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Aquatic Impacts of the Pittsburg and Contra Costa Power Plants

Department of Water Resources

Division of Environmental Services

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Executive Summary

The following report reviews the aquatic impacts of the Contra Costa Power Plant and the Pittsburg Power Plant, These two facilities were selected because they: 1) are located near the confluence of the Sacramento and San Joaquin rivers, a key location for sensitive fishes; and 2) both have historically diverted large quantities of water for cooling purposes. The total maximum nonconsumptive intake of cooling water is 3,240 cubic feet per second, which can exceed 10% of the total net outflow of the Sacramento and San Joaquin rivers, depending on hydrology. However, pumping rates are often significantly lower under normal operation. Potential impacts to aquatic species include chemical and thermal pollution, and entrainment.

Chemical impacts may occur as a result of chlorination for control of "condenser slime", which was historically conducted weekly. This treatment at Contra Costa Power Plant consumed a little over 1 ton of chlorine a month, or 13 tons per year. The discharge water was not historically dechorinated or subject to regular monitoring for residual chlorine.

Thermal pollution represents an additional concern for aquatic species. Temperature objectives set by the California Regional Water Quality Control Board include: "No discharge shall cause a surface water temperature rise greater than 4 ºF above the natural temperature of the receiving water at any time or place"; and "The maximum temperature of thermal waste discharge shall not exceed 86 ºF." Both plants discharge water at temperatures in excess of 86 °F 10% of the time, and surface water temperature plumes in the receiving water at each plant exceed $^{+}4$ °F for areas up to 100 acres. The previous owner, Pacific Gas and Electric (PG&E), sought and received exemptions to the above limitations.

Entrainment effects may occur from large pressure decreases (>1 atm.) across the condenser at both power plants, and impingement on fish screens. In 1951 the Department of Fish and Game (DFG) recognized the power plants presented a potential issue for the salmon and striped bass resources of the area as both plants were originally equipped with inefficient fish barrier. At the time, DFG estimated that as many as 19 million small striped bass might pass through the Contra Costa plant and be killed each year between April and mid-August. As a result of these concerns, DFG and PG&E conducted a monitoring study to evaluate entrainment. In 1979, consultants estimated the total average annual entrainment to be 86 million smelt, 345,000 splittail, and 24,000 salmon. The total average annual impingement was estimated to be 178,000 smelt, 21,000 splittail, and 2,600 salmon. It's unclear whether these are relevant to current entrainment trends as populations of smelt are highly variable, and power plant operations have changed.

Pacific Gas and Electric prepared its last proposed habitat conservation plan in 1998 as a condition of the regular permitting process and to obtain an incidental take permit from the Fish and Wildlife Service under the Endangered Species Act. The information and assessments presented in their plan proposed that there is no significant impact of their operations on the environment and that a Finding of No Significant Impact should be adopted by the lead agencies.

Southern Energy Delta bought PG&E's Delta power plants in 1999 and started pursuing modernization. Southern Energy Delta became Mirant Delta LLC on January 01, 2001. They have submitted revisions to a new habitat conservation plan.

Introduction

The San Francisco Estuary (Figure 1) represents an exceptionally heavily modified estuary in the United States (Nichols et al 1986). Major changes to the system include construction of upstream dams, water diversions, channelization, habitat loss and contaminant inputs. The impacts of these changes have been substantial, leading to declines in many aquatic organisms (Bennett and Moyle 1995). In recent years, much of the management emphasis has been trying to understand and reduce the effects of water diversions. In this context, there have been major studies on the effects of the Central Valley Project and State Water Project on fish entrainment (Brown et al. 1996; Kimmerer 2002) and hydrodynamics (Kimmerer 2002.). Additional studies have been conducted on the potential effects of agricultural diversions (Nobriga et al. 2004). However, very little is known about the potential aquatic effects of one of the other major types of water diversions, power plants.

The purpose of this report is to summarize available information on the past effects of Pacific Gas and Electric's (PG&E) Pittsburg Power Plant (PPP) and Contra Costa Power Plant (CCPP) on the Delta's aquatic environment (Figure 1), and to document PG&E's efforts to minimize the power plants' impacts. To the extent possible, information is provided about potential recent impacts. These two facilities were selected because they: 1) are located near the confluence of the Sacramento and San Joaquin rivers, a key location for sensitive fishes; and 2) both have historically diverted relatively large quantities of water for cooling purposes. Although there are other substantial power plants in the region including recently-constructed facilities, they were either located in less critical parts of the distribution of target aquatic species, or do not divert similarly large amounts of water from the estuary.

This report is organized to address each power plant independently. Information was gathered from the Department of Water Resources, Environmental Services Office (DWR, ESO) library and from the Central Valley Regional Water Quality Control Board's (CVWQCB) files. The primary sources of information were documents dated prior to 1998, but include some later information. Additional information was sought from the recent owners Southern Energy Delta (SED), the Department of Fish and Game (DFG) and the U.S. Fish and Wildlife Service (FWS), but the available data were limited. SED bought the PPP and CCPP from PG&E in April 1999. This report also provides some information about the operation of PPP and CCPP by SED, now Mirant Delta LLC; however, the most recent data are relatively limited.

The power plants produce a large thermal plume and have had a combined nonconsumptive intake of water that can exceed 10% of the total net outflow of the Sacramento and San Joaquin rivers, depending on hydrology. However, pumping rates are often significantly lower under normal operation. Nonetheless, there are concerns that the power plants could have a major effect on the surrounding aquatic environment. Prior to the start of CCPP construction in 1949, DFG lacking the authority of present environmental laws recognized the need for provisions to protect young and small fish from water diversions used for condenser cooling [(6)]. DFG felt it presented a potential threat to the valuable salmon and striped bass resources of the area [(6)]. Most fish studies conducted by PG&E to address DFG's concerns focused on these 2 species. As of the

mid 1990's the CCPP is located within the designated critical habitat zone for delta smelt, a listed species, and the PPP is within the designated habitat zones for 2 listed species, the winter-run

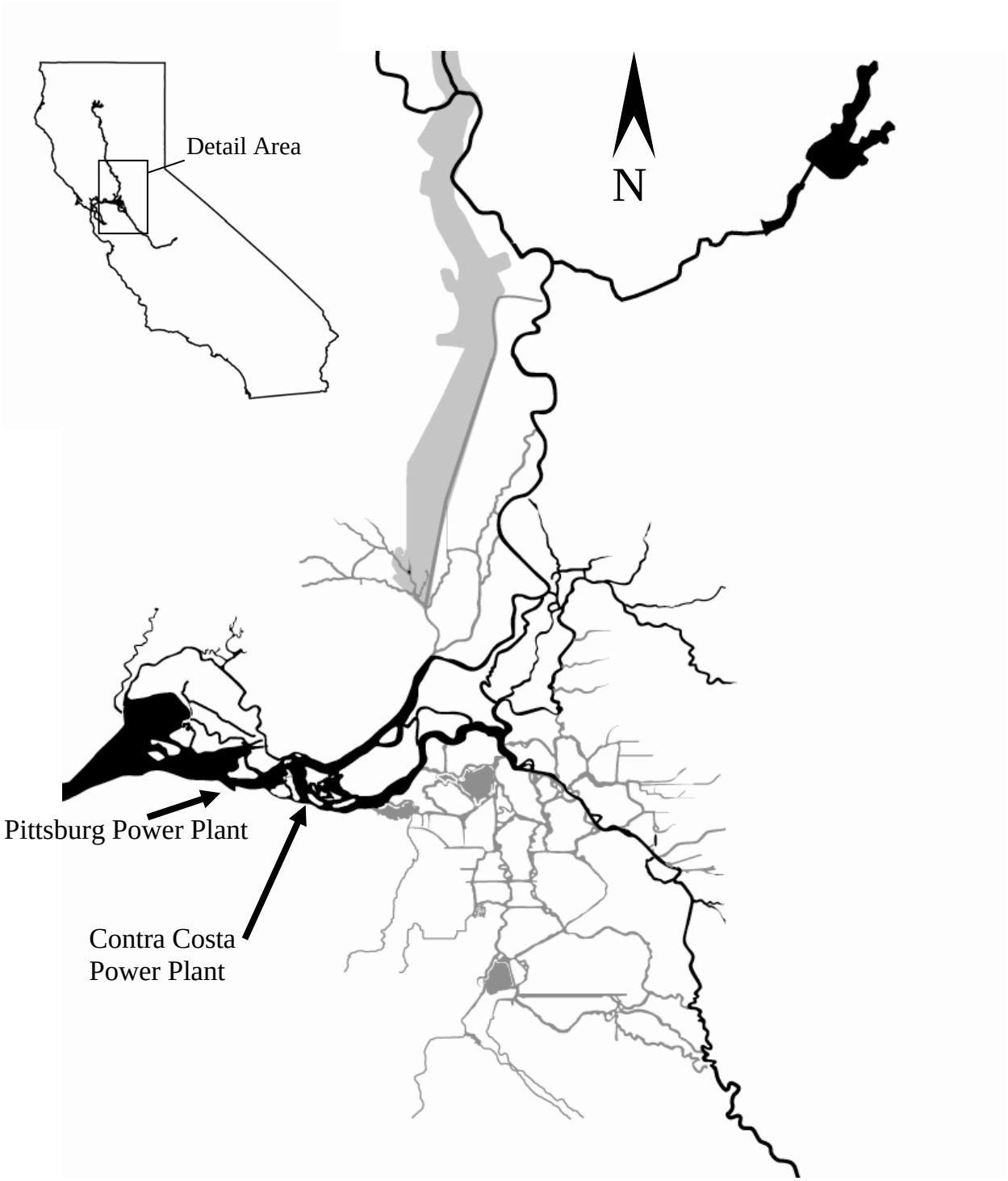

Figure 1: Location map of the Pittsburg and Contra Costa power plants.

salmon and the delta smelt [7]. Since that time, 3 additional species have been listed (spring-run Chinook, steelhead-Central Valley evolutionarily significant unit (ESU) and Sacramento splittail) and 1 species (Chinook salmon-Central Valley fall/late fall-run ESU) is on the federal proposed list.

The power plants operate under permits from both the federal and state governments. Agencies currently involved include:

- California Regional Water Quality Control Board (CRWQCB)
- State Water Resources Control Board (SWRCB)
- California Department of Fish and Game (DFG)
- U.S. Environmental Protection Agency (EPA)
- U.S. Fish and Wildlife Service (USFW)
- U.S. National Oceanic and Atmospheric Administration Fisheries (NOAA Fisheries)
- U.S. Army Corps of Engineers
- Federal Energy Regulatory Commission (FERC)

Wastewater discharge permits are issued by the CRWQCB every 5 years, most recently to CCPP in 1995 by Order No. 95-234 under NPDES No. CA0004863, and to PPP in 1995 by Order No. 95-225 under NPDES No. CA0004880. The permits for both power plants expired in 2000. Applications for renewal were filed by Mirant.

PG&E prepared its last Habitat Conservation Plan (HCP) in 1998, as a condition of the regular permitting process and to obtain an incidental take permit from FWS under the Endangered Species Act (ESA). The plan proposed that there is no significant impact of their operations on the environment and that a Finding of No Significant Impact (FONSI) should be adopted by the lead agencies [7]. If the plan was accepted, they were proposing to set aside 139 acres for mitigation at the Montezuma Enhancement Site (MES) west of Collinsville (Figure 1). Normally the HCP and its accompanying permits would be transferable to SED, but DFG was about to seek a new HCP due to major changes planned by the new owners (Suzanne DeLeon of DFG, personal communication, 2000). SED stated at that time, it was revising the prior draft HCP in order to propose testing new technology and is in consultations with FWS, NOAA Fisheries, and DFG. UPDATE STATUS?

PG&E entered into a Section 2081 Management Authorization with DFG in December 1997 to address PG&E's impacts on state-listed species under the California Endangered Species Act (CESA) [7]. Because of their location, and the importance of these power plants to maintain the transmission system, authorization was needed for the incidental take of federally listed species under ESA, as well as the unlisted species of concern show below (Table 1) [7].

Table 1
Endangered, Threatened, and Candidate Species Potentially Occurring in the Vicinity of the Power Plants

Common and Scientific Names	Status
Delta smelt (*Hypomesus transpacificus)*	FT, ST
Winter-run Chinook salmon (*Oncorhynchus tshawytscha)*	FE, SE
Spring-run Chinook salmon[3] (*Oncorhynchus tshawytscha)*	FPE[1]
Fall/late fall-run Chinook salmon[3] (*Oncorhynchus tshawytscha)*	FPT

Steelhead	(*Oncorhynchus mykiss)*	FT
Sacramento splittail	(*Pogonichthys macrolepitomus)*	SSC
Green sturgeon[3]	(*Acipenser mediostris)*	FPT

Key:

FE = ESA listed as endangered
FT = ESA listed as threatened
SE = CESA listed as endangered
ST = CESA listed as threatened
FPE = federally proposed as endangered
FPT = federally proposed as threatened
SSC = state species of special concern

Power Plant Facilities

CCPP, construction of which began in February 1949 by PG&E, is a 500,000 kilowatt (kw) steam plant located 2.5 miles upstream from the city of Antioch (Figure 1). The first units were operational in June 1951. By 1975, with expansions, the power plant incorporated 7 main power-generating units and 3 smaller house units operating at 1,298 megawatt (mw) gross capacity [(8)], enough to power 1,298,000 homes. In 1995, Units 1-5 were decommissioned by PG&E due to their inefficiency and atmospheric pollution concerns. When all units were operating, the cooling water flows into Units 1-5 and Units 6-7 were up to 946 and 681 cubic feet per second (cfs), respectively [(8)]. Cooling water was diverted by 2 separate intake arrangements. Water for Units 1-5 was taken from near the river bottom at the headwork's 410 ft offshore and for Units 6-7 from a shoreline intake system located 500 ft east of the headwork's (Figure 2). Water was carried at 3.8 ft/sec to 5 recessed onshore traveling trash screens, with 3/8-inch square-opening wire mesh (Figure 3). Calculated screen approach velocities averaged about 1.3 ft/sec with velocities of 2.0 ft/sec through the mesh [(6)]. Discharge canals return the heated water to the river. For Units 1-5 water was returned 750 ft west of its uptake and for Units 6-7 it is returned 750 ft east of its uptake (Figure 2). Under normal full-load operation the temperature of the discharge water was raised a mean of 16.2 °F and at peak loads the maximum differential between intake and discharge temperature was 21 °F, creating a thermal plume (4 °F isotherm), concentrated near the surface and shoreline, extending over an area of approximately 100 acres [(6,8)].

PPP is a 2,060-megawatt facility located on the south shore of Suisun Bay (Figure 1) just west of Pittsburg. The PPP is a fossil-fueled steam generation plant and consists of 7 power generating units. Construction began in 1953 and the 7 units were commissioned in 3 phases; Units1-4 in 1954, Units 5 and 6 in 1960, and Unit 7 in 1961 [(9)]. Units 1-6 withdraw and return cooling water to Suisun Bay (Figure 4). Their intake structures are located on the shoreline about 1,000 feet to the west of the discharge structure [(9)]. Discharge is located 10 - 30 feet offshore in about 10 feet of water [(6)]. Unit 7 uses offstream mechanical-draft cooling towers and therefore is not considered in this report, but does use 45 cfs of water to make up for loss [(9)]. Total cooling water flow for Units 1-6 when all pumps are running is 1,612 cfs. The maximum cooling water flow for each unit follows [(9)]:

Unit Number	Cooling CFS
1	224
2	224
3	224

4	224
5	358
6	358

The average production factor, as a percent of capacity, for the 5-year period from 1970 to 1975 was 40% for Units 1-4 and 50% for Units 5 and 6 [9]. During this time Unit 7 was not operated and the average flows were approximately 1,254 cfs [9].

Subsequent to fisheries studies conducted at the CCPP prior to 1953, PG&E altered the design of the intake structures for the PPP to protect fish [6]. The traveling screens, with 3/8-inch square mesh, are not recessed as at CCPP and are instead placed at the mouth of the intake [6]. An open cage design trash rack, with 4-inch slits is located 15 feet ahead of the traveling screen for protection against larger debris (Figure 7) [6]. This arrangement allows for unrestricted fish movement and for the lateral clearing sweeps of the currents. The circulation water pumps are 30 feet behind the screen. Screen approach velocities can reach 0.8 ft/sec for all units [7]. The maximum calculated water velocities occur through the traveling screens (Figure 7). These velocities are 1.5 ft/sec for Units 5 and 6, and 2.0 ft/sec for Units 1 through 4 [6]. High-pressure spray washing removes debris and impinged organisms retained by the screens at 4 hr intervals or when hydraulic differential exceeds limits [7]. Screen-wash discharge is returned to the bay by 3 large-diameter trash/fish pumps with 6-cfs capacity [7].

In 1980 PG&E contracted with Ecological Analysts (EA) to conduct a comprehensive review of recent information on intake technologies that minimize the loss of aquatic organisms [10]. Factors reducing the number and mortality of impingements were examined by EA, with emphasis on cooling water system design, intake location, and intake structure design. Among items considered were uses of guidance, diversion, fish return systems, and the design and use of various fish screens.

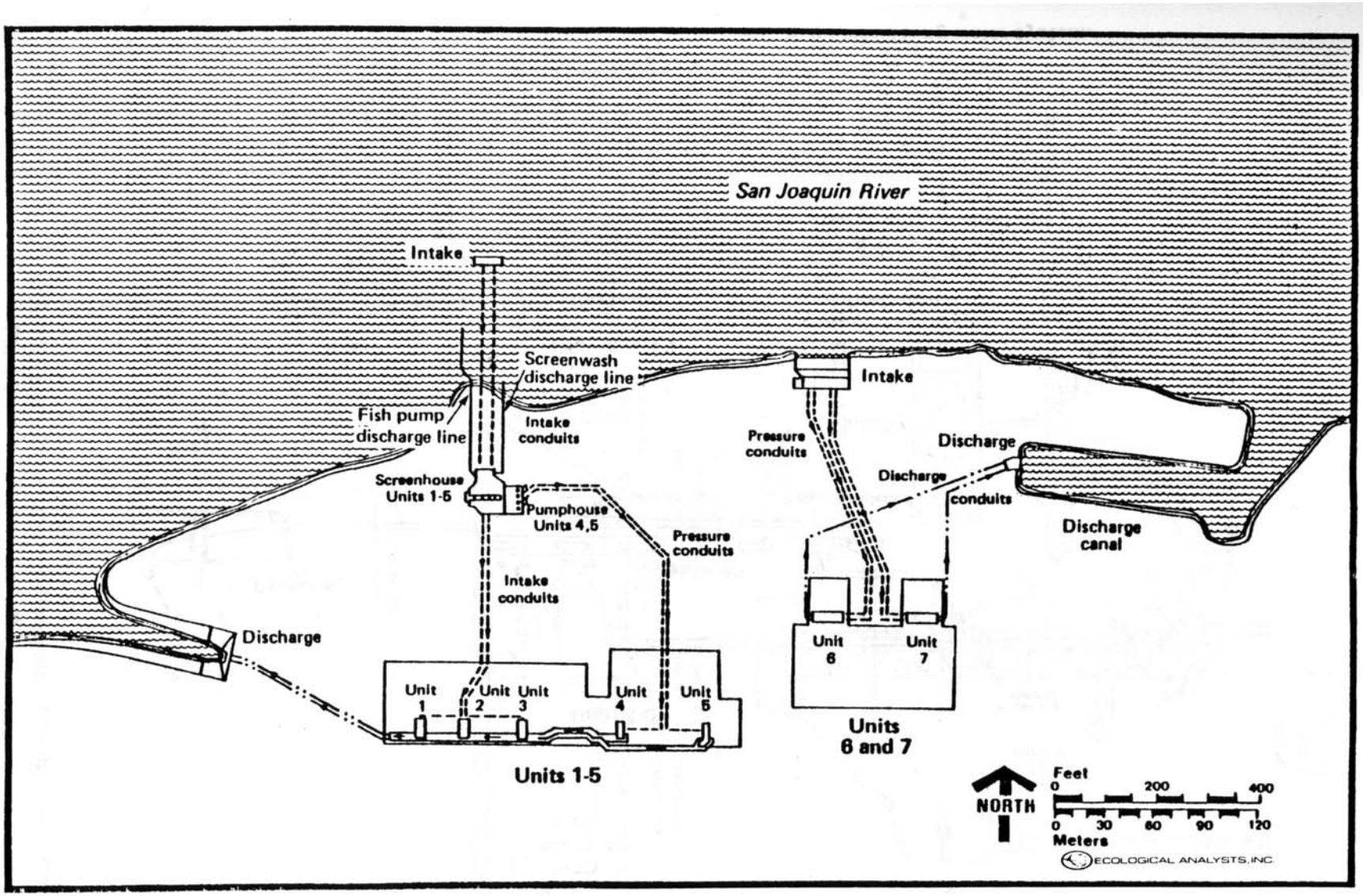

Figure 2: General configuration of Contra Costa Power Plant circulating water system.

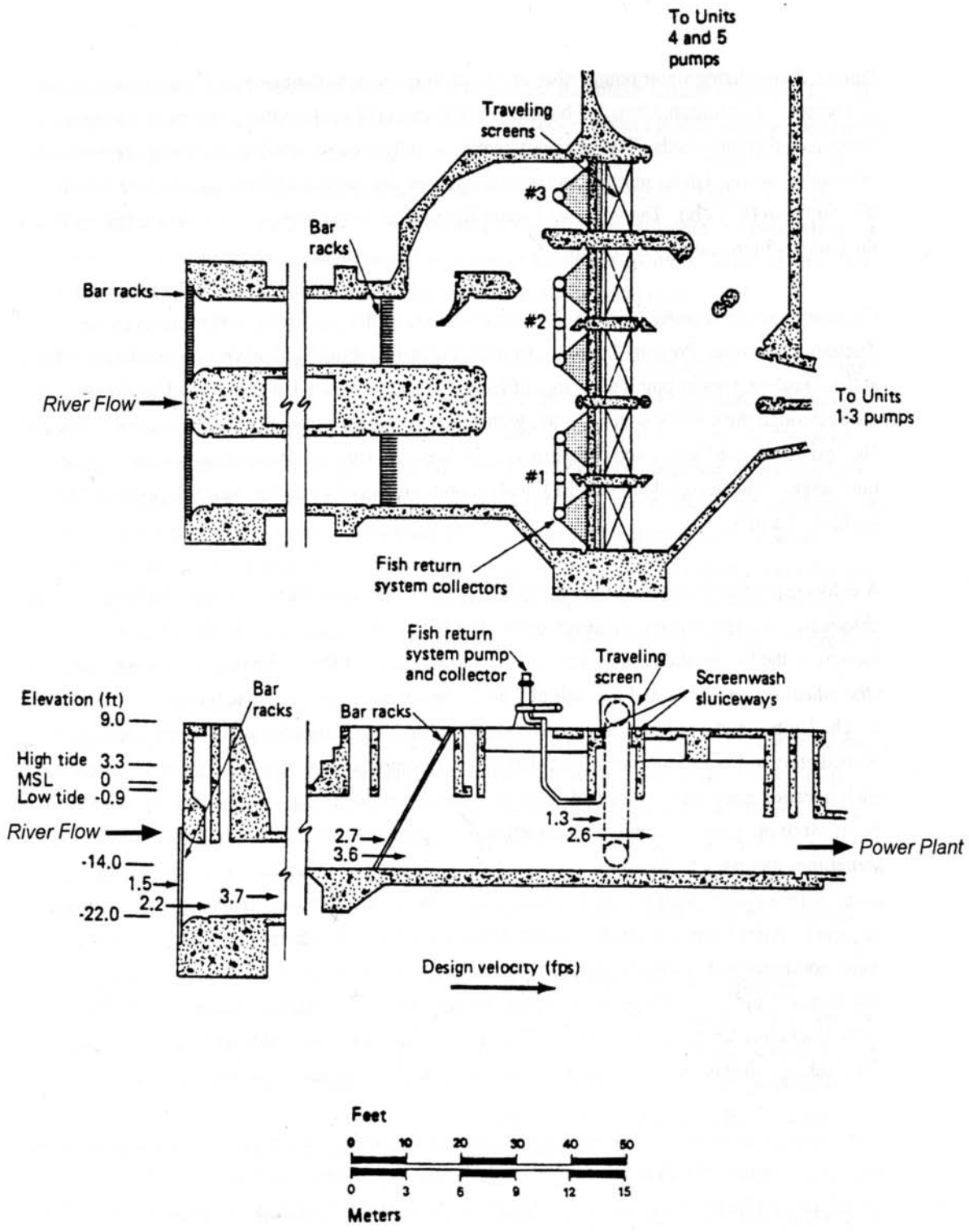

Figure 3: Plan and section schematic diagrams of Contra Costa Power Plant Units 1-5 intake structure. (PG&E)

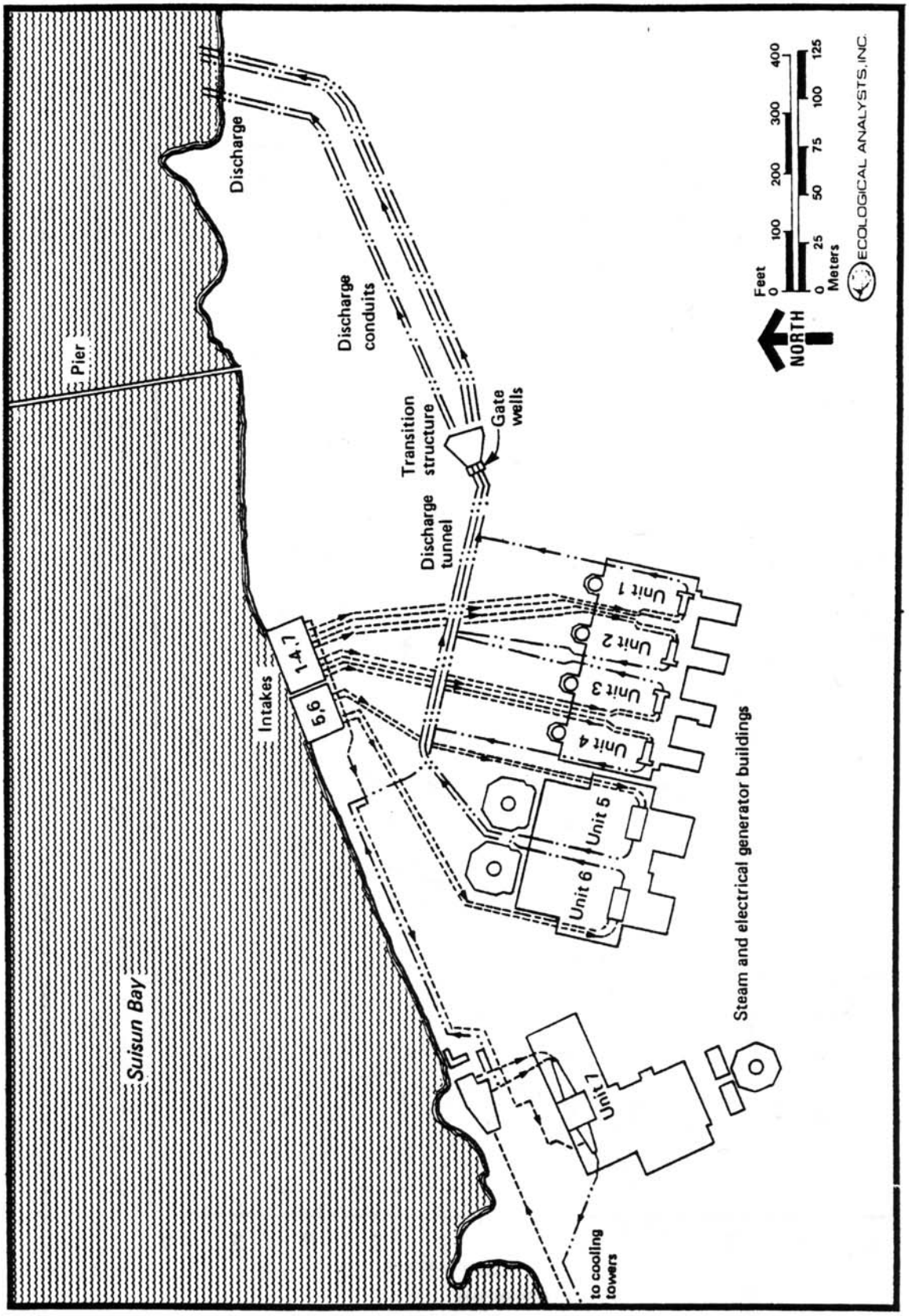

Figure 5: General configuration of Pittsburg Power Plant circulating water system.

Occurrence of Aquatic Species Near the Power Plants

As described in the Introduction, there are several aquatic species of special concern in the project areas (Table 1). Information about the occurrence of species is available from PG&E studies as well as Interagency Ecological Program (IEP) Monitoring near the project areas.

Power Plant Studies

Fish species occurring in the shallow channel and shoal areas adjacent to the power plants include striped bass, Chinook salmon, longfin and delta smelt, wakasagi, threespine stickleback, tule perch, Sacramento squawfish, gobies, inland silverside, starry flounder, Sacramento splittail, carp, largemouth bass, and catfish [(7)]. At times when the Delta outflows are between 7,500 and 15,000 cfs, the null zone, X2, is located in the vicinity of the PPP and the distribution of larval delta smelt and other species of concern have increased susceptibility and exposure to the circulating-water system at the power plant [(7)].

Fish Sampling: As part of a PG&E program to evaluate potential biological impact of the plants intake system, EA conducted a fishery study near CCPP from August 1978 through July 1979 [(11)]. The purpose of the study was to describe the relative abundance and spatial and seasonal distributions of juvenile and adult fish found near the cooling water intake and to determine the nature of usage by the fish. Sampling was done at stations near both of the intake and discharge locations with active and passive gear [(11)].

In 117 samples, 4,666 fish of 32 species were caught [(11)]:

Species	Percent
Striped bass	37.9
Inland silverside	29.5
White catfish	9.2
Threadfin shad	5.7
Yellowfin goby	3.4
Splittail	3.3
Sac. squawfish	3.0
Carp	2.3
Tule perch	1.4
Black crappie	0.9
Am. shad	0.4
Steelhead trout	0.1
Chinook salmon	0.1
Other fish	2.8

The results support the conclusion that the area in the vicinity of CCPP serves as a nursery for juvenile striped bass and that in winter striped bass are attracted to and concentrate in the area influenced by the warm water discharge [(11)]. There is some indication that white catfish and splittail are also attracted to thermal plume area [(11)].

From November 1968 through 1970, fish were sampled quarterly at 5 locations near the PPP [9]. Fish were collected using 3 techniques at each location; the otter trawl, the floating gill net, and the sinking gill net. The largest numbers, 239 fish of 11 different species, were captured at station 5. At station 1, 38 fish of 11 different species were captured. A total of 403 fish were caught with 92% being of 5 introduced species [9]. The most numerous species caught were [9]:

Striped bass = 78.7%
White catfish = 6.7%
Carp = 4.0%
Am. shad =2.0%

Other species each account for less than 2% of the total catch.

In 1981, as part of report 316(b), a fishery study conducted from Aug. 1978 through July 1980 by EA near the PPP and 2 miles west at the proposed expansion site, describes the primary aquatic habitats, the study design, and the methods used in collection [12,13]. Fyke nets, beach seines, otter trawls, gill nets, and electroshocking gear were used [12,13]. With 118 sampling efforts at the PPP and 172 at the west site, the most abundant species collected were [12,13]:

SPECIES	PPP%	WEST%
1. Striped bass	45.3	34.9
2. Splittail	13.9	20.3
3. Tule perch	8.4	--
4. Threadfin shad	6.6	6.3
5. Yellowfin goby	5.7	14.0
6. Sac. squawfish	5.6	3.7
7. Inland silversides	4.2	7.4
8. Delta smelt	1.8	--
9. Blackfish	--	4.4
10. Carp	1.5	--
11. Chinook salmon	1.2	0.8 (2 yr. avg.)

Note that information on direct entrainment and occurrence of delta smelt near the power plants is limited because of taxonomic problems with earlier studies. Young delta smelt and longfin smelt are difficult to differentiate; so much of the early data is at the family (Osmeridae) level only. The available information suggests that larval and juvenile smelt, including delta smelt and longfin smelt, were historically one of the most abundant fish taxa in the area. Fishery surveys using a combination of gear types found that delta smelt comprised 1.8 percent of the catch of all species near Pittsburg Power Plant from August 1978-July 1979 (Ecological Analysts 1981c) as compared to 1.1 percent at discharge and reference sites in from July 1991 to June 1992 (PG&E 1992a). Studies near Contra Costa Power Plant reported that delta smelt constituted only 0.1 percent of the catch in 1978-1979 (Ecological Analysts 1981d), but 0.7 percent in 1991-1992 (PG&E 1992a).

Plankton sampling: PG&E had a study conducted by EA [14] near the CCPP from May 1978 through April 1979 as part of PG&E's study 316(b) [10]. Results from this study were presented with an emphasis on the most abundant species including fish eggs, larvae and planktonic invertebrates [14]. Samples were collected with a pair of conical plankton nets mounted on a steel sled. The nets had a mesh of 505-µm, were 2.5 m long and had a 0.5-m mouth.

Summary of findings [14]:

1. Striped bass eggs were collected in the highest density in late May from the main river channel.
2. Striped bass, sculpin, smelt, and threadfin shad constituted 98% of the larval and juvenile fish collected.
3. The highest densities of larval fish occurred in May, and striped bass strongly dominated those collections.
4. Fish ranged in length from 3 to 100 mm, but most were less than 40 mm long.
5. Striped bass larvae were in higher numbers in the main channel, while juveniles were collected at slightly higher numbers outside the main river channel.
6. No consistent diel pattern in striped bass abundance was apparent, but shrimp (Neomysis mercedis) peaked in night collections and were consistently found in higher densities in bottom collections.
7. Osmeridae were the third most abundant near Contra Costa Power Plant.

The Delta-Suisun Surveillance Program collected phytoplankton throughout the Delta, including 6 stations near the PPP, at monthly intervals from Nov. 1968 through December 1970 [9]. During the summer, the western Delta between the junction of the Sacramento and San Joaquin rivers and Carquinez Strait usually had the highest concentration of phytoplankton in the estuary [9]. Algal populations never reached problem levels [9]. The most dominant genera were diatoms of Cyclotella, Melosira, and Coscinodiscus. Green algae Chlorophyceae and Cryptophyceae were also found in abundance [9].

A plankton study by EA for PG&E near the PPP and 2 miles west, at the proposed expansion site, was conducted from May 1978 through April 1979 [15,16]. Samples were collected with a pair of conical plankton nets mounted on a steel sled. The nets had a mesh of 505-µm, were 2.5 m long and had a 0.5-m mouth. Results were presented with an emphasis on the most abundant species. The study state the following [15,16]:

1. The eggs of northern anchovy and striped bass constituted 98% of those identified. No striped bass eggs were collected at sites near the PPP.
2. Smelt, striped bass, Pacific herring, northern anchovy, sculpin, and gobies constituted 96% of the fish larvae and juveniles. Striped bass, smelt, sculpin, and northern anchovy were 93% of the catch at the PPP.
3. Highest densities, dominated by striped bass in the west and smelt near the PPP, were found in May and June.
4. Fish ranged from 1 to 145 mm, but were mostly less than 40 mm long.
5. Striped bass yolk-sac larvae had no diel pattern, but larvae and juveniles along with Neomysis were in greater densities in bottom samples.
6. Osmeridae were the most common group collected in ichthyoplankton samples near Pittsburgh Power Plant.

Benthos Sampling

Previous studies by Tetra Tech (TT) of the biomass of benthic organisms in and around Suisun Bay indicate that diversity is limited to a few species and the total volume of benthos to be small [(9)]. Benthic dredge samples were collected quarterly from 10 locations near the PPP [(9)]. Sample sites were selected to represent different plume exposure intensities. Forty-one species and 19,236 specimens were collected in this study. The amphipods Corophium and Ericthonius were the most abundant specimens at 84% of the catch and the annelid worm Boccardia was next at 6% [(9)]. TT also found that the taxa collected do not correspond closely with those reported by other studies, but TT does not cite these other studies. Despite these differences, the data on the benthic fauna near the PPP did not show it to be depauperate or decimated [(9)]. The sample site receiving the greatest exposure to the thermal discharge consistently had high benthic fauna densities and taxonomic diversity [(9)].

IEP Studies

The Interagency Ecological Program (IEP) for the San Francisco Bay / Sacramento-San Joaquin Estuary consists of ten member agencies, three State (Department of Water Resources, Department of Fish and Game, and State Water Resources Control Board), six Federal (Fish and Wildlife Service, Bureau of Reclamation, Geological Survey, Army Corps of Engineers, National Oceanic and Atmospheric Administration - Fisheries, and Environmental Protection Agency), and one non-government organization. These ten program partners work together to develop a better understanding of the estuary's ecology and the effects of the State Water Project (SWP) and Federal Central Valley Project (CVP) operations on the physical, chemical, and biological conditions of the San Francisco Bay-Delta estuary. The IEP represents one of the most comprehensive estuarine monitoring programs in the United States. One of the longest running surveys is the Fall Midwater Trawl, which was implemented to sample the distribution and abundance of age-0 striped bass and the pelagic fish community in the Delta and upper estuary. Data from this survey is available at the IEP website (www.delta.dfg.ca.gov).

Fall Midwater Trawl: Sampling at stations closest to the two power plants indicates that abundance of smelt has been highly variable since the mid-1970s. As shown in Figure 5, the mean catch of delta smelt declined in the 1980s at stations located upstream of Pittsburg Power Plant. However, some years during the past decade have had similar or higher levels than the 1970s. At station 802, a site near Contra Costa Power Plant, mean catch of delta smelt showed similar highly variable trends.

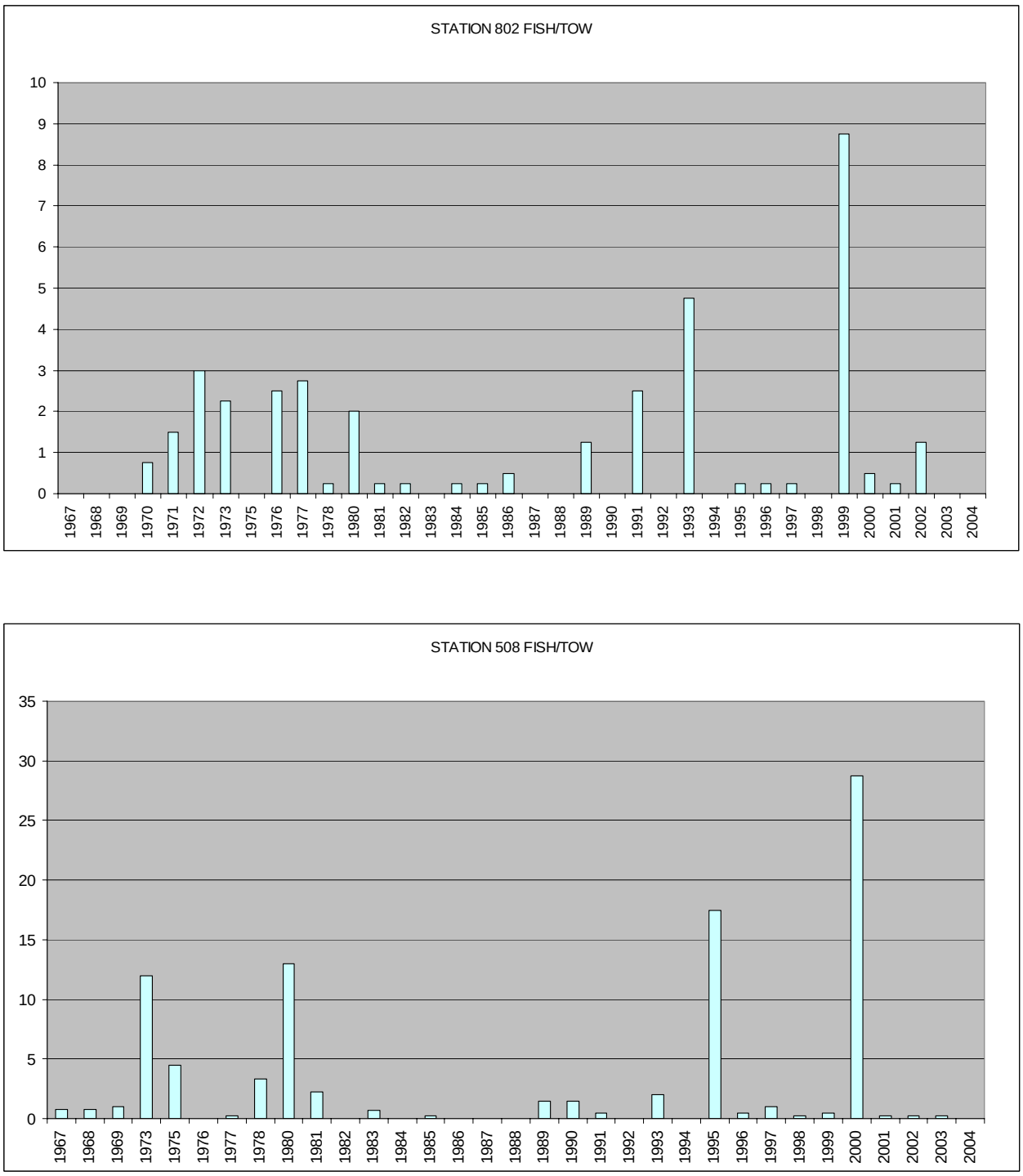

Figure 5: IEP Fall Midwater Trawls nearest Contra Costa Power Plant intake (Station 802) and the Pittsburg Power Plant intake (Station 508). Graphs show average Delta smelt per tow per year.

POTENTIAL AQUATIC IMPACTS

Contra Costa Power Plant

Thermal Effects

Thermal effects may result in direct mortality, behavioral attraction, avoidance or blockage or increased predation. The CCPP occasionally did not comply with the numerical temperature objectives in the California Thermal Plan [17]. The specific objectives in the Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California as adopted on May 18, 1972 by the State Water Resources Control Board are as follows [17]:

5. Estuaries
   a. Existing discharges
      Elevated temperature waste discharge shall comply with the following:

      - The maximum temperature shall not exceed the natural receiving water temperature by more than 20 °F.
      - Elevated temperature waste discharges either individually or combined with other discharges shall not create a zone, defined by water temperatures of more than 1 °F above natural receiving water temperature, which exceeds 25% of the cross-sectional area of a main river channel at any point.
      - No discharge shall cause a surface water temperature rise greater than 4 °F above the natural temperature of the receiving waters at any time or place.

Thermal waste discharges shall comply with the provisions of the above and, in addition, the maximum temperature of thermal waste discharges shall not exceed 86 °F.

As a consequence, the CRWQCB had the following limitations stated in the Thermal Plan portion of the NPDES [17, 9] for the power plants.

- "No discharge shall cause a surface water temperature rise greater than 4 ºF above the natural temperature of the receiving water at any time or place."
- "The maximum discharge temperature shall not exceed the natural receiving water temperature by more than 20 ºF."
- "The maximum temperature of thermal waste discharge shall not exceed 86 ºF."

The plant discharged cooling water at temperatures in excess of 86 °F 10% of the time, all during the summer months, and surface temperatures in the receiving water exceed the 4 °F above ambient requirement for areas up to 100 acres [7]. The plant could increase temperatures from 0.5 to 1.0 °F over several thousand acres (Figure 6). Temperature increases periodically exceeded 20 °F, depending on plant load and cleanliness of the condenser tubes [7].

- In 1973, PG&E prepared a report that describes plant operations and presents results for the determination of compliance with the State Thermal Plan [17]. The report stated that although discharges were sometimes not in compliance with water quality objectives, cooling water had been discharged into a tidal estuary for over 22 years with no deleterious effects on beneficial uses. According to the report, this lack of effect when compared with the monetary and environmental costs of alternatives justified an exception from both state and federal thermal limitations [17].

They believed that the CCPP should therefore qualify for an exception from the Water Quality Control Plan, which included the following provision:

> "Compliance by existing dischargers with specific water quality objectives would require modification of operations or facilities not commensurate with benefit to the aquatic environment."

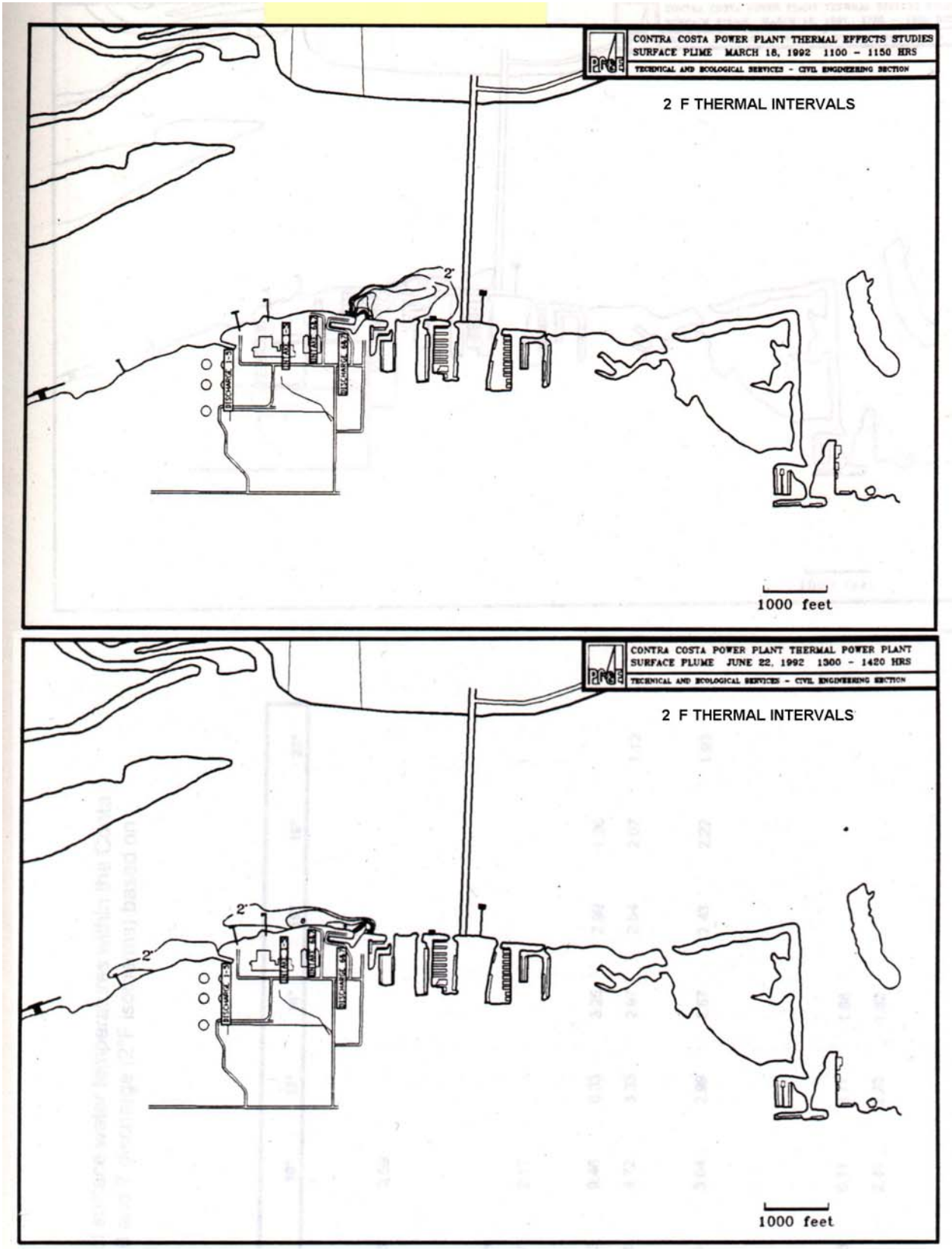

Figure 4: Thermal Plumes at Contra Costa Power Plant During Incoming and Outgoing Tides

Furthermore, under section 316 of the Federal Water Pollution Control Act Amendments of 1972, the state may impose less restrictive effluent limitations if the required limitation is [17]:

> "--- more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife in and on the body of water into which the discharge is to be made ---"

In 1990 CRWQCB granted PG&E exemptions to the three limitations stated in the thermal plan portion of the NPDES (see above). However, PG&E was required by provisions of the NPDES permit to conduct studies of the effects of heated water discharges at both plants [18]. The objective of the thermal effects assessment program was to assess the effects of water temperature on striped bass larvae and other organisms within the area of influence of the power plants discharges. The investigative study, conducted from July 1991 through June 1992, monitored and profiled the power plants discharges and receiving waters, and included monthly fishery surveys at locations outside and inside the discharge plumes. Based on field observations of the CCPP plant, the study reported the following conclusions [18]:

- The receiving waters support diverse fish communities.
- The catch per unit effort (CPUE) of striped bass and other fish was greater at the discharge sites.
- No adverse effects on abundance and species composition in the vicinity of the thermal discharges were detected.
- The majority of fish collected (>95%) were in good health with no evidence of external parasites, sores, or abnormalities.
- Temperatures within the Contra Costa Units 6 and 7 discharge canal periodically exceed the threshold for increased predation on juvenile salmon.
- Carp, catfish, largemouth bass, sunfish and crappie are seasonally attracted to water temperatures occurring within the CCPP Units 6 and 7 discharge canal.
- Water temperatures within Contra Costa Unit 6 and 7 discharge canal periodically exceeded avoidance temperatures for striped bass and Chinook salmon.
- The discharge plumes are typically located along the shoreline and have a surface orientation, thereby reducing or eliminating temperature exposure for migrating fish.
- Delta smelt, longfin smelt, Sacramento splittail, and Chinook salmon were collected at both discharge and reference sites.

To summarize, the study found greater numbers of some fish species near thermal discharge sites, but no evidence for direct mortality of striped bass and no thermal blockage of migratory species including Chinook salmon, striped bass or American shad. Insufficient numbers of delta smelt were collected to draw any conclusions about how they are affected by the thermal discharges. Predation on juvenile Chinook salmon and larval striped bass from thermal stress may be higher in Contra Costa Units 6 and 7 discharge canal, but the report concluded the effect is probably minimal. The overall effects of thermal discharges on delta smelt are not known, but sampling indicates that there is no behavioral attraction.

Chemical Effects

Chlorination for control of condenser slime was historically conducted weekly [17]. For 1971, where all units plus 1 house unit were running at average capacities, it was reported that chlorine was injected into 1 suction pumps flow at a time for 40 minutes 2 or 3 times a week [17]. The number of injections varied from once a week to 2-3 times per week, depending on season and need. This treatment consumed a little over 1 ton of chlorine a month, or 13 tons for the year [17]. The feed rates in that year were approximately [17]:

Units 1-3:
75 lbs./hr for January and February
63 lbs./hr for balance of 1971
Note: 17 lbs./hr are added to this feed when the house unit was operating.

Units 4 and 5:
33 lbs./ hr

Units 6 and 7:
84 lbs./hr

The discharge water was not historically dechorinated or subject to regular monitoring for residual chlorine.

Some field studies have failed to separate the effects of temperature increases from the effects of chlorination of other plant operations. Field tests by PG&E demonstrated that it was far less hazardous to pass young salmon and striped bass through the cooling water system of this power plant than to screen the fish at the entrance [17]. Survival may be reduced during condenser chlorination. Maximum chlorine concentration tolerated by a given species or life stage is a function of the exposure duration [19 cited in 20]. Entrained organism passing through the system could be exposed to chlorine for up to 3 minutes [7]. The maximum tolerated by sensitive marine and freshwater species are 0.34 and 0.99 mg/l of total residual chlorine, respectively, when exposure is 5 minutes [19 cited in 20]. Chlorine at 0.05 mg/l was the critical level for young pacific salmon exposed for 23 days [19 cited in 20]. The lethal threshold for Chinook salmon for a 72-hour exposure was noted by these investigators to be less than 0.1 mg/l chlorine. Results also showed that at 59 °F and salinity at 30‰ mature copepods (Eurytemona affinis) have difficulty in surviving exposures to chlorine. In this study it was suggested that free residual chlorine in seawater in excess of 0.01 mg/l could be hazardous to marine life [20].

Entrainment Effects

Entrainment effects may occur from large pressure decreases (>1 atm.) across the condenser at both power plants, and impingement on fish screens. Large pressure decreases (>1 atm.) across the condenser at both power plants may damage entrained organisms and discharge temperatures greater than 86 °F reduce entrainment survival [21]. Survival may be further reduced during condenser chlorination.

Information on occurrence and direct entrainment of delta smelt near PG&E plants is limited because of taxonomic problems with earlier studies [22]. Young smelt were difficult to differentiate prior to 1990, so most of the early data is at the family (Osmeridae) level only. Available information suggests that larval and juvenile smelt were historically one of the most abundant fish taxa in the area [22]. From April 1978 to August 1979, more than 16 million smelt larvae were entrained at CCPP, and an additional 6,400 juveniles were impinged on the screens [22]. However, it is unclear whether these levels are representative of recent trends as populations levels have been highly variable (Figure 5).

Entrainment mortality was shown to vary widely among species. Families of fishes whose larvae are most sensitive include Clupeidae, Engraulidae, Atherinidae, and Ammodytidae [21]. Mortality of striped bass larvae at CCPP ranged from 19% to 40% [21]. Mortality of Neomysis mercedis ranged from 10% to 28%, and that of gammarideans 4-5% [21].

Based on results of PG&E's monitoring conducted by EA over a 1-year study period in 1978 and 1979, estimates of the numbers of eggs to adult fish entrained and impinged annually at the CCPP were calculated [7]. Entrainment was defined here as the hydraulic capture and subsequent passage of organisms through the circulating-water system. This involves organisms generally less than 38 mm long and capable of passing through the 3/8-inch mesh of the intake screens [7]. Impingement occurs when an organism is held against the intake screens and typically involves juvenile fish longer than 38 mm or an adult that is a weak swimmer [7]. These estimates assume no survival of organisms returned to the receiving water [7]. PG&E compiled the following table in 1998. These estimates were developed from low catch rates taken from large volumes of water and with limited seasonal efforts. Due to difficulties in identification prior to 1990, larval longfin and delta smelt were combined and reported as Osmeridae [7].

Estimated Annual Entrainment and Impingement
at CCPP (March 1978 – March 1979) [7]

Fish Species	Estimated Entrainment	Estimated Impingement
Delta smelt	21,887 ± 23,881	8,253 ± 1,595
Longfin smelt	0	19,475 ± 11,758
Larval Osmeridae	20,543,854 ± 5,601,594	0
Sacramento splittail	189,659 ± 118,820	12,455 ± 3,422
Winter-run Chinook salmon	0	53 ± 22
Spring-run Chinook salmon	0	275 ± 114
Fall/late fall-run Chinook salmon	10,318 ± 18,820	755 ± 313
Steelhead	0	38 ± 39.2
Green sturgeon	0	0

PG&E had an entrainment and impingement program designed to provide site-specific data on the size-specific densities and seasonal distribution of striped bass entrained and impinged at the power plants, and to assess striped bass losses occurring at the plants and the percentage reduction in losses each year. The program included 3 principal study elements designed to provide the biological data necessary to [23]:

1. Define the size specific seasonal and geographic distribution in the densities of entrained larval and juvenile striped bass at the CCPP.

2. Determine the annual commencement date and end date of the resource management plan.
3. Define the size specific seasonal distribution in the numbers of juvenile striped bass impinged on intake screens at the CCPP.

To establish compliance with objectives of the State Thermal Plan, PG&E conducted a survey of angler use and catch in the vicinity of CCPP's discharge [8]. The creel census at CCPP was conducted during 14 days from July 1, 1974 to October 26, 1974. The CCPP census was broken down into 3 survey zones surrounding Units 6-7. Zone 1 was within the discharge channel, zone 2 was the area surrounding the outflow, and zone 3 was the area between the outflow and its intake. Catch rates for most species were highest within zone 1, the discharge canal. Shore anglers during this study took 12 species of fish. Striped bass represented 60.7% of the total catch, and white catfish accounted for 34.8% [8].

From 1967 to 1976, PG&E contracted with TT to conduct studies to provide additional data on the possible effects of the power plant cooling system on Neomysis and striped bass populations. These studies found that concentrations of Neomysis in the intake at CCPP were approximately 4% to 17% of concentrations at mid-channel, and that plant operations could account for 1% to 2% of the total loss rate for striped bass young-of-the-year [24]. Combined effect of CCPP and PPP could account for 4% to 8% of the total loss rate of striped bass [24].

Improvements to Protect Aquatic Species

The CCPP power generation facility was initially recognized to as a potential threat to Chinook salmon and striped bass resources of the area [6] and operates within the range of delta smelt. Intakes for all units at the power plant employ a screening system to remove debris, but the screens allowed entrainment of fish smaller than about 38 mm and impingement of larger fish [22]. Fish were removed from the traveling screens for Units 1 - 5 by a vertical fish lift, or fish pump (Figure 3), consisting of 2 vertical 8-inch oblong slotted collector pipes, 1 installed on each side of the approach channel to the screens, a fish pump and a discharge pipe [6]. It was thought that high velocity cleaning flows through the oblong slots of the collector pipes would forcibly and safely depopulate the screen area of fish [6]. Passage time for fish, from the traveling screens to the discharge structure, was estimated to be less than 4 minutes [6]. The fish pumps ceased operating in 1995 with the decommissioning of Units 1 – 5.

During the start-up period the vertical hydraulic fish pump proved inadequate in removing the great numbers of fish present and survival of the fish recovered by the lift was low, only 13% [6]. DFG was concerned about the thermal plume from cooling water discharges and the possibility of many fish passing through the plant [6]. DFG biologists recovered many dead striped bass by netting in the discharge cooling water [6]. Mortality here was attributed to the 12 °F rise of the cooling water. In 1951, DFG estimated that as many as 19 million small bass might pass through the plant and be killed each year between April and mid-August [6]. DFG recommended that the plant load be reduced so that cooling water would not increase more than 10 °F, that finer mesh screens be used, and that the screens be located at the intake [6].

Due to higher rates of mortality, a fish research and protection program was initiated by DFG and a facility was built adjacent to the CCPP's intake screen structures. The following ideas, listed with their results, were tried or considered as rescue measures [6]:

- Noisemaking and vibrating devices were tried--all without effective results.
- Traveling screens, intended to operate intermittently, were run continuously for a period with reduced washing pressure. Mortality was reduced less than 10%.
- Placing cups on the screen was studied but rejected.
- Lights were tried as a means of attracting fish to rescue zones from hazard areas with little effect.
- Different traps were constructed and installed in quiet areas, all with negative results.
- Bucket conveyors were considered, but their use was not practical.
- A mechanical dip net was designed to replace hand dip netting. It compared favorably and its use was continued.
- Hand dip netting, at times on a 24-hr / 7-day per week basis, returned 12,000 bass to the river alive, during September and October.

Concurrent with these efforts, DFG and PG&E conducted studies to find a permanent solution. Research included studies of fish stratification and behavior, velocity, temperature, mesh size, screen operation, electric screens, barriers, and vertical fish lift [6]. From these studies, DFG concluded that approach velocities and avenues of escape were more important considerations than is mesh size. Little difference was found in the swimming abilities of juvenile striped bass and young salmon. They observed that larval bass had little ability to resist currents, even below 0.5 ft/sec, but yearlings of both species were found to handle up to 2.75 ft/sec for up to 10 minutes. Research revealed that small fish could safely pass through the condensers under maximum plant load conditions with survival rates greater than 95%, and that yearling bass could withstand a sudden rise of 16 °F and a maximum temperature of 90 °F, while salmon could tolerate a rise of 25 °F and a maximum of 83 °F [6].

The most important accomplishment of the program was the development of a dramatically improved fish pump collector [6]. The new collector consisted of a horizontal pan 6 inches high, hung from the under side of the curtain wall approximately 5 inches away from the traveling screen and extending the full width of the approach channel. The pan gradually converges to a 6-inch suction pipe connected to an 8-inch open impeller-type centrifugal pump capable of 2,000 gal/min. Each collector was capable of safely handling hundreds of fish per hour up to 14 inches in length with a survival of 98% or more [6].

Pittsburg Power Plant

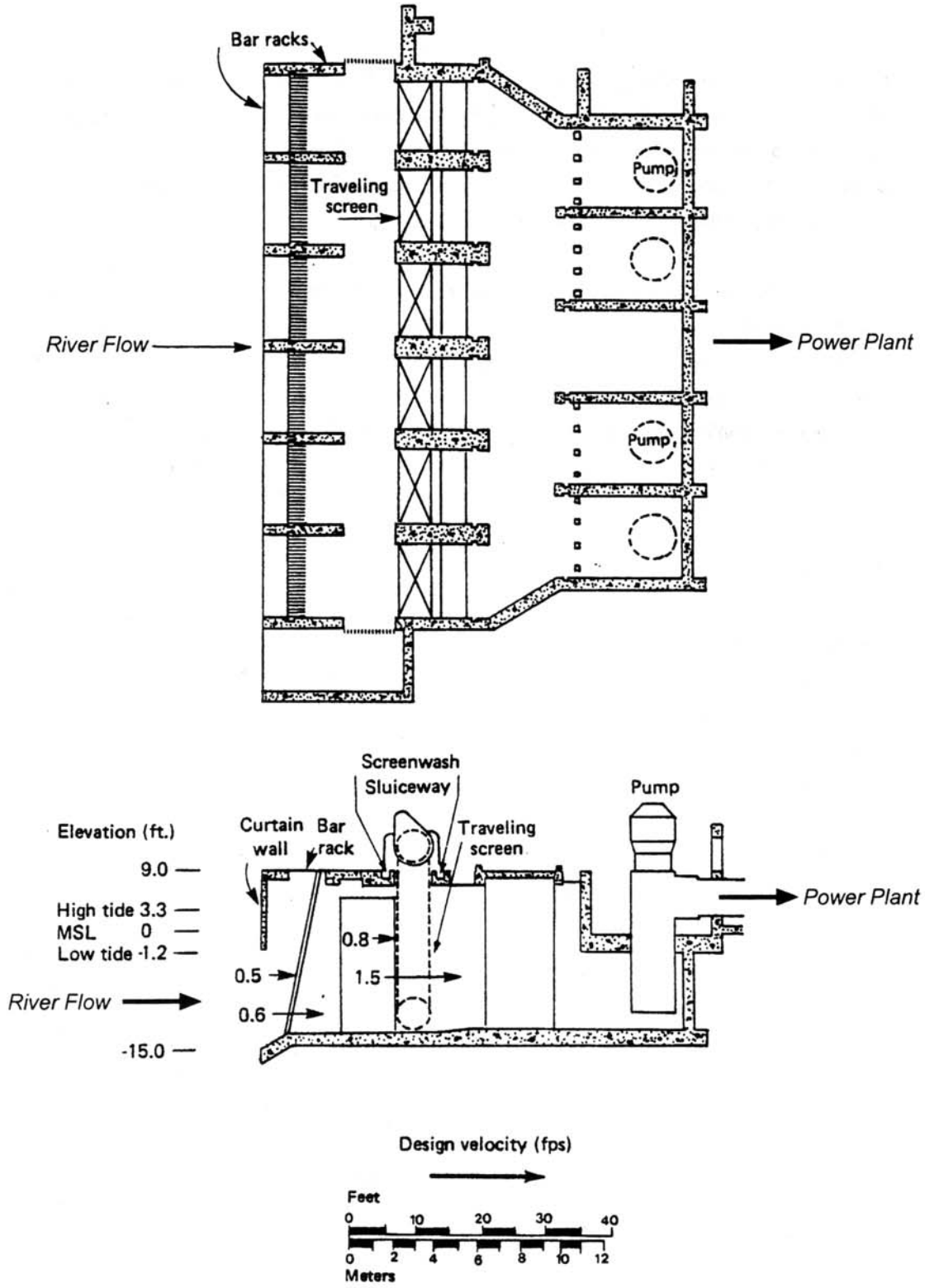

Figure 6: **Plan and section schematic diagrams of Pittsburg Power Plant Units 5 & 6 intake structure. (PG&E)**

Thermal Plume

The PPP occasionally did not meet the numerical objectives stipulated in the California Thermal Plan. The CRWQCB includes the following limitations in the Thermal Plan portion of the NPDES [9]:

- "No discharge shall cause a surface water temperature rise greater than 4 ºF above the natural temperature of the receiving water at any time or place."
- "The maximum discharge temperature shall not exceed the natural receiving water temperature by more than 20 ºF."
- "The maximum temperature of thermal waste discharge shall not exceed 86 ºF."

The plant discharged cooling water at temperatures in excess of 86 °F 10% of the time, all during the summer months, and surface temperatures in the receiving water exceed the 4 °F above ambient requirement for areas up to 100 acres [7]. The plant could increase temperatures from 0.5 - 1.0 °F over several thousand acres (Figure 7) [7]. Temperature increases sometimes exceed 20 °F, depending on plant load and cleanliness of the condenser tubes [7]. In 1990 CRWQCB granted PPP an exception to these limitations.

A 1976 study by TT for PG&E concluded that the thermal discharges have no appreciable detrimental effect on benthos, plankton, or fish of the receiving water [9]. But the life histories and thermal tolerance data for Neomysis, striped bass, and Chinook salmon indicate that plant operations may affect Neomysis and young striped bass [9]. Analysis by TT of Neomysis entrainment mortalities indicates that although 28 - 43 billion organisms may be killed, this was a small fraction of the total loss rate [9]. TT found that large bass were attracted to the outflow plume but no detrimental effects were evident [9]. The analysis of striped bass entrainment mortalities indicates that up to 5% of the Delta population of young bass, 18 - 38 mm, may be killed by PPP each year [9].

Chlorination

Condenser tubs are periodically chlorinated to control "slime" buildup [7]. Chlorine gas was applied for 30 min to each condenser section in sequence [7]. Application varies seasonally; 3X/day in August, September, and October; 3X/week in late October through late April; and daily from late April to early August. Feed rates are as follows: Units 1-4 @ 56 lbs./hr and Units 5 &6 @ 89 lbs./hr [7]. Dechlorination at PPP was not practiced [7]. Residual chlorine in the outlet was presumed by PG&E to be undetectable most of the time although no data is available to confirm this. In the 1995 NPDES discharge permit, total residual chlorine in the discharge effluent was limited to 0.00 mg/l, but no monitoring data is presented to show they meet this [7].

Chlorine at 0.05 mg/l was the critical level for young pacific salmon exposed for 23 days [19 cited in 20]. The lethal threshold for Chinook salmon and coho salmon for 72-hour exposure was noted by these investigators to be less than 0.1 mg/l. chlorine. Their results also show that at 59 °F and salinity at 30‰ mature copepods (Eurytemona affinis) have difficulty surviving exposures to chlorine. It was suggested in this investigation that free residual chlorine in seawater in excess of 0.01 mg/l could be hazardous to marine life.

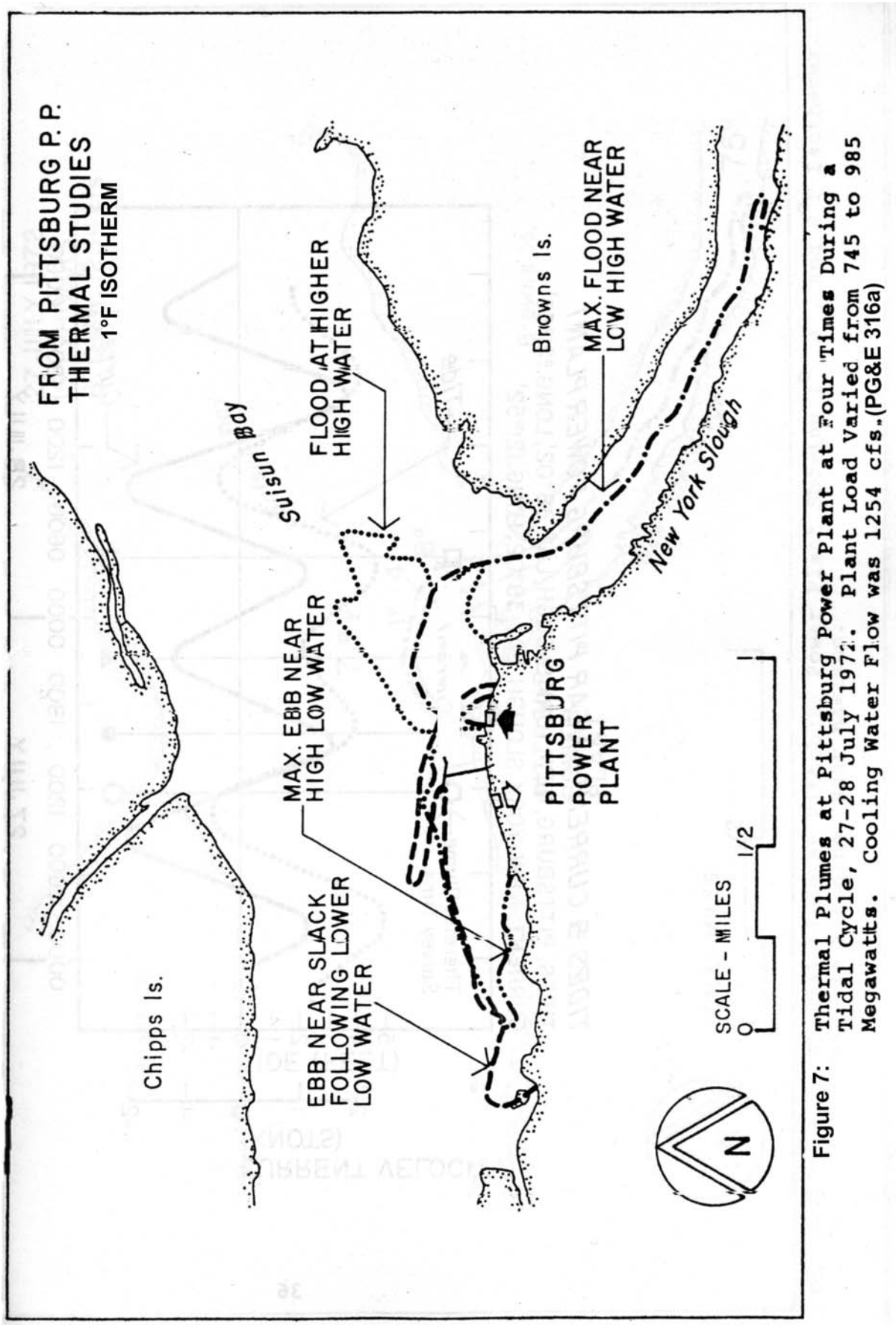

Figure 7: Thermal Plumes at Pittsburg Power Plant at Four Times During a Tidal Cycle, 27-28 July 1972. Plant Load Varied from 745 to 985 Megawatts. Cooling Water Flow was 1254 cfs.(PG&E 316a)

Entrainment

Based on results of PG&E's PPP monitoring conducted over a 1 year study period in 1978 and 1979, estimates of the numbers of eggs to adult fish entrained and impinged annually at the PPP were calculated [7]. Entrainment was defined here as the hydraulic capture and subsequent passage of organisms through the circulating-water system. This involves organisms generally less than 38 mm long and capable of passing through the 3/8-inch mesh of the intake screens [7]. Impingement occurs when an organism is held against the intake screens and typically involves juvenile fish longer than 38 mm or adults that are weak swimmers [7]. These estimates assume no survival of the organisms returned to the receiving water [7]. PG&E compiled the following table in 1998. These estimates were developed from low catch rates taken from large volumes of water and with limited seasonal efforts. Due to difficulties in identification prior to 1990, larval longfin and delta smelt were combined and reported as Osmeridae [7].

Estimated Annual Entrainment and Impingement
at PPP (March 1978 – March 1979) [7]

Fish Species	Estimated Entrainment	Estimated Impingement
Delta smelt	455,413 ± 184,516	14,082 ± 6,454
Longfin smelt	190,229 ± 198,009	137,261 ± 55,576
Larval Osmeridae	64,784,071 ± 29,475,225	25 ± 29
Sacramento splittail	155,289 ± 60,064	8,732 ± 4,596
Winter-run Chinook salmon	0	323 ± 132
Spring-run Chinook salmon	0	469 ± 192
Fall/late fall-run Chinook salmon	23,598 ± 35,468	776 ± 318
Steelhead	0	0
Green sturgeon	0	0

PG&E's PPP power generation facility operates within the seasonal range of adult delta smelt. Intakes for all units employ a screening system to remove debris, but the screens allow entrainment of fish smaller than about 38 mm and impingement of larger fish [22]. Entrainment survival studies conducted by EA for PG&E at the PPP during 1978 and 1979 focused on striped bass larvae, gammaridean amphipods, and Neomysis mercedis [10]. Results indicate that at discharge temperatures below 86 °F mortalities are low [10]. Mortality of striped bass larvae and juveniles ranged from 19 to 40%, of Neomysis 10 to 28%, and that of the amphipods from 4 to 5% [10].

Young smelt were difficult to differentiate, so most of the early data is at the family (Osmeridae) level only [22]. Available information suggests that larval and juvenile smelt were historically one of the most abundant fish taxa in the area [22]. In 1981 PG&E reported that from April 1978 to August 1979, more than 50 million smelt larvae were entrained at the PPP, and an additional 11,000 juveniles were impinged on the screens [12, 13]. However, it is unclear whether these data are comparable to recent levels as smelt abundance is highly variable in this region (Figure 5).

The draft NPDES permits being considered in 1983 for the PPP included a resource management plan provision for an entrainment-monitoring program, to be implemented by PG&E during the striped bass entrainment period. Because of variability in water temperatures on the striped bass spawning grounds, fresh water outflow during the spring, and the timing of spawning activity, it was expected that the period of larval bass susceptibility to entrainment would vary between years [25]. Therefore, it was agreed that the entrainment period should commence on May 15 or later [25]. PG&E analyzed historical data to establish a relationship between susceptibility of larval bass to entrainment and physical variables which could be used to predict commencement dates. PG&E and DFG concluded that the commencement date for the resource management plan could be set annually using results of the daily entrainment monitoring program [25]. The sampling design for the above plan was based on the program conducted in 1978 and 1979. Samples were collected for 3 hours by filtering water pumped from the discharge gate well into a 0.5-m plankton net with 505-μm mesh, to retain all 9-10 mm juvenile bass [25].

The program was designed to provide site-specific data on the size-specific densities and the seasonal distributions of striped bass entrained and impinged at the power plant, to assess striped bass losses occurring at the plant, and the percentage reduction in losses each year [23]. The program included 3 principal study elements designed to provide the biological data necessary to [23]:

1. Define the size specific seasonal and geographic distribution in the densities of entrained larval and juvenile striped bass at the PPP.
2. Determine the annual commencement date and end date of the resource management plan.
3. Define the size specific seasonal distribution in the numbers of juvenile striped bass impinged on intake screens at the PPP.

Improvements to Protect Aquatic Species

In 1992 PG&E wrote a Best Technology Available (BTA) report. As required in the resource management plan, striped bass monitoring and cooling-water system operating data were used in calculating the relative percent reduction in striped bass losses during the entrainment period, starting May 1 and ending when the 38 mm striped bass index is set at the end of June [26]. A summary of the significant findings and conclusions related to the provisions of the BTA Monitoring Program is presented below [26]:

- Reductions in cooling water system operations and striped bass losses were achieved at the PPP as a result of measures implemented during the 1992 striped bass entrainment period. The entrainment period stated on May 15, based on when densities of striped bass entrained exceeded the threshold results, and was terminated June 25, the date predicted that the 38 mm striped bass index would be set.
- Measures implemented during the period at the plant included operation of the variable speed circulating water pump controls; removal of circulating water from service as soon as practical to reduce cooling water volumes on units not in operation; preferential operation of Unit 7; minimizing the frequency of discharge temperatures exceeding 86 ºF; reduce unit loading; initiation of the entrainment period based on results of the Threshold Monitoring Program; and preferential use of units based on the geographic distribution of larval and juvenile striped bass.

- The relative reduction in striped bass losses achieved during the period was 76.6%. The estimated loss of 150-mm equivalent striped bass was reduced to 13,852 fish.
- Unit 7 was operated 100% during the entrainment period.
- PPP's Units1-6 are equipped with temperature-modified variable speed circulating water pump controls that contributed to a reduction in cooling water volumes. The monthly cooling water flow ($m^3 \times 10^6$) by unit group during May and June 1992 are presented below.

PPP Units	May	June
Units 1-4 & 7	30.6	26.8
Units 5 & 6	17.9	19.6

Note: This is equivalent to an average cooling water flow in cfs of:

PPP Units	May	June
Units 1-4 & 7	403	365
Units 5 & 6	236	267

- A total of 300,000 hatchery striped bass were released in May 1992, at various locations in the Central Valley, but not in the Delta.

In 1991, PG&E was required by provision D.6 of the NPDES permit to conduct a study on the effects of heated water discharge for PPP [18]. The objective of the thermal effects assessment program was to assess effects of water temperature on striped bass larvae and other organisms within the area of influence of the power plants discharge [18]. This investigation, conducted from July 1991 through June 1992, monitored and profiled the power plant's discharges and receiving waters, and included monthly fishery surveys at locations outside and inside the discharge plumes. The study at the PPP plant stated that [18]:

- The receiving waters support diverse fish communities.
- The CPUE of striped bass and other fish was greater at the discharge sites.
- No adverse effects on abundance and species composition in the vicinity of the thermal discharges were detected.
- The majority of fish collected (>95%) were in good health with no evidence of external parasites, sores, or abnormalities.
- The discharge plumes are typically located along the shoreline and have a surface orientation, thereby reducing or eliminating temperature exposure for migrating fish.
- Delta smelt, longfin smelt, Sacramento splittail, and Chinook salmon were collected at the discharge and reference sites.

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Notes

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