Technical Memorandum

DATE: February 29, 2012

TO: Karin Graves, EPA Region 9 Water Division

FROM: Amy King and Sen Bai

SUBJECT: Appendix D – EDFC Bacteria Regional Source Assessment for the Long Beach City Beaches and the Los Angeles River Estuary

The Long Beach City beaches (LBC beaches) were listed as impaired by the U.S. Environmental Protection Agency (USEPA) due to elevated concentrations of indicator bacteria in 2006. This impairment stretches 4.7 miles along the coastline between the Los Angeles River (LAR) Estuary and the San Gabriel River (SGR) Estuary and Alamitos Bay. Moreover, a recent review of available bacteria data identified an impairment of the LAR Estuary from Willow Street to the mouth of the estuary (Appendix A). These impaired segments are both located in Los Angeles County in southern California (Figure 1); the general area of the beaches is further defined by hydrological unit 405.12 in the Los Angeles Regional Water Quality Control Board (Regional Board) Basin Plan.

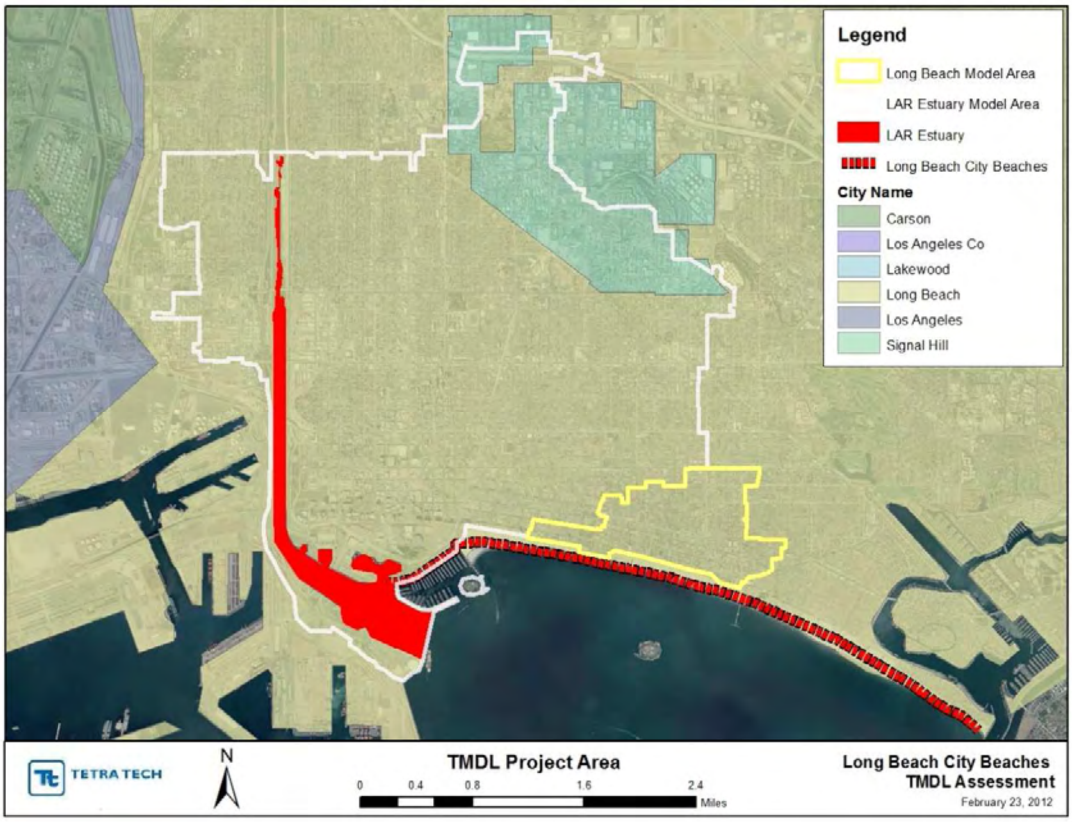


Figure 1. Long Beach City beaches and LAR Estuary location and jurisdictions

To address these impairments, TMDLs are required. The proximity of the LAR and SGR watersheds to the impaired segments (Figure 2) suggests that loadings from these watersheds could impact bacteria water quality at the LBC beaches (note: given that the LAR watershed is a primary source to the LAR Estuary, it clearly impacts the estuary water quality and there is a separate bacteria TMDL for the Los Angeles River itself [LARWQCB, 2010]; additional direct loadings to the estuary are presented in Appendices B and C and are represented as inputs to the EFDC model by the nearshore watersheds). To investigate this potential relationship, recent modeling efforts associated with the Los Angeles/Long Beach (LA/LB) Harbors toxics TMDLs (Tetra Tech, 2011; LARWQCB, 2011) were used to evaluate conditions in the receiving waters near the LBC beaches. Specifically, the receiving water hydrodynamics including freshwater inflows were simulated and bacteria concentrations were qualitatively evaluated to identify regional sources of bacteria to the LBC beaches for TMDL source assessment. This analysis provided an important tool in determining the conditions during which the LAR and SGR watersheds could potentially contribute bacteria loadings to the LBC beaches (note: other smaller watersheds, represented by the nearshore watersheds in the figures below, were also simulated; however, their impact is much smaller and, therefore, harder to visually detect from the LAR and SGR watersheds). This memo presents the regional source assessment approach used for development of the LBC beaches and LAR Estuary TMDLs.

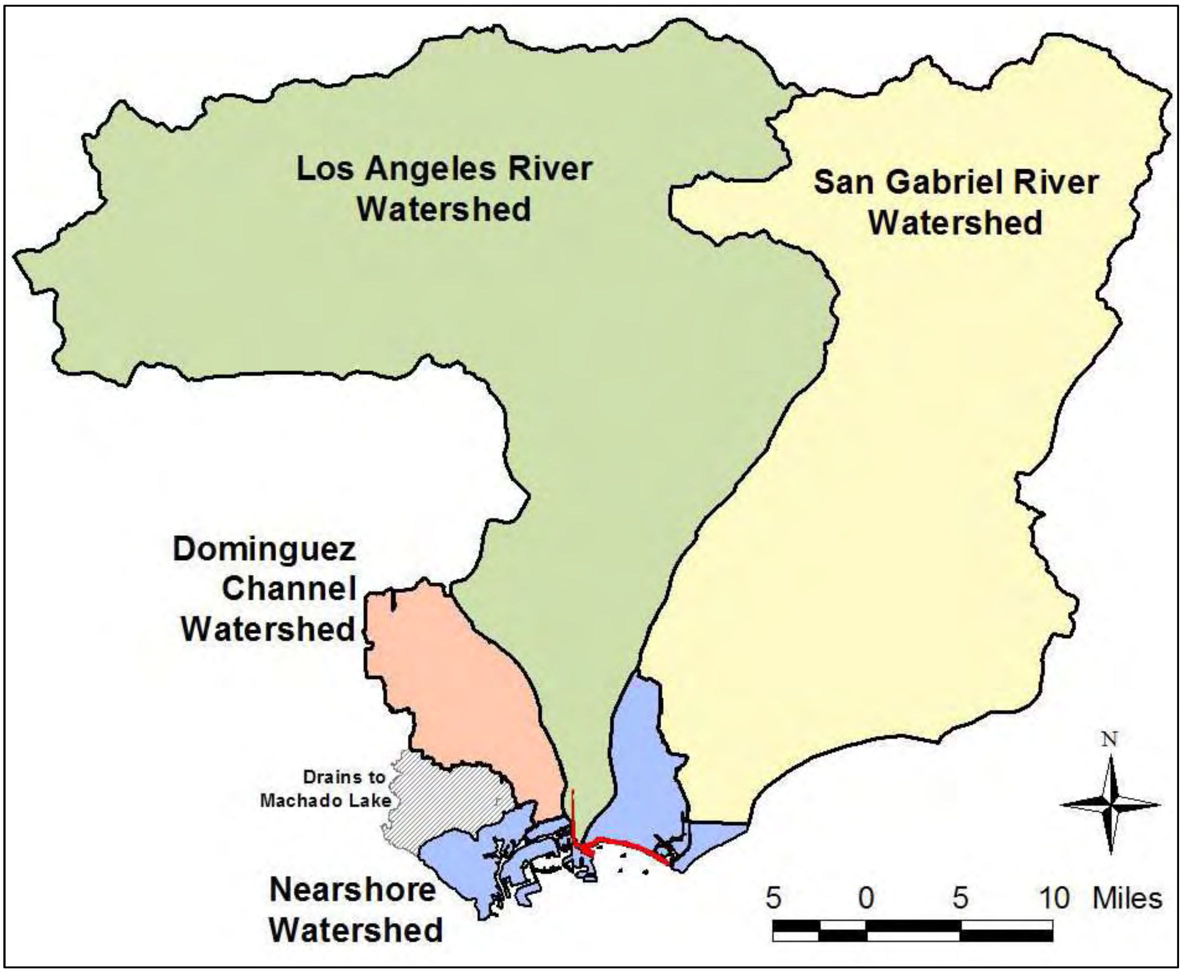


Figure 2. Watersheds draining to the Los Angeles/Long Beach Harbors and San Pedro Bay

(note: impaired LBC beaches and LAR Estuary segments shown in red)

D.1. REGIONAL ASSESSMENT AND MODEL APPLICATION

To evaluate regional hydrodynamic conditions, a computer model of LA/LB Harbors and San Pedro Bay (SPB) was used to simulate the dynamic effects of freshwater inputs and tidal flushing to the beaches. This model was used to evaluate water circulation patterns and conditions in which specific waterbodies, namely the LAR and SGR watersheds, including Alamitos Bay, would impact the impaired LBC beaches. The purpose of the hydrodynamic model is to qualitatively simulate water circulation and the fate and transport of bacteria from the rivers to the beaches. The model used in this TMDL source assessment effort was originally developed and calibrated for the LA/LB Harbor toxics TMDLs (LARWQCB, 2011) using the Environmental Fluids Dynamic Code (EFDC) (Hamrick, 1992; Hamrick and Wu; 1997; Park et al., 1995).

EFDC is a general purpose modeling package for simulating one-, two-, and three-dimensional flow, transport, and bio-geochemical processes in surface water systems including rivers, lakes, estuaries, reservoirs, wetlands, and coastal regions. In addition to hydrodynamic, salinity, and temperature transport simulation capabilities, EFDC is capable of simulating cohesive and non-cohesive sediment transport, near field and far field discharge dilution from multiple sources, eutrophication processes, the transport and fate of toxic contaminants in the water and sediment phases, and the transport and fate of various life stages of finfish and shellfish. The EFDC model was first developed at the Virginia Institute of Marine Science for estuarine and coastal applications. This model is now being supported by USEPA and has been used extensively to support TMDL development throughout the country and has been used for more than 100 surface water modeling applications including nutrient TMDL development (Wool et al., 2003; Zou et al., 2006) and metals and organic contaminant fate and transport at conventional (Ji et al., 2002; King County, 1999) and superfund sites (U. S. EPA, Region 1, 2006; U. S. EPA Region 10, 2006).

The structure of the EFDC model includes four major modules: (1) a hydrodynamic sub-model, (2) a water quality sub-model, (3) a sediment transport sub-model, and (4) a toxics sub-model. The water quality portion of the model simulates the spatial and temporal distributions of 22 water quality parameters including dissolved oxygen, suspended algae (3 groups), attached algae, various components of carbon, nitrogen, phosphorus and silica cycles, and bacteria. For TMDL source assessment development and to evaluate conditions impacting the LBC beaches, both the hydrodynamic and water quality modules were applied. These modules allowed for the temporal and spatial evaluation of river plumes during various conditions.

During the LA/LB Harbors TMDL development, a multi-resolution, curvilinear spatial grid of the greater LA/LB Harbors waters and SPB was constructed using the using the Visual Orthogonal Grid Generation (VOGG) grid generation system (Tetra Tech, 2002). Specific shoreline boundaries for the grid were based on the NOAA/NOS electronic navigation charts in GIS format. The grid and shoreline areas in the vicinity of the impaired segments are shown in Figure 3. This grid is nearly identical to the one used for the LA/LB Harbors toxics TMDLs (Tetra Tech, 2011). The only difference in the model grid was the inclusion of a breakwater near the mouth of Alamitos Bay and the SGR Estuary. The breakwater was added in to the model for a more detailed evaluation of these areas on the LBC beaches.

In the LA/LB Harbors modeling effort, hydrodynamics were calibrated, which involved comparison of model output to observed measurements at monitoring locations throughout the Harbor waters. The model was subsequently calibrated for water and sediment quality for various toxic compounds. This process was repeated until the simulated results closely represented the system and reproduced observed hydrodynamic and water and sediment quality patterns and magnitudes. The hydrodynamics associated with the LA/LB Harbors TMDL model were directly applied to evaluate impacts along the LBC beaches; however, the model was not initially calibrated for bacteria. Therefore, minor updates were made to the model to simulate bacteria.

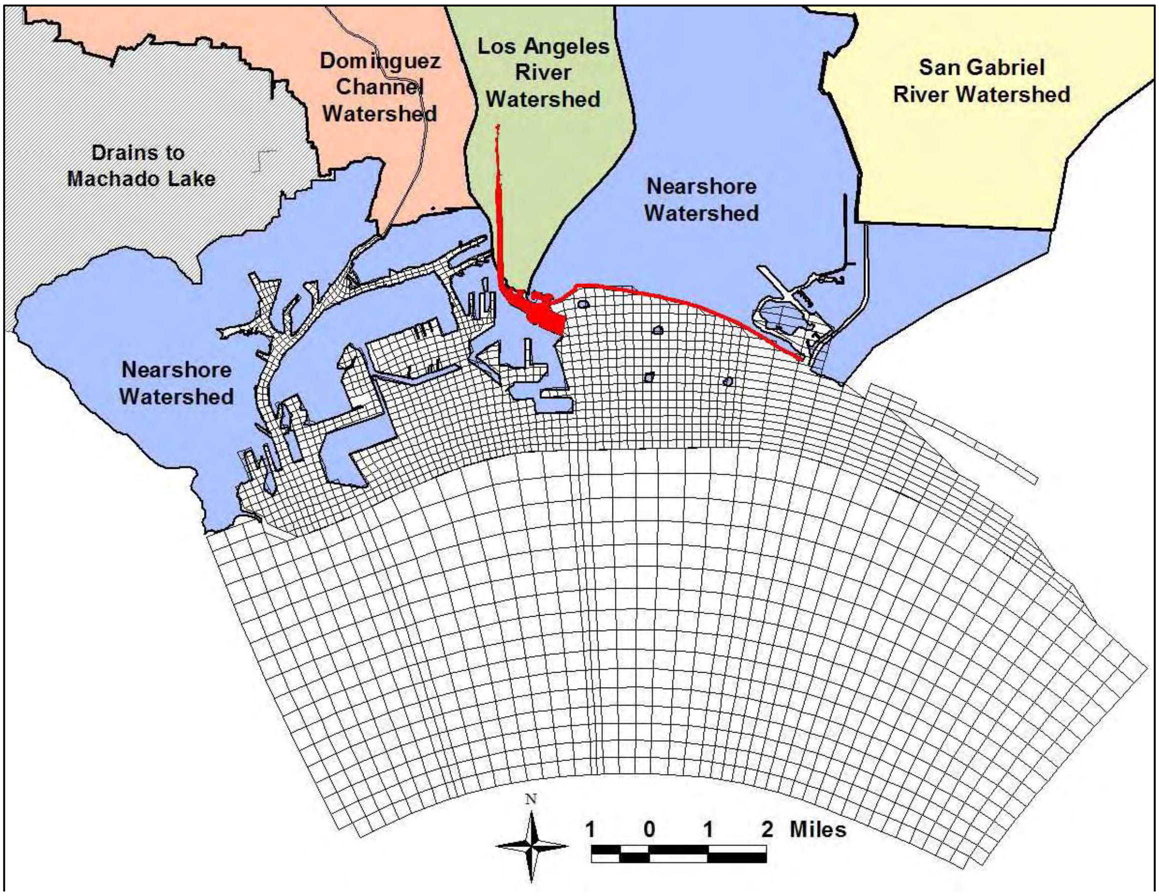


Figure 3. EFDC grid for the Los Angeles/Long Beach Harbors and San Pedro Bay

(note: impaired LBC beaches and LAR Estuary segments shown in red)

Specifically, seasonal geometric mean *enterococcus* concentrations from Los Angeles County Department of Public Works (LACDPW) 2009-2010 annual stormwater monitoring report were used to represent inflow bacteria concentrations from the freshwaters sources to the LA/LB Harbors and SPB (LACDPW, 2010a, 2010b). Table 1 presents the wet and dry weather *enterococcus* concentrations by watershed. The LAR, SGR, and Dominguez Channel concentrations were based on monitoring stations located near the mouth of each river, while the nearshore watershed concentrations were an average of the various tributary monitoring stations located in the region.

Table 1. Bacteria Concentrations to Represent Freshwater Inputs to the EFDC Model

	Enterococcus Concentration (MPN/100 mL)	
Freshwater Inflow	**Dry Weather**	**Wet Weather**
Los Angeles River	70	167,451
San Gabriel River	110	61,262
Dominguez Channel	176	186,700
Nearshore watershed	1,307	190,038

These concentrations were applied to their associated inflow in the model timeseries input files. Considering the prior calibration efforts (Tetra Tech, 2011) and since the objective of the regional source assessment used for these TMDLs was not to establish loadings, but rather to qualitatively assess regional loading potential, additional water quality calibration for bacteria was not performed. The remainder of this memo discusses the EFDC model results and the potential impacts on the LBC beaches.

D.2. MODEL RESULTS

The EFDC receiving water model was run for 2002-2005. This time period corresponds with the LA/LB Harbors toxics TMDLs modeling period (Tetra Tech, 2011; LARWQCB, 2011). During the entire simulation period, four specific modeling periods were identified for closer evaluation. These specific periods overlap with the TMDL seasons:

- Wet weather: any day with 0.1 inches of rain or more and the following three days
- Winter dry weather: any non-wet weather day from November 1st through March 31st
- Summer dry weather: any non-wet weather day from April 1st through October 31st

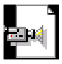
Two wet period evaluations were performed to characterize the maximum and average wet periods during 2002-2005 (based on the highest and average daily rainfall, respectively). In addition, both salinity and bacteria (*enterococcus*) concentrations were reviewed for the maximum wet model period. *Enterococcus* was used in the modeling because there is an associated marine water quality objective (note: *E. coli* loading was characterized for the freshwater inputs in Appendices B and C. While these *enterococcus* results are not directly comparable to the wet and dry weather *E. coli* loadings, it is assumed that the bacteria sources are similar). Each *enterococcus* map presents a representation of wind speed and direction using wind rose plots (using wind data from the Pier F NOAA monitoring location, which is just west of the LAR Estuary mouth) These plots were created using hourly wind data over the course of each simulated day (i.e., 24 hourly values were summarized for each day). The wind rose plots depict the frequency of occurrence of winds in each of the specified wind direction sectors and wind speed classes for a given location and time period. The plots show a total of 16 direction sectors (i.e., four in each quadrant [e.g., N, NNE, NE, ENE]), along with six wind classes. The circular graphs show the wind direction data sorted in the 16 sectors in which the radius of each of the segments represents the percentage of time that the wind blew from each direction. Wind speed is superimposed on each direction to indicate the average wind speed when the wind blows from a particular segment's direction. Wind speeds up to and including 0.514 m/s(1 knot) are considered to be calm. Calm winds are not shown on the wind rose plots because they have no direction (however, the frequency is provided).

Overall, the model outputs for the various periods were visually evaluated to qualitatively identify the impact of the LAR and SGR (including Alamitos Bay) watersheds on the LBC beaches. It is important to note that there are bacteria sources along the beach areas due to direct run-off (represented by the nearshore watersheds); however, the magnitudes of these sources are much lower than those from the major rivers. Once watershed loads enter the receiving water, they are transported by the circulation in the harbor. Circulation in the harbor is determined by a combination of freshwater inflows, tides, and wind speed and direction. Wind generally impacts only a thin layer of water at the surface and the snapshots of surface concentrations are averaged over several meters; therefore, direct correlations between the wind influences and surface concentrations cannot be made with these analyses. Each model period is discussed below along with a figure illustrating the salinity or *enterococcus* concentration at the water surface and a link to a movie showing the full simulation for each specific model period.

D.2.1. Maximum Wet Weather Event

Simulations of salinity and *enterococcus* concentrations were evaluated for the maximum wet weather event observed during the modeling period (December 28-29, 2004). The salinity map (Figure 4) illustrates the influx of freshwater from the LAR and SGR/Alamitos Bay (shown by the blue color, which represents water with lower simulated salinity) during the maximum wet weather event. Specifically, freshwater from the LAR, extends beyond the LAR Estuary and reaches the western portion of the LBC beaches. SGR/Alamitos Bay freshwater moves past the breakwater at the mouth of these waterbodies. This water with depressed salinity touches the western LBC beaches.

The full salinity simulation during the maximum wet weather event can be viewed at:



Salinity - Max Wet Event

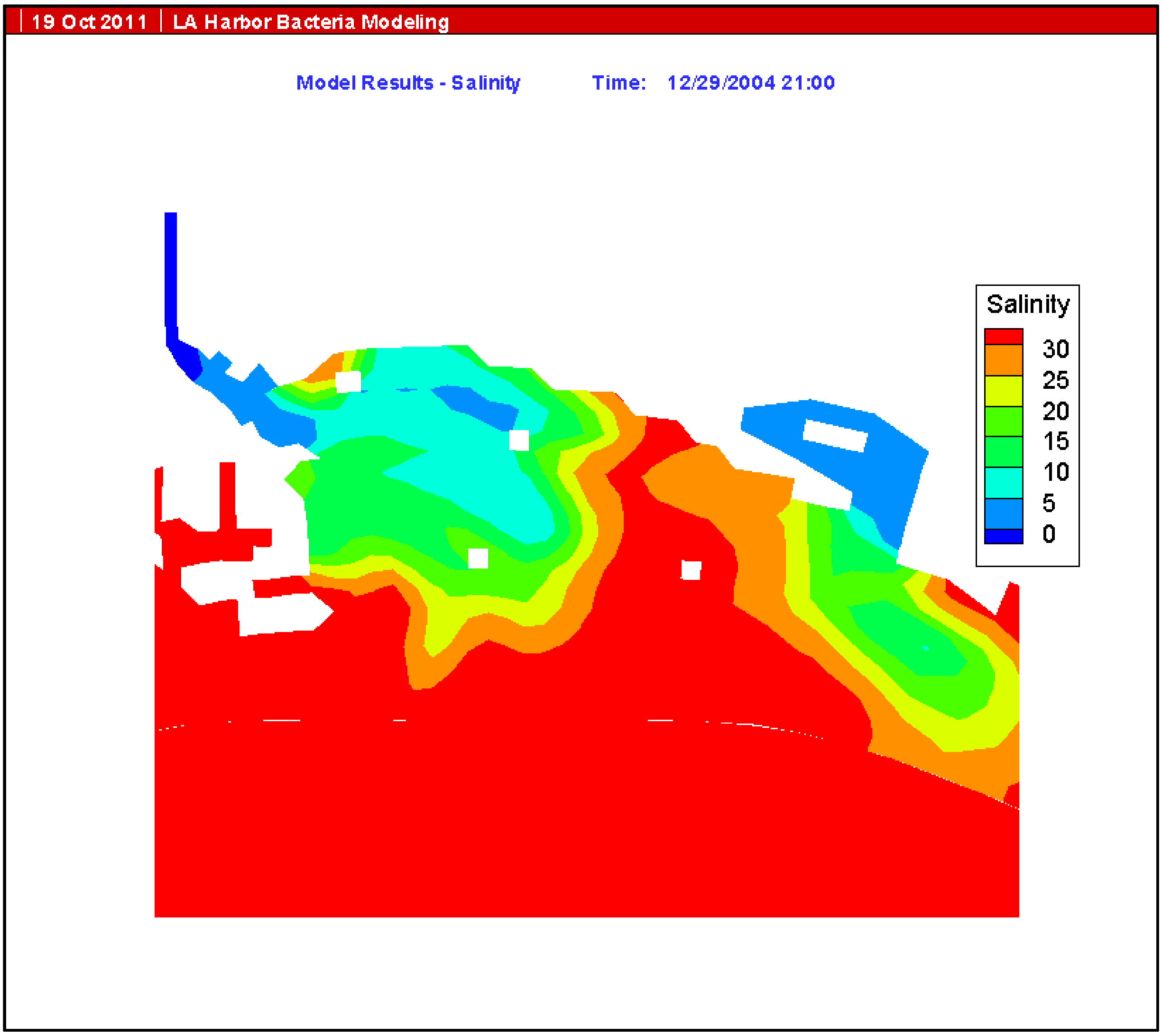
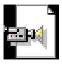


Figure 4. Simulated salinity (ppt) during the maximum wet weather event

Similar *enterococcus* simulations were run to demonstrate the extent of bacteria loading from the LAR and SGR/Alamitos Bay watersheds during the maximum wet weather event (Figure 5). This map illustrates the surface concentrations of *enterococcus* along the LBC beaches. The red and orange shades have the highest concentrations. During the maximum wet weather event, the concentrations from the LAR were high and they ultimately reached the western LBC beaches with little dilution. As shown in the wind rose plots, the winds throughout this day were largely moving from the northeast. Wind and tidal influences may have kept the LAR bacteria load near the beach area (although it should be noted that wind generally impacts only a thin layer of water at the surface, while the surface concentrations are averaged over several meters). On the other hand, loading from the SGR/Alamitos Bay moved out of the breakwater and generally towards the east. The concentrations from this area creeping to the west may have been due to tidal influence or wind. Along the entire LBC beaches segment, surface concentrations of *enterococcus* during the maximum wet weather event were over 2,000 MPN/100mL.

The full *enterococcus* simulation during the maximum wet weather event can be viewed at:



Entero - Max Wet Event

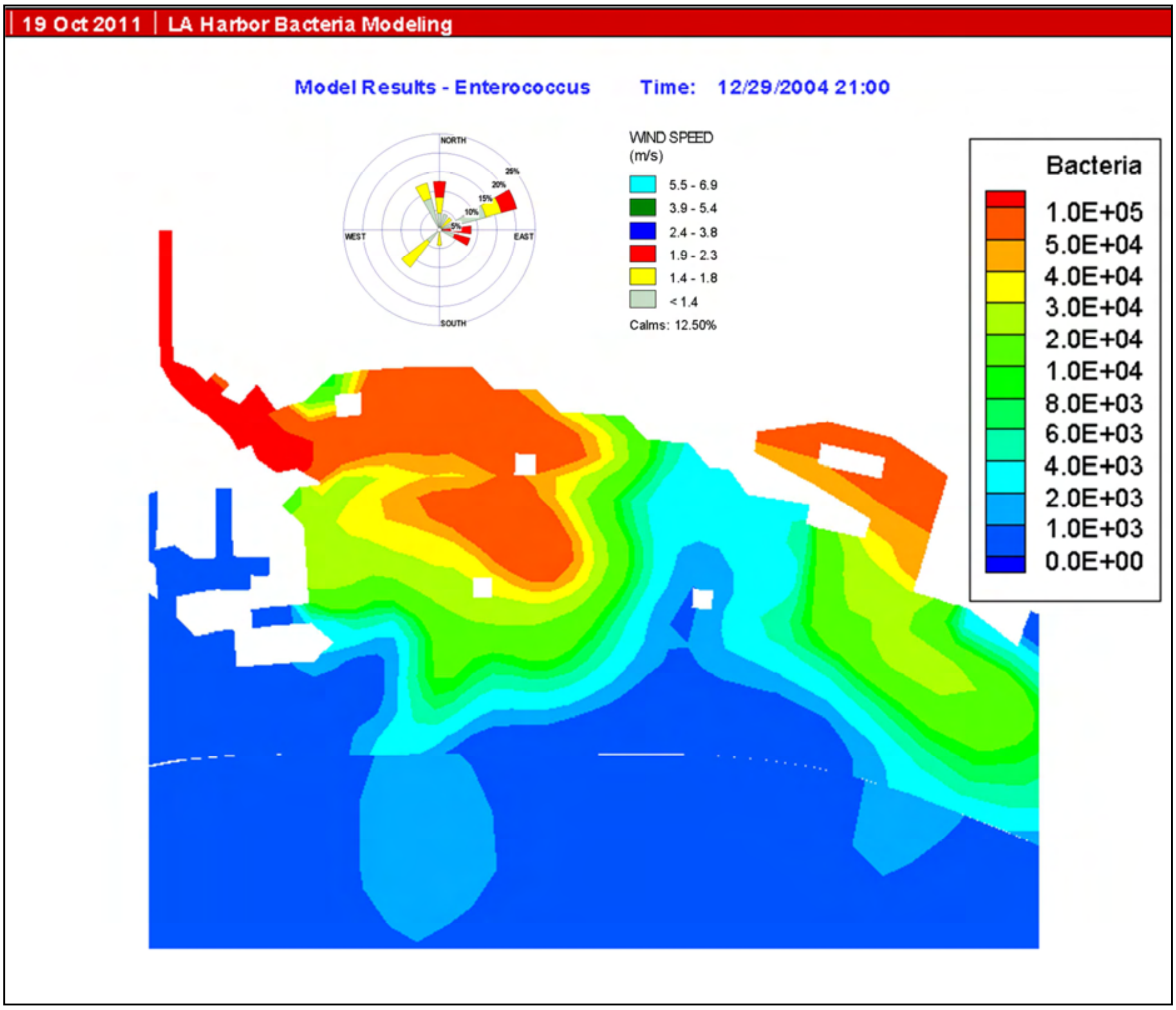
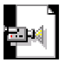


Figure 5. Simulated *enterococcus* concentration (MPN/100mL) during maximum wet weather event

D.2.2. Average Wet Weather Event

In addition to the winter wet weather event, an average wet weather event was simulated to represent more common wet weather conditions along the LBC beaches (Figure 6). As expected, the magnitude of *enterococcus* concentrations is lower during the average wet weather event. In addition, as shown in the wind rose plot for this day, winds were generally moving from the southwest. Wind and tidal influences may have pushed the LAR loading toward the LBC beaches, likely contributing to the elevated surface concentrations along the western LBC beaches. Loading from the SGR/Alamitos Bay followed a similar pattern to the maximum wet weather event; however, the magnitudes were lower and the overall bacteria plume was smaller. During this particular average wet weather event (Figure 6), surface concentrations of *enterococcus* were elevated along the entire LBC beaches segment, but to a much lesser extent than the maximum wet weather event (Figure 5).

The full *enterococcus* simulation during the average wet weather event can be viewed at:



Entero - Average Wet Event

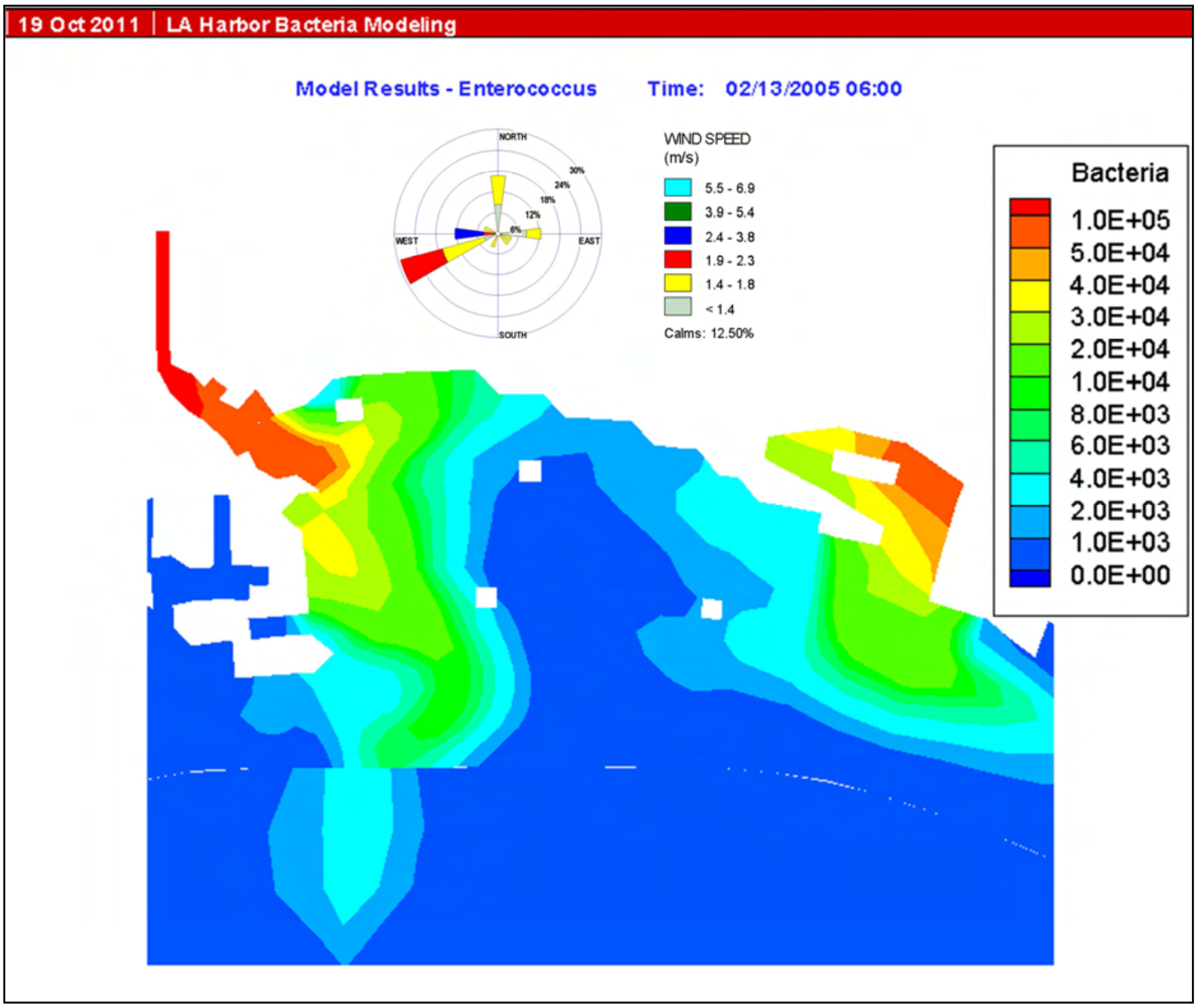


Figure 6. Simulated *enterococcus* concentration (MPN/100mL) during average wet weather event

D.2.3. Average Summer Dry Weather Event

Dry weather simulations were split by summer and winter months as described above. Average summer dry conditions were identified for each season in the simulation period by selecting the time period furthest from a rain event. Simulations showed low *enterococcus* concentrations from both the LAR and SGR/Alamitos Bay during the average summer dry period (Figure 7) and the breakwater near the mouth of SGR/Alamitos Bay funneled the loadings away from the LBC beaches. Surface concentrations of *enterococcus* along the LBC beaches remained unaffected by the major river inputs. As shown in the wind rose plots, the winds were largely moving from the west; however, its exact impact on the bacteria concentrations is unknown as both wind and tidal influences can impact surface concentrations.

The full *enterococcus* simulation during the average summer dry weather event can be viewed at:

Entero - Summer Dry

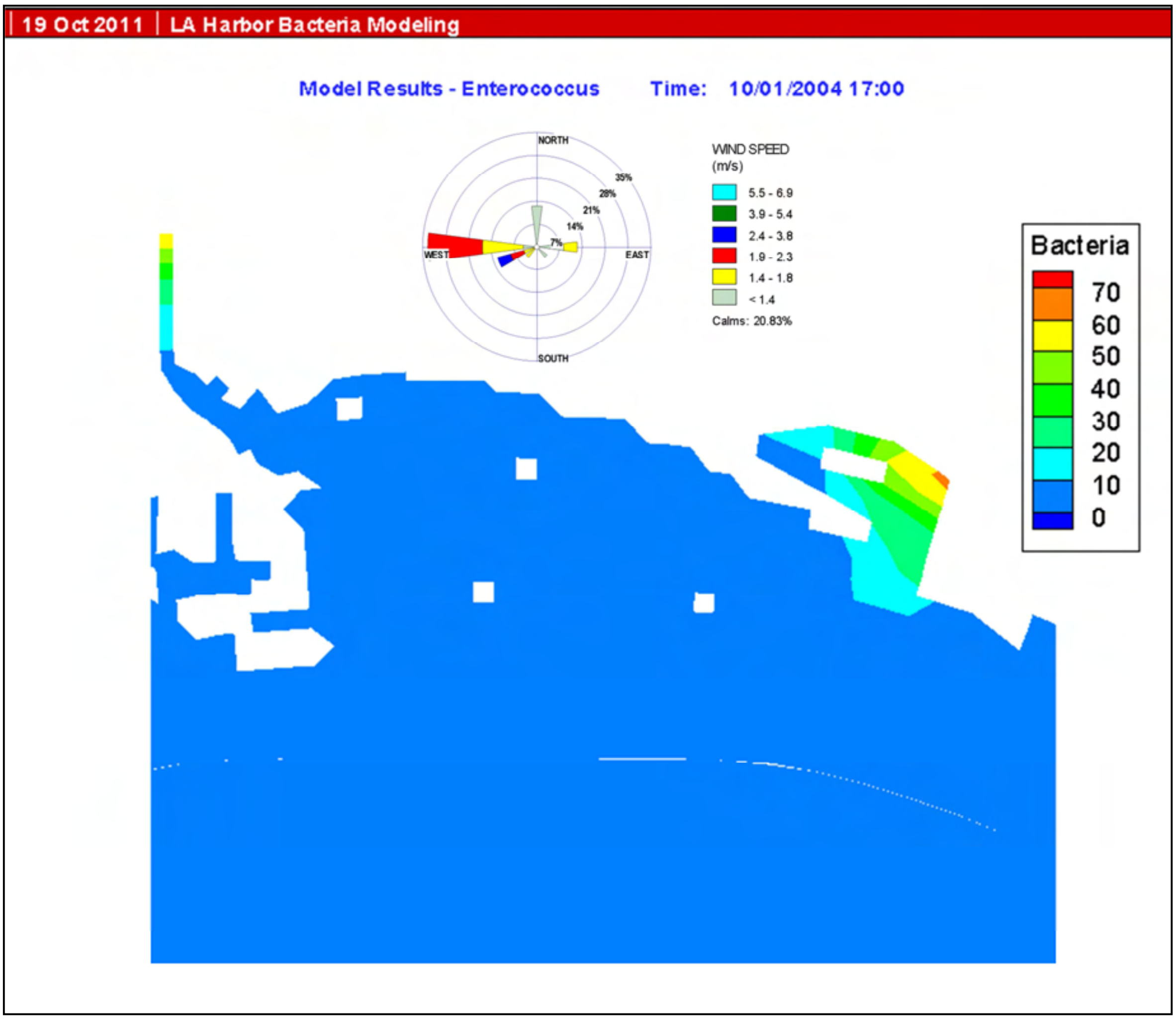


Figure 7. Simulated *enterococcus* concentration (MPN/100mL) during average summer dry period

D.2.4. Average Winter Dry Weather Event

The average winter dry period *enterococcus* results (Figure 8) were nearly identical to the summer dry results (Figure 7). Specifically the LAR and SGR/Alamitos Bay loadings do not appear to impact bacterial water quality at the LBC beaches. In general, the map shows that the SGR/Alamitos Bay breakwater prohibited the nearby loadings from reaching the LBC beaches. During this winter dry period, the wind was moving from the north. As previously noted, both wind and tidal processes can impact the overall direction of water and pollutant loading in the harbors. Overall, surface concentrations of *enterococcus* along the LBC beaches were low and were unaffected by the LAR and SGR/Alamitos Bay loadings.

The full *enterococcus* simulation during the average winter dry weather event can be viewed at:

Entero - Winter Dry

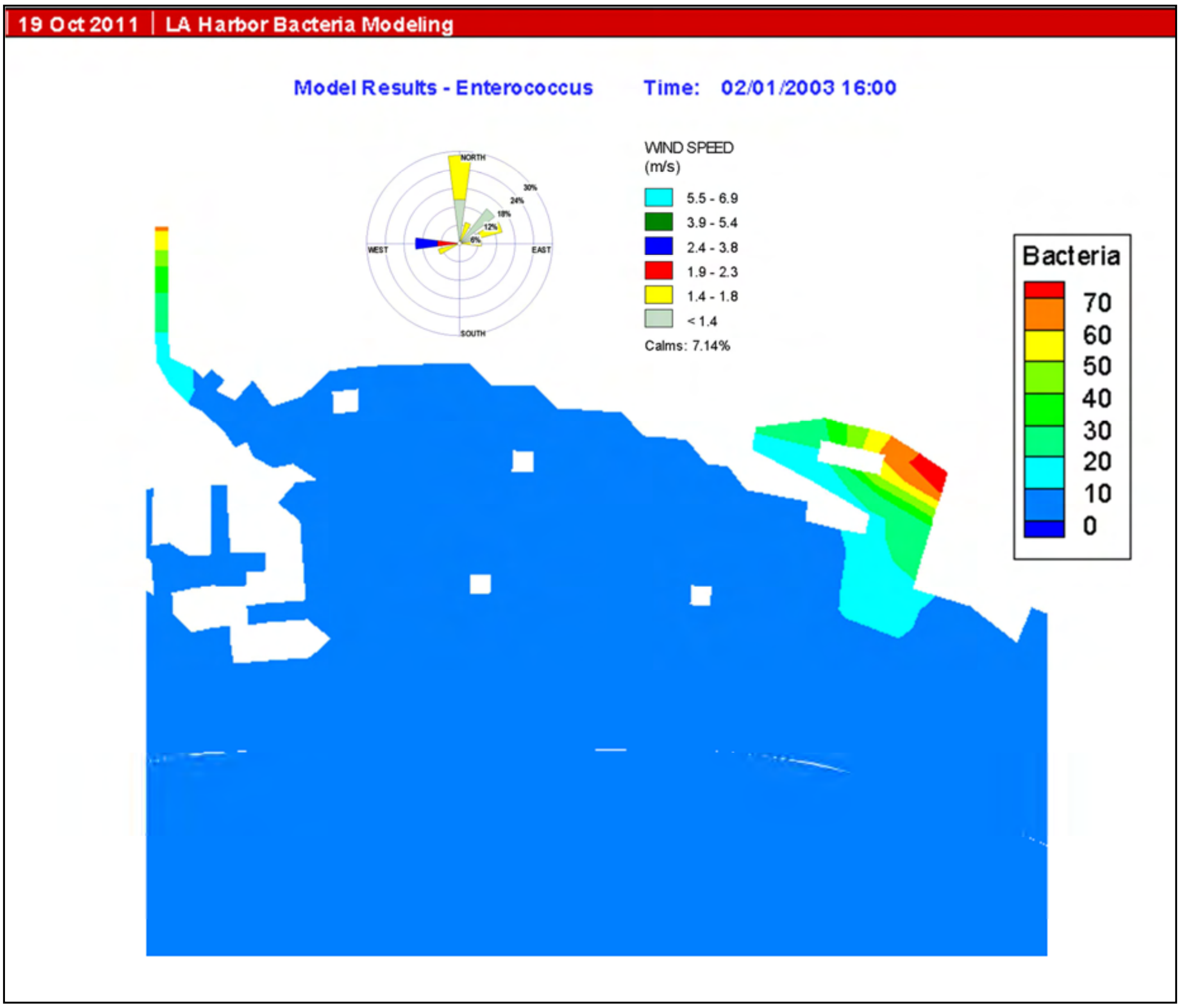


Figure 8. Simulated *enterococcus* concentration (MPN/100mL) during average winter dry period

D.3. REFERENCES

Hamrick, J. M., 1992: A three-dimensional environmental fluid dynamics computer code: Theoretical and computational aspects. The College of William and Mary, Virginia Institute of Marine Science, Special Report 317, 63 pp.

Hamrick, J. M., and T. S. Wu, 1997: Computational design and optimization of the EFDC/HEM3D surface water hydrodynamic and eutrophication models. *Next Generation Environmental Models and Computational Methods.* G. Delich and M. F. Wheeler, Eds., Society of Industrial and Applied Mathematics, Philadelphia, 143-156.

Ji, Z.-G., J. H. Hamrick, and J. Pagenkopf, 2002: Sediment and metals modeling in shallow river, *Journal of Environmental Engineering*, 128, 105-119.

King County, 1999: Water quality assessment of Elliot Bay and the Duwamish River. King County Department of Natural Resources, Seattle, WA. Available at: http://dnr.metrokc.gov/wlr/waterres/wqa/wqrep.htm

Los Angeles Regional Water Quality Control Board (LARWQCB). 2010. Los Angeles River Watershed Bacteria Total Maximum Daily Load. Los Angeles Regional Water Quality Control Board, Los Angeles, CA.

Los Angeles Regional Water Quality Control Board (LARWQCB). 2011. Dominguez Channel and Greater Los Angeles and Long Beach Harbor Waters Toxic Pollutants Total Maximum Daily Loads. Los Angeles Regional Water Quality Control Board, Los Angeles, CA. May 2011.

Los Angeles County Department of Public Works (LACDPW). 2010a. Los Angeles County 2009-2010 Stormwater Monitoring Report. Appendix B.1: 2009-2010 Annual Report Wet Weather Emission and Tributary Station Concentrations. Available at: http://ladpw.org/wmd/NPDES/2009-10tc.cfm

Los Angeles County Department of Public Works (LACDPW). 2010b. Los Angeles County 2009-2010 Stormwater Monitoring Report. Appendix B.2: 2009-2010 Annual Report Dry Weather Emission and Tributary Station Concentrations. Available at: http://ladpw.org/wmd/NPDES/2009-10tc.cfm

Park, K., A. Y. Kuo, J. Shen, and J. M. Hamrick, 1995: A three-dimensional hydrodynamic-eutrophication model (HEM3D): description of water quality and sediment processes submodels. The College of William and Mary, Virginia Institute of Marine Science. Special Report 327, 113 pp.

Tetra Tech, Inc. 2002. VOGG: A visual orthogonal grid generation tool for hydrodynamic and water quality modeling. A report to U. S. EPA, Region 4, August 2002, 62 pp.

Tetra Tech, Inc., 2011. Los Angeles/Long Beach Harbors and San Pedro Bay Hydrodynamic and Sediment-Contaminant Transport Model Report. Report prepared for USEPA Region 9 and the Los Angeles Regional Water Quality Control Board by Tetra Tech, Inc, San Diego, CA. May 2011.

U. S. Environmental Protection Agency, Region 1, 2006: Link to Housatonic River PCB Superfund web page. http://www.epa.gov/region01/ge/thesite/restofriver-reports.html

U. S. Environmental Protection Agency, Region 10, 2006: Link to Portland Harbor Superfund web page. http://yosemite.epa.gov/R10/CLEANUP.NSF/ph/fact+sheets/$FILE/1001PH.pdf

Wool, T. A., S. R. Davie, and H. N. Rodriguez, 2003: Development of three-dimensional hydrodynamic and water quality models to support TMDL decision process for the Neuse River estuary, North Carolina. *Journal of Water Resources Planning and Management*, 129, 295-306.

Zou, R., Carter, S., Shoemaker, L., Parker, A., and Henry, T., 2006. An integrated hydrodynamic and water quality modeling system to support nutrient TMDL development for Wissahickon Creek. *Journal of Environmental Engineering*, 132, 555-566.