moffatt & nichol

3780 Kilroy Airport Way, Suite 600
Long Beach, CA 90806

(562) 426-9551 Fax (562) 424-7489
www.moffattnichol.com

Memorandum

To: Amy Bodek, City of Long Beach

From: Chris Webb and Weixia Jin

Date: October 22, 2015

Subject: Modeling of Water Residence Time Within Alamitos Bay

Project: Alamitos Bay Water Quality

1.0 INTRODUCTION

The City of Long Beach (the City) has retained Moffatt & Nichol (M&N) to analyze the changes to tidal circulation and water residence time within Alamitos Bay as a result of ceasing pumping at the Haynes Generating Station (HGS) and the AES Alamitos generating facility. The locations of the intakes and outfalls from these generating stations within Alamitos Bay can be seen in Figure 1-1.

Both of these generating stations employ a procedure known as Once-Through Cooling (OTC) to condense steam into water during the electricity-generating process. What this means is that these stations pump water from Alamitos Bay, circulate this water through the plant, and discharge it to the San Gabriel River. However, this pumping is expected to end due to legislation approved by the California State Water Resources Control Board (SWRCB) in 2010 to phase out OTC throughout the State.

The high pumping rates associated with OTC contribute to water circulation and flushing within Alamitos Bay, therefore reducing seawater residence time. The City is interested in quantifying the changes to tidal circulation and water residence time because of the secondary impacts associated with water quality, marine life, sedimentation, and possible other factors.

M&N updated a modeling suite that couples hydrodymanics with tidal circulation efficiency created for Alamitos Bay to simulate tidal circulation under three different operational scenarios: a baseline, an alternative without pumping from the HGS Plant (Alternative 1), and an alternative without pumping from either station (Alternative 2).

This phasing schedule is based on a progress report by the California Energy Commission (2015) indicating that HGS will cease OTC before AES.

Figure 1-1. Power Plant Cooling Water Intake and Outfall Locations

2.0 SCOPE OF WORK

This study follows the scope of work agreed upon between the City and M&N on March 19, 2015. Specific tasks include:

1. **Model the Power Plant Pumping Scenarios of Baseline and Alternatives 1 and 2:** In 2007, M&N developed a numerical model to simulate the hydrodynamics in Alamitos Bay (Moffatt & Nichol, 2007); its output included the residence time at various points within Alamitos Bay. In 2011, this model was updated as part of the Los Cerritos Wetlands Conceptual Restoration Plan (CRP) (Moffatt & Nichol, 2011). This task entails modifying the boundary conditions to reflect baseline (current) pumping conditions, and the reduced pumping conditions described by Alternatives 1 and 2. Simulations were performed under each of these three scenarios.

2. **Prepare Maps of Residence Time Results:** Maps showing results of residence time predictions (days) throughout Alamitos Bay will be prepared.
3. **Analyze Secondary Impacts to Water Quality, Biology, Sedimentation and Possibly Other Factors:** This task involves qualitatively evaluating potential impacts on water quality parameters of temperature and dissolved oxygen, and possible effects to marine biology. Potential changes to sedimentation patterns will also be assessed based on hydrodynamic modeling results (velocity). This task will be limited based on available data.

3.0 METHODS

The model developed for this study is a two-dimensional depth averaged finite element hydrodynamic numerical model referred to as RMA, a federally-developed and approved model for assessing hydrodynamic problems and solutions. Boundary conditions for the model consist of tidal inputs and pumping rates. Dry conditions (i.e., no storm flows from the San Gabriel River and the Los Cerritos Channel) and no sea level rise were assumed.

3.1 Model Description

RMA is part of the TABS2 collection of generalized computer pre- and post-processor utility codes integrated into a numerical modeling system, used for studying two-dimensional (2-D) depth-averaged hydrodynamics, transport and sedimentation problems in rivers, reservoirs, bays and estuaries. The TABS2 (McAnally and Thomas, 1980) modeling system was developed by the U.S. Army Corps of Engineers (USACE), and consists of two-dimensional, vertically averaged finite element hydrodynamics (RMA2), pollutant transport/water quality (RMA4) and sediment transport models (SED2D). RMA2 and RMA4 were used for this analysis. A complete description of this modelling suite – including a rationale for its selection for this application, computation details, and model calibration – can be found in Moffatt & Nichol, 2011.

3.1.1 Hydrodynamic Analysis

RMA2 simulates 2-D flow by solving the depth-averaged Navier Stokes equations for flow velocity and water depth. The equations account for friction losses, eddy viscosity, Coriolis forces and surface wind stresses. It uses a finite element grid, suitable for irregular topography/bathymetry and shorelines of wetlands. At each node in the grid, flow characteristics are assumed to be uniform throughout the water column at each node such that stratification is not described.

3.1.2 Residence Time Analysis

RMA4 is a finite element water quality transport numerical model in which the depth concentration distribution is assumed uniform. It can compute concentrations for up to 6 constituents, either conservative or non-conservative, within the computational mesh domain based on the RMA2 results.

In this case, RMA4 was used to simulate the tidal flushing efficiency of water quality constituents within the model domain. It was used specifically to calculate residence time, which describes the average time that a particle resides in a hydraulic system and thus provides a useful measure of the rate at which water in the hydraulic system is renewed. Because constituent concentrations in a water body reflect a balance between the rate of constituent supply and the rate of constituent removal by tidal flushing, residence time provides an indirect measure of water quality. Additional details on calculating residence time from RMA4 results can be seen in Moffatt & Nichol, 2007.

3.2 Model Domain

The RMA model suite requires the hydraulic system to be represented by a network of nodal points defined by coordinates in the horizontal plane and by water depths; elements are created by connecting these adjacent points to form areas. Nodes can be connected to form 1- and 2-dimensional elements, having two to four nodes. The resulting nodal/element network is commonly called a finite element mesh and provides a computerized representation of the basin geometry and bathymetry.

As stated in Section 1.0, the RMA2 model for this study was the same as for the Los Cerritos Wetlands modeling study (Moffatt & Nichol, 2011). The domain of this model included the entire Alamitos Bay, Marine Stadium, Colorado Lagoon, several miles along the San Gabriel River and Los Cerritos Channel, and the nearshore ocean. The ocean boundary is approximately two miles from the shoreline; this distance was deemed to be sufficient to minimize boundary effects within the area of interest. The model grid can be seen in Figure 3-1; a complete description of the model is contained in Moffatt & Nichol, 2011.

Figure 3-1. Finite Element Model for the Los Cerritos Wetlands (aerial image courtesy of Google Earth)

3.3 Boundary Conditions

Boundary conditions are the inputs to the model. For this study, boundary conditions include tides and pumping rates. Because dry conditions were assumed, runoff is negligible in comparison to tidal forcing and is not included in the simulations. Groundwater within the study area has a relatively high elevation, has been found to be saline and is strongly influenced by tidal movement (AECOM, 2011); however it is not a relevant factor for hydraulic modeling of pumping impacts.

3.3.1 Tides

There are no official tide stations within Alamitos Bay; the nearest tide station administered by National Oceanic and Atmospheric Administration (NOAA) at Los Angeles Outer Harbor (NOAA, 2004) was assumed to represent the ocean boundary tidal conditions. The diurnal tide range is approximately 5.49 feet from Mean Lower Low

Water to Mean Higher High Water. Tidal data over a 19-year tidal epoch were analyzed to extract a 15.6 day period selected to represent typical spring tide conditions; these tidal data can be seen in Figure 3-2. The tidal boundary conditions also include a 1.2 day (29.4 hours) warmup period, as indicated in Figure 3-2.

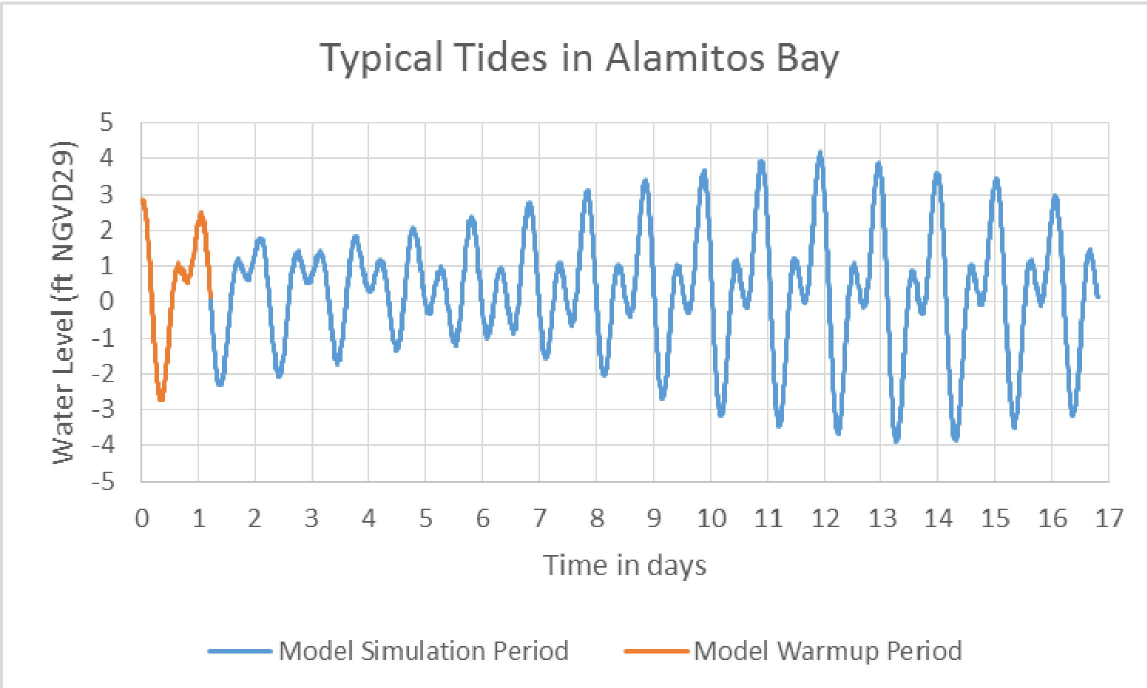

Figure 3-2. Tidal Range Used for RMA2 Boundary Conditions

3.3.2 Pumping Rates

As mentioned in Section 1.0, three alternative pumping scenarios were assumed. These scenarios are:

- Baseline: current conditions, as of today, with pumps operating;
- Alternative 1: the HGS (all units) shuts down and the AES Alamitos facility continues pumping; and
- Alterative 2: both HGS (all units) and the AES facility (all units) shut down.

Typical pumping rates were determined from recent pumping data provided from the two facilities. A description of the two facilities and derivation of representative pumping rates is described below. Pumping was simulated by a constant flow rate.

Haynes Generating Station

The HGS withdraws water from Alamitos Bay through seven openings in a bulkhead wall in the northeast corner of the Long Beach Marina. Seven 8-foot diameter pipes lead under the San Gabriel River to a manmade canal 1.5 miles northeast of the station, where screen houses draw the water into the facility itself. Once-through cooled water is combined with low-volume waste discharges generated by HGS and discharged through one of six outfalls to the San Gabriel River. Inlet and outlet locations are provided in Figure 1-1 (Tetra Tech, 2008).

Representative pumping rates were determined from data provided by the facility (Hansen, 2015). Dry season pumping rates from 2013-2015 were averaged over one- and two-week periods, as can be seen in Figure 3-3. The lowest two-week average pumping rate over this time period was 422.2 cubic feet per second; this value was selected for the HGS pumping boundary condition in RMA2 modeling. The lowest observed pumping rate was selected so that baseline residence time values would be conservative.

AES Alamitos Power Station

The AES facility withdraws water from the Los Cerritos Channel through two man-made canals. Once-through cooled water is combined with low-volume waste discharges generated by the facility and discharged through one of three outfalls to the San Gabriel River. Inlet and outlet locations are provided in Figure 1-1 (Tetra Tech, 2008).

Representative pumping rates were determined from data provided by the facility (O'Kane, 2015). Dry season pumping rates from 2013-2015 were averaged over one and two week periods, as can be seen in Figure 3-4. The lowest two-week average pumping rate over this time period was 143.9 cubic feet per second; this value was selected for the HGS pumping boundary condition in RMA2 modeling. The lowest observed pumping rate was selected so that baseline residence time values would be conservative.

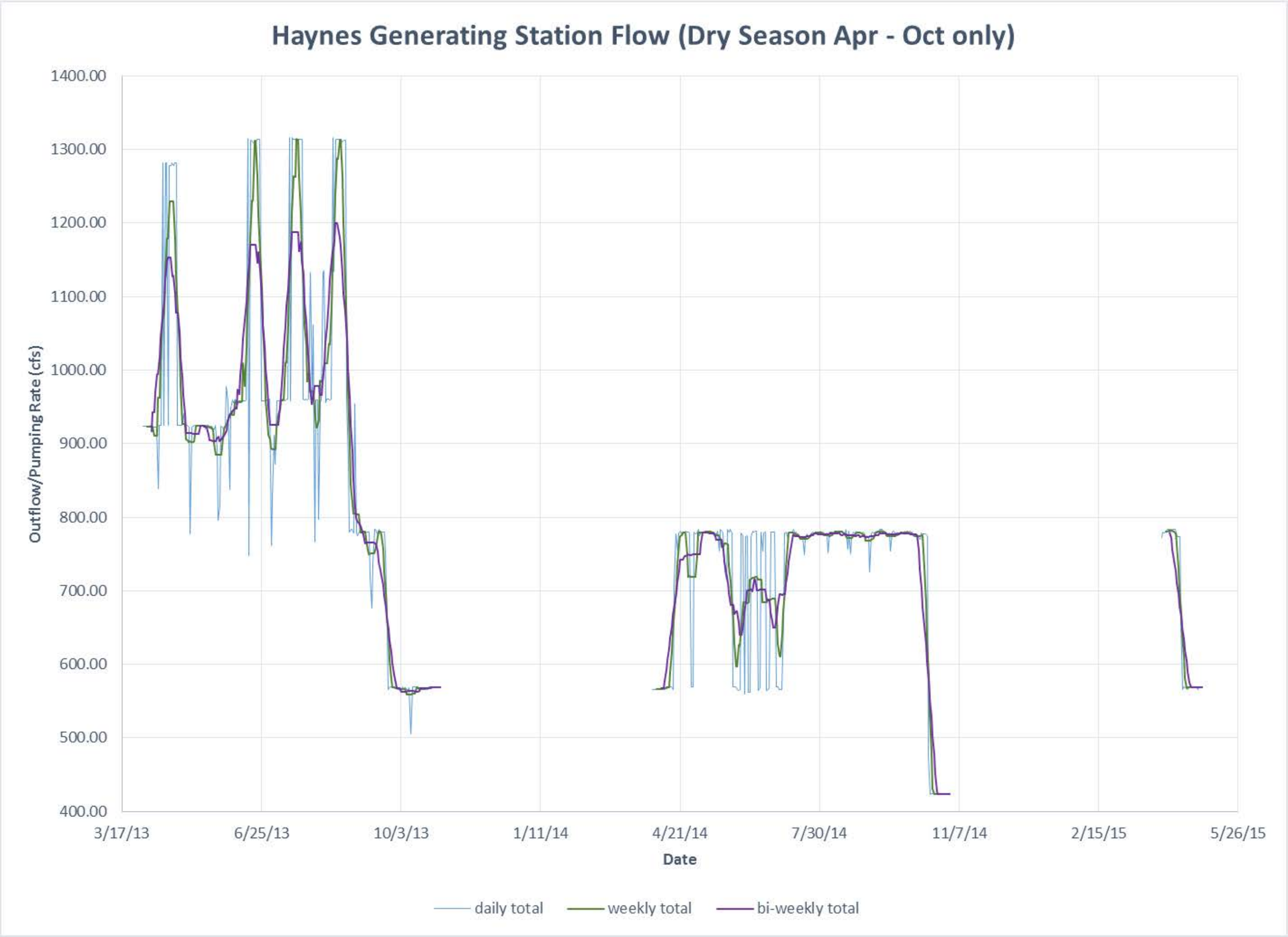

Figure 3-3. HGS Dry Season Pumping Rates, 2013-2015

Source: City of Los Angeles, 2015

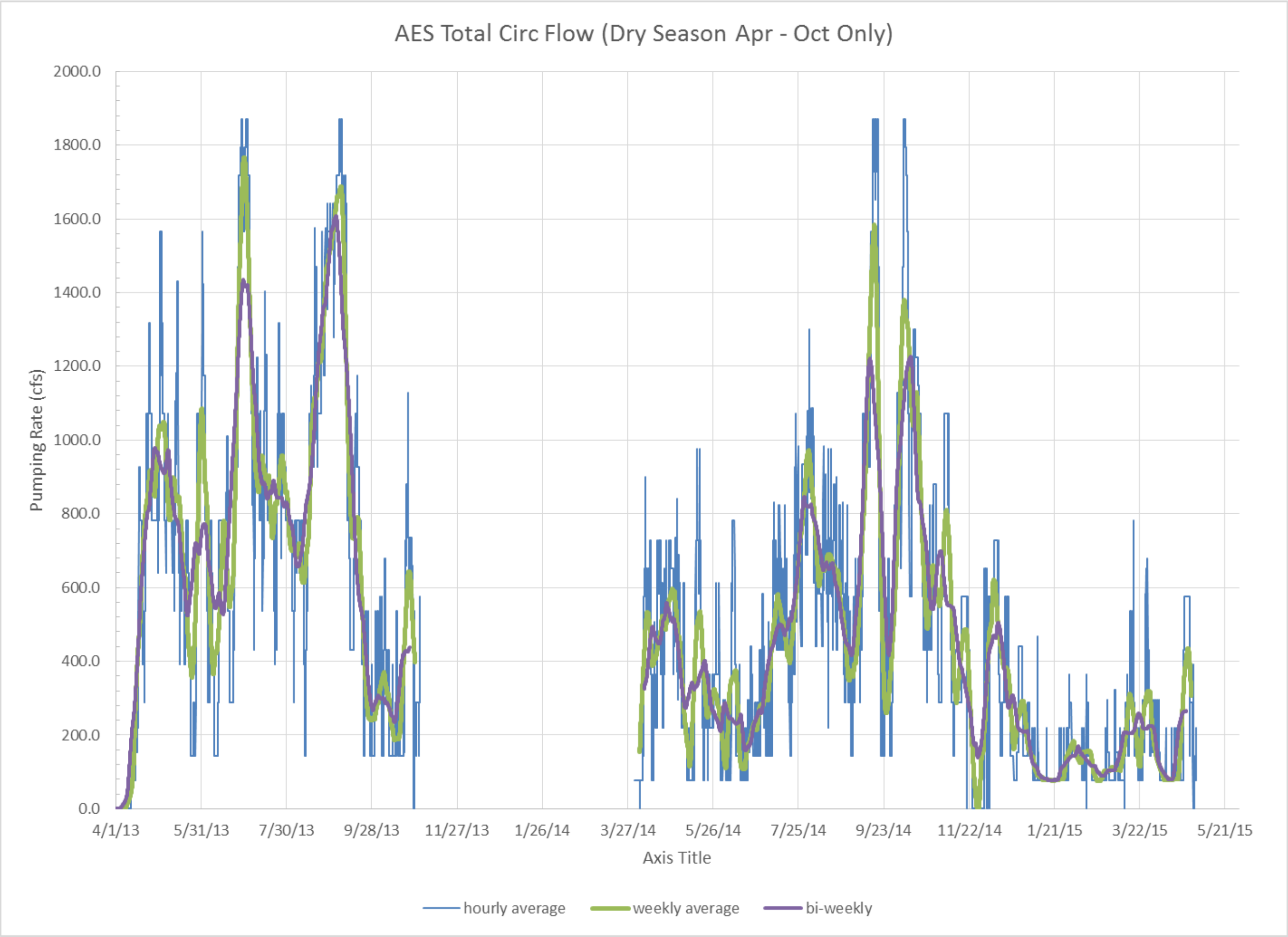

Figure 3-4. AES Alamitos Dry Season Pumping Rates, 2013-2015

Source: AES, 2015

3.4 Simulations

The RMA2 simulation lasted approximately 16.8 days, including both the warmup period and the typical spring and neap tide cycles. The RMA4 simulations used RMA2 output beginning after 29.4 hour warmup period, and continued until sufficient tidal flushing had occurred to determine residence times; RMA2 output was repeated where the RMA4 simulation duration exceeded the RMA2 simulation duration. For the Baseline and Alternative 1 scenarios where RMA4 simulation lasted 15.6 days, or the entire typical tidal period. For the Alternative 2 scenario the RMA4 simulated 20 days. All simulations were performed using the NGVD29 vertical datum.

3.5 Analysis of Secondary Impacts

Seawater residence time in water bodies can affect multiple systems. Because it represents the amount of time for a system to be “flushed” by water from outside the system, it is often used to approximate water quality within a system. Relatively short residence times reflect relatively good water quality, while longer residence times reflect poor water quality while the rest of parameters are assumed equal. This analysis does not consider varying inputs of contaminants and assumes all inputs remain equal throughout the modeling and analysis time period, except the power plants’ pumping rates.

Several water quality parameters could be affected by seawater residence time. These impacts to water quality parameters could in turn affect marine biology by altering habitat in Alamitos Bay. Previous studies have indicated residence times of more than seven days to be problematic for marine habitat (County of Orange, 1996). Predicted residence times will be compared throughout Alamitos Bay for relative qualitative comparisons of water quality parameters of dissolved oxygen and temperature, and for potential effects on biology.

Finally, modeled tidal flow velocity can yield information related to patterns of possible erosion and deposition of sediment. Potential erosion and sedimentation sites will be inferred from model-predicted tidal flow velocities.

4.0 RESULTS

The results of the RMA2 and RMA4 modeling include maps of Alamitos Bay noting the residence time at various locations. The City was particularly interested in the residence time at recreation areas such as Colorado Lagoon and Mother’s Beach; these locations can be seen in Figure 4-1.

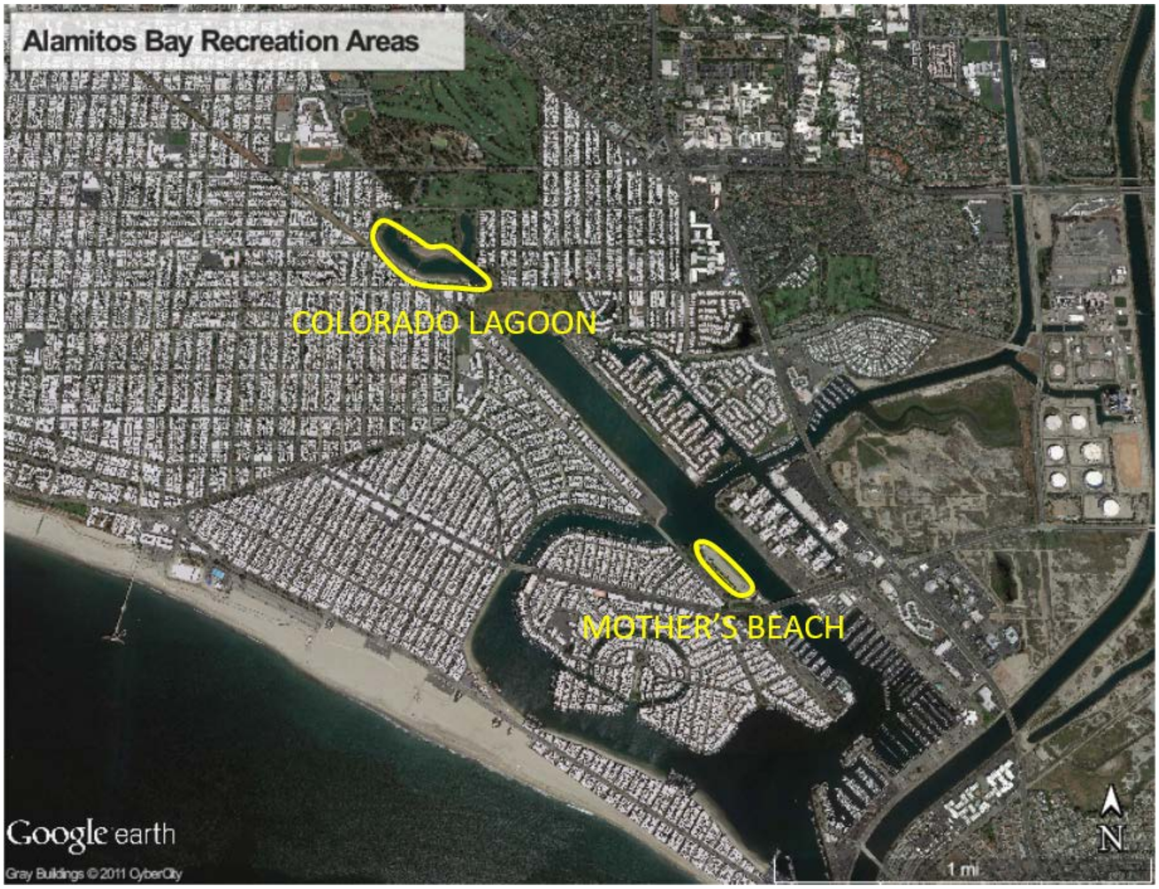

Figure 4-1. Alamitos Bay Recreation Areas

4.1 Residence Times

Residence times throughout Alamitos Bay can be seen in Figure 4-2 through Figure 4-4. These data are also presented in tabular form in Table 4-1. These results indicate that each plant has a significant role in tidal flushing.

Both plants contribute to tidal flushing throughout the entire Bay, while the relative impacts of shutting down each plant are felt more strongly local to the respective intakes. For example, the more seaward points – Alamitos Bay entrance, Alamitos Bay northeast, and the three Naples Channel points – exhibit a higher percent increase in residence time by shutting down the nearby HGS pumps. By contrast, the other, more landward points see a sharper increase in residence time due to restrictions on pumping at the nearby AES facility. Overall, shutdown of the AES plant appears to impact residence time more significantly than shutdown of the Haynes Generating Station.

Table 4-1. Residence Times throughout Alamitos Bay

Alternative	Base Line Condition	Alternative 1	Alternative 2	Impacts of	
Puming Scenarios	AES pumps at 144 cfs	AES pumps at 144 cfs	AES pumps at 0 cfs	HGS Shutdown	AES Shutdown
	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%)
AES Intake North	9.0	11.2	17.0	2.2 (24%)	5.8 (52%)
AES 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%)

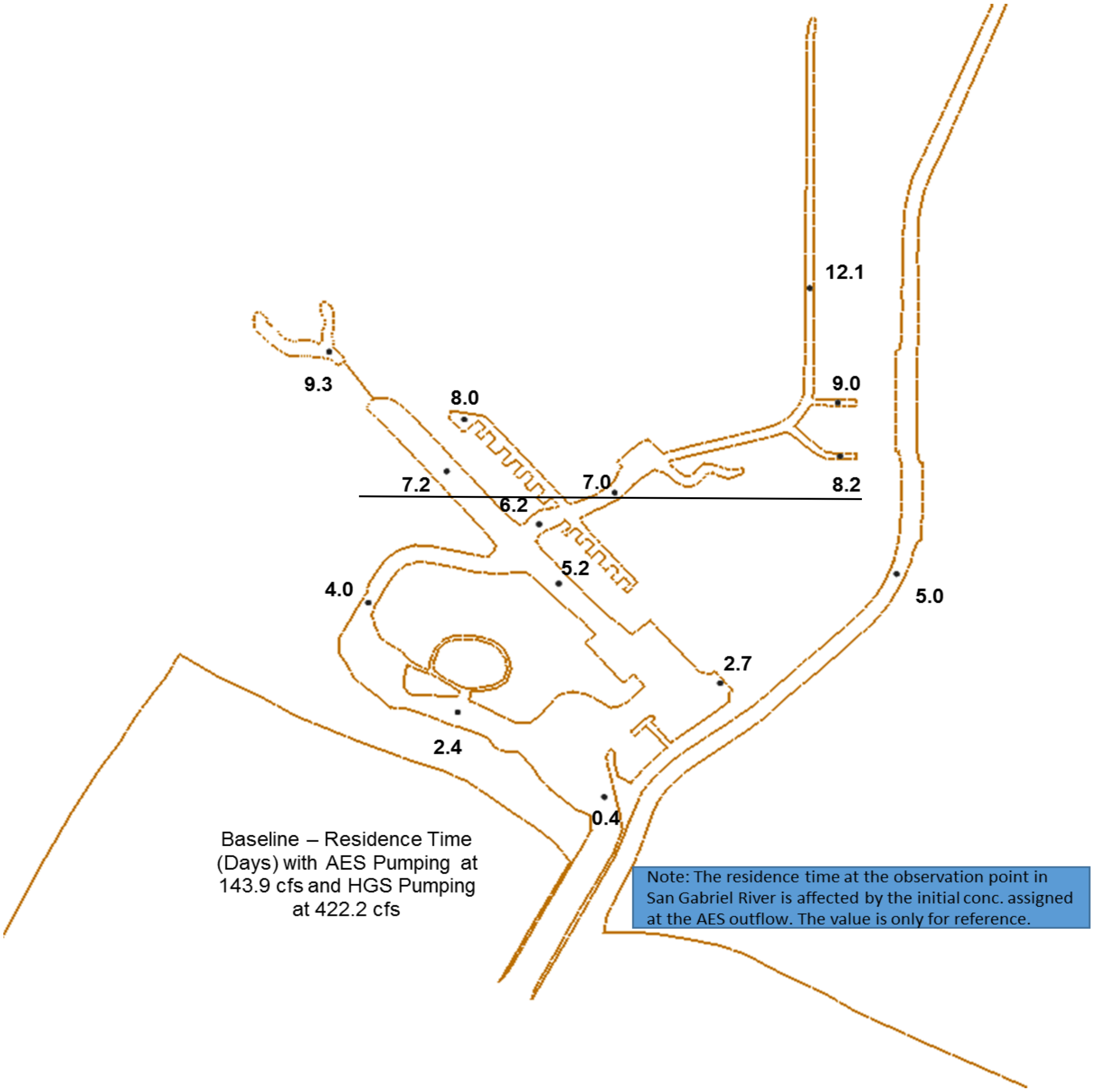

Figure 4-2. Residence Times Throughout Alamitos Bay Under Baseline Conditions

Note: Horizontal line denotes seven day residence time threshold location.

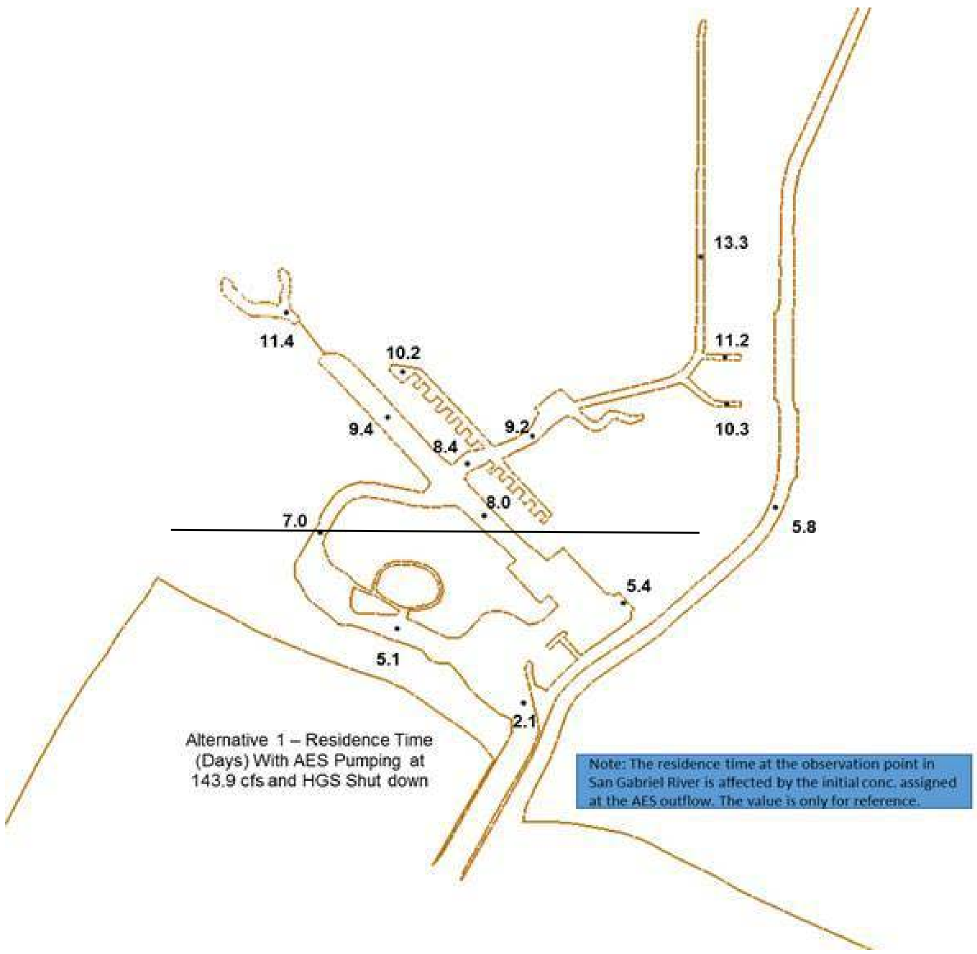

Figure 4-3. Residence Times Throughout Alamitos Bay Under Alternative 1

Note: Horizontal line denotes seven day residence time threshold location.

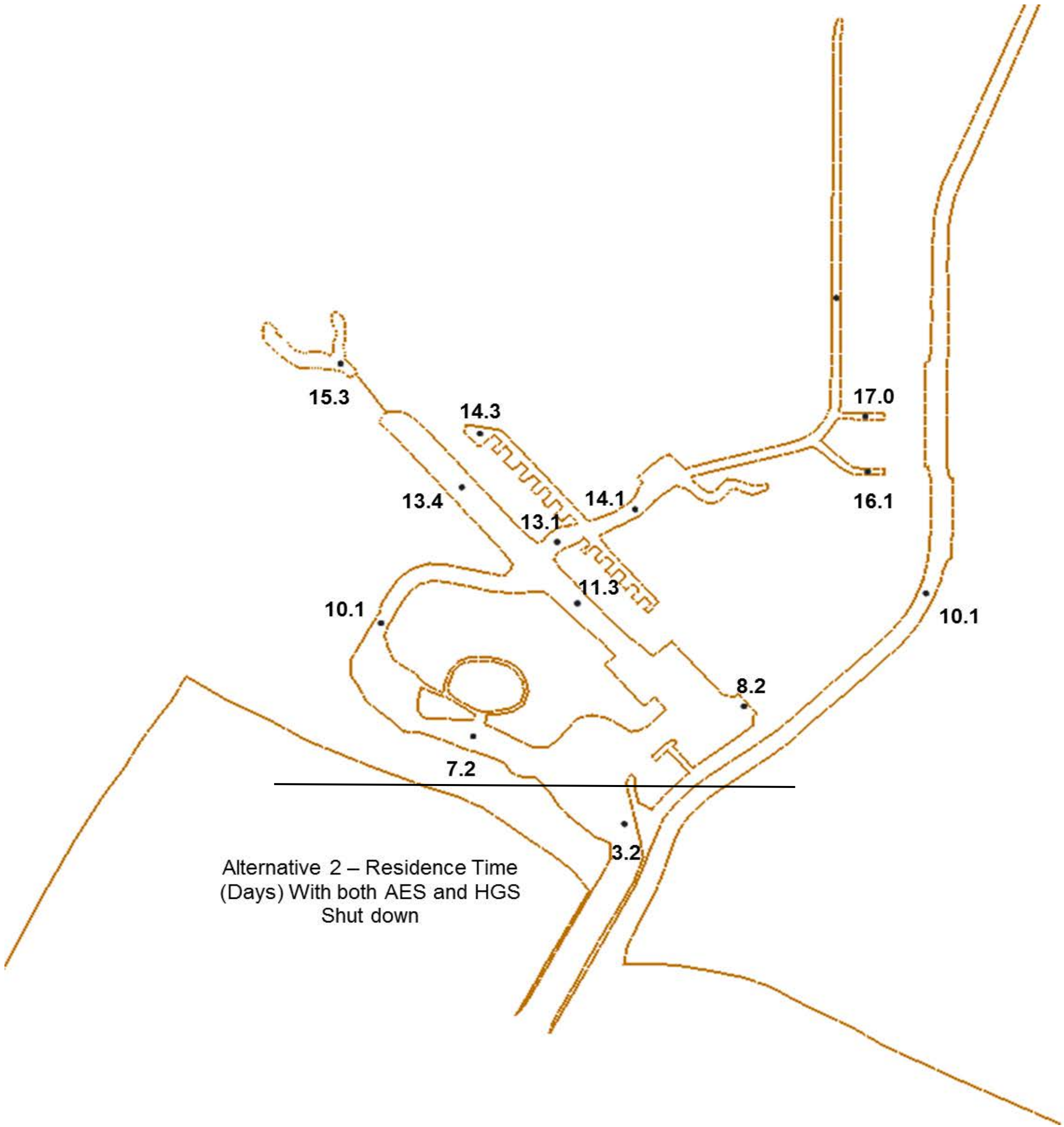

Figure 4-4. Residence Times Throughout Alamitos Bay Under Alternative 2

Note: Horizontal line denotes seven day residence time threshold location.

4.2 Analysis of Secondary Impacts

Secondary impacts on water quality, marine biology, and sedimentation patterns are assessed based on hydrodynamic modeling results. Each impact is addressed below.

4.2.1 Water Quality

In this analysis, the source of seawater is the Pacific Ocean off of Long Beach. Very short residence times within Alamitos Bay, up to 2 days, indicate water quality similar to its source. Ocean seawater near Long Beach has a moderate temperature (57 to 69 degrees Fahrenheit (F), depending on location (NOAA, 2015). The salinity of this seawater is usually between 33 and 35 parts per million (ppm), and the dissolved oxygen (DO) content remains at approximately 10 milligrams per liter (mg/l). Finally, seawater pH is recorded at between 7.5 and 8.5 (Anderson, 2003).

An inverse relationship exists between water DO levels and temperature, with temperature being a causal factor (Anderson, 2003). As the temperature of water increases, its saturation point for dissolved oxygen drops – impeding its ability retain DO. As the temperature of water decreases, the opposite occurs. Therefore, warmer water typically has lower DO than cooler water.

As residence time increases, the water quality in Alamitos Bay may change from that of the Pacific Ocean and begin to reflect typical water quality of enclosed bays. In enclosed bays, water may sit over time without being replenished by new ocean water and thus may begin to accumulate constituents released into the bay. If the bay is relatively stagnant, the top layer tends to heat more rapidly than lower layers, consequently becoming more buoyant and thus supressing vertical mixing throughout the water column. This increases the surface temperature of the water, thus causing DO at the surface to be released into the atmosphere. In addition, this stratification prevents deeper water from replenishing DO used by marine organisms. However, if water continues to circulate, the flow-induced turbulence mixes the water column – thus reducing the build-up of heat energy in surface layers to create a more constant temperature throughout the water column and permitting contact between the oxygen-rich atmosphere and the water throughout the water column.

While DO levels of ocean water remain near 10 mg/l, DO decreases as water stagnates and stratifies. The California Ocean Plan by the State Water Resources Control Board (2012) specifies that DO should remain at 7.0 mg/l long-term to provide suitable marine habitat, and not drop below levels of 5.0 mg/l at a minimum. These lower levels can cause fish and other organisms to stress and potentially 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).

Although DO data are not readily available for Alamitos Bay, it is reasonable to assume that DO levels approximate those of the ocean (near 10 gm/l) at locations close to the ocean entrance channel. Levels of DO in more distant areas of Alamitos Bay are potentially lower depending on seawater residence time. However, DO levels in the Bay will not likely drop to levels that threaten marine life as the Bay is relatively deep and well-oxygenated, and water is not expected to stagnate throughout the main channels, even under reduced pumping conditions. Therefore, DO may not be threatened by relatively long residence times in Alamitos Bay with the possible exception of the enclosed area of Colorado Lagoon.

Colorado Lagoon may possess an existing residence time of 9.3 days, and that could increase to 15.3 days with cessation of pumping. An increase in residence time of 66% could lead to long-term issues with DO in Colorado Lagoon during summer. M&N has previously performed DO monitoring at Colorado Lagoon, and California State

University, Long Beach has an ongoing monitoring program. Levels of DO in the Lagoon typically range from 4 to 8 mg/l (M&N, 2011b). In May through August of 2015 the DO levels in Colorado Lagoon were recorded at between 2.8 and 5.2 mg/l with an average value of 4.8 mg/l. An increase in residence time could impact this site in terms of DO levels.

Although not included in the scope of work it should be noted that changes to residence time may impact bacteria populations. Bacteria is an important water quality constituent as it may be the cause of beach postings and closures at Mother's Beach. Residence time may indicate the system's ability to disperse the organisms via tidal currents. Shorter residence times suggest better circulation and dispersal of constituents in the water column, while longer residence times suggest poorer circulation and accumulation/build-up of constituents in the water column. Thus, problematic locations such as Mother's Beach would benefit from relatively short residence times; residence times at this location trend from 5 days under existing conditions, to 8 days under Alternative 1 and 11 days under Alternative 2. Longer residence times at Mother's Beach may exacerbate the existing situation of periodic closures due to high bacteria levels.

4.2.2 Biology

Water quality changes have the potential to impact marine biology through placing stresses on aquatic habitat. It has been suggested that the threshold seawater residence time for suitable water quality for habitat is seven days (County of Orange, 1996). Above this threshold, marine habitat may begin to feel stresses due to higher water temperatures and lower DO.

Figures 4-2 through 4-4 show the approximate location of exceedance of the seven day threshold. For existing conditions, that threshold is reached and exceeded within Marine Stadium and at areas farther upstream and upstream of Pacific Coast Highway (PCH) within the Los Cerritos Channel. As pumping ceases first at HGS, the location of exceedance of the seven day threshold moves farther downstream to near Mother's Beach and Bayshore Aquatic Park. As pumping ceases at both HGS and AES, the location of exceedance of the seven day threshold moves farthest downstream to the most downstream end of Alamitos Bay.

Habitat areas most susceptible to adverse impacts from longer residence times include Colorado Lagoon and Los Cerritos Wetlands (Steamshovel Slough on the Synergy Property). Both sites possess functioning salt water wetland habitat that may experience increased stress as residence time increases. Stresses on wetlands may in turn affect fish, invertebrates, plants, birds, and animals.

Limited water circulation and relatively long residence times can encourage algal blooms due to accumulation of nutrients that enter the water column from upland sources (urban low flows). Algae blooms as a mat over the water surface, causing DO levels to fluctuate more significantly, especially becoming depressed just prior to sunrise (from plant respiration throughout the night). As algal blooms die off over time, they sink to the seabed and begin to decay, a process that requires significant amounts of DO and may cause the water column to become anoxic. This process is known as eutrophication and is associated with extremely poor water quality. The presence of algal blooms is an indicator of compromised water quality and is observed in Colorado Lagoon even after its restoration. Algal blooms also occur in the Steamshovel Slough site within Los Cerritos Wetlands.

4.2.3 Sedimentation

Patterns of sedimentation and erosion are influenced by tidal flow velocity. Peak velocities were extracted from the modeling results at the points shown in Figure 4-5 and can be seen in Table 4-2. Tidal flow velocities are all relatively low, and changes from pumping variations should not result in different patterns of erosion or sedimentation than presently exist. The difference in tidal flow velocities between the alternatives is within 0.3 feet per second and would not likely be measurable in the field. Therefore, based on analyses of these data, ceasing pumping will likely not result in noticeable changes in sediment deposition or erosion in Alamitos Bay.

Table 4-2. Tidal Flow Velocities Throughout Alamitos Bay

Location	Pt Name	Maximum Velocity (feet per second)			Difference Between Base Case and Alternative 2
		Base - both on	Alternative 1 - AES pumping only	Alternative 2 - both off	
Alamitos Bay Entrance	P1	1.0	1.0	1.0	0.0
2nd St. Bridge @ SGR	P2	1.3	1.1	1.0	-0.3
Mother's Beach	P3	0.6	0.5	0.6	0.0
2nd St. @ W. Naples Island Ch	P4	0.5	0.5	0.5	0.0
Los Cerritos Channel Entrance	P5	0.7	0.7	0.7	0.0
PCH Bridge @ Los Cerritos Ch	P6	0.4	0.4	0.5	0.0
AES Intake 6	P7	0.2	0.2	0.0	-0.1
AES Intake 5	P8	0.2	0.2	0.0	-0.2
7th St. @ Los Cerritos Ch	P9	0.5	0.5	0.5	0.0
Spinnaker Bay	P10	0.0	0.0	0.0	0.0
Marine Stadium	P11	0.1	0.1	0.1	0.0
Naples Canal Entrance	P12	0.4	0.4	0.4	0.0
Haynes Intake	P13	0.1	0.0	0.0	-0.1
Colorado Lagoon	P14	0.1	0.1	0.1	0.0

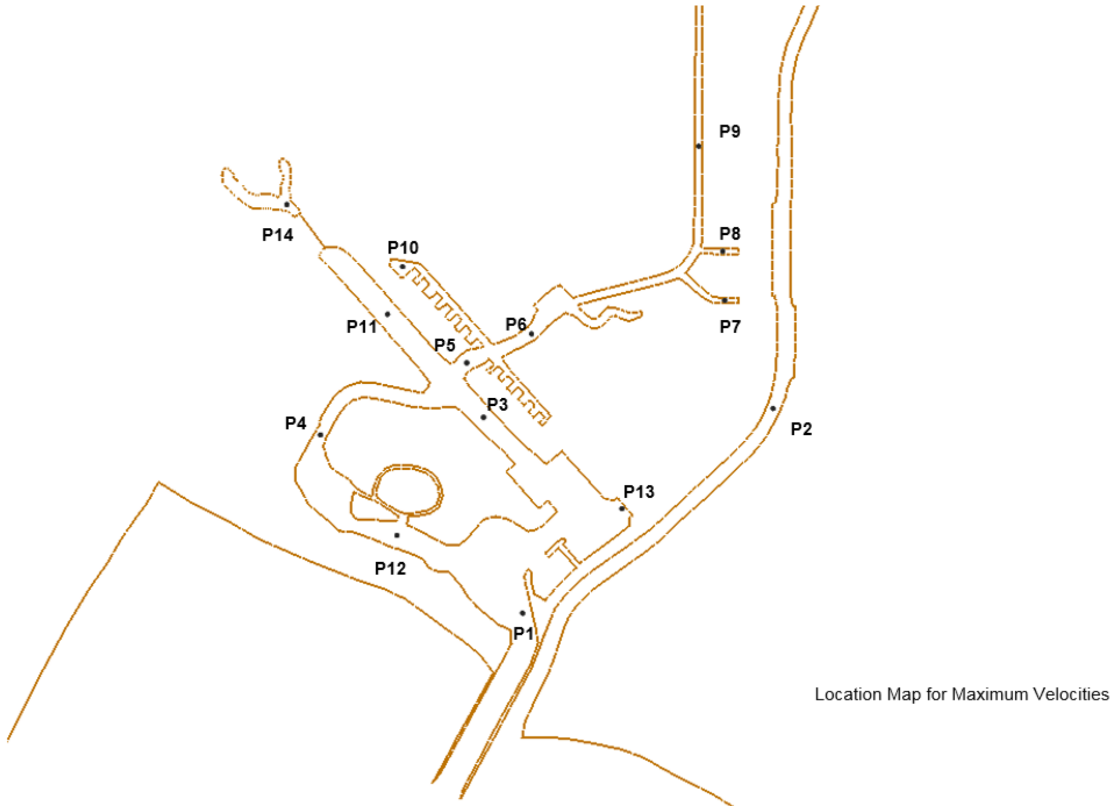

Figure 4-5. Locations Within Alamitos Bay For Tidal Velocity Predictions

5.0 CONCLUSIONS

Numerical modeling of tidal hydrodynamics within Alamitos Bay in Long Beach was conducted to determine potential effects on seawater residence times and related water quality impacts due to cessation of pumping operations at two local power plants. A base line condition and two alternatives were analyzed; these alternatives consisted of the Haynes Generating Station (HGS) ceasing pumping while AES plant continues to pump (Alternative 1), and both plants ceasing pumping (Alternative 2). Results were compared to existing conditions (base line) primarily for seawater residence time, and then analyzed for potential impacts to water quality, biology, and erosion/sedimentation.

Results indicate the following:

1. Seawater residence time increases significantly with shutdown of the AES plant. AES appears to impact residence times more so than shutdown of the Haynes Generating Station. Residence times double in some locations with cessation of pumping by AES relative to existing conditions, and increase by approximately an additional 50% in other locations with cessation of pumping by both plants.

2. Longer residence times have the potential to increase temperatures and reduce DO levels in enclosed bays, especially if stagnation and stratification occurs. However, circulation and mixing is expected to continue even after ceasing pumping, and therefore temperature and DO levels may not be significantly impacted with the exception of Colorado Lagoon that presently experiences low DO levels. However, locations such as Mother's Beach that experience high bacteria levels would benefit from relatively short residence times to dissipate high bacteria concentrations. Bacteria levels may begin to elevate due to lack of dilution/dispersion as residence times at Mother's Beach trend from 5 days under existing condition, to 8 days under Alternative 1, and 11 days under Alternative 2.

3. Under existing conditions the seawater residence time exceeds seven days (a threshold value proposed for healthy aquatic life) within Marine Stadium, Colorado Lagoon, and upstream of Pacific Coast Highway. As pumping ceases at HGS, the location of exceedance of the seven day threshold moves farther downstream to near Mother's Beach and Bayshore Aquatic Park. As pumping ceases at both HGS and AES, the location of exceedance of the seven day threshold moves farthest downstream to the most downstream end of Alamitos Bay. Biological habitat may not be threatened by relatively long residence times in Alamitos Bay with the possible exceptions of Colorado Lagoon and Steamshovel Slough.

4. Varying the power plant pumping scenarios will likely not result in noticeable changes in sediment deposition or erosion in Alamitos Bay. Flow velocities will drop with pumping ceased, but only by a very small amount and the result should not change from existing conditions.

6.0 REFERENCES

AECOM Technical Services, Inc. 2011. Jurisdictional Delineation Report for Waters of the U.S. and State of California, Marketplace Marsh, Long Beach, California, Prepared for the LCWA. April 2011.

Anderson, Genny. 2003. Marine Science. Updated October 8, 2008.

California Energy Commission, 2015. Once-Through Cooling Phase Out. <http://www.energy.ca.gov/renewables/tracking_progress/documents/once_throut h_cooling.pdf>: Updated February 17, 2015.

County of Orange. 1996. Recirculated Draft Environmental Impact Report for the Bolsa Chica Report, Local Coastal Program. State Clearinghouse Number 93-071064. County of Orange. March 20, 1996.

Hansen, M., 2015. "Haynes Generation Station Flow Rates." E-mail to Webb, C.: May 26, 2015.

McAnally, W.H. and Thomas, W.A., 1980. Shear Stress Computations in a Numerical Model or Estuarine Sediment Transport. Memorandum for Record, U.S. Army Corps of Engineers Waterwas Experiment Station, Vicksburg, MS: 1980.

Moffatt & Nichol, 2007. Alamitos Bay Circulation Study. Prepared for the City of Long Beach: August 2007.

_______________, 2011. Los Cerritos Wetlands Conceptual Restoration Plan Hydrology and Hydraulic Baseline Report. Prepared for Los Cerritos Wetlands Authority: September 2011.

_______________, 2011b. Final Pre- and Post-Construction Water Quality Monitoring Report, Colorado Lagoon Improvements, Water Quality Monitoring Program. November 2011.

NOAA, 2004. National Oceanic and Atmospheric Administration, Oceanographic Products and Services division. Web site: http:/ / www.co-ops.nos.noaa.gov/ tide_pred.html.

NOAA, 2015. https://www.nodc.noaa.gov/dsdt/cwtg/all_meanT.html.

O'Kane, S., 2015. "RE: AES plant pump rates." E-mail to Webb, C.: May 1, 2015.

Southern California Coastal Waters Research Project. 2012. Science Supporting Dissolved Oxygen Objectives in California Estuaries. Technical Report 684. December 2012.

State Water Resources Control Board. 2012. California Ocean Plan, Water Quality Control Plan, Ocean Waters Of California. California Environmental Protection Agency.

Sutula M., H. Bailey, and S. Poucher (2012). Science Supporting Dissolved Oxygen Objectives in California Estuaries. Southern California Coastal Water Research Project Technical Report No. 684. December 2012. www.sccwrp.org

Tetra Tech, 2008. California's Coastal Power Plants: Alternative Cooling System Analysis. Prepared for the California Ocean Protection Council: February 2008.