Evaluation of Using Existing Alamitos Generating Station Intake System to Maintain Water Quality in Alamitos Bay

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1.0 Introduction

This report provides information on the potential to use the existing cooling water intake system at the AES Southland Alamitos Generating Station (AGS) to maintain flow through Alamitos Bay in Long Beach, California. In addition, this report addresses the potential for water quality in the Bay to degrade when the Los Angeles Department of Water and Power (LADWP) Haynes Generating Station (HGS) and AGS stop withdrawing water from the Bay and Cerritos Channel for power plant cooling. As a result of the adoption of the Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling (Policy) by the State Water Resource Control Board (SWRCB) on May 4, 2010 (Resolution No. 2010-0020), all of the plants using ocean water for cooling were required to come into compliance with the new Policy. One approach to compliance in the Policy was through replacement of the existing once-through cooling (OTC) system with a closed cycle system that would reduce the use of ocean water by a minimum of 93% (Track 1). Plants could also implement technologies to reduce the effects of the cooling water intake system (CWIS) on marine organisms from impingement of larger individuals on the intake screens or entrainment of smaller organisms (plankton) through the screens and into the system by a minimum of 90% of the level achieved with a closed system (Track 2). The Policy also established compliance dates for all of the power plant units in the state. The compliance date in the Policy for the units at AGS was December 31, 2020; the date for the HGS was set at December 31, 2019. While AES has agreed to comply with the Policy by retiring the OTC systems at the AGS on or before the required data of compliance, LADWP negotiated an agreement with the SWRCB extending the compliance schedule for HGS until December 31, 2029.

As a result of the adoption of the State Policy on OTC, both the AGS and HGS will stop withdrawing water from Alamitos Bay over the next 5–15 years. Currently the two plants withdraw water from the Bay at two locations (**Figure 1**). Oceanographic studies associated with the original 316(b) study of the HGS intake system showed that the flows from the two plants reduce the residence time of the water in Alamitos Bay to approximately one day (IRC 1981). One of the benefits of this increased flow through the bay is improved water quality. The IRC studies estimated that the cooling water flows annually supply the bay with 45,000 kg (50 tons) of additional oxygen relative to the supply provided by natural exchange processes (i.e., tidal exchange). A recently completed study by Moffatt & Nichol (2007) quantified circulation throughout Alamitos Bay. The study was prompted by continuously poor water quality (high bacteria counts) at Mother's Beach, a popular swimming beach, and other locations within Alamitos Bay. The study concluded that the cooling water flow rate at the AGS has the most significant effect on circulation within Alamitos Bay by removing some of the water from the upstream areas of the Bay (closest to Cerritos Channel) that have the lowest turnover due to tidal exchange. The low turnover of the waters in these areas of the Bay appear to be a major factor contributing to the high bacteria levels at Mother's Beach.

This report provides information on the AGS cooling water intake system (CWIS) and the potential for retrofitting the intake to improve water quality by increasing circulation in the upstream areas of the Bay. This report is organized into four sections in addition to this

Introduction. Section 2.0 provides background information on the AGS cooling system, and the physical and biological characteristics of Alamitos Bay and the San Gabriel River. Section 3.0 provides information on the potential effects on marine resources in the Bay and San Gabriel River using biological data collected from the NPDES monitoring for the two power plants and the 316(b) study on entrainment at the AGS, peer-reviewed literature, and agency-supplied studies. Section 4.0 provides information on the feasibility of replacing the existing circulating water pumps at the AGS with “fish friendly” pumps that will minimize the effects of entrainment. The effects of these pumps will only focus on the effects of entrainment since it is assumed that the through screen velocities of the modified system will be low enough to eliminate any concerns regarding impingement. Finally, Section 5.0 will provide our conclusions from the study.

Figure 1. Image showing locations of Alamitos and Haynes Generating Stations (GS) in Alamitos Bay and locations of Cerritos Channel and San Gabriel River.

2.0 Power Plant and Environmental Setting

This section provides background information on the AGS cooling water intake system, and the physical and biological characteristics of Alamitos Bay and the San Gabriel River. Much of the information in this section is summarized from the assessment of the AGS intake completed in 2007 (MBC and Tenera 2007).

2.1 AGS Cooling Water Intake System

The AGS is located in the city of Long Beach in Los Angeles County, CA, in the inner reaches of Alamitos Bay along the shoreline of the lower San Gabriel River flood control channel (**Figure 1**). The AGS has six natural gas fueled generating units (Units 1–6) that have a combined output of 1,950 MW. There are separate CWIS for Units 1&2, Units 3&4, and Units 5&6; however, the intake canal for Units 5&6 is separate from the common intake canal for Units 1&2 and Units 3&4 (**Figure 2**). All three intakes withdraw water from the Los Cerritos Channel and Alamitos Bay and the water is discharged into the San Gabriel River. The three intakes combined can withdraw a maximum of 4,818,678 m^3 per day (1,272.96 mgd) of cooling water from the Los Cerritos Channel, although the plant has rarely operated at full capacity for several years.

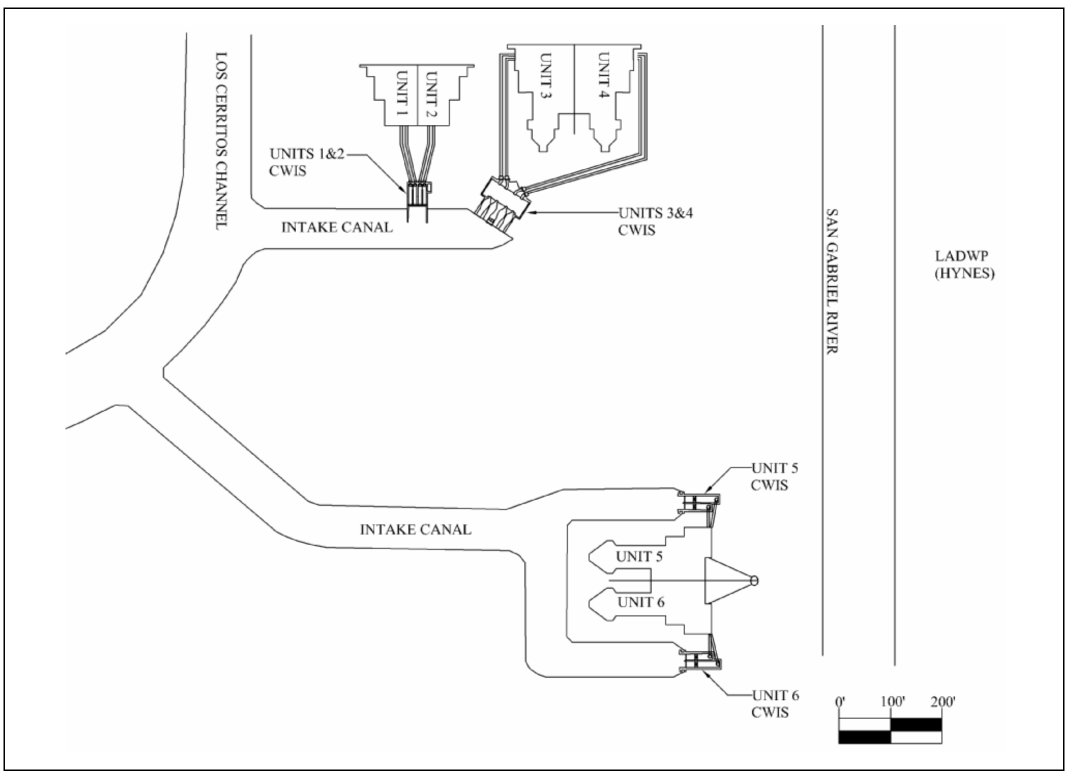

Figure 2. Location of the AGS intake structures (metric measurement units not included).

The designs of the three intake structures are all different. There are bar racks installed across the onshore intake structures to prevent large debris from entering the intake bays at Units 1&2 and Units 5&6, which are not installed at Units 3&4 (**Figure 3**). All three intakes have traveling water screens, which are installed behind the bar racks at Units 1&2 (**Figure 3a**) and Units 5&6 (**Figure 3c**), to strain out smaller debris. Circulating water pumps located downstream of the traveling water screens provide flow to the condensers. The traveling water screens installed at Units 1&2 and Units 3&4 are inclined screens (**Figure 3b**), while conventional vertical traveling screens are installed at Units 5&6.

The traveling water screens for Units 1&2 and Units 3&4 were designed by Farm Pump and Irrigation (F.P.I). The screens at Units 1&2 are angled at 33.3° from vertical (**Figure 3a**), while the screens at Units 3&4 are angled at 34° from vertical (**Figure 3b**). The screen material for both intakes is a wire belt material that uses a continuous mesh loop that allows for a slimmer profile than standard traveling water screens while providing a greater screening area. The screen mesh is 12 gauge wire with 24 wire loops per foot wide and 20 cross rods per foot length (24-20-12), resulting in a 68% open area through the mesh with a 12.7 mm (0.5 in) long and 19.1 mm (0.75 in) wide (maximum) openings. The Units 1&2 screens are 2.47 m (8.1 ft) wide, while the screens at Units 3&4 are 2.4 m (8 ft) wide. There are two screens per unit at each of the intakes. The screens can be operated either manually or in automatic mode. In automatic mode, the screens are rotated at 2.3 m/min (7.6 ft/min) when there is a debris on the screens that results in a pressure differential of 20.3 cm (8 in.) across the screens. When the pressure differential reaches 15.2 cm (6 in.), the screens stop. Screens are cleaned with a backwash system that uses 85–90 pounds per square inch gauge (psig) of water. Fish and debris removed from the screens are deposited in a dumpster for disposal.

The traveling screens for Units 5&6 are vertical, traveling water screens with 0.6 m (2 ft) high and 3.1 m (10 ft) wide screen panels. There are two screens in front of each unit. The screen mesh is constructed out of 15.9-mm (5/8-in.) woven wire mesh. The screens rotate automatically when there is a 22.9 cm (9 in.) differential pressure on the screens, or they can also be rotated manually. Fish and debris removed from the screens are deposited in a dumpster for disposal.

There are two screen bays and circulating water pumps for each of the six units at the AGS. The pumping capacities of the three intakes are shown in **Table 1**. The total daily flow for the AGS with all the pumps operating at full capacity is almost 1.3 billion gallons.

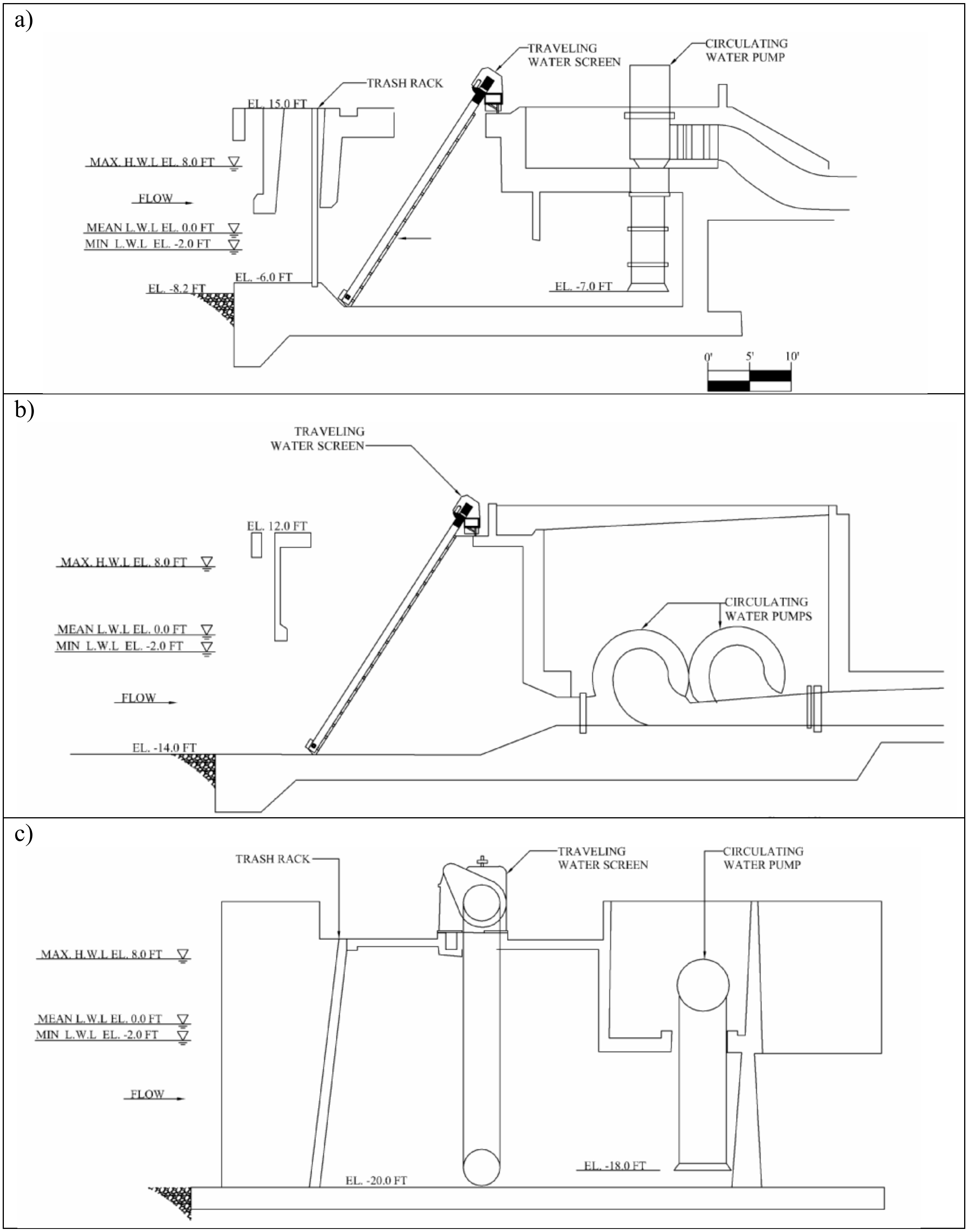

Figure 3. Intake structures for a) Units 1&2, b) Units 3&4, and c) Units 5&6.

Table 1. Pump capacities for each of the intakes at the AGS.

Intake	Intake Bays (# of screens)	Circulating Water Pumps	Pump Volume (m^3 [gal] / minute)	Total Intake Flow Rate (m^3 [gal] per minute)	Total Intake Capacity (m^3 [gal] per day)
Units 1&2	4	4	136.3 (36,000)	545.1 (144,000)	784,944 (207,360,000)
Units 3&4	4	4	257.4 (68,000)	1029.6 (272,000)	1,482,624 (391,680,000)
Units 5&6	4	4	442.9 (117,000)	1771.4 (468,000)	2,550,816 (673,920,000)
Total				3346.1 (884,000)	4,818,384 (1,272,960,000)

2.2 Physical Setting

The following section describes the physical and biological environments in Alamitos Bay and the lower San Gabriel River.

2.2.1 Physical Description

2.2.1.1 Alamitos Bay

Alamitos Bay is a man-made, small-vessel harbor that was constructed at the mouth of the San Gabriel River (**Figure 1**). It was once an estuary with tidal marshes and mud flats. It is relatively shallow with water depths throughout most of the Bay between 3.6 and 5.5 m (12 and 18 ft). The bay is exposed to semidiurnal tides with a mean range of 1.1 m (3.6 ft). The Bay has a surface area of approximately 1.2 km^2 (285 acres) (CSWRCB et al. 1998). Prominent features within Alamitos Bay include Naples Island, which is a marshland constructed of material dredged from the bay in 1908 and 1909 (Reish and Winter 1954), and the Marine Stadium originally consisted of tidal flats and marshlands, and was dredged for rowing events for the 1932 U.S. Olympics (Reish and Winter 1954). Marinas within Alamitos Bay provide approximately 4,000 slips for boats.

Los Cerritos Channel is a flood control channel that connects with Alamitos Bay through the Marine Stadium. The tidal prism extends from Alamitos Bay to Anaheim Road. The channel is listed on the U.S. EPA 303(d) list of impaired water bodies by the LARWQCB due to elevated ammonia, phthalate, chlordane, several metals, coliform bacteria, and trash, all originating as non-point source pollution or from unknown sources (LARWQCB 2007). The Los Cerritos Wetlands are located at the point where Los Cerritos Channel joins Alamitos Bay. The area of the wetlands is approximately 0.5 km^2 (130 acres), with an additional 3.2 km^2 (800 acres) of degraded habitat proposed for restoration. Historically the wetlands consisted of about 9.7 km^2 (2,400 acres) and included most of what is now Alamitos Bay.

The volume of Alamitos Bay and Cerritos Channel was estimated using data from Moffatt & Nichol (2007) and from NOAA electronic navigation charts (ENC) data for the entrainment evaluation in MBC and Tenera (2007). Some editing of these data was done to more closely match the depth and elevations derived from NOAA navigation data that included coverage for the entire harbor and associated NOAA charts. MLLW depths were adjusted to MSL (shallower by 0.86 m (2.8 ft) per the tide gauge at Station 9410660 Los Angeles, CA). The corrected depth data were merged and exported to a new depth point GIS layer relative to MSL. A 20 m (65.6 ft) surface grid representing the bathymetry relative to MSL was constructed from this new set of combined points resulting in contours at 1 m intervals. The resulting bathymetry surface grids were then converted into a polygon shapefile, clipped to the coastline, boundary of the source water, and used for area and volume calculations. The volume estimate of 7,738,746 m^3 (6,274 acre ft) included the inshore water of Alamitos Bay and Los Cerritos Channel. The estimate also included portions of Colorado Lagoon. Larvae produced in Colorado Lagoon could be transported into the Bay where they could be entrained by the AGS.

2.2.1.2 San Gabriel River

The lower San Gabriel River empties into San Pedro Bay just downcoast, and adjacent to, the jetty that forms the entrance to Alamitos Bay (**Figure 1**). The River originates in the San Gabriel Mountains, and historically flowed through to the Los Angeles River. In 1867, flooding altered the River's course, causing it to empty into Alamitos Bay. Catastrophic flooding in 1914 prompted flood protection measures on a basin-wide scale. During the 1920s, 1930s, and 1940s, several rivers, including the San Gabriel, were substantially dammed and channelized to prevent flooding and allow basin recharging. As a result, significant flow of freshwater into the lower reaches of the river is highest during periods with heavy rainfall. Dry weather freshwater flows occur as a result of discharges from two water reclamation plants, Los Coyote and Long Beach further upstream, and non-point source urban runoff along the river (Ackerman and Stein 2007). Currently, the largest source of water discharged into the river is from the two power plants, AGS and HGS. The current concrete channel in the lower reach of the river in the area where the AGS discharge is located was built by the Army Corps of Engineers in 1964 and is designed for a maximum flow of approximately 13,000 mgd (EQA and MBC 1973).

2.2.2 Water Quality

Waters within Alamitos Bay and the lower San Gabriel River at and below the area where the discharge from the AGS occurs are primarily marine (30–35 practical salinity units [PSU]) with water temperatures ranging from about 13°C (55°F) in winter to 25°C (77°F) in summer (Allen and Horn 1975; IRC 1981).

The temperature and salinity of the waters offshore Alamitos Bay have been measured semiannually or annually for many years as part of the AGS NPDES monitoring program. The monitoring program consists of nine (9) stations in the nearshore waters off Alamitos Bay and the mouth of the San Gabriel River flood control channel, from depths of 3.6 to 12.2 m (12 to 40 ft). Three additional stations are monitored within the San Gabriel River. From 2000 through 2004, all stations were sampled during both ebb and flood tides during five winter surveys and five summer surveys. Salinity is not a required monitoring component but results have been measured and reported since 2001.

In general, water temperatures at the monitoring stations were usually several degrees warmer in summer than in winter, with bottom waters consistently colder than surface waters (**Table 2**). Temperatures throughout the water column in the study area are usually warmest in the afternoon due to solar heating, and the formation of a thermocline is especially common during summer, though thermoclines may also develop in winter. Salinity at the monitoring stations was relatively uniform, ranging from 28.8 to 33.9 practical salinity units (PSU), typical for nearshore waters of southern California. Salinity was usually slightly higher near bottom than at the surface. Lowest salinity typically occurred directly offshore the mouth of the San Gabriel River.

Table 2. Temperature and salinity of surface and bottom waters off Alamitos Bay, 2001–2004. From MBC and Tenera (2007).

Season	Parameter	Surface	Bottom
Winter	Minimum temperature °C (°F)	14.5 (58.2)	13.5 (56.3)
	Average temperature °C (°F)	16.7 (62.1)	14.6 (58.3)
	Maximum temperature °C (°F)	23.5 (74.2)	16.6 (61.9)
Summer	Minimum temperature °C (°F)	18.5 (65.3)	13.9 (57.1)
	Average temperature °C (°F)	21.3 (70.4)	18.1 (64.6)
	Maximum temperature °C (°F)	27.4 (81.3)	21.8 (71.2)
Winter	Minimum salinity (PSU)	28.8	32.4
	Average salinity (PSU)	32.1	33.2
	Maximum salinity (PSU)	33.4	33.6
Summer	Minimum salinity (PSU)	32.3	33.2
	Average salinity (PSU)	33.2	33.5
	Maximum salinity (PSU)	33.6	33.9

Additional water quality monitoring was performed at the AGS intake canals during spring and summer (April–June) 2004 (MBC 2005). Water temperatures at the surface and a depth of one meter ranged from about 19.5°C (67.1°F) to 22.0°C (71.6°F) during sampling, with little or no difference between the two depths. Salinity consistently ranged between 33.2 and 34.8 PSU, typical of marine waters in the outer portions of Alamitos Bay.

Water quality sampling at three locations associated with a hydrodynamic study of the lower San Gabriel River by the Southern California Water Research Project (SCCWRP) found average salinities were approximately 31.5 psu at both the surface and bottom at the two stations furthest downstream (Ackerman and Stein 2007). Average salinities at the surface ranged from approximately 27 to 31 psu at the station furthest upstream near the AGS discharge during the two sampling periods used to calibrate and validate the modeling. The reduced salinities at the surface at the station furthest upstream reflect freshwater inflows into the river from sources upstream.

2.2.3 Tides and Currents

Astronomical tides in southern California are classified as mixed, semi-diurnal, with two unequal high tides (high water and higher high water) and two unequal low tides (low water and lower low water) each lunar day (approximately 24.5 hr). Between 1997 and 2002, water level extremes in Outer Los Angeles Harbor ranged from –0.6 m to +2.35 m (–1.97 ft to + 7.71 ft) above Mean Lower Low Water (MLLW). The tidal prism of Alamitos Bay (defined as the body of water contained within the mean tidal range) is approximately 1.96 x 10^6 m^3 (517.8 million gallons) (IRC 1981).

The estimation of the source water areas for the larvae potentially entrained by the AGS included accounting for larvae from Alamitos Bay that are transported into nearshore areas by ebbing tidal currents where they are still subject to entrainment due to subsequent flows back into the bay (MBC and Tenera 2007). This transport occurs on a daily basis and was estimated using hourly changes in bathymetric volumes of the bay as a function of tidal heights, together with estimated power plant flows of both AGS and the HGS. The tidal heights in Alamitos Bay were estimated using records of pressure from an ADCP deployed during the study in San Pedro Bay just outside the entrance to Alamitos Bay. Changes in atmospheric pressure were corrected using sea level pressure measurements made at the Los Angeles International Airport. Port of Los Angeles Moffatt & Nichol (2004) showed that tidal levels and timing at the Marine Stadium in Alamitos Bay were very similar to those predicted at Los Angeles Outer Harbor. Estimates of the daily Alamitos Bay outflows from January through December 2006 were calculated using these data (**Figure 4**).

The levels and timing of the tides in the lower San Gabriel River in the area of the AGS discharge should also be similar to the predicted tides from the Los Angeles Outer Harbor, since the tidal prism extends approximately 7,900 m (26,000 ft) upstream from the ocean, approximately twice the distance upstream from the location of the AGS discharge (EQA and MBC 1973).

Modeling done of the lower San Gabriel River by the SCCWRP showed that during periods when the AGS and HGS are discharging, the residence time of the water in the lower river areas upstream (ca. 4,200 m [13,800 ft]) just past the AGS discharges is on the order of a few hours under both spring and neap tide conditions (Ackerman and Stein 2007), basically indicating that all of the water is exchanged during the daily tidal cycle. In the absence of any discharge flow from the power plants, the residency time of the water in the lower river is similar during spring tides, but would be expected to increase to approximately two days during periods with neap tides. During the sampling, the measured salinity at the bottom of the river remained at approximately 30 psu, which is within the range of salinity values measured in the ocean just outside the entrance to Alamitos Bay and the river (**Table 2**).

2.3 Habitats and Biological Communities

This section provides information on the habitats and biological communities in Alamitos Bay and the lower San Gabriel River. Although both terrestrial and aquatic habitats occur in the area, this section focuses on the aquatic habitats for fishes and invertebrates that could be subject to entrainment through the modified intake system. General descriptions of the organisms in the various habitats are provided in CRM Inc. (2009). The habitats identified in the U. S. Fish and Wildlife Service (USFWS) National Wetland Inventory for the area around Alamitos Bay and the lower San Gabriel River are shown in **Figure 5**.

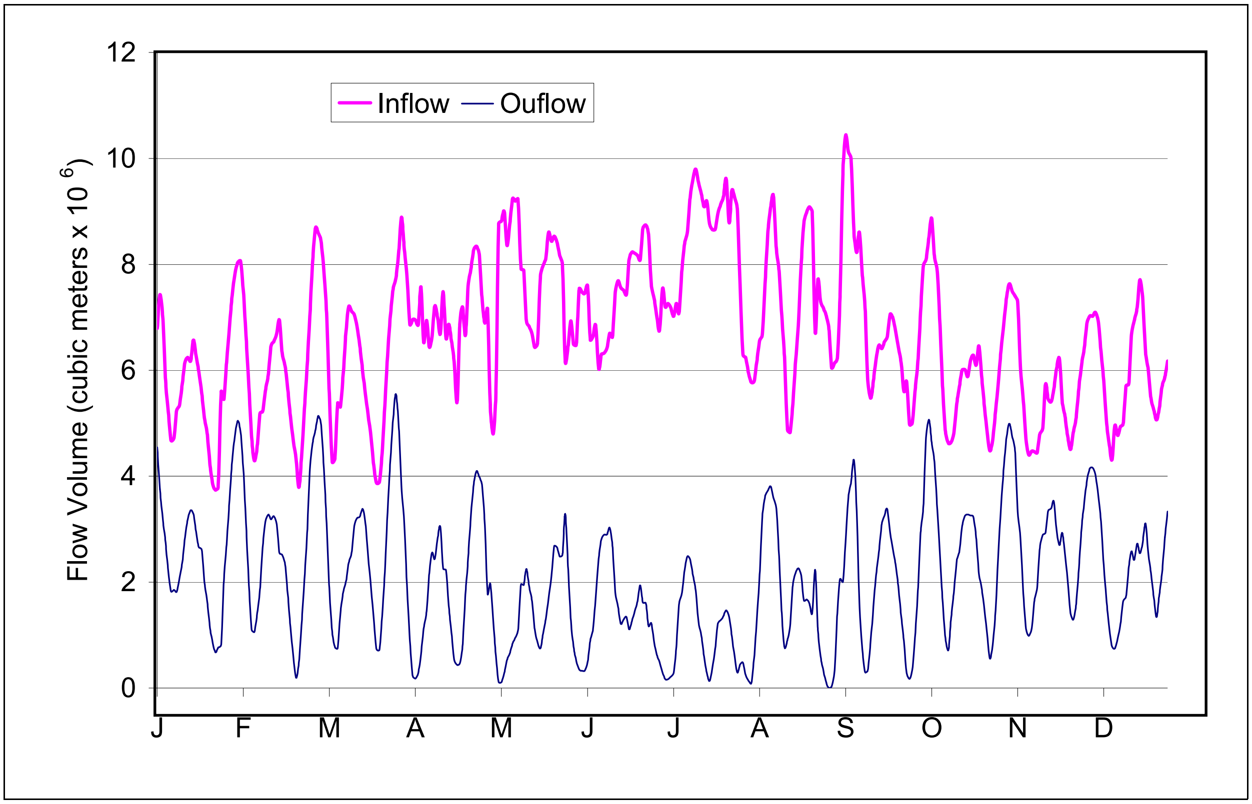

Figure 4. Estimates of Alamitos Bay daily inflow and outflow volumes, January–December 2006 (from MBC and Tenera 2007).

Alamitos Bay was originally a tidal embayment formed at the mouth of the San Gabriel River with marsh and mudflat habitat. The Bay has been extensively modified by the channelization of the San Gabriel River, construction of the jetties at the entrance, dredging associated with the construction of the Bay, and filing of areas in the construction of features such as Naples Island. The major habitats in the Bay are now the open areas of the channels, associated marinas and on the Bay and unvegetated and vegetated areas with sediments that consist of sand, silt, and clay (**Figure 5**). Eelgrass (*Zostera marina*) is a marine plant that provides important habitat in the shallow intertidal and subtidal areas of the Bay with soft sediments. Eelgrass is present at various locations throughout the Bay including near the entrance channel, near the west end and in the canals of Naples Island, in the Marine Stadium arm of the Bay, in Spinnaker Bay near the entrance to the Cerritos Channel and along the Cerritos Channel (Valle et al. 1999, CRM Inc. 2009).

Hard habitat is also provided by the jetties at the entrance to the harbor and which also occur along the channels throughout the Bay. These manmade structures provide habitat for marine algae and attached and motile invertebrates that are similar to the types of organisms found in natural rocky reef areas. Additional habitat is provided by the docks and pilings that occur throughout the Bay. The fouling communities on these structures include algae and attached invertebrates such as mussels, barnacles, bryozoans, and tunicates.

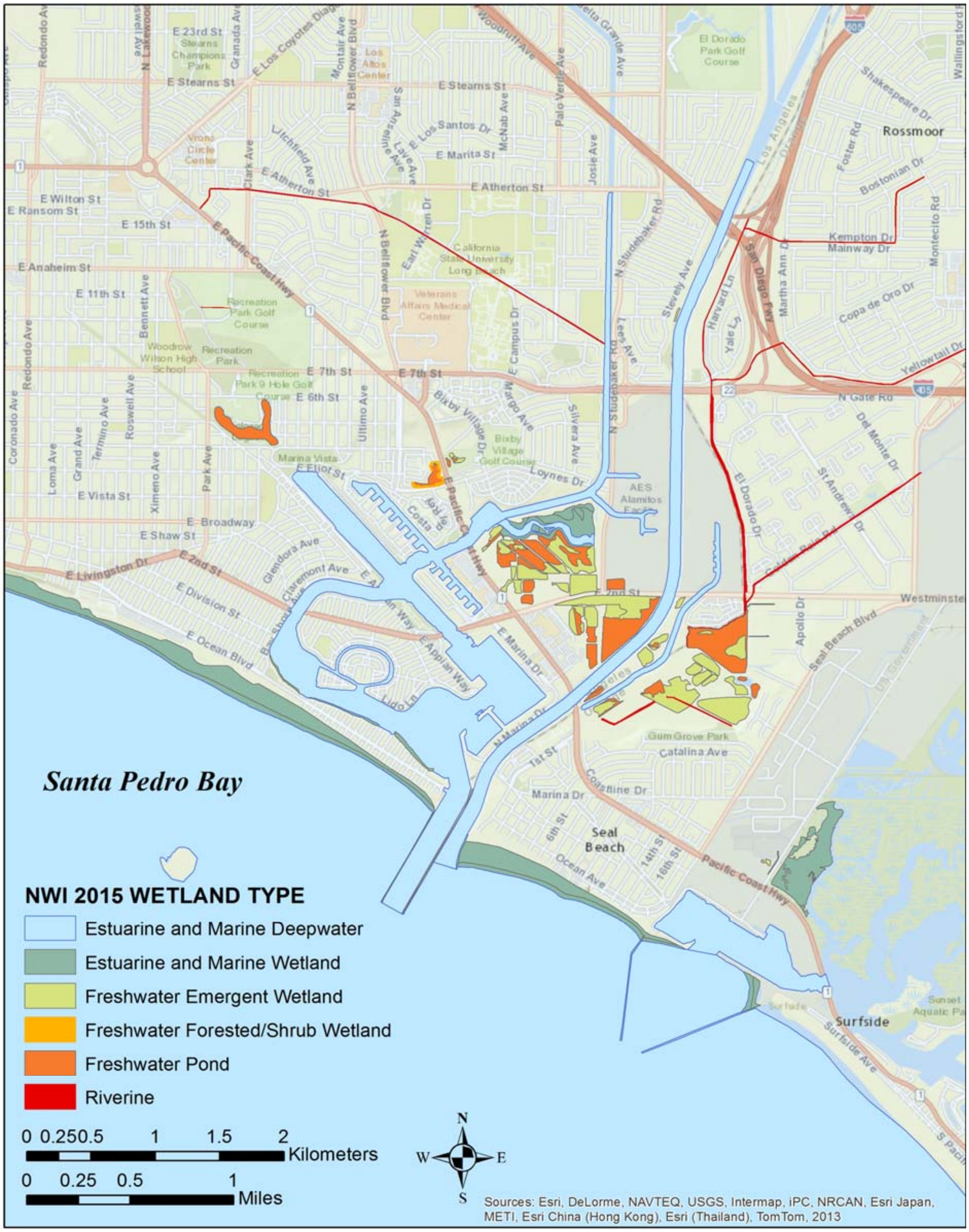

Figure 5. Map of habitats in the vicinity of Alamitos Bay, Long Beach, California. Source: U. S. Fish and Wildlife Service (USFWS) National Wetland Inventory Wetland Mapper.

The habitats in the lower San Gabriel River are similar to the habitats at the entrance to Alamitos Bay with hard habitat being provided by the rock jetties and shallow soft substrates along the shores and bottom of the River.

2.3.1 Organisms Potentially Affected by Modified Intake System

Each of the habitats in Alamitos Bay support a different suite of fishes, but the organisms potentially affected by the operation of a modified intake system at the AGS are best characterized by those species collected during the impingement and entrainment sampling at the plant.

Extensive impingement sampling at the AGS was conducted from October 1978 through September 1980 (SCE 1982), and more recently from January through December 2006 (MBC and Tenera 2007). During the 1978–1980 period, 24-hour impingement samples were collected once weekly except for the period from August 1979 through July 1980 when samples were collected twice per week. Data were only provided in SCE (1982) for taxa that were targeted for the assessment. A total of 276,843 fishes were collected with 147,918 individuals from thirteen of the target species (**Table 3**). Pacific pompano, shiner perch, and queenfish composed 39, 6, and 4% of all the fish collected, respectively. During the impingement sampling in 2006 fewer fishes were collected (28,082), partially due to the fewer numbers of sampling events (**Table 4**). It is unclear how the number of taxa (57) compare with the earlier SCE study where only the target species were reported. Fishes that were included as target species in the earlier study that were collected in high numbers, such as Pacific pompano and white surfperch, were collected in far fewer numbers in 2006. Silversides (including topsmelt) were the most abundant taxa collected during the 2006 study, but the numbers of silversides were not available from the SCE (1982) study since it was not identified as a target species.

The SCE (1982) study of entrainment at the AGS was based on data collected jointly with the HGS (also reported in IRC 1981) and was not collected in the intake canals for the plant. The most comprehensive data on potential entrainment at the AGS were collected from January through December 2006 (MBC and Tenera 2007). Data were collected from the Units1-4 and Units 5&6 intake canals that are connected to the Cerritos Channel every two weeks from January through December 2006 (**Figure 2**). The combined data from the two intake canals show that gobies and blennies combined account for approximately 90% of the total concentration of fish larvae (**Table 5**).

The three most abundant fish larvae in the impingement and entrainment samples from the 2006 study reflect the prominent habitats in the vicinity of the AGS intakes. The most abundant fishes in the impingement samples were silversides (74%) which are associated with the open water channel areas in Alamitos Bay (**Table 4**). The three most abundant taxa of fish larvae collected from entrainment comprising approximately 93% of the total concentration were gobies associated with mudflat habitat along the channels and in the Cerritos wetland, combtooth blennies associated with the rock jetties and fouling community, and silversides associated with the open water areas in the channels (**Table 5**).

Table 3. Summary of fishes collected during impingement sampling at the AGS from October 1978 through September 1980 (Source of data: SCE [1982]).

Taxon	Common Name	Number Collected	Percent of All Fishes
Peprilus simillimus	Pacific pompano	109,091	39.41
Cymatogaster aggregata	shiner perch	15,854	5.73
Seriphus politus	queenfish	11,954	4.32
Phanerodon furcatus	white seaperch	3,390	1.22
Genyonemus lineatus	white croaker	2,598	0.94
Engraulis mordax	northern anchovy	1,949	0.70
Hyperprosopon argenteum	walleye surfperch	1,345	0.49
Embiotoca jacksoni	black surfperch	1,217	0.44
Umbrina roncador	yellowfin croaker	208	0.08
Paralabrax nebulifer	barred sand bass	192	0.07
Cheilotrema saturnum	black croaker	63	0.02
Anisotremus davidsonii	sargo	30	0.01
Paralabrax clathratus	kelp bass	27	0.01
Total Target Species		147,918	53.43
Total All Species		276,483	

Table 4. Summary of fishes collected during impingement sampling at the AGS from January through December 2006 (Source of data: MBC and Tenera [2007]).

Taxon	Common Name	Number Collected.	Wt. (kg)	Percent of Total
Atherinops affinis	topsmelt	11,694	186.32	41.642
Atherinopsidae	silverside, unid.	9,118	162.62	32.469
Cymatogaster aggregata	shiner perch	3,660	22.49	13.033
Leptocottus armatus	Pacific staghorn sculpin	1,279	16.64	4.555
Engraulis mordax larvae	northern anchovy larvae	628	0.03	2.236
Seriphus politus	queenfish	301	1.34	1.072
Gillichthys mirabilis	longjaw mudsucker	238	0.99	0.848
Engraulis mordax	northern anchovy	174	0.28	0.620
Syngnathus leptorhynchus	bay pipefish	169	0.25	0.602
Pleuronichthys guttulatus	diamond turbot	143	30.22	0.509
Anchoa delicatissima	slough anchovy	94	0.36	0.335
Acanthogobius flavimanus	yellowfin goby	63	2.25	0.224
Porichthys myriaster	specklefin midshipman	52	14.69	0.185
Sardinops sagax	Pacific sardine	50	0.88	0.178
Syngnathus sp	pipefish, unid.	44	0.07	0.157
Anchoa compressa	deepbody anchovy	38	0.47	0.135
Paralichthys californicus	California halibut	37	20.52	0.132
Fundulus parvipinnis	California killifish	31	0.13	0.110
Urobatis halleri	round stingray	30	10.18	0.107
Hypsoblennius gentilis	bay blenny	21	0.33	0.075
Menticirrhus undulatus	California corbina	20	13.83	0.071
Myliobatis californica	bat ray	20	5.90	0.071
Umbrina roncador	yellowfin croaker	19	2.71	0.068
Heterostichus rostratus	giant kelpfish	19	0.22	0.068
Atherinopsis californiensis	jacksmelt	12	1.97	0.043
Genyonemus lineatus	white croaker	12	0.42	0.043
Embiotoca jacksoni	black perch	11	0.95	0.039
Leuresthes tenuis	California grunion	11	0.12	0.039
Syngnathus californiensis	kelp pipefish	10	0.03	0.036
Trachurus symmetricus	jack mackerel	10	0.84	0.036
Strongylura exilis	California needlefish	9	0.28	0.032
Pleuronichthys ritteri	spotted turbot	7	0.01	0.025
Xenistius californiensis	salema	7	0.09	0.025
Sphyraena argentea	Pacific barracuda	5	0.01	0.018
Hypsoblennius gilberti	rockpool blenny	4	0.08	0.014
Atractoscion nobilis	white seabass	4	0.03	0.014
Paraclinus integripinnis	reef finspot	3	0.01	0.011
Cichlidae	tilapia, unid.	3	0.06	0.011
Scomber japonicus	Pacific chub mackerel	3	0.79	0.011
Phanerodon furcatus	white surfperch	3	0.10	0.011
Porichthys notatus	plainfin midshipman	2	0.46	0.007
Gibbonsia elegans	spotted kelpfish	2	0.05	0.007
Cheilotrema saturnum	black croaker	2	0.01	0.007
Xystreurys liolepis	fantail sole	2	0.40	0.007
Ameiurus sp	bullhead catfish, unid.	2	0.12	0.007
Gobiesox rhessodon	California clingfish	2	0.01	0.007
Porichthys sp	midshipman, unid.	2	0.10	0.007
Anisotremus davidsonii	sargo	2	0.01	0.007
Symphurus atricaudus	California tonguefish	2	0.04	0.007
Lepidogobius lepidus	bay goby	1	0.00	0.004

table continued

Table 4 (*continued*). Summary of fishes collected during impingement sampling at the AGS from January through December 2006 (Source of data: MBC and Tenera [2007]).

Taxon	Common Name	Number Collected.	Wt. (kg)	Percent of Total
Pleuronichthys sp	righteyed flounder, unid.	1	0.05	0.004
Mustelus californicus	grey smoothhound	1	0.06	0.004
Pleuronichthys verticalis	hornyhead turbot	1	0.07	0.004
Hypsoblennius jenkinsi	mussel blenny	1	0.01	0.004
Anchoa sp	anchovy, unid.	1	0.01	0.004
Peprilus simillimus	Pacific pompano	1	0.03	0.004
Sciaenidae	croaker, unid.	1	1.90	0.004
Totals:		28,082	502.803	

Table 5. Summary of fishes collected during entrainment sampling at the AGS from January through December 2006 (Source of data: MBC and Tenera [2007]).

Taxon	Common Name	Total Collected	Average Density per 1000 m^3	Percent of Total
Gobiidae unid.	gobies	11,656	3077.6	65.677
Hypsoblennius spp.	combtooth blennies	4,207	1108.1	23.647
Atherinopsidae unid.	silversides	605	170.4	3.636
Labrisomidae unid.	labrisomid blennies	420	107.3	2.291
Gobiesocidae unid.	clingfishes	187	48.7	1.039
Engraulidae unid.	anchovies	144	40.8	0.871
Gillichthys mirabilis	longjaw mudsucker	111	30.7	0.654
larval/post-larval fish unid.	larval fishes	96	24.3	0.519
Acanthogobius flavimanus	yellowfin goby	77	20.4	0.435
Gibbonsia spp.	clinid kelpfishes	61	16.2	0.346
Genyonemus lineatus	white croaker	40	10.7	0.229
Syngnathus spp.	pipefishes	35	9.3	0.199
Pleuronichthys guttulatus	diamond turbot	15	3.8	0.082
Typhlogobius californiensis	blind goby	12	3.1	0.067
Sciaenidae unid.	croakers	11	2.8	0.061
Seriphus politus	queenfish	6	1.7	0.036
Clinocottus spp.	sculpins	5	1.4	0.029
Cottidae unid.	sculpins	4	1.1	0.024
Tridentiger trigonocephalus	chameleon goby	3	0.9	0.020
Clinidae unid.	kelp blennies	3	0.8	0.018
Paralichthys californicus	California halibut	3	0.8	0.018
Heterostichus rostratus	giant kelpfish	3	0.8	0.017
Chaenopsidae unid.	tube blennies	3	0.7	0.016
Leptocottus armatus	Pacific staghorn sculpin	2	0.6	0.012
Oxyjulis californica	senorita	2	0.6	0.012
Roncador stearnsi	spotfin croaker	1	0.3	0.006
Pleuronectiformes unid.	flatfishes	1	0.3	0.006
Ruscarius creaseri	roughcheek sculpin	1	0.3	0.005
Blennioidei unid.	blennies	1	0.3	0.005
Lepidogobius lepidus	bay goby	1	0.2	0.005
Menticirrhus undulatus	California corbina	1	0.2	0.005
Hypsypops rubicundus	garibaldi	1	0.2	0.005
Triphoturus mexicanus	Mexican lampfish	1	0.2	0.005
Cheilotrema saturnum	black croaker	1	0.2	0.005
Totals		17,720	4686.0	

The freshwater zone of the San Gabriel River Tidal Prism (to the end of the concrete lining) consists mostly of Los Angeles County Sanitation Districts' (LACSD) reclaimed water, and contains some freshwater algae and a few invertebrate species. Brackish water communities occur in the unlined region of estuarine tidal action, where organisms must tolerate cycles in salinity, temperature, oxygen, and organic matter. Marine communities of the lower San Gabriel River, where most of the power plant discharges occur, are more diverse (LACSD 1995). Benthic animals along the San Gabriel River generally include tube-dwelling worms and crustaceans, with diversity and species richness varying greatly by salinity conditions and the presence/absence of predators (LACSD 1995). Large freshwater populations of oligochaete worms and chironomid insect larvae are collected only in Coyote Creek, above the Long Beach Water Reclamation Plant. The Mozambique tilapia (*Oreochromis mossambica*) is the dominant fish in freshwater areas of the river and occasionally down into the tidal prism. California Department of Fish and Game surveys in the late 1970s found tilapia accounted for more than 99% of all fish in the tidal prism.

Analysis of long-term biological resource surveys conducted just offshore of Alamitos Bay and the mouth of the lower San Gabriel River since the early 1970s collected a total of 66 fish species, with about 30 species on average being collected annually (MBC and Tenera 2007). Surveys were dominated by oceanic species such as northern anchovy (*Engraulis mordax*), white croaker (*Genyonemus lineatus*), queenfish (*Seriphus politus*), and California tonguefish (*Symphurus atricaudus*). These species combined account for 90% of the trawl-caught abundance. It is likely that the warm waters near the mouth of the San Gabriel River flood control channel leads to increased productivity and diversity in that area, especially in winter when both productivity and diversity would normally decrease (EQA and MBC 1973). Therefore, the composition of the fish community collected at the river mouth has been similar to that collected at surrounding stations and other stations within the southern California Bight. For example, recent surveys in 2014 found the most common species collected were California lizardfish, speckled sanddab, northern anchovy, and white croaker (Sedlacek 2015). All of these are common marine fish species also found on the inner shelf of southern California.

Invertebrates collected during these trawl surveys were dominated by blackspotted bay shrimp (*Crangon nigromaculata*), tuberculate pear crab (*Pyromaia tuberculata*), and spiny sand star (*Astropecten armatus*), accounting for 84% of the invertebrate abundance. *Diopatra splendidissima*, a tubiculous polychaete, was the most abundant invertebrate recorded during the surveys (MBC and Tenera 2007).

3.0 Potential Effects on Marine Resources

This section provides information of the potential effects on marine resources from continued operation of a modified intake system at the AGS designed to increase water circulation in the inner reaches of Alamitos Bay. The assessment of potential effects assumes that the modified intake system will result in velocities through the intake screens that are less than 15 cm/sec (0.5 ft/sec), which is the standard used in the SWRCB Policy for minimizing any potential effects of impingement at cooling water system intakes. Therefore, the assessment in this section will focus on the potential effects of entrainment and differences in water quality between Alamitos Bay and the lower San Gabriel River that could affect fishes transported between the two water bodies through the system. The potential effects of the modified pumps used for the system are presented in the next section (Section 4.0).

3.1 Effects of Water Quality on Biological Resources

3.1.1 Effects of Entrainment

The results from the 2006 entrainment study at the AGS can be used to estimate the total annual number of fish larvae that would be transported from the inner reaches of Alamitos Bay into the lower San Gabriel River by multiplying the estimates of larval concentration in **Table 4** by the total annual flow of the pumps installed in the modified intake system. For example, if the modified intake system had a capacity of 378,500 m^3 (100 million gallons) per day, would result in larval entrainment of approximately 1.77 million per day or 647.5 million per year through the system, based on the average concentration of all fish larvae in **Table 5**. The annual estimate would only be accurate if the pumps were operated without interruption. Entrainment samples at AGS were collected every two weeks, allowing estimates to be calculated based on actual flows that would be expected to vary throughout the year.

The current SWRCB Policy assumes 100% mortality of all the organisms entrained by ocean intakes. This assumption was based on the current pump technology used at all of the coastal power plants at the time the Policy was adopted. As described in Section 4.0, pump designs have been developed that have been shown to dramatically reduce mortality to adult fish and larvae. The potential reductions in mortality due to entrainment resulting from the use of these "fish friendly" pumps are described in Section 4.0. Therefore, the other potential source of mortality resulting from entrainment and discharge of fish larvae into the lower San Gabriel River is the potential differences in water quality between the two water bodies.

3.2 Assessment Effects on Water Quality Due to Pumping

Water quality conditions in Alamitos Bay and to some extent the lower San Gabriel River are strongly tied to the power plants. Moffatt & Nichol (2007) found that the cooling water flow rate at the AGS has the most significant effect on circulation within Alamitos Bay since it removes some of the "aging and poor quality water" from upstream areas of the Bay and discharges it into the San Gabriel River. Without the draw of water from the plants, poor-quality water would be found during ebb tides downstream past Mother's Beach and towards the Haynes intake and the ocean. Poor water quality in turn can cause a number of biological issues within the Bay, including reductions in dissolved oxygen which can lead to mortality in a number of fish species that use Alamitos Bay. Substantial changes in the residence time for seawater in Alamitos Bay can affect multiple systems because it represents the amount of time it takes for a system to be "flushed" by water from outside the system. Residence time also is often used to approximate water quality within a system, with relatively short residence times reflecting relatively good water quality and longer residence times often leading to poor water quality. While both AGS and HGS contribute to circulation and residence time in the bay, the shutdown of AGS appears to impact residence time more significantly than shutdown of HGS (Moffat & Nichol 2015). **Table 6** shows the residence times throughout Alamitos Bay and the potential impact on residence times from plant shutdown.

Table 6. Residence times (days) of water at various locations within Alamitos Bay based on maximum and no operation of the current pumps at AGS and HGS (Source: Table 4-1 in Moffat and Nichol [2015]).

Alternative	Baseline Condition	Alternative 1	Alternative 2	Impacts of	
	AGS Pumps at 144 cfs	AGS Pumps at 144 cfs	AGS Pumps at 0 cfs	HGS Shutdown	AGS Shutdown
Pumping Scenarios	HGS pumps at 422 cfs	HGS pumps at 0 cfs	HGS pumps at 0 cfs	Days (% increase)	
Los Cerritos Channel North	12.1	13.3	19.0	1.2 (10%)	5.7 (43%)
Los Cerritos Channel Central	7.0	9.2	14.1	2.2 (31%	4.9 (53%)
Los Cerritos Channel South	6.2	8.4	13.1	2.2 (35%)	4.7 (56%)
AGS Intake North	9.0	11.2	17.0	2.2 (24%)	5.8 (52%)
AGS Intake South	8.2	10.3	16.1	2.1 (26%)	5.8 (56%)
Spinnaker Bay	8.0	10.2	14.3	2.2 (28%)	4.1 (40%)
Colorado Lagoon	9.3	11.4	15.3	2.1 (23%)	3.9 (34%)
Marine Stadium	7.2	9.4	13.4	2.2 (31%)	4.0 (43%)
Naples Channel North	5.2	8.0	11.3	2.8 (54%)	3.3 (41%)
Naples Channel West	4.0	7.0	10.1	3.0 (75%)	3.1 (44%)
Naples Channel South	2.4	5.1	7.2	2.7 (113%)	2.1 (41%)
Alamitos Bay Northeast (HGS Intake)	2.7	5.4	8.2	2.7 (100%)	2.8 (52%)
Alamitos Bay Entrance	0.4	2.1	3.2	1.7 (425%)	1.1 (52%)
San Gabriel River at Effluent Points	5.0	5.8	10.1	0.8 (16%)	4.3 (74%)

The relationship between residence time and water quality is well documented. For Alamitos Bay, as residence times increase, water quality may change from that of the source water (Pacific Ocean) to reflect water quality more typical of enclosed bays (Moffat & Nichol 2015). Similarly, if a bay is relatively stagnant, the upper water column tends to heat more rapidly than lower and deeper layers, and can become more buoyant, leading to reduced vertical mixing throughout the water column. Subsequently, this can prevent deeper water from replenishing dissolved oxygen

(DO) used by marine organisms. However, if water continues to circulate, mixing occurs in the water column (less potential for stratification) and more constant temperatures are found throughout the water column, permitting contact between the oxygen-rich atmosphere and the water throughout the water column.

DO levels of ocean water are typically around 10 mg/l; decreased DO concentrations are found in stagnant and stratified waters. The California Ocean Plan (COP) states that DO concentrations of ~7.0 mg/l are necessary for long-term health of marine habitats. DO concentrations below approximately 5.0 mg/l can increase stress on marine organisms such as fishes and potentially cause the organisms to die from decreased respiration. Studies done recently show that levels above 5.8 mg/l are sufficient to sustain marine life for chronic low DO conditions, and above 2.8 mg/l for acute low DO conditions (Sutula et al. 2012).

The water quality in the lower San Gabriel River should be similar in salinity and temperature to the conditions in the inner portions of Alamitos Bay where the AGS intakes are located. The area where the AGS discharges are located are within the tidal prism and therefore experience periodic flushing with ocean waters during incoming tides. During periods of heavy rainfall when there may be increased flow of freshwater into the lower San Gabriel River, there should be similar increased input of freshwater into the inner reaches of Alamitos Bay from the Cerritos Channel. Therefore, conditions in the two water bodies should be similar and not affect the ability of fish larvae to survive in the lower San Gabriel River that have been transported from Alamitos Bay.

4.0 Assessment of Fish Friendly Pumps

4.1 Overview of Fish Friendly Pump Design

Fish-friendly pumps were first developed in Europe in response to the adverse effects from the use of conventional pumps on fish stock, especially for species such as the European eel. The need for the development of fish friendly pumps resulted from the introduction of the 2009 Eels Regulations (England and Wales) No. 3344 ('the Eel Regulations') and the need to address potential losses (mortality) of European eels and other fish species from passage through pumping stations. To be deemed "eel- and fish-friendly" pumps were required to have the capability to pass live eels and other fishes without incurring any internal or external injuries. Most fish mortality is caused when fish are struck by impeller blades and/or guide vanes when passing through conventional pumping system.

The impeller and guide vanes of fish friendly pumps are designed to create optimal water flow, while allowing fish to pass through the pump safely. Fish friendly pumps generally have impeller blades with rounded edges and the wider spacing between impeller blades, which substantially reduces the impact risk to fishes (**Figure 6**).

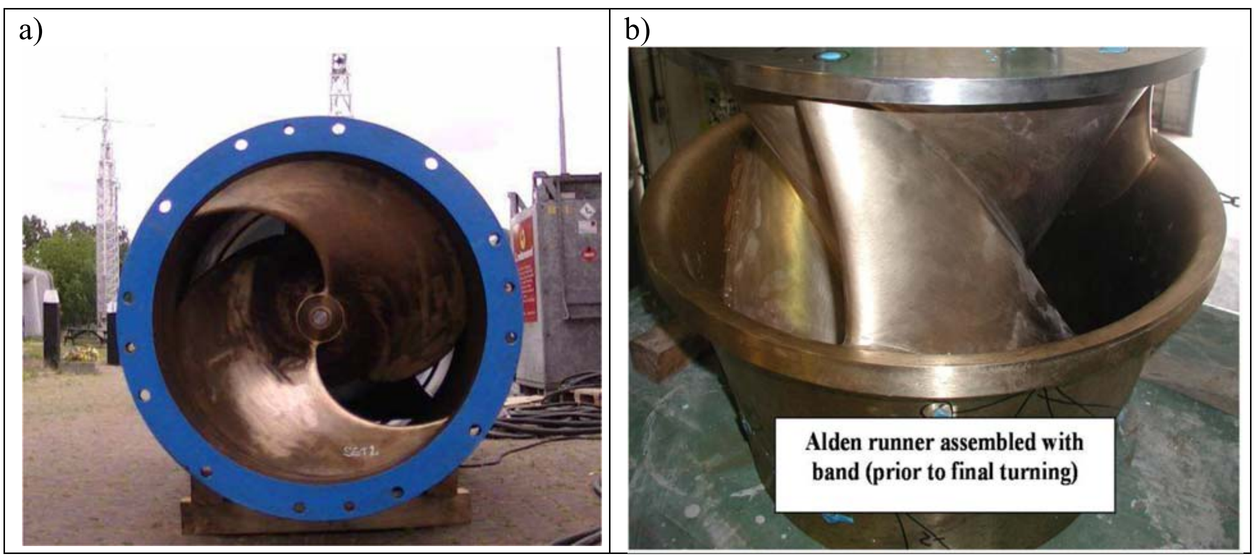

Figure 6. Impeller designs for two fish friendly pumps: a) Bedford pumps SAF.90.05.12 (Spierts and Vis 2012), and b) Alden turbine runner (EPRI 2011).

4.2 Review of Studies on Effects of Fish Friendly Pumps

In 1993, representatives from the Department of Energy (DOE), the Electric Power Research Institute (EPRI), and the R&D Committee of the National Hydropower Association (NHA) met in Denver, CO to discuss ideas for developing "fish-friendly" turbines (EPRI and DOE 2011).

The principle objective of this meeting was to discuss ways to improve the survival of fish passage through turbines to the point where fish bypass systems and spillways were no longer required, thereby maintaining, and possibly improving, hydropower generation. The NHA formed the non-profit Hydropower Research Foundation (HRF) to support turbine development and with an initial financial contribution of $500,000 from EPRI and a coalition of industry supporters that was matched by DOE. The resulting Advanced Hydropower Turbine System (AHTS) program involved a three-phase, multi-year effort: Phase I – conceptual designs; Phase II – detailed designs and model testing; and Phase III – construction and testing of full-sized prototypes (EPRI and DOE 2011).

One of the results of the AHTS was the developmental engineering of a "fish-friendly" hydropower turbine called the Alden turbine (**Figure 6b**) (EPRI and DOE 2011). The main objective behind the development of the new turbine design was to avoid the need to install bypass systems at hydroelectric facilities to avoid the passage of fishes such as salmon through the turbines. The bypass systems reduce water flow through the dam's turbine system that results in lower electrical output. The goal of the project was the development of a turbine that would improve the survival of fish passage to the point where fish bypass systems and spillways are no longer required. The turbine design incorporates a blade geometry that optimizes fish survival using criteria for maximum shear, maximum pressure change rate, and minimum absolute pressure through the pump. Previous studies by Alden had demonstrated that a shear threshold of 360 s^{-1}, reduced damage to fish, although tests by PNNL (Nietzel et al. 2000 in EPRI and DOE 2011) indicated that salmonids were tolerate of a higher value, about 500 s^{-1}. Pilot testing of the turbine showed survival rates of 97–100% for fishes less than 20 cm (8 in.) in length (Dixon and Hogan 2015).

Bedford Pumps Ltd. (Bedford, UK), a subsidiary of Hidrostal Holdings AG, developed an Axial Flow Fish Friendly pump that underwent rigorous tests at a dry dock in Holland (**Figure 6a**). Studies were conducted to expose three representative groups of fish in two size classes (0–15 cm [0–6 in.] and fish greater than 16 cm [>6 in.]) to the pump. The pump drew a volume of 1,300 L/sec (~343 g/sec) with a 1.5m head at running at speeds of 330, 425 and 518 rpm, consecutively. Results indicated that the pump achieved 100% survival of eels passing through the pump, with some minor scale loss of some fishes. It should be noted that scale loss in fishes were not caused by the pump impeller, but by the impact of the fish hitting the water after passing through the pump. In natural situations, the discharge pipe would be at or near the water level to minimize any scale loss.

Jackson (2013) suggested that eels and fish that have been encouraged/diverted into a safe area and need to be transferred (i.e., as part of their migration), can achieve survival rates approaching 100% by adapting a pumping solution. The fish friendly pumps described by Jackson (2013) are all centrifugal types with open volutes and impellers that have a single spiral vane and large free passages to help ensure safe passage of fishes through the pump.

The U.S. Bureau of Reclamation funded a number of fish friendly pump studies at Red Bluff Pumping Plant on the Upper Sacramento River in the early 2000s (McNabb et al. 2003, Bothwick and Liston 2003). Bothwick and Liston (2003) determined survival, descaling, and injury rates for 200–300 mm fork length rainbow trout (*Oncorhynchus mykiss*) that were passed through an Archimedes lift and a Hidrostal pump. Results of this study indicated that both the Archimedes lift and the Hidrostal pump can pass small and large fish with high survival (> 90 percent) and low injury (< 10 percent) rates (**Table 7**). While fish that passed through the Archimedes lift had slightly higher survival rates than fish passed through the Hidrostal pump, the overall results support previous work suggesting that these devices can safely transport a significant proportion of fish at diversion structures.

Table 7. Summary of the results of Tracy Fish Collection Facility tests. Source: Jackson (2013).

Species	Length (mm)	Immediate Survival (%)	96-Hour Survival (%)
Striped Bass (*Morone saxatilis*)	78-360 (mean = 177)	99	96
Steelhead (*Oncorhynchus mykiss*)	165-313 (mean 252)	100	99
Delta Smelt (*Hypomesus transpacificus*)	50-94 (mean 72.2)	99.7	92.7
Wakasagi (*Hypomesus nipponensis*)	48-114 (mean 87.9)	97.5	96

Fish mortality studies with Hidrostal pump installations have been conducted for a number of fish species, including trout (Rodgers and Patrick 1985), American eel (Patrick & McKinley 1987), and other non-salmonids (Rodgers & Patrick 1985). Although many of these studies suggested little immediate mortality associated with passage through some large (>5.0-m diameter) hydropower Hidrostal pump systems, Baumgartner et al. (2009) found that passage mortality for some non-salmonids on smaller-scale (0.3–0.9 m diameter) irrigation pumps was dependent on operational speeds. Thompson and Glasgow (2011) found juvenile salmonid mortality in experimental passage trials through Hidrostal pumps varied according to impeller pitch, rotational speed and fish body size. This study found instantaneous mortality rates ranged from 0 to 4% for high-pitch impeller trials and from 3 to 10% for low-pitch trials. The Thompson and Glasgow study also found that larger fish experienced sublethal injury at higher pump rates (approximately 60% injured) compared to smaller fish (approximately 23% injured) and exhibited greater susceptibility to injury at higher pump speed.

There are fewer studies on the effects of fish friendly pump designs on fish larvae, although designs using lower rotational speeds and fewer impellers with rounded edges should have limited impacts on fish larvae. The designs of the pumps should result in survival rates that at least equal the levels measured for juvenile fishes which are at much greater risk of being impacted by the pump impellers. Although no studies were found that involved testing of larval fish, there were studies of larval fish survival through conventional pumps. As reported in EPRI (2011), Morgan et al. (1976) studied the effects of shear on white perch and striped bass larvae and fertilized eggs. Tests were done using different levels of shear levels. Mortality rates of 50% mortality occurred at shear rates of 415 to 785 dynes/cm^2 for one minute of exposure, which is longer than the expected exposure period for larvae passing through a pump. Fish friendly pump designs such as the Alden design have maximum shear values below this range which only occur at the surface of the blades (EPRI and DOE 2011). Using a 46 cm (18 in.) diameter propeller, Killgore et al. (2001) evaluated survival following entrainment of early life stages of shovelnose sturgeon larvae, lake sturgeon larvae, paddlefish eggs and larvae, and blue sucker larvae. Testing was done to achieve shear stresses of 634, 1613, 3,058, and 4,743 dynes/cm^2. While, mortality was as high as 86.0% at shear forces of 4,743 dynes/cm^2 and was significantly greater than control mortality for most species, mortality rates were not significantly different from the control mortality at shear stresses below 1,613 dynes/cm^2, a value far above the levels in fish friendly pumps. These results showing survival of larvae through conventional pumps is not surprising as pumps with modified impellers have been used for many years as one of the methods for sampling ichthyoplankton larvae.

5.0 Conclusions

This report summarized existing information on the AGS cooling water intake system (CWIS) and the potential for retrofitting the intake to improve water quality by increasing circulation in the upstream areas of the Bay. Information was also provided on the AGS cooling system, and the physical and biological characteristics of Alamitos Bay and the San Gabriel River, as well as potential effects on marine resources in the Bay and San Gabriel River from operation of the plants and potential impacts from non-pumping scenarios. A discussion of the possibility of replacing the existing circulating water pumps at the AGS after the plant has ceased using the system for power plant cooling with "fish friendly" pumps was presented that could minimize the effects of entrainment as well as maintain flow and water quality in both Alamitos Bay and lower San Gabriel River.

Information provided in this report indicates that the habitats within the lower San Gabriel River and Alamitos Bay are similar to those in other areas of the southern California Bight, including riprap, mudflat, and open water. For Alamitos Bay, as residence time increases, water quality may change from that of the source water (Pacific Ocean) to reflect water quality more typical of enclosed bays. Similarly, if a bay is relatively stagnant, the upper water column tends to heat more rapidly than lower and deeper layers, and can become more buoyant, leading to reduced vertical mixing throughout the water column. However, if water continues to circulate, mixing occurs in the water column (less potential for stratification) and more constant temperatures are found throughout the water column, permitting contact between the oxygen-rich atmosphere and the water throughout the water column. Good water quality conditions are likely the direct result of circulation within Alamitos Bay that is being maintained not only by tidal influences, but also by the pumping activities of the power plants.

Ackerman and Stein (2007) completed hydrodynamic model simulations for the lower San Gabriel River and showed that during periods when the AGS and HGS are discharging, the residence time of the water in the lower river areas upstream past the AGS discharges is on the order of a few hours under both spring and neap tide conditions. This indicates that most of the water is exchanged during the daily tidal cycle. In the absence of any discharge flow from the power plants, the residency time of the water in the lower river is similar during spring tides, but would likely increase during periods with neap tides. Salinity at the bottom of the river also remained at or above approximately 30 psu, which is within the range of salinity values measured in the ocean just outside the entrance to Alamitos Bay and the river. It is important to note that planktonic marine organisms discharged into these habitats by the power plants have a greater chance of survival because existing water quality conditions in the lower San Gabriel River are essentially the same as those in Alamitos Bay and represent ambient marine conditions.

The most common marine biological resources are based on impingement and entrainment samples and represent prominent habitats in the vicinity of the AGS intakes. For example, the most abundant fishes in the most recent impingement samples were silversides (74%) which are associated with the open water channel areas in Alamitos Bay. Moreover, the three most abundant taxa of fish larvae collected from entrainment were gobies associated with mudflat habitat along the channels and in the Cerritos wetland, combtooth blennies associated with the rock jetties and fouling community, and silversides associated with the open water areas in the channels. These three taxa accounted for approximately 93% of the total concentration of entrained fish. The same habitats associated with these three taxa are also the prominent habitats in the lower San Gabriel River. Studies conducted in the lower San Gabriel River near the power plant discharges also found that the composition of the fish community collected at the river mouth has been similar to that collected at surrounding stations and other stations within the southern California Bight. For example, the most common species collected in these studies were California lizardfish, speckled sanddab, northern anchovy, and white croaker. All of these are marine species commonly found in nearshore coastal marine habitats off southern California.

Europe started developing “fish friendly” pumps in response to the adverse effects from the use of conventional pumps on fish stocks. During the same time period, the U.S. Bureau of Reclamation funded a number of fish friendly pump studies to determine survival, descaling, and injury rates for fishes that were passed through an Archimedes lift and a Hidrostal pump. Results of many of the European and North American studies indicate that these types of pumps can substantially reduce injury, descaling, and mortality associated with fish traveling through these types of pumps. Although little information exists on survival and mortality of ichthyoplankton through “fish-friendly” pumps, it is likely that survival would be high for these extremely small planktonic organisms since the pump designs use lower rotational speeds and fewer impellers with rounded edges. To maintain flow and good water quality conditions in the lower San Gabriel River and Alamitos Bay, the power plant(s) should continue pumping but also implement new technologies, such as “fish-friendly” pumps, to reduce or eliminate potential impacts to marine biological resources. Without continued power plant pumping, changes in circulation (residence time) and water quality conditions could have substantial impacts on biological resources. Fish communities in both the lower San Gabriel River and Alamitos Bay would experience periods of stagnant water that could have higher temperatures, lower salinities (from increased freshwater input from the river), and decreased DO. All of these conditions could cause fish kills and result in higher bacterial levels and odors in the Bay.

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