HARBOR GENERATING STATION

SUMMARY OF EXISTING PHYSICAL AND BIOLOGICAL INFORMATION AND IMPINGEMENT MORTALITY AND ENTRAINMENT CHARACTERIZATION STUDY SAMPLING PLAN

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1.0 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) published Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities on July 9, 2004. These §316(b) requirements went into effect in September 2004, and apply to existing generating stations with cooling water intake structures that withdraw at least 50 million gallons per day (mgd) from rivers, streams, lakes, reservoirs, oceans, estuaries, or other waters of the United States. At the Harbor Generating Station (HGS), two circulating water pumps that serve Unit 5 withdraw a maximum cooling water volume of 108 mgd. The HGS originally consisted of five steam electric generating units that went on-line between 1943 and 1949. At present, the facility consists of two combined-cycle combustion turbines (Units 1&2), one steam turbine (Unit 5), and five simple-cycle gas combustion turbines (Units 10–14). The HGS is capable of generating 473 Megawatts (MW).

Only Unit 5 uses ocean water for cooling purposes; Units 1&2 are equipped with heat recovery steam generators and Units 10–14 use cooling towers. Cooling water for Unit 5 is withdrawn from a bulkhead intake in Slip 5 of Inner Los Angeles Harbor. As part of the Proposal for Information Collection (PIC), Phase II facilities are required to provide:

- *A list and description of any historical studies characterizing impingement mortality and entrainment (IM&E), and/or the physical and biological conditions in the vicinity of the cooling water intake structures and their relevance to this proposed Study. If you propose to use existing data, you must demonstrate that the data are representative of current conditions and were collected using appropriate quality assurance/quality control procedures.*
- *A sampling plan for any new studies you plan to conduct in order to ensure that you have sufficient data to develop a scientifically valid estimate of IM&E at your site. The sampling plan must document all methods and quality assurance/quality control procedures for sampling and data analysis. The sampling and data analysis methods you propose must be appropriate for a quantitative survey and include consideration of the methods used in other studies performed in the source waterbody. The sampling plan must include a description of the study area (including the area of influence of the cooling water intake structure [CWIS]), and provide taxonomic identifications of the sampled or evaluated biological assemblages (including all life stages of fish and shellfish).*

This document provides this information. As part of the §316(b) Comprehensive Demonstration Study (CDS) required under the new regulations, a facility may be required to submit an Impingement Mortality and Entrainment Characterization Study depending on the chosen compliance pathway. The Impingement Mortality component is not required if a facility's through-screen intake velocity is less than or equal to 0.5 ft/s (15 cm/s). The Entrainment Characterization component is not required if a facility: (a) has a capacity utilization rate of less than 15 percent; (b) withdraws cooling water from a lake or reservoir, excluding the Great Lakes; or (c) withdraws less than five percent of the mean annual flow of a freshwater river or stream. Based on previously collected intake velocity measurements and plant operating characteristics, both the Impingement Mortality and Entrainment components of the Study apply at the HGS.

According to the §316(b) Phase II Regulations, the Impingement Mortality and Entrainment Characterization Study must include the following (for all applicable components):

- Taxonomic identifications of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) that are in the vicinity of the cooling water intake structure(s) and are susceptible to impingement and entrainment;
- A characterization of all life stages of fish, shellfish, and any species protected under

Federal, State, or Tribal Law (including threatened or endangered species) identified in the taxonomic identification noted previously, including a description of the abundance and temporal and spatial characteristics in the vicinity of the cooling water intake structure(s), based on sufficient data to characterize the annual, seasonal, and diel variations in impingement mortality and entrainment; and

- Documentation of current impingement mortality and entrainment of all life stages of fish, shellfish, and any protected species identified previously and an estimate of impingement mortality and entrainment to be used as the calculation baseline.

The Rule allows facilities to use four sources of information in developing the Impingement Mortality and Entrainment Characterization Baseline. These include:

- Use of historical studies
- Use of source waterbody biological information
- Use of data from other facilities
- Results of new studies

As discussed below, LADWP plans to use a combination of these sources of information to prepare the HGS Impingement Mortality and Entrainment Characterization Study Report. Since the through-screen velocity at the HGS is greater than 0.5 ft/s, and the capacity factor is greater than 15 percent, an Impingement Mortality and Entrainment Characterization Study is also required for the HGS.

1.1 Environmental Setting

The HGS (33°45’53'' N, 118°15'49'' W) is located in the city of Wilmington (**Figure 1-1**). Cooling water for Unit 5 is withdrawn from Inner Los Angeles Harbor. A single curtain wall intake withdraws cooling water from Slip 5, and the water is subsequently discharged at a submerged, multi-port discharge structure located in the northeast corner of West Basin. The Los Angeles-Long Beach Harbor Complex was developed from the estuarine outlets of the Los Angeles and San Gabriel Rivers. This development altered the historic shallow, estuarine habitat into primarily deepwater habitat. From the early to mid 1900s, three breakwaters were built to protect the Harbor Complex from destructive wave action. From then on, development within the Harbors involved a series of dredge and fill operations to deepen channels to accommodate deep-draft vessels and to provide additional land area for terminal development.

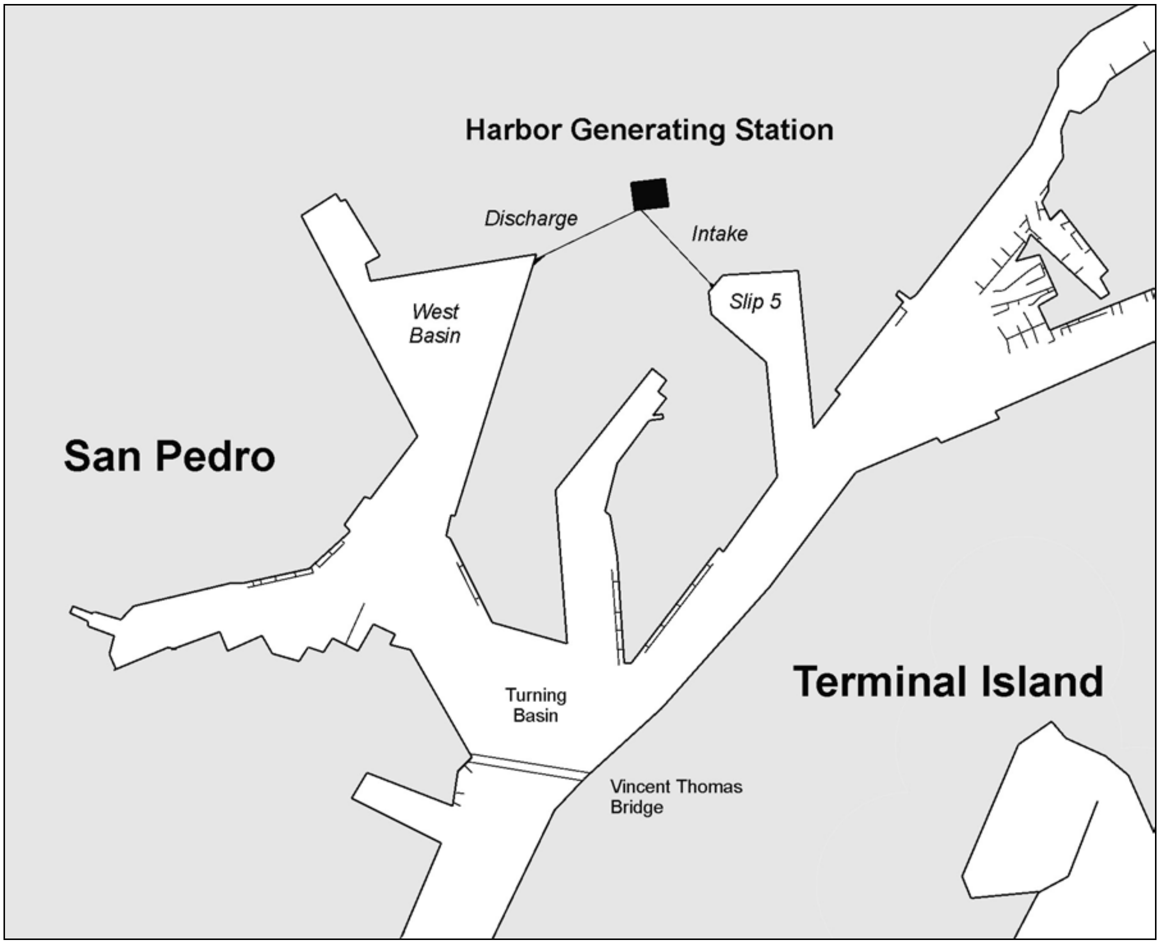

Figure 1-1. Location of the Harbor Generating Station.

2.0 HISTORICAL PHYSICAL AND BIOLOGICAL STUDIES

The following identifies and summarizes previous physical and biological studies conducted at the HGS and relevant studies from Los Angeles and Long Beach Harbors. These studies were conducted when the total cooling water flow at HGS was greater than the current conditions where only Unit 5 is using once-through cooling. The current maximum flow volume at the HGS is only about 23% of the maximum during the 1978-1979 study.

2.1 1978-1979 HGS 316(b) Demonstration

From October 1978 through November 1979, the LADWP studied entrainment and impingement at the HGS cooling water intake system as part of a 316(b) Demonstration Program (IRC 1981). Entrainment and field (source water) plankton samples were collected biweekly, and impingement samples were collected weekly during the portion of the year the generating station was operational. No impingement surveys were conducted in April and May 1979.

Daytime and nighttime plankton samples were collected using a combination of sampling gear. Entrainment samples were collected by pump from mid-depth at the intake structure in Slip 5. During each sampling period, two replicates of approximately 15,850 gal (60 m^3) were collected. At the two source water stations (one in Slip 5 [near-field] and one in Outer Long Beach Harbor [far-field]), daylight sampling was conducted monthly at the far-field station and biweekly at the near-field station (See Figure 3-1 for description of station locations). Nighttime samples were collected biweekly at both locations. At all stations, samples were filtered through 0.013-inch (335-μm) mesh during the first seven surveys and through 0.008-inch (202-μm) mesh during the remaining surveys. Source water samples were collected using Manta nets for surface samples, bongo nets for water column samples, and wheeled bongos for epibenthic samples. However, a preliminary study determined that daytime near-field samples were adequately sampled by pump at the intake, so daytime near-field collections were made at the intake.

Data analysis focused on target (critical) taxa that were selected in consultation with the California Department of Fish and Game and the Los Angeles Regional Water Quality Control Board (LARWQCB) prior to initiation of field sampling. The critical taxa included zooplankton taxa (all crustaceans) that would not be included in any new studies because the new Rule only requires quantifying IM&E for fishes and shellfishes. The critical taxa also included fish eggs from three taxa (northern anchovy, bay/slough anchovy, and a complex consisting of diamond turbot and croakers), and six larval fish taxa. Entrainment results for the critical fish and shellfish taxa that would also be quantified in studies for the new 316(b) Phase II Regulations are presented in Table 2-1.

Entrainment was highest from January through August, with lowest concentrations occurring from September through December (IRC 1981). Nighttime entrainment was significantly greater than daytime entrainment for larval fish taxa, and probably resulted from nighttime vertical migrations. The most abundant critical fish taxa included the larvae of gobies and anchovies, and the eggs of the Sciaenid species complex (croakers) and diamond turbot (**Table 2-1**).

Table 2-1. Annual entrainment estimates and adult equivalent loss estimates reported by IRC (1981) at the HGS in 1978-1979.

Target Taxa Relevant to New 316(b) Rule		Estimated Annual Entrainment	Estimated Adult Equivalents
Fish eggs			
Engraulis mordax	northern anchovy	-	
Sciaenid spp complex and *Pleuronichthys guttulatus*	croakers and diamond turbot	390,000,000	3,530
Anchoa spp	anchovies	-	
Fish larvae			
Engraulid spp complex	anchovies	100,000,000	1,320
Gobiid spp complex	gobies	520,000,000	8,870,000
Hypsoblennius spp	combtooth blennies	19,000,000	70,600
Genyonemus lineatus	white croaker	52,000,000	4,300
Seriphus politus	queenfish	-	
Pleuronichthys guttulatus	diamond turbot	-	

- Not collected in sufficient numbers for analysis.

During thirty-four 24-hr impingement surveys, a total of 17,632 fish weighing 685 lbs (311 kg) was collected (**Table 2-2**). The mean daily impingement rate was 450 fish per day, which extrapolated to an annual impingement estimate of 164,250 fish weighing 6,234 lbs (2,827 kg). The most abundant fish species impinged were Pacific pompano (*Peprilus simillimus*), white croaker (*Genyonemus lineatus*), and queenfish (*Seriphus politus*). Impingement varied by species, but peaked between December and February. Impingement of yellowfin goby (*Acanthogobius flavimanus*) occurred following periods of non-operation, suggesting this species inhabited the intake conduits when the cooling water system was not operational.

Table 2-2. Total numbers of fishes collected during 34 24-hr impingement surveys at the HGS in 1978–1979.

Fish Taxa		Impingement Totals
Target Species		
Genyonemus lineatus	white croaker	5,102
Seriphus politus	queenfish	2,935
Cymatogaster aggregata	shiner perch	1,873
Anchoa compressa	deepbody anchovy	113
Engraulis mordax	northern anchovy	48
Non-target Species		
Peprilus simillimus	Pacific pompano	5,396
Acanthogobius flavimanus	yellowfin goby	1,130
Trachurus symmetricus	jack mackerel	237
Urobatis halleri	round stingray	163
Other taxa		635
	Total:	17,632

Impact analyses were conducted using several techniques. Entrainment losses were compared to source water populations (standing stocks). Estimates of ichthyoplankton losses were also evaluated using an adult equivalent loss model. Impingement losses were compared with source populations calculated from demersal fish surveys, as well as recreational and commercial fishing landings. Lastly, impingement mortality was compared with instantaneous mortality rates for three fish species. In summary, there were no significant effects from the HGS on the standing crop and natural mortality rates of the taxa analyzed. Consistent with the 316(b) guidelines, it was determined that the HGS cooling water system represented the best technology available.

The sampling program was conducted with the approval of the Los Angeles Regional Water Quality Control Board (LARWQCB), and detailed procedures and methodologies, as well as Quality Assurance/Quality Control (QA/QC) methods, can be found in Appendices G (Biological Field Procedures), H (Laboratory Procedures), and I (Statistical and Analytical Procedures) of IRC (1981).

2.2 1997 HGS 316(b) Update

In 1997, available information was synthesized to update the original 316(b) assessment from 1978-1979 for the HGS; no additional biological data was collected or analyzed (MBC 1997). No additional recent data on through-plant effects on entrained organisms were included in the 316(b) update. Cooling water flow at the HGS was approximately 62% of maximum design flow during the 1978-1979 316(b) studies, and 32% of design flow between 1982 and 1995. Therefore, estimated losses from the previous 316(b) demonstration were considered “worst-case” estimates. It was determined that the HGS was minimizing losses of plankton and fishes through the use of the existing intake system.

2.3 2003–2004 HGS Fish and Macroinvertebrate Impingement Monitoring

Composition, abundance, and biomass of juvenile and adult fish and macroinvertebrates entrapped and impinged on the traveling screens at the HGS have been studied since 2003 as part of a continuing NPDES monitoring program. The HGS NPDES permit requires semiannual impingement sampling during heat treatments; however, heat treatments are not normally conducted at the HGS, so normal operations samples were collected. In addition, beginning in 2004, generating station personnel preserved impinged fishes and macroinvertebrates during routine traveling screen operations. These organisms were later analyzed by biologists.

During normal operation surveys, the traveling screens were rotated for an approximate 10-minute rotation, and the impingement collection baskets were cleared of accumulated debris. If this was not possible, a tarp was laid across the debris to separate it from the subsequent collection. Approximately 24 hr later, the screens were rotated again, and all material that accumulated from that screen wash, and any other washes that occurred in the prior 24 hr, was considered part of that normal operation sample. All fish and macroinvertebrates were separated from incidental debris, identified, and counted. Up to 200 individuals of each fish species were measured, examined for external parasites, anatomical anomalies, and other abnormalities. Aggregate weights were taken for each fish and macroinvertebrate species. When LADWP collected organisms for impingement samples, the screens were rotated and all impinged fishes and macroinvertebrates were placed in labeled plastic bags and frozen. These samples were transferred to biologists on a bimonthly basis, and the organisms were then identified, enumerated, measured, and weighed.

A summary of results from the 2003–2004 impingement monitoring is presented in **Table 2-3**. A total of five normal operation impingement surveys and 20 impingement collections by plant personnel were performed in 2003-2004 (MBC 2004a). Of the 58 fish collected in normal operation surveys, 44 (76%) were round stingrays (*Urobatis halleri*), 4 (7%) were giant kelpfish (*Heterostichus rostratus*), and 3 (5%) were black perch (*Embiotoca jacksoni*). The remaining six species were each represented by two individuals or less. Of the 38 macroinvertebrates impinged during the five surveys, abundance was dominated by tuberculate pear crab (*Pyromaia tuberculata*; 53%) and intertidal coastal shrimp (*Heptacarpus palpator*; 16%); the remaining seven taxa were each represented by three individuals or less.

Table 2-3. Fish and macroinvertebrate abundance during impingement surveys at the HGS, 2003-2004.

	Normal Operation Surveys			HGS Collections*
	2003	2004	Average	2004
Fish abundance	47	11	29	255
Macroinvertebrate abundance	2	36	19	21
Number of surveys	2	3	3	20
Fish per survey	24	4	14	13
Macroinvertebrates per survey	1	12	7	1

** = Collections by LADWP personnel.*

HGS personnel collected a total of 255 fishes during 20 traveling screen surveys between February and October 2004. Abundance was dominated by round stingray (36%), black perch (26%), and yellowfin goby (24%). The remaining 15 taxa were each represented by five individuals or less. Abundance was highest in February and March. Only 21 macroinvertebrates were collected by plant personnel during the 20 surveys. The most abundant invertebrate was the two-spotted octopus (*Octopus bimaculatus/bimaculoides*; 7 individuals).

Impingement sampling was done in conformance with specifications set forth by LARWQCB in the NPDES permits. Specimens of uncertain identity were crosschecked against taxonomic voucher collections maintained by MBC, as well as available taxonomic literature. Scales used to measure biomass (spring and electronic) were calibrated every three months.

The following measures were employed to ensure accuracy of all data entered into computer databases and spreadsheets:

- Upon return from the field, all field data sheets were checked by the Project Manager for completeness and any obvious errors;
- Data were entered into pre-formatted spreadsheets;
- After data were entered, copies of the spreadsheets were checked against the field data sheets;
- Data were submitted annually to the LARWQCB, U.S. EPA Region IX, and the California Department of Fish and Game.

2.4 2004 HGS Entrainment Review

In preparation for potential 316(b) studies, available larval fish data from the vicinity of the HGS intake were assembled (MBC 2004b). Ichthyoplankton densities from samples collected in Inner Los Angeles Harbor, including one station within 0.8 km of the intake structure, were multiplied by the maximum annual HGS cooling water flow volume to estimate entrainment. The ichthyoplankton samples were collected quarterly in 2000 using a combination of sampling gear: surface by Manta net, mid-water by oblique bongo tow, and the epibenthos by wheeled bongo. All samples were collected at night to minimize avoidance (MEC 2002).

At the station nearest to the intake, mid-water larval fish eggs were comprised primarily of croakers (Sciaenidae; 60%) and unidentified fishes (38%). The mid-water larval fish community was comprised primarily of yellowfin goby (29%), bay goby (*Lepidogobius lepidus*; 22%), northern anchovy (12%), Goby Type A (11%), and combtooth blennies (10%). Goby Type A was comprised of three species that cannot be distinguished in their earliest life stages: arrow goby (*Clevelandia ios*), cheekspot goby (*Ilypnus gilberti*), and shadow goby (*Quietula y-cauda*). When compared to results from the 1978-1979 HGS entrainment study (IRC 1981), community composition was very similar. One major exception was the prevalence of yellowfin goby in 2000. Yellowfin goby is native to Asia, and was first discovered in Los Angeles Harbor in 1977 (Haaker 1979).

2.5 Studies on the Physical Environment in the Vicinity of the HGS

Waters within the Harbor Complex are primarily marine, though there are fresh water inputs from regulated discharges, urban runoff, and Dominguez Channel, which enters Los Angeles Harbor approximately three kilometers northeast of the HGS intake. Results of recent water quality studies within Inner Los Angeles Harbor (near the HGS intake structure) indicated water temperatures averaged 61° to 64°F (16° to 18°C), dissolved oxygen averaged 6 to 7 mg/l, pH averaged 7.9, salinity averaged 32.7 to 33.4 parts per thousand (ppt), and light transmission averaged 64 to 68% (MEC 2002). The flushing of Slip 5 (the immediate source water of the HGS intake) is considerably accelerated over retention times within that body of water which would not occur without the cooling water withdrawal (IRC 1981). Water current movement within Slip 5 is predominantly associated with tidal forces.

Intake Zone of Influence

Hydrodynamic studies of the waters at the HGS intake structure were performed during the 1978–1979 316(b) Demonstration (IRC 1981) when the maximum flow at the plant was over four times the current maximum flow. Although the results of these studies are not particularly relevant to the current plant conditions they did show that the highest flows in front of the intake were generally confined to the middle of the water column, that the probability of entrainment was estimated at 50% at a distance of about 1,280 ft (390 m) from the intake structure, and that the probability of recirculation for the water discharged into West Basin was less than one percent even under the increased flows present during the studies.

Current meters were deployed at several locations approximately 1.6 ft (0.5 m) upcurrent from the skimmer wall of the intake opening. During the deployment, the cooling water flow rate was 276,000 gallons per minute (gpm), or maximum flow at the time of the study. Maximum mean velocity at the intake was 2.3 fps (69 cm/s) but was highly localized at a depth of -21 ft (-6.4 m) Mean Sea Level (MSL). Highest velocities were measured approximately one meter from the bottom. Intake velocities can be affected by marine growth on the bar racks, which can reduce the effective cross-sectional area of flow, increasing the average approach velocity. The bar racks were reportedly fouled with encrusting organisms during the measurements. The highest intensity flow was confined to the middle half of the water column at the bulkhead intake, and surface waters showed no sign of turbulence during the study.

Probability of Entrainment Isopleths were developed for the HGS based on dye experiments, current meter data, and meteorological data (IRC 1981). Dye results were normalized to reflect a case where 73% of maximum cooling water volume was being used (equivalent to about three times the current maximum flow at the HGS). The Probability of Entrainment Isopleths were temporally averaged. The 50% Probability of Entrainment Isopleth extended to about 1,280 ft (390 m) from the intake structure. Recirculation of cooling water, which is discharged into West Basin, was <0.15% over a 75-hr period.

IRC (1981) determined "*waters within Los Angeles Harbor found between the seaward entrance to Main Channel and Cerritos Channel, at approximately the Bascule Bridge crossing, comprise the principal source waters for the Harbor Generating Station. Over sixteen days would be required for a once-through flow of 13 m^3/s for the Harbor Generating Station to utilize a 5-meter-thick mid-depth water layer contained within the primary source region described above.*" (The Bascule Bridge is now the Ford Avenue railroad bridge, located just west of the Commodore Heim Lift Bridge, and current maximum flow is approximately 4 m^3/s). They further rationalized that due to different vertical mixing processes within the Inner Harbor and Outer Harbor "*a smaller fraction of the source water would be expected to come from the Cerritos Channel direction than from the direction of the Turning Basin. It appears that within the mentioned geographical confines a rather isolated source water body exists which maintains its distinctive water mass properties at least two weeks.*"

3.0 PROPOSED NEW BIOLOGICAL STUDIES

The proposed impingement mortality and entrainment (IM&E) studies will examine losses at HGS resulting from both impingement of juvenile and adult fish and shellfishes on traveling screens at the intake during normal operations and from entrainment of larval fishes and shellfishes into the cooling water intake system. Proposed sampling methodologies and analysis techniques are designed to collect the data necessary for compliance with the §316(b) Phase II Final Rule and are similar to recent impingement and entrainment studies conducted for the AES Huntington Beach Generating Station (MBC and Tenera 2005), the Duke Energy South Bay Power Plant (Tenera 2004), and the Cabrillo Power I LLC, Encina Power Station (Tenera, in progress). The studies at Huntington Beach were performed as part of the California Energy Commission CEQA process for permitting power plant modernization projects, while the South Bay and Encina projects were for §316(b) compliance.

The new 316(b) regulations require that new studies include "*Documentation of current impingement mortality and entrainment of all life stages of fish, shellfish, and any protected species identified previously and an estimate of impingement mortality and entrainment to be used as the calculation baseline.*" For the purposes of this study we are defining the term '*shellfish*' as commercially and recreationally important species of crustaceans (crabs, lobsters, shrimp, etc.) and mollusks (clams, squid, and octopus) that are currently being harvested on a regular basis from the coastal areas surrounding the HGS. This would not include organisms such as clams, mussels, and other crustaceans and mollusks that may only be harvested occasionally for recreational purposes. We have included this definition in this plan because '*shellfish*' could also be considered as including all species of shelled invertebrates and clarification of the term is not included in the regulations.

Under the new 316(b) regulations the impingement mortality component of the IM&E studies is not required if a facility's through-screen intake velocity is less than or equal to 0.5 ft/s (15 cm/s). The through-screen velocity at the HGS intake currently exceeds this value, so LADWP is proposing to conduct a yearlong impingement monitoring study at the intake. The goal of the proposed impingement study is to characterize the fishes and shellfishes affected by impingement by the cooling water intake structure (CWIS). The §316(b) Final Regulations allow the use of "historical data that are representative of the current operation of your facility and of biological conditions at the site." Therefore, historical impingement data may be used to supplement results from the 316(b) study for the impingement mortality characterization.

The proposed 316(b) entrainment study plan incorporates design elements that reflect the present uncertainties surrounding the use of restoration for compliance with the new rule. The use of restoration in offsetting IM&E losses under the new 316(b) rules is currently being challenged in the courts. If the use of restoration is not allowed as a result of the court decision, only an estimate of entrainment losses would be required to calculate the commercial and recreational values of adult fish losses in a cost benefit analysis of various technology and operational alternatives to comply with required reductions in entrainment mortality. Larval fish and shellfish abundances can vary greatly through the year and therefore biweekly sampling is proposed for characterizing entrainment. If the restoration option is upheld in the court decision, models of the conditional mortality due to entrainment would be used in designing appropriate restoration projects for offsetting entrainment losses. These models are based on proportional comparisons of entrainment and source water abundances and are theoretically insensitive to seasonal or annual changes in the abundance of entrained species. Therefore, source water sampling is being proposed monthly which is consistent with the sampling frequency for recently completed studies in southern California. The frequency of the entrainment sampling and the continuation of source water sampling may change depending on the outcome of the court decision. Similar to impingement, historical entrainment data may be used to supplement results from the 316(b) study for the entrainment characterization.

The proposed impingement mortality and entrainment (IM&E) studies are designed to optimally sample groups of organisms that have historically been the focus of 316(b) assessments and have been used in recent IM&E studies in southern California, including the AES Huntington Beach Generating Station (MBC and Tenera 2005), the Duke Energy South Bay Power Plant (Tenera 2004), and the Cabrillo Power I LLC, Encina Power Station. The life stages of the fishes and shellfishes collected from impingement and entrainment samples are identified in the sections below (Sections 3.1 and 3.2). Consistent with the regulatory requirements, impingement mortality and entrainment estimates for the fishes and shellfishes identified from the samples will be generated based on cooling water volumes representative of operations during the past five years. A group of organisms from the impingement and entrainment studies will be selected for more detailed assessment (Section 4.0) based on their abundances in the samples, ecological roles, and commercial and/or recreational fisheries importance. Based on studies conducted since the 1970's, no threatened or endangered fish or shellfish species have been entrained or impinged at the HGS.

All of the work for the impingement and entrainment studies will be conducted using a detailed QA/QC program. Procedures for field data collection and laboratory processing will be included with the Comprehensive Demonstration Study Report.

3.1 Impingement Study

Impingement sampling has been conducted at the HGS since 2003. The existing NPDES permit for the plant requires impingement sampling semiannually during heat treatments. However, heat treatments are not conducted at the HGS, so samples are collected during periods of normal operations. Fish and invertebrate impingement data from the 2003 and 2004 NPDES annual reporting periods are summarized in Section 2.3. The proposed impingement sampling methods are similar to the NPDES monitoring program, but the sampling frequency is higher and the study is designed to collect additional data on diel variation in impingement and sizes of impinged shellfishes.

3.1.1 Impingement Sampling

The purpose of the proposed 316(b) impingement study will be to characterize the juvenile and adult fishes and shellfishes (e.g., rock crabs, lobsters, and squid) impinged by the HGS CWIS. The sampling program is designed to provide current estimates on the abundance, biomass, taxonomic composition, diel periodicity, and seasonality of organisms impinged at the HGS. In particular, the study will focus on the rates (i.e., number and biomass of organisms per water volume flowing per time into the plant) at which various species of fishes and shellfishes are impinged. The impingement rate is subject to tidal and seasonal influences that vary on several temporal scales (e.g., hourly, daily, and monthly) while the rate of cooling water flow varies with power plant operations and can change at any time.

If the traveling screens are operating in the continuous mode, then sampling will be coordinated with the intake crew so samples can be collected safely. A log containing hourly observations of the operating status (on or off) of the circulating water pumps for the entire study period will be obtained from the power plant operation staff. This will provide a record of the amount of cooling water pumped by the plant, which will then be used to calculate impingement

In accordance with procedures employed in similar studies, impingement sampling will occur over a 24-hour period one day per week. Before each sampling effort, the traveling screens will be rotated and washed clean of all impinged debris and organisms. The sluiceways and collection baskets will also be cleaned before the start of each sampling effort. The operating status of the circulating water pumps will be recorded on an hourly basis during the collection period. Each 24-hour sampling period will be divided into four 6-hour cycles. The traveling screens will remain stationary for a period of 5.5 hours then they will be rotated and washed for 30 minutes. The impinged material from the screens will be rinsed into the collection baskets associated with each set of screens. If during the 24-hour sampling an extreme event occurs resulting in the impingement of a large number of fishes or shellfishes, sampling may continue for one or two additional days to obtain a more representative estimate of the impingement rate for the sampling period. Based on historical impingement data, an extreme impingement event during normal operation impingement sampling would be defined as a sample comprised of greater than 100 fishes and/or 200 shellfishes impinged in a 24-hr normal operation survey. Large numbers of organisms in impingement samples could potentially result from the entrainment of a school of fish (such as anchovies or sardines) that would not necessarily reflect impingement for the sampling period.

All fishes and the following shellfishes will be collected from impingement samples, counted, identified, and measured:

- rock crabs
- shrimp
- octopus
- squid
- California spiny lobster

These same shellfishes have been enumerated in other recent impingement studies in southern California. All other macroinvertebrates will be identified from the samples but not enumerated and measured.

Depending on the number of individuals of a given species present in the sample, one of two specific procedures is used, as described below. Each of these procedures involves the following measurements and observations:

1. The appropriate linear measurement for individual fish and shellfish will be determined and recorded. These measurements will be recorded to the nearest 0.04 inch (1 mm). The following standard linear measurements will be used for the animal groups indicated:
    - Fishes - Total body length for sharks and rays and standard lengths for bony fishes.
    - Crabs - Maximum carapace width.
    - Shrimps & Lobsters - Carapace length, measured from the anterior margin of carapace between the eyes to the posterior margin of the carapace.
    - Octopus - Maximum “tentacle” spread, measured from the tip of one tentacle to the tip of the opposite tentacle.
    - Squid – Dorsal mantle length, measured from the edge of the mantle to the posterior end of the body.
2. The wet body weight of individual fish and shellfish will be determined after shaking loose water from the body. Total weight of all individuals combined will be determined in the same manner. All weights will be recorded to the nearest 0.035 ounce (1 g).
3. The qualitative body condition of individual fish and shellfish will be determined and recorded, using codes for decomposition and physical damage.

4. Other macroinvertebrates will be identified to species and their presence recorded, but will not be counted, weighed or measured. Rare occurrences of other impinged animals, such as dead marine birds, will also be recorded.

5. The amount and type of debris (e.g., *Mytilus* shell fragments, wood fragments, etc.) and any unusual operating conditions in the screen well system will be noted by writing specific comments in the "Notes" section of the data sheet. Information on weather, tide and sea conditions will also be recorded during each collection.

The following specific procedures will be used for processing fishes and shellfishes when the number of individuals per species in the sample or subsample is < 30:

- For each individual of a given species the linear measurement, weight, and body condition codes will be determined and recorded.

The following specific subsampling procedures will be used for fishes and shellfishes when the number of individuals per species is >30:

- The linear measurement, individual weight, and body condition codes for a subsample of 30 individuals will be recorded individually on the data sheet. The individuals selected for measurement will be selected after spreading out all of the individuals in a sorting container, making sure that they are well mixed and not segregated into size groups. Individuals with missing heads or other major body parts will not be measured.

- The linear measurements of up to 200 individuals of each taxon will be recorded.

- The total number and total weight of all the remaining individuals combined will be determined and recorded separately.

3.1.2 Impingement Sampling QA/QC Program

A quality assurance/quality control (QA/QC) program will be implemented to ensure that all of the organisms are removed from the debris and that the correct identification, enumeration, length and weight measurements of the organisms are recorded on the data sheet. Random cycles will be chosen for QA/QC re-sorting to verify that all the collected organisms were removed from the impinged material. Quality control surveys will be done on a quarterly or more frequent basis if necessary during the study. If the count of any of individual taxon made during the QA/QC survey varies by more than 5 percent (or one individual if the total number of individuals is less than 20) from the count recorded by the observer then the next three sampling cycles for that observer will be checked. The survey procedures will be reviewed with all personnel prior to the start of the study and all personnel will be given printed copies of the procedures that will also be included with the final IM&E study report.

3.2 Entrainment Study

As a result of the present uncertainties surrounding the use of restoration for compliance with the new rule, the proposed entrainment study plan incorporates two design elements 1) cooling water intake system sampling and 2) source water sampling. If restoration is not upheld by the court as an alternative to comply with entrainment mortality reduction requirements, then only the number of larval fish and shellfish collected in the entrainment sampling would be used with various demographic modeling techniques to estimate the theoretical loss of adult fish and shellfish. In this case, the commercial and recreational values of adult fish and shellfish losses would be calculated and compared in a cost benefit analysis to the cost of various technology and operational alternatives to comply with required reductions in entrainment mortality. However, if restoration prevails, the source water populations of entrained fish and shellfish larvae will be sampled to estimate the proportional entrainment losses, using a conditional mortality model that could be used to determine appropriate restoration projects for offsetting entrainment.

This study plan also incorporates a sampling frequency strategy that recognizes the basic difference in the statistical uncertainty of the two design elements. Abundances of larval fishes and shellfishes in entrainment vary throughout the year due to changes in composition and the oceanographic environment. The models used to estimate adult equivalents from larval entrainment vary directly with these natural changes in abundance. Therefore, entrainment sampling is proposed to occur biweekly. In contrast, estimates of conditional mortality, using the Empirical Transport Model (*ETM*) or other proportional loss models, are theoretically less sensitive to seasonal or annual changes in the abundance of entrained species, and thus source water sampling can be conducted less frequently on a monthly basis. The monthly sampling frequency is consistent with other recently completed entrainment studies conducted for the AES Huntington Beach Generating Station (MBC and Tenera 2005), the Duke Energy South Bay Power Plant (Tenera 2004), and the Cabrillo Power I LLC, Encina Power Station (Tenera, in progress).

The continuation of the proposed source water sampling and the frequency of the entrainment sampling will depend on the court decision regarding the use of restoration for compliance with the new rule. If restoration is not upheld by the court as an alternative to comply with entrainment mortality reduction requirements, then a decision may be made to discontinue the source water sampling since it would be primarily used in scaling restoration projects. If the use of restoration is upheld, the frequency of entrainment sampling may be reduced so that only the surveys that occur concurrently with source water sampling are continued.

3.2.1 Cooling-Water Intake System Entrainment Sampling

Ocean water for cooling purposes is conveyed to the generating station form the northwest corner of Slip 5 in Inner Los Angeles Harbor. Water flows from a curtain wall intake structure (56 ft wide by 10 ft high, or 17 by 3 m) in the bulkhead of the harbor through two 8-ft (2.4-m) diameter closed conduits approximately 1,100 ft (335 m) to the screen and pump chamber at the generating station. After passing through the condensers, the cooling water is discharged into a two-sided chamber running the length of the generating station. From this chamber, the water is conveyed through two 8-ft (2.4 m) diameter underground conduits approximately 1,600 ft (490 m) in length to a submerged, multi-port discharge structure located in the pier-head in the northeast corner of West Basin of Inner Los Angeles Harbor.

To determine composition and abundance of ichthyoplankton and shellfishes entrained by the generating station, sampling in the immediate proximity of the intake structure is proposed to be conducted every two weeks from January through December 2006 (Station E1, **Figure 3-1**). During the previous 316(b) demonstration, horizontal inflow at the intake structure was measured at all intake depths (-11 ft to –21ft [-3.3 to –6.4 m] MLLW), though velocities were highest in the mid-section of the intake, at about -16 ft (-5 m) (IRC 1981). Therefore, entrainment samples will be collected using an oblique tow through the water column at a station located just offshore from the intake structure. The samples will be collected using an oblique tow that will sample the water column from the surface down to approximately 6 inches (13 cm) off the bottom, and back to the surface (Figure 3-1). Two replicate tows will be taken at the intake with a target sample volume of 4,000 to 5,300 gal (15 to 20 m^3) for each net on the bongo frame. The net will be redeployed if the target volume is not collected during the initial tow. Sampling will be conducted four times per 24-hr period--once every six hours.

The wheeled bongo frame proposed for sampling has 2 ft (60 cm) diameter net rings with plankton nets constructed of 333-*u*m Nitex® nylon mesh, similar to the nets used by the California Cooperative Oceanic Fisheries Investigations (CalCOFI). These nets will use a smaller mesh than the mesh size used in the sampling done for the EPA 316(b) rule-making. This smaller mesh is being proposed to ensure collection of smaller fish larvae that may be extruded through a larger sized mesh. Each net will be fitted with a Dacron sleeve and a plastic cod-end container to retain the organisms. Each net will be equipped with a calibrated General Oceanics flowmeter, allowing the calculation of the amount of water filtered. If the target volume (4,000 to 5,300 gal [15 to 20 m^3] per net) is not met with one oblique tow, subsequent tows will be performed at the station until the target volume is collected. Coordinates of each sampling station will be determined using a differential global positioning system (DGPS). At the end of each tow, nets will be retrieved and the contents of the net gently rinsed into the cod-end with seawater. Contents will be washed down from the outside of the net to avoid the introduction of plankton from the wash-down water. Samples will then be carefully transferred to prelabeled jars with preprinted internal labels. Samples from both of the nets will be preserved in 4 to 10 percent buffered formalin-seawater.

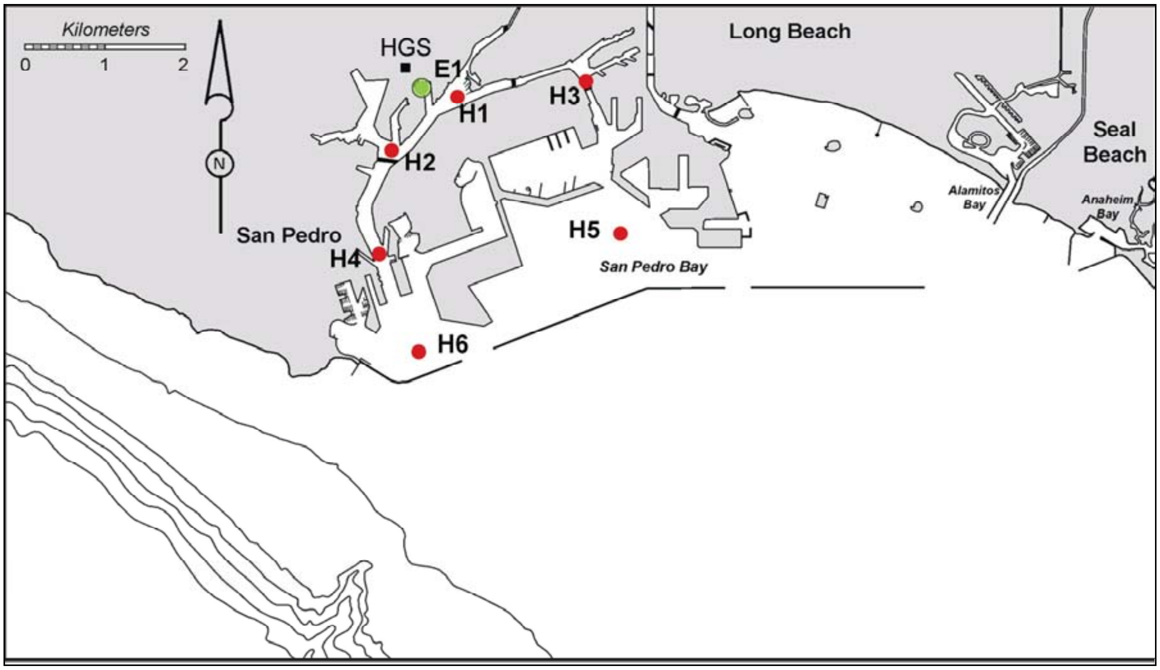

Figure 3-1. Location of HGS entrainment (E1) and source water sampling stations (H1–H6). IRC's source water stations from 1978–1979 were located adjacent to Station E1 (Near-Field) and approximately 1 km southeast from Station H5 (Far-Field).

3.2.2 Source Water Sampling

The source water study area is designed to 1) characterize the larvae of fishes and shellfishes potentially entrained by the HGS cooling water intake, and 2) be representative of the habitats in Los Angeles Harbor source waters.

To determine composition and abundance of ichthyoplankton in the source water, source water sampling will be done monthly on the same day that the entrainment stations are sampled. The scope of the source water sampling design is being proposed because of the need to estimate densities in the appropriate source water area during each survey. IRC (1981) estimated the source waters of the HGS to lie mainly in Los Angeles Harbor. However, it is likely that some organisms are transported from Long Beach Harbor, as well. Therefore, the proposed source water sampling stations are designed to characterize areas in both harbors.

All stations will be sampled using the same wheeled bongo plankton net and oblique tow described for entrainment sampling (Stations H1-H6, **Figure 3-1**) described in Section 3.2.1. Samples will also be treated using the same procedures described for entrainment sampling. Coordinates of each sampling station will be determined using a differential global positioning system (DGPS). During each source water survey, the additional six source water stations (plus the entrainment station) will be sampled four times per 24-hr period--once every six hours. This allows adequate time to conduct all source water and entrainment sampling. During each sample cycle the order that the stations are sampled will be varied to avoid introducing a systematic bias into the data.

3.2.3 Laboratory Processing

Samples will be returned to the laboratory and after approximately 72 hours the samples preserved in 4 to 10 percent buffered formalin-seawater will be transferred to 70 to 80 percent ethanol. All entrainment and source water samples will be processed. Samples will be examined under dissecting microscopes and all fish larvae and the following shellfish larvae will be removed from debris and other zooplankton and placed in labeled vials:

- rock crab megalopal larvae
- market squid hatchlings [larvae]
- California spiny lobster phyllosoma larvae

These same fishes and shellfishes were processed from samples collected in other entrainment studies recently completed in southern California and are also being proposed in the study plans being prepared for the other LADWP generating stations. These three groups of shellfishes were selected because of their respective ecological roles and commercial and/or recreational fisheries importance. All of these organism groups (fishes, rock crabs, squid, and lobster) will be removed from the samples, counted, and identified to the lowest taxonomic level possible. Fish eggs will not be sorted or identified because they cannot be identified to the same taxonomic levels as fish larvae.

The power plant also entrains numerous other planktonic (phyto- and zooplankton) and larval life forms that will be collected during the sampling, especially since the nets proposed for this study use a finer mesh than was used by EPA in their sampling programs designed to collect data to support the 316(b) rule-making. These other organisms will not be processed from the samples. The samples will potentially include the larvae of other crustaceans and mollusks (shellfish) that will not be processed because they are not part of a local commercial and/or recreational shellfish fishery (see Section 3.0 Introduction). The processing also focuses on specific life stages of crabs and lobster that can be easily identified. The identification of the earlier life stages to the species level is problematic and would likely lead to uncertainty in the estimates of their abundance. Including these other life stages in the processing is also unnecessary because the methods used in the assessment (Section 4.0) account for entrainment of these other life stages in the analyses.

Fish eggs will not be processed from the samples because a full assessment of their abundance would require different sampling techniques and they cannot be identified to the same taxonomic levels as fish larvae. In addition, recent studies at other coastal power plants near estuarine or harbor areas similar to the HGS, have shown that entrainment is largely dominated by fishes that do not have an entrainable planktonic egg stage. Even though egg life stages will not be quantified from the entrainment and source water samples, entrainment effects on fishes with planktonic egg stages will be accounted for in the assessment models (Section 4.0).

Normally the data from the two nets will be combined for analysis, but if the quantity of material in the two samples is very large only one of the two samples will be processed and analyzed. The samples from the two nets are normally preserved in separate 400 ml jars. If the quantity of material in a jar exceeds 200 ml then the sample is split into multiple jars to ensure that the material is properly preserved. When this quantity of material is collected, only the material from one of the nets would be processed depending upon the nature of the material. In some cases ctenophores, salps, and other larger planktonic organisms may result in samples with large volumes of material, but these can be separated from other plankton and may not be split depending upon the final volume of the material.

A maximum of 200 representative fish larvae from each taxa analyzed in the assessment (see Section 4.0) will be measured using a dissecting microscope and image analysis system. Larvae will be measured to the nearest 0.02 inch (0.5 mm).

3.2.4 Entrainment Sampling QA/QC Program

A QA/QC program will be implemented for the field and laboratory components of the study. Quality control surveys will be done on a quarterly or more frequent basis to ensure that the field sampling is properly conducted. The field survey procedures will be reviewed with all personnel prior to the start of the study and all personnel will be given printed copies of the procedures that will be included with the final IM&E study report.

A more detailed QA/QC program will be applied to all laboratory processing. The first ten samples sorted by an individual will be resorted by a designated QC sorter. A sorter is allowed to miss one organism when the total number of organisms in the sample is less than 20. For samples with 20 or greater organisms the sorter must maintain a sorting accuracy of 90 percent. After a sorter has ten consecutive samples with greater than 90 percent accuracy, the sorter will have one of their next ten samples randomly selected for a QA/QC check. If the sorter fails to achieve an accuracy level of 90 percent their next ten samples will be resorted by the QC sorter until they meet the required level of accuracy. If the sorter maintains the required level of accuracy one of their next ten samples will be resorted by QC personnel.

A similar QA/QC program will be conducted for the taxonomists identifying the samples. The first ten samples of fish or shellfish identified by an individual taxonomist will be completely re-identified by a designated QC taxonomist. A total of at least 50 individual fish larvae from at least five taxa must be present in these first ten samples; if not, additional samples will be reidentified until this criterion is met. Taxonomists are required to maintain a 95 percent identification accuracy level in these first ten samples. After the taxonomist has identified ten consecutive samples with greater than 95 percent accuracy, they will have one of their next ten samples checked by a QC taxonomist. If the taxonomist maintains an accuracy level of 95 percent then they will continue to have one of each ten samples checked by a QC taxonomist. If they fall below this level then ten consecutive samples they have identified will be checked for accuracy. Samples will be re-identified until ten consecutive samples meet the 95 percent criterion. Identifications will be cross-checked against taxonomic voucher collections maintained by MBC and Tenera Environmental.

Field and laboratory data will be recorded on preprinted data sheets formatted for entry into a computer database for analysis and archiving. On a monthly basis these data will be transmitted to Tenera Environmental for entry into the project database and eventual analysis. Printed spreadsheets will be checked for accuracy against original field and laboratory data sheets.

4.0 ANALYTICAL METHODS

Power plant intake effects occur due to impingement of larger organisms onto the intake screens and entrainment of organisms into the CWIS that are smaller than the screen mesh on the intake screens. Consistent with the Phase II regulations, we assume for purposes of the entrainment characterization that all entrainable organisms do not survive. Considerable effort among regulatory agencies and the scientific community has been expended on the evaluation of power plant intake effects over the past three decades. The variety of approaches developed reflects the many differences in power plant locations and resource settings. MacCall et al. (1983), in their review of the various approaches, divided them into those that offer a judgment on the presence or absence of impact and those that describe the sensitivity of populations to varying operational conditions. These efforts have helped to establish the context for the modeling approaches that may be used to estimate impingement and entrainment effects at the HGS. Impact assessment approaches that will be considered in the final evaluation in the Comprehensive Demonstration Study (CDS) include:

Methods used in estimating the calculation baseline:

- Annual estimates of total individuals impinged and entrained
- Annual estimates of total biomass impinged

Methods for evaluating CWIS effects and cost benefit analysis:

- Adult-equivalent loss (*AEL*) (Horst 1975; Goodyear 1978)
- Fecundity hindcasting (*FH*) proposed by Alec MacCall, NOAA/NMFS, which is related to the adult-equivalent loss approach
- Production Foregone (*PF*) (Rago 1984)

Methods for evaluating population-level effects and estimating appropriate restoration efforts:

- Empirical transport model (*ETM*), which is similar to the approach described by MacCall et al. (1983), and used by Parker and DeMartini (1989).

The Rule provides flexibility in terms of demonstrating compliance and therefore the need for and nature of additional analysis that may be conducted will be based on the compliance alternative and options selected by LADWP. Consistent with the regulatory requirements, impingement mortality and entrainment estimates for all fish and shellfish species for each life stage will be generated based on cooling water volumes representative of operations during the past five years.

The assessment approach used in the final report that will be submitted as part of the CDS for the HGS will also depend upon the facility's baseline calculations and its method(s) of compliance with the new §316(b) rule's performance standards for reductions in impingement mortality and entrainment. Compliance at HGS may be achieved singly, or in combination, by technological or operational changes to the CWIS (Technology Installation and Operation Plan, or TIOP), restoration methods, and site-specific Best Technology Available (BTA) standards. In order to demonstrate compliance through the TIOP it is only necessary to analyze entrainment data to determine baseline entrainment levels and assess those levels against the improvements achieved through the implementation of the TIOP. In the case where restoration is limited to only commercially or recreationally important species, entrainment data may be adequate to assess the levels of restoration necessary to offset entrainment and impingement losses if there are valid stock assessments for the species. In assessing compliance with the performance standard in whole or in part through restoration of habitat to include forage species in addition to the losses of recreational and commercial species it is necessary to assess the entrainment and impingement losses from the source water using a combination of assessment methods to determine the commensurate level of restoration. The same source water and entrainment data, and assessment methods, would also be used to determine a site-specific BTA standard based on cost-benefit analysis of both use and forage entrainment losses. Source water data would not be necessary for cost-benefit analysis based simply on the value of commercial and recreational species losses.

4.1 Selection of Taxa for Assessment

The proposed impingement mortality and entrainment (IM&E) studies have been designed to optimally sample fishes and shellfishes that have historically been the focus of 316(b) assessments and have been used in recent IM&E studies in southern California, including the AES Huntington Beach Generating Station (MBC and Tenera 2005), the Duke Energy South Bay Power Plant (Tenera 2004), and the Cabrillo Power I LLC, Encina Power Station. Consistent with the regulatory requirements, impingement mortality and entrainment estimates for all fish and shellfish species will be generated based on cooling water volumes representative of operations during the past five years.

The specific taxa (species or group of species) that will be analyzed in the assessment will be limited to the taxa that are sufficiently abundant to provide reasonable assessment of impacts. For the purposes of this study plan, the taxa analyzed in the assessment will be limited to the most abundant taxa that together comprise 90-95 percent of all larvae entrained and/or juveniles and adults impinged by the generating station. The most abundant taxa are used in the assessment because they provide the most robust and reliable estimates for the purpose of scaling restoration projects or quantification of the ecological benefits under the cost-benefit test. Since the most abundant organisms may not necessarily be the organisms that experience the greatest effects on the population level, the data will be examined carefully before the final selection of taxa to determine if additional taxa should be included in the assessment. This may include commercially or recreationally important taxa, and taxa with limited habitats. In addition, any threatened or endangered fish or shellfish species would be included in the assessment, but since the 1970's no listed species have been entrained or impinged at the HGS.

4.1.1 Impingement

The list of organisms that will be identified, counted, and measured from impingement samples are provided in Section 3.1.1. This same group of organisms has been used in other recent impingement studies in southern California. Estimates of annual impingement will be calculated for all of these organisms. As noted in the Introduction to this section these estimates will be used in estimating the calculation baseline. A more detailed analysis for the purposes of evaluating CWIS effects, cost benefit analyses, population-level effects, and scaling potential restoration efforts will only be conducted on the most abundant taxa in the samples and taxa that may be part of a commercial and/or recreational fishery.

4.1.2 Entrainment

The list of organisms that will be identified, counted, and measured from entrainment samples are provided in Section 3.2.3. This same group of organisms has been used in other recent entrainment studies in southern California. Estimates of annual entrainment will be calculated for all of these organisms and will be used in estimating the calculation baseline. A more detailed analysis for the purposes of evaluating CWIS effects, cost benefit analyses, population-level effects, and scaling potential restoration efforts will only be conducted on the most abundant taxa in the samples and taxa that may be part of a commercial and/or recreational fishery.

The egg stages of fishes and the life stages of the shellfishes that are more difficult to identify, and which are not included in the sample processing, will be included in the entrainment assessment. This will be done by calculating the survival to the sampled life stage in the demographic models and the larval durations of fish egg and earlier life stages of shellfishes in the *ETM* calculations. This approach assumes that the proportional mortality estimate used in the modeling of larval entrainment also applies to these other stages. The *ETM* model also provides a means of examining the potential effects on other organisms not included in the processing or assessment by assuming that they are uniformly distributed in the source water area and are withdrawn at a rate equal to the volumetric ratio of the cooling water flow to the source water volume. The effect of entrainment on these organisms also depends on their larval duration or the time period they are exposed to entrainment.

4.2 Impingement Assessment

The impingement mortality study will estimate the rates (i.e., number and biomass of organisms per water volume flowing per time into the plant) at which various species of fishes and shellfishes are impinged. Annual impingement estimates will be calculated by extrapolating the impingement rates measured during normal operations over the weekly survey periods. The impingement mortality estimates for each period will be added to provide annual estimates of impingement for each species.

The estimates of total annual impingement can be combined with estimates of equivalent adults from entrainment to provide total impact assessment for a taxon. The demographic models used to calculate these estimates (described in Section 4.3) are limited to taxa that have sufficient life history information available.

4.3 Entrainment Assessment

Estimates of daily and annual larval entrainment at the HGS will be calculated from data collected at the entrainment station. Estimates of entrainment loss, in conjunction with available demographic data collected from the fisheries literature, will permit modeling of adult equivalent loss (*AEL*) and fecundity hindcasting (*FH*). Data from sampling of the potential source populations of larvae will be used to calculate estimates of proportional entrainment (*PE*) that are used to estimate the probability of mortality due to entrainment using the Empirical Transport Model (*ETM*). In the HGS entrainment and impingement studies we will use each approach (i.e., *AEL*, *FH*, and *ETM*) as appropriate to assess power plant losses.

The various modeling approaches that will be considered for the assessment at HGS can be placed under the umbrella of two general approaches: demographic models that rely on species life history information such as the equivalent adult model (*EAM*; Horst 1975; Goodyear 1978) which includes adult equivalent loss (*AEL*) and fecundity-hindcasting (*FH*); and models that estimate the conditional mortality on a population resulting from power plant CWIS operations such as the empirical transport model (*ETM*; Boreman et al. 1978).

The application of several models to estimate power plant effects is not unique (Murdoch et al. 1989; PSE&G 1993; Tenera 2000a; Tenera 2000b). Equivalent adult loss modeling (*AEL* and *FH*) is an accepted method that may be used at HGS and has been applied in other 316(b) demonstrations (PSE&G 1993; Tenera 2000a; Tenera 2000b). The advantage of these demographic modeling approaches, which includes production foregone (*PF*), is that they translate losses into adult fishes that are familiar units to resource managers, but they require life history data that are not available for many species. These estimates can be also combined with estimated losses to adult and juvenile organisms due to impingement to provide combined estimates of cooling water system effects.

The empirical transport model (*ETM*) has been proposed by the U.S. Fish and Wildlife Service to estimate mortality rates resulting from cooling water withdrawals at power plants

(Boreman et al. 1978, 1981). Variations of this model have been discussed in MacCall et al. (1983) and used to assess impacts at the San Onofre Nuclear Generating Station (Parker and DeMartini 1989). The *ETM* has also been used to assess impacts at the Diablo Canyon Power Plant and Huntington Beach Generating Station in California (Tenera 2000a, MBC and Tenera 2005), and at the Salem Nuclear Generating Station in Delaware Bay, New Jersey (PSE&G 1993), as well as other power stations along the East Coast. Empirical transport modeling permits the estimation of conditional mortality due to entrainment while accounting for the spatial and temporal variability in distribution and vulnerability of each life stage to power plant withdrawals. The *ETM* provides an estimate of power plant effects that may be less subject to inter-annual variation than demographic model estimates. It also provides an estimate of population-level effects not provided by demographic approaches.

The results of the *ETM* modeling provide the best and most direct estimates of the effects of entrainment on source water populations since the effects are estimated on the larval populations being affected. The *ETM* estimates can be used to appropriately scale restoration projects that might be used to help offset entrainment losses. The estimates can also be used to provide a context for demographic model estimates that are based solely on entrainment estimates. For example, especially in estuarine systems, entrainment estimates may show large losses of fish larvae that are sometimes difficult to interpret and put in context without estimates of the adult or larval source water populations. The *ETM* provides a context for these estimates that can account for some of the uncertainty associated with determining an appropriate level of entrainment reduction.

4.3.1 Demographic Approaches

Adult equivalent loss models evolved from impact assessments that compared power plant losses to commercial fisheries harvests and/or estimates of the abundance of adults. In the case of adult fishes impinged by intake screens, the comparison was relatively straightforward. To compare the numbers of impinged sub-adults and juveniles and entrained larval fishes to adults, it was necessary to convert all these losses to adult equivalents. Horst (1975) provided an early example of the equivalent adult model (*EAM*) to convert numbers of entrained early life stages of fishes to their hypothetical adult equivalency. Goodyear (1978) extended the method to include the extrapolation of impinged juvenile losses to equivalent adults.

Demographic approaches, exemplified by the *EAM*, produce an absolute measure of loss beginning with simple numerical inventories of entrained or impinged individuals and increasing in complexity when the inventory results are extrapolated to estimate numbers of adult fishes or biomass. We propose the potential use of two different but related demographic approaches in assessing entrainment effects at the HGS: *AEL*, which expresses effects as absolute losses of numbers of adults, and *FH*, which estimates the number of adult females whose reproductive output has been effectively eliminated by entrainment of larvae. Both estimates require an estimate of the age at entrainment. These estimates will be obtained by measuring a random sample of up to 200 larvae of each of the taxa being analyzed from the entrainment samples and using published larval growth rates to estimate the age at entrainment. The age at entrainment will be calculated by dividing the difference between the size at hatching and the average size of the larvae from entrainment by a growth rate obtained from the literature.

Age-specific survival and fecundity rates are required for *AEL* and *FH*. Adult-equivalent loss estimates require survivorship estimates from the age at entrainment to adult recruitment; *FH* requires egg and larval survivorship until entrainment. Furthermore, to make estimation practical, the affected population is assumed to be stable and stationary, and age-specific survival and fecundity rates are assumed to be constant over time. Each of these approaches provides estimates of adult fish loss, which will still need to be placed into context regarding standing stocks of adult fishes.

Species-specific survivorship information (e.g., age-specific mortality) from egg or larvae to adulthood is limited for many of the taxa likely to be considered in this assessment. Thus, in many cases, these rates must be inferred from the literature along with their measures of uncertainty. Uncertainty surrounding published demographic parameters is seldom known and rarely reported, but the likelihood that it is very large should be considered when interpreting results from the demographic approaches for estimating entrainment effects. For some well-studied species (e.g., northern anchovy), portions of early mortality schedules and fecundity have been reported (e.g., Parker 1980; Zweifel and Smith 1981; Hewitt 1982; Hewitt and Methot 1982; Hewitt and Brewer 1983; Lo 1983, 1985, and 1986; McGurk 1986). Because the accuracy of the estimated entrainment effects from *AEL* and *FH* will depend on the accuracy of age-specific mortality and fecundity estimates, lack of demographic information may limit the utility of these approaches.

The precursor to the *AEL* and *FH* calculations is an estimate of total annual larval entrainment. Estimates of larval entrainment at the HGS will be based on the biweekly sampling where E_T is the estimate of total entrainment and E_i is the biweekly entrainment estimate. Estimates of total entrainment are based on two-stage sampling designs, with days within each sampling period and cycles within days. The within-day sampling is based on a stratified random sampling scheme with four temporal cycles and two replicates per cycle.

<u>Adult Equivalent Loss *(AEL*</u>)

The *AEL* approach uses estimates of the abundance of the entrained or impinged organisms to project the loss of equivalent numbers of adults based on mortality schedules and age-at-recruitment. The primary advantage of this approach is that it translates power plant-induced early life-stage mortality into numbers of adult fishes that are familiar units to resource managers. Adult equivalent loss does not require source water estimates of larval abundance in assessing effects. This latter advantage may be offset by the need to gather age-specific mortality rates to predict adult losses and the need for information on the adult population of interest for estimating population-level effects (i.e., fractional losses).

Starting with the number of age class j larvae entrained, $P_M = 1 - \sum_{i=1}^{N} f_i \left(1 - PE_i\right)^q$, it is conceptually easy to convert these numbers to an equivalent number of adults lost (AEL) at some specified age class from the formula:

$$AEL = \sum_{j=1}^{n} E_j S_j \tag{1}$$

where

n = number of age classes;

E_j = estimated number of larvae lost in age class j; and

S_j = survival probability for the j th class to adulthood (Goodyear 1978).

Age-specific survival rates from larval stage to recruitment into the fishery must be included in this assessment method. For some commercial species, natural survival rates are known after the fish recruit into the commercial fishery. For the earlier years of development, this information is not well known and may not exist for non-commercial species.

An alternative expression of adult-equivalent loss would be to standardize AEL by the size of the adult population of interest to estimate the relative magnitude of the equivalent adult loss such that,

$$RAEL = \frac{AEL}{P} \tag{2}$$

where P = estimated size of the adult population of interest. Information on adult source populations will be limited for many species and thereby limit the utility of Equation (2), although the same approach will be used to place the estimated losses into context for taxa with published commercial or recreational fishery catch data.

<u>Fecundity Hindcasting (*FH*)</u>

The *FH* approach compares larval entrainment losses with adult fecundity to estimate the amount of adult female reproductive output eliminated by entrainment, hindcasting the numbers of adult females effectively removed from the reproductively active population. The accuracy of *FH* estimates, as with those of the *AEL* above, is dependent upon accurate estimates of age-specific mortality from the egg and early larval stages to entrainment and accurate estimates of the total lifetime female fecundity. If it can be assumed that the adult population has been stable at some current level of exploitation and that the male:female ratio is constant and 50:50, then fecundity and mortality are integrated into an estimate of loss by converting entrained larvae back into females (i.e., hindcasting).

A potential advantage of *FH* is that survivorship need only be estimated for a relatively short period of the larval stage (i.e., egg to larval entrainment). The method requires age-specific mortality rates and fecundities to estimate entrainment effects and some knowledge of the abundance of adults to assess the fractional losses these effects represent. This method assumes that the loss of a single female's reproductive potential is equivalent to the loss of an adult fish.

In the *FH* approach, the total of larval entrainment for a species E_T will be projected backward to estimate the number of breeding females required to provide the numbers of larvae entrained at the HGS. The estimated number of breeding females FH whose fecundity is equal to the total loss of entrained larvae would be calculated as follows:

$$FH = \frac{E_T}{TLF \cdot \prod_{j=1}^{n} S_j} \tag{3}$$

where

E_T = total entrainment estimate;

S_j = survival rate from eggs to entrained larvae of the j th stage ;

TLF = average total lifetime fecundity for females, equivalent to the average number of eggs spawned per female over their reproductive years.

The two key input parameters in Equation (3) are total lifetime fecundity TLF and very early survival rates S_j from spawning to entrainment. Descriptions of these parameters may be limited for many species and are a possible limitation of the method.

Similar to *AEL*, an alternative interpretation of *FH* is possible by expressing the estimate in terms of the relative size of the adult fish stock in the source populations where

$$RFH = \frac{FH}{P} \tag{4}$$

where P = estimated size of the adult population of interest. Information on adult source populations will be limited for many species and thereby limit the utility of Equation (4), although the same approach can be used to place the estimated losses into context for taxa with published commercial or recreational fishery catch data where *RFH* is the proportion of the breeding females whose fecundity was lost due to entrainment by the HGS.

4.3.2 Empirical Transport Model (*ETM*)

The *ETM* calculations provide an estimate of the probability of mortality due to power plant entrainment. The calculations require not only the abundance of larvae entrained but also the abundance of the larval populations at risk of entrainment. Sampling at the cooling water intake is used to estimate the total number of larvae entrainment for a given time period, while sampling in the nearshore waters around the HGS intake is used to estimate the source population for the same period.

On any one sampling day, the conditional entrainment mortality can be expressed as

$$PE_i = \frac{E_i}{R_i} \tag{5}$$

where

E_i = total numbers of larvae entrained during the *i* th survey; and

R_i = numbers of larvae at risk of entrainment, i.e., abundance of larvae in source water.

The values used in calculating *PE* are population estimates based on the respective densities and volumes of the cooling water system flow and source water areas. The abundance of larvae at risk in the source water during the *i* th survey can be directly expressed as

$$R_i = V_i \overline{\rho}_{S_i} \tag{6}$$

where V_i denotes the static volume of the source water (S_i), and $\overline{\rho}_{S_i}$ denotes an estimate of the average density in the source water.

Regardless of whether the species has a single spawning period per year or multiple overlapping spawnings the estimate of total larval entrainment mortality can be expressed by

$$P_M = 1 - \sum_{i=1}^{n} f_i (1 - PE_i)^q \tag{7}$$

where

q = number of days that the eggs and larvae are susceptible to entrainment, and

f_i = estimated annual fraction of total larvae hatched during the i th survey period.

To establish independent survey estimates, it is assumed that during each survey a new and distinct cohort of larvae is subject to entrainment. Each of the monthly surveys is weighted by f_i and estimated as the proportion of the total source population present during the i th survey period.

As shown in Equations 5 and 6 the estimates of *PE* are based on population estimates of specific volumes of water. While a reasonably accurate estimate of the volume of the cooling water intake flow can be obtained, estimating the volume of the source water is more difficult and will vary depending upon oceanographic conditions and taxon. Source water volumes may be estimated separately for each taxon during each survey. Current measurements from the harbor complex will be analyzed to determine if the source waters for the HGS are a fixed volume or if the source water volume varies with time. The maximum age at entrainment will be calculated using the lengths of a random sample of up to 200 larvae from the entrainment samples for each taxon being analyzed. The maximum age at entrainment will be calculated by dividing the difference between the upper 95th percentile value of the lengths measured from the samples minus the hatch length by the growth rate.

5.0 REPORTING

Tenera Environmental and MBC Applied Environmental Sciences will produce a final Impingement Mortality and Entrainment Characterization report on the findings from the entrainment and impingement studies. This report will include results from field surveys will be presented, and loss estimates derived from one or more of the assessment methods will be presented for each of the analyzed taxa. The report will be submitted as part of the Comprehensive Demonstration Study for the HGS. Depending on the final compliance alternative(s) selected additional analysis as described in Section 4 will be provided in support of the necessary CDS documents (i.e. Restoration Plan, Benefit Valuation Study, etc).

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