CITY OF LONG BEACH
ALAMITOS BAY WATER QUALITY EHANCEMENT PROJECT

Modeling and Alternatives Analysis for Water Quality Improvements in Alamitos Bay

Prepared for:

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DO	Dissolved Oxygen
EPA	U.S. Environmental Protection Agency
FIB	Fecal Indicator Bacteria
HGS	Haynes Generating Station
LACDPW	Los Angeles County Department of Public Works
LARWQCB	Los Angeles Regional Water Quality Control Board
LCC	Los Cerritos Channel
M&N	Moffatt & Nichol
mgd	Million Gallons per Day
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
MSL	Mean Sea Level
MW	Megawatt
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OTC	Once Through Cooling
the Policy	Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling
RMA Model	Resource Management Associates Model
SGR	San Gabriel River
SLR	Sea Level Rise
State Water Board	State Water Resources Control Board
TEA	Tidal Epoch Analysis
TMDL	Total Maximum Daily Load
TSO	Time Schedule Order
USACE	U.S. Army Corps of Engineers

1. Introduction

The City of Long Beach's (the City's) mission is to maintain clean and safe water for recreational and domestic use. Through various programs – including trash collection, restoration projects, and stormwater treatment – the City has been able to achieve and maintain high water quality in the Alamitos Bay (the Bay) system, which includes Marine Stadium, Los Cerritos Wetlands, Sims Pond, Los Cerritos Channel (LCC) Estuary, and the Long Beach Marina.

The high quality water condition is a result of forced circulation for tidal pressures and the existing pumping associated with once through cooling (OTC) at the AES Alamitos Facility (AES) and Haynes Generating Station (HGS), which contribute to the circulation and, ultimately, the water quality within the Bay. The average annual pump rate for the last 9 years through the HGS is 581 million gallons per day (mgd [900 cubic feet per second, cfs]) and 326 mgd (505 cfs) through the AES facility. Summed, the average annual pump rate for the last 9 years is 907 mgd. The average lowest pump rates that have been observed over a 2-week period (calculated for 2013-2015, dry season, Apr-Oct only) is 93 mgd through the AES facility and 273 mgd through the HGS. Summed, the average lowest pump rate during the dry season over a two-year period is 366 mgd. Pumping of water from the Bay to the San Gabriel River (San Gabriel River (SGR) and the effects of resulting increased circulation within the Bay has created the condition that sets the current water quality and recreational uses of the Bay. however, due to recent policy changes, the pumps will be stopped and it is estimated the water quality condition will be significantly altered.

On May 4, 2010, the State Water Resources Control Board (State Water Board) adopted a Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling (the Policy). The Policy became effective on October 1, 2010. The Policy establishes technology-based standards to implement Federal Clean Water Act Section 316(b) and reduce the harmful effects associated with cooling water intake structures for power generating facilities on marine and estuarine life. The Policy applied to 19 existing power plants using a single-pass system, also known as OTC.

AES has six OTC pumps and HGS has five OTC pumps that are scheduled for removal to comply with the Policy. The final compliance date for the AES facility is December 31, 2020; however, Units 1, 2, and 6 are expected to retire early, by December 31, 2019, to provide emissions offsets for the new 640 megawatt (MW) Combined Cycle Gas Turbine, which has a planned commercial operation date of April 1, 2020. Units 3, 4, and 5 are still expected to meet the Policy compliance date of December 31, 2020. It is possible that an extension will be necessary to meet local capacity needs in the Western Los Angeles Basin due to the delay of the Mesa Loop-In Project. HGS is scheduled to shut down their pumps in 2029.

Previous studies support the fact that the Bay enjoys good water quality partially resulting from the AES and HGS water pumping activities, which create currents. These currents pull ocean water into the Bay and promote mixing (M&N 2007, 2015). Cessation of pumping by the AES facility and HGS will retard water circulation patterns in the Bay. Specifically, tidal flushing is predicted to decrease and seawater residence time will increase by several days in certain portions of the Bay (M&N 2007, 2011). This increase in residence time is expected to increase the concentrations of bacteria and other constituents in certain areas of the Bay and result in degraded water quality. In addition, cessation of the pumps will limit water movement in the intake channels, leaving those areas to stagnate.

A similar condition recently occurred in Oxnard at Channel Islands Harbor. NRG Energy shut down the Mandalay Generating Station, which used OTC, on February 18, 2018. That summer, poor water quality (green appearance, algal blooms, and low dissolved oxygen [DO]) was observed. To date, the City of

Oxnard has not been successful in finding a solution to return the water quality to pre-shutdown conditions.

The City is working to avoid a similar situation at the Bay by identifying strategies to keep active circulation in place as the OTC pumps are stopped.

1.1 Approach

Multiple strategies have been considered to maintain water quality within the Bay after the pumps shut. Long-term strategies are primarily related to source control from the watershed, with possibly some limited continued pumping, and short-term strategies consist of maintaining pumping that enhances circulation within the Bay. This study focuses on a pumping solution and builds on other studies that examined alternative pumping locations or water structures to enhance circulation. A numerical model was used to analyze the effectiveness of the following on circulation times (i.e., residence times):

- New tidal inlet near 54th Street along Belmont Shore
- Circulators to move water focused on certain areas
- Pumping from various locations in the Bay to SGR, the mouth of the Bay, and other areas in the Bay

The most effective method of moving water through the Bay was pumping from the AES facility to the SGR due to bay-wide effects of removing water from the uppermost portions of the Bay to draw in new seawater. As such, establishing the optimum pumping rate through the AES facility that provides the most similar level of circulation but is protective of fish to minimize or prevent fish impingement related impacts will be evaluated. This study also evaluates water quality issues associated with continued pumping, as the SGR has established water quality limits for effluent. The study approach consists of the following:

- Use a hydrodynamic model to show the change in residence time and qualitatively discuss how increased residence time leads to increased potential of exceedances of bacteria.
- Reevaluate the pumping effectiveness of alternative pump locations in influencing residence time and the potential water quality exceedances of bacteria at Mother's Beach using fish-friendly pump rates.
- Evaluate copper loading to the SGR under current and future pumping scenarios.

1.2 Objective

The primary purpose of this report is to confirm the optimal pumping rate and assess the effects of pumping on residence time and apply that information to estimate bacteria levels within the Bay. This assessment is based on hydrodynamic modeling that quantifies the benefit of pumping at AES under different pumping alternatives, including different pumping rates and frequencies, as shown in Table 1-1. The results are used to determine optimal pumping operations that contribute to the highest water quality.

Table 1-1: Pumping Scenarios Simulated at Current AES Pumping Locations

Pumping Scenario	Pumping Rate
1	No pumping
2	400 cfs/constant
3	600 cfs/intermittent (12 hours)
4	600 cfs/intermittent (ebb tides only)

Moffatt & Nichol (M&N) developed a two-dimensional (2-D) finite element model system to simulate the changes in these metrics/constituents throughout the system under different pumping schemes. Model output includes residence time estimates and bacterial concentrations at various locations within the Bay including: LCC North, LCC Central, LCC South, AES Intake North, AES Intake South, Spinnaker Bay, Colorado Lagoon, Marine Stadium, Naples Channel North, Naples Channel West, Naples Channel South, AES Bay Northeast, and Alamitos Bay Entrance.

Additional simulations were performed to investigate residence times and bacteria levels resulting from pumping[1] at various intake and discharge locations during both dry weather and wet weather (2-year and 50-year storms) at a constant 400 cfs, as follows:

1. Pumping from the existing station at Mother's Beach to San Pedro Bay via underwater pipeline.
2. Pumping from the existing station near Bayshore Park to San Pedro Bay via underwater pipeline.
3. Pumping from AES Plant to the mouth of the Bay.

1.3 Previous Studies

The City has long been engaged in studies to understand circulation and water quality within the Bay and continues to explore short- and long-term actions to maintain high water quality. The following studies were completed pertaining to water quality at the Bay:

- In 2007, the City commissioned a study of water circulation throughout the Bay to identify any potential causes of stagnation or other conditions that could lead to poor flushing and poor water quality (M&N 2007). The study indicated that pumping associated with OTC at the AES and HGS plants plays a crucial role in circulation within the Bay; quantitatively, pumping reduces residence times by approximately 50% (indicating that pumping approximately doubles the circulation efficiency).
- In 2011, the M&N 2007 study was applied to the Los Cerritos Wetlands Conceptual Restoration Plan (CRP) Project, with additional expansion of including the Northern Area (Synergy Property) . The findings of circulation patterns within the Bay remained the same as the 2007 study.
- A subsequent study in 2015 (M&N) compared the effect of pumping at the two facilities on overall circulation within the Bay. The result was that the AES plant has a much more substantial impact on circulation, approximately 50% of the observed circulation is due to the AES pumps. Because AES intakes are located farther upstream of HGS, its impact encompasses a greater portion of the Bay. Moreover, its location on LCC allows for trash from LCC sources to be collected prior to entering into the Bay.
- In 2016, M&N performed an assessment of water quality in the Bay, focusing on water quality sampling and analysis of water quality programs and policies. Water quality monitoring showed the Bay to have relatively high water quality, with the exception of exceedances of water quality objectives for copper and bacteria in specific locations. This effort also included an evaluation of fish-friendly pump technology, showing these pumps to have over 95% fish survival rates.
- In 2019, an engineering feasibility study to evaluate the effectiveness of installing new fish friendly

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[1] *The model is a hydrodynamic and transport model that is capable of modeling flow dynamics and conservative constituents. It does not have chemical fate and sediment transport added to it for total and dissolved metals (copper). This study uses a conservative approach and dilution to illustrate effectiveness of pumping. If the water does not move, the concentrations stay similar in that area longer. Days of exceedance were modeled to illustrate potential for extended water quality impacts when pumps work at different rates.*

pumps at the AES facility was conducted (M&N 2019a). The feasibility study included preliminary drawings, permitting considerations, and coordination with AES and the Los Angeles Regional Water Quality Control Board (LARWQCB). A key finding of this study confirmed 400 cfs, approximately 258 mgd, is the maximum pumping rate that is protective of fish to reduce impingement impacts.

- In 2019 a current water quality conditions summary (M&N 2019b) compiling copper and bacteria data within the Bay and developing water quality summary for copper, enterococcus, fecal coliform, and total coliform for wet and dry conditions was developed. These distributions form the basis for the existing water quality as used in this report.

2. Physical Factors that Promote Circulation

Circulation in the Bay is driven by three primary sources: tidal flushing, riverine inflows, and pumping. Each of these processes are described below.

Circulation for most of the Bay is constant and well-distributed throughout the Bay. There are only a few confined areas that suffer from relatively low mixing (e.g., Colorado Lagoon, which is connected to Marine Stadium by a culvert).

2.1 Tidal Flushing

Tidal flushing is the key driver of circulation within the Bay. Flood tides cause the movement of clean ocean water into the Bay, where it mixes with the water within the Bay. During ebb tides, the well-mixed water is removed from the Bay.

Long Beach has mixed semi-diurnal tides, meaning that there are approximately two high and low tides each day, with one high tide and one low tide being more severe than the other (i.e., a higher high tide and a lower low tide). As a result, the process described above occurs twice per day, with more ocean water advected into the system during the higher high tide and more water being returned to the ocean during the lower low tide.

Each individual flood and ebb tide results in a short-duration (~6 hour) net upstream and net downstream flow, respectively. Over an entire tidal cycle, however, there is zero net flow (i.e., the volume that flows into the Bay is equal to the amount of water that flows out of the Bay); the overall result of tidal flushing is the net circulation of water.

Tidal data in Long Beach is based on the nearest tide station administered by National Oceanic and Atmospheric Administration (NOAA) at Los Angeles Outer Harbor (NOAA 2004). Data from this station was used to represent the ocean boundary tidal conditions. The diurnal tide range is approximately 5.49 feet between Mean Lower Low Water (MLLW) and Mean Higher High Water (MHHW). Mean Sea Level (MSL) is 2.82 feet above MLLW.

Tidal data is applied to the hydrodynamic model at the offshore boundaries, as described in Section 3.2.2.1.

2.2 Riverine Inflows

LCC receives drainage from a 17,711-acre watershed and discharges an average of 2 cfs during dry weather and has a 2-year storm discharge of just under 5,000 cfs. (USEPA 2010).

Freshwater discharge from LCC and stormwater also contribute to flushing within the Bay. Freshwater discharged to the Bay creates a net flow towards the ocean, causing water within the Bay to flow towards the Ocean. However, freshwater input from LCC and stormwater are key sources of pollution to the Bay. As shown by the data compiled by M&N (2019b), high bacteria concentrations generally follow storm event bacteria from the LCC watershed into the Bay. Moreover, observations by the City indicate that LCC is a key source of trash to the Bay.

Colorado Lagoon has much lower storm discharges than LCC, with a 2-year storm flow under 100 cfs. However, because the storage capacity of Colorado Lagoon is similarly small, and because exchange between Colorado Lagoon and the Bay is inefficient, runoff events cause the constituent concentrations within Colorado Lagoon to reflect the concentrations in the runoff for extended periods of time.

Therefore, these storm flows are important to include in the model because they drive concentrations within Colorado Lagoon.

SGR has a very high discharge rate, with a 2-year storm exceeding 17,000 cfs. These discharges cause very fast flushing of the SGR to the ocean. Thus, while they do not contribute to flushing within the Bay, they do accelerate the transport of AES discharge to the ocean.

M&N compiled riverine inflow data from multiple sources. The hydrograph for the LCC was provided by Los Angeles County Department of Public Works (Imaa 2015), the hydrograph of outflow from the Colorado Lagoon was provided by Everest International Consultants, Inc. (2007), and the hydrograph for the SGR was derived from USACE (1991). Section 3.2.2.2 describes how riverine inflow was applied to the hydrodynamic model.

2.3 Pumping

As shown by M&N (2007), pumping accelerates the circulation caused by tidal flushing. From a physical perspective, pumping stimulates tidal flushing in the Bay and riverine flushing in the SGR, effectively increasing circulation in both water bodies. In the Bay, pumping augments the flow caused by flood tides, amplifying the rate at which ocean water moves upstream. The water is pumped to the SGR, where it has the same effect as adding riverine flow, causing a net ocean-ward flow of the power plant discharge and enhancing flushing of the SGR estuary.

Pumping currently occurs at both AES and HGS; the intake and outfall (i.e., discharge) locations are shown in Figure 2-1. It is anticipated that pumping at AES will terminate in 2020 and that pumping at HGS will terminate in 2029.

Figure 2-1:Power Plant Cooling Water Intake and Outfall Locations

The historical pumping data from AES were provided by AES in 2018. The flow statistics are compiled for the three discharge locations (EFF-001, EFF-002, and EFF-003), provided in Table 2-1. The monthly average pumping rates and the permitted pumping rates are plotted in Figure 2-2. The average pump rate ranges from 200 to 500 mgd (combined effluent of EFF-001, EFF-002, and EFF-003). For each effluent location, the percent of time each pump was performing at the maximum permitted rate was assessed. The maximum pumping rate occurred between 4 and 16% of the time, depending on the effluent location (i.e., EFF-001, EFF-002, and EFF-003). Therefore, actual pumping was much less than the permit limits.

Table 2-1: Discharge Statistics at AES Effluents EFF-01, EFF-02 and EFF-03[1]

Location	Permitted Daily Discharge (mgd)	Daily Discharge (Mgal)			Annual Total (Mgal)	Dry Season Total (Mgal)	Wet Season Total (Mgal)
		Max	Mean	STD			
EFF-001	208.2	260 (4%[2])	82	69	29,834	16,335	13,479
EFF-002	389	392 (16%[2])	189	112	68,985	38,676	30,310
EFF-003	674.1	668 (9%[2])	104	150	38,028	27,878	10,150
Total	1271.3	N/A	375	N/A	136,847	82,889	43,789

[1] Statistics calculated from one-year data between 2016 to 2018 with best data coverage. Data gaps were filled with linear interpolation.

[2] Percent of the time when pumps are at max discharge rate (> 90% of the permitted discharge rate).

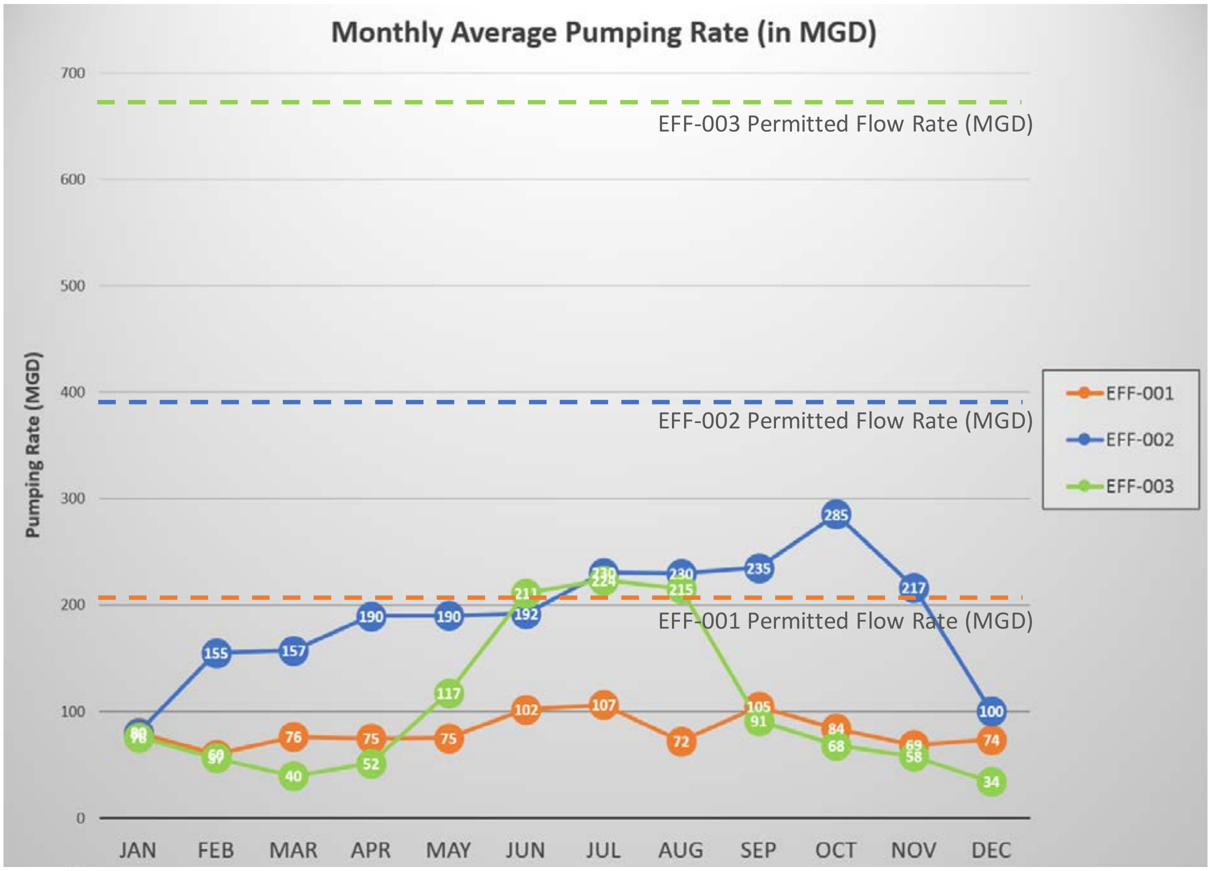

Figure 2-2: Monthly Average Pumping Data at AES Effluents

As noted above, hydrodynamic modeling investigated the effects of pumping at 258 mgd in order to minimize fish impingement. The simulations assume no pumping at HGS as this study is focused on evaluating the pumping impact from AES only. From previous work (M&N 2011) it was demonstrated that the HGS pumps had much less impact on overall Bay circulation than the AES pumps. This was further confirmed with a model sensitivity run (pumping at both HGS and AES was again compared to pumping only at AES). The impacts are discussed in Section 4.1.3.

3. Hydrodynamic Model

M&N used the 2-D Adaptive Hydraulics (AdH) model to assess residence time and bacteria concentrations within the Bay. This section focuses on the hydrodynamic model; it is the basis for simulating water circulation and water quality within the Bay. The hydrodynamic module of the AdH model simulates the following: typical tidal conditions, riverine inflows, and pumping rates. Residence time and water quality constituent concentrations were then solved by the AdH transport module. This section describes the model domain and bathymetry, hydrodynamic model setup and verification, and induces the different model scenarios considered. The details of the AdH transport module, including the details and results of modeling residence time and bacteria concentrations, are presented in Section 4.

3.1 Model Description

The AdH model is a finite element numerical modeling package, originally developed by the U.S. Army Corps of Engineers (USACE). It is capable of modeling one-, two- and three-dimensional flow and transport. The AdH model can simulate a wide range of flow conditions, including tidal flow, high and low flow riverine and channel discharges, and overland flow during flooding. AdH can also simulate the transport of conservative tracers, salinity, and water temperature within the water column, as well as sediment transport that is coupled to bed and hydrodynamic changes.

This study specifically uses the 2-D shallow water module in the AdH model and simulates hydrodynamics 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 wetland shorelines. At each node in the grid, flow characteristics are assumed to be uniform throughout the water column such that stratification does not occur. This is a reasonable assumption as the Bay is shallow without deep pockets to promote stratification.

3.2 Model Setup

3.2.1 Model Domain and Bathymetry

The model domain indicated in Figure 3-1 includes all of the Bay and its components (LCC, Colorado Lagoon, Marine Stadium, Spinnaker Bay, and Los Cerritos Wetland), the SGR, and the nearshore Pacific Ocean.

The 2-D AdH model uses linear triangular elements. The model mesh for this study has total of 9,817 nodes and 17,449 elements. This finite element mesh includes a sufficiently large model domain such that offshore boundaries are well away from the area of interest. The boundaries at LCC and SGR are located upstream of tidal influence, such that boundary conditions include only freshwater runoff (therefore, tidal boundary conditions are not required). The model mesh is constructed in a way that smooth bathymetric contours, gradual element area changes, and mild depth changes are followed. A minimum of three elements across the channel are implemented throughout the model to provide sufficient resolution for accurate representation of channel conveyance. The culverts that connects the Colorado Lagoon and Marine Stadium are modeled as a hydraulic structure in the model.

Figure 3-1:AdH Model Mesh Developed for this Study

The model bathymetry shown in Figure 3-2 is composed by the following sources of data, as described in a previous report (M&N 2007):

- Nautical chart #18749 by NOAA;
- February 2004 survey of Colorado Lagoon and partial Marine Stadium by Los Angeles County Department of Public Works (LACDPW);
- Culvert design drawings by the City; and
- Depth readings of LCC and SGR from the City.

These bathymetric data were compiled and then interpolated to the model mesh. The model mesh is projected to NAD 83 California Zone 6 horizontal coordinate system, and the bathymetry is feet, relative to NGVD 29 vertical datum. The color palette in Figure 3-2 represents the model bathymetry from 15 feet above and 35 feet below the vertical datum - NGVD 29. The colors represent depth contours. The offshore boundary is at a depth of 55.5 feet, relative to NGVD 29.

Figure 3-2:AdH Model Domain and Model Bathymetry

3.2.2 Boundary Conditions

3.2.2.1 Tides

Modeling an average hydrologic condition has been done using average spring tide conditions over the recent 19-year tidal epoch, referred to as a Tidal Epoch Analysis (TEA) tide series. The benefit of using a TEA tide is that the average and long-term condition can be modeled over a shorter time period with less computation time. The average tidal elevations are shown in Figure 3-3: . It starts with a 1.2-day warmup period, followed by a 15.6-day period of spring neap tidal cycle. This tidal cycle can be repeated for simulations over a longer period.

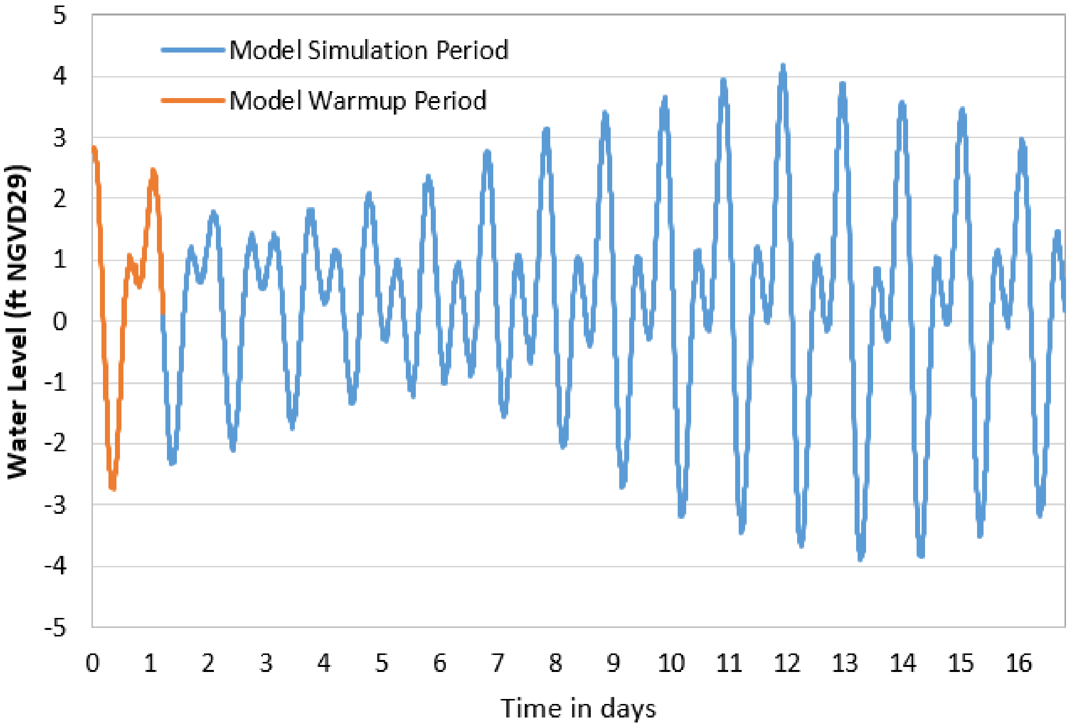

Figure 3-3:Average Tide Series Applied in AdH Modeling

3.2.2.2 Riverine Inflows

Riverine inflows are included in wet weather simulations. The wet weather simulation considered simultaneously occurring riverine inflows from the LCC, SGR, and Colorado Lagoon. Two storm intensities were modeled: a 50-year storm and a 2-year storm. The hydrographs of LCC, SGR, and Colorado Lagoon for both storm events are presented in Figure 3-4 and Figure 3-5.

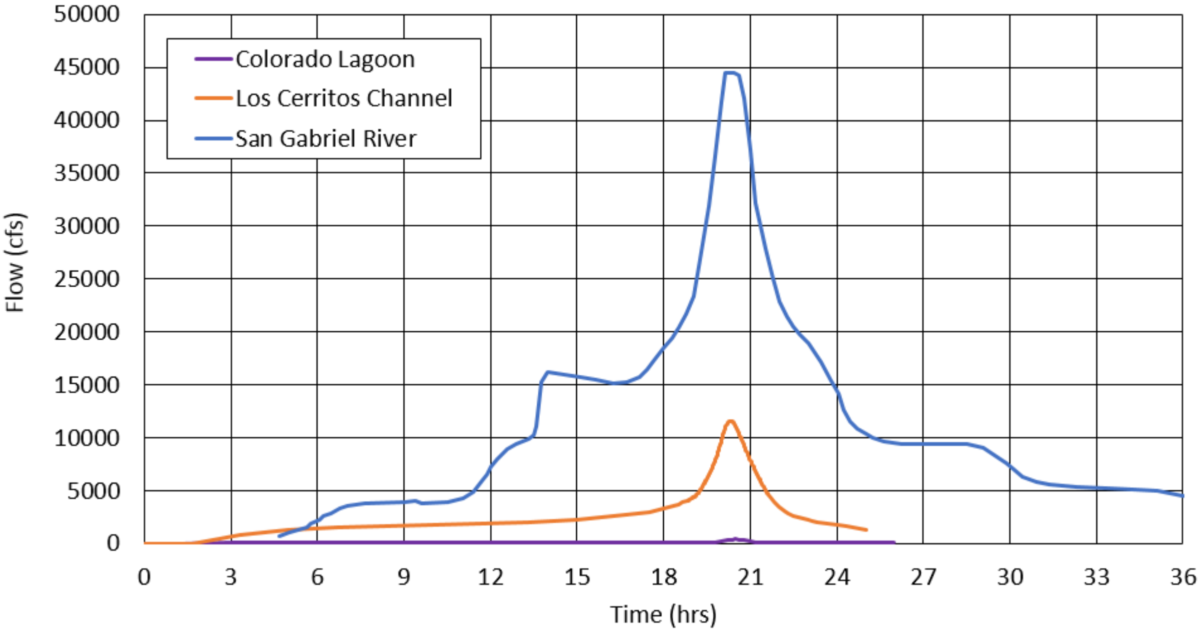

Figure 3-4:50-year Hydrographs

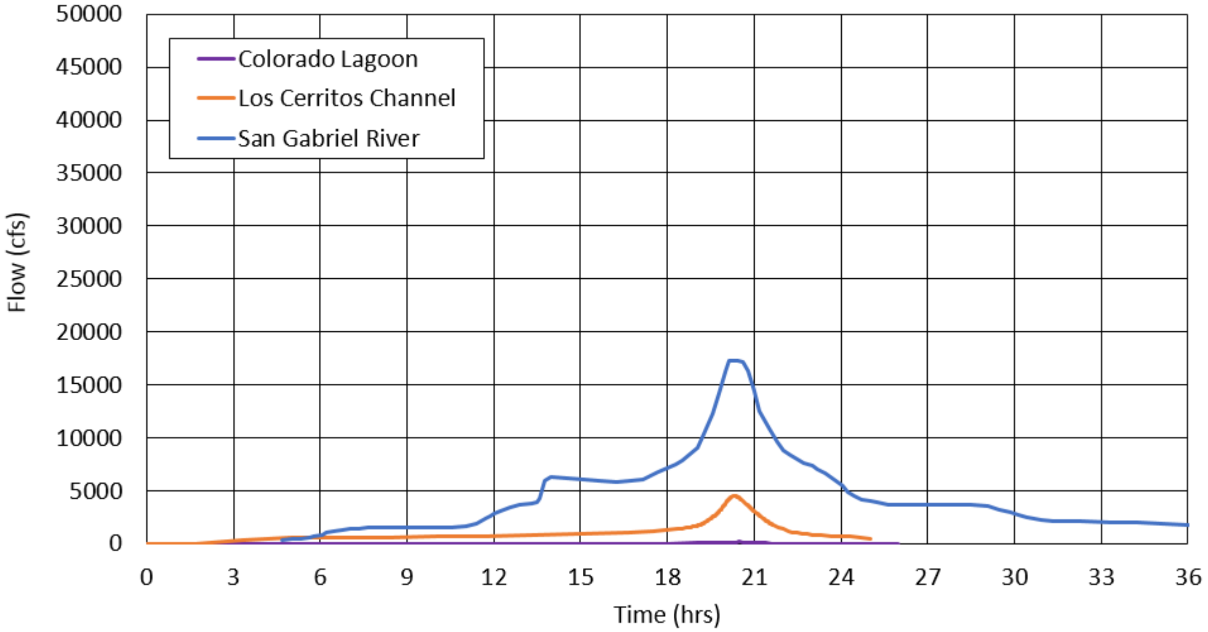

Figure 3-5:2-year Hydrographs

3.2.2.3 Pumping

Pumping scenarios considered in this study are mainly separated into two aspects: 1) Alternative pumping rates and schedules at AES pumping intakes; and 2) Alternative pumping intake and effluent locations. Table 3-1 lists the multiple pumping scenarios that were simulated in this study. Simulations for each scenario were performed under dry weather and wet weather (2-year and 50-year storms) to assess the residence time and bacteria levels within the Bay. In the numerical model, pumping at the AES location occurs from both intakes, split evenly. Discharge to the SGR occurs through the existing Outfall 3.

Scenario 1 is the baseline scenario with no pumping. Scenarios 2-4 include different pumping operations at the AES location. Scenarios 5-7 investigate alternative pumping locations (see Figure 3-6). These scenarios were used with varying discharge rates in the evaluation of residence time and bacteria. Specific model runs for each of these constituents are described in Section 4.

Table 3-1: Modeled Pumping Scenarios

Scenario	Pumping Rate	Pumping Schedule	Intake Location	Effluent Location	Output for Assessment
1	No Pumping	N/A	N/A	N/A	Residence Time Bacteria Level
2	400 cfs	Constant	AES Intakes	SGR	Residence Time Bacteria Level
3	600 cfs	Intermittent (every 12 hours)	AES Intakes	SGR	Residence Time
4	600 cfs	Intermittent (ebb tides only)	AES Intakes	SGR	Residence Time
5	400 cfs	Constant	Mother's Beach	San Pedro Bay	Residence Time Bacteria Level
6	400 cfs	Constant	Bayshore Park	San Pedro Bay	Residence Time Bacteria Level
7	400 cfs	Constant	AES Intakes	Alamitos Bay Mouth	Residence Time Bacteria Level

Figure 3-6: Alternative Intake/Discharge Locations

3.3 Model Verification

The proposed AdH model has been verified in a previous sea level rise (SLR) impact study performed for the Upper Los Cerritos Wetlands Restoration Project (M&N 2007, 2017). The AdH model was based on a previously developed and calibrated Resource Management Associates (RMA) model covering the same domain. Tidal elevations simulated by the AdH model during the average spring tidal condition were compared with those simulated by the calibrated RMA2 model at three locations in LCC and the Bay. Both models are finite element models developed by USACE that solve the same set of equations. The advantage of AdH is that it has a larger memory and thus allows for more nodes (i.e., greater resolution). The Manning's roughness coefficients and eddy viscosity coefficients for each individual sub-area are adopted from a previously calibrated Los Cerritos Wetland RMA2 model (M&N 2007). The two sets of model results aligned so closely that it was decided to forgo rerunning the calibration process. Therefore, the calibration from the previous RMA model holds for the present AdH model.

The final aspect of model verification included a comparison of modeled residence time under the AdH model versus modeled residence time under the RMA model[2] (M&N 2007). This comparison can be seen in Figure 3-7. The resulted residence time between the two models are very close, and the differences at various locations within the Bay are less than 0.7 days, equivalent to a max of 6% change in residence time. Therefore, the AdH transport model is proved to be as valid as the previous RMA model (M&N 2007).

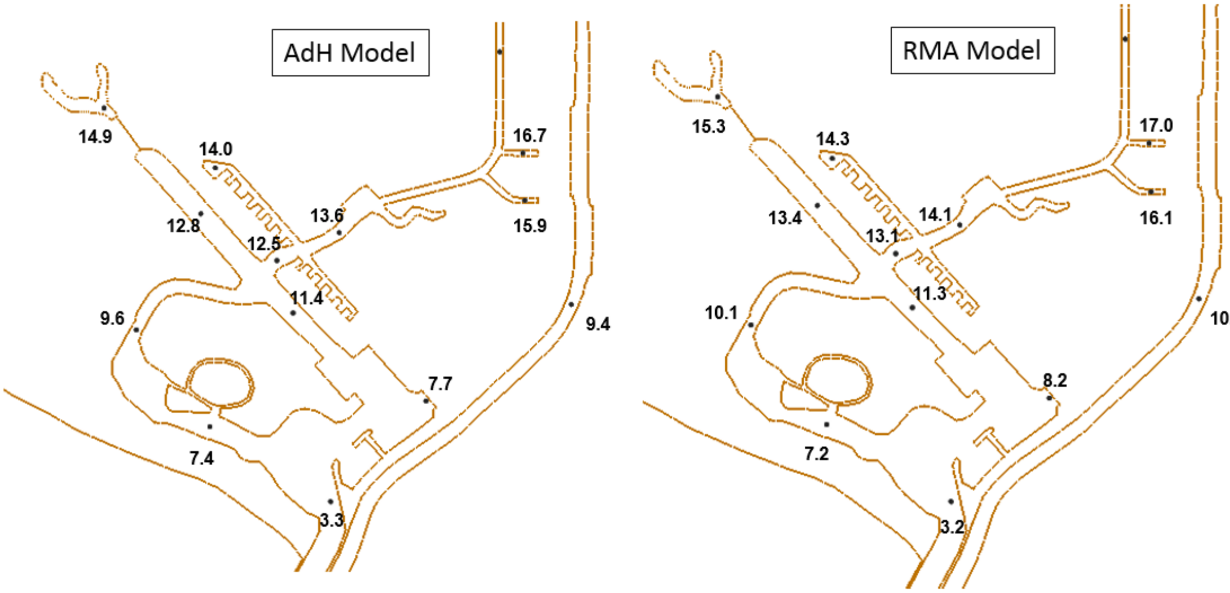

Figure 3-7: Modeled Residence Time (in Days) within Alamitos Bay under Dry Weather Condition (Model Verification - AdH Model vs. RMA Model)

3.4 Model Scenarios

As noted above, the hydrodynamic model described throughout Section 3 served as the base model providing flow conditions. The hydrodynamic flow conditions were further coupled with the transport model to estimate changes in residence time and bacteria concentrations. The specific model scenarios

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[2] RMA was calibrated for hydrodynamics by installing several tide gages and flow velocity meters in Alamitos Bay, LCC, and the SGR in 2007. The model results for existing conditions (a specific tidal event that occurred while instruments were deployed in the Bay) were compared to the data and the model parameters modified, as appropriate, to result in comparable conditions (M&N 2007). As AdH is a Further-developed model extended from RMA and is based on the same set of finite element model equations, it stands to reason that if AdH results agree with RMA results for the same tidal event that was measured, then the AdH model is also calibrated correctly.

are listed below by different water quality aspects, and the model setup and results of these aspects are presented in Section 4.

Table 4-6 list the modeling scenarios for bacteria. A total of 7 scenarios, tabulated in Table 4-6, were modeled for bacteria within the Bay. Only wet weather (2-year and 50-year storm) events were simulated, as bacteria concentrations are low during dry weather (M&N 2019b).

4. Transport Model

The residence time and bacteria concentrations are modeled as conservative tracers in the transport module. The transport module uses the results of the hydrodynamic module to model the transport of constituents through the AdH model domain. The model simulates the transport of matters in the water column by advection and dispersion. It is assumed there are no sources of heavy metals and no decay of the bacteria during the process.

Residence time simulations were performed only for dry weather conditions; the high flows associated with storm conditions flush the Bay and lead to naturally low residence times, such that there is little difference between pumping and non-pumping alternatives. Bacteria was simulated only during wet conditions, as bacteria concentrations are low during dry conditions.

4.1 Residence Time

Residence time is a means of quantifying the exchange of water in an enclosed bay (such as Alamitos Bay) and the ocean. Residence time is a measure of the amount of time it takes for the water within an area to be replaced by water from offshore. It is commonly referred to as “flushing time” as it represents the rate at which waters in a hydraulic system are renewed.

Largier and Taggart (2006) express the importance of circulation (i.e., low residence times) in enclosed bays in preventing high bacterial concentrations: “While weak circulation and long residence may not be the cause of high *[fecal indicator bacteria]* FIB levels, it is a confounding factor and enhancing circulation may serve to flush high levels from the bay and the vicinity of the beach.”

4.1.1 Methodology and Model Setup

The model was used to simulate tidal flushing efficiency of water quality constituents within the model domain. Consider the reduction of a tracer concentration in a tidal embayment due to flushing after being released (Fischer et al. 1979), in which C_0 is initial concentration, K is a reduction coefficient and C(t) is the concentration at time, t.

$$C(t) = C_0 e^{-Kt}$$

The residence time of the tracer in the embayment is determined from

$$T_r = \frac{\int_0^\infty tC(t)dt}{\int_0^\infty C(t)dt} = \frac{1}{K}$$

Since the concentration at $t = T_r$ is

$$C(T_r) = C_0 e^{-1} = \frac{C_0}{e}$$

T_r can be calculated from a regression analysis of the tracer concentration time series computed by the transport module in AdH. Based on the methodology above, the residence times for different locations within the Bay is calculated by the following:

- Assign initial concentration within the Bay as 1, and offshore area as 0.
- Run the model with an adequate number of tidal cycles until the concentration at interested locations falls below $\frac{1}{e}$ (approximately 37%) of the initial concentration.

- Find the residence time at the interested locations from the concentration curves.

Figure 4-1 below shows the residence time computed from a modeled concentration curve.

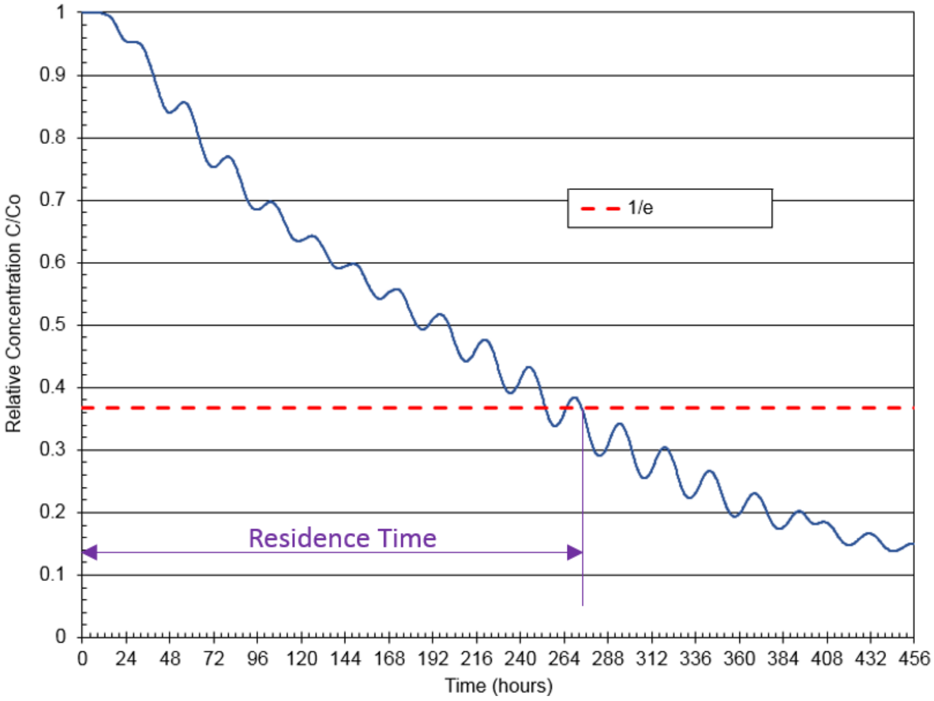

Figure 4-1: Example of Modeled Residence Time at an Interested Location

4.1.2 Model Scenarios

Analysis of residence time in the Bay focused on dry weather conditions. During wet weather, high runoff naturally reduces residence time such that it shows little difference under various pumping scenarios. Table 4-1 lists the model scenarios that were simulated for residence time under dry weather. Simulations R-1 through R-4 include an investigation of different pumping rates/intervals using the existing AES intake and discharge locations. Simulations R-5 through R-7 investigate three alternative intake and discharge locations within the Bay, which are shown in Figure 3-6.

Table 4-1: Alternative Modeling Scenarios for Residence Times

#	Output	Runoff	Pumping Rate	Notes
R-1	Residence Time	Dry weather	No pumping	Simulation 1 determines the baseline residence times throughout the Bay under dry weather without pumping
R-2	Residence Time	Dry weather	400 cfs	Simulation 2 determines the residence times throughout the Bay under dry weather with constant pumping from AES Plant to SGR
R-2A	Residence Time	Dry weather	400 cfs	Simulation 2A is the same as Simulation 2, but with HGS pumping at the same time
R-3	Residence Time	Dry weather	600 cfs Intermittent (every 12 hours)	Simulation 3 determines the residence times throughout the Bay under dry weather with intermittent pumping from AES Plant to SGR

#	Output	Runoff	Pumping Rate	Notes
R-4	Residence Time	Dry weather	600 cfs Intermittent (ebb tides only)	Simulation 4 determines the residence times throughout the Bay under dry weather with intermittent pumping from AES Plant to SGR
R-5	Residence Time	Dry weather	400 cfs	Simulation 5 determines the residence times throughout the Bay under dry weather with constant pumping from Mother's Beach to San Pedro Bay
R-6	Residence Time	Dry weather	400 cfs	Simulation 6 determines the residence times throughout the Bay under dry weather with constant pumping from Bayshore Park to San Pedro Bay
R-7	Residence Time	Dry weather	400 cfs	Simulation 7 determines the residence times throughout the Bay under dry weather with constant pumping from AES Plant to mouth of the Bay

4.1.3 Results

The modeled residence times are reported at multiple monitoring locations within the Bay (Figure 4-2). The modeled residence times at these locations are tabulated in Table 4-2 and Table 4-3. In general, residence times are shortest at locations relatively close to the ocean entrance and increase upstream at Colorado Lagoon, Spinnaker Bay, and upstream of LCC. Shorter residence times suggest better circulation and dilution of constituents, while longer residence times suggest poorer circulation and increased accumulation/build-up of constituents. Table 4-2 and Table 4-3 also include the percent change in residence time relative to the “baseline scenario” without pumping (Scenario R-1).

Figure 4-2: Monitor Locations of Residence Times within Alamitos Bay

Table 4-2: Residence Times throughout Alamitos Bay and Associated Reduction Percentages to Baseline – Phase 1, Task 2

Locations	**Residence Time (days)**				**Impacts to Residence Time (% Reduction to Baseline)**[1]		
Alternatives	***R-1 (Baseline)***	**R-2**	**R-3**	**R-4**	**R-2**	**R-3**	**R-4**
Pumping Scenarios	No Pumping	400 cfs	600 cfs (every 12 hours)	600 cfs (ebb tides only)	400 cfs	600 cfs (every 12 hours)	600 cfs (ebb tides only)
Runoff	Dry Weather	Dry Weather	Dry Weather	Dry Weather	Dry Weather	Dry Weather	Dry Weather
Los Cerritos Channel North	18.3	9.2	10.3	10.4	50%	44%	43%
Los Cerritos Channel Central	13.6	5.5	6.5	6.8	60%	52%	50%
Los Cerritos Channel South	12.5	4.9	6.3	6.4	61%	50%	49%
AES Intake North	16.7	6.1	7.4	8.1	63%	56%	51%
AES Intake South	15.9	5.9	7.3	7.4	63%	54%	53%
Spinnaker Bay	14	6.7	7.8	8.1	52%	44%	42%
Colorado Lagoon	14.9	8.8	9.7	10.3	41%	35%	31%
Marine Stadium	12.8	6.1	7.4	7.5	52%	42%	41%
Naples Channel North (Mother's Beach)	11.4	4.4	5.3	5.5	61%	54%	52%
Naples Channel West	9.6	3.9	4.9	5.2	59%	49%	46%

Naples Channel South	7.4	2.7	3.5	3.6	64%	53%	51%
Alamitos Bay Basin 4 near HGS Intake	7.7	2.9	3.7	3.9	62%	52%	49%
Alamitos Bay Entrance	3.3	0.6	1.4	1.4	82%	58%	58%
San Gabriel River at Effluent Points	9.4	6.7	8.4	8.6	29%	11%	9%

[1] Percentage of reduction in residence time is compared to the "no pumping" baseline scenario.

Table 4-3: Residence Times throughout Alamitos Bay and Associated Reduction Percentages to Baseline – Phase 2, Task 1

Locations	**Residence Time (days)**				**Impacts to Residence Time (% Reduction to Baseline)**[1]		
Alternatives	***R-1 (Baseline)***	**R-5**	**R-6**	**R-7**	**R-5**	**R-6**	**R-7**
Pumping Scenarios	No Pumping	400 cfs Mother's Beach to San Pedro Bay	400 cfs Bayshore Park to San Pedro Bay	400 cfs AES to Mouth of Alamitos Bay	400 cfs Mother's Beach San Pedro Bay	400 cfs Bayshore Park to San Pedro Bay	400 cfs AES to Mouth of Alamitos Bay
Runoff	Dry Weather	Dry Weather	Dry Weather	Dry Weather	Dry Weather	Dry Weather	Dry Weather
Los Cerritos Channel North	18.3	14.7	14.7	10.4	20%	20%	43%
Los Cerritos Channel Central	13.6	10.4	10.5	6.8	24%	23%	50%
Los Cerritos Channel South	12.5	9.2	9.4	6.5	26%	25%	48%
AES Intake North	16.7	13.6	14.5	7.5	19%	13%	55%
AES Intake South	15.9	12.7	13.6	7.4	20%	14%	53%
Spinnaker Bay	14	10.7	10.7	8.1	24%	24%	42%

Colorado Lagoon	14.9	11.6	11.8	10.4	22%	21%	30%
Marine Stadium	12.8	9.6	9.7	7.6	25%	24%	41%
Naples Channel North (Mother's Beach)	11.4	7.4	7.4	5.7	35%	35%	50%
Naples Channel West	9.6	4.9	6.5	5.5	49%	32%	43%
Naples Channel South	7.4	2.8	2.7	3.8	62%	64%	49%
Alamitos Bay Basin 4 near HGS Intake	7.7	3.7	3.8	4.2	52%	51%	45%
Alamitos Bay Entrance	3.3	0.6	0.6	2.4	82%	82%	27%
San Gabriel River at Effluent Points	9.4	9.4	9.4	9.4	0%	0%	0%

[1] *Percentage of reduction in residence time is compared to the "no pumping" baseline scenario.*

The results show that all pumping scenarios decrease residence times in the Bay relative to the no pumping baseline. Comparison of Scenarios R-2 through R-4 show that a consistent pumping rate of 400 cfs (R-2) is more effective in promoting circulation than intermittent pumping of 600 cfs (Scenarios R-3 and R-4). The two intermittent scenarios yield similar residence times; since Scenario R-3 is operationally superior to R-4 (which requires detailed pumping management to pump during ebb tides), only Scenario R-3 has been carried forward into Sections 4.3 and 4.2.

Scenarios R-2 and R-5 through R-7 each consider consistent pumping of 400 cfs. As the results show, scenario R-2 results in a much larger decrease in residence time than R-5 through R-7. These results are consistent with the M&N 2015 study, which showed that pumping at the AES location is more efficient at driving circulation than the HGS location due to the intake being located further upstream (away from the ocean inlet). Similarly, the AES intake simulated in Scenario R-2 is further upstream than the intake locations in Scenarios R-5 and R-6. In comparing Scenarios R-2 and R-7, the residence time is less under R-2 because no short-circuiting occurs. In Scenario R-7, the water discharged at the mouth of the Bay can move upstream and, therefore, is not replaced by ocean water. The results at Mother's Beach are tabulated below in Table 4-4 to demonstrate the impacts from pumping locations.

Table 4-4: Residence Time Comparison at Mother's Beach – Alternative Pumping Locations

Pumping Alternative	**R-2**	**R-5**	**R-6**	**R-7**
Pumping Rate	400 cfs	400 cfs	400 cfs	400 cfs
Pumping Location	AES to SGR	Mothers Beach to San Pedro Bay	Bayshore Park to San Pedro Bay	AES to Mouth of the Bay
Residence Time	4.4	7.4	7.4	5.7

A scenario that included pumping at HGS was simulated as a sensitivity analysis. The simulated pumping rate at HGS was 422 cfs, which represents the lowest 2-week average pumping rate during the 2013-2015 period. Figure 4-3 shows the effect of HGS pumping on residence time. Pumping at HGS lowers residence time by about 1 day throughout the Bay; this reduction in residence time is much smaller than that caused by pumping at AES.

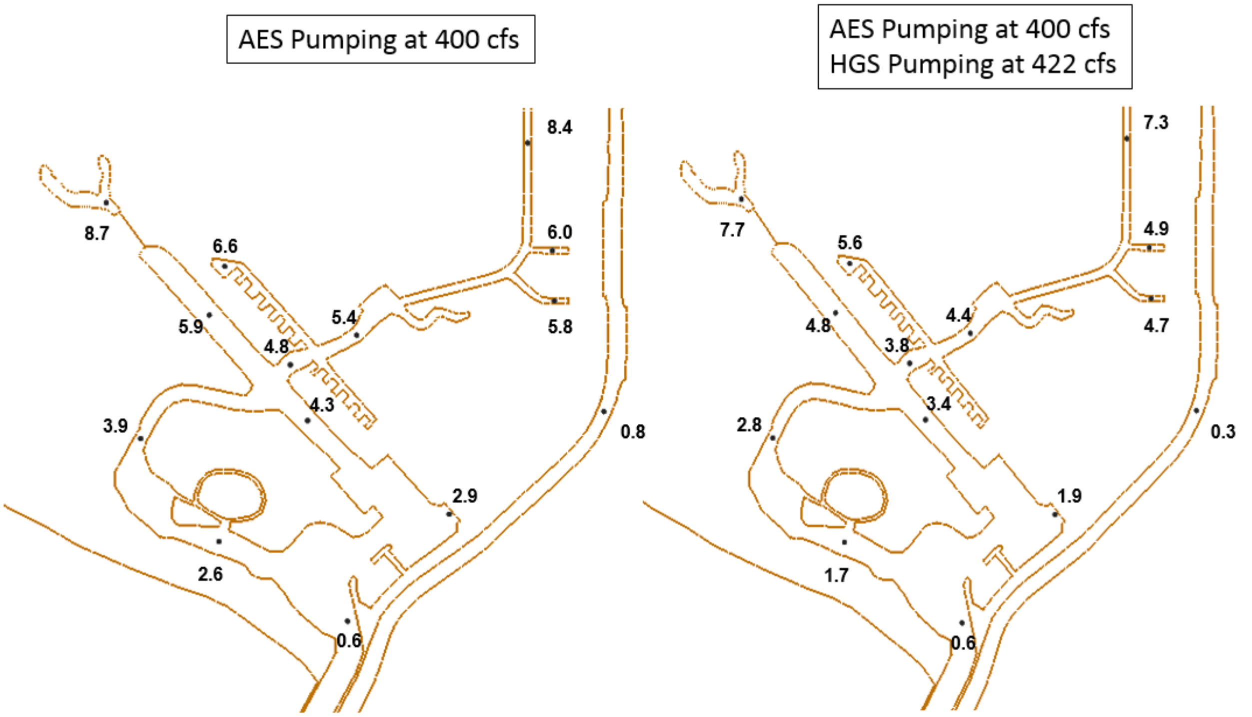

Figure 4-3: Modeled Residence Time (in Days) within Alamitos Bay under AES Constant Pumping (Model Sensitivity - without vs. with HGS Pumping)

4.2 Bacteria Modeling

Bacteria is a critical water quality constituent in the Bay because high bacteria concentrations threaten recreational use of the Bay. Therefore, the City is interested in a pumping program that reduces in-bay bacteria concentrations. The SGR Estuary also has high bacteria levels. A total maximum daily load (TMDL) prepared for indicator bacteria in the SGR (LARWQCB 2015) establishes water quality objectives for bacteria that have been adopted into the current AES permit for sanitary discharge.

4.2.1 Existing Bacteria Concentrations

M&N compiled water quality data from several sources into current water quality conditions summary (M&N 2019b). Data are available from the AES plant discharge, the City's sampling program, and the M&N sampling program. The specific number of samples varied for the specific constituent, but overall there were over 500 dry weather samples and over 100 wet weather samples. The results showed that water quality criteria are rarely exceeded during dry weather but are frequently exceeded (~50% probability) during wet weather. Three indicator bacteria species were measured: total coliform, fecal coliform, and enterococcus.

4.2.2 Regulatory Considerations

The TMDL establishes waste load allocations for stormwater permittees in the upstream watershed. Other discharges "are not expected to be a significant source of bacteria." Specifically, "the Alamitos and Haynes stations have no limits for bacteria and are not considered significant sources of bacteria to the watershed" (LARWQCB 2015).

The existing AES permit includes bacteria limits for the treated sanitary effluent, but not for the OTC discharge. Table 4-5 shows the water quality objectives for the Bay and the SGR Estuary.

Table 4-5: Bacteria Water Quality Objectives in Alamitos Bay and in the San Gabriel River

Water Quality Objective	Single Sample Limit	Geometric Mean Limit
Fecal Coliform	400/100 ml	200/100 ml
Enterococcus	104/100 ml	35/100 ml
Total Coliform	10,000/100 ml	1,000/100 ml

Compliance with water quality objectives and with permit effluent limitations is based on the number of days/periods that the discharge exceeds the above concentrations.

4.2.3 Methodology and Model Setup

This study explicitly modeled enterococcus. Measured data shows a high correlation between the three indicator bacteria species; therefore, the conclusions from enterococcus modeling apply to all three species of indicator bacteria.

The initial enterococcus concentrations are applied to the Bay, the ocean, and inflow. The model was run for an adequate number of tidal cycles after the storm event until sufficient flushing occurs so that the concentration falls below the regulatory limit. The duration of time that enterococcus concentration exceeds the limit are calculated at the monitoring locations shown in Figure 4-2.

The model was run with multiple scenarios for enterococcus, as presented in Table 4-6. Scenarios B-2 through B-4 investigate different pumping operations, and B-5 through B-7 investigate alternative locations.

Table 4-6: Alternative Modeling Scenarios for Bacteria Levels

Scenario	Output	Runoff	Pumping Rate	Notes
B-1	Bacteria Level	2-year Storm	No pumping	Simulation 1 determines the baseline bacteria level under 2-year storm event without pumping
B-2	Bacteria Level	2-year Storm	400 cfs	Simulation 2 determines the bacteria level under 2-year storm event with constant pumping from AES Plant to SGR
B-3	Bacteria Level	50-year Storm	No pumping	Simulation 3 determines the baseline bacteria level under 50-year storm event without pumping
B-4	Bacteria Level	50-year Storm	400 cfs	Simulation 4 determines the bacteria level under 50-year storm event with constant pumping from AES Plant to SGR
B-5	Bacteria Level	2-year Storm	400 cfs	Simulation 5 determines the bacteria level under 2-year storm event with constant pumping from Mother's Beach to San Pedro Bay
B-6	Bacteria Level	2-year Storm	400 cfs	Simulation 6 determines the bacteria level under 2-year storm event with constant pumping from Bayshore Park to San Pedro Bay
B-7	Bacteria Level	2-year Storm	400 cfs	Simulation 7 determines the bacteria level under 2-year storm event with constant pumping from AES Plant to mouth of the Bay

The initial enterococcus concentration was set at 10/100 ml (lower limit of detectable level) within the Bay and 0/100 ml in the open ocean. The enterococcus concentrations from riverine inflows at LCC, SGR, and Colorado Lagoon were set at 2005 MPN/100 ml (upper limit of detectable level). Based on M&N's current water quality conditions summary (2019b), more than 10% of the examples reach the upper limit value of 2005 MPN/100 ml during wet weather, and the lower limit of 10 MPN/100 ml represent about 40% of the samples.

Figure 4-4 shows an example of the time that bacteria concentration exceeds the criteria value of 104 MPN/100 ml. Multiple modeling scenarios are evaluated and compared using the time duration illustrated in the figure.

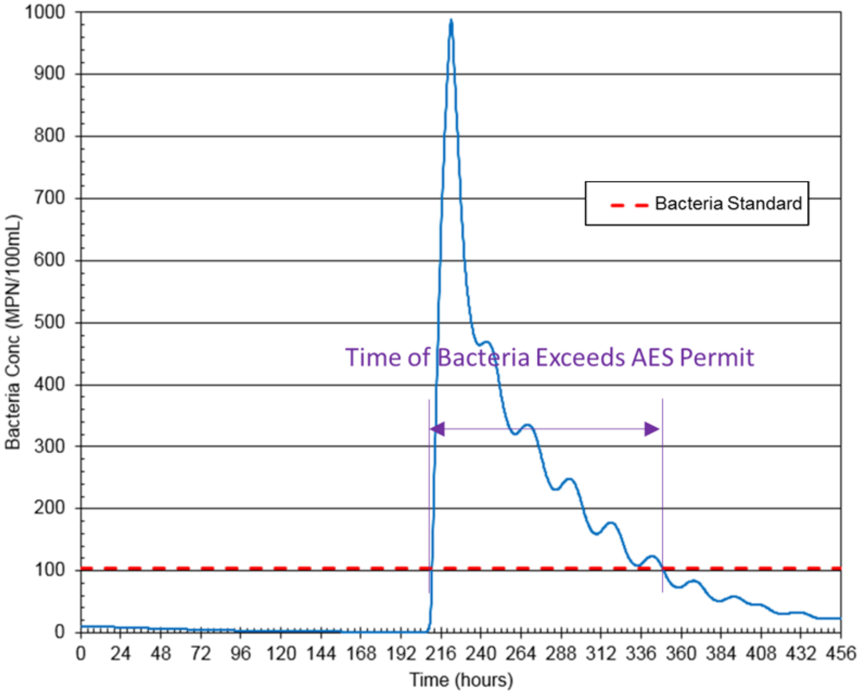

Figure 4-4: Example of Enterococcus Concentration Exceeded Time at an Interested Location

4.2.4 Results

As noted above, compliance with bacteria effluent limitations are based on the number of days that bacteria concentrations exceed the effluent limitations. These results are presented in Table 4-7 and Table 4-8 for each monitoring location. Assessing different pumping schemes using the existing AES intake and discharge show that there is a 70% to 80% reduction in the number of days that enterococcus concentration exceeds the permitted value throughout the Bay with the pumps operating at 400 cfs constantly.

Table 4-8 examines the effect of alternate intake and discharge locations. These results also show reduced bacteria concentrations with pumping. Among the alternative pumping locations, Mother's Beach and Bayshore Park pumping stations are not as efficient as AES pumps, as their bacteria exceeded days are significantly longer than pumping at AES location, especially at LCC, Spinnaker Bay, and Marine Stadium.

Table 4-7: Modeled Exceeded Times of Enterococcus throughout Alamitos Bay and their Reduction Percentages to Baseline

Locations	**Time Exceeds Permitted Value[1] (days)**				**Impacts to Time Exceeds Permitted Value (% Reduction to Baseline)[2]**	
Alternatives	**B-1 (2-yr Baseline)**	**B-2**	**B-3 (50-yr Baseline)**	**B-4**	**B-2**	**B-4**
Pumping Scenarios	No Pumping	400 cfs	No Pumping	400 cfs	400 cfs	400 cfs
Runoff	2-year Storm	2-year Storm	50-year Storm	50-year Storm	2-year Storm	50-year Storm
Los Cerritos Channel North	[3]	15.7	50.3	18.8	[3]	[3]
Los Cerritos Channel Central	25.4	6.8	41.4	10.8	73%	74%
Los Cerritos Channel South	23.5	6.0	37.3	10.0	74%	73%
AES Intake North	33.3	8.3	46.6	11.9	75%	74%
AES Intake South	30.4	7.5	45.6	11.2	75%	75%
Spinnaker Bay	25.0	7.5	39.1	11.7	70%	70%
Colorado Lagoon	27.0	10.4	40.5	15.6	61%	61%
Marine Stadium	23.8	6.9	37.5	11.5	71%	69%
Naples Channel North (Mother's Beach)	21.4	5.8	35.7	8.9	73%	75%
Naples Channel West	20.1	4.9	32.6	8.4	76%	74%
Naples Channel South	16.0	3.2	30.0	6.7	80%	78%
Alamitos Bay Entrance (HGS Intake)	17.2	3.8	30.1	7.0	78%	77%
Alamitos Bay Entrance	11.9	2.2	18.9	4.7	82%	75%
San Gabriel River at Effluent Points	19.6	8.9	28.9	12.3	55%	57%

[1] *Permitted value of enterococcus is 104 MPN/100 ml*

[2] *Percentage of time reduction is compared to the "no pumping" baseline scenario*

[3] *No percentage of time reduction is calculated, as baseline scenario at this location has an enterococcus exceedance time longer than the simulated period*

Table 4-8: Modeled Exceeded Times of Enterococcus throughout Alamitos Bay and their Reduction Percentages to Baseline

Locations	**Time Exceeds Permitted Value[1] (days)**				**Impacts to Time Exceeds Permitted Value (% Reduction to Baseline)[2]**		
Alternatives	***B-1 (Baseline)***	**B-5**	**B-6**	**B-7**	**B-5**	**B-6**	**B-7**
Pumping Scenarios	No Pumping	400 cfs Mothers Beach to San Pedro Bay	400 cfs Bayshore Park to San Pedro Bay	400 cfs AES to Mouth of Alamitos Bay	400 cfs Mothers Beach to San Pedro Bay	400 cfs Bayshore Park to San Pedro Bay	400 cfs AES to Mouth of Alamitos Bay
Runoff	2-year Storm	2-year Storm	2-year Storm	2-year Storm	2-year Storm	2-year Storm	2-year Storm
Los Cerritos Channel North	[3]	[3]	[3]	17.8	[3]	[3]	[3]
Los Cerritos Channel Central	25.4	18.6	20.8	8.8	27%	18%	65%
Los Cerritos Channel South	23.5	15.4	18.6	8.5	34%	21%	64%
AES Intake North	33.3	24	[3]	10	28%	[3]	70%
AES Intake South	30.4	23.9	[3]	9.9	21%	[3]	67%
Spinnaker Bay	25.0	17.3	19.9	9.7	31%	20%	61%
Colorado Lagoon	27.0	18.4	21.5	13.3	32%	20%	51%
Marine Stadium	23.8	15.3	18.5	9.3	36%	22%	61%
Naples Channel North (Mother's Beach)	21.4	13.2	16.4	7.8	38%	23%	64%
Naples Channel West	20.1	9.3	14.4	7.0	54%	28%	65%
Naples Channel South	16.0	5.4	7.5	5.4	66%	53%	66%
Alamitos Bay Entrance (HGS Intake)	17.2	6.8	9.6	5.9	60%	44%	66%
Alamitos Bay Entrance	11.9	3.2	3.4	4.7	73%	71%	61%
San Gabriel River at Effluent Points	19.6	19.6	19.7	19.6	0%	-1%	0%

[1] *Permitted value of enterococcus is 104 MPN/100 ml*

[2] *Percentage of time reduction is compared to the "no pumping" baseline scenario*

[3] *No percentage of time reduction is calculated, as baseline scenario at this location has an enterococcus exceedance time longer than the simulated period*

4.3 Copper Modeling

The LARWQCB and the U.S. Environmental Protection Agency (EPA) have recognized the SGR Estuary as impaired for high copper concentrations. A TMDL prepared for metals in the SGR (USEPA 2007) establishes water quality objectives for copper were considered by the LARWQCB in their determination of effluent limitations in the AES permit. This modeling study investigated copper concentrations from a regulatory perspective to understand how pumping at the AES location might affect copper concentrations relative to these existing effluent limitations.

4.3.1 Existing Copper Concentrations

M&N compiled water quality data from several sources into current water quality conditions summary (M&N 2019b). Data is available from the AES plant discharge, the City's sampling program, and the M&N sampling program. In total, these sources include 62 dry weather samples and 17 wet weather samples. The average copper concentrations are 8.1 µg/L during dry weather and 7.7 µg/L during wet weather. Appendix A includes the most recent water quality sampling data for the Bay used to inform model.

4.3.2 Regulatory Considerations

The SGR metals TMDL (USEPA 2007) states that "other direct discharges to the Estuary, including storm water and non-storm water point sources, are assigned concentration-based waste load allocations equal to the Estuary copper numeric target of 3.7 µg/L." The TMDL also notes a 3.1 µg/L waste load allocation for the AES plant.

The existing AES permit limitations for total copper are 2.7 µg/L as a monthly average and 4.6 ug/L as a daily maximum under dry weather conditions, and 3.2 µg/L and 5.5 µg/L during wet weather conditions. The mass (pounds per day [lbs/day]) limitations are also provided based on the permitted discharge flow for each AES discharge point (see Table 4-9).

Table 4-9: AES Effluent Limitations for Copper (LARWQCB, 2015)

Parameter	**Units**	**Effluent Limitations**		
		Average Monthly	Maximum Daily	Instantaneous Minimum/Maximum
Copper, Total Recoverable, Dry Weather	µg/L	2.7	4.6	-
	lbs/day	EFF-001: 4.7 EFF-002: 8.7 EFF-003: 15	EFF-001: 8.0 EFF-002: 15 EFF-003: 26	-
Copper, Total Recoverable, Wet Weather	µg/L	3.2	5.5	-
	lbs/day	EFF-001: 5.6 EFF-002: 11 EFF-003: 18	EFF-001: 9.6 EFF-002: 18 EFF-003: 31	-

4.3.3 Estimated Copper Loading to San Gabriel River

The current AES permit includes mass loading limitations for copper reported in lbs/day; these limitations are presented in Table 4-9 and reproduced in the 3rd column of Table 4-10 and Table 4-11. The mass loading (lbs/day) AMELs are based on the permitted discharge flow for each discharge point (208.2 mgd for Discharge Point 001, 389.0 for Discharge Point 002, and 674.1 for Discharge Point 003) and copper concentrations of 2.7 μg/L and 3.2 μg/L in dry weather and wet weather, respectively.

Mass (lbs/day) = Flow (mgd) x Concentration (mg/L) x 8.34 (conversion factor)

Table 4-10 and Table 4-11 also include the actual mass loading (last column), which is calculated from the measured concentration and flow rate.

Table 4-10: Mass Loading During Wet Weather

Discharge	Permitted mgd	Current Permit Limit (AMEL), Wet Weather (lbs/day)	Actual Mean (mgd)	Average Wet Season (mgd)	Conversion of mg/L to lbs/gal	Average Wet Season Copper Concentration (mg/L)	Average Monthly Copper Discharge, Wet Weather (lbs/day)
EFF-001	208.2	5.6	82	75	8.34	0.0081	5.07
EFF-002	389.0	11.0	189	168	8.34	0.0081	11.35
EFF-003	674.1	18.0	104	56	8.34	0.0081	3.78
Total	1271.3	34.6	375	300	8.34	0.0081	20.27

Table 4-11: Mass Loading During Dry Weather

Discharge	Permitted mgd	Current permit Limit (AMEL), Dry Weather (lbs/day)	Actual Mean (mgd)	Average Dry Season (mgd)	Conversion of mg/L to lbs/gal	Average Dry Season Copper Concentration (mg/L)	Average Monthly Copper Discharge, Dry Weather (lbs/day)
EFF-001	208.2	4.7	82	91	8.34	0.0077	5.83
EFF-002	389.0	8.7	189	215	8.34	0.0077	13.80
EFF-003	674.1	15.0	104	155	8.34	0.0077	9.95
Total	1271.3	28.4	375	460	8.34	0.0077	29.57

The future pumps are planned to have a total discharge capacity of 387 mgd (approximately 30% of the existing permitted rate). If the average wet and dry copper concentrations are applied into the future, the average copper loading (lbs/day) is expected to be 26.1 during wet months and 24.9 during dry months. These are less than the current total limit (3 effluents combined) on the National Pollutant Discharge Elimination System (NPDES) permit. Therefore, if similar concentration limits for copper are applied, then future pumping activities with a total capacity of 387 mgd are expected to meet the overall copper loading limits. Moreover, it should be reiterated that the future pumps are not expected to operate at full capacity; the City expects an average pumping rate of 258 mgd, which would correspond to loadings of 17.4 lb/day during wet weather and 16.6 lb/day during dry weather; this represents a reduction in copper loading relative to the existing discharge.

Additional actions are expected to limit future copper loading. The biggest impact to copper is the implementation of the Los Cerritos Metals TMDL, San Gabriel Selenium and Metals TMDL, and the implementation actions in the watershed management plans. With the brake pad initiative and the Department of Pesticide copper boat paint reductions, we expect a 50% reduction of copper in the next

5 years. In addition, no industrial discharges from the AES facility will be included, the future pumping action will only move water from Los Cerritos Channel and Alamitos Bay.

5. Conclusions and Recommendations

This report summarizes a modeling study to investigate the effect of different pumping operations and pumping locations on residence time and bacteria concentrations in the Bay and copper loading to the SGR. The analysis used the AdH hydrodynamic module to resolve velocities and water levels within the Bay, and the transport module to simulate the residence times, copper concentration, and bacteria concentration. Effects to copper and bacteria concentrations were evaluated by comparing the durations of exceedance of existing AES permit limits.

The City's goal is to implement the pumping program prior to the shutoff of the existing AES pumps. To provide the data needed to secure the permit the proposed approach will include the following:

- Use hydrodynamic model to show the change in residence time and qualitatively discuss how increased residence time leads to increased potential of occurrence of water quality objective exceedances.
- Use models to predict future bacteria concentrations with and without pumping.
  - Different pumping schemes were evaluated to determine the optimal pump rate and frequency through the existing AES intake and outfall structures. Consistent pumping at 400 cfs resulted in the greatest mixing (decrease in residence time) in the Bay. The reduced residence times reduced the estimated bacteria concentration exceedance duration by 70%-80%.
- Evaluate copper loading to SGR under current and future pumping scenarios.
  - The future pumps are planned to have a total discharge capacity of 387 mgd (approximately 30% of the existing permitted rate). If the average wet and dry copper concentrations are applied into the future, the average copper loading (lbs/day) is expected to be 26.1 during wet months and 24.9 during dry months. These are less than the current total limit (3 effluents combined) on the NPDES permit.
  - Additional actions are expected to limit future copper loading. The biggest impact to copper is the implementation of the Los Cerritos Metals TMDL, San Gabriel Selenium and Metals TMDL, and the implementation actions in the watershed management plans. With the brake pad initiative and the Department of Pesticide Regulation copper boat paint reductions, we expect a 50% reduction of copper in the next 5 years.
- Demonstrate the efficacy of pumping through AES facility to SGR in comparison to other intake and outfall areas
  - The alternative pumping locations (Mother's Beach and Bayshore Park) showed reductions in residence times in the downstream portions of the Bay (such as around Naples Island South and the Entrance to Alamitos Bay). However, pumping at AES is twice as effective as pumping at Bayshore Park or Mother's Beach.
- Use models to predict future bacteria concentrations with and without pumping.
  - Consistent pumping at 400 cfs resulted in a decrease in residence time in the Bay, which is estimated to reduce the bacteria concentration by 70%-80% versus a no pumping scenario.

6. References

California Regional Water quality Control Board Los Angeles Region (LARWQCB). 2015. Total Maximum Daily Load for Indicator Bacteria in San Gabriel River, Estuary and Tributaries.

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Appendix A Water Quality Sampling Data

Table 1: Water quality sampling conditions

ID	Date	Time	Tide	Water Elevation	Precipitation
AES-1	10/4/18	7:00 AM	High	4.3	dry
MB-1	10/4/18	7:15 AM	High	4.3	dry
AES-2	10/8/18	7:30 AM	High	4.8	dry
AES-3	10/15/18	7:45 AM	Low	3.2	wet
AES-4	11/29/18	7:45 AM	Low	3.5	wet
MB-2	11/29/18	8:00 AM	Low	3.5	wet
AES-5	12/17/18	8:45 AM	Low	3	dry
AES-6	12/27/18	7:45 AM	Low	2.6	dry
AES-7	1/16/19	7:30 AM	High	4.5	wet
MB-3	1/16/19	7:45 AM	High	4.26	wet
AES-8	1/17/19	7:45 AM	High	5.06	wet
MB-4	1/17/19	8:00 AM	High	4.93	wet
2ST-1	3/14/19	8:30 AM	Neap Low	1.5	dry
INT-1	3/14/19	9:00 AM	Neap Low	1.5	dry
7ST-1	3/14/19	9:30 AM	Neap Low	1.5	dry
2ST-2	3/21/19	9:30 AM	Spring High	6.1	wet
AES-9	3/21/19	9:45 AM	Spring High	6.1	wet
NINT-1	3/21/19	10:00 AM	Spring High	6.1	wet
7ST-2	3/21/19	10:15 AM	Spring High	6.1	wet
2ST-3	3/26/19	11:45 AM	Mid-Neap Incoming	2	dry
AES-10	3/26/19	12:00 PM	Mid-Neap Incoming	2	dry
NINT-2	3/26/19	12:15 PM	Mid-Neap Incoming	2	dry
7ST-3	3/26/19	12:30 PM	Mid-Neap Incoming	2	dry
2ST-4	4/1/19	10:30 AM	Mid-Spring Outgoing	2.6	dry
AES-11	4/1/19	10:45 AM	Mid-Spring Outgoing	2.6	dry
NINT-3	4/1/19	11:00 AM	Mid-Spring Outgoing	2.6	dry
7ST-4	4/1/19	11:15 AM	Mid-Spring Outgoing	2.6	dry
2ST-5	4/10/19	2:00 PM	Neap High	2.8	dry
AES-12	4/10/19	2:15 PM	Neap High	2.8	dry
NINT-4	4/10/19	2:30 PM	Neap High	2.8	dry
7ST-5	4/10/19	2:45 PM	Neap High	2.8	dry
2ST-6	4/16/19	2:00 PM	Spring Low	-0.6	dry
AES-13	4/16/19	2:15 PM	Spring Low	-0.6	dry
NINT-5	4/16/19	2:30 PM	Spring Low	-0.6	dry
7ST-6	4/16/19	2:45 PM	Spring Low	-0.6	dry

ID	Date	Time	Tide	Water Elevation	Precipitation
2ST-7	4/25/19	7:00 AM	Mid-Neap Outgoing	2	dry
AES-14	4/25/19	7:15 AM	Mid-Neap Outgoing	2	dry
NINT-6	4/25/19	7:30 AM	Mid-Neap Outgoing	2	dry
7ST-7	4/25/19	7:45 AM	Mid-Neap Outgoing	2	dry
2ST-8	4/29/19	9:45 AM	Mid Outgoing	2.3	dry
AES-15	4/29/19	10:00 AM	Mid Outgoing	2.3	dry
NINT-7	4/29/19	10:15 AM	Mid Outgoing	2.3	dry
7ST-8	4/29/19	10:30 AM	Mid Outgoing	2.3	dry

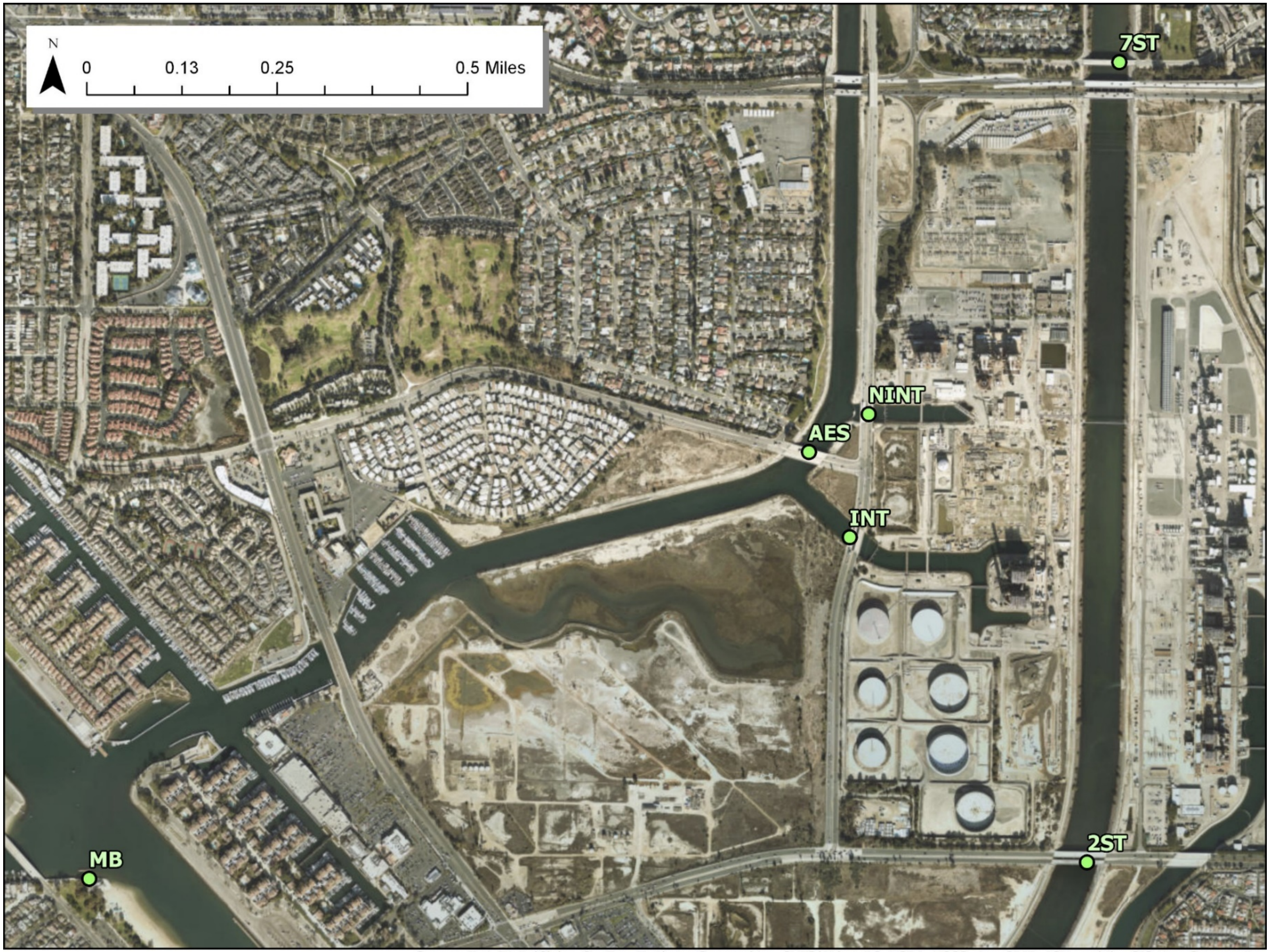
Table 2: Water quality sampling results. Samples collected below reporting limits are denoted with “.”

ID	OilGr	Amm	Cr6	TRChl	Hg	Ar	Be	Cd	Cr	Cu(T)	Cu(D)	Pb	Ni	Se	Ag	Zn	B	Fcol	Tcol	Ent
AES-1	.	.	.	.	.	19.7	.	.	.	17		.	.	.	.	201	3160	< 10	41	< 10
MB-1	.	.	.	.	.	21.9	.	.	.	18.8		.	.	.	.	186	3060	< 10	51	< 10
AES-2	.	.	.	.	.	27.3	.	.	.	10.7		.	.	.	.	.	3630	< 10	106	< 10
AES-3	1	0.1	0.044	.	.	.	.	.	.	26.1		.	.	.	.	87.7	2030	>24196	>24196	>2005
AES-4	.	0.11	.	.	.	.	.	.	.	16.2		.	.	.	.	101	890	120	>24196	>2005
MB-2	.	.	.	.	.	.	.	.	.	12.3		.	.	.	.	.	4280	159	3130	697
AES-5	1	0.34	.	.	.	.	.	.	.	95.1		.	.	.	.	.	3340	< 10	1126	111
AES-6	.	.	.	.	.	.	.	.	.	14.4		.	.	.	.	.	3340	13	703	10
AES-7	1.7	0.061	.	.	0.0651	1.23	.	.	1.73	6.28		2.7	1.31	.	.	48.7	89.7	26	24196	>2005
MB-3	1.3	.	.	.	0.0766	1.36	.	.	1.96	9.75		4.78	1.69	.	.	32.1	477	124	19863	>2005
AES-8	1	.	.	.	.	1.31	.	.	1.16	6.94		3.42	1.42	.	.	60.1	143	4750	>24196	>2005
MB-4	.	.	.	.	.	1.15	.	.	1.04	6.37		4.22	1.31	.	.	41.7	364	770	>24196	>2005
2ST-1										1.71			3.51			27.9		39	12997	87
INT-1										2.35			3.44			24.1		<10	3654	42
7ST-1										1.57			4.06			25.9		125	19863	124
2ST-2										5.18			5.86			36.8		20190	>24196	>2005
AES-9										8.56			2.49			67.1		>24196	>24196	>2005
NINT-1										9.59			2.61			170		>24196	>24196	>2005
7ST-2										3.82			4.48			92.4		26	24196	>2005

ID	OilGr	Amm	Cr6	TRChl	Hg	Ar	Be	Cd	Cr	Cu(T)	Cu(D)	Pb	Ni	Se	Ag	Zn	B	Fcol	Tcol	Ent
2ST-3										3.49			6.88			35.2		26	4106	53
AES-10										3.42			7.54			34.9		<10	990	10
NINT-2										3.47			6.99			44.2		1247	>24196	>2005
7ST-3										3.5			5.26			46.5		40	7915	288
2ST-4										2.88			5.35			27		127	5794	1091
AES-11										2.35			7.42			18.8		<10	602	10
NINT-3										2.89			7.39			27.5		<10	301	<10
7ST-4										3.61			6.85			40		53	7701	697
2ST-5										3.14			6.66			25.1		<10	2909	20
AES-12										3.1			6.46			23		<10	146	10
NINT-4										2.93			6.67			25.6		<10	148	<10
7ST-5										2.61			1.18			8.89		<10	8164	87
2ST-6										3.79	3.33		9.22			33.7		82	2282	<10
AES-13										2.83	2.75		9.24			18.7		<10	448	42
NINT-5										2.58	2.54		10.3			16.9		40	993	<10
7ST-6										4.69	3.55		7.3			52.1		1002	12997	111
2ST-7										3.16	3.01		6.87			22.4		699	12997	20
AES-14										3.24	3.09		7.88			17.9		53	1616	10
NINT-6										3.13	3.05		8.82			21.3		68	2224	<10
7ST-7										4.34	3.04		5.82			29.2		2843	>24196	178
2ST-8										3.06	2.97							511	6131	53
AES-15										3.44	3.13							107	15531	238
NINT-7										3.07	2.94							13	9804	192
7ST-8										4.38	4.2							2618	>24196	>2005

Table 3: Water quality sampling parameters and units

Data	Description	Unit
Water Elevation	Tidal elevation	feet MLLW, taken from NOAA data at Newport Bay Entrance
Precipitation	Wet or dry conditions	Wet conditions include 72 hours after significant rainfall
Fcol	Fecal coliforms	MPN per 100ml
Tcol	Total coliforms	MPN per 100ml
Ent	Enterococcus	MPN per 100ml
OilGr	HEM: Oil and Grease	mg/L
Amm	Ammonia (as N)	mg/L
Cr6	Chromium, Hexavalent	mg/L
TRChl	Chlorine, Total Residual	mg/L
Hg	Mercury	ug/L
Ar	Arsenic	ug/L
Be	Beryllium	ug/L
Cd	Cadmium	ug/L
Cr	Chromium	ug/L
Cu(T)	Copper, Total Recoverable	ug/L
Cu(D)	Copper, Dissolved	ug/L
Pb	Lead	ug/L
Ni	Nickel	ug/L
Se	Selenium	ug/L
Ag	Silver	ug/L
Zn	Zinc	ug/L
B	Boron	ug/L



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community