APPENDIX A: ADDITIONAL LINKAGE ANALYSIS USING THE WRAP AND BIOACCUMUALTION MODEL

1 Introduction

The Ports of Long Beach and Los Angeles have developed a linked hydrodynamic, sediment transport, chemical fate, and bioaccumulation model to better understand how compliance with the Harbor Toxics TMDL may be achieved. The model provides the Ports with a tool for evaluating the relative effectiveness of different management alternatives at reducing fish tissue concentrations, and can be used to evaluate the link between sources and fish tissue concentrations of PCBs and DDT (also referred to below as organics).

The site-specific model, hereafter referred to as the linked model, integrates hydrodynamic, sediment transport, chemical fate of organic pollutants, and bioaccumulation processes. Model calibration studies were performed with sensitivity and uncertainty analyses and the models were peer-reviewed. The linked model has been used to evaluate the impact of ongoing sources and the relative contribution of water column and sediment sources to the fish receptors of concern, estimate recovery time, and the effectiveness of specific remedial actions.

2 Linked Model Overview

The successful linkage between the WRAP model (Everest, 2017) and bioaccumulation model (Anchor QEA, 2017a) was demonstrated during the model calibrations. The linkage provided daily averaged organic concentrations within the fish movement zones predicted by the WRAP model to the bioaccumulation model. The organics concentrations provided to the bioaccumulation model consisted of total, freely dissolved, and carbon-normalized concentrations in the water column and surface sediment. These organic concentrations simulated in the WRAP model reflect environmental conditions of the Harbor and exposure of PCB and DDT sources to the Harbor food web. The bioaccumulation model then simulates the transfer of contaminants from primary food sources (plankton, water column invertebrates, and benthic invertebrates) to the target fish species, accounting for diet and migration patterns.

The WRAP model development and calibrations have been described in detail in the WRAP Model Development report (Everest, 2017). The WRAP model was used to determine water and bed concentrations of organics for various management scenarios. Sediment bed concentrations were limited to the top 5-centimeter layer. Transfer of organics concentrations was represented by total, freely dissolved, and carbon-normalized concentrations.

The site-specific components of the bioaccumulation model include the food web structure, species-specific bioenergetics and body composition, water temperature, PCB and DDT chemical properties, and contaminant exposure concentrations. The PCB and DDT bioaccumulation model computes the uptake and loss of PCBs and DDT in fish based on principles of mass and energy conservation. A detailed description of the bioaccumulation model is included in the *Bioaccumulation Model Report* (Anchor QEA, 2017a).

Overall, the linked model was found to accurately simulate the relationship between sediment and water concentrations of organics and those in target fish species.

3 Peer Review of Individual and Linked Models

A peer review of the individual WRAP and bioaccumulation models, as well as the linked model, was conducted by a panel of recognized experts. This peer review provided an independent, third-party evaluation of the overall modeling framework and suitability to address TMDL compliance strategies. The panel was comprised of three model experts with specialized experience to individually evaluate the WRAP model, bioaccumulation model, and linked model. These model experts were selected based on professional expertise and availability to participate and complete the peer review process. The experts included:

- Dr. Todd Bridges, a Senior Research Scientist at the U.S. Army Engineer Research and Development Center, familiar with sediment remedial investigations, feasibility studies, and the implementation of sediment remediation programs. Dr. Bridges also serves as the Program Manager for the USACE Dredging Operations Environmental Research program, the Director of the Center for Contaminated Sediments, and the Chair of the Environmental Commission in the World Association for Waterborne Transport Infrastructure.

- Dr. Jon Arnot, the president and Principal Scientist with ARC Arnot Research and Consulting Inc., is a bioaccumulation modeler and practiced independent reviewer of models. He has over 19 years of research experience in the development, application, and evaluation of methods and models to assess the exposure, hazard, and risk of organic chemicals to humans and the environment.

- Dr. Weiming Wu, a professor in the Department of Civil and Environmental Engineering at Clarkson University, is an expert in sediment transport. He teaches and studies hydro- and morphodynamics in rivers, estuaries, coastal waters and uplands; surge and wave attenuation by vegetation; interaction between surface and subsurface flows; free surface flow and sediment transport modeling; and water quality and aquatic ecosystem/ecotoxicology modeling. He has developed a suite of computational models for flow, sediment transport, pollutant transport and aquatic ecology in riverine and coastal waters.

The purpose of the peer review was to assess the following:

- Will the linked model provide a means to compare the relative benefit of management strategies in reducing fish tissue concentrations in fish movement zones?
- Does the calibration appropriately incorporate and provide a reasonable comparison to the available data?
- Is the linked model appropriate for assessing the relative contribution of PCB and DDT sources to harbor fish contaminant levels and evaluating processes that impact the evaluation of the relative benefits of management strategies, including recontamination potential?

The peer review process involved several teleconferences to coordinate and discuss comments and an in-person meeting to promote dialog between the model development team and peer reviewers. The peer review process was documented based on formal comments from the peer reviewers, response to comments by the model development team, and final peer reviewer reports (Amec Foster Wheeler, 2017).

Comments were made by the peer review panel to strengthen the technical approach to address TMDL issues. The linked modeling framework with contaminant fate and transport modeling combined with bioaccumulation modeling was found to be a technically sound approach that is appropriate for this TMDL process (Bridges, 2016a). Individually, the WRAP and bioaccumulation models were reviewed based on model parameters, inputs, assumptions, and calibrations and found to be sufficient for the project objectives (Wu, 2016) (Arnot, 2016). Overall, the peer review panel determined that the modeling approach was sound and reached a consensus that the WRAP, bioaccumulation, and linked models are adequate for investigating the relative effectiveness of the management scenarios evaluated to support TMDL objectives. In addition, the peer reviewers provided recommendations for future model development and comments on the existing TMDL (Arnot, 2016) (Bridges, 2016a) (Bridges, 2016b).

4 Linked Model Management Scenarios

Through implementation of this TMDL, an important objective is to reduce fish tissue contaminant concentrations in the Harbor. The linked model was used to run simulations designed to evaluate the relative effectiveness of different management scenarios (Anchor QEA and Everest, 2018). This model-based approach for evaluating management action effectiveness is a standard practice used at numerous contaminated sediment sites throughout the United States, under the Comprehensive Environmental Response, Compensation, and Liability Act (often referred to as CERCLA or Superfund) and the Resource Conservation and Recovery Act.

Management scenarios were developed based on reductions of PCB and DDT sources from the Harbor. Reductions in contaminant sources were modeled as achieved through potential source control measures such as watershed loading reductions or sediment remediation. The scenarios were developed through the HTWG. Each management scenario focused on implementation of a specific source reduction strategy. A total of nine management scenarios were developed, each having different combinations of source reduction or sediment remediation in different fish movement zones. A 10^{th} baseline scenario was developed in order to evaluate the effectiveness of each management scenario by comparing fish tissue concentrations without source reductions. In general, the management scenarios were designed to address key issues:

- Linkages between PCB and DDT sources and fish tissue concentrations
- Time to compliance for various source control measures identified in TMDL

Table 1 shows a matrix of the management scenarios to summarize the description, objectives, and modeling assumptions for each scenario. Several management scenarios (Scenario 0, 1, 3, 7 and 6) were developed mainly to inform linkages between PCB and DDT sources and fish tissue concentration by focusing on individual sources, specifically watershed loadings, sediment sources, and regional sources (i.e., outside of the harbor). Three scenarios (Scenario 4, 5, and 6) included combinations of source control strategies. Two scenarios (Scenario 8 and 9) examined the timing of source reductions.

For each management scenario, the linked model was used to estimate water, sediment, and tissue concentrations – the WRAP model determined changes in water and sediment concentrations due to source reductions while the bioaccumulation model determined response in fish tissue concentrations. Because responses in fish tissue concentrations occur over several years rather than immediately, model simulations were conducted over an arbitrary 20-year period with source reductions applied at the start of the simulation (i.e., time = 0). In the WRAP model, hydrodynamic and sediment conditions were kept the same for all model scenarios to allow for direct comparison between management scenarios. The bioaccumulation model determined tissue concentrations in three target fish species. A market basket approach was used to represent fish tissue concentrations in which the market basket concentration is the average tissue concentration in the three target species: white croaker, California halibut, and surfperch. Complete details on the scenario development, environmental conditions, and model inputs are provided in the appendices of the linked model data summary report (Anchor QEA and Everest 2018)

Table 1 Management Scenarios for Evaluation of Sources Controls

Model Scenario Description	**Modeling Assumptions**	**Objective of Model Run**
Scenario 0 **Baseline** - Baseline model for purposes of comparison with management/source reduction model runs - Represents expected future projections (due to natural recovery and recovery due to port operations, including dredging) without specific source reductions - Predicts changing chemical concentrations in sediment and fish over decades	- Watershed loadings at inflow boundary: use existing data (2004 to 2013) to define future watershed loads - Post-dredge surface residual concentrations: 50% decline in surface sediment concentrations for areas affected by anticipated Ports' capital improvement projects - WRAP model grid changes: planned Port capital improvement programs (e.g., deepening and terminal redevelopment that are on grid scale) set at time zero - Other considerations: incorporation of Los Angeles River Estuary maintenance dredging conducted every 5 years	Establish baseline estimate of time to achieve fish tissue and related sediment compliance targets if no targeted management alternatives are implemented, for comparison with other scenarios.
Scenario 1 **Baseline + 100% Watershed Load Reduction (WLR) (ie no contributions from land sources, at all)** - Contribution of watershed loadings to Harbor sediment and fish tissue PCBs/DDT	- 100% WLR, organics set to 0 - WLR completed at Time = 0	Determine the contribution of watershed loadings to fish tissue PCB/DDT concentrations relative to baseline, during the 20-year simulation period.
Scenario 2 **Baseline + 50% WLR** - Contribution of watershed loadings to Harbor sediment and fish tissue PCBs/DDT	- 50% WLR reduction - WLR completed at Time = 0	If watershed loadings are shown to contribute to fish tissue body burdens (Run #1 relative to Baseline), then estimate time to achieve compliance (i.e., fish and sediment targets) if a 50% reduction in watershed loading was implemented, relative to Baseline and Run #1. This run may be important for understanding the impacts of source control because it is unlikely that watershed loads can be reduced by 100%.

Scenario 3 **Baseline + Sediment Load Reduction (SedLR) to Target** - Contribution of sediment bed loadings to fish tissue PCBs/DDT	- Sediments set to TMDL Fish-Associated Sediment Target - Remediate sediment at Time = 0 - No change in hydrodynamics or water depth	Estimate time to TMDL compliance by only reducing sediment PCBs/DDT concentrations to TMDL targets.
Scenario 4 **Baseline + 100% WLR + Dominguez Channel Estuary (DCE) SedLR** - Contribution of DCE sediments in addition to watershed loadings to fish tissue PCBs/DDT	- 100% WLR reduction - Sediments set to TMDL Fish-Associated Sediment Target in DCE - WLR completed at Time = 0 - Remediate sediment at Time = 0 - No change in hydrodynamics or water depth	Evaluate how remediation of the DCE hot spot will further reduce Harbor fish tissue PCBs/DDT beyond Run #1, due to the reduction in the PCB/DDT load coming from DCE.
Scenario 5 **Baseline + 100% WLR +** **Hot Spot SedLR** - Additional contribution of named Harbor hot spots (Consolidated Slip (CS) + Fish Harbor (FH)), along with ongoing sources and Dominguez Channel Estuary (DCE) sediment to fish tissue PCBs/DDT	- 100% WLR reduction - Sediments set to TMDL Fish-Associated Sediment Target in CS, FH, and DCE - WLR completed at Time = 0 - Remediate sediment at Time = 0 - No change in hydrodynamics or water depth	Evaluate how remediation of TMDL-named hot spots will further reduce fish tissue PCBs/DDT beyond Run #4. Evaluate whether TMDL compliance will be achieved through WLR and TMDL-specified actions.
Scenario 6 **Baseline + 100% WLR +** **100% SedLR** – Influence of recontamination of the Harbor due to the influence of outside Harbor influences (PV Shelf, regional fish tissue, and exchange with Harbor)	- DCE sediments set to zero - 100% WLR: organics set to zero - Harbor sediments set to zero - WLR completed at Time = 0 - Remediate sediment at Time = 0 - No change in hydrodynamics or water depth	Evaluate the level to which the Harbor will re-contaminate over time from exchange of Harbor water and sediment with regional DDT/PCB sources (e.g., PV Shelf Superfund site and outside Harbor areas) and due to fish movement and exposure to off-site DDT/PCB sources (i.e., outside Harbor)
Scenario 7 **Baseline + Hot Spot SedLR** - Contribution of DCE sediment and other named Harbor hot spots (CS + FH) to fish tissue PCBs/DDT	- Sediments set to TMDL Fish-Associated Sediment Target in DCE, CS, and FH - Remediate at Time = 0 - No change in hydrodynamics or water depth	Evaluate how remediation of TMDL-named hot spots (including DCE) without watershed load reductions will reduce fish tissue PCBs/DDT.

Scenario 8 **Baseline + 50% WLR + *T=0* Hot Spot SedLR** - Impact of watershed loading reductions along with time zero DCE sediment and other named Harbor hot spots (CS +FH) SedLR on fish tissue PCBs/DDT	- 50% WLR reduction - Sediments set to TMDL Fish-Associated Sediment Target in CS, FH, and DCE - WLR completed at Time = 0 - Remediate sediment at Time = 0 - No change in hydrodynamics or water depth	Evaluate how remediation of TMDL-named hot spots (including DCE) along with estimated watershed load reductions will reduce fish tissue PCBs/DDT.
Scenario 9 **Baseline + 50% WLR + *T=20* Hot Spot SedLR** - Impact of watershed loading reductions along with year 20 DCE sediment and other named Harbor hot spots (CS +FH) SedLR on fish tissue PCBs/DDT	- 50% WLR reduction - Sediments set to TMDL Fish-Associated Sediment Target in CS, FH, and DCE - WLR completed at Time = 0 - Remediate sediment at Time = Year 20 - No change in hydrodynamics or water depth	Compare to Scenario 8 to examine the difference in fish tissue PCBs/DDT if sediments are reduced before sources are reduced.

Notes:
CS: Consolidated Slip (TMDL hot spot)
PV: Palos Verdes
DCE: Dominguez Channel Estuary (TMDL hot spot upstream of Consolidated Slip
SedLR: sediment load reduction
FH: Fish Harbor (TMDL hot spot)
WLR: watershed load reduction

Table 2 shows the linked model Year 1 sediment, water, and market basket fish tissue PCB and DDT concentrations that represent average conditions during the first year of the simulation (i.e., time zero to year 1). These concentrations reflect current conditions that were established from measured sediment, water, and fish tissue data. Further details on the environmental conditions, WRAP model inputs, and bioaccumulation model initial conditions for the model scenarios are provided in the appendices of the linked model data summary report (Anchor QEA and Everest, 2018).

Table 2 Linked Model Results after Year 1 (Current Condition) Simulation for Sediment, Water Column, and Fish Market Basket Total PCB and Total DDT Concentrations

Fish Movement Zone	Sediment PCB (a)	Sediment DDT(a)	Water particulate PCB(b)	Water particulate DDT(b)	Water Dissolved PCB (c)	Water Dissolved DDT (c)	Fish Tissue PCB (d)	Fish Tissue DDT (d)
Dominguez Channel Estuary	14.67	7.28	12.56	13.60	10.92	9.38	385.56	260.80
Consolidated Slip	24.21	8.29	2.46	2.21	2.14	1.52	265.76	159.55
Los Angeles Inner Harbor	4.09	3.93	0.66	0.70	0.57	0.48	137.93	212.27
Fish Harbor	8.07	5.14	0.68	0.45	0.59	0.31	79.60	53.06
Seaplane Lagoon	2.31	2.29	0.41	0.47	0.36	0.33	71.43	77.61
Los Angeles Outer Harbor	1.44	3.61	0.32	0.43	0.28	0.30	52.25	129.61
Long Beach Inner Harbor North	2.60	1.26	0.64	0.68	0.56	0.47	92.49	74.73
Long Beach Inner Harbor South	4.88	2.80	0.44	0.48	0.38	0.33	69.77	80.10
Long Beach Outer Harbor	1.18	2.77	0.31	0.40	0.27	0.28	94.19	77.18
Los Angeles River Estuary	4.01	0.95	1.78	1.42	1.55	0.98	144.06	70.93
Eastern San Pedro Bay	1.80	1.35	0.45	0.49	0.39	0.34	121.21	64.50

Notes:
(a) Sediment in micrograms per gram organic carbon (ug/g OC)
(b) Water particulate in micrograms per gram organic carbon (ug/g OC)
(c) Water column dissolved in nanograms per liter (ng/L)
(d) Market Basket Fish Tissue in micrograms per kilogram wet weight (µg/kg ww)
Market Basket: weighted-average of three representative fish species: white croaker, California halibut, and surfperches

5 Linked Model Management Scenarios Evaluation

All results of linked WRAP and bioaccumulation model simulations are provided in Anchor QEA and Everest 2018. Three scenario summaries are provided here for the baseline condition (Scenario 0), the ideal condition with the assumption of 100% watershed load reduction and hotspots sediment load reduction (Scenario 5), and the average condition with the assumption of 50% watershed load reduction and hotspot sediment load reduction (Scenario 8). Scenario 8 most closely approximates the anticipated conditions for implementation of the TMDL.

5.1 Scenario 0 – Baseline Condition

The baseline scenario was designed to represent both ongoing natural recovery processes and other sediment recovery processes that are associated with recurring stormwater controls and routine port operations. For this baseline scenario, declines in water and sediment bed concentrations are attributed to natural recovery; it is assumed that there are no targeted source reductions. Table 3 provides predicted sediment, water column, and fish market basket [1] total PCB and DDT concentrations for different fish movement zones of the baseline model scenario, which represents the changes in market basket fish tissue PCB and DDT associated with both ongoing natural recovery processes and other sediment recovery processes in the Harbor that are associated with recurring port operations The baseline scenario will be compared with the management scenarios to evaluate the source control strategies.

Recovery in the Harbor has indeed been observed based on historical sediment, mussel, and fish (i.e., white croaker) data. However, there is substantial variability in recovery levels (i.e., 2% to 4% and approximately 4% declines for PCB and DDT in mussels, respectively) and declines are slow (Anchor QEA, 2014a). This recovery is likely the result of both natural and anthropogenic effects. Natural recovery in the Harbor may be ongoing due to the deposition of less contaminated sediments from watershed sources over the past few decades and associated reductions in surface sediment deposits of PCB and DDT in the Harbor. Dredging of sediments and port fills (e.g., in a confined disposal facility) over the past 20 years also have been recurring and are expected to continue over the next 20 years as part of normal port operations.

[1] Market Basket: weighted average of three representative fish species: white croaker, California halibut, and surfperches

Table 3 Baseline Scenario (Scenario 0) Year 20 Predicted Sediment, Water Column, and Fish Market Basket Total PCB and Total DDT Concentrations

Fish Movement Zone	Sediment PCB (a)	Sediment DDT(a)	Water particulate PCB(b)	Water particulate DDT(b)	Water Dissolved PCB ©	Water Dissolved DDT ©	Fish Tissue PCB (d)	Fish Tissue DDT (d)
Dominguez Channel Estuary	11.44	5.05	4.86	7.04	4.22	4.85	132.23	115.77
Consolidated Slip	8.20	3.09	0.68	0.83	0.59	0.57	85.25	72.56
Los Angeles Inner Harbor	2.52	3.24	0.31	0.34	0.27	0.23	61.80	189.49
Fish Harbor	5.55	4.71	0.49	0.26	0.42	0.18	55.36	41.00
Seaplane Lagoon	1.56	2.12	0.26	0.27	0.22	0.19	41.80	55.01
Los Angeles Outer Harbor	0.97	3.01	0.22	0.26	0.19	0.18	34.01	114.42
Long Beach Inner Harbor North	1.45	1.01	0.27	0.30	0.24	0.20	44.35	47.76
Long Beach Inner Harbor South	2.49	2.37	0.23	0.24	0.20	0.16	35.10	64.66
Long Beach Outer Harbor	0.65	2.31	0.20	0.23	0.18	0.16	54.16	57.32
Los Angeles River Estuary	0.55	0.13	1.32	1.02	1.15	0.70	77.92	45.54
Eastern San Pedro Bay	0.93	0.95	0.30	0.30	0.26	0.21	73.11	43.85

Notes:
(a) Sediment in micrograms per gram organic carbon (ug/g OC)
(b) Water particulate in micrograms per gram organic carbon (ug/g OC)
© Water column dissolved in nanograms per liter (ng/L)
(d) Market Basket Fish Tissue in micrograms per kilogram wet weight (µg/kg ww)
Market Basket: weighted-average of three representative fish species: white croaker, California halibut, and surfperches

5.2 Scenario 5 – 100% Watershed Load Reduction (WLR) Plus Hot Spot Sediment Load Reduction (SedLR)

Scenario 5 incorporates major components of the TMDL implementation plan; it combines a 100% Waste Load Reduction with Sediment Load Reduction in the TMDL-named hot spots: Dominguez Channel Estuary, Consolidated Slip, and Fish Harbor. Table 4 provides year 20 linked model results for Scenario 5 including predicted sediment, water column, and fish market basket total PCB and DDT concentrations for each fish movement zone, which represent changes in PCB and DDT concentrations in fish tissue 20 years after 100% WLR and hot spot sediment remediation occurs

Table 4 Scenario 5 (100% WRL and Hotspots Cleanup) – Year 20 Predicted Sediment, Water Column, and Fish Market Basket Total PCB and Total DDT Concentrations

Fish Movement Zone	Sediment PCB (a)	Sediment DDT(a)	Water particulate PCB(b)	Water particulate DDT(b)	Water Dissolved PCB ©	Water Dissolved DDT ©	Fish Tissue PCB (d)	Fish Tissue DDT (d)
Dominguez Channel Estuary	0.05	0.03	0.11	0.10	0.09	0.07	20.21	24.41
Consolidated Slip	0.04	0.02	0.25	0.21	0.22	0.15	22.53	30.01
Los Angeles Inner Harbor	2.51	3.24	0.24	0.24	0.21	0.17	35.53	171.75
Fish Harbor	0.13	0.09	0.15	0.20	0.13	0.14	13.42	26.20
Seaplane Lagoon	1.54	2.12	0.23	0.25	0.20	0.17	35.88	50.95
Los Angeles Outer Harbor	0.97	3.01	0.20	0.24	0.17	0.16	29.58	110.49
Long Beach Inner Harbor North	1.44	1.00	0.21	0.21	0.18	0.14	35.69	40.86
Long Beach Inner Harbor South	2.48	2.37	0.20	0.20	0.18	0.14	27.72	57.96
Long Beach Outer Harbor	0.64	2.31	0.18	0.21	0.16	0.14	49.31	53.19
Los Angeles River Estuary	0.53	0.13	0.15	0.15	0.13	0.10	47.64	27.27
Eastern San Pedro Bay	0.91	0.95	0.17	0.20	0.15	0.14	54.90	32.52

Notes:
(a) Sediment in micrograms per gram organic carbon (ug/g OC)
(b) Water particulate in micrograms per gram organic carbon (ug/g OC)
© Water column dissolved in nanograms per liter (ng/L)
(d) Market Basket Fish Tissue in micrograms per kilogram wet weight (µg/kg ww)
Market Basket: weighted-average of three representative fish species: white croaker, California halibut, and surfperches

5.3 Scenario 8 – 50% Watershed Load reduction plus Hot Spots Sediment Load Reduction

This scenario was designed to represent ongoing natural recovery processes as well as regional reductions expected to be achieved through watershed reductions as well as the added benefit of hot spot remediation. Table 5 provides the results of Scenario 8, which represents the changes in market basket fish tissue PCB and DDT associated with a 50% WLR and hot spots sediment remediation.

Table 5 Scenario 8 (50% WRL and Hotspots Cleanup) – Year 20 Predicted Sediment, Water Column, and Fish Market Basket Total PCB and Total DDT Concentrations

Fish Movement Zone	Sediment PCB (a)	Sediment DDT(a)	Water particulate PCB(b)	Water particulate DDT(b)	Water Dissolved PCB ©	Water Dissolved DDT ©	Fish Tissue PCB (d)	Fish Tissue DDT (d)
Dominguez Channel Estuary	0.07	0.03	1.70	2.59	1.47	1.79	41.35	50.11
Consolidated Slip	0.05	0.02	0.35	0.42	0.30	0.29	29.05	39.11
Los Angeles Inner Harbor	2.51	3.24	0.26	0.28	0.23	0.19	38.46	175.77
Fish Harbor	0.13	0.09	0.15	0.21	0.13	0.14	14.27	26.94
Seaplane Lagoon	1.55	2.12	0.24	0.26	0.21	0.18	37.44	52.50
Los Angeles Outer Harbor	0.97	3.01	0.20	0.25	0.18	0.17	30.69	111.71
Long Beach Inner Harbor North	1.44	1.00	0.23	0.24	0.20	0.17	37.72	43.35
Long Beach Inner Harbor South	2.48	2.37	0.21	0.22	0.19	0.15	29.61	60.22
Long Beach Outer Harbor	0.65	2.31	0.19	0.22	0.17	0.15	51.37	55.02
Los Angeles River Estuary	0.54	0.13	0.74	0.58	0.64	0.40	62.63	36.32
Eastern San Pedro Bay	0.92	0.95	0.24	0.25	0.21	0.17	63.85	38.09

Notes:
(a) Sediment in micrograms per gram organic carbon (ug/g OC)
(b) Water particulate in micrograms per gram organic carbon (ug/g OC)
© Water column dissolved in nanograms per liter (ng/L)
(d) Market Basket Fish Tissue in micrograms per kilogram wet weight (µg/kg ww)
Market Basket: weighted-average of three representative fish species: white croaker, California halibut, and surfperches

5.4 Percent Reduction of Fish Tissue Concentration in 20-Year Model Simulation

Model- predicted percent reductions in market basket fish tissue PCB and DDT concentrations achieved in 20 years for PCBs and DDT for each fish movement zones are shown in Table 6 and Table 7, respectively, for every scenario. The greatest reductions in predicted fish tissue concentrations are associated with hot spots sediment load reductions (including Dominguez Channel estuary, Consolidated Slip, and Fish Harbor).

Table 6 Percent Reduction of Market Basket PCBs in 20 Years

Fish Movement Zone	**Scenario 0**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**
Dominguez Channel Estuary	66	75	70	77	81	93	97	79	86	70
Consolidated Slip	68	72	70	88	71	89	95	83	86	70
LA Inner Harbor	55	59	57	77	58	70	83	66	68	57
Fish Harbor	30	32	31	80	31	80	83	78	79	31
Seaplane Lagoon	41	44	42	68	43	46	75	44	45	42
LA Outer Harbor	35	38	36	56	37	40	62	37	39	36
LB Inner Harbor North	52	55	53	75	53	57	81	54	55	53
LB Inner Harbor South	50	54	52	72	53	57	79	52	54	52
LB Outer Harbor	42	45	44	68	45	45	75	42	44	44
LA River Estuary	46	62	54	63	62	62	86	46	54	54
Eastern San Pedro Bay	40	51	45	64	51	51	82	40	45	45

Table 7 Percent Reduction in Market Basket DDT in 20 Years

Fish Movement Zone	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Dominguez Channel Estuary	56	73	64	64	79	87	92	64	75	64
Consolidated Slip	55	64	59	71	64	76	85	64	70	59
LA Inner Harbor	11	13	12	24	12	15	26	12	13	12
Fish Harbor	23	24	23	48	24	47	50	45	46	23
Seaplane Lagoon	29	31	30	61	31	32	66	30	31	30
LA Outer Harbor	12	13	12	44	13	13	47	12	13	12
LB Inner Harbor North	36	40	38	46	39	40	51	36	38	38
LB Inner Harbor South	19	23	21	32	22	24	37	20	22	21
LB Outer Harbor	26	29	27	41	28	28	46	25	27	27
LA River Estuary	36	55	45	44	55	55	67	36	45	45
Eastern San Pedro Bay	32	45	38	44	45	45	60	32	38	38

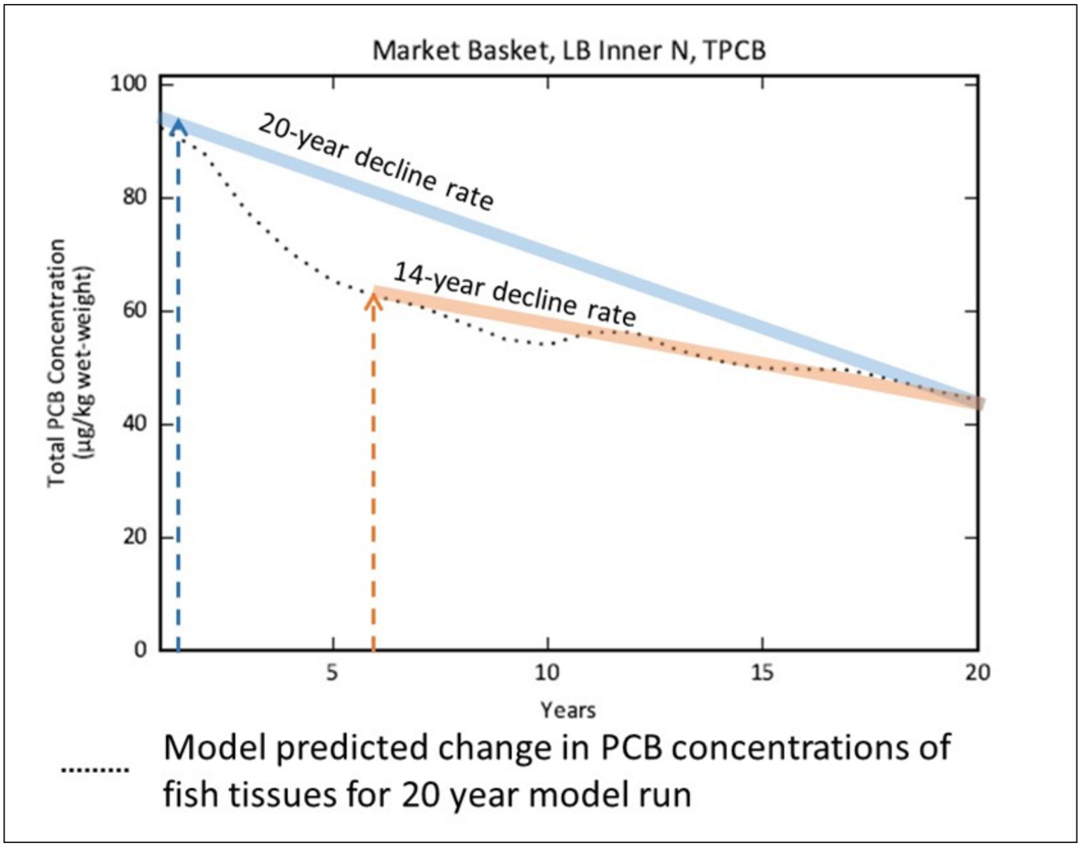
5.5 Predicted Time to Meet Fish Tissue Associated Sediment Targets

The linked WRAP and bioaccumulation model simulations were conducted to evaluate the relative effectiveness of the different management scenarios at reducing fish tissue PCBs and DDT concentrations in the Greater Harbor waters. The approximate number of years that the model estimates it will take for PCB and DDT concentrations in fish tissue to reach the TMDL fish-associated sediment targets for PCBs and DDT are summarized below.

It is anticipated that the rate of fish tissue contaminant decline will be greater at first and then decrease and stabilize. Given that the model scenarios were limited to 20 years, if the model estimated that the market basket fish concentrations would not reach the targets within the 20-year simulation period, the approximate number of years to reach the targets were estimated using two different decline rates: i) an initial decline rate called the 20-year decline rate starting from year 1 to year 20 and projected to the future; and ii) a second decline rate called the 14-year decline rate using a stabilized decline rate starting at year 6 to year 20 and projected to the future (Figure 1).

While these approaches can estimate years to targets, there are uncertainties regarding the fact that the model was not designed to predict conditions beyond 2034 and that the model input parameters (including, but not limited to, BASF, water column particulates, ocean boundary, etc.) greatly impact the relative contribution of sources, sediment contribution to the fish tissue, and the resulting estimated time to meet the TMDL targets. Additional data collected in the future should be used to confirm and/or refine the model estimations.

Figure 1 Illustration with Hypothetical Slopes to Compare 20-Year and 14-Year Model Predicted Decline Rates



5.5.1 Predicted Time to Meet the FCG

Table 8 and Table 9 show the approximate number of years that the model estimates it will take for the market basket fish tissue PCB and DDT concentrations to reach the TMDL fish-associated sediment targets for PCBs and DDT, respectively, using the 20-year decline rate (first approach) to calculate the rate of decline.

Table 10 and Table 11 show the approximate number of years that the model estimates it will take for the market basket fish tissue PCB and DDT concentrations to reach the TMDL fish-associated sediment targets for PCBs and DDT, respectively, using the 14-year decline rate (second approach) to calculate the rate of decline. Model results for all scenarios are provided in the Linked Model Data Summary Report submitted to the Los Angeles Water Board in November 2018 (Anchor QEA and Everest, 2018).

Table 8 Model Estimated Time (years) to Meet TMDL Fish Associated Sediment Target for PCBs Using 20-year Decline Rate

Fish Movement Zone	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Dominguez Channel Estuary	97	69	83	74	58	35	26	71	52	83
Consolidated Slip	80	69	75	45	71	40	27	54	47	75
LA Inner Harbor	95	84	89	55	88	67	44	79	73	89
Fish Harbor	160	151	155	41	155	39	35	43	41	155
Seaplane Lagoon	119	107	113	62	112	106	47	118	112	113
LA Outer Harbor	126	112	119	74	119	112	62	126	119	119
LB Inner Harbor North	97	86	91	55	92	86	44	99	92	91
LB Inner Harbor South	89	77	83	52	81	75	40	88	81	83
LB Outer Harbor	116	104	110	63	107	106	50	119	113	110
LA River Estuary	136	77	104	95	77	77	38	137	104	104
Eastern San Pedro Bay	145	98	120	83	99	99	43	147	121	120

Notes:

Start Year: 2014

Total Maximum Daily Load (TMDL) Target = 3.6 micrograms per kilogram (µg/kg)

SedLR: sediment load reduction

WLR: watershed load reduction

Table 9 Model Estimated Time (years)to Meet TMDL Fish Associated Sediment Target for DDT Using 20-Year Decline Rate

Fish Movement Zone	**Scenario 0**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**
Dominguez Channel Estuary	69	38	52	55	30	22	7	57	37	52
Consolidated Slip	54	39	46	34	39	26	7	43	34	46
LA Inner Harbor	306	260	282	190	304	292	180	353	320	282
Fish Harbor	66	61	63	27	62	28	24	30	29	63
Seaplane Lagoon	72	64	68	27	66	65	22	73	69	68
LA Outer Harbor	211	196	203	66	204	199	59	215	207	203
LB Inner Harbor North	58	48	53	44	50	49	35	61	55	53
LB Inner Harbor South	105	87	96	69	94	90	58	110	99	96
LB Outer Harbor	77	67	72	48	68	68	40	79	73	72
LA River Estuary	60	27	41	46	27	27	9	61	41	41
Eastern San Pedro Bay	56	34	44	39	34	34	22	57	44	44

Notes:

Start Year: 2014

Total Maximum Daily Load (TMDL) Target = 21 micrograms per kilogram (µg/kg)

SedLR: sediment load reduction

WLR: watershed load reduction

Table 10 Model Estimated Time (years)-to Meet TMDL Fish Associated Sediment Target for PCBs Using 14-year Decline Rate

Fish Movement Zone	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Dominguez Channel Estuary	142	100	121	156	85	65	38	187	129	121
Consolidated Slip	106	91	98	89	93	80	49	124	103	98
LA Inner Harbor	129	117	123	147	123	161	179	185	173	123
Fish Harbor	191	186	188	95	190	91	83	102	97	188
Seaplane Lagoon	166	158	162	183	166	183	288	191	187	162
LA Outer Harbor	189	179	184	229	194	214	329	225	220	184
LB Inner Harbor North	136	126	131	149	134	141	272	152	147	131
LB Inner Harbor South	124	112	118	124	121	124	149	139	131	118
LB Outer Harbor	145	135	140	163	139	140	179	150	145	140
LA River Estuary	178	110	144	276	111	111	108	179	145	144
Eastern San Pedro Bay	180	134	157	250	135	136	139	182	159	157

Notes:

Start Year: 2014

Total Maximum Daily Load (TMDL) Target = 3.6 micrograms per kilogram (µg/kg)

SedLR: sediment load reduction

WLR: watershed load reduction

Table 11 Model Estimated Time (years)to Meet TMDL Fish Associated Sediment Target for DDT Using 14-year Decline Rate

Fish Movement Zone	**Scenario 0**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**
Dominguez Channel Estuary	105	55	80	102	42	26	7	138	82	80
Consolidated Slip	75	53	64	57	54	43	7	90	67	64
LA Inner Harbor	399	392	395	533	460	668	790	653	660	395
Fish Harbor	106	102	104	42	107	41	35	47	44	104
Seaplane Lagoon	114	108	111	42	113	116	29	122	120	111
LA Outer Harbor	277	273	275	171	286	293	169	296	295	275
LB Inner Harbor North	102	93	97	86	107	111	87	118	114	97
LB Inner Harbor South	170	162	166	152	191	198	177	204	201	166
LB Outer Harbor	115	107	111	84	112	113	74	121	117	111
LA River Estuary	91	38	65	81	38	38	9	93	65	65
Eastern San Pedro Bay	85	52	69	68	53	53	28	87	70	69

Notes:
Start Year: 2014
Total Maximum Daily Load (TMDL) Target = 3.6 micrograms per kilogram (µg/kg)
SedLR: sediment load reduction
WLR: watershed load reduction

5.5.2 Predicted Time to Meet ATL3

The Sediment Quality Provisions (SQPs) provide an alternative fish tissue consumption risk level relevant to sediment quality condition. While the ultimate TMDL goal is attainment of the Fish Contaminant Goals (FCG), attainment of the advisory tissue level associated with three meals per week (ATL3) is used to determine if the sediment quality condition is protective of human health risks associated with fish consumption under SQP assessment. Therefore, the time to meet the ATL3 is an alternate estimate approach to confirm if sediment quality condition is meeting human health protection.

Table 12 and Table 13 show the approximate number of years that the model estimates it will take for the market basket fish tissue PCB and DDT concentrations to reach the ATL3 for PCBs and DDT, respectively, using the 20-year decline rate to calculate the rate of decline.

Table 14 and Table 15 show the approximate number of years that the model estimates it will take for the market basket fish tissue PCB and DDT concentrations to reach the advisory tissue level associated with three meals per week (ATL3) for PCBs and DDT, respectively, using the 14-year decline rate to calculate the rate of decline. For DDT, the ATL3 is achieved under current conditions, thus the time to ATL3 compliance is 0 years.

Table 12 Model Estimated Time (years) for PCBs to Meet ATL3 Using 20-Year Decline Rate

Fish Movement Zone	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Dominguez Channel Estuary	59	42	50	44	34	16	6	39	29	50
Consolidated Slip	47	40	43	24	40	21	6	28	24	43
LA Inner Harbor	48	43	45	25	44	31	7	36	33	45
Fish Harbor	70	65	67	6	67	5	5	6	5	67
Seaplane Lagoon	48	42	45	20	43	40	4	46	43	45
LA Outer Harbor	43	38	40	21	38	35	5	40	37	40
LB Inner Harbor North	43	38	40	19	39	35	4	41	38	40
LB Inner Harbor South	36	31	33	8	31	27	4	33	30	33
LB Outer Harbor	54	48	51	26	48	48	8	54	51	51
LA River Estuary	70	38	52	45	38	38	6	70	52	52
Eastern San Pedro Bay	72	48	59	38	48	48	7	72	59	59

Notes:

Start Year: 2014

ATL3: Advisory Tissue Level based on consumption of three meals per week

ATL3 Target: 21 micrograms per kilogram (µg/kg)

SedLR: sediment load reduction

WLR: watershed load reduction

Table 13 Model Estimated Time (years) for DDT to Meet ATL3 Using 20-Year Decline Rate

Fish Movement Zone	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Dominguez Channel Estuary	0	0	0	0	0	0	0	0	0	0
Consolidated Slip	0	0	0	0	0	0	0	0	0	0
LA Inner Harbor	0	0	0	0	0	0	0	0	0	0
Fish Harbor	0	0	0	0	0	0	0	0	0	0
Seaplane Lagoon	0	0	0	0	0	0	0	0	0	0
LA Outer Harbor	0	0	0	0	0	0	0	0	0	0
LB Inner Harbor North	0	0	0	0	0	0	0	0	0	0
LB Inner Harbor South	0	0	0	0	0	0	0	0	0	0
LB Outer Harbor	0	0	0	0	0	0	0	0	0	0
LA River Estuary	0	0	0	0	0	0	0	0	0	0
Eastern San Pedro Bay	0	0	0	0	0	0	0	0	0	0

Notes:

Start Year: 2014

ATL3: Advisory Tissue Level based on consumption of three meals per week

ATL3 Target: 520 micrograms per kilogram (µg/kg)

SedLR: sediment load reduction

WLR: watershed load reduction

Table 14 Model Estimated Time (years) for PCBs to Meet ATL3 Using 14-Year Decline Rate

Fish Movement Zone	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Dominguez Channel Estuary	82	56	69	80	44	16	6	84	50	69
Consolidated Slip	58	49	53	31	49	22	6	44	33	53
LA Inner Harbor	61	55	58	38	56	52	7	66	59	58
Fish Harbor	81	78	79	6	79	5	5	6	5	79
Seaplane Lagoon	61	56	58	20	57	58	4	64	61	58
LA Outer Harbor	56	50	53	23	52	52	5	59	55	53
LB Inner Harbor North	54	49	52	19	50	48	4	55	52	52
LB Inner Harbor South	44	37	40	8	38	34	4	42	38	40
LB Outer Harbor	64	58	61	38	59	59	8	65	62	61
LA River Estuary	87	49	68	104	49	49	6	88	68	68
Eastern San Pedro Bay	86	61	73	83	61	61	7	87	74	73

Notes:

Start Year: 2014

ATL3: Advisory Tissue Level based on consumption of three meals per week

ATL3 Target: 21 micrograms per kilogram (µg/kg)

SedLR: sediment load reduction

WLR: watershed load reduction

Table 15 Model Estimated Time (years) for DDT to Meet ATL3 Using 14-Year Decline Rate

Fish Movement Zone	**Scenario 0**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**
Dominguez Channel Estuary	0	0	0	0	0	0	0	0	0	0
Consolidated Slip	0	0	0	0	0	0	0	0	0	0
LA Inner Harbor	0	0	0	0	0	0	0	0	0	0
Fish Harbor	0	0	0	0	0	0	0	0	0	0
Seaplane Lagoon	0	0	0	0	0	0	0	0	0	0
LA Outer Harbor	0	0	0	0	0	0	0	0	0	0
LB Inner Harbor North	0	0	0	0	0	0	0	0	0	0
LB Inner Harbor South	0	0	0	0	0	0	0	0	0	0
LB Outer Harbor	0	0	0	0	0	0	0	0	0	0
LA River Estuary	0	0	0	0	0	0	0	0	0	0
Eastern San Pedro Bay	0	0	0	0	0	0	0	0	0	0

Notes:

Start Year: 2014

ATL3: Advisory Tissue Level based on consumption of three meals per week

ATL3 Target: 520 micrograms per kilogram (µg/kg)

SedLR: sediment load reduction

WLR: watershed load reduction

6 References

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