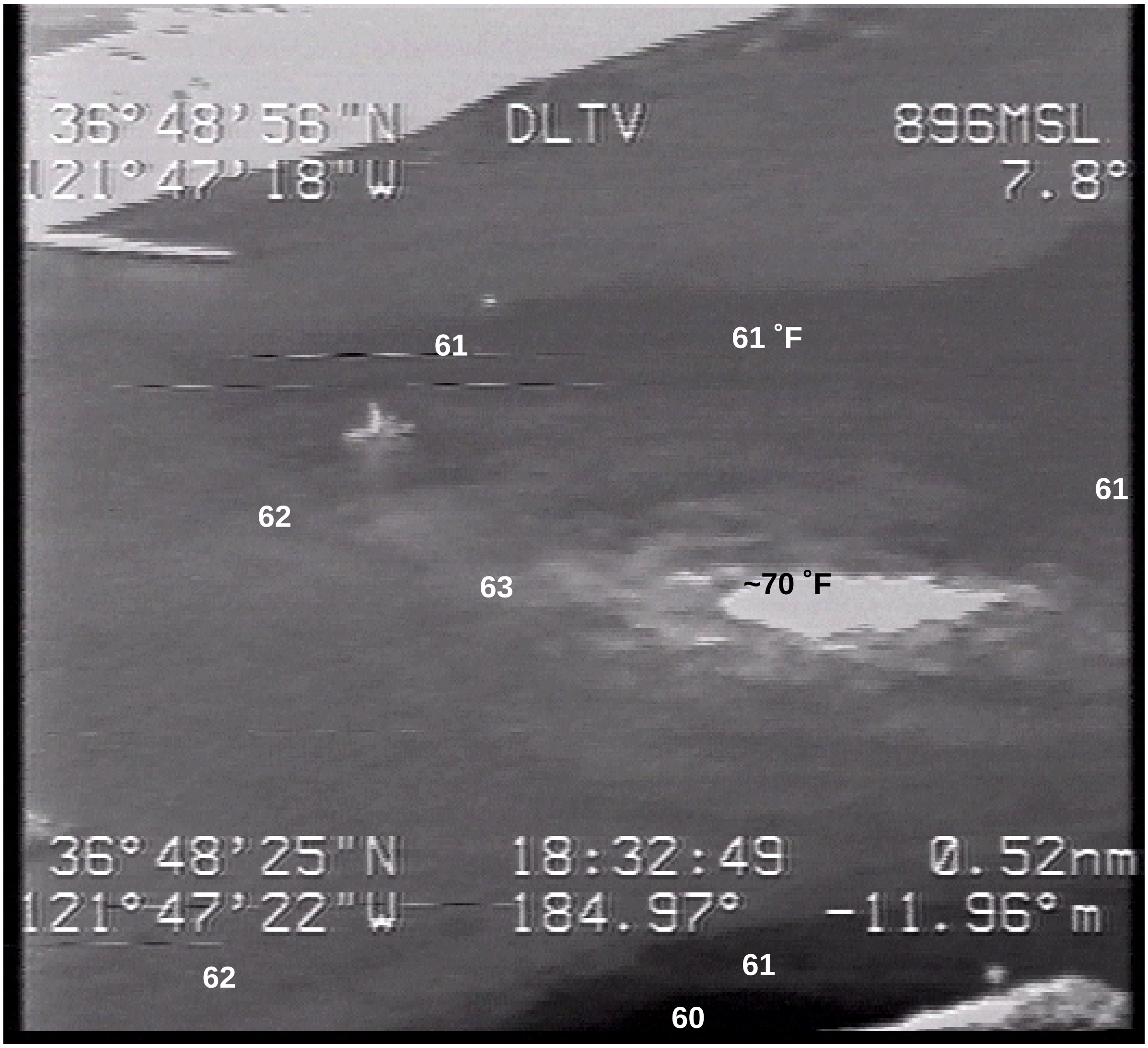


Figure 2-11. Sample IR image from Survey #2 on 27 July 1999 at 11:32 PDT (18:32 GMT) showing warm water from the MLPP discharge plume (lightest shades). The view is looking south. The survey boat is visible near the center of the image between Sandholdt Pier and the MLPP discharge. The end of the southern breakwater is visible in the lower right corner. Temperature values are estimated from survey data of Figures 2-14 and 2-16.

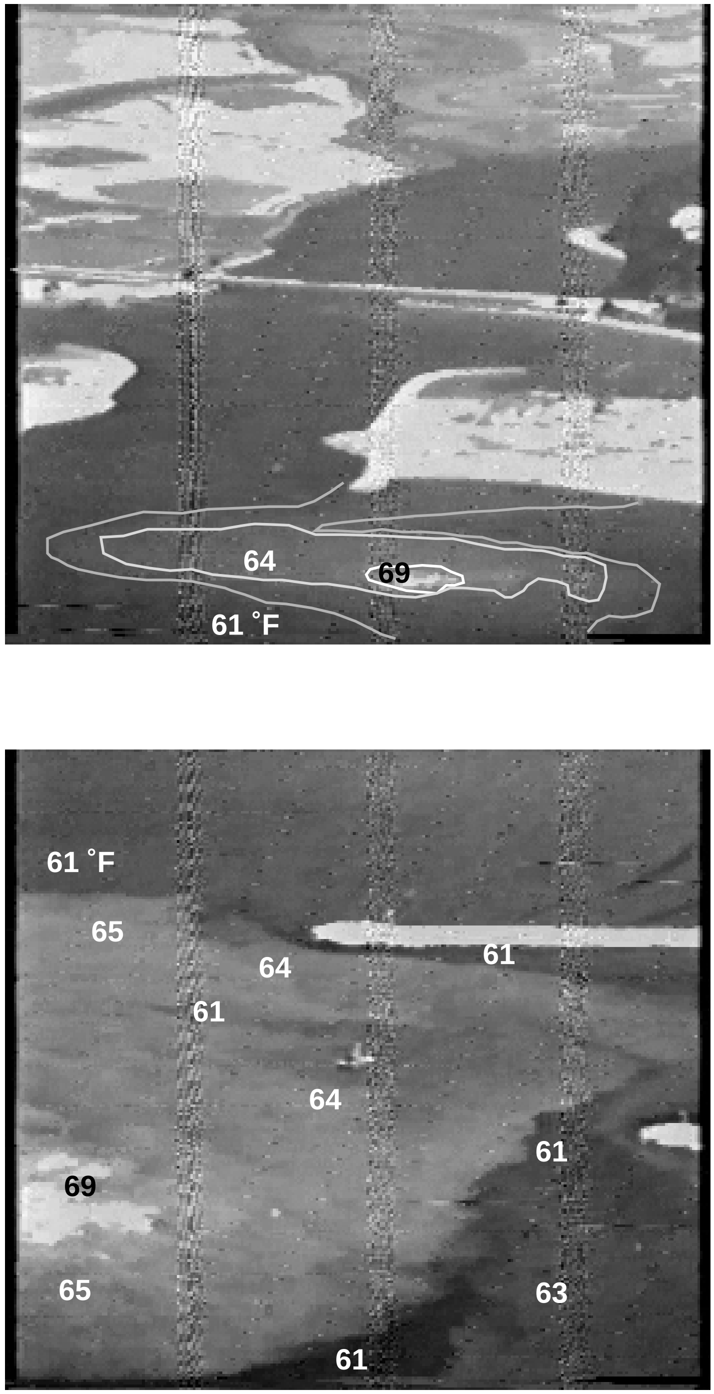


Figure 2-12. Sample IR images from Survey #3 on 27 July 1999 around 18:00 PDT (upper) and 18:30 PDT (lower) looking East and Northeast, respectively, showing warm water from the MLPP discharge plume (lightest shades) crossing, but not completely filling, the harbor entrance. Notice also the wedge of cooler water between the discharge and the beach. Temperature values are estimated from survey data of Figures 2-15 and 2-16.

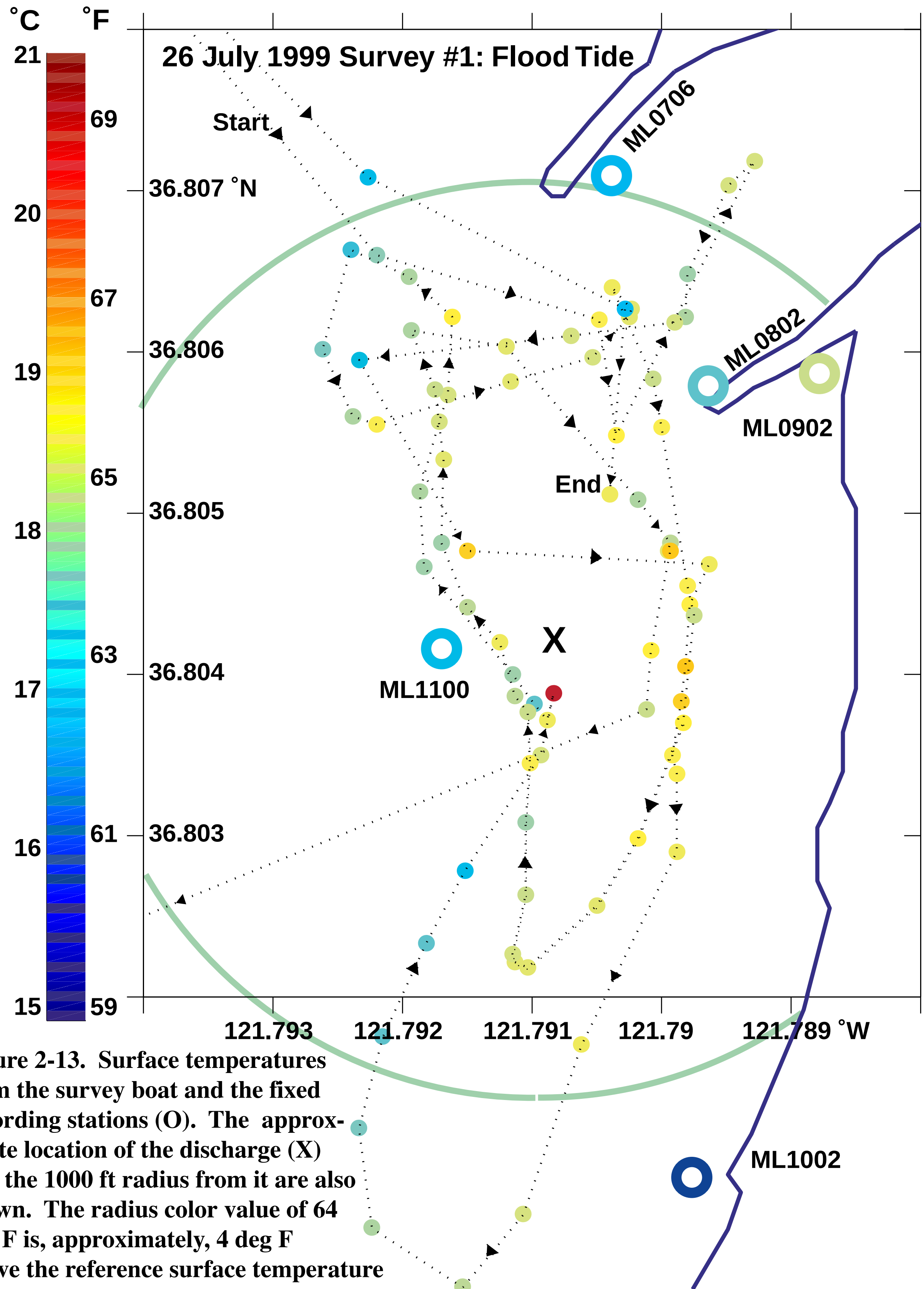


Figure 2-13. Surface temperatures from the survey boat and the fixed recording stations (O). The approximate location of the discharge (X) and the 1000 ft radius from it are also shown. The radius color value of 64 deg F is, approximately, 4 deg F above the reference surface temperature measured further offshore.

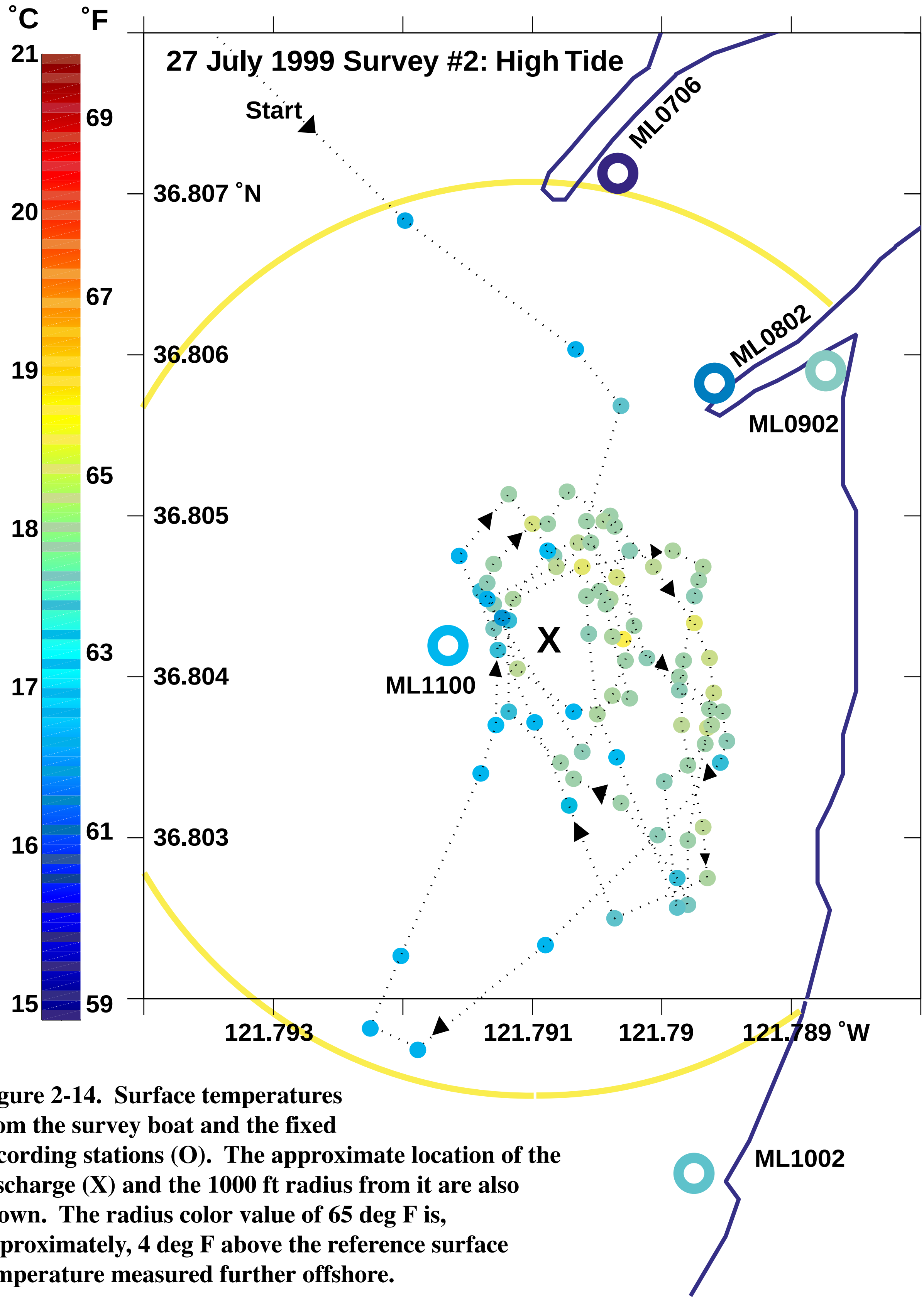


Figure 2-14. Surface temperatures from the survey boat and the fixed recording stations (O). The approximate location of the discharge (X) and the 1000 ft radius from it are also shown. The radius color value of 65 deg F is, approximately, 4 deg F above the reference surface temperature measured further offshore.

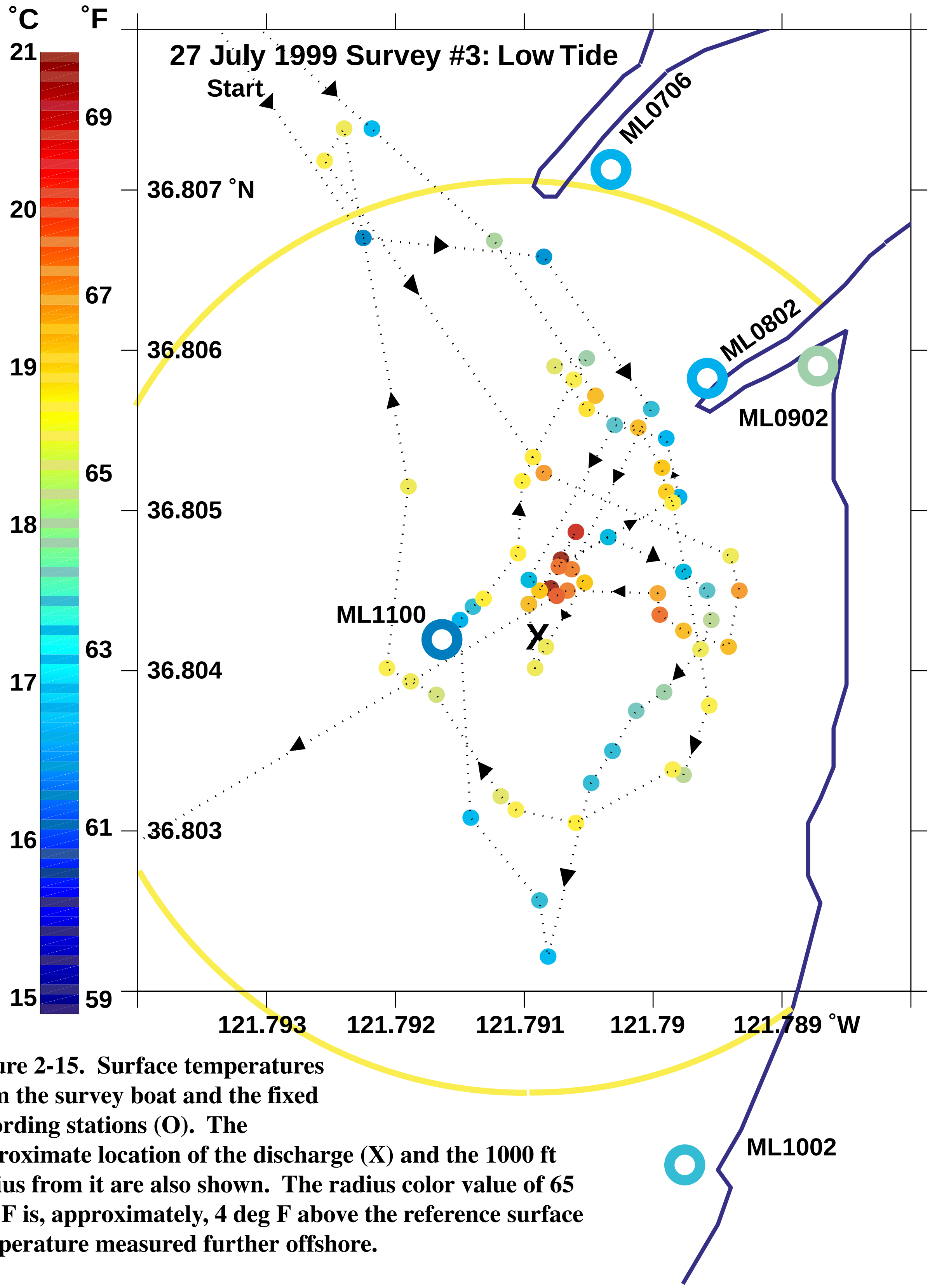


Figure 2-15. Surface temperatures from the survey boat and the fixed recording stations (O). The approximate location of the discharge (X) and the 1000 ft radius from it are also shown. The radius color value of 65 deg F is, approximately, 4 deg F above the reference surface temperature measured further offshore.

crisscrossing path of the survey boat is also visible in the presentations, which helps to explain some of the complicated temperature patterns where very cool water is juxtaposed next to the warmest water observed. This can happen when the boat travels back over its own cold-water wake, which is why this type of data should be looked at directly rather than as part of a heavily smoothed contour map.

As suggested by the IR images, the warmest surface discharge temperatures were seen in the first and third surveys when the tide was low or flooding. The overall warmest temperatures (~69 ºF) were observed in Survey #3, which both followed the outgoing tide and was about four hours into a period of high plant operations. As shown below (Figure 2-16), reference surface temperatures measured well outside the plume were ~60 ºF during Survey #1 and ~61 ºF during Survey #2 and Survey #3. At ranges well less than 1,000 feet, observed surface temperatures drop to less than 4 ºF above this reference value during all three surveys, including the warmest conditions in Survey #3. One exception are the surface temperatures in the southern portion of Survey #1 during flood tide conditions, which are, approximately, 4 ºF above the offshore reference values some 1,300 feet from the discharge. Because the instantaneous IR images from the Pelican aircraft during this survey show flow toward the North, this warm water is likely to be part of a remnant plume of naturally warmed and discharged water from Elkhorn Slough during the previous outgoing tide.

The temperature information in Figures 2-13, 2-14, and 2-15 also includes data from the fixed recorder stations. In this case, the average temperature observed at the recording station during the particular survey period is plotted on the respective figure. The fixed recorder data derive from two feet below MLLW, except for the surface data from the floating Navigation Buoy, and data from the North Breakwater, which were only available from six feet below MLLW during the survey periods. Temperature readings from the subsurface recorders can be expected to be lower than surface values at the same location. For example, the mean surface temperature at the Navigation Buoy in July was 2.7 ºF more than the temperature 10 feet below. The standard deviation of the temperature difference was 1.9 ºF. Similar vertical temperature differences were seen with Moss Landing Harbor as is shown in the next subsection.

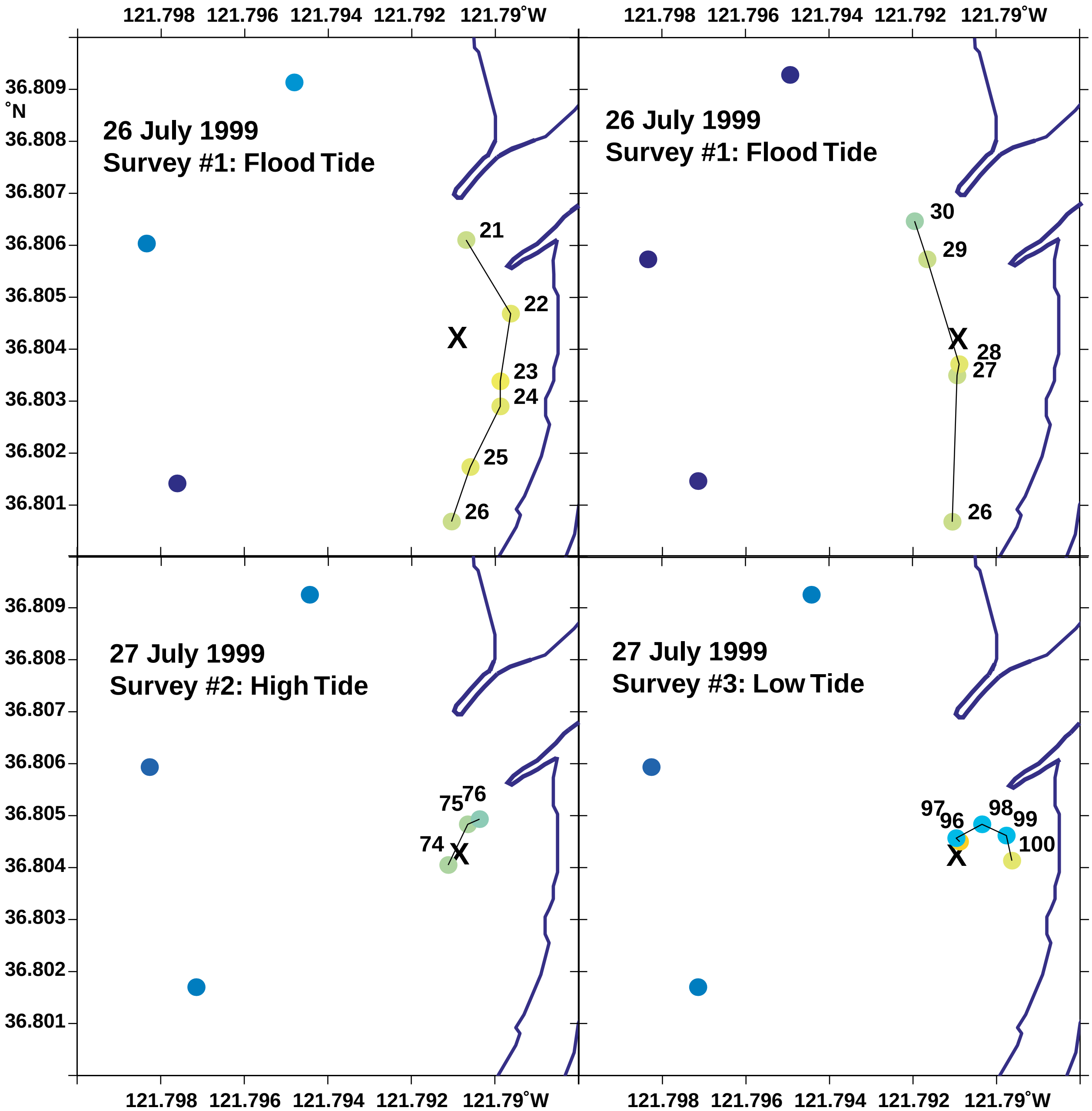


Figure 2-16. Locations of reference temperature measurements (three outer symbols) and CTD profiles at various times during the July survey periods. The surface temperatures at each station are represented using the same color scale as Figure 2-15.

The question of vertical temperature gradients can be extended to the thermal plume itself, which is expected to exist as a buoyant plume within a few feet of the surface. To look at the subsurface structure of the discharge plume, vertical information from the boat surveys was extracted for stations running through the plume during each survey period. Sequential station numbers were assigned to each time and location when the CTD on the survey vessel was lowered to the bottom. After that, an attempt was made to select stations that transected the plume area, avoiding stations that were a repeat sampling of nearly the same location during a single survey. The extracted plume station locations relative to the boat trajectory are shown in Figure 2-16. The figure includes two separate transects in Survey #1 and one transect each for Survey #2 and Survey #3. Surface temperatures were recorded at three offshore reference stations before and after each survey. The locations of these reference points are also shown in Figure 2-16. In some, but not all, cases vertical temperature profiles were collected at the reference stations. The timing of these reference profiles is indicated in Figure 2-8 relative to the three survey periods. At this point, it should be reiterated that the position accuracy of the survey data in Figures 2-13 through 2-16 is likely to be about 100 ft. Furthermore, critical reference positions, such as the locations of the MLPP discharge and the breakwaters, were estimated, independently, from the NOAA navigation chart (#18685). This means that relative locations on these figures should be viewed with this position uncertainty in mind.

Vertical profiles at the numbered plume stations are shown in Figure 2-17. Vertical profiles from the offshore reference stations are also included in the figure, which makes it possible to see the vertical extent of elevated temperatures at the plume stations. Despite a rather large change in background conditions in which a cold bottom layer moved into the area between Survey #1 and Survey #2, the profiles show consistent elevated temperatures in the vicinity of the discharge with a warm surface layer in the upper 5-15 feet. The maximum temperature increases are 4-5 ºF above background and are found at the surface. At all depths, the elevated temperature values decay toward background conditions at distances less than 1,000 ft from the discharge, consistent with the surface temperature results in Figures 2-13, 2-14, and 2-15.

The temperature profiles in Figure 2-17 also illustrate that the vertical mixing very near the discharge is high, which has been postulated based on the configuration of the two discharge pipes pointed upward roughly forty feet apart on center. This is also suggested by the IR

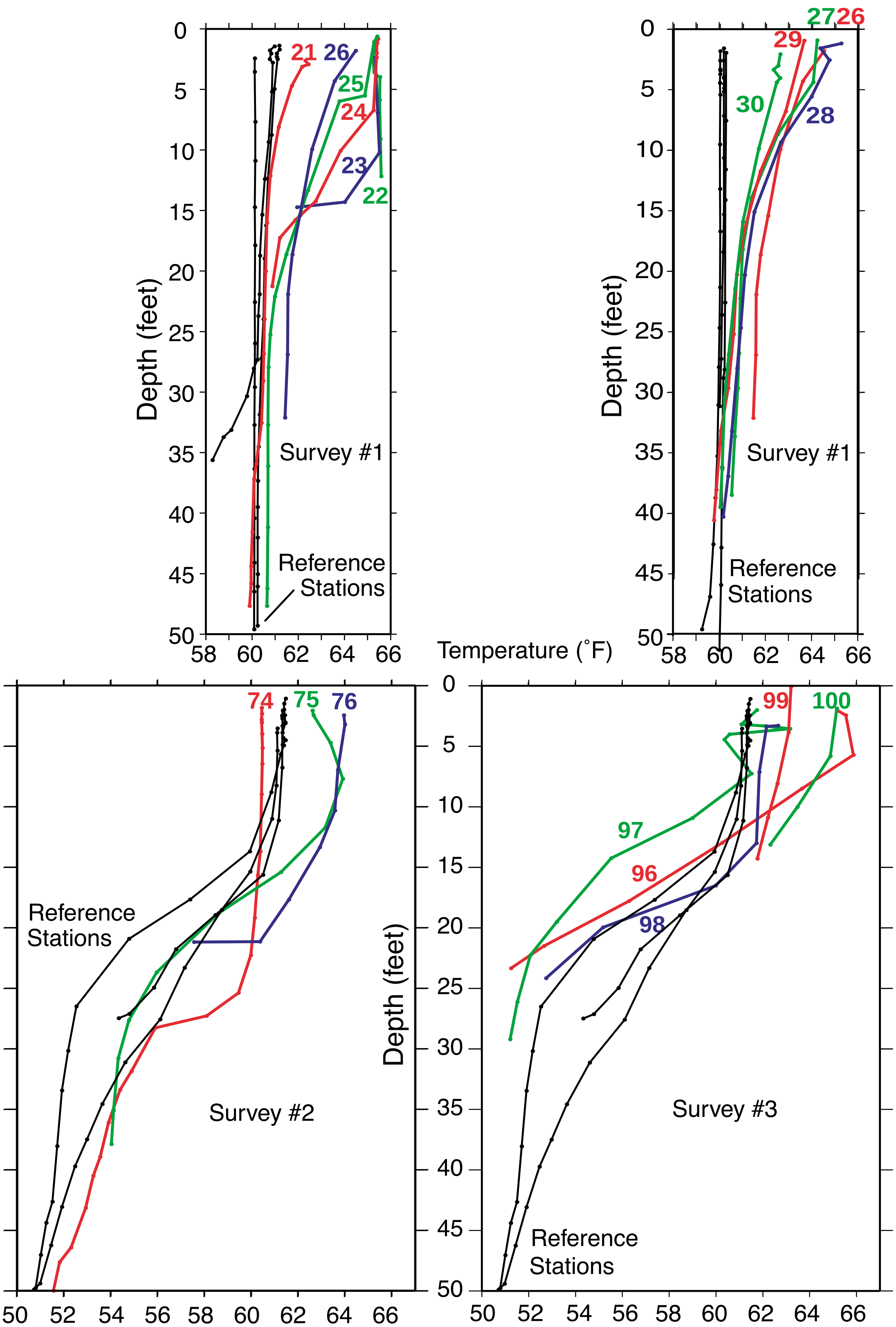


Figure 2-17. Temperature profiles from reference and numbered stations in Figure 2-16. The reference station times are shown in Figure 2-8 relative to the survey periods.

imagery collected during the survey periods in which intense turbulent mixing is seen within a few hundred feet of the discharge location. In Figure 2-17, the temperature profile at station 74 is particularly interesting. It appears to be very close to the MLPP discharge but, given its depth, the actual station location must have been slightly offshore of where it appears in Figure 2-17. At that site, strong vertical mixing produced a deeper mixed layer than at the reference stations. As a result, the surface temperature at station 74 is slightly cooler than at the reference stations, despite its proximity to the discharge. Other stations also suggest that the strongest mixing occurred nearest the discharge (e.g., stations 22, 23, 96, and 100).

The thermal study results for the present operating conditions are summarized by location in the list below:

Present Thermal Plume in Monterey Bay

- Results from the present study demonstrate that the existing discharge partially complies with the Thermal Plan for new discharges in that the discharge does not exceed 4 °F above natural receiving water temperatures for more than 50 percent of the duration of a tidal cycle at the shoreline, the surface of any ocean substrate, or the ocean surface beyond 1,000 feet from the discharge system. The temperature survey data at stations half way between the discharge and the beach show elevated temperatures 4-5 °F above receiving water temperatures at the surface during highest plant loads. These data combined with data from the fixed recorder stations at the beach suggest that temperatures at the beach are generally within 4 °F of ambient during worst-case conditions, and well below this value during most of the tidal cycle.

- Surface temperature data from the three July survey periods were used in two ways: (1) to look at the absolute number value of Delta-T near the 1000 foot range or near the beach or breakwater and, (2) to look for signs of the horizontal decay of Delta-T with distance from the discharge. The results here are not conclusive because the boat sampling pattern was not adequate. However, the Delta-T values observed were either under 4 °F at the 1000 feet threshold, or they were close to that value with a detectable decay with distance from the discharge. Defining Delta-T at all depends on knowing the temperature of the natural receiving waters in the absence of the discharge plume. For the surface temperatures, the reference value should be the temperature at the surface in the absence of the discharge plume. In this report, the reference values used were a conservative approximation to those natural receiving water temperatures. That is, the values used were the coldest surface temperatures in the region offshore of the discharge. The true Delta-Ts above the natural receiving water temperatures would have been less than or equal to these values because the area around the discharge is naturally bathed in warm water from Elkhorn Slough during part of the tidal cycle.

- The time series measurements as illustrated in Figures 2-7, 2-8, and 2-9, show a large degree of natural temperature variability on the order of 5-9 °F is present due to tidal-period fluctuations plus the solar heating and cooling cycle.

- The natural temperature variations are equal to or larger than the MLPP-induced variations, except within a very short distance (~200 feet) from the discharge. Hence, the MLPP discharge is not producing temperatures that exceed natural variation.

- The long temperature records collected suggest, through the correlation analysis in Table 2-3, that temperature variations in Elkhorn Slough and Moss Landing Harbor are dominated by natural tidal-induced variations. Only stations surrounding the discharge (Nav Buoy, Beach, and Sandholdt Pier) had temperature variations that were correlated with MLPP load.

Present Conditions in Moss Landing Harbor and Channel

- Figures 2-7, 2-8, and 2-9 and the correlation results in Table 2-3 show that temperature variations in the Harbor entrance are controlled by the tidal cycle. Temperatures in the Harbor increase on the falling tide due to the replacement of Bay water by Slough water. The range of tidal-period temperature fluctuations in the Harbor increases as inland waters become even warmer during summer months.

- Figures 2-7, 2-8, and 2-9 and the IR imagery collected during the survey periods demonstrate that conditions along the northern side of the channel are independent of conditions along the southern side of the channel and are tightly coupled to conditions under the Highway 1 bridge and inside Elkhorn Slough, especially during the summer months.

- The floating temperature records in Moss Landing Harbor in the vicinity of the Units 6 and 7 intake structure exhibit the highest correlation with time of day, suggesting that solar heating dominated those records. The variations of the deeper intake temperatures themselves, as shown below, are more controlled by tidal exchange and correlate strongly with temperatures along the southern side of the channel entrance.

Present Conditions in Elkhorn Slough

- The following findings and observation illustrate both the relative lack of any perceived impact of the thermal discharge on Elkhorn Slough, and at the same time the correlation between the natural heat loading from the Slough and the plant discharge. The data from temperature recorders in Elkhorn Slough showed no correlation with Units 6 and 7 discharge-related temperatures. Instead, high correlations were seen with sea level fluctuations and the associated natural temperature variations between inland and Bay waters.

2.4.3 Future Plume Conditions

Prior to describing the methodology and analysis behind the projection of future plumes, it is useful to clarify how temperature will be measured with respect to the receiving waters.

Methodology for Defining MLPP Receiving Water Temperature

For many reasons, the MLPP in-plant intake temperatures which record temperatures of water drawn in the intake structure several feet below the surface of Moss Landing Harbor (i.e., station ML0510) represent an important data set. It is these temperatures that are used to establish maximum and averaged ΔT values for compliance with restrictions on the temperature rise at the point of discharge. Once discharged into the ocean, the discharged water is cooled—through intense mixing with the surrounding ocean water—by several degrees by the time it reaches the surface some 20 feet above the discharge point. Furthermore, the in-plant temperature of water drawn in from several feet below the surface is likely to be colder than the surface temperature in the Harbor near the intake. For this reason, the in-plant temperature may be closer to the surface temperature near the open ocean discharge site than the surface temperature in the Harbor, which is an important consideration when choosing a reference temperature.

For practical reasons, it is desirable to use in-plant temperature readings to monitor compliance with the Thermal Plan. Therefore, it is important to characterize the in-plant temperatures relative to the receiving water temperatures. To that end, a tabulation of the temperature difference between all recording sites and the MLPP in-plant temperature is presented in Table 2-4 for the overlapping time period of September and October 1999. Temperatures at the surface everywhere and two feet below the surface outside the Harbor are typically 1-3° F higher than the in-plant temperature. Temperatures 2-6 feet below the surface in the channel and in Elkhorn Slough are typically within 1 ºF of the in-plant temperatures.

Of all the records available, temperature measurements from 10 feet below the Navigation Buoy (ML1110) come closest to characterizing the temperature of the receiving water at the point of discharge. These data are below the level of the typical surface plume and are some 150 feet away from the discharge. There is obviously no way to measure the actual receiving water temperature because sensors at the point of discharge would be warmed by the discharge itself. It is also not possible to measure the natural temperature of the receiving water at the discharge location by moving a great distance away from the discharge. This is because the area around the discharge is influenced by water moving in and out of Moss Landing Harbor and Elkhorn Slough, which in most cases would tend to make the natural temperatures in that area warmer than temperatures just a few hundred feet offshore during much of the tidal cycle. The subsurface temperature measurements at the Navigation Buoy are a good compromise between being too close or too far from the discharge location. The statistical comparisons in Table 2-3 support this contention in that the correlations between temperatures at the Navigation Buoy and MLPP load are very high for the surface values but much less for temperatures at 10 feet below the surface.

Because data from Station ML1110 are most representative of the receiving waters, the Technical Working Group of the RWOCB chose to use this station to document the relationship

Table 2-4. Temperature difference statistics for April-October 1999 for the indicated station minus the MLPP in-plant recorder (ML0510) based on 24-hr average temperatures.

Station/Depth	Mean (ºF)	Median (ºF)
Units 1-5 Discharge 01/02	1.02	0.84
Units 1-5 Discharge 01/06	0.95	0.73
North HWY 1 Bridge 02/02	1.13	1.07
North HWY 1 Bridge 02/06	0.99	0.92
South HWY 1 Bridge 03/02	0.55	0.41
South HWY 1 Bridge 03/06	0.31	0.14
Elkhorn Yacht Club 04/00	3.38	2.94
Units 6 & 7 Intake 05/00	3.20	2.52
Floating Dock (S. Harbor) 06/00	3.62	3.00
North Breakwater 07/02	-0.10	0.20
North Breakwater 07/06	-0.27	0.06
South Breakwater 08/02	0.37	0.44
South Breakwater 08/06	0.18	0.28
Beach 09/02	2.37	2.76
Sandholdt Pier 10/02	0.86	0.74
Navigation Buoy 11/00	0.48	0.67
Navigation Buoy 11/10	-2.36	-1.74

between temperature at station ML1110 and the in-plant temperature at station ML0510. Additional data for the months of November 1999 through January 2000 were obtained for each of these stations immediately prior to completion of this report. The temperature differences, based on 24-hr averaged values, are presented for the entire overlap period of April 1999 through January 2000 in Table 2-5. In addition, the temperature differences are presented month-by-month, which shows that the water temperatures 10 feet below the Navigation Buoy are typically less than 1° F cooler than the in-plant values in winter and between 2 to 3.8°F cooler than the in-plant values in summer.

Both the median and mean temperature differences in Table 2-5 exhibit a smooth transition between winter months when the differences are low and summer months when the differences are slightly larger. This implies that the 24-hour averaged temperature near the receiving waters, as measured 10 feet below the surface at the Navigation Buoy, can be accurately estimated using only in-plant measurements from Station ML0510 after correcting for the observed bias. Because it is impractical and unreliable to depend on real-time temperature measurements from

Table 2.5. Temperature Difference ML1110-ML0510 (deg F) based on 24-Hr. Averaged Values for Each Record

Time Period	Min ºF	Max ºF	Mean ºF	MedianºF
April 1999-Jan00	-5.15	0.16	**-1.93**	-1.77
April 1999	-2.86	-0.29	-1.72	-1.77
May 1999	-2.11	-0.01	-1.03	-1.04
June 1999	-3.55	-0.16	-2.01	-1.95
July 1999	-4.34	-1.04	-2.76	-2.49
August 1999	-5.15	-2.13	-3.77	-3.92
September 1999	-4.16	-0.59	-2.42	-2.38
October 1999	-4.65	-0.88	-2.70	-2.74
November 1999	-1.97	-0.23	-1.16	-1.12
December 1999	-1.81	0.12	-0.70	-0.66
January 2000	-1.83	0.16	-0.77	-0.73

an offshore location such as the Navigation Buoy to verify day-to-day compliance with temperature limits, it is proposed that the mean temperature difference for the entire data set from Table 2-5 be used to correct for the bias between intake and receiving water temperatures. This mean temperature difference is 1.9º F. In operational terms, this means that 1.9ºF would be subtracted from the plant intake temperature to account for the fact that the receiving water temperature in Monterey Bay is slightly colder than the water drawn in from 10 feet down in Moss Landing Harbor. This 1.9º F correction factor will be used to determine the MLPP's compliance with the Thermal Plan's standard of 20º F Delta-T between the "receiving water" and the discharge. Due to the ongoing operation of Units 6 and 7 at a 28º F Delta-T and its combined discharge with the new combined Cycle (CC) units (the CC's will meet a 20º F Delta-T), a range of values between 20-28º F Delta-T is being recommended as the correct parameter for the NPDES Permit.

Methodology for Scaling the Future Thermal Plume

The methodology adopted to develop a scaling function for future MLPP load conditions consisted of the following steps:

1. Select the three long-term recording stations surrounding the MLPP discharge location as primary projection sites based on their locations and their previously shown correlation with

MLPP load data. These are the Navigation Buoy (ML1100), the Beach (ML0902) and the Sandholdt Pier (ML1002) sites.

2. Create a temperature difference time series between each primary site and a range of reference locations.
3. Remove the best-fit semidiurnal constituent from each day of the difference time series.
4. Compute the best-fit slope and intercept for the residual temperature difference as a function of MLPP load.
5. Compute the correlation between residual temperature difference and MLPP load.
6. Compute the average slope and intercept values for the cases with highest correlation.
7. Compute the extrapolated temperature difference using the average slope and a MLPP load representative of future peak operating conditions.

The results of this projection study are outlined below. Before that, more information is provided about the critical issue of choosing a station and depth to serve as reference data set.

Future Thermal Plume Projection Model

The projection model was developed using the sequence of steps outlined above and a range of reference locations and dates. For the desired goal of developing a transfer function between MLPP load and temperature rise near the discharge, there is no unambiguous choice of a reference temperature location because of the complex interactions between natural temperature variations and MLPP-induced temperature rises. The preferred reference depth would be at the surface, but only if the primary recording stations were also moving up and down with the ocean surface, which is not the case here. For these several reasons, it was decided to use a range of reference station options to develop an average transfer model with some measurable uncertainty. Reference locations included two floating surface recorders inside Moss Landing Harbor (ML0500 and ML0600), two fixed-depth Highway 1 bridge recorders (ML0202 and ML0302), and three fixed-depth breakwater recorders (ML0702, ML0706, and ML0802). Two date ranges were used: July 15 - August 24, and August 25 - September 29, 1999. (Data for

October 1999 were not used because that month included anomalous, nearly-constant MLPP loads, which eliminates any possible correlation with temperature variations around the discharge.) Results using each of these reference stations and date ranges are shown in Table 2-6 for each of the three primary temperature locations surrounding the MLPP discharge. The best-fit slope and intercept values are reassuringly similar for the many cases with high correlation, say above 0.40.

Table 2-6. MLPP Thermal Data Correlations for normalized temperatures.

Station/Depth: Primary–Reference		Dates (1999) Mn/Dy–Mn/Dy				Slope (ºF/MW)	Intercept (ºF)	Correlation
11/00	08/02	7	15	8	25	0.00175	-1.35	0.45
11/00	07/06	7	15	8	25	0.00205	-1.59	0.45
11/00	03/02	7	15	8	25	0.00250	-1.93	0.53
11/00	02/02	7	15	8	25	0.00260	-2.01	0.54
11/00	06/00	7	15	8	25	-0.00092	0.71	-0.22
11/00	05/00	7	15	8	25	0.00050	-0.39	0.12
10/02	08/02	7	15	8	25	0.00151	-1.17	0.46
10/02	07/02	7	15	8	25	0.00182	-1.40	0.44
10/02	03/02	7	15	8	25	0.00225	-1.74	0.58
10/02	02/02	7	15	8	25	0.00235	-1.82	0.59
10/02	06/00	7	15	8	25	-0.00117	0.90	-0.34
10/02	05/00	7	15	8	25	0.00025	-0.19	0.07
09/02	08/02	7	15	8	25	0.00192	-1.49	0.61
09/02	07/02	7	15	8	25	0.00225	-1.74	0.56
09/02	03/02	7	15	8	25	0.00267	-2.06	0.64
09/02	02/02	7	15	8	25	0.00277	-2.14	0.65
09/02	06/00	7	15	8	25	-0.00075	0.58	-0.22
09/02	05/00	7	15	8	25	0.00066	-0.51	0.17
11/00	08/02	8	25	9	30	0.00146	-1.42	0.45
11/00	07/02	8	25	9	30	0.00166	-1.61	0.43
11/00	03/02	8	25	9	30	0.00202	-1.96	0.51
11/00	02/02	8	25	9	30	0.00208	-2.02	0.53
11/00	06/00	8	25	9	30	0.00019	-0.18	0.05
11/00	05/00	8	25	9	30	0.00149	-1.45	0.35
10/02	08/02	8	25	9	30	0.00156	-1.52	0.47
10/02	07/06	8	25	9	30	0.00176	-1.71	0.46
10/02	03/03	8	25	9	30	0.00212	-2.06	0.58
10/02	02/02	8	25	9	30	0.00219	-2.13	0.59
10/02	06/00	8	25	9	30	0.00029	-0.29	0.09
10/02	05/00	8	25	9	30	0.00160	-1.56	0.37
09/02	08/02	8	25	9	30	0.00178	-1.73	0.58
09/02	07/06	8	25	9	30	0.00198	-1.93	0.52
09/02	03/02	8	25	9	30	0.00234	-2.28	0.60
09/02	02/02	8	25	9	30	0.00241	-2.34	0.62
09/02	06/00	8	25	9	30	0.00051	-0.50	0.16
09/02	05/00	8	25	9	30	0.00181	-1.76	0.42

An example of the best-fit model development for a single case is shown in Figure 2-18 for the ten-day period 15-25 July 1999. The ensemble of best-fit results are shown in Figure 2-19 for all of the cases with correlation values greater than 0.40. In the single example, the temperature difference is shown for the primary Beach station and the South Breakwater reference station. The daily tidal fit to that same record and the de-tided residual record are also shown. It is the latter record that is fit to the MLPP load data with a correlation, for this case, of 0.70.
At this stage it is recognized that the projection model developed here is a compromise in that it does not provide a detailed spatial map of temperatures under future MLPP load conditions. The primary stations surround the discharge at ranges of, approximately, 200 ft, 600 ft, and 1,000 ft for the Navigation Buoy, Beach, and Sandholdt Pier stations, respectively, but the model results do not separate significantly by range. The ensemble average model is, however, based on a wide range of inputs and conditions and can, therefore, be expected to characterize the future, assuming mixing conditions in the open ocean around the discharge will be substantially the same.

The application of the projection model developed here assumes that spatial variations in the thermal discharge plume will remain the same in the future. Only the magnitude of the temperature rise is projected to change according to the best-fit model (Figure 2-19). The penultimate step in the estimation of future temperatures is to assign a worst-case MLPP load value to the future operating conditions. In this regard, it is important to take into account the greatly increased efficiency of the combined cycle units proposed for the modernized MLPP. The projection model developed here used the available continuous data on MLPP load, that is hourly values of electrical output in megawatts. Under the present conditions, these values are expected to relate linearly to the more thermally relevant value of heat discharged in Btu/min. In the future, higher efficiencies will mean that more electrical output will be produced for the same amount of heat discharged. For this reason, it is not appropriate to project maximum future temperatures using the projected maximum future electrical output of 2,590 MW (Table 1-1). Instead, the ratio of the projected to present-day maximum heat load, 182.0/128.7 (Table 1-1), is used to increase the present-day maximum electrical output by 41.4 percent. Following this argument a projection value of 2,121 MW is used to estimate future temperature rises in Figure 2-19.

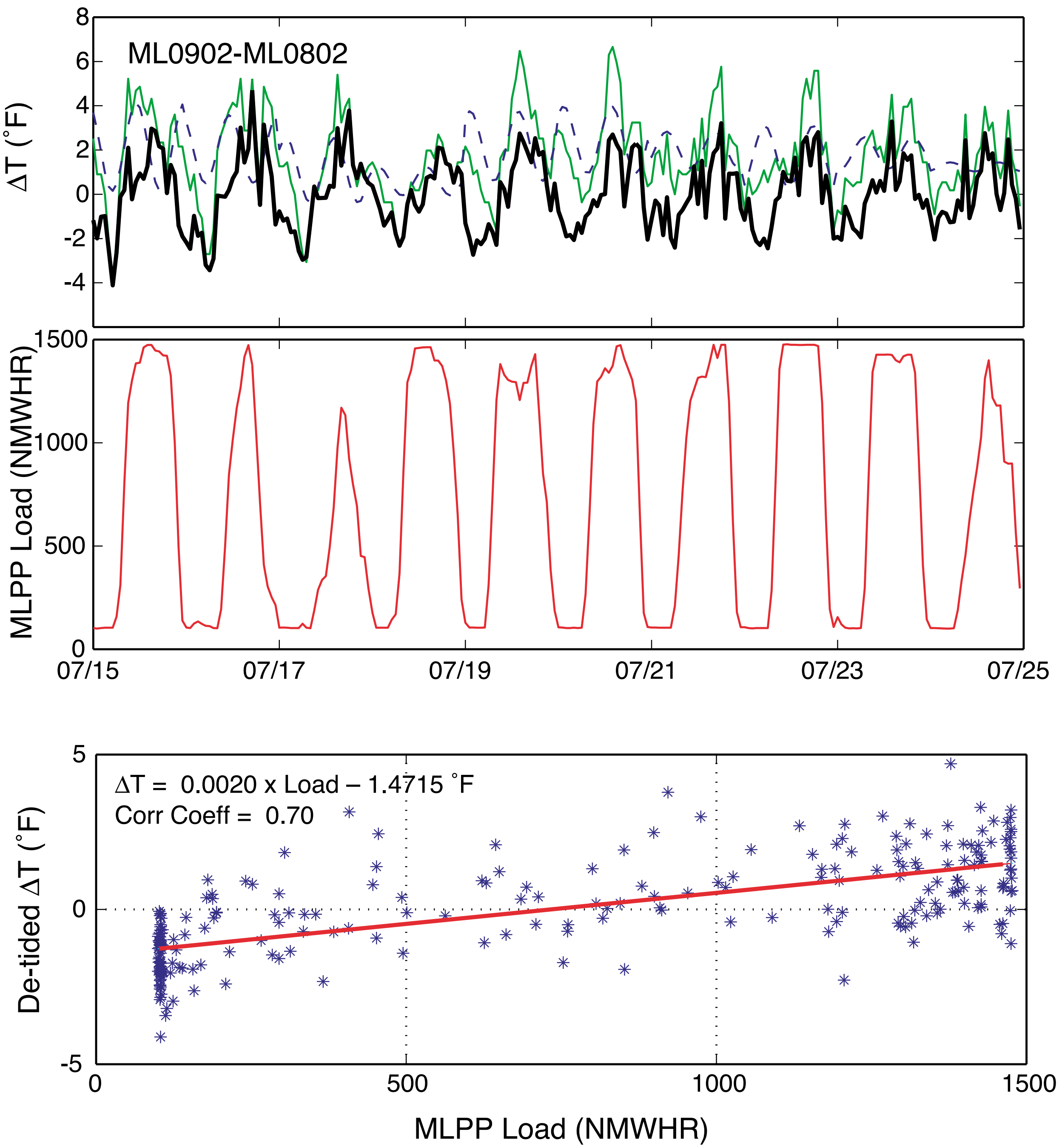


Figure 2-18. Sample projection model case showing the temperature difference between the primary Beach station and the S. Breakwater reference station (light green), the daily best-fit semidiurnal constituent (dashed blue), and the de-tided residual temperature difference (heavy black). MLPP load data (red) is fit to the de-tided temperature difference in the lower panel.

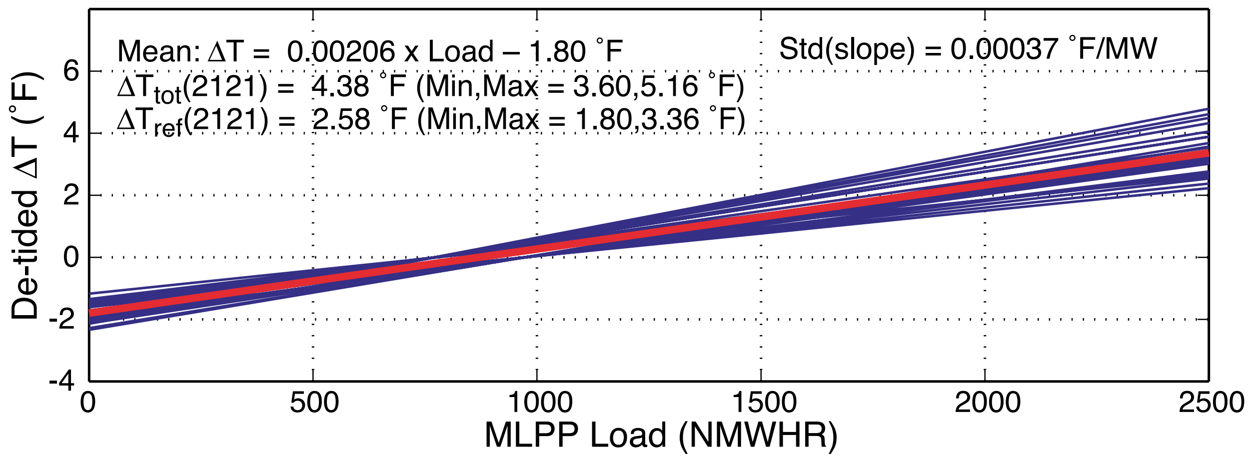


Figure 2-19. Ensemble of best-fit lines and the average result (heavy red) for all cases in Table 2-6 with resulting correlation values greater than 0.40. Projected temperature increases and ranges under future MLPP load conditions are shown as a total increase, including intercept values, and as an increase beyond the reference temperature.

Finally, it is necessary to interpret the projection results in terms of the requirement for new discharges that surface temperatures be no more than 4 ºF above the receiving water temperature at a distance of 1,000 feet from the discharge for more than 50 percent of a complete tidal cycle. Using the de-tided model results in Figure 2-19, it is reasonable to assume that this requirement will be met for the worst-case future conditions. Only the maximum predicted temperature rise (5.16 ºF), which derives from the upper range of best-fit model slopes, is significantly above the 4 ºF threshold. In addition, the predicted values are most appropriate for distances ~600 feet from the discharge location, which allows for a temperature reduction at the 1,000 ft range, and these worst-case temperature rises are relative to the zero-load temperatures at the primary recording stations. In the model results, the primary stations all are typically cooler than the reference stations under zero MLPP load conditions. Hence, if the reference temperatures themselves are assumed to characterize the receiving water temperature, then the lower temperature rise values in Figure 2-19 (ΔT_{ref}) should be used.

To provide a qualitative view of the projected worst-case conditions (flood tide combined with maximum MLPP load), the flood-tide observations in Figures 2-10 and 2-13 were used to estimate the expected worst-case surface temperature increases shown in Figure 2-20. In this example, the temperature increases observed by the survey vessel were subjectively overlain on the IR image from Survey #1. The values were then multiplied by 1.4 in keeping with the ratio of future-to-present peak load conditions suggested by the regression model in Figure 2-19. Since the survey vessel did not make direct observations of surface temperatures within about 300 ft of the shoreline, the predicted temperature rise in that region is relatively uncertain.

The frequency of occurrence of the worst-case condition diagramed in Figure 2-20 is a function of two components occurring simultaneously, flood tide and all (existing and proposed) power plant units operating at maximum load. It is likely to occur once each day in which flood tide aligns with all units of the plant operating at maximum load. Although the tidal conditions will obviously occur each day, with a projected 90 percent annual capacity factor for the combined-cycle units and a projected 40 percent annual capacity factor for Units 6 and 7, fewer than half of the days each year are likely to have maximum plant load conditions coinciding with the flood tide conditions. The tidal influence can be expected to be weaker than that captured in Figure 2–20 every two weeks due to the spring-neap cycle. Anomalous periods, such as in October 1999

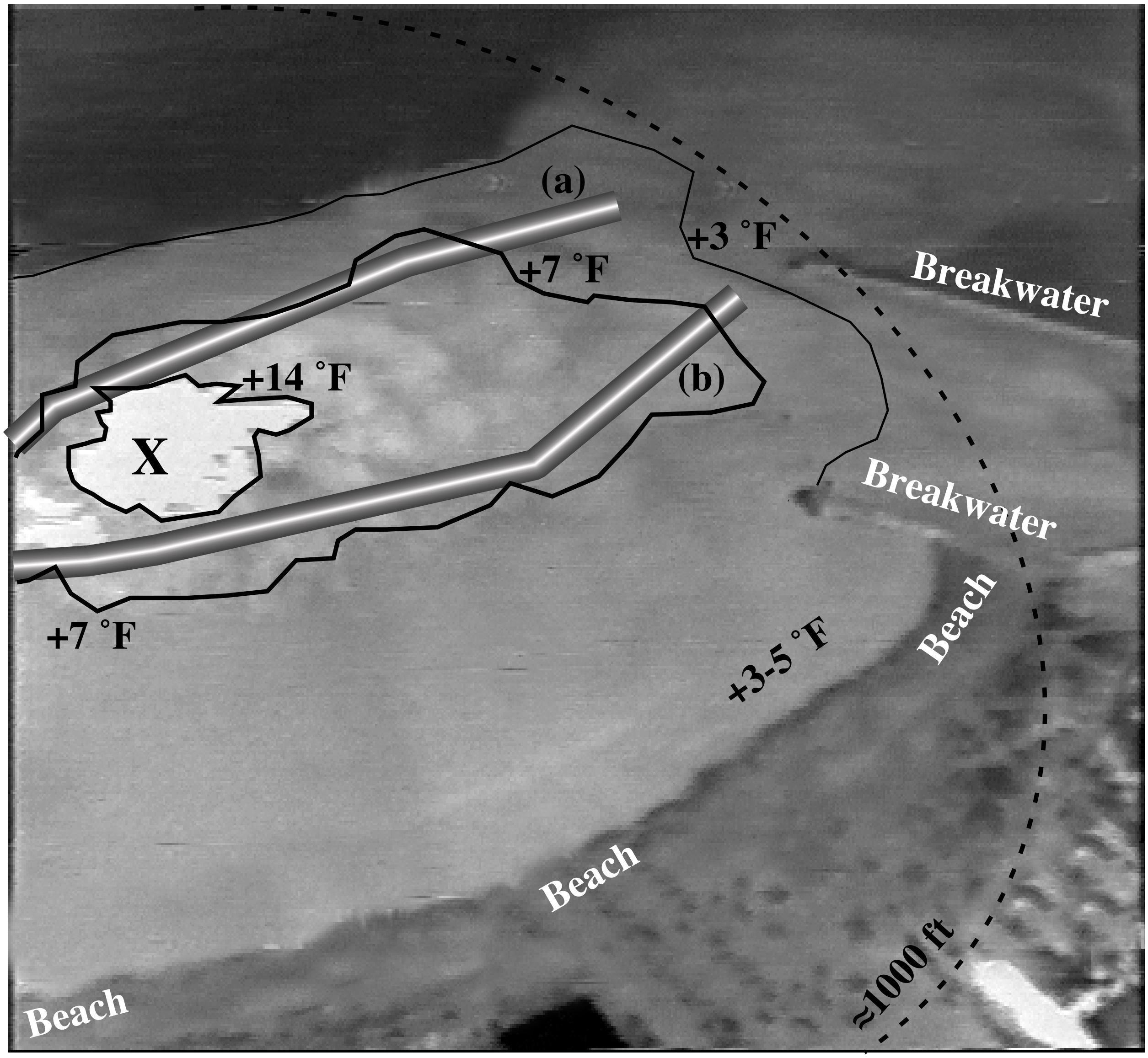


Figure 2-20. Projected worst-case (flood tide with maximum MLPP load) surface temperature rise relative to offshore reference values based on present conditions, as shown in Figure 2-10, and the statistical model of Figure 2-19. According to the model, surface temperature observations in Figure 2-13 were increased by a factor of 1.4 in order to mimic future conditions. Approximate locations of the CTD survey lines in Figure 2-21 are also shown (a, b).

when the MLPP load on Units 6 and 7 was maximum over several tidal cycles, hold the potential to exhibit temperature increases along the shoreline that exceed those estimated in Figure 2-20. This would only happen if the discharge plume were not substantially dispersed during offshore (ebb tide) flow, however. The example in Figure 2-9 shows that, although temperatures along the coast were warm during October 1999, the surface temperatures did not continually increase from tidal cycle to tidal cycle as would be expected if the heat input were allowed to accumulate in the surface waters.

The spatial extent of the projected discharge plume in Figure 2-20 is identical to the spatial extent of the present-day plume observed on 26 July 1999 (Figure 2-10). Only the magnitudes of the temperature increases have been adjusted. The assumption inherent in this projection is that the size of the discharge plume is not proportional to the amount of heat discharged, but rather it is controlled by the nature of the turbulent mixing between the cold receiving waters and the highly buoyant plume as it leaves the discharge structure. Thus mixing is expected to be stronger when both of the Units 6 and 7 discharges are operating. Stronger mixing with cold receiving waters could actually reduce the spatial extent of the plume even under increased thermal loading.

Future Plume Projection Summary

Future plume conditions were estimated in this report by making two basic assumptions: 1) the future plume will have the same spatial extent as the existing plume; and 2) the Delta-T values in the future plume will be greater than the present-day values by an amount proportional to the future increase in heat loading. The first assumption is justified on the grounds that it is probably not possible to accurately model the dispersion of the highly turbulent two-port discharge system for Units 6 and 7 and that it is likely that the turbulent mixing of warm discharged water with the infinite reservoir of cold ocean water will be increased under future conditions. This will act to negate some fraction of the effect of the larger volume loading.

The report attempts to fulfill the second basic assumption through a correlation of the observed temperature differences around the discharge with the variable MLPP load. It was shown that the correlation between Delta-T and MLPP load can be improved by removing a best-fit tidal signal from the various temperature difference time series. This leads to a linear regression model of Delta-T against MLPP load.

Consistent with the model results, a map of the predicted future surface temperature conditions under full MLPP load and incoming (flood) tidal currents (Figure 2-20) was produced by simply changing the observed Delta-T values for a comparable present-day situation to be larger by an amount proportional to the future increase in heat loading (~41%). In order to visualize the three dimensional structure of the future thermal plume, the temperature profile data from Survey #1 (Figure 2-17) were plotted as two vertical sections in Figure 2-21 (The approximate locations for the two vertical sections are shown on Figure 2-20). In Figure 2-21, the average temperature in the deeper waters below 25 feet was subtracted from the profile data. The resulting temperature anomalies were then multiplied by 1.4 to estimate future worst-case plume temperature conditions.

At the increased future levels, Delta-T values near the 1,000 ft. threshold are predicted to be at or slightly over the 4 °F value during peak load, incoming tide conditions. In all cases, the Delta-T values are expected to drop during other tidal phases or during lower MLPP load conditions. Thus, the conclusion is that the observations and assumptions do not point to a likelihood of Delta-T values above 4 °F at 1,000 feet for extended time periods under future conditions.

Characterizations of future MLPP thermal plume conditions based upon this study include the following:

- The future plume under worst-case conditions (full load, flood tide) is projected to have a configuration similar to that of the present plume, as illustrated in Figures 2-13, with temperature increases ~600 feet from the discharge up to 41% higher (e.g., if a present temperature increase of 5 °F occurs on the surface, in the future worst-case it could be 7 °F).

- The temperatures in the future thermal plume are not expected to exceed 4 °F above natural water temperatures at the shoreline, the surface of any ocean substrate, or the ocean surface beyond 1,000 feet from the discharge for more than 50 percent of the duration of any complete tidal cycle.

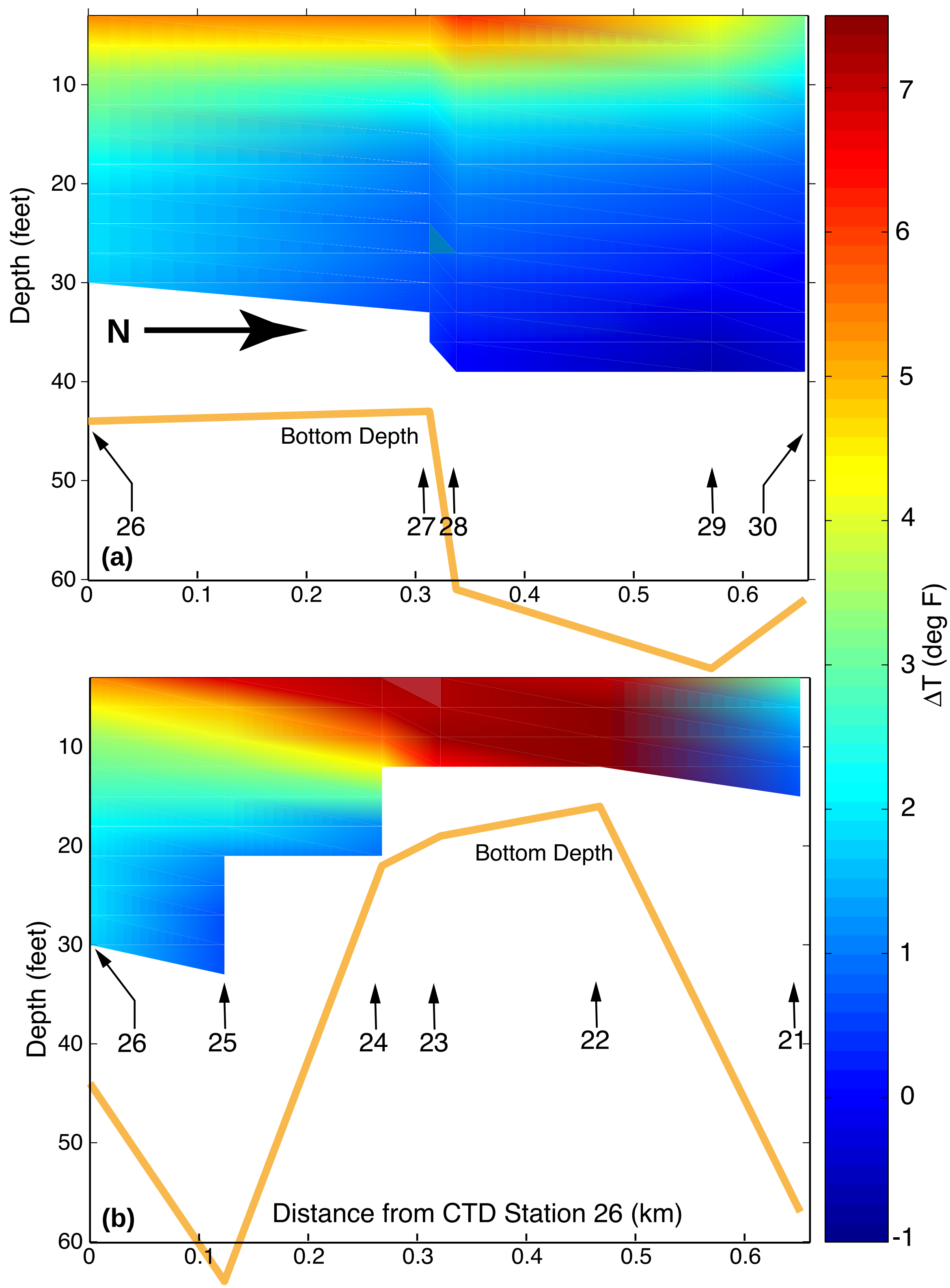


Figure 2-21. Projected worst-case vertical temperature anomaly sections from CTD stations 26–30 (a) and 26–21 (b). Anomalies were computed by subtracting the mean temperature below 25 feet and multiplying by 1.4 to approximate future peak conditions.

- The turbulent mixing within the future thermal plume near the discharge is expected to increase with increased thermal load and velocity at the point of exit, which will counteract some fraction of the increased surface temperatures through increased mixing with cold water around and below the plume.

- The maximum temperatures of the future thermal plume are not expected to exceed the natural water temperatures by more than 20 °F at any point on the ocean surface based on the vigorous mixing that occurs with surrounding ocean waters at the submerged discharge.

- The excursion, and therefore effect, of heated water from the future thermal plume on Moss Landing Harbor and Elkhorn Slough temperatures is expected to remain insignificant under future conditions due to the dominance of natural heating and tidal variations in these water bodies absent any direct discharge into Elkhorn Slough.

Given these results, it is concluded that operation of MLPP with the proposed modifications will comply with the Thermal Plan for new facilities in all aspects with regard to the 4 °F requirement for conditions within the environment of the receiving waters. However, the maximum temperature of the thermal discharge will exceed the natural temperature of the receiving water by more than 20 °F under some operating conditions. For this reason, as referenced in the July 21, 1999 RWQCB report request, the following section of this report includes an analysis of alternatives and modifications available for achieving full compliance with Thermal Plan requirements.

3.0 ALTERNATIVES FOR ACHIEVING COMPLIANCE WITH THE THERMAL PLAN

3.1 Introduction

This section of the report includes an analysis of alternatives and modifications potentially available for achieving compliance with the Thermal Plan standards for new facilities, as referenced in the July 21, 1999 RWQCB requirements letter. This section evaluates potential alternatives that could be implemented (subject to further environmental review) at the MLPP to achieve strict compliance with the Thermal Plan.

This analysis includes alternatives to the proposed cooling water discharge for the new combined-cycle (CC) units at MLPP, modifications to the existing discharge system, and modifications to MLPP operations after installation of the new CC units. Each alternative is evaluated in terms of its effectiveness in achieving the Thermal Plan standards, feasibility of application at the Moss Landing location, secondary impacts including environmental impacts, and the benefits realized in proportion to the economic costs.

Duke Energy believes that the proposed project modifications to the existing once-through cooling water system to serve the new CC units represents the preferred case in terms of balancing environmental impacts and costs to the consumers. The combination of advanced combined-cycle technology with the superior thermodynamic efficiency of once-through seawater cooling minimizes both environmental impacts and the cost of generation to the consumer. As explained in the following descriptions, each of the suggested alternatives would cause undesirable secondary environmental impacts, increase generation costs through plant efficiency reductions, and/or increase investment costs which are less desirable than the proposed project base case.

The following alternatives are discussed in this section:

1. A new, separate offshore discharge for once-through cooling water from the new CC units,

2. Closed-cycle cooling systems in lieu of the proposed once-through cooling water system for the new CC units, including:

    - mechanical draft cooling towers
    - natural draft cooling tower
    - air cooled condensers

3. Increased once-through cooling water pumping rate for the CC units to reduce the temperature of the combined Units 6 and 7 plus CC units discharge,

4. Generation curtailment of Units 6 and 7 to limit the maximum 24-hour average cooling water discharge temperature.

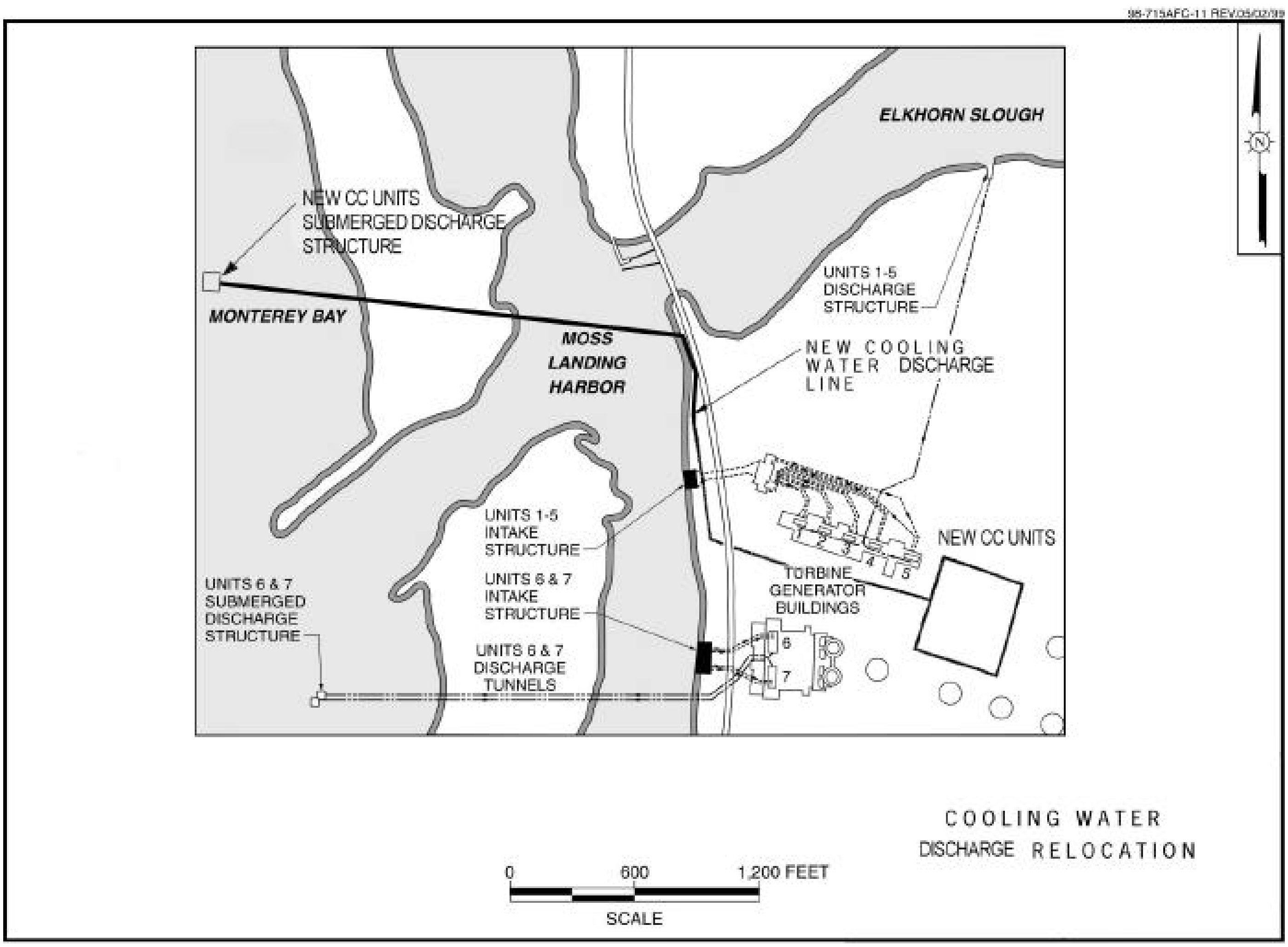
3.2 Separate Offshore Discharge for the Combined-Cycle Units

This alternative evaluates a new offshore cooling water discharge location for the combined-cycle plant. The purpose of this alternative is to separate the new discharge from the existing MLPP discharge so that the Thermal Plan requirements for new facilities would apply only to the new CC units, even though it wouldn't decrease the total heat or flow discharged into Monterey Bay compared to that of the proposed project. Although, as previously described, the Thermal Plan requirements for impact to shorelines are expected to be met with the proposed combined discharge, it was decided to evaluate a new cooling water discharge location in Monterey Bay, north of the breakwater at the Harbor entrance.

The proposed location and routing of the offshore discharge line is shown in Figure 3-1. This alternative consists of installing two new 10-foot diameter concrete pipes (one for each of the new combined-cycle units) extending from the new CC units westward through the existing

MLPP and under Pacific Coast Highway to the eastern shoreline of Moss Landing Harbor. From there the new lines would run to the north along the seaward side of Highway, undersea across the mouth of the slough, underground across the beach north of the breakwater, and out to sea for a distance of about 700 feet offshore, at a depth of about 30 feet below the water surface. This routing generally follows the right-of-way of the existing fuel oil tanker unloading line. The outlet would consist of two vertical pipe sections discharging upward, similar to the existing Units 6 and 7 outfall system.

Figure 3-1. Alternate Combined-Cycle Cooling Water Discharge Location.



The estimated additional capital investment for a new dedicated offshore discharge for the new CC units is about $19 million more than the estimated cost of the cooling water modifications currently included in the project. This cost includes the installation of approximately 6,900 feet of 10-foot diameter discharge pipe.

This new discharge would by necessity create a new thermal disturbance within the Monterey Bay National Marine Sanctuary, although the standards of the Thermal Plan would be met.   The standing prohibition of disturbances of the ocean floor in the enabling legislation of the National Marine Sanctuary may be a serious impediment to this alternative. This alternative will require extensive environmental analysis to obtain permits, with associated potentially significant costs, and would receive close scrutiny from the RWQCB, the U.S. Army Corps of Engineers, California Department of Fish and Game, the California Coastal Commission and numerous other agencies as well as the public. In addition, CalTrans may have special requirements for the Highway 1 crossing which may not be fully considered in the present cost estimate. Unavoidable construction impacts will result from trenching and armoring the offshore length of pipeline and discharge risers, as well as disruption in the Harbor to install the underwater crossing at the mouth of Elkhorn Slough and potential disturbance of cultural resource sites in the western area of the plant.

The combination of the new CC units cooling water discharge with the existing discharge from Units 6 and 7, as currently proposed in the project, will result in reduced discharge temperatures as compared to the discharge of Units 6 and 7 alone. Under most circumstances, this combined discharge would also meet the Thermal Plan requirements, including the 20 ºF Delta-T. The installation of a separately located discharge to serve only the new units would not have the beneficial effect of reducing the Units 6 and 7 cooling water discharge temperature when those units are operating at higher loads, and would also result in the unavoidable impacts of creating an entirely new discharge in the Bay. Duke Energy believes that the project proposal of a combined discharge is the environmentally preferable choice and the separate discharge alternative is eliminated from further consideration.

3.3 Closed-Cycle Cooling Systems

The once-through cooling water system modifications as proposed for the project will result in a highly efficient power generation facility and optimize the use of existing infrastructure resources. Alternative closed-cycle cooling water systems for the new CC units could reduce ocean thermal impacts by decreasing or, in the case of air cooled condensers, essentially eliminating seawater used for cooling. These alternatives would, however, produce power less efficiently (i.e., more fuel used for the same MW-hrs generated) and result in certain undesirable secondary impacts, such as salt drift onto adjoining properties and adverse visual impacts.

The alternatives considered would replace the once-through ocean cooling water system proposed for the new CC units with either a recirculating cooling water system (cooling towers) or air cooled condensers. In the case of a recirculating cooling water system, either mechanical draft or natural draft cooling towers could be used.

3.3.1 Mechanical Draft Cooling Tower

Two possibilities for a source of recirculating cooling water exist at the Moss Landing site, fresh ground water or sea water. Although freshwater systems have the advantage of smaller makeup water requirements due to less dissolved solids, a continuous freshwater makeup supply of about 5,400 gpm would be required for a freshwater cooling tower system serving the new CC units at Moss Landing Power Plant. Due to the current and expected future limitations of freshwater supply in the area, it was decided that a freshwater system was not realistic and the evaluation would consider sea water cooling towers.

With the mechanical draft cooling tower scheme, warm water from the steam turbine condensers and other cooling water users in the plant would flow to a new cooling tower(s) consisting of air-water contact surfaces (slats) and electric motor-driven fans. The recirculating water to be cooled falls from the top through the tower where it contacts a high air flow drawn through the tower by the fans. Cooling occurs though partial evaporation of the falling water (similar to the operation of a “swamp” cooler) and contact cooling of the water by the cooler air. Cooled water collects in a large basin beneath the tower where cooling water circulation pumps return the water to the condensers and other users to repeat the cycle.

Recirculating water is lost from the process principally in two ways: evaporation from the tower and a continuous "blowdown" (purge) stream. The blowdown stream is intentionally withdrawn to prevent the buildup and precipitation of dissolved solids in the recirculating water since the solids do not evaporate in the tower. A third minor loss consists of liquid water droplets (drift) entrained with the air and water vapor leaving the top of the cooling tower. The evaporation, blowdown, and drift losses must be replenished by adding replacement ("makeup") water to the system. For a sea water recirculating cooling system serving the new CC units, the estimated ocean water required for makeup would be about five to seven percent of the ocean water use for an equivalent once-through cooling water system.

Sea water mechanical draft cooling towers for the Moss Landing CC units would consist of two structures, one per unit, each approximately 410 ft x 53 ft x 55 ft high. Ocean water makeup for this system would be supplied from the existing Units 6 & 7 cooling water pumps or new pumps at the existing Units 1–5 pumpwell. The circulating water and blowdown stream would contain salinity (dissolved solids) approximately 50 percent greater than local sea water. The estimated combined full capacity flow rates for both towers are:

Recirculating water	250,000 gpm
Blowdown (returned to ocean)	7,800 gpm
Makeup (withdrawn from ocean)	12,000 gpm

The blowdown stream will contain residual concentrations of biocides, dispersants, and other conditioning chemicals, in higher concentrations than the existing once-through cooling water discharge. Blowdown will be disposed by discharge to the ocean at a temperature of approximately 84 °F. The estimated total installed capital costs associated with the two forced draft mechanical cooling towers for the new CC units including towers, basins, cooling water circulating pumps, chemical additive systems, and supporting systems are about $12 million more than the proposed once-through cooling water system.[1] Figure 3-2 shows a possible location where the new cooling towers could be installed at MLPP.

Mechanical draft cooling towers would significantly diminish the net power output and operating efficiency of the modernized plant. The combination of the higher steam turbine condenser temperatures caused by the recirculating cooling system and the higher plant electrical load compared to the once-through cooling water case would decrease the net power output available from the new CC units by about 25 MW (for the same fuel consumption). This reduction in capacity will have to be made up by other, probably less efficient and more polluting power sources. The estimated annual revenue losses from this decrease in capacity are approximately $2 million per year.[2] Over the life of the project, the use of cooling towers would cost approximately $60 million.

Visible fog plumes could be expected (probably frequently during the winter) due to condensation in the atmosphere of the considerable amount of water vapor emitted from the top of towers.

Cooling tower drift "raining" out of the plume could cause nuisance salt water deposition on the surrounding area which could result in increase equipment maintenance requirements in the plant and adverse effects on nearby agriculture. Drift would also lead to increased fine particulate salt emissions from the facility in the form of dissolved solids emitted with the drift droplets. For the salt water tower considered, the estimated additional particulate emissions to the atmosphere associated with drift would be about 750 lb/day.[3] This quantity would represent a substantial increase in PM10 emissions from the project and could cause adverse air quality impacts.

Cooling towers are a significant potential source of overall power plant noise impacts on surrounding areas, due to the significant quantity of elevated equipment such as fans, motors, and gears. For all the above reasons, the proposed once-through cooling water system is preferred to a mechanical draft tower.

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[1] The amount shown is the additional capital investment required to substitute mechanical draft cooling towers for the proposed once-through cooling water system.
[2] Based on a net margin approximately $10/MW-hr and a 90 percent capacity factor.
[3] Assuming drift is 0.0005% of recirculating water rate at about 50 ppt total dissolved solids.

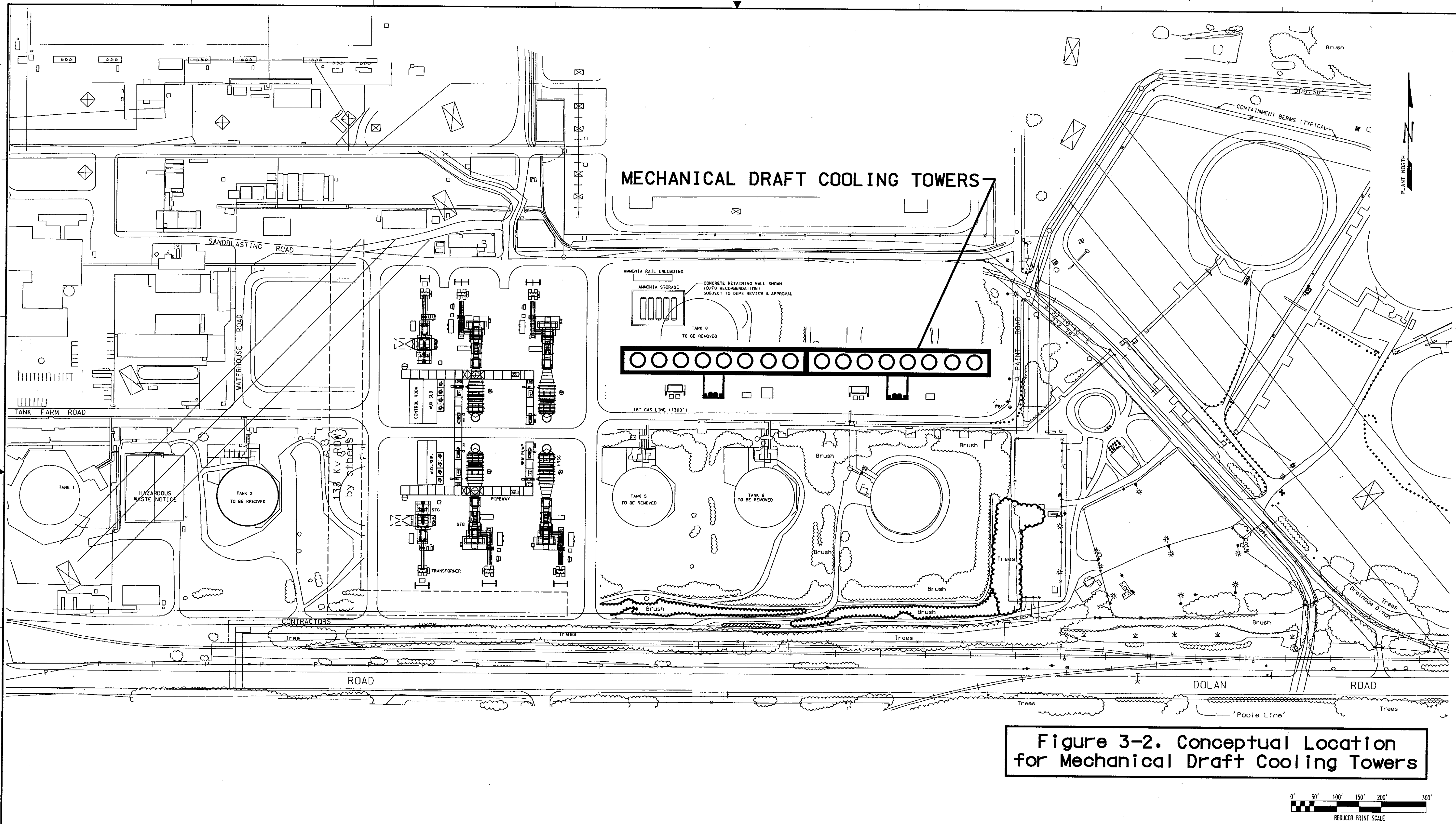

Figure 3-2. Conceptual Location for Mechanical Draft Cooling Towers

0' 50' 100' 150' 200' 300'
REDUCED PRINT SCALE

REV.	DATE	REVISION DESCRIPTION	DRWN CHK.	LAYO MECH	CIVIL ELEC	ENGM PROJ	REV.	DATE	REVISION DESCRIPTION	DRWN CHK.	LAYO MECH	CIVIL ELEC	ENGM PROJ	DWG.NO.	REFERENCE DRAWINGS

DUKE/FLUOR DANIEL

DRAWN BY	T. QUINLAN	INITIALS/DATE
CHECKED BY		INITIALS/DATE
LAYOUT APPROVAL	R. MANNING	2/2/00
MECHANICAL APPROVAL	H. REINHART	INITIALS/DATE
CIVIL APPROVAL		INITIALS/DATE
ELECTRICAL APPROVAL		INITIALS/DATE
ENGINEERING MANAGER	T. MUALLEM	INITIALS/DATE
PROJECT DIRECTOR		INITIALS/DATE

PLOT PLAN
GTG
COMBINED CYCLE

MOSS LANDING
CONCEPTUAL DESIGN
MECHANICAL DRAFT COOLING TOWER OPTION

SCALE	CONTRACT NUMBER	UNIT No	DOC TYPE	FUNC	SUBJECT CODE	SEQ No	REV.
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3.3.2 Natural Draft Cooling Tower

A natural draft cooling tower system is similar in principal to the mechanical draft system. The primary difference is that the mechanical fans to move the cooling air are replaced by what is essentially a very large chimney. Air is drawn in at the base of the tower due to the less dense (more buoyant), warmer air exiting the top of the tower. This natural air circulation contacts the returned cooling water inside the tower and cools the water by evaporation and direct contact with the cooler air, similar to the cooling which occurs in a mechanical draft tower. Thus the cooling water recirculation, blowdown, and makeup rates and quality are about the same as for the mechanical (forced draft) system.

A natural draft cooling tower to serve the Moss Landing combined-cycle units would be approximately 250 feet in diameter at the base and about 370 feet in height. Figure 3-3 shows a conceptual location for the new natural draft cooling tower. The estimated total installed cost for the new natural draft tower is about $13 million more than the proposed upgrade to existing facilities utilizing a once-through cooling water system.[4]

Most of the potential negative impacts described for the mechanical draft towers would also be associated with a new natural draft tower for the MLPP. The blowdown discharge to the ocean would be the same. Drift losses and the resulting PM10 emissions would also occur, although at somewhat reduced rates. Noise impacts would be less. The auxiliary power requirement would be reduced, due to the lack of mechanical fans, but the steam turbines output would still be decreased by about 22 MW. The estimated annual revenue losses from this decrease in capacity are approximately $1.7 million per year.[5] Over the 30-year life of the project, the use of a natural draft cooling tower would increase power costs by approximately $51 million.

Visible condensate plumes would also periodically occur at the top of the tower and, obviously, the overall visual impact due to the size of the tower is much more significant. This alternative was eliminated, primarily because of the very adverse visual impacts of such a massive structure and the high capital investment required.

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[4] Incremental capital investment above cost of proposed once-through cooling water system.
[5] Based on a net margin of $10/ MW-hr and a 90percent capacity factor.

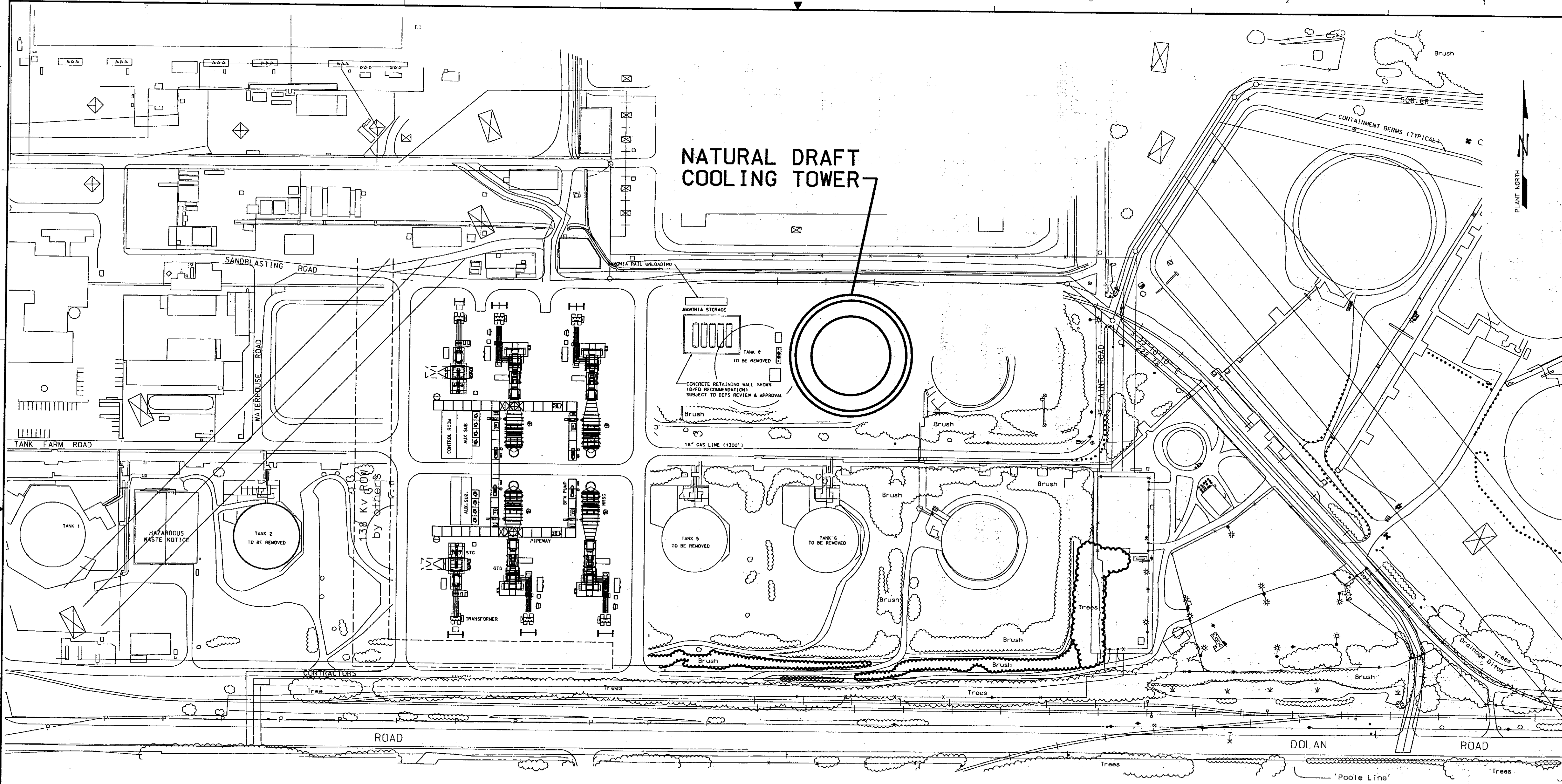

Figure 3-3. Conceptual Location for Natural Draft Cooling Tower

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DUKE/FLUOR DANIEL[sm]

	INITIALS/DATE
DRAWN BY T. QUINLAN	
CHECKED BY	
LAYOUT APPROVAL R. MANNING	12/22/99
MECHANICAL APPROVAL H. REINHART	
CIVIL APPROVAL	
ELECTRICAL APPROVAL	
ENGINEERING MANAGER T. MUALLEM	
PROJECT DIRECTOR	

PLOT PLAN
GTG
COMBINED CYCLE

MOSS LANDING
CONCEPTUAL DESIGN
NATURAL DRAFT COOLING TOWER OPTION

SCALE	CONTRACT NUMBER	UNIT No	DOC TYPE	UNIC	SUBJECT CODE	SEQ No	REV.
1"=200'	226781	0	SK	5		07	A

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3.3.3 Air Cooled Condensers

Air cooled condenser systems for power plant heat rejection are sometimes used when insufficient water supplies are available for a once-through or recirculating cooling water system. In an air-cooled condenser system, exhaust steam from the steam turbine generator is cooled and condensed in a large external heat exchanger using atmospheric air as the cooling medium. Large, electric motor-driven fans move large quantities of air across finned tubes (similar in principle to an automobile radiator) through which the exhaust steam is flowing. Heat transfer from the hot steam to the air cools the steam causing it to condense. The heated air is exhausted to the atmosphere. In this case, there would be no seawater required for condenser cooling and therefore essentially no thermal discharge from the new CC units to surface waters.

Air-cooled condensers for power plants are very large structures and consume significant amounts of power for operation of the fans. Noise impacts are substantial and, without extensive abatement, are generally greater than for mechanical towers. Air cooled condensers also significantly reduce steam turbine output due to higher condensing temperatures as compared to once-through or recirculating water condensers.

It is estimated that air-cooled condensers for the new CC units, one for each unit, would each occupy about 0.75 acre of plot space and extend to a height of 80 to 90 feet. Overall, the net electrical output for the two CC units would be reduced by a total of more than 60 MW [6] (the size of a small power plant). Figure 3-4 shows the plot space that would be consumed.

The estimated additional total installed cost for the two air cooled condensers compared to the once-through cooling water system is about $15 million, combined total costs for both CC units. The estimated annual revenue losses from the associated decrease in capacity is about $3.8 million per year.[7] Over the 30-year expected life of the project, the use of air cooled condensers would cost about $114 million.

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[6] For summertime operation; the corresponding reduction for winter operation is about 37 MW.

[7] Based on a net margin of $10/MW-hr and a 90percent capacity factor, and assuming an annual average capacity reduction of 48.5 MW.

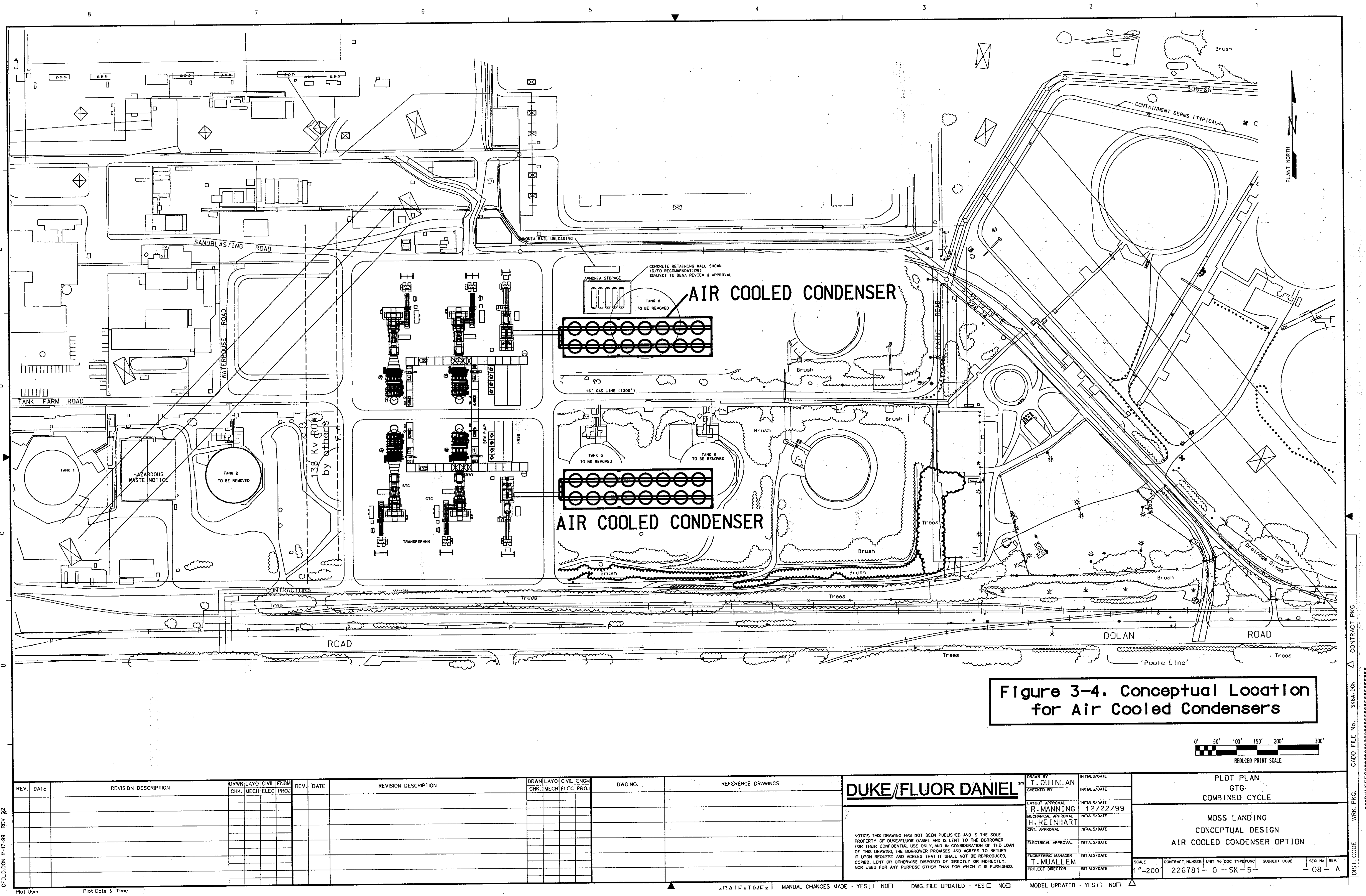

Figure 3-4. Conceptual Location for Air Cooled Condensers

Because of the substantial loss in net power output, the significant adverse visual impacts of these systems, and the large associated costs, the air-cooled condenser option is eliminated from additional consideration.

3.4 Additional Pumping to Limit Temperature Rise

The new CC units will be designed to maintain a maximum cooling water temperature rise across the condensers of less than 20 ºF, and therefore will meet the 20 ºF requirement of the Thermal Plan. However, when existing Units 6 and 7 are operating close to maximum capacity, the combined cooling water discharge from Units 6 and 7 plus the CC units will exceed the 20 ºF requirement due to the greater temperature rise for Units 6 and 7.

This alternative considers adding cooling water pumping capability to the new CC units to reduce the combined discharge to less than the Thermal Plan requirement. This dilution water could be utilized both when the CC units are operating and when the CC units are off line by pumping through the condensers while one or both units are shut down. The following table (Table 3-1) illustrates this alternative.

Table 3-1. Cooling Water Dilution Alternative.

Units 6 and 7			CC Units			Combined discharge	
Output, MW	**CW flow, gpm**	**Temperature rise, ºF**	**Output, MW**	**CW flow, gpm**	**Temperature rise, ºF**	**CW flow, gpm**	**Temperature rise, ºF**
1500	600,000	28	0	250,000	0 *	850,000	20
1500	600,000	28	1060	490,000	10.2	1,090,000	20
750	300,000	28	1060	370,000	13.5	670,000	20

* Assumes CC plant cooling water pumps operate when CC units are shut down and ocean water temperature is 55 °F.

As shown in the table, almost twice the once-through cooling water flow rate for the CC units as currently proposed in the project (490,000 gpm versus 250,000 gpm) would be required to dilute the Units 6 and 7 discharge to meet the 20 ºF temperature rise criterion for the complete range of MLPP operating scenarios.

The changes required for this alternative would be extensive and costly. The existing Units 1-5 intake structure would need to be replaced or expanded to handle the significantly increased cooling water flow for the new CC units. The new CC unit cooling water circulating pumps and piping would be substantially larger. Most significantly, major modifications would be needed to increase the flow capacity of the existing Units 6 and 7 discharge system, which presently has just enough capacity to handle only the full design flow from Units 6 and 7 plus the 250,000 gpm currently proposed for the new CC units. The entire existing dual discharge system from the Unit 6 and 7 condensers to the offshore outfalls would need to be replaced with a new, larger single discharge conduit capable of handling the much larger combined flow rates. The estimated total costs for these changes are well in excess of $20 million above the costs of the proposed modernization project.

The secondary effects associated with this alternative are also significant. Most importantly, the entrainment and impingement effects to marine organisms resulting from the project, which are roughly proportional to cooling water flow rate, would be substantially increased and may not be justified by the relatively small thermal benefits. The construction impacts in the Bay and Harbor, although temporary, would have additional environmental impacts over those of the proposed project. Using dilution to lower the discharge temperatures may not be the most acceptable regulatory solution to the meet the Thermal Plan standard of 20 ºF temperature rise at MLPP. The plant internal power loads needed to pump such large quantities of water would be significantly increased as compared to the proposed project. Finally, although the discharge temperature from the plant would be reduced, the total heat released to the ocean (in terms of Btus) would be the same.

For all these reasons, this alternative is eliminated.

3.5 Generation Curtailment

Periodic partial curtailment of existing Units 6 and 7 could be used to achieve the Thermal Plan temperature rise standard. The thermal benefits of curtailing Units 6 and 7, however, would be diminished in the future due to the fact that these units would normally be dispatched after the new CC units and therefore will operate less frequently and at lower loads as compared to present operations. Since the new CC units will meet the 20 ºF requirement across the range of operating conditions, no partial curtailment would be necessary for these units.

This option would consist of limiting the maximum output of Units 6 and 7 to the level that corresponds to a temperature rise of 20 ºF at the maximum possible cooling water flow rate. This option would allow the MLPP to satisfy the Thermal Plan for any operating combination of Unit 6, Unit 7, and the new CC units. The maximum output from each of Units 6 and 7 in this case would be limited to about 535 MW[8], a combined loss of about 430 MW in generating capacity to the state grid.

This limit should apply on a 24-hr average basis, to be consistent with the 24-hr averaging requirement incorporated in the current facility NPDES permit. Thus, either unit could exceed 535 MW for a portion of a given day as long as offsetting operation occurred at reduced loads on the same day to produce a daily average output less than or equal to the limit.

This alternative would result in a permanent loss of generation assets to Duke Energy. The cost to replace this lost capacity at today's prices would require a new capital investment of about \$150 million[9] to \$260 million.[10]

Units 6 and 7 are among the most efficient fossil fuel generating units in the state. The relatively small thermal discharge reduction benefit (if any) resulting from this alternative does not justify removing highly efficient capacity from the state system. The deficit created will have to be made up by marginal units, which will consume more fuel to produce the same amount of power and probably create more pollution in the process. For this reason and considering the severe financial burden, this alternative is eliminated.

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[8] Based on a nominal 28 °F temperature rise at 750 MW output for either unit and assuming that heat rejection is approximately proportional to generation output.

[9] Based on average cost for new U.S. generation of \$341/kW of capacity. Source: *1998-1999 Gas Turbine World Handbook.*

[10] Based on an assumed more typical cost of new generation in California of about \$600/kW.

3.6 Conclusions Regarding Alternatives

From the above review of alternatives for achieving full compliance with the requirements of the Thermal Plan for new facilities, it is clear that there are no reasonable alternatives for implementation at the proposed MLPP modernization project. The only component of the proposed discharge that results in it being characterized as "new" is the addition of the cooling water from the new combined-cycle units, and that component of the discharge will be in full compliance with all requirements of the Thermal Plan. Even with the blending of the discharge water from the existing and proposed units, the discharge will be in compliance with the 4 ºF requirement of the Thermal Plan at all times, and of the 20 ºF requirement much of the time. Also, as has been concluded in the past, and again in Section 4.0 of this report, the beneficial uses, including a balanced indigenous community of organisms, of the receiving water have been, and will continue to be, protected with the utilization of the cooling water discharge structure into Monterey Bay. Therefore, considering the near full compliance with the Thermal Plan for new discharges, the protection of beneficial uses, and the high capital, operating, environmental, and other societal costs, there are no sound reasons to implement any of the available alternatives.

4.0 PREDICTED THERMAL DISCHARGE EFFECTS ON ORGANISMS

The July 21, 1999 RWQCB "requirements letter" requested "*c. An evaluation and comparison of the differences in thermal discharge effects between historical (with and without the operation of Units 1-5) and new operation conditions. This evaluation may be based on empirical data and plume dispersion modeling.*" In addition to the physical aspects of the historical, present, and proposed discharges previously discussed in Section 2.0 of this report, this section discusses the biological aspects of the thermal discharges. These discussions result from information gathered from existing studies.

An increase in maximum potential Btu loading of approximately 41 percent over present at the Units 6 and 7 discharge will occur. This 100 percent capacity operating scenario is the least efficient and would be the last to be dispatched at the plant. The plant's preferred operating condition is to dispatch the most efficient combined-cycle units first. Therefore, during these preferred operating conditions, a lower temperature discharge than at present would prevail. If units are not in use, (e.g., if either Unit 6 or Unit 7 is shut down) circulating cooling water pumps could be shut down as soon as possible which would reduce both entrainment rates and discharge volumes. The typical preferred operating scenario of running only the combined-cycle units provides an additional degree of assurance to the findings of our assessment of CWS effects at 100 percent capacity.

4.1 Habitats Exposed to Thermal Plume and Potential Effects of Thermal Discharge

A wide range of field studies documented a near absence of thermal effects from the existing Units 6 and 7 discharge. These findings are applicable to the new plume, since the discharge Delta–T° will be slightly cooler. Under peak operating conditions the total thermal loading will increase, with a 42 percent increase in flow (600,000 gpm to 850,000 gpm), and a 41 percent increase over the current peak in Btu loading. However, a 41 percent increase in Btu combined with the increased flow will result in a lower Delta-T° from current peak operating conditions.

In assessing the incremental plume exposure, laboratory thermal tolerance data are used in combination with the site's field study results to augment the range of predictive information. To this end, information on the thermal tolerance and behavior of species that could come in contact with the modernized MLPP's thermal discharge is summarized in our review.

The effects of the MLPP CWS discharges have been previously studied. PG&E (1973) biologists and oceanographers studied the effects of the offshore discharge of Units 6 and 7 and the discharge from Units 1 through 5 in Elkhorn Slough. Their thermal discharge studies included aerial infrared (IR) thermal imagery mapping of both of the power plant's discharge plumes at full load and under varying tide and oceanographic conditions.

Synoptic trawl and gillnet samples of fishes, and grab samples of shoreline and bottom dwelling organisms, were collected from sampling locations in the discharge areas (PG&E, 1973). The biological sample results were statistically analyzed and compared to temperature measurements and plume IR images. Results from these studies provide an excellent basis for understanding the distribution and dispersion of these discharge surface plumes and the organisms exposed to them. An absence of significant thermal effects was demonstrated by these results.

PG&E (1973) studies of the discharges from the early seventies were followed immediately from July 1974 to July 1976 by the studies of Drs. Nybakken, Cailliet, and Broenkow (Nybakken et al., 1977). In 1978, PG&E contracted for studies of Elkhorn Slough for a 316(a) Demonstration of the Units 1 through 5 thermal discharge effects. Studies by Drs. Nybakken, Cailliet, and Broenkow (Nybakken et al., 1977) provided the first fully integrated study of the benthos, fishes, zooplankton, and hydrography of the Harbor and Slough. Baseline ecological studies conducted in Elkhorn Slough by professors and students of the Moss Landing Marine Laboratories have contributed to the understanding of the MLPP discharge effects.

Dr. E. H. Smith, a professor at University of Pacific, published his study's findings in another synoptic report on Units 1 through 5 thermal discharge effects on adult and larval fishes, invertebrates, birds, and mammals of the Elkhorn Slough and Moss Landing Harbor (Smith, 1977). His findings, along with findings from other studies such as PG&E (1973) and Nybakken et al. (1977), were used to assess, using EPA 316(a) guidance, the impacts of the Units 1 through 5 discharge on the Slough and Harbor's habitats and species (PG&E, 1978). The Demonstration found that although the discharge exceeded the Thermal Plan numerical limits, the discharge location, temperature, and volume protected the beneficial uses of the receiving waters.

Based on the 316(a) Demonstration conclusion of no thermal effects, the RWQCB found that the beneficial uses of the receiving water were protected. This finding was made even with the concentrated nature of the Units 1 through 5 discharge into the narrow confines of Elkhorn Slough. This is relevant to the assessment of the modernized MLPP offshore open-water discharge. The combined-cycle and Units 6 and 7 discharge plume is expected to contact a portion of sandy beach currently used as a dredge spoil dumpsite. It is not expected to contact the sea bottom at the point of discharge. Based on the evidence that the larval and adult fishes in the area of the Units 1 through 5 concentrated discharge showed no effects from the thermal plume, we believe that there will be an absence of appreciable harm from the modernized Units 6 and 7 discharge, even at 100 percent generating capacity. Existing waste discharge requirements for MLPP (Order 95-22; NPDES No. CA 0006254) find that the present thermal discharge limitations for the Units 6 and 7 discharge “are adequate to assure protection of the beneficial uses of Monterey Bay.”

A number of other studies provide significant baseline information on the Monterey Canyon's nearshore benthic habitat (Oliver and Slattery, 1973; Oliver et al., 1976) and hydrography of the Harbor and Slough (Smith, 1973; Malzone and Kvitek, 1994; Lindquist, 1998). Data and information contained in existing studies, as well as new confirmatory information, are reviewed and summarized in this report. While the primary goal of this section is to clarify what information and data are available, we have also provided some level of synthesis that includes information on when and where the studies were conducted. The geographical location of studies, the period of time the studies were conducted, and the type of study are illustrated along with information on concurrent power plant operating conditions. We also provide a discussion of how the findings fit together to provide data that are adequate to assess the MLPP modernization discharge. Table 4-1 shows habitats in the vicinity of MLPP and its thermal discharge into Monterey Bay, and the predicted degree of contact of the proposed modernized project thermal plume with the habitats. Figure 4-1 shows locations of marine substrate habitats in the area of the discharge, overlain on the Figure 2-20 depiction of projected worst-case future plume water surface Delta-T conditions.

Table 4-1. MLPP Habitat Locations and Predicted Degree of Modernized Thermal Plume Contact. (Note: Potentially affected areas assume a thermal plume, as illustrated in Figures 2-20 and 4-1, based on worst-case conditions of Units 6 and 7 and new combined-cycle units operating at peak loads on incoming (flood) tides.)

	Monterey Bay	**Moss Landing Harbor**	**Yacht Harbor**	**Elkhorn Slough**
Shoreline Plume Contact	Beach immediately inshore of discharge.	Breakwaters at harbor entrance.	Possible at harbor entrance.	Possible at slough entrance.
Thermal Effects				
A Water Column Larval Fishes (ichthyoplankton)	3.5 to 14 °FΔ_t plume.	No predicted contact inside harbor except 3.5 °FΔ_t at surface at entrance.	No predicted contact.	No predicted contact.
B Water Column Adult Fishes (pelagic fishes)	Fish able to chose in or out of 3.5 to 14 °FΔ_t plume.	No predicted contact inside harbor except 3.5 °FΔ_t at surface at entrance.	No predicted contact.	No predicted contact.
C Bottom Habitat (benthos)	No predicted contact; however unexpected contact with downwelling of plume posssible.	No predicted contact.	No predicted contact.	No predicted contact.
D Sandy Beach	Permanent dredge spoil disposal site, USACE. Possible contact with 3.5 °FΔ_t surface plume in surf zone.	No predicted contact.;	No predicted contact.	No predicted contact..
E Breakwater Rip-rap Seaweed and shellfish (macroalgae and invertebrates)	Possible contact with 3.5 °FΔ_t surface plume.	No predicted contact inside harbor except 3.5 °FΔ_t at surface at entrance.	No predicted contact.	No predicted contact.
F Eelgrass (*Zostera marina*)	Not applicable habitat.	No predicted contact.	No predicted contact..	No predicted contact.
G Mudflats	Habitat not applicable to bay.	No predicted contact.	No predicted contact.	No predicted contact.
Marine mammals	Animals able to chose to be in or out of 3.5 to 14 °FΔ_t plume.	No predicted contact inside harbor except 3.5 °FΔ_t at surface at entrance.	No predicted contact.	No predicted contact.

Several relevant reports have been particularly useful in assessing the potential for thermal effects that would result from the thermal plume contact on habitats summarized in Table 4-1.

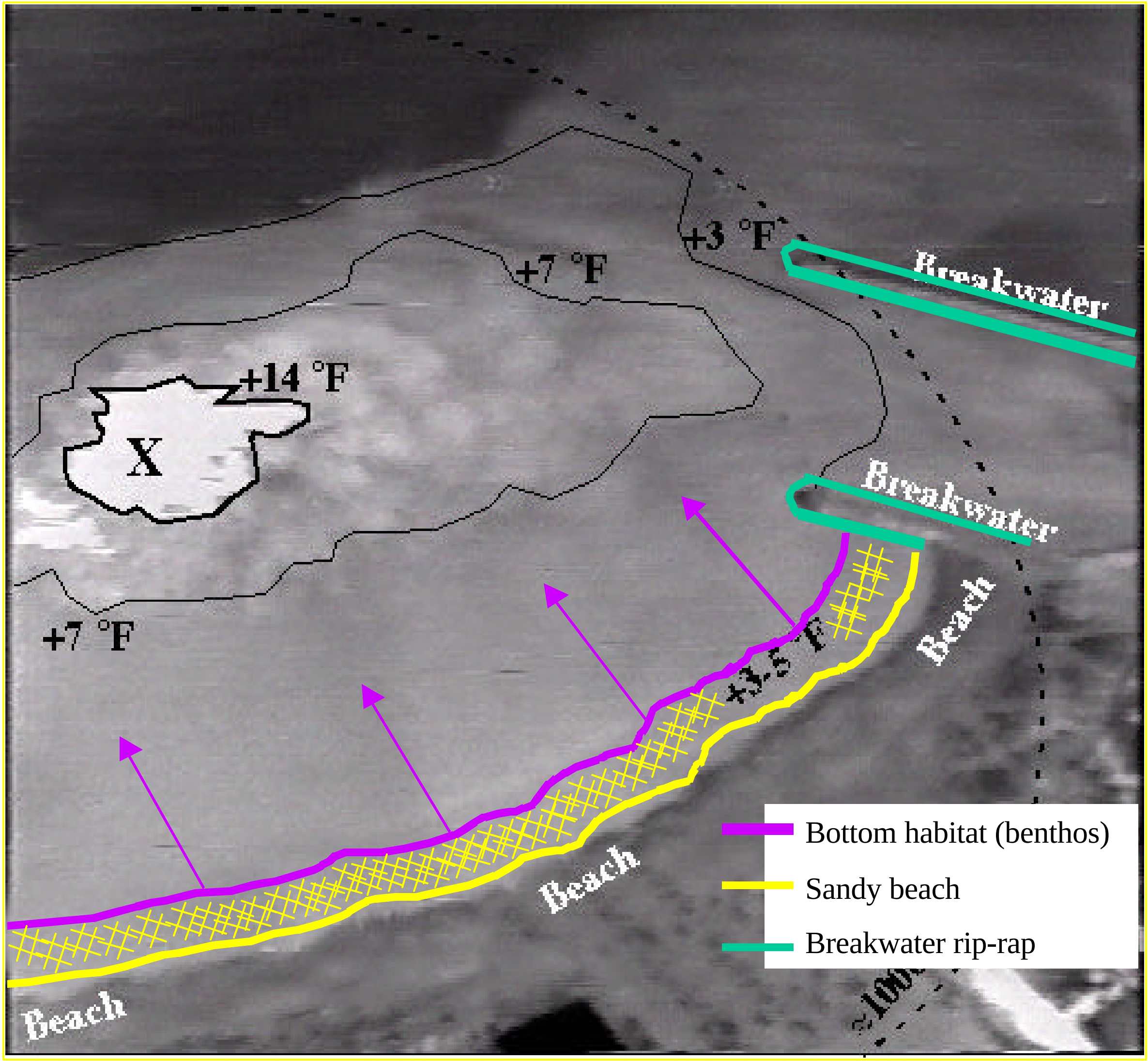

Figure 4-1. Locations of marine substrate habitats in the area of the MLPP discharge. Projected worst-case plume water surface Delta-T conditions are shown. Benthos is not expected to be thermally affected.

Four of these reports provided studies of MLPP thermal plume effects:

1. *Effects of Cooling Water Discharges on the Beneficial Uses of Receiving Waters at the Moss Landing Power Plant*. PG&E, 1973.

2. *Moss Landing Power Plants Units 1-5 316(a) Demonstration Program*. PG&E. 1978.

3. *Moss Landing Power Plants 1-5 316(a) Demonstration and Abundance of Ichthyoplankton and Macrozooplankton in Moss Landing Harbor and Elkhorn Slough.* PG&E. 1981a.

4. *Moss Landing Power Plant Units 1-5 316(a) Demonstration Supplement Infaunal Analysis and Fish Predator Prey Study*. PG&E. 1981b.

Other studies (Oliver et al., 1976; Nybakken et al., 1977; PG&E, 1983; Yoklavich et al., 1991; 1992, Starr et al., 1998) provide an understanding of the species composition and abundance of organisms living in the various habitat types found in the vicinity of the Moss Landing Power Plant. In addition to these studies, the results of laboratory experiments, such as those conducted on the thermal tolerance of several species from different habitats, are also referenced.

Characterizations of the habitats potentially affected by the Units 6 and 7 discharge plume, and the potential effects of the discharge on organisms living in them, are discussed in Sections 4.1.1 through 4.1.6, below.

4.1.1 Discharge Water Column

Water currents and warmer temperatures created by the Units 6 and 7 discharge is expected to attract fishes to the area offshore of the discharge plume (PG&E, 1973 see page 10). It is common to find large numbers of topsmelt in discharge plumes. The discharge flow movement of particles may create a feeding advantage for these planktivorous species. Other species of fishes may be attracted to the rock armoring at the base of the discharge where they find cover and feeding opportunities afforded by the reef-like habitat on an otherwise flat sandy mud bottom. This attraction has been observed in numerous SCUBA surveys of offshore vertical discharges conducted as part of thermal effects studies at Southern California Energy's San Onofre Nuclear Generating Station (D. Mayer, TENERA, pers. comm.)

The Monterey submarine canyon influences fish fauna in the area of the Units 6 and 7 discharge; typically deepwater species are found in the shallower nearshore waters of the bay. Important fishes in these areas include sharks and rays, silversides, anchovy, herring, flatfish, and rockfish.

The vertical direction of the discharge and buoyancy of the thermal plume virtually assuresthe plume does not contact the ocean bottom in the area of the discharge or disturb fishes occupying bottom habitat. Vertical temperature profiles of the Units 6 and 7 thermal plume were collected when both units were operating at full capacity (PG&E, 1973). Samples were also collected under varying tide conditions. . More recent surveys of the discharge plume have confirmed the vertical mixing and dispersion of the plume as illustrated in Figure 2-17. A distinct thermocline can be seen in all of the figures. The depth of the thermocline varies from approximately two to six meters, but does not appear to come into contact with the bottom. The only probable location of plume contact with the substrate is directly adjacent to the discharge plume, on the jetty and beach.

Adult Fishes in Monterey Bay

Some adult fishes may be attracted to the combined-cycle and Units 6 and 7 offshore discharge. The attraction may be in response to turbulence, prey availability, or elevated temperature. During PG&E (1973) studies of fish in the vicinity of the Units 6 and 7 discharge area of Monterey Bay, the ambient Delta–T° temperature was 0–0.9 °F, the transitional Delta–T° temperatures, 1.5–2.2 °F above ambient, and discharge Delta–T°, 2.3–3.4 °F above ambient. The temperature ranges were arbitrarily based on natural temperature groupings. Most of the fishes (64.5 percent) occurred in the transitional temperature range (4.7 fish caught per unit effort), with 21.9 percent in the ambient temperature range (13.7 fish caught per unit effort), and 13.8 percent in the discharge temperature range (0 fish caught per unit effort). Of the total fishes captured at Monterey Bay, 3.0 fish per unit effort were categorized into a thermal temperature range by station location. Sixty-seven percent of the associated fish species occurred in both the transitional and discharge temperature ranges with 33.4 percent found in the ambient temperature range. Of the 66.7 percent of the species found in the discharge temperature range, most of them

(41.7 percent) also occurred in the transitional temperature range with a smaller fraction (16.7 percent) of them occurring also in the ambient temperature range. The fishes associated with the Units 6 and 7 discharge appear to be eurythermal, with most of them occurring in the transitional temperature range with more than half of the species being thermophilic.

Discharge Area Larval Fishes

The design of the combined-cycle and Units 6 and 7 discharge structure promotes the rapid dispersal of the plume within the open area of Monterey Bay. An absence of effects on larval fishes from the historical concentrated Units 1 through 5 discharge provides evidence of an absence of potential effects on larval fishes found in the proposed combined-cycle and Units 6 and 7 offshore discharge. The results of larval fish studies by Nybakken et al. (1977) indicate that spawning and larval-rearing occurred in the Slough throughout most of the year in the presence of this concentrated discharge.

Though water temperature has been identified as a factor in the initiation of spawning (Coutant, 1970), there is no evidence that the elevated discharge water temperatures had triggered any unusual spawning activities or cycles among the Elkhorn Slough's fish populations. Larval fishes of the same species that were unaffected by the Units 1 through 5 discharge will also pass though the same area as the Units 6 and 7 discharge. Since there was no apparent effect at the Harbor entrance during studies of the combined discharges of Units 1 through 5 and Units 6 and 7, no effects are expected in this area as a result of the modernized Unit 6 and 7 discharge. The RWQCB Technical Working Group decided to examine this extrapolated conclusion by sampling ichthyoplankton concentrations within and outside the Units 6 and 7 discharge plume.

Nybakken's et al. (1977) Appendix N results of larval fish studies in the Moss Landing Harbor and Elkhorn Sough showed, by combining all five of their sampling stations, that the northern anchovy *Engraulis mordax*, was the most abundant fish larvae in the Slough. Larval fish samples collected by Smith (1977) recorded *E. mordax* as the second most abundant larval fish after *Gillichthys mirabilis*, the longjaw mudsucker. High numbers of *E. mordax* were common in the upper reaches of the Slough and at the Monterey Bay station (Harbor entrance). This pattern suggested the possibility of Units 1 through 5 discharge thermal plume effect. Even though the temperature of the discharge plume during the sampling period exceeded the laboratory thermal tolerance limits of the larval anchovies, large numbers of anchovy were found in the upper reaches of the Slough where water temperatures were commonly equal to or greater than Units 1 through 5 discharge temperatures. These Slough temperatures also exceeded the expected surface temperatures of the combined-cycle and Units 6 and 7 discharge. Consequently, no effects are anticipated for this species.

4.1.2 Discharge Structure Area Benthos

The habitat near the discharge structure is composed of sandy silts and clay. The base of the discharge is located in approximately 40 feet of water and releases cooling water approximately 20 feet below the surface of the bay. Seasonal changes in sediments and benthic organisms occur as shoaling or scouring results from wave action.

The discharge effects of the MLPP CWS have been extensively studied and documented. Biologists and oceanographers studied both specifically and extensively the effects of the discharge from Units 1 through 5 in Elkhorn Slough and the offshore discharge of Units 6 and 7 (PG&E, 1973). Their thermal discharge studies included aerial infrared (IR) thermal imagery mapping of the power plant's discharge plumes at full load and under varying tide and oceanographic conditions. Synoptic trawl and gillnet samples of fish, grab samples of shoreline and marine organisms were collected from sampling locations in the discharge areas. The biological sample results were statistically analyzed and compared to temperature measurements and plume IR images. Results from these studies still provide a basis to an understanding of the distribution and dispersion of these discharge surface plumes and demonstrate an absence of significant thermal effects.

The vertical direction of the discharge and buoyancy of the thermal plume assures that it does not contact the ocean bottom in the area of the discharge or invertebrate species living on or in (epifauna or infauna) the sandy mud bottom (benthic) habitat. Vertical temperature profiles of the Units 6 and 7 thermal plume were collected when both the units were at full capacity. Samples were also collected under varying tide conditions. The results of these thermal plume studies are found in PG&E (1973).

The vertical mixing and dispersion of the discharge plume was confirmed in the recent 1999 surveys as illustrated in Figure 2-17. All the figures show a distinct thermocline. The depth of the warm surface layer above the thermocline varies from approximately two to six meters, but does not appear to reach the bottom. Cold upwelling currents from the Monterey Canyon to the west and warm tidal flows from the Harbor and Elkhorn Slough to the east produce complex receiving water conditions of currents and water temperatures. The twice-daily tidal discharge from the Harbor and Slough, which consists of a relatively consistent temperature from surface to substrate, represents the largest thermal discharge into the Monterey Bay. This natural thermal discharge with temperature differences (Delta T) commonly between 6º and 10º F intercepts the existing Units 6 & 7 discharge to combine both at the surface and depth. Some of this Harbor/Slough discharge is expected to move around the tip of the south breakwater and carry south into the surf zone towards Sandholdt Pier. This water mass often commingles with Units' 6 & 7 discharge, and contacts the subtidal areas at the base of the breakwater rip-rap and the shallows in the breaker zone. Bottom contact of the projected power plume discharge in the Delta-T of 3.5 °F range would be very difficult to separate from the larger volume of equally warm Harbor/Slough discharge expected to also contact these benthic habitats.

Infaunal samples were collected from benthic stations in and around the discharge and results are reported in PG&E (1973) and Oliver et al. (1976).

Statistical analysis of the sampling results from PG&E (1973) found no significant thermal plume effects on the composition and abundance of infaunal taxa. Benthic habitat in this area is strongly influenced by large seasonal changes in ocean and weather conditions. It is not unusual for the seasonal cycles in wave energy to move several meters of bottom sediments to and from the shallow areas inshore of the Units 6 and 7 discharge. The abundance and distribution of infaunal organisms that live in these rapidly changing sediments vary significantly with these and other seasonal changes. Only an extreme change in water temperature would be expected to produce any measurable effect on these benthic organisms. Because the Units 6 and 7 thermal plume is primarily a surface phenomenon and is unlikely to contact the bottom in areas other than the breakwater and beach, no discharge effects are expected, no discharge effects on the area's subtidal habitats (benthos). In the shallow beach and breakwater areas of potential benthic plume contact, waves and beach currents produce a dynamic and unstable benthic habitat of constant change masking biological changes that might be associated with the Units 6 & 7 discharge plume. Mixing of the plume's relatively small Delta-T's with the natural Harbor and Slough discharge would also conceal power plant thermal effects. Benthic organisms totaling 9,583 individuals, represented by 187 species or taxa were identified and counted in the Moss Landing Power Plant study. The clam *Macoma inconspicua* was the most common species and appeared in 68.9 percent of the benthic samples. Mollusca comprised 41.3 percent of the total organisms for all quarters, followed by Crustacea at 37.9 percent and Polychaeta at 13.6 percent. The relative percent composition of the major groups did not seem to show any response to the thermal discharge.

Comparisons were made of the variations in the species diversity index with five different physical variables using a stepwise multiple regression analysis. The five physical variables were: 1) median particle size, 2) percent particles in the 30–60 micron ranges, 3) percent organic matter, 4) water depth, and 5) relative power plant influence, as measured by the temperature increase above ambient.

The analysis showed that there was no significant correlation between temperature increase and diversity index and for any sampling period. Therefore, discharge temperatures were not related to the abundance or the numbers of species of benthic organisms.

A linear regression analysis compared the abundance and diversity of benthic species to the relative power plant influence by combining data for all replicate samples at a station for each quarter (Table 4-2). There were no significant correlations between the temperature increase and the abundance or diversity of benthic organisms in any sampling period during the Moss Landing Power Plant study.

The study design used a modified analysis of variance block design without seasonal or annual replication. Sampling station locations were selected with respect to distance from the discharge and repeatedly sampled within calendar period quarters in order to observe temporal changes against potential temperature effects with respect to distance from the discharge. The statistical power (the probability of a Type II error) of the study's analysis is nominally indeterminate due to lack of replication of seasonal or annual sampling. Statistical power of the study, if treated, as a repeated-sampling (quarterly) of a gradient study would be relatively low (<20) due to the high temporal variability (seasonal) of benthic communities in shallow open coast habitat (as discussed above).

Table 4-2. Correlation of Temperature Increase Above Ambient and the Diversity Index, Number of Species, and Number of Benthic Organisms Sampled at MLPP Units 6 and 7 Discharge Area.

Collecting date→	November 30, 1971	February 10, 1972	August 7, 1972
Diversity Index	0.0819 N.S.	0.2559 N.S.	-0.2128 N.S
Number of Species	0.7008 N.S.	0.1236 N.S	-0.4754 N.S.
Number of Organisms	0.8879 N.S.	-0.5592 N.S.	-0.7464 N.S.
	N= 5	N= 5	N=5

Source: PG&E, 1973

N.S.= Not significant correlation, S.= Significant correlation at p= 0.05, H.S.= Highly significant correlation at p= 0.01

4.1.3 Sandy Beach

The disturbance to sandy beach habitat resulting from the long term depositing of Harbor dredge spoils on the beach by the Corps of Engineers reduces the possibility of significant thermal effects in the affected beach populations. The deposition of these spoils would certainly mask any but the most severe thermal effect. No such effect is anticipated, and therefore utilization of sandy beach habitat is unlikely to be affected by the modernized Units 6 and 7 discharge. Sandy beach communities of worms, crustaceans, and clams are adapted to a dynamic and unstable habitat of constantly changing tides, wave energy, and sediments. In addition to the unlikely possibility of detecting thermal plume effects in these constantly changing populations, the sandy beach habitat immediately inshore of the thermal discharge is designated for use as a long-term dredge spoil disposal site.

Discharge temperatures elevated above ambient from the modernized Units 6 and 7 discharge under full load are predicted to contact the sandy beach immediately inshore of the offshore discharge. The estimated increases in beach water temperatures due to plume contact under worst case conditions are discussed in Section 2.4.3. Buoyancy of the thermal plume prevents bottom contact until a combination of wind and currents carry it to the shoreline in the discharge area. During the movement of the plume towards the shore, the plume continues to rise and cool in an ever thinning surface layer. Once the plume reaches the shoreline, either at the beach or the Harbor entrance jetties, it is mixed by frequently high energy waves and surf into deeper cooler water. The effect of wave mixing on the thermal plume can be seen in aerial IR thermal images where the thermal plume appears to disappear as it comes in contact with the surf zone and beach.

Monterey Bay's sandy beach habitat extends in a nearly continuous reach of approximately 20 miles from Santa Cruz to Monterey. Beach habitat in the area of Moss Landing is exposed to high-energy waves from the northwest. Large quantities of sand are annually transported on and off the beach shoreline by the strong waves and longshore currents found in this reach of the bay. The continuously changing nature of this habitat favors mobile invertebrate and fish species that adjust quickly to the depletion and accretion of sediments. Lacking stable substrate, attached organisms are unable to occupy this habitat, other than the scant hydroids and algae attached to Pismo clams protruding above the sandy bottom. Organisms of the sandy beach habitat are constantly moving and adjusting to their changing environment. Relatively few species are able to succeed in this habitat.

The most successful organisms are burrowers (such as bivalves and polychaete worms) and those animals that live in the surf zone and migrate up and down the beach according to the tidal cycle (sand crabs, amphipods, and others). Some minute forms (e.g., harpacticoid copepods and isopods) also live among the sand grains in the surface layers.

The three main macrofaunal groups represented in this habitat are polychaetes, molluscs, and crustaceans. Usually the dominant sandy beach taxa, in terms of numbers of species and individuals, are crustaceans (WEI, 1973). Most common in the Moss Landing area are two species of sand crabs *(Emerita analoga* and *Blepharipoda occidentalis),* a mysid *(Archaeomysis maculata),* isopods (especially *Cirolana harfordi),* and amphipods (beach hoppers; *Metopa spp.* and *Orchestoidea spp.)* (Berger, 1970).

Thermal effects studies of the sandy beach habitat north of Sandholdt Pier, inshore from the Units 6 and 7 discharge, were conducted by PG&E (1973). The sampling results of their beach survey which were statistically analyzed showed no significant thermal effects of the Units 6 and 7 discharge under full load operating conditions.

The referenced study employed a sampling design using a modified analysis of variance block design without seasonal or annual replication. Intertidal sampling station locations were selected with respect to distance from the discharge and repeatedly sampled within calendar period (quarters). The design was selected to measure temporal changes against potential temperature effects as a function of distance from the thermal discharge. The statistical power (the probability of a Type II error) of the study's analysis is nominally indeterminate due to lack of replication of seasonal or annual sampling. Statistical power of the study, if treated as a repeated-sampling (quarterly) of a gradient study, would be relatively low (<20) due to the high temporal variability (seasonal) of sandy beach communities in shallow open coast habitat (as previously discussed above).

4.1.4 Rock Rip-Rap Harbor Entrance and Shoreline

Given the previous discussion of the masking of the thermal discharge plume by the flushing of warm Slough water twice daily, it is very unlikely that jetty habitat organisms will be affected by the modernized Units 6 and 7 discharge to a detectable degree. Based on field observations (TENERA, 1999), the rock rip-rap used to create jetties along the entrance to Moss Landing Harbor are sparsely populated with attached seaweeds, invertebrates, and fishes. Rocky shore communities are adapted to a dynamic of high wave energy, sediment scouring and exposure to desiccation during low tide. The rocky habitat provided by the Harbor entrance rip-rap is marginalized by constantly changing water quality conditions as Harbor/Slough water is flushed over them twice a day with every outgoing tide. The habitat is further degraded by its proximity to large amounts of wave born sands and sediments from the Harbor/Slough/beach area that can scour sporelings, both larval and adult forms, from their rocky attachments. Laboratory thermal tolerance information for species typical of this habitat indicates that the relatively small amounts of elevated surface plume temperature that could reach this habitat would not represent a thermal risk. The repeated disturbance of water quality changes and scouring in this habitat would obviate any possibility of detecting thermal effects in the populations found here. The habitat is located in an area that is extremely difficult to survey because of strong wave action, poor underwater visibility, and strong currents.

Channel rip-rap at the Moss Landing Harbor entrance and along interior edges of the Harbor provides rocky intertidal habitat occupied by typical algae, invertebrates, and fish species found in California's enclosed bays. Pilings and piers in the Harbor support growth of so-called fouling communities, containing exotic species accidentally introduced from boat hulls and bilges.

Rocky intertidal habitats are found along both sides of Moss Landing Harbor and the jetty system extending into Monterey Bay. These habitats support barnacles, mussels, sea anemones, limpets, and periwinkles. Within the outer Harbor, barnacles predominate, but periwinkles and limpets are found as well. Houk et al. (1972) identified 47 species of animals and 17 species of plants inhabiting the jetty.

Rocky substrates are encrusted with barnacles, bryozoans, and sponges. Limpets and snails populate rocky surfaces and crevices where they graze on layers of microscopic diatoms growing on the rocks. The diversity of species in this habitat decreases rapidly as the Harbor's water quality and circulation diminish with distance from the entrance. Fish species common to the habitat, such as rockfish, cabezon, lingcod and surf perch, utilize the cover and feeding opportunities provided by the habitat's structure and attached organisms. The habitat's structure also attracts open-water, schooling species such as anchovy and smelt.

The results of an extensive collection of algal species in the area of the Units 6 and 7 discharge are summarized in Table 4-3. Dr. Mike Foster of Moss Landing Marine Laboratories made the collection’s existence known to TENERA. The list of species also appears in Jensen and Tanner (1973). Dr. Foster arranged for Tenera personnel to access the collection and collect species names and other collection notes. The collection was inventoried the first week of November 1999. Mr. Scott Kimura of TENERA then reviewed the list of collection species and updated nomenclature that was out of date. Both the old and new nomenclature are presented in Table 4-3. The list of revised names also includes the species’ geographic ranges. There are no species of unique concern, occurrence, or range. Species in the list were also assigned to either an ephemeral or perennial category. From this it appears that a great number of species on the jetty are ephemeral, indicating the disturbed/fluctuating nature of the jetty’s habitat is due to natural

Table 4-3. Algae Occurring on the Moss Landing Harbor Jetty in 1972.

Current Nomenclature	Previous Synonym	Pacific Coast Distribution	Life-History[a]	Tolerant of Increased Water Temperatures[b]
Chlorophyta				
Bryopsis corticulans		Br. Columbia - Baja Calif.	E	
Chaetomorpha aerea	*C. linum*	Marin Co. - San Diego	E	
Cladophora elmorei	*C. ovoides, C. sakaii*	San Mateo - San Pedro	E	
Cladophora microcladioides		Br. Columbia - Baja, Gulf of Calif.	E	
Endophyton ramosum		Washington - Redondo Beach	E	
Enteromorpha flexuosa	*Enteromorpha tubulosa*	Br. Columbia - Central America	E	
Enteromorpha linza		Alaska - Chile	E	X
Prasiola meridionalis		Friday Harbor - Carmel	E	
Ulva californica	*Ulva angusta*	Oregon - Ventura, CA; Baja Calif.	E	X
Ulva cosata		Santa Barbara - Baja Calif.	E	X
Ulva lactuca (?).	*Ulva linnaeus*	Bering Sea - Chile	E	X
Ulva lobata		Oregon - Mexico; Central America	E	X
Ulva taeniata		Oregon - Ventura	E	X
Phaeophyta				
Desmarestia ligulata	*Desmarestia herbacea*	Alaska - S. America	E	X
Egregia menziesii	*Egregia laevigata*	Alaska - Baja Calif.	E	
Petalonia facia	*Petalonia debilis*	Alaska - Baja Calif.	E	
Petrospongium rugosum	*Cylindrocarpus rugosus*	Sonoma Co. - Baja Calif.		
Phaeostrophion irregulare		Alaska - Santa Barbara	E	X
Ralfsia pacifica		Alaska - Mexico		X
Scytosiphon dotyi		Oregon - Baja Calif.	E	X
Scytosiphon lomentaria		Bering Sea - Baja Calif.	E	X
Rhodophyta				
Acrochaetium subimmersum		Br. Columbia - Channel Islands	E	
Ahnfeltiopsis leptophylla	*Gymnogongrus leptophyllus*	Alaska - Baja Calif.		
Ahnfeltiopsis linearis	*Gymnogongrus linearis*	Br. Columbia - Point Conception		X
Bossiella orbigniana ssp. dichotoma	*Bossiella (Bossea) dichotoma*	Br. Columbia - Baja Calif.		X
Callithamnion pikeanum		Alaska - L.A. County		
Callophyllis obtusifolia		Marin Co. - Baja Calif.		
Centroceras clavulatum		Santa Cruz - San Diego; Baja Calif/Peru		X
Ceramium eatonianum		Washington - Baja Calif.	E	X
Ceramium sp.		Alaska - Baja Calif.	E	X
Chondrocanthus corymbiferus	*Gigartina corymbifera;*	Washington - Baja Calif.		X
Chondrocanthus exasperata	*Gigartina exasperata*	Br. Columbia - Baja Calif.		X
Chondrocanthus harveyanus	*Gigartina harveyana*	Washinton - Baja Calif.		X
Corallina officinalis/chilensis		Alaska - Chile		X
Cryptonemia ovalifolia		Alaska - Baja Calif.	E	

Cryptopleura lobulifera		Washington - Baja Calif.	E	
Cryptopleura violacea		Br. Columbia - Baja Calif.	E	X
Cumagloia andersonii		Br. Columbia - Baja Calif.	E	
Farlowia mollis		Alaska - San Diego, Co.		X
Gastroclonium subarticulatum	*Gastroclonium coulteri*	Br. Columbia - Baja Calif.		X
Gracilariopsis lemaneiformis	*Gracilaria sjoestedtii*	Br. Columbia - Costa Rica		
Grateloupia doryphora		Washington - Peru		X
Griffithsia pacifica		Br. Columbia - Baja Calif.	E	
Gymnogongrus chiton	*Gymnogongrus platyphyllus*	Br. Columbia - Baja Calif.		
Halymenia schizymenioides		Washington - Santa Barbara		
Mastocarpus jardinii	*Gigartina agardhii, G. jardinii*	Br. Columbia - San Luis Obispo, Co.		
Mastocarpus papillatus	*Gigartina cristata; G. dichotoma, G. papillata*	Alaska - Baja Calif.		X
Mazzaella californica	*Rhodoglossum americanum*	Br. Columbia - Baja Calif.		
Mazzaella flaccida	*Iridaea flaccida*	Alaska - Baja Calif.		
Mazzaella heterocarpa	*Iridaea heterocarpum*	Alaska - Ventura		
Mazzaella leptorhynchos	*Gigartina leptorhynchos*	Humboldt Co. - Baja Calif.	E	X
Mazzaella lilacina	*Iridaea splendens; I. coriacea??*	Br. Columbia - Baja Calif.		
Mazzaella linearis	*Iridaea lineare*	Alaska - Ventura		
Mazzaella volans	*Gigartina volans*	Oregon - Baja Calif.		
Microcladia borealis		Alaska - San Luis Obispo, Co.		
Microcladia coulteri		Br. Columbia - Baja Calif.	E	
Nemalion helminthoides	*Nemalion lubricum*	Alaska - Baja Calif.	E	
Nienburgia andersoniana		Br. Columbia - Baja Calif.	E	X
Pikea californica		Br. Columbia - Baja Calif.		X
Platythamnion pectinatum		Br. Columbia - Baja Calif.	E	
Platythamnion villosum		Alaska - Baja Calif.	E	
Pleonosporium vancouverianum	*Pleonosporium abysicola*	Br. Columbia - Baja Calif.	E	
Polyneura latissima		Br. Columbia - Baja Calif.	E	
Polysiphonia hendryi		Alaska - Baja Calif.	E	X
Polysiphonia paniculata		Br. Columbia - Baja Calif.	E	X
Polysiphonia sp.		??	E	X
Pophyrella gardneri		Alaska - San Luis Obispo; Baja Calif.	E	
Porphyra perforata		Washington - San Luis Obispo Co.	E	X
Porphyra smithii		Br. Columbia - Monterey Co.	E	
Prionitis lyallii	*Prionitis andersonii*	Br. Columbia - Baja Calif.; Chile		X
Pterosiphonia dendroidea		Br. Columbia - Baja Calif.	E	X
Sarcodiotheca gaudichaudii	*Agardhiella tenera*	Br. Columbia - Mexico; Peru		
Schizymenia pacifica		Alaska - Baja Calif.		
Smithora naiadum		Br. Columbia - Baja Calif.	E	

\a E = Ephemeral; otherwise perennial

\b Based on increase or persistence in DCPP discharge cove after power plant start-up or persistence (preliminary) high temperatures and varying salinities of Elkhorn Slough and Moss Landing Harbor tidal discharges. Mr. Kimura's observations of the jetty algae were that they were weakly formed and sparse in growth and form compared to other undisturbed outer coast rocky habitats. Obviously the jetty does not support a kelp bed. Only the feather boa kelp *Egregia* (a typically perennial species) was on the list and probably occurred on the jetty tips. Species on the jetty are also relatively common in the intertidal/shallow subtidal zones of Diablo Cove that exhibit thermal effects of the DCPP discharge. The Moss Landing jetty also experiences large shifts in salinity that greatly affect the abundance and distribution of marine open coast species. Also included (Table 4-4) is a summary of the Diablo Canyon Power Plant (DCPP) thermal effects laboratory results for the seaweeds.

The combined-cycle project discharge is predicted to increase temperatures in jetty habitat areas closest to the existing Units 6 and 7 discharge a maximum of about 3.5° F Δ_t above Monterey Bay ambient temperatures. These maximum Δ_t's are predicted to occur only on high tide conditions. In other words, the maximum 3.5° F Δ_t occurs at maximum flood tide, a period less than one half of the tide cycle. Alternating contact with the 3.5° F Δ_t plume between high and low tide (twelve hours apart) produces an extremely short and low level thermal dose well below laboratory threshold temperature effects.

Results of thermal effects monitoring of the DCPP thermal plume have demonstrated discharge effects on algal communities in the vicinity of the power plant's shoreline. Long-term effects have been detected at annual average discharge Δ_t's of 5 °F. These changes have been detected only with the aid of an accumulated twenty years of systematic frequent monitoring. Many of the changes are a result of the combination of natural thermal and biological phenomenon with the DCPP discharge plume temperatures. During normal DCPP operations, discharge plume temperatures in the affected areas are nearly always higher than ambient temperatures. In contrast, the combined discharge at MLPP (Units 6 and 7 and combined-cycle units) will be constantly changing with the Elkhorn Slough and Harbor tidal flows. As illustrated in Figure 2-9, water temperatures from the Slough and particularly the shallow Yacht Harbor commonly exceed Units 6 and 7 discharge temperatures contacting the closest jetty habitat. Harbor and Slough temperature records from the North Harbor, Highway 1 bridge, and the discontinued

Table 4-4. Results of DCPP Laboratory Thermal Tolerance Experiments on Species of Algae and Surfgrass.

a.) Heat tolerance

Note: Species are subjectively ranked according to temperature sensitivity, from most temperature sensitive to least sensitive. Note: Higher LT 50s could have been achieved if higher light energy regimes had been used, and lower LT 50s could have resulted if experiments were extended over longer periods. Plants were initially placed into treatment groups, and the temperature raised approximately 1°C per day until the target temperature was achieved.

Plant Species*	96 hour LT 50	216 hour LT 50	44 day LT 50	60 day LT 50
1. *Nereocystis luetkeana* (s)	-	-	>15.9°C	-
2, *Cryptopleura ruprechtiana* (s)	>19.1°C (some bleaching)	-	-	-
3. *Pterygophora californica* (s)	19.1°C	-	-	-
4. *Mazzaella flaccida* (cultured plants)	-	-	-	inconclusive
5. *M. flaccida* (field-collected plants)	-	-	-	>19.5°C
6. *Calliarthron tuberculosum*	-	some bleaching at 23.8°C	-	-
7. *Gastroclonium subarticulatum*	-	no mortality at 23.8°C	-	-
8. *Phyllospadix scouleri*	-	no mortality at 24.3°C	-	-

*(s) = sporophyte. Life history stage of others not reported.

Source: PG&E 1982

b.) Optimum temperatures (°C) for spore germination and initial growth, gametophyte development, gametophyte fertility, and early sporophyte growth.

Plant Species*	Zoospore Germination	Gametophyte Germ Tube Development	Gametophyte Early Growth	Gametophyte Fertility (f, female; m, male)	Sporophyte Growth
1. *Nereocystis luetkeana* (s)	9-21[\a]	13-17[\b]	12.9-17.8[\c]	16.7-17.8(f,m)[\b]	10.2-15.9[\d]
2. *Pterygophora californica* (s)	8.9-20.7[\a]	16.7[\a]	17.4-19.1[\e]	9.2-12.3(f)[\c] (m; unk)	14[\f]
3. *Laminaria setchellii* (s)	8.0-18.4[\b]	16.7[\a]	not reported	10.0-17.9 (m)[\b] 12.8-15.4 (f)[\b]	12.8-15.4[\f]
4. *Cryptopleura ruprechtiana**			16.0[\f]		16.0[\f]

*(s) = sporophyte. Life history stage of *C. ruprechtiana* not reported.

Plant Species	Early Gametophyte Development from Tetraspore Settlement	Early Sporophyte Development from Carpospore Settlement	Gametophyte Growth
1. *Mazzaella flaccida*	17.4[\a]	17.3[\e]	inconclusive
2. *Mazzaella flaccida*	-	-	15.4-18.7[\f]

\a = no marked effect
\b = strong effect of light intensity
\c = light saturation nearly achieved
\d = light saturation not achieved
\e = light saturation achieved
\f = effects of light not studied

Units 1 through 5 discharge stations, as shown in Figure 2-9, represent Slough Delta-T's of 6 to 9 ºF above the Units 6 and 7 receiving water ambient temperatures.

Not only are the new combined units discharge temperatures predicted to be small, (short-duration increases over ambient), but the resulting thermal plume is a thin surface phenomenon where it comes ashore. Predicted worst-case discharge temperature increase conditions of 3.5° F Δ_t, as shown in Figure 2-20, are the result of a relatively thin surface plume spreading buoyantly from the deep offshore Units 6 and 7 discharge. The appearance of boat wakes in the thin surface, as shown in Figure 2-10, graphically illustrates the shallow nature of any shoreline plume contact. The shoreline contact of the MLPP plume is dramatically different from DCPP discharge shoreline contact, where the thermal plumes may be 20 feet deep or more. The depth of the DCPP plume is a result of the weakly mixed shoreline discharge, and therefore the plume contacts intertidal habitat throughout the whole tide range at all tidal stages.

A number of affected algal species that have been studied at the Diablo Canyon site are at the southern end of their geographical range. Some of these species ranges are limited by the increasing temperature stress of the warmer, southern latitude ocean temperatures. Natural occurrences, such as El Nino warming events, have caused the Diablo Canyon site species to shift further north. Temperature effects of the DCPP discharge on these temperature-limited species may not be relevant to projecting effects on populations in the center of their geographical range.

For this reason and the others discussed above, field thermal effects associated with the DCPP discharge conditions cannot be simply extrapolated to the Moss Landing jetty algal community. If extrapolations were possible, they would not be done on the basis of Delta-T similarity, but by absolute temperature in as much as organisms are affected by absolute temperature at temperature thresholds, not relative Delta-T. However, even given the inappropriate nature of such a comparison, there is no reason to expect thermal effects on this community from the predicted maximum 3.5° F MLPP discharge Δt using laboratory thermal tolerance information presented in above Table 4-4.

The results of laboratory thermal effects studies of several of the jetty's species are summarized in Table 4-4. Given the normally cold high tide temperatures found at the head of the deep Monterey Canyon, the expected small power plant discharge temperature increases and large natural Harbor and Slough discharge temperatures in this area, the discharge of the new combined-cycle project is not expected to have a detectable thermal effect on the jetty's algal community.

4.1.5 Eelgrass Beds and Macroalgae in Lower End of Elkhorn and Bennett Sloughs

Water quality, temperature, and light determine the distribution and extent of submerged aquatic vegetation habitat in Elkhorn Slough and Moss Landing Harbor. Light transmissivity in these waters is reduced by a combination of flow-suspended particles, sediments from the Slough and marsh, and by phytoplankton production stimulated by nutrients and temperatures. Populations of the eelgrass *Zostera marina* are found scattered along the edges of the channel from the Highway 1 Bridge to the Dairies. Small patches of eelgrass are located across from the old Units 1 through 5 discharge on the northern side of the Slough, from the Highway 1 Bridge on the south bank of the Slough to the Units 1 through 5 discharge structure, and in the North Harbor. Continuing on toward The Dairies, rather dense areas of *Zostera* line one or both sides of the channel. Eelgrass is also found in the area near the mouth of Rubis Creek (TENERA, pers. observ., 1999) The shallow depths, stable substrate, and clearer bay water in these areas combine to support eelgrass growth.

Thick growths of various species of the green algae *Ulva* spp. and the filamentous red algae, *Gracilaria* spp. are distributed on the mid and low tide rip-rap and mudflats, respectively, bordering the lower ends of Elkhorn Slough and the yacht harbor entrances. Both of these taxa are warm water tolerant and found in habitats of varying salinity and turbidity conditions.

Before the Harbor opened in 1947, eelgrass formed conspicuous beds of submerged aquatic vegetation in the lower reaches of Elkhorn Slough and its old channel to the north of the Harbor entrance. Dense beds of eelgrass could also be found at the head of the Slough, but are no longer seen in this area (NERR, 1999). Because of increased water depth and scouring currents, eelgrass beds have nearly disappeared from the region near the Harbor entrance. Species of macroalgae also provide submerged vegetation habitat on the lower Slough's shallow mudflats and on the jetty rocks lining the Harbor entrance. Sand transported by strong waves and currents from the surrounding sandy beaches creates abrasion that limits the settlement and growth of macroalgae on the jetty's rocky habitat. These algae are necessarily able to withstand the constant tidal fluctuations in relatively constant Monterey Bay water temperatures and water temperatures from the Harbor and Slough areas. These temperature changes as a result of Harbor/Slough tidal flow changes every 6 hours can be significant increases in the summer and decreases in the winter. The algae are similarly exposed to fluctuations in salinity resulting from freshwater inflows during the rainy season and evaporation during the dry season. Any discharge temperature changes that might reach these algae would be well within their normal exposure to tidal temperature changes.

4.2 Thermal Tolerance and Conclusions Regarding Specific Organisms Relative to Thermal Plume Exposure

PG&E conducted studies of the thermal discharge effects on many species of fishes. Their findings were reported their conclusions in the *Effects of Cooling Water Discharges on the Beneficial Uses of Receiving Waters at the Moss Landing Power Plant* (PG&E, 1973). The fish species showed no temperature response to the thermal plume, except for English sole, which preferred ambient temperatures, and topsmelt, which preferred discharge temperatures; this indicated a possible preference for restricted temperature ranges.

4.2.1 Topsmelt

Several studies of the thermal resistance of the topsmelt *Atherinops affinis* have been reported. Hubbs (1965) found that the maximum upper temperature tolerance for normal egg development is between 27 °C and 28.5 °C (80 °F and 83.3 °F). Eggs exposed to a temperature of 28.5 °C (83.3 °F) expired shortly after circulatory system development. Carpelan (1955) notes the wide range of natural temperature tolerance of *A. affinis* (25 °C; 26.4–77 °F) and the species' remarkable tolerance of high temperatures (up to 33 °C; 91.4 °F). Doudoroff (1945) reported similar findings of the species' high temperature tolerances on specimens that he had acclimated for a period of three days at 20 °C. *A. affinis* tolerated temperatures ranging from 10.4 to

31.7 °C (50.7 to 89.1 °F). As mentioned in Section 4.1.1, it is common to find large numbers of topsmelt in the Units 6 and 7 discharge plume, and as concluded in PG&E's earlier studies (PG&E 1973), topsmelt are classified as exhibiting a preference for warm water. The projected future operation of MLPP will not negatively affect this species.

4.2.2 Pacific Herring

Surface plume temperatures from the modernized Units 6 and 7 offshore discharge will not affect Pacific herring. A temperature tolerance range (20.8 to 24.7 °C, 69.4 to 76.5 °F) is reported for egg survival of the Pacific herring, *Clupea pallasi* (EPA, 1971). Blaxter (1960) studied the effects of extreme temperatures on the larvae of Atlantic herring. The lethal temperature was determined graphically by plotting pliant dead at a given temperature against time. He found that the upper lethal temperatures for larvae acclimatized to 7.5 to 15 °C (45.5 to 59 °F) were 22 to 24 °C (71.6 to 75.2 °F). Herring larvae were rarely found in larval fish surveys of the Slough (Nybakken et al. 1977; Smith 1977), though limited spawning has been reported in the lower reaches of the Slough (Miller and Schmidtke, 1956). Relocation of the Units 1 through 5 discharge from Elkhorn Slough to the offshore discharge location will significantly reduced the risk to herring that spawn on eelgrass and other macrophytes in Elkhorn and Bennett Sloughs.

4.2.3 Black Surfperch

Laboratory thermal tolerance of black surfperch exceeds the expected nearshore temperatures of the modernized Units 6 and 7 discharge plume, as demonstrated in Table 4- 5.

Table 4-5. Diablo Canyon Power Plant Laboratory Thermal Tolerance Studies on Black Surfperch.

Taxa (stage)	Common name	Acclimation temperature (°C)	96hr-LT_{50} (°C)	Critical thermal maximum (°C)
Embiotoca jacksoni (juv)	Black surfperch	12.2	24.5	-
Embiotoca jacksoni (juv)	Black surfperch	16.0	25.6	-
Embiotoca jacksoni (adult)	Black surfperch	16.0	-	28.8

Source: PG&E, 1982

4.2.4 Shiner Perch

Shiner surfperch found in the area of the combined-cycle and Units 6 and 7 discharge would be attracted to discharge temperatures. Wicke (1968) warm summer temperatures followed by cool winter temperatures are necessary for proper embryo development. Ehrlich (communication dated 7 September 1977 from C. Ehrlich, Lockheed Center for Marine Research, Avila Beach, Ca.) found in a series of behavioral experiments that 22.8 °C (73 °F) is the preferred temperature of juvenile *C. aggregata* and 20.1 °C (68.2 °F) the preferred temperature of adults.

4.2.5 Staghorn Sculpin

Morris (1961) in preliminary tolerance tests of the species found that 25 °C (77 °F) represented the highest temperature at which immature forms could be held without injury. In his studies of five Oregon cottid species, staghorn sculpin *Leptocottus armatus* exhibited the greatest degree of seasonal change in metabolic rate. Morris found that the rate of respiration in *L. armatus* is highest in winter and the species' Q10 lowest in summer. His findings suggest that the temperature resistance of *L. armatus* is higher in the summer than the winter. Altman and Dittmar (1966) reported that 29.5 °C (85 °F) represented the upper tolerance limit for the adult staghorn sculpin. Based on their tolerances and the habitats they utilize, the projected future operation of MLPP will not negatively affect this species.

4.2.6 Northern Anchovy

Adult anchovy swimming in the areas of the combined-cycle and Units 6 and 7 offshore discharge would not be affected by plume temperatures. Thermal tolerance data for northern anchovy indicate that hatching and larval development are normal at temperatures below 27 °C, although most spawning occurs at temperatures between 13 and 18 °C (Brewer, 1976). The water temperatures recorded in the Harbor and Slough during the survey would not limit spawning activity or the survival of anchovy eggs and larvae in Elkhorn Slough.

4.2.7 Zooplankton

The thermal plume of modernized Units 6 and 7 offshore discharge will entrain zooplankton as it rises to the surface, but its temperatures will not harm the Monterey Bay's nearshore zooplankton. Zooplankton, organisms typically microscopic in size, are found in dense concentrations drifting in Monterey Bay's ocean currents. They feed on unicellular algae, detritus, bacteria, and other zooplankton. Their rapid growth and reproduction provides the transfer of phytoplankton primary production energy to higher trophic levels such as larval fishes. Studies of zooplankton thermal tolerance suggest that, in general, temperatures in excess of 30 °C (86 °F) are required to cause significant mortality. Lauer et al. (1974) reported that *Acartia tonsa*, an abundant copepod of Moss Landing Harbor, Elkhorn Slough, and Monterey Bay, may tolerate 15 minute exposures to temperatures as high as 33.5 °C (92.3 °F). The reported thermal tolerance limit of *Acartia tonsa* and *Eurytemora affinis* are 35 °C and 30 °C (95 °F and 86 °F), respectively (EPA, 1971). *Calanus finmarchius* has been shown to have a thermal tolerance limit of between 26–29 °C (78.8–84.2 °F) (EPA, 1971). With the exception of the thermal tolerance temperature for *C. finmarchius*, these temperatures are above predicted discharge plume temperature conditions for the combined-cycle and Units 6 and 7 discharge plume.

4.2.8 Phytoplankton

The thermal plume of the combined-cycle and Units 6 and 7 offshore discharge will entrain phytoplankton as it rises to the surface, but its temperatures will not harm the Monterey Bay's nearshore phytoplankton. Phytoplankton, unicellular floating algae, provide the base of the ocean's food chains through primary production. A number of studies have demonstrated their high degree of thermal tolerance. This thermal tolerance combined with the short generation times of many algal species (Fogg, 1965) increases their ability to compensate rapidly for any localized changes.

Phytoplankton studies at other estuarine and marine power plant sites found:

- During cooler months, the photosynthetic rates of entrained phytoplankton may increase, but no changes in the species composition or overall abundance of algal populations so affected would be expected (Brooks et al., 1974; Jensen and Martin, 1974; Smith et al., 1974; Hamilton et al., 1970; Heffner et al., 1971);

- During warmer months, the photosynthetic rates of entrained phytoplankton may decrease temporarily without altering the photosynthetic capacity of the receiving waterbody phytoplankton populations (Brooks et al. 1974; Jensen and Martin 1974; Smith et al. 1974; Hamilton et al. 1970; Heffner at al. 1971);

- Discharge temperatures in excess of 32 °C (90 °F) are generally required before reductions in the photosynthetic capacity of entrained phytoplankton populations occur (Hamilton et al. 1970; Brooks et al. 1974). Some studies indicate that the crucial discharge temperature may be closer to 38 °C (100 °F) (Heffner et al. 1971; New York University, 1975). Patrick (1969) reported lethal temperatures for most algal species studied ranging from 33.1 to 45 °C (91.5 to 113 °F), with the majority near 43.9 °C (111 °F).

The thermal discharge of the combined-cycle and Units 6 and 7 will not exceed the reported temperature tolerances of phytoplankton. Therefore, the modernized Units 6 and 7 discharge is not expected to have any significant adverse impact on the local phytoplankton community

4.2.9 Pismo Clams

The densities of Pismo clams in thermal studies of the Morro Bay shoreline discharge were found to increase in areas contacted by the thermal plume. The highest numbers of clams surveyed were located in beach habitat exposed to discharge Delta–T° of 1.4 to 4.8 °F. The authors reported findings consistent with observations that "warm-water" years have provided some of the best sets of young Pismo clams. The authors reported no significant effects of the discharge on the sand crab populations in their studies. There was no indication of detrimental effects of the power plant's thermal discharge from discharge temperatures 70.5 °F to 78.5 °F and Delta–T°'s up to 20 °F (6.8 °F measured on the beach). Temperatures of the combined-cycle and Units 6 and 7 MLPP discharge on the beach will be less, and will not adversely affect any Pismo clams that may be contacted by water in the discharge plume.

4.2.10 Sand Crabs

Dugan et al. (1994) reported the results of her studies on geographic variations in the life history characteristics of *Emertia analoga*. Water temperatures were inversely correlated with several life histories characteristics. As water temperature increased, the size of female crabs at sexual maturity, the largest ovigerous and smallest overigous females, and largest male crabs all declined. The remaining environmental variables tested, surf zone chlorophyll and sediment characteristics, were inconsistently correlated with life history characteristics over the five-year study. Surf zone water temperatures varied geographically, ranging form 11.5 °C to 25.6 °C. With the exception of geographic variations in life history characteristics, normal population levels of sand crabs were sampled within this temperature range. Based on the high thermal tolerance of sand crabs, the combined-cycle and Units 6 and 7 discharge is not expected to affect their population abundance or distribution in the sandy beach habitat contacted by the plume. The beach area is currently used as an Army Corps of Engineers dredge disposal site.

4.3 Potential Effects of the Thermal Plume on Protected Species

There are several protected species found in the greater Monterey Bay area. In addition to the four listed below (Southern sea otter, California brown pelican, tidewater goby, and steelhead trout) which may come in proximity to the MLPP discharge, the recently de-listed American peregrine falcon range in the area, and Pacific right whale and Guadelupe fur seal are found in Monterey Bay on very rare occasions.

4.3.1 Southern Sea Otter

The Southern sea otter (*Enhydra lutris nereis*) is a fully protected marine species presently found in the Monterey Bay. The successful restoration of the southern sea otter is illustrated by the population's wide geographic expansion along California's central coast into the Southern Bight. Their progress along the way has been marked by dramatic reductions in abalone, urchin and crab populations. The otters range throughout the bay from shallow areas of suitable feeding depths to open ocean areas. The otters' search for food, as their over-harvest diminishes available local prey, takes them into a wide variety of bay habitats. As the otter's predation depleted their favorite prey in the Monterey peninsula's rocky subtidal habitats, their foraging activities spread to the Bay's sandy beach and shallow subtidal populations of clams and other mollusks.

Sea otters can freely swim in and out of the influence of the discharge, and will be able to continue to do so.

4.3.2 California Brown Pelican

In 1970, the USFWS listed the California brown pelican (*Pelecanus occidentalis californicus*) as an endangered species. California listed the brown pelican as endangered in 1971. The peregrine falcon (*Falco peregrinus anatum*) is listed as an endangered species, but is being considered for delisting by the USFWS. The California least tern (*Sterna antillarum browni*) was also declared an endangered species in 1970.

The California brown pelican (*Pelecanus occidentalis californiacus*), is observed year-round in the Monterey Bay area, visiting from nearby nesting colonies on Anacapa Island in the Channel Islands. It is most abundant on the coast from August to November, with nesting occurring from February through November. Peak egg-laying occurs in March and April; two or three eggs hatch after a 1-month incubation period (Perrins and Middleton, 1985). After the 1972 Environmental Protection Agency (EPA) ban on the use of DDT, there has been an increase in the nesting success of brown pelicans (USFWS, 1998). The southern California population of brown pelicans is estimated at 4,500 to 5,000 breeding pairs (USFWS, 1998). Although frequently foraging in waters greater than 1 mile from the coast, the pelicans commonly roost on buoys, rocks, piers, and jetties in nearshore waters, including those near MLPP.

There is no reason to expect the modernized MLPP discharge will affect the area’s pelican populations. Individual birds may be attracted to fishes at the surface discharge plume.

4.3.3 Tidewater Goby

The tidewater goby (*Eucyclogobius newberryi*) can be found at the upper ends of lagoons and brackish bays at the mouths of coastal streams ranging from Tillas Slough in Del Norte County to Aqua Hedionda Lagoon in San Diego County, California (Swift et al., 1989). It is not distributed continuously throughout its range however, and is absent in several sections of coastline in northern California. Within the Monterey Bay/Moss Landing Harbor/Elkhorn Slough area, 62 tidewater gobies were documented in beach seine collections in Bennett Slough in June 1981 (Swift et al., 1989). A range wide status survey conducted in 1984 found that tidewater goby were still existent, but none were found in local waters during a 1990 survey (NDDB, 1998). Endangered tidewater goby adults were recently collected in Bennett Slough in October 1999 (M. Sazaki, pers.com.). Larval tidewater gobies can be distinguished from other gobies and none were collected during any entrainment (weekly 24-hour sampling for 12 months at both power plant intakes) or source water (once per month) sampling surveys. The U. S. Fish and Wildlife Service has recently proposed tidewater goby, north of Orange County, for delisting from their "endangered" status.

All life stages of the tidewater goby are restricted to California coastal wetlands with low salinities (< 10 parts per thousand [ppt]). They congregate on sandy substrate in lagoons and lower parts of creeks in water generally less than 3 feet deep. The gobies are most abundant during the fall and late summer, and before and after winter flood events when lagoons and creeks can be scoured by intermittent flooding. The few fish that do survive repopulate suitable habitats in the spring (Rathburn et al., 1993). Nesting activities begin in late April and continue through early May. Gobies require clean, coarse sand, and water temperatures ranging from 75.6 to 79.6 ºF, for building nesting burrows. The lack of a marine phase restricts movements between populations and greatly lowers the ability of this species to recolonize an area once it has been extirpated. In summary, there are no reasons to expect operation of the existing or proposed MLPP discharge into Monterey Bay to have any effects on this species.

4.3.4 Steelhead Trout

Steelhead (Oncorhynchus mykiss) are the anadromous form of rainbow trout found in watersheds along the Pacific coast from Alaska to southern California. Steelhead trout are extinct or at low levels throughout the West Coast because of a combination of human activities and poor natural conditions. Habitat degradation, hatchery production, and over-harvest have reduced the fish's ability to cope with variable environmental conditions (Capelli, 1998). The most recent findings show that the distribution of steelhead in California has been greatly reduced. Estimates place the total statewide population at 250,000 adults (McEwan and Jackson, 1996). Known spawning populations are found in coastal streams from Malibu Creek in Los Angeles County to the Smith River near the Oregon border, and in the Sacramento River system. Much of the coastline of southern Monterey and San Luis Obispo counties is relatively undeveloped so many of the small coastal streams still contain healthy steelhead populations. There are two life history types (races) of steelhead: "stream-maturing" (summer steelhead) and "ocean-maturing" (winter steelhead). The southern steelhead (those found south of San Francisco Bay) are winter steelhead. Southern steelhead are the most jeopardized of all of California's steelhead populations. The southern stocks have adapted genetically to withstand variations in habitat that are not tolerated by northern stocks (e.g. warm water temperatures, low dissolved oxygen and extended drought conditions (Capelli, 1998)).

Steelhead trout require clean gravel-bottom substrate and clear flowing waters for spawning. Fry emerge from the gravel approximately four to six weeks after hatching. During their juvenile life phase, a fresh water habitat and low-salinity estuarine environment is vital to the steelhead's survival. Juveniles usually spend from one to three years in fresh water before migrating to marine waters. In the warmer waters of a southern stream, it was found that juveniles grew to smolt size rapidly and were able to migrate to ocean waters after just one year (Moore, 1980). Juveniles migrate to sea when they are from six to eight inches in length. This out-migration is usually in the spring, but there are steelhead entering the ocean year round throughout their range (J. Nelson, pers.comm.). Most of their growth occurs in the ocean, and steelhead reside in marine waters from one to four years before returning to their natal stream to spawn.

Southern steelhead trout migration is more dependent on rainfall than the northern steelhead populations. Studies have found that some southern steelhead migrate as soon as the sandbars break open at mouths of rivers, whenever this may happen. The preferred temperature range for migration is 46 to 52º F. (McEwan and Jackson, 1996). Optimal spawning temperatures are from 39 to 52º F. Steelhead prefer to spawn in areas with water velocities of about 2 ft/s (Bovee, 1978). Until water velocities reach 10 to 13 ft/s, the swimming ability of adult steelhead is not hampered (Capelli, 1998). Egg mortality begins to occur at 56 º F. Steelhead have difficulty extracting oxygen from water at temperatures greater than 70º F (Hooper, 1973).

The Pajaro River to the north and the Salinas River to the south of Moss Landing Harbor represent the nearest locations of steelhead trout habitat. Steelhead use both of these rivers as migration corridors to get to tributaries with perennial water flow. (J. Nelson, pers.comm). Steelhead have been documented by CDFG in the Atascadero, Paso Robles and Arroyo Seco creeks of the Salinas River system. The Pajaro River steelhead population has been greatly reduced; the 1991 escapement was less than 100 fish. No steelhead have been found in the lower portions of the river (McEwan and Jackson, 1996). Neither Elkhorn Slough nor Tembladero Slough offers the type of habitat necessary for steelhead to spawn. It is doubtful that steelhead use either of the sloughs as a migration corridor as neither offers a good connection to the Salinas River (J. Nelson, pers. comm.). Any steelhead that may come near the influence of the MLPP discharge could easily avoid it, if they choose to do so, based on their thermal affinities and behavioral swimming capabilities.

4.4 Supplemental Thermal Discharge Effects Study

Duke Energy, its consultants, the Central Coast Regional Water Quality Control Board and its consultants (Drs. Raimondi and Cailliet), and the California Department of Fish and Game are members of a MLPP Technical Working Group. This group was formed in part to develop a plan for studying the potential impacts on larval fishes and cancer crab megalops associated with the modernization of the MLPP. Working group meetings are scheduled as work products are finished. The group has provided invaluable input into the development of the study plan. All members have reviewed and commented on several drafts of the study plan.

Among other questions, related to potential CWS intake effects and characterization of the discharge, the studies included in the study plan also included a component designed to address the following:

- What is the potential for the thermal discharges to interfere with the exchange of larval fishes between Elkhorn Slough/Moss Landing Harbor?

This portion of the study was designed to examine the extent, if any, to which the dispersed thermal discharge from MLPP acts as a barrier that interferes with larval fish exchange between the Elkhorn Slough/Moss Landing Harbor and Monterey Bay. To supplement historic and ongoing sampling in the Harbor, larval fishes from samples collected inside and outside of the areas where thermal differences are detected were identified, enumerated, and their concentrations compared. Composition and abundance within and outside of the areas where thermal differences are detected were used to determine if there are statistically significant differences between the larval fish assemblages found there.

Samples were collected during an incoming tide from five stations, the locations determined by temperature measurements taken from the boat during sampling. Tows were conducted at three stations that were located so that collections occurred in the areas where elevated temperature from the discharge was detected. Tows were conducted at two stations outside of the area where the heated water from the discharge could be detected but which are otherwise comparable in bathymetry to the stations where elevated temperatures are detected. Two tows were conducted at each station.

Samples were collected once in June 1999, when larval fishes are generally present in high concentrations (Moser, 1996) and when tides were favorable for sampling. Surface and oblique tows were collected simultaneously at all stations. The source water study's entrance station was also sampled during the thermal plume larval fish collections. Samples were collected by towing a bongo frame with 0.71 m diameter openings and equipped with two 335 µm mesh plankton nets and codends. Each net mouth was fitted with a calibrated flowmeter to record the volume of filtered water. The volume of water filtered by both nets combined was at least 40 m3 (20m3/net).

Sample results from this survey were analyzed for potential relationships between fish abundance and areas of thermal plume influence. However, the concentrations and number of larval fishes collected from the survey stations were insufficient (a total of 12) to enable a meaningful test of abundance as a function of thermal plume influence. Also, the influence of naturally warm water temperatures associated with tidal flows from the Moss Landing Harbor and Sloughs made it difficult if not impossible to distinguish boundaries of the thermal plume. The scale and dynamic nature of hydraulic processes at the Harbor entrance and extensive vertical mixing of the thermal discharge essentially preclude any reasonable sampling design that could separate the Harbor's warm water tidal plume from the MLPP cooling water discharge. A clear distinction of these two thermal influences would be necessary to attempt to compare any biological patterns in the observed relatively sparse concentrations of larval fish to the thermal plume location.

Following review of the study's findings, the Technical Working Group has no plans to attempt any further tests of the thermal plume influence on larval fish concentrations based on the absence of any expected or indicated significant effect, and the lack of a tenable test of any such effect.

4.5 Conclusions Regarding Potential Thermal Discharge Effects of the Modernized MLPP on Biological Resources

Data available from existing reports and confirmatory studies and evaluations presented in this report have provided a set of findings that are useful in assessing the potential effects of the modernized MLPP thermal discharge. These support the following conclusions:

- Results of past thermal plume studies at peak power plant loading still provide a solid basis to an understanding of the distribution and dispersion of these discharge surface plumes and an absence of significant thermal effects.

- The plume dispersion figures in this report depict the magnitude and extent of the thermal plumes with respect to available data from both past and recent thermal discharge studies.

- Findings from past marine biological studies of MLPP thermal effects showed no effects on intertidal mudflat, eelgrass, or sandy beach habitats.

- Results from previous extensive studies of the concentrated historical Units 1 through 5 discharge in Elkhorn Slough demonstrated an attraction of adult fishes.

- Because the thermal plume from the discharge into Monterey Bay is a surface phenomenon, there is little possibility of temperature effects from the discharge on the area's subtidal habitats (benthos) deeper than 2–3 meters.

- Studies conducted at peak operating conditions revealed almost no thermal effects, which strongly indicates a lack of potential appreciable harm from the modernization project's offshore discharge in Monterey Bay, even at 100 percent generating capacity.

- As has been the case in the past, the proposed combined discharge of Units 6 and 7 and the combined-cycle units in Monterey Bay will continue to protect beneficial uses of the receiving water, and will assure the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife in and on the receiving waters.

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