DRAFT

CONTAMINATED SEDIMENT MANAGEMENT PLAN: LONG BEACH HARBOR, EASTERN SAN PEDRO BAY, AND LOS ANGELES RIVER ESTUARY

In Support of

Final Dominguez Channel and Greater Los Angeles and Long Beach Harbor Waters Toxic Pollutants Total Maximum Daily Loads

Submitted to

California Regional Water Quality Control Board, Los Angeles Region

Submitted by

City of Long Beach Harbor and Public Works Department

Prepared by

Anchor QEA, LLC
27201 Puerta Real, Suite 350
Mission Viejo, California 92691

March 2014

TABLE OF CONTENTS

List of Tables

List of Figures

List of Appendices

LIST OF ACRONYMS AND ABBREVIATIONS

AOEC	Area of ecological concern
Basin Plan Amendment	Attachment A to Resolution No. R11-008, *Amendment to the Water Quality Control Plan – Los Angeles Region*
BMP	best management practice
BRAC	Base Realignment and Closure
CCC	California Coastal Commission
CCMRP	Coordinated Compliance Monitoring and Reporting Program
CDFW	California Department of Fish and Wildlife
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIMP	Coordinated Integrated Monitoring Programs
CSM	conceptual site model
CSMP	Contaminated Sediment Management Plan
CSTF	Contaminated Sediment Task Force
DDT	dichlorodiphenyltrichloroethane
DMMT	Dredged Material Management Team
EWMP	enhanced watershed management program
FS	Feasibility Study
Harbor Toxics TMDL	*Final Dominguez Channel and Greater Los Angeles and Long Beach Harbor Waters Toxic Pollutants Total Maximum Daily Loads*
IR	Installation Restoration
LA	load allocation
LARE	Los Angeles River Estuary
LBNC	Long Beach Naval Complex
MLOE	multiple lines of evidence
MNR	monitored natural recovery
MOA	Memoranda of Agreement

Montrose	Montrose Chemical Corporation
MOU	Memoranda of Understanding
MS4	municipal separate storm sewer system
NMFS	National Marine Fisheries Services
NPDES	National Pollutant Discharge Elimination System
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
POLA	Port of Los Angeles
POLB	Port of Long Beach
PRP	potential responsible party
RI	Remedial Investigation
ROD	Record of Decision
RWQCB	Regional Water Quality Control Board
SGRE	San Gabriel River Estuary
SMO	Sediment Management Objective
SQO	Sediment Quality Objective
TBT	tributyltin
TIWRP	Terminal Island Water Reclamation Plant
TMDL	total maximum daily load
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USEPA Guidance Document	*Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*
WLA	waste load allocation
WMP	Watershed Management Program
WRAP	Water Resources Action Plan

1 INTRODUCTION

The Long Beach Harbor, Eastern San Pedro Bay, and Los Angeles River Estuary Contaminated Sediment Management Plan (CSMP) was developed to support the long-term recovery of sediment and water quality in the Long Beach Harbor, Eastern San Pedro Bay, and Los Angeles River Estuary (LARE). The City of Long Beach Harbor Department has led the development of this CSMP that addresses bedded sediment within the Study Area and is submitting it on behalf of Los Angeles County Flood Control District, City of Los Angeles, and the City of Long Beach. This CSMP has been developed to be consistent with other CSMPs developed for the Dominguez Channel Estuary and Los Angeles Harbor.

Section 1 of the CSMP provides the regulatory background requiring the creation of a CSMP and a summary of the relevant information needed to support the sediment management decision process. A description of the physical setting and known contaminant-related issues, including the 303(d) listing and subsequent development of the *Final Dominguez Channel and Greater Los Angeles and Long Beach Harbor Waters Toxic Pollutants Total Maximum Daily Loads* (Harbor Toxics TMDL), is also included. The Harbor Toxics TMDL compliance requirements, TMDL schedule, CSMP requirements, and integration with the stormwater programs are provided, as is a summary of regional regulatory programs and the national guidance for contaminated sediment management.

Section 2 of the CSMP describes an approach designed to form the basis for all CSMPs developed to support sediment contaminant reductions in affected waterbodies as noted in the Harbor Toxics TMDL. The process for defining actions and decisions to be implemented for each of five identified milestones to support contaminated sediment management is defined.

Section 3 of the CSMP summarizes specific actions and decisions relevant to the Study Area. A description of current site conditions is included along with a recommended approach for integrating the CSMP with other water quality related programs. A schedule linking CSMP milestones to the Harbor Toxics TMDL implementation schedule is also presented.

1.1 Setting: Long Beach Harbor, Eastern San Pedro Bay, and Los Angeles River Estuary

The Greater Los Angeles/Long Beach Harbor Waters include waterbodies defined as Long Beach Inner Harbor, Long Beach Outer Harbor, Los Angeles Inner Harbor and Los Angeles Outer Harbor, Consolidated Slip, Fish Harbor, Cabrillo Marina, Inner Cabrillo Beach, LARE, and San Pedro Bay (RWQCB and USEPA 2011). This CSMP addresses sediments within the boundaries of the City of Long Beach and includes portions of Inner and Outer Harbor, LARE, and Eastern San Pedro Bay (Figure 1).

The Los Angeles/Long Beach Harbor complex consists of approximately 15,000 acres in land and water in western San Pedro Bay, to the northeast of Palos Verdes peninsula. It is bounded on the landward side by the communities of San Pedro and Wilmington and the city of Long Beach and on the seaward side by the three breakwaters that protect the port facilities. Terminal Island, which is shared by the two ports and supports a number of large cargo terminals and other port uses, comprises nearly a quarter of the total land area and is separated from the mainland by the Los Angeles Main Channel, Long Beach Back Channel, and the Cerritos Channel that links the two. A major drainage channel, the Dominguez Channel, discharges into Los Angeles Harbor via Consolidated Slip, and the Los Angeles River discharges into Eastern San Pedro Bay at the east side of Long Beach Harbor.

Most of the land and water in the Los Angeles/Long Beach Harbor is owned by the cities of Los Angeles and Long Beach, acting under the Tidelands Trust Act through their respective harbor commissions, but some properties remain owned by private parties and other governmental entities (Ports 2009). Port of Long Beach (POLB) was founded in 1911 and covers approximately 3,200 acres with 10 piers, 80 berths, and 22 shipping terminals.

The Inner Harbor has been extensively developed and consists of piers for ship loading and unloading and commercial marinas. The Outer Harbor (the greater San Pedro Bay) also contains commercial and industrial uses but has increased circulation and more open water than the Inner Harbor. The Los Angeles/Long Beach Harbor supports a great diversity of marine life. It is connected to the ocean at Angeles Gate, Queen's Gate, and at its eastern end. San Pedro Bay receives discharges from nearshore land uses, the Dominguez Channel, Los Angeles River, and San Gabriel River and intermittent flows to the Los Angeles Inner

Harbor from Machado Lake. The Dominguez Watershed drains approximately 110 square miles and is composed of two hydrologic sub-units. The northern sub-unit drains into Dominguez Channel whereas the southern sub-unit drains directly into to the Los Angeles/Long Beach Harbor. The northern sub-unit drains into the Dominguez Channel, which discharges into the Los Angeles Harbor via Consolidated Slip (RWQCB and USEPA 2011). The boundaries of the harbor districts were established on the basis of legal delineations rather than natural hydrography; however, modeling results associated with the *Water Resources Action Plan* (WRAP) indicate that with the exception of the portion of the Long Beach Harbor District east of Pier H, hydrodynamics indicates harbor waters are largely separate from the eastern portion of Eastern San Pedro Bay (Ports 2009).

The City of Long Beach owns and operates a municipal separate storm sewer system (MS4) that conveys and discharges stormwater into surface waters under the jurisdiction of the Los Angeles Regional Water Quality Control Board (RWQCB; 2014). The permitted area covers approximately 47.7 square miles and is a mix of residential, commercial, and industrial land uses. The MS4 discharges flow into surface waters located in the Los Angeles River Watershed, Dominguez Channel and Greater Los Angeles/Long Beach Harbor Watershed Management Area, Los Cerritos Channel and Alamitos Bay Watershed Management Area, and San Gabriel Watershed (RWQCB 2013).

The majority of stormwater outfalls located in the Long Beach Harbor discharge stormwater that originates inside the Harbor District. POLB's storm drain infrastructure drains a largely impervious and highly industrialized sub-watershed (Ports 2009).

In addition to stormwater, there are approximately 60 active individual National Pollutant Discharge Elimination System (NPDES) permitted discharges to the Dominguez Channel and the Los Angeles/Long Beach Harbor and approximately 50 active, general NPDES permitted discharges in the Dominguez Watershed. Two generating stations discharge directly to the Inner Harbor while the Terminal Island Water Reclamation Plant (TIWRP) discharges secondary-treated effluent[1] to the Outer Harbor (RWQCB and USEPA 2011).

[1] The TIWRP is under a time schedule order to eliminate discharge into surface waters.

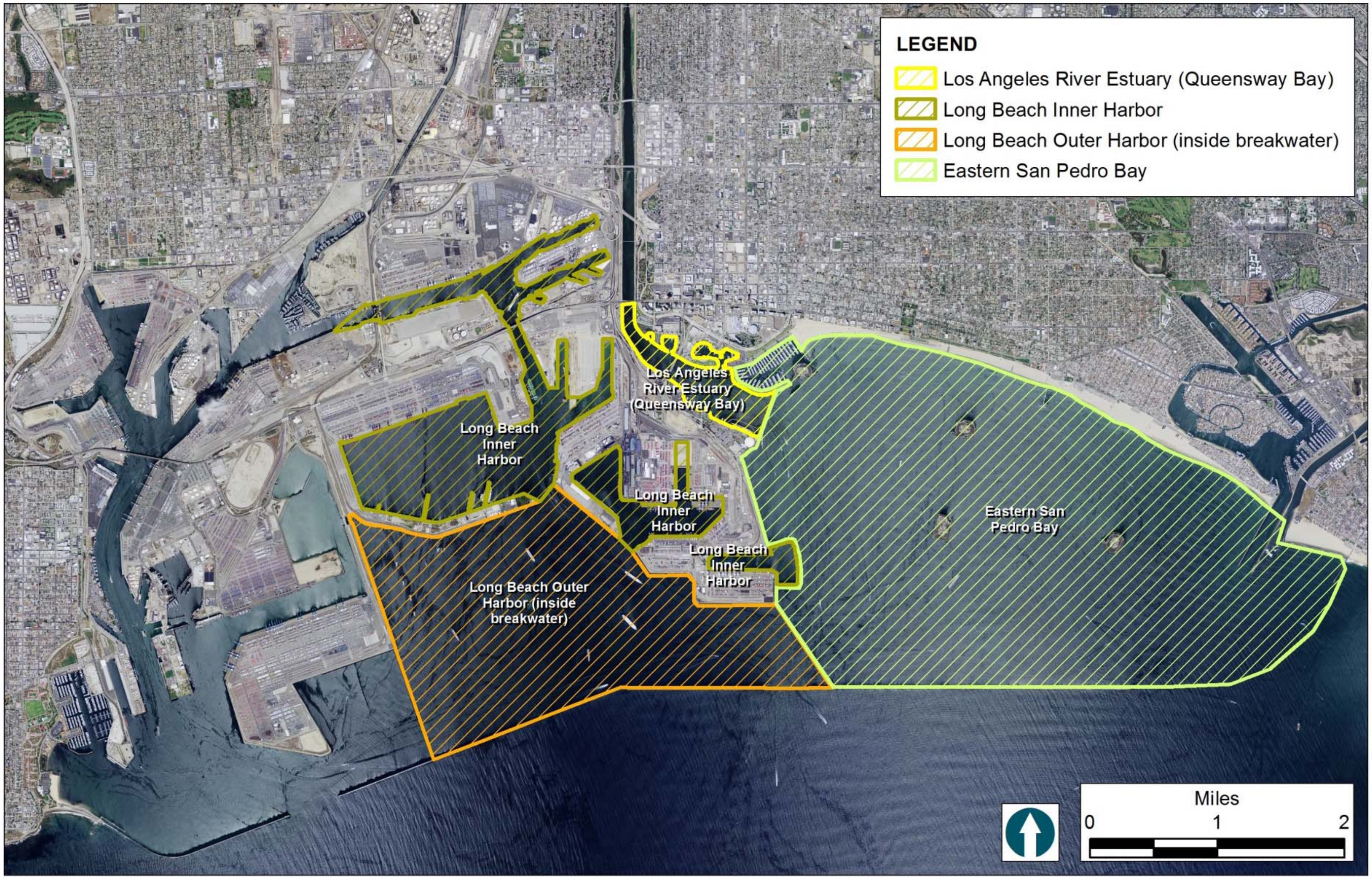

Figure 1

Long Beach Harbor, Eastern San Pedro Bay, and Los Angeles River Estuary Waterbodies

Eastern San Pedro Bay receives discharges of the Los Angeles and San Gabriel Rivers. The Los Angeles River is dominated by treated waste water flows and drains a watershed of 834 square miles. The San Gabriel River watershed, which includes the Los Cerritos Channel and Alamitos Bay), is approximately 689 square miles and largely developed near San Pedro Bay (RWQCB and USEPA 2011).

The Dominguez Watershed contains the Montrose Chemical Corporation (Montrose) and the Del Amo Superfund sites. Montrose manufactured dichlorodiphenyltrichloroethane (DDT) on a 13 acre site in a light industrial/residential area in the city of Torrance from 1947 to 1982. Contaminants of concern at the Montrose site are DDT, chlorobenzene, and benzene hexachloride. DDT has been found in soils at the former plant property and surrounding areas, in sediments and soils in the historical stormwater pathway from the site (Kenwood Drain and Dominguez Channel), and in the groundwater close to the former plant property.

Shell Oil Company (Shell), Dow Chemical Company, and several other companies operated the Del Amo Synthetic Rubber Manufacturing plant from 1955 to 1972 to produce synthetic rubber for the United States military operations. In 1972, the plant was dismantled, and the buildings were demolished (USEPA 1999). Contaminants of concern at the Del Amo site are volatile organic compounds, including benzene and toluene, polycyclic aromatic hydrocarbons (PAHs), and semi-volatile organic compounds (Lyons and Birosik 2007).

1.2 Harbor Toxics TMDL

TMDLs are established to attain and maintain applicable water quality standards for impaired waterbodies. TMDLs provide pollutant limits that are implemented through permits (e.g., MS4 and NPDES). This CSMP has been developed in response to the Harbor Toxics TMDL, which addresses localized sediment quality and regional fish tissue quality and is expected to achieve attainment of sediment, water, and fish tissue quality through source reduction, source control, management actions, and monitored natural recovery (MNR).

On March 23, 2012, the Harbor Toxics TMDL was promulgated to protect and restore fish tissue, water, and sediment quality in the Dominguez Channel and Greater Los Angeles/Long

Beach Harbor Waters by managing contaminated sediments through remediation of bedded sediments and control of ongoing and future contaminated sediment loading from the Dominguez Watershed. The Harbor Toxics TMDL includes assessment of chemical loads entering San Pedro Bay from LARE and San Gabriel River Estuary (SGRE); however, this TMDL is not addressing impairments of each of these waterbodies from their respective watersheds. The Harbor Toxics TMDL does include load allocations (LAs) and waste load allocations (WLAs) for LARE.

California's 303(d) List of Water Quality Limited Segments (SWRCB 2010) includes the following designated waterbodies within the Long Beach Harbor, Eastern San Pedro Bay, and LARE: Long Beach Inner Harbor, Long Beach Outer Harbor (inside breakwater), San Pedro Bay Near/Off Shore Zones, LARE (Queensway Bay), and SGRE. Metals TMDLs have already been completed for the Los Angeles and San Gabriel rivers; however, TMDLs for LARE and SGRE to address impairments due to chlordane, DDT, PCBs, sediment toxicity (LARE), and dioxin (SGRE) are not scheduled to be completed until 2019 and 2021, respectively.

1.2.1 TMDL Compliance

The Harbor Toxics TMDL set WLAs in waterbodies within the Dominguez Watershed to limit sediment-bound pollutant loadings from upstream and on-land sources. In addition, the Harbor Toxics TMDL set LAs in waterbodies to limit concentrations in bedded sediments believed to impact marine benthos (direct effects) and fish tissue (indirect effects). Mass-based limits for chemical constituents are provided in Table 1 and Attachment A to Resolution No. R11-008, Amendment to the *Water Quality Control Plan – Los Angeles Region* (Basin Plan Amendment; RWQCB and USEPA 2011).

Table 1
Final, Mass-Based TMDLs and Allocations for Metals, PAHs, DDT, and PCBs

Waterbody	Total Mercury (kg/year)	Total Lead (kg/year)	Total Zinc (kg/year)	Total PAHs (kg/year)	Total DDT (g/year)	Total PCBs (g/year)
Long Beach Inner Harbor	76.7	105.3	338.3	9.1	3.56	7.22
Long Beach Outer Harbor	81.6	112.1	360.1	9.7	3.79	7.68
Eastern San Pedro Bay	648	890	2858	76.6	30.1	61.0
LARE	735	1009	3242	86.9	34.1	69.2

Notes:
kg = kilogram
g = gram

Compliance with sediments may be demonstrated via any one of three different means:

1. Final sediment allocations, as presented in the Basin Plan Amendment (RWQCB and USEPA 2011), are met.
2. The qualitative sediment condition ranking of "unimpacted" or "likely unimpacted" by interpreting and integrating multiple lines of evidence (MLOE) as defined in the Sediment Quality Objective (SQO) Part 1 is met.
3. Sediment numeric targets are met in bedded sediments over a 3-year averaging period.

The SQO program provides guidance for applying the *Water Quality Control Plan for Enclosed Bays and Estuaries: Sediment Quality Plan* (SWRCB 2009). SQOs have been developed for contaminants of concern in bays and estuaries in California based on an approach that incorporates MLOE (Bay et al. 2009). These MLOE include sediment chemistry, sediment toxicity, and benthic community condition.

Compliance with fish tissues may be demonstrated via any one of four different means:

1. Fish tissue targets are met in species resident to the Harbor Toxics TMDL waterbodies.
2. Final sediment allocations, as presented in the Basin Plan Amendment (RWQCB and USEPA 2011), are met.

3. Sediment numeric targets to protect fish tissue are met in bedded sediments over a 3-year averaging period.
4. Demonstrate that the sediment quality condition protective of fish tissue is achieved per the *Water Quality Control Plan for Enclosed Bays and Estuaries: Sediment Quality Plan* (SWRCB 2009), as amended to address contaminants in resident finfish and wildlife.

Numeric targets, implementation schedules, and listed contaminants of concern may be revised during the TMDL reopener, tentatively scheduled for spring 2018.

1.2.2 TMDL Schedule

The Harbor Toxics TMDL schedule is divided into three phases:

- Phase I, completed 5 years after effective date of the Harbor Toxics TMDL (March 2017)
- Phase II, completed 10 years after effective date of the Harbor Toxics TMDL (March 2022)
- Phase III, completed 20 years after effective date of the Harbor Toxics TMDL (March 2027)

The purpose of Phase I actions is to reduce the amount of sediment transport from point sources that directly or indirectly discharge to the Dominguez Channel and Greater Los Angeles/Long Beach Harbor Waters. For Long Beach Harbor, the Harbor Toxics TMDL calls for the continuation of source reduction, source control, and sediment management actions throughout the nearshore watershed. Phase I actions will include instituting watershed-wide best management practices (BMPs) actions and developing CSMPs. Actions to achieve WLAs and LAs may be implemented in phases with information from each phase being used to inform the implementation of the next phase.

As per the TMDL, pollutant reduction actions at the POLB during Phase I should be developed to address different sources that contribute loadings to the Los Angeles/Long Beach Harbor, such as harbor-wide activities and associated control measures for sediment and water and to reduce discharges from various land uses in the harbor, nearshore discharges, and on-water discharges. Phase I actions should be focused on source reduction, source control, and sediment management. The WRAP was developed to summarize and prioritize activities that could be conducted to control discharges of polluted stormwater and contaminated sediments to the harbor (Ports 2009). Actions identified in the WRAP will address Phase I source reduction activities.

Standard port operations frequently result in the net improvement of sediment conditions through routine maintenance dredging, implementation of capital improvement projects such as terminal development and channel deepening, and development of habitat improvement projects. Throughout these operations, impacted sediments are encountered and removed from the environment, which improves overall water and sediment quality. The effects of these programs are evident in the marked reductions in water and sediment concentrations within the Harbor Complex over the past 20 years.

Specific proposed implementation actions listed in the Harbor Toxics TMDL that may be implemented during Phase I include:

- Removal of contaminated sediment within areas of known concern
- Development of a sediment management plan (e.g., CSMP)
- Coordination of any TMDL activities within Montrose Superfund Site Operable Units with the U.S. Environmental Protection Agency's (USEPA's) Superfund Division

During Phase I, responsible parties in the Los Angeles River and San Gabriel River watersheds will be implementing other TMDLs, which will directly or indirectly support the goals of the Harbor Toxics TMDL. For example, TMDLs aimed at reducing point source discharges into these waterbodies will directly affect future harbor conditions. During Phases II and III, implementation actions within the Los Angeles River and San Gabriel River watersheds may be required as necessary to meet the numeric targets in the Greater Los Angeles/Long Beach Harbor Waters. TMDLs to allocate contaminant loads between dischargers in the Los Angeles and San Gabriel River watersheds may also be developed, if necessary.

Phase II should include the implementation of additional BMPs and site remedial actions in the nearshore watershed and in the Long Beach Harbor, as determined to be effective based on the success of upstream source control, TMDL monitoring data evaluations, WRAP activities implemented during Phase I, and targeted source reduction activities as identified in Phase I (RWQCB and USEPA 2011).

Phase III should include implementation of secondary and additional remedial actions as necessary to be in compliance with the final allocations by the end of the implementation period (RWQCB and USEPA 2011).

1.2.3 Integration with MS4 Permit Requirements

The City of Long Beach intends to develop a single Watershed Management Program (WMP) in accordance with the Final Waste Discharge Requirements for MS4 Discharges within the City of Long Beach (Long Beach MS4 Permit) for the three watersheds with drainage originating only from jurisdictions within City of Long Beach: the Dominguez Channel Estuary, the Long Beach Beaches and LARE, and Alamitos Bay watersheds. The City of Long Beach is also a stakeholder in three other WMPs developed in accordance with the Los Angeles County MS4 Permit (Order No. R4-2012-0175).

These WMPs will prioritize water quality issues resulting from stormwater and non-stormwater discharges from the MS4 to receiving waters. They will identify and implement strategies, control measures, and BMPs to achieve reductions in contaminant concentration from the watersheds; execute an integrated monitoring and assessment program to determine progress; and modify strategies, control measures, and BMPs as necessary based on analysis of monitoring data collected to ensure that milestones and goals set forth in the WMPs are achieved in the required timeframes. Participation in the WMP process will allow the City of Long Beach to prioritize this TMDL resulting in targeted contaminant load reductions from the watershed.

1.2.4 Contaminated Sediment Management Plan

Meeting goals and targets in complicated TMDLs requires a holistic approach that includes source identification and control from multiple sources within the watershed, water column, and in-place (bedded) sediments. Developing a CSMP is only one component in a larger effort to meet the goals of a TMDL focused on legacy pollutants in existing sediments. Components of a holistic approach include:

- Monitoring plans
- WMPs
- Sediment management plans
- Special studies, such as stressor identification, source identification, BMP effectiveness, sedimentation investigations to evaluate natural recovery, and chemical fate and transport mechanisms and processes investigations
- Coordinating standard port operations such as maintenance dredging, capital improvement programs, and habitat restoration projects with the TMDL to remove areas of known contamination

The Harbor Toxics TMDL requires development of a CSMP to describe an approach for contaminated sediment management. Implementation of management actions will require coordination among stakeholders and regulators across multiple regulatory programs. Because management actions are often very costly and contaminant sources to sediment are believed to be ongoing, it is critical that source reductions are coupled with the implementation of management actions in a strategic approach to ensure those actions are effective and result in meaningful improvements to sediment, water, and fish tissue quality.

This CSMP is designed to meet requirements of the Harbor Toxics TMDL and identify, prioritize, and manage contaminated sediments for protecting and improving benthic community condition and human health from fish consumption. This risk-based approach will assess impacts and provide information on source identification and the nature and extent of impacted areas. This CSMP provides an approach for identifying potential management areas and associated alternatives based on relevant sediment and tissue data and special studies. Management alternatives will be selected based on a stakeholder and potential responsible parties (PRPs) process, while environmental and human health risks of each alternative are considered.

The Harbor Toxics TMDL encourages collaboration and coordination of monitoring, reporting, and implementation efforts. The City of Long Beach is the only named responsible party with a load allocation to the Long Beach Harbor and Eastern San Pedro Bay. Named responsible parties with load allocations to LARE include:

- Los Angeles County Flood Control District
- California Department of Transportation
- City of Los Angeles
- City of Long Beach
- City of Signal Hill

1.3 Regional Sediment Management Regulatory Process

Management actions identified in the Harbor Toxics TMDL include targeted sediment remediation within areas of known concern, which includes the Dominguez Channel, Dominguez Channel Estuary, Consolidated Slip, and portions of the Los Angeles/Long Beach Inner Harbor. Within the Long Beach Harbor, only Installation Restoration (IR) Site 7 (a former U.S. Navy facility in the POLB) included a defined removal action for contaminated sediment identified as a proposed implementation action during Phase I of the Harbor Toxics TMDL.

Sediment management actions implemented for TMDL compliance must comply with state and federal regulatory authority. Like any other area of the United States, any voluntary in-water construction activities in navigable waters are regulated activities, which are subject to a variety of state and federal statutes, such as the California Environmental Quality Act, Porter-Cologne Water Quality Control Act, National Environmental Policy Act, Rivers and Harbors Act of 1899, and Clean Water Act. In addition, existing state and federal programs provide guidance on sediment management and should be the basis for CSMPs developed in response to TMDL requirements.

Guidelines for capping, dredging, disposal, and long-term management of contaminated sediments in the Los Angeles Region were developed by the Los Angeles Contaminated Sediment Task Force (CSTF). The CSTF includes representatives from the U.S. Army Corps of Engineers (USACE), USEPA, National Marine Fisheries Services (NMFS), California Coastal Commission (CCC), RWQCB, California Department of Fish and Wildlife (CDFW), POLB, Port of Los Angeles (POLA), City of Long Beach, Los Angeles County Beaches and

Harbors, Heal the Bay, and other interested parties. After developing the *Los Angeles Regional Contaminated Sediments Task Force: Long-Term Management Strategy* (CSTF 2005), the CSTF's role in the region shifted to that of an advisory group that convenes routinely to review and comment on procedural issues related to sediment management. The Los Angeles Dredged Material Management Team (DMMT), led by the USACE and USEPA Region 9, is the regional regulatory group responsible for managing and authorizing sediment management programs. Participants include all state and federal permitting agencies, such as the CCC, CDFW, NMFS, and RWQCB. Using the CSTF document as its guidance, this group meets monthly to review and discuss permit applications, approve sampling plans, and provide guidance on appropriate management alternatives for contaminated and clean sediments. Strategies for managing contaminated sediment disposal are prioritized to meet regional objectives. The preferred management strategy for contaminated sediments is beneficial reuse in a port fill (nearshore confined disposal facility), temporary storage in an approved upland area (until a fill project becomes available), treatment and reuse as a marketable product (e.g., cement), other beneficial upland placement, or placement in a confined aquatic disposal site.

Implementing voluntary in-water construction activities within the jurisdiction of a port, a city, or a county would be designed, managed, and implemented by the respective staff within that port, city, or county or their representatives based on regional, state, and federal guidelines and strategies.

Involuntary sediment management actions, such as a response to a RWQCB Cleanup and Abatement Order for violating the Clean Water Act, a remedial action detailed in a Record of Decision under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or a NPDES permit action, would be managed as directed by the lead regulatory agency for each respective program. For example, the USEPA has developed a formal process under CERCLA for assessing site risks, evaluating suitable numeric and narrative cleanup objectives, selecting a remedy that best meets the goals for the target action, and monitoring the effectiveness of the remedy. Regulatory oversight for sediment remediation activities within CERCLA or NPDES cleanup programs may only involve the DMMT and CSTF if material disposal was planned for an in-water confined disposal facility within the region, or in an advisory role.

1.4 Federal Sediment Management Guidance

Federal regulations (CERCLA, Superfund Amendments and Reauthorization Act, and Resource and Recovery Conservation Act) provide mechanisms for the USEPA to address contaminated sediments believed to impair beneficial uses of rivers and harbors. In 2005, the USEPA provided technical and policy guidance for project managers and management teams making remedy decisions for contaminated sediment sites. This guidance, *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA Guidance Document; USEPA 2005), incorporates experiences and lessons learned from more than 20 years at contaminated sediment sites and identifies 11 risk management principles that should be applied when managing contaminated sediment sites. The guidance, which remains as the primary guide for USEPA staff and project managers, also provides a formal process and is based on the following 11 principles:

- Control sources early.
- Involve the community early and often.
- Coordinate with states, local governments, Indian tribes, and natural resource trustees.
- Develop and refine a conceptual site model (CSM) that considers sediment stability.
- Use an iterative approach in a risk-based framework.
- Carefully evaluate the assumptions and uncertainties associated with site characterization data and site models.
- Select site-, project-, and sediment-specific risk management approaches that will achieve risk-based goals.
- Ensure that sediment cleanup levels are clearly tied to risk management goals.
- Maximize the effectiveness of institutional controls and recognize their limitations.
- Design remedies to minimize short-term risks while achieving long-term protection.
- Monitor during and after sediment remediation to assess and document remedy effectiveness.

The first principle of controlling sources early, prior to conducting remediation, is critical to the effectiveness of any sediment cleanup, because the site may become re-contaminated without source control (Nadeau et al. 2009). The other principles are designed to guide the project manager through understanding site conditions (e.g., CSM development) and identifying the site's risk drivers, which can then be used to evaluate potential remedial alternatives. Based on the CSM and risk assessments, remedial action objectives are derived and should reflect objectives that are achievable from remediation of the site. Some goals, such as lifting a fish consumption advisory, may require watershed level actions that are outside the scope of the site cleanup and may not be achievable on a short-term or even a long-term basis regardless of the subject site's remediation success (Nadeau et al. 2009).

Specific sediment remedy alternatives are identified in the USEPA Guidance Document (2005). These include MNR, capping, dredging, in situ treatments, and combining alternatives. Nadeau et al. (2009) and Bridges et al. (2008) review implementation and residual risks for various remedies. Nadeau et al. (2009) provides an overview of MNR, capping, and dredging, whereas Bridges et al. (2008) focuses on resuspension, release, residual, and risk of environmental dredging. In 2013, the Office of Superfund Remediation and Technology Innovation published *Use of Amendments for In Situ Remediation at Superfund Sediment Sites* (USEPA 2013), providing an overview of technologies to treat contaminated sediments in situ. This document introduces promising amendments for in situ remediation and summarizes some of the information on contaminated sediment sites that have employed amendments. Although this document is not intended to be a guidance or design document, the authors note that the USACE Engineer Research Development Center is developing technical guidelines for in situ sediment remediation.

2 CONTAMINATED SEDIMENT MANAGEMENT APPROACH OVERVIEW

To ensure management actions are ecologically beneficial and logistically and economically feasible, this CSMP was developed to identify, prioritize, and manage chemically impacted sediments where necessary to protect and improve benthic community condition and human health from fish consumption. This CSMP uses a risk-based approach to assess impacts due to chemically mediated effects as a means for determining the magnitude and extent of possible management actions. Overall, this approach follows guidance and lessons learned from the USEPA Guidance Document (USEPA 2005). The initial step in a CSMP is to identify impacted sediments and initiate source identification through sediment characterization and water quality measurements of inflows to the waterbody. A five step or milestone approach has been developed to logically assess and evaluate potential management actions. The initial step in a CSMP is to analyze available data, identify data gaps, collaborate with regional monitoring programs, conduct special studies as needed, and identify sources and the nature and extent of impacted sediments. Sediment and water quality will be evaluated as part of the required Harbor Toxics TMDL monitoring program, MS4 and NPDES permits' required monitoring programs, regional monitoring programs, and related special studies. The second milestone focuses on identification of potential management areas and includes identification of PRPs. Following this step, the next step will be reached when management alternatives will be identified for each area and will consider passive and remedial actions. The fourth step focuses on the selection of management action and approval from the RWQCB. The final step commences when management actions are initiated. A flowchart demonstrating each of these milestones is shown in Figure 2.

2.1 Milestone 1: Monitoring and Data Collection Program

Sediment, water, and fish tissue monitoring will be conducted through approved Coordinated Integrated Monitoring Programs (CIMP) including monitoring by assigned responsible parties for the Los Angeles and San Gabriel rivers, Coordinated Compliance Monitoring and Reporting Programs (CCMRP), regional monitoring programs (e.g., Southern California Bight), MS4 and NPDES permits' required monitoring, and special studies.

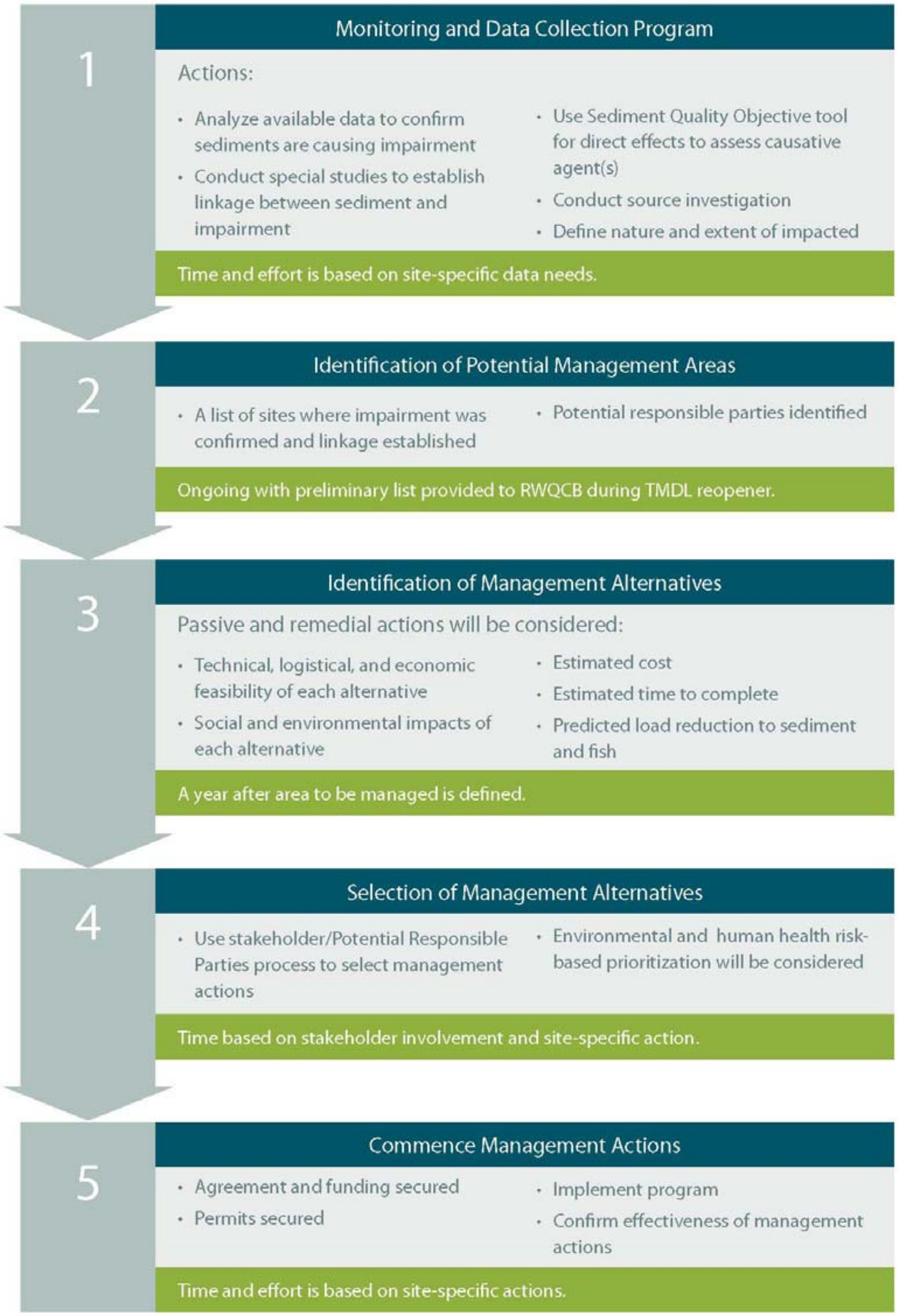

Figure 2

CSMP Milestones

If multiple programs are employed within the watershed, every effort should be made to engage in a data sharing program among jurisdictional groups to ensure, where possible, data gaps are filled and that all relevant and available data are compiled and analyzed prior to making a conditional assessment on the watershed. Special study data collection programs may be implemented to fill data gaps, examine the spatial and temporal patterns of contaminants, establish linkage between sediment contaminant concentrations and impairment, and identify and quantify sources.

Part 1 of the *Water Quality Control Plan for Enclosed Bays and Estuaries: Sediment Quality Plan* (SWRCB 2009) provides recommendations for additional investigations to be conducted to confirm impairment and identify causative agents. Potential studies/tools may include statistical procedures (principle components analysis and multiple regression analysis), toxicity identification evaluations, bioavailability studies, and dose/response spiking studies. These data will be used to:

- Analyze available data to confirm sediments are causing impairment.
- Conduct special studies to establish linkage between sediments and impairment.
- Use the SQO tool for direct effects to assess causative agent(s).
- Conduct source investigation.
- Define nature and extent of impacted areas.

The time and effort needed to collect data to address site-specific needs is dependent on the site and the processes that influence the fate and transport of contaminants in that system. It is also dependent on the stakeholder collaboration process and the integration and concurrence of available data.

2.2 Milestone 2: Identification of Potential Management Areas

The entire waterbody or a sub-area of the waterbody may be defined as an area to be managed. The Harbor Toxics TMDL identifies certain areas as priority areas; however, through the CSMP process, sub-areas within a priority waterbody may be identified and prioritized using a similar process as the USEPA's risk-based process for evaluating contaminated sediment sites. The PRPs will be identified. PRPs include cities, agencies, and dischargers with an LA as well as current and historical dischargers of the causative agent.

The preliminary list of sites to be managed will be provided to the RWQCB during the reopener. As new information is gained, potential management areas will be identified.

2.3 Milestone 3: Identification of Management Alternatives

For potential management areas, a range of sediment management alternatives will be summarized and their effectiveness at meeting water quality requirements within the TMDL schedule will be considered. Developing and evaluating remedial alternatives should follow the USEPA Guidance Document (USEPA 2005), which bases alternatives development on a CSM and risk assessments. Alternatives will range from passive actions (MNR and source control) to active remedial actions (treatment, capping, and/or dredging).

At a minimum, the following typical contaminated sediment management alternatives will be considered for each area:

- *Source Control.* Source control includes the process of identifying contaminant sources and implementing corrective actions to reduce or eliminate existing contaminants from entering the management area. Contaminants may enter the management area via one or more pathways: direct discharge from stormwater or industrial outfalls, surface runoff, sediment transport, and/or deposition. Source control actions may address the contaminant or pathway and range from passive approaches such as public education to increasingly more active approaches such as regulating or terminating discharges to the system and upgrading infrastructure to reduce contaminant loadings. Source control measures are a pre-requisite to any management alternative listed below and are most often associated with MNR and enhanced natural recovery.
- *Monitored Natural Recovery.* Natural recovery is defined as the process through which deposition of non-contaminated sediments and other natural processes (e.g., degradation, diffusion, and burial) decrease sediment contaminant concentrations over time. It is necessary to determine the rate of natural recovery in a particular area to determine its effectiveness as a remedial alternative. As recommended in the USEPA Guidance Document (USEPA 2005), MLOE are needed to establish the rate of natural recovery in a system. Typically, these lines of evidence include demonstrating decreasing fish or invertebrate tissue chemistry concentrations,

decreasing water column chemical concentrations, and decreasing surface sediment chemistry trends.

- *Enhanced Natural Recovery.* Enhanced natural recovery typically refers to the activity of placing a thin-layer clean cap of sediments over the contaminated surface to enhance the natural recovery process through mixing via bioturbation or currents. This clean layer is not intended to provide complete containment of the underlying contaminated sediments but generally provides for a cleaner substrate and sufficient initial isolation that, along with future deposition of new material, will reduce contaminant migration. The degree of improvement depends on surface sediment conditions prior to placing the clean material and rate of mixing. In general, the clean material reduces average surface sediment concentrations and levels of exposure to organisms.
- *Capping.* Engineered capping involves placing clean material on top of contaminated sediments to effectively isolate the sediments in perpetuity. Engineered caps typically are 3 to 5 feet thick to account for potential erosion, contaminant mobility, and bioturbation. At sites where propeller wash or high current velocities or waves may impact the stability of the cap, an armor layer may be required to prevent cap erosion. Similarly, in areas where potential groundwater upwelling may occur, a reactive treatment layer using products such as activated carbon can be applied to filter the porewater as it fluxes up through the thin-layer clean cap.
- *In Situ Treatment.* In situ treatment of sediments refers to technologies that immobilize, transform, or destroy contaminants of concern while leaving sediments in place (i.e., without first removing sediments). In situ treatment technologies are effective for broad categories of contaminants. Carbon amendment (alone or in conjunction with other technologies) is an innovative technology that has been explored for application with organic compounds, including polychlorinated biphenyls (PCBs). Bench- and pilot-scale studies are likely required to demonstrate that the technology will be effective for specific compounds in specific areas.
- *Dredging.* Physically removing contaminated sediments is the most common method of sediment remediation. Removal typically involves dredging, using either mechanical or hydraulic dredging equipment. Land-based excavation equipment can sometimes be used if contaminated sediments are located within reach of the shore. Removal is always combined with some form of disposal option (e.g., upland landfill,

port fill, aquatic containment, or ocean disposal). Depending on the nature of the material being removed (grain size, chemistry, etc.), dredge residuals may be a concern that will require additional management through measures, such as thin layer capping of the dredge footprint.

Further information on evaluating remedial options for contaminated sediments is provided in Appendix A. Nadeau et al. (2009) highlights key risk-based, decision-making factors necessary to realistically evaluate risk reduction associated with each remedial option. This paper is based upon the decision-making process recommended by the USEPA Guidance Document (USEPA 2005).

For each potential management alternative, the following should be considered:

- Technical, logistical, and economic feasibility
- Social and environmental impacts
- Estimated cost
- Estimated time to complete
- Predicted load reduction to sediment and fish

2.4 Milestone 4: Selection of Management Alternatives

Once an area is designated for some form of remediation and available management alternatives are summarized, the relevant stakeholder group can evaluate and select the appropriate action. The makeup of the stakeholder group, and the memoranda of agreement (MOAs) or memoranda of understanding (MOUs) between the stakeholders, will define the process for selecting one or more management alternatives. The MOA or MOU will likely detail the communication process, cost-share agreements, and roles and responsibilities of each agency or stakeholder.

Environmental and human health risk levels may be considered to assist in selecting the most appropriate remediation target. The nature and extent of contaminants—including their potential to bioaccumulate, the potential for the area to scour and contribute to contaminant mobility, the presence of sensitive habitats and/or species, and the potential for the area to be re-contaminated—can be considered during selection of an appropriate management action. When possible, management activities may be coupled with other infrastructure and maintenance programs to increase economic and logistic efficiencies. These opportunities may reprioritize management actions.

The timing of the selection of management alternatives is dependent on stakeholder involvement and site-specific actions.

2.5 Milestone 5: Commence Management Action

Once all parties agree to the selected management approach and funding mechanisms are secured, the management action can be scheduled and implemented. When a sediment management action is required to meet a specific objective, post-construction verification that the action was successful in meeting cleanup objectives is required by the regulatory agencies. Methods for determining the effectiveness of the chosen action will be agreed upon prior to the management action being implemented to confirm the success of the action.

3 DEFINED PRIORITY SITES: LONG BEACH HARBOR, EASTERN SAN PEDRO BAY, AND LOS ANGLES RIVER ESTUARY

Historical activities in the Dominguez Watershed have contributed to the current elevated sediment concentrations observed throughout Long Beach Harbor, San Pedro Bay, and the LARE. Watershed discharge limitations required under state and federal laws have significantly reduced inputs to the Long Beach Harbor area, and these programs are expected to continue improving sediment quality in the coming years. POLB and POLA engage in routine maintenance dredging programs, capital improvement programs, and habitat improvement projects that frequently remove contaminated sediment and improve surface conditions. POLB and POLA dredge approximately 30 percent of the Inner Harbor surface area every 10 years and a large percentage of that material is chemically impacted. This approach has resulted in millions of cubic yards of dredge material being removed and managed by POLB and POLA, and these activities have contributed significantly to the overall reduction of contaminants in sediment throughout the Los Angeles/Long Beach Harbor over the past 30 years. Maintenance dredging programs return sediment elevations to design depths to support improved navigation. The effectiveness of maintenance dredging programs in reducing contaminated sediments continues to improve as ongoing sources continue to decline. Capital dredging programs deepen waterways to allow for expanded commerce and bring sediment surface layers to pre-industrial chemical concentrations. Habitat improvement programs are propelled through mitigation requirements for improvements that result in loss of marine habitat or unavoidable impacts. Habitat improvement programs often place clean material in an area to create a shallow water habitat that supports higher valued marine life, like nursery grounds and essential fish habitat. In summary, maintenance dredging, capital improvement dredging and habitat enhancement programs currently managed by POLB and POLA will continue to serve as the major mechanism for the continued reduction in surface sediment contaminant concentrations. These activities are tied to port operations and will need to be implemented along with port business driven mechanisms. It is recognized that additional management strategies may be required to further improve surface sediment condition. These management actions will be implemented through this CSMP.

Attaining sediment, water, and fish tissue quality will likely be achieved through a combination of source reduction, source control, sediment removal, and MNR. The Harbor Toxics TMDL, the recent Los Angeles County MS4 Permit (Order No. R4-2012-0175) and the City of Long Beach MS4 Permit (Order No. R4-2014-0024) describe specific components to inform and enhance water and sediment management. These components include establishing regional monitoring coalitions, coordinated monitoring plans, WMPs, enhanced watershed management programs (EWMPs), CSMPs, and special studies. This CSMP is being developed to provide a mechanism for determining and prioritizing one or more sediment management alternatives predicated on the information and data collection obtained from the monitoring efforts of the responsible stakeholder group(s).

CSMP milestones are summarized in Figure 2. Sediment quality will be evaluated as part of the required monitoring program. Impacts of sediment-bound contaminants will be evaluated through the SQO process developed by the State Water Resource Control Board (SWRCB 2009). If chemicals within sediments are contributing to impairment, then causative agent(s) will be determined using SQO recommended procedures. Impacted sediments will then be included in the list of sites to be managed. This process will prioritize management efforts at sites that have the greatest impact to the overall health of the benthic community and risk to humans from fish consumption. The prioritization process will allow sites with lower risks to be addressed in later phases of the TMDL schedule. The site will then be managed and improvements confirmed through a sediment monitoring program. For areas where sediment has been demonstrated to cause impairment, activities and key questions to be addressed in each milestone shown in Figure 2 are summarized below.

3.1 Monitoring and Data Collection Program

Sediment, water, and fish tissue monitoring will be conducted through approved CIMP, CCMRP, regional monitoring programs (e.g., Southern California Bight), MS4 Permits (Order No. R4-2012-0175 and R4-2014-0024), NPDES permits' required monitoring, and special studies. If multiple programs are employed within the watershed, every effort should be made to engage in a data sharing program among jurisdictional groups to ensure, where possible, data gaps are filled and that all relevant and available data are compiled and analyzed prior to making a conditional assessment on the watershed.

The CCMRP has been submitted to the Executive Officer of the RWQCB for approval. Briefly, the CCMRP will include sediment, water, and fish tissue sampling for the Los Angeles Harbor, Long Beach Harbor, LARE, and Eastern San Pedro Bay as it is defined in the Harbor Toxics TMDL, Los Angeles County MS4 Permit (Order No. R4-2012-0175), and City of Long Beach MS4 Permit (Order No. R4-2014-0024). The PRPs identified in the effective metals TMDLs for the Los Angeles and San Gabriel rivers are responsible for conducting water and sediment monitoring above LARE and at the mouth of the San Gabriel River, respectively, to determine the rivers' contribution to the impairments in the Greater Los Angeles/Long Beach Harbor Waters.

A thorough data review of sediments and fish tissue has been conducted, and validated data are included in the POLB and POLA sediment chemistry database. The database also includes an extensive compilation of data collected by a variety of agencies as part of other characterization and monitoring studies conducted between 1980 and 2011. Data from the Los Angeles/Long Beach Harbor, Eastern San Pedro Bay, Dominguez Channel Estuary, and nearshore areas along the Southern California Bight were also included in the compilation.

In addition to monitoring programs, POLB (with POLA) is engaged in developing a series of special studies examining the fate and effect of chemicals of concern in the Greater Los Angeles/Long Beach Harbor Waters area to determine the cause and source of observed impairments. These studies include identifying stressors and sources to benthic impairments and sources and linkage fish tissue impairments. Identifying sources of fish tissue impairments is the first critical step in evaluating potential remedies directed at reducing fish tissue concentrations. It is necessary to establish the causes of elevated fish tissue concentrations (i.e., harbor sediments, ongoing sources, and off-site regional sources) and determine the necessary reductions of these sources that will effectively reduce fish tissue concentrations prior to developing management strategies. To establish these causes, scientific- and data-based models of the conditions in the harbor and the food web are necessary. Integrating hydrodynamic, sediment transport, chemical fate, and bioaccumulation processes through site-specific models will allow the City of Long Beach to evaluate the limitations of background concentrations, effectiveness of specific remedial actions including MNR, and the impact of out-of-harbor sources (e.g., Palos Verdes Shelf). These studies are using the WRAP Model and expanding it to incorporate chemical fate of

PCBs and DDTs. The expanded WRAP Model will then be linked to a site-specific bioaccumulation model. The bioaccumulation model will be used to evaluate the relative contribution of water column and sediment sources to the fish receptors of concern.

3.2 Identification of Potential Management Areas

The areas recommended for potential management will be better defined after data gaps are fulfilled. Identifying these areas will be informed by data collection efforts as well as information from WMPs within the Dominguez Watershed. Meeting the sediment targets in the Harbor Toxics TMDL requires a watershed-based approach that includes both land-side and sediment-based programs that focus on identifying sources and source reduction alternatives.

A single site has been identified thus far for proposed implementation action in the Harbor Toxics TMDL: IR Site 7. Other sites within Long Beach Harbor, Eastern San Pedro Bay, and LARE will be evaluated through the process outlined below and advancement of management alternatives for these sites will be documented using the five milestones of the CSMP. Any additional sites requiring potential management will be identified during the TMDL reopener, tentatively scheduled for spring 2018.

3.3 Identification of Management Alternatives

For each potential management area, a range of alternatives will be summarized and their effectiveness at meeting the target water quality requirements within the TMDL schedule will be considered. As recommended by the USEPA Guidance Document (USEPA 2005), and described above in Section 2, the first step in selecting an appropriate management alternative for a priority site is to implement an effective source control program. None of the available alternatives can be successful if the potential for recontamination is still present; therefore, the effectiveness of source control for inputs to the Long Beach Harbor, Eastern San Pedro Bay, and LARE must be evaluated prior to other sediment management actions. Once management actions are identified and implemented through special studies, WRAP, and City of Long Beach MS4 programs to reduce pollutants in effluent and stormwater inputs to Long Beach Harbor, Eastern San Pedro Bay, and LARE, these management actions will be incorporated into the CSMP.

POLB and POLA are implementing source reduction strategies through the WRAP (Ports 2009). These actions have been developed to address sources of pollutants related to port land use discharges, watershed discharges, and legacy pollutants in sediments. The WRAP was developed by POLB and POLA in cooperation with the RWQCB, USEPA, and other stakeholders to establish programs and control measures to improve water and sediment quality within the Los Angeles/Long Beach Harbor. The WRAP is currently being implemented as a living document and will be updated as needed.

Structural BMPs and non-structural BMPs are being evaluated. In addition, POLB has developed and implemented a port-specific guidance manual for design of new and redeveloped facilities, including design criteria and appropriate structural BMPs for differing land uses and potential contaminants of concern. POLB and POLA are developing approaches to expand upon existing stormwater/dust control programs for vacant/undeveloped property. Control measures may include introducing sustainable landscaping, using swales and berms, and appropriate re-grading to reduce erosion and levels of suspended solids and other pollutants in stormwater. Street and parking lot sweeping is currently conducted by POLB and POLA throughout the Harbor District; however, debris is still present. POLB and POLA plan to enhance and expand these programs based on an evaluation of the current sweeping/cleaning activities and inspecting all sites to assess debris levels and problem areas. POLB and POLA plan to evaluate the construction permitting process and procedures to determine areas for improvement in permitting compliance that would reduce pollutant runoff from such sites.

As discussed above, maintenance dredging, capital dredging, and habitat improvement programs result in improvement in surface condition. These programs are implemented through the CSTF process where it is necessary to demonstrate that post-dredge surfaces are better quality, chemically, than pre-dredge conditions.

During the TMDL reopener, a summary of each potential management alternative for remediating identified priority areas of the Long Beach Harbor, Eastern San Pedro Bay, and LARE along with a detailed feasibility study evaluating each option against a range of topics will be provided. Included in that evaluation will be a consideration of the following topics:

- Technical, logistical, and economic feasibility

- Social and environmental impacts
- Estimated cost
- Estimated time to complete
- Predicted load reduction to sediment and fish
- Potential for recontamination (despite best attempts at controlling sources)

3.4 Selection of Management Alternatives

Once an area has been identified for remediation and available management alternatives are summarized, the relevant stakeholder group can select the appropriate management action for the area. The makeup of the stakeholder group and agreements between the stakeholders will define the process for selecting management alternatives. As stated above, the maintenance dredging, capital improvement dredging, and habitat enhancement programs will serve as the major mechanism for the continuation of reduction in surface sediment contaminant concentrations. These activities coincide with port operations and will need to be implemented along with port business-driven mechanisms.

3.5 Commence Management Actions

The selected management action can be scheduled for implementation only after all the parties agree to the management approach and funding mechanisms.

3.5.1 IR Site 7

IR Site 7 comprises approximately 700 acres of submerged land in the POLB's West Basin and used by the U.S. Navy for training troops and maneuvering, anchoring, berthing, and maintaining vessels. The site is adjacent to three former dry docks used by the U.S. Navy at the former Long Beach Naval Complex (LBNC). In 1935, the U.S. Navy negotiated a 30-year lease with the City of Long Beach for developing the property into a naval facility. The U.S. Navy additionally purchased a strip of coastline along the southern portion of Terminal Island from the cities of Long Beach and Los Angeles in 1938. Beginning in 1938, the U.S. Navy operated the LBNC for naval and other marine activities, such as providing maintenance facilities for the berthing operations of tugboats, scows, and similar vessels. The LBNC provided logistical support for assigned ships and performed work in connection with construction, conversion, overhaul, repair, alteration, dry-docking, and fitting out of ships.

During naval operations, various fuels, oils, paints, and other organic and metal wastes were disposed of at the LBNC, including discharge into the West Basin. After more than 50 years of service, the Naval Station Long Beach was closed on September 30, 1994, under Base Realignment and Closure (BRAC) II. During this same year, the U.S. Navy initiated a comprehensive field sampling effort to support a Remedial Investigation (RI) of IR Site 7 sediments (Bechtel 1997) following CERCLA guidance. Included in the RI were detailed ecological and human health risk assessments for potential exposures to site sediments. On September 30, 1997, LBNC was closed under BRAC IV. During this period, site ownership of the submerged land (except the 100-foot annulus) within IR Site 7 was formally reverted back to the POLB.

The results of the RI were published in 1997 (Bechtel) with the conclusion that no potential human health risks were posed by site sediments. The RI did, however, conclude that ecological risks could occur to benthic organisms residing in IR Site 7 sediments. As a result, a subsequent Feasibility Study (FS) was conducted to identify potential areas of ecological concern (AOECs) and possible remedial alternatives for managing these risks (Bechtel 2003). The final FS was published in September 2003; it identified several areas for sediment remediation and selected dredging with on-site disposal as the preferred alternative. For this alternative, contaminated sediments would be placed within a diked containment area along the U.S. Navy Mole, capped with clean sediment, and covered with asphalt (Bechtel 2003). The final FS was later amended to accept off-site disposal as an equally effective alternative. In August 2007, a Record of Decision (ROD) issued by the USEPA was executed by the U.S. Navy in order to accept the proposed remedies from the final FS. Shortly thereafter, the POLB, in accordance with the Lease in Furtherance of Conveyance, began developing the necessary remedial design and planning documents for implementing the selected remedy.

The remedial alternative for IR Site 7 (developed through the FS process) was selected to provide the greatest level of protection to IR Site 7 benthic communities, achieve remedial action objectives set forth in the ROD (USEPA 2007), and provide the greatest level of long-term effectiveness and permanence as well as selected for its ability to be easily implemented. The selected remedies included:

- **AOEC-A and AOEC-C.** Removal and disposal of AOEC sediments at an off-site (outside of IR Site 7) location was necessary to create clean substrate supporting the presence of an ecologically productive and diverse benthic community. AOEC-C was later divided into a West and East component for remediation purposes.
- **AOEC-B.** No remedial action was necessary to protect the environment, as chemical concentrations did not result in sediment toxicity or adverse effects on the benthic community.
- **AOEC-E, AOEC-F, and AOEC-G (Pier AOECs).** Limited action was necessary to implement institutional controls for preventing unauthorized or uncontrolled disturbance and/or exposure of beneath-pier chemically impacted sediments.
- **AOEC-D.** No remedial action was necessary, accepted as a no action area.

Sediment Management Objective (SMO) criteria were developed during the FS process as target cleanup goals to be used for verifying successful removal of chemically impacted sediments. These SMOs were then used to develop a remedial design for the site. Remedial design is the phase in an IR site cleanup where the technical specifications for cleanup remedies and technologies are designed. The remedial action follows the remedial design phase and involves the actual construction or implementation phase of IR site cleanup. The Remedial Design/Remedial Action was based on the specifications described in the ROD (USEPA 2007). For IR Site 7, the remedial design phase focused on developing the dredging plan (vertical and horizontal extents) required to achieve the targeted sediment management objectives. The remedial action was the actual construction activity of removing sediments and placing them inside the Pier G slip fill site.

Dredging of IR Site 7 officially began on July 26, 2010, and was completed on February 12, 2011. Using a clamshell bucket and dump scows, a total of 502,984 cubic yards of sediment was removed and placed inside the Pier G slip fill containment area (located within POLB) and covered with up to 24 feet of clean fill material. Routine bathymetric surveys and sediment grab samples were collected during construction to verify successful removal of the impacted sediments.

Confirmatory sediment core samples were collected after dredging was completed. These samples showed that the surface-weighted average concentrations for the chemicals of potential concern were all below the target SMOs for the site. Thus, POLB concluded that AOEC-A, AOEC-C West, and AOEC-C East were successfully remediated in accordance with the ROD. No remedial action was required for AOEC-D or AOEC-B. Institutional controls were enacted at AOEC-E, AOEC-F, and AOEC-G to ensure disturbance of sediments beneath existing pier structures does not occur in the future. In June 2013 the California Department of Toxic Substances Control officially closed the IR Site 7 remediation project and concluded that the POLB had successfully completed its remediation requirements.

3.6 CSMP Schedule

The CSMP schedule is outlined in Table 2.

Table 2
CSMP Schedule

Deliverables to RWQCB	Task	Date	Alignment with Basin Plan Amendment	Alignment with TMDL and MS4 Permit Requirements
CSMP	Submit CSMP for Long Beach Harbor, Eastern San Pedro Bay, and LARE to RWQCB for consideration by Executive Director	March 23, 2014 (2 years after effective date of TMDL)	Meets required submittal timeline	WRAP: Continue to implement source reduction practices EWMP: Identify opportunities to incorporate management actions (e.g., BMPs and their effectiveness into CSMP process [see Section 3.3]) CCMRP: Outline monitoring program to be used to identify areas to be managed (see Section 3.1) Special Studies: Through the Harbor Technical Work Group special studies will be implemented to characterize the impairment and appropriate management actions
CSMP Stakeholder Meetings	Conduct as-needed stakeholder meetings	As-needed meeting agendas and minutes to stakeholders	Meets coordination and cooperation of stakeholders	EWMP: Annual review of EWMP management strategies, actions, and special studies that may inform change of conditions in Long Beach Harbor, Eastern San Pedro Bay, and LARE.

Deliverables to RWQCB	Task	Date	Alignment with Basin Plan Amendment	Alignment with TMDL and MS4 Permit Requirements
CSMP Update	Submit CSMP Update for Long Beach Harbor, Eastern San Pedro Bay, and LARE to RWQCB	March 23, 2017 (5 years after effective date of TMDL)	Provides updated list of sites to be managed submitted to RWQCB during TMDL reopener	
CSMP Update	Submit CSMP Update Long Beach Harbor, Eastern San Pedro Bay, and LARE to RWQCB	March 23, 2022 (10 years after effective date of TMDL)	Demonstrates progress toward sediment management actions and provides updated list of sites to be managed	
CSMP Update	Submit CSMP Update for Long Beach Harbor, Eastern San Pedro Bay, and LARE to RWQCB	March 23, 2027 (15 years after effective date of TMDL)	Demonstrates progress toward sediment management actions and provides updated list of sites to be managed	
CSMP Update	Submit CSMP Update for Long Beach Harbor, Eastern San Pedro Bay, and LARE to RWQCB	March 23, 2032 (20 years after effective date of TMDL)	Demonstrates attainment of LAs using the means identified in Basin Plan Amendment	

4 SUMMARY

This CSMP is designed to meet requirements of the TMDL schedule for the Harbor Toxics TMDL, which states that responsible parties in the Dominguez Watershed develop a CSMP to address contaminated sediments in Long Beach Harbor, Eastern San Pedro Bay, and LARE. This CSMP is based on established guidance and is consistent with other CSMPs being developed for Dominguez Channel Estuary and Los Angeles Harbor.

The objective of this CSMP is to establish specific steps to identify, prioritize, and implement sediment management actions. Initial steps were designed to inform subsequent technical and decision-making tasks and include:

- Data collection and evaluation (including chemical source investigations and defining nature and extent of impacts)
- Identification of potential management areas (including identifying PRPs)
- Identification of management alternatives
- Selection of management alternatives (considering ecological and human health risks and net benefits)
- Commencement of management actions

This approach encourages collaboration with regional monitoring programs, WMPs, and existing sediment remediation programs (e.g., Montrose Superfund site) to inform management alternatives and schedules. Source identification and reduction is included in the first step in the management plan and will be completed through data evaluation, data gap identification, and data collection and analyses prior to identifying and implementing remedies. A schedule of deliverables is included in this CSMP to reflect requirements set forth in the TMDL for submitting the CSMP and providing annual reports and updates to the RWQCB. This CSMP is an adaptive plan that provides for stakeholder and RWQCB review and interaction and provides a plan for protecting and improving benthic community condition and human health from fish consumption.

5 REFERENCES

Bay, S.M., D.J. Greenstein, J.A. Ranasinghe, D.W. Diehl, and A.E. Fetscher, 2009. *Sediment Quality Assessment Draft Technical Support Manual*. Technical Report 582. Southern California Coastal Water Research Project. May 2009.

Bridges, T.S., P. Schroeder, S. Ells, D. Hayes, D. Mount, S. Nadeau, M. Palermo, C. Patmont, 2008. *The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and* Risk. Prepared for U.S. Army Corps of Engineers. ERDC/EL TR-08-4. January 2008.

Bechtel International, Inc. (Bechtel), 2003. *Final Feasibility Study Report, Installation Restoration Site 7, Naval Station Long Beach*.

Bechtel, 1997. *Final Remedial Investigation Report, Installation Restoration Site 7 (West Basin), Naval Station Long Beach*. Long Beach, California. December 1997.

CSTF (Contaminated Sediment Task Force), 2005. Los Angeles Regional Contaminated Sediments Task Forc*e: Long-Term Management Strateg*y.

Lyons, J.M., and S. Birosik, 2007. *Water Quality in the Dominguez Channel and Los Angeles/Long Beach Harbor Watershed Management Area Under the Surface Water Ambient Monitoring Program Fiscal Year 2002-2003*. California Regional Water Quality Control Board, Los Angeles Region.

Nadeau, S.C., M.C. MuCulloch, and T.S. Bridges, 2009. Principles for Evaluating Remedial Options for Contaminated Sediment Sites. 5th International Conference on Remediation of Contaminated Sediments, Jacksonville, Florida. 2009.

Ports (Ports of Los Angeles and Long Beach), 2009. Water Resources Action Plan, Final Report. August 2009.

RWQCB (Regional Water Quality Control Board), 2014. Final Waste Discharge Requirements for Municipal Separate Storm Sewer System (MS4) Discharges within the City of Long Beach MS4. Available from: http://www.waterboards.ca.gov/rwqcb4/water_issues/programs/stormwater/municipal/.

RWQCB and USEPA (U.S. Environmental Protection Agency), 2011. *Final Dominguez Channel and Greater Los Angeles and Long Beach Harbor Waters Toxic Pollutants Total Maximum Daily Loads*. May 2011.

SWRCB (State Water Resources Control Board), 2009. *Water Quality Control Plan for Enclosed Bays and Estuaries: Sediment Quality Plan*. Final Staff Report. August 2009.

SWRCB, 2010. Integrated Report (Clean Water Act Section 303(d) List / 305(b) Report. Available from: http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml.

USEPA (U.S. Environmental Protection Agency), 1999. Record of Decision: Dual Site Groundwater Operable Unit Montrose Chemical and Del Amo Superfund Sites. USEPA Region IX.

USEPA, 2005. *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*. USEPA-540-R-05-012. Office of Solid Waste and Emergency Response OSWER 9355.0-85. December 2005.

USEPA, 2007. Record of Decision, Installation Restoration Site 7 Operable Unit 3 Former Long Beach Naval Complex. Long Beach, California.

USEPA, 2013. *Use of Amendments for In Situ Remediation at Superfund Sediment Sites. Office of Superfund Remediation and Technology Innovation*. OSWER 9200.2-128FS. April 2013.

APPENDIX A
PRINCIPLES FOR EVALUATING REMEDIAL OPTIONS FOR CONTAMINATED SEDIMENT SITES

Principles for Evaluating Remedial Options for Contaminated Sediment Sites

Steven C. Nadeau (snadeau@honigman.com) and Megan C. McCulloch (Honigman Miller Schwartz and Cohn LLP, Detroit, MI), Todd S. Bridges (U.S. Army Engineer Research and Development Center, Vicksburg, MS)

ABSTRACT: The complexity inherent in contaminated sediment sites requires that they undergo a detailed evaluation of site conditions and sediment management options in order to optimize the effectiveness of their potential remediation and risk reduction. Experiences gained at numerous sediment sites over the last 20 years can be tapped by Project Managers in the form of lessons learned. This knowledge should be integrated into the decision-making process as recommended by the U.S. EPA Contaminated Sediment Remediation Guidance For Hazardous Waste Sites (2005). This paper will review risk management principles for complex contaminated sediment sites and several of the key risk-based decision-making factors necessary to realistically evaluate the potential risk reduction associated with each remedial option.

INTRODUCTION

Contaminated sediment is pervasive across the United States. In 2004, U.S. EPA identified 96 watersheds as containing "areas of probable concern," defined as areas where fish and benthic organisms may be frequently exposed to contaminated sediment (U.S. EPA 2004). As of September 2005, through U.S. EPA's Superfund program, remedies have been selected for over 150 contaminated sediment sites, of which over 65 are large enough to be tracked at the national level (U.S. EPA 2008). Investigations are on-going at over 50 other contaminated sediment sites (U.S. EPA 2008).

Sediment sites pose challenging technical problems and addressing these problems consumes an enormous amount of resources. There are over 11 Superfund "mega" sites where the cost of the sediment remedy exceeded $50 million (U.S. EPA 2008). A number of other sites are expected to become "mega" sites as site investigations are completed and remedies are selected for them. An example of the high cost of remediating contaminated sediment is the Fox River's Operable Units 2 – 5, where the sediment remedy was estimated to cost $390 million in the Amended Record of Decision (U.S. EPA and WDNR 2007). Moreover, the cost estimate for remediating approximately 75 million cubic yards of contaminated sediment within Great Lakes Areas of Concern ranged from $1.5 billion to $4.5 billion, depending on the types of remedies selected (Great Lakes Regional Collaboration 2005).

Due to the number, size, and high cost of sediment sites across the U.S., efficient and effective remediation of these sites will require a decision-making process that integrates the key lessons learned from the remediation efforts at numerous sediment sites over the last 20 years and the application of risk-management principles in a comprehensive remedy evaluation process. Key considerations in remedy evaluation and selection are discussed and key questions to consider when evaluating and selecting remedies are presented.

RISK MANAGEMENT PRINCIPLE #1: SOURCE CONTROL

The first principle for managing risks associated with contaminated sediment sites is to "Control Sources Early" (U.S. EPA 2002). Identifying and controlling sources prior to conducting remediation is critical to the effectiveness of any sediment cleanup (U.S. EPA 2005). Without source control, the site may become recontaminated.

The risk of recontamination is not theoretical. A 2007 survey of recently completed contaminated sediment remedial actions identified 20 sites in which sediment had become recontaminated (Nadeau and Skaggs 2007). Common sources of recontamination are combined sewer overflows, storm sewer outfalls, other point sources, other sediment sources, including upstream sources and unremediated nearby sediments, runoff, atmospheric deposition, and contaminated groundwater advection (U.S. EPA 2002; U.S. EPA 2005; Nadeau and Skaggs 2007). Thus, prior to initiating any sediment cleanup, project managers should identify and control existing sources, consider whether there is a potential for recontamination and factor that potential into the remedy selection process. Table 1 identifies key questions to consider regarding source control.

TABLE 1. Key source control questions to consider during site evaluation and remedy evaluation and selection (from Evison 2008).

- What steps have been taken to identify sources and are these steps sufficient?
- Have continuing sources been identified?
- Will all continuing sources be controlled prior to remediation?
- If not, should remediation proceed and what accommodations/expectations/plans exist about those sources?

A VALUABLE TOOL: CONCEPTUAL SITE MODEL

A conceptual site model (CSM) represents the current understanding of the site conditions by incorporating information about contaminant sources, transport pathways, exposure pathways and receptors (U.S. EPA 2005). The CSM not only summarizes much of the information related to site risks to human and ecological receptors, it identifies the nature and source of the risk. This identification of the site's risk drivers can be used to evaluate which of the proposed remedial alternatives would effectively mitigate site risks to human and ecological receptors by addressing the site elements that are creating the risks (U.S. EPA 2005). Therefore, the value of a CSM for evaluating the potential effectiveness of remedial alternatives should not be underestimated. Table 2 identifies key questions to consider regarding the CSM.

TABLE 2. Key CSM questions to consider during site evaluation and remedy evaluation and selection (adapted from Evison 2008).

- Have the following data been collected and evaluated in developing the conceptual site model?
  -- Sources of contaminants of concern
  -- Human exposure pathways
  -- Human receptors
  -- Biota exposure pathways
  -- Ecological receptors
  -- Contaminant transport pathways
- If not, why not?
- What are the principal contaminants of concern and exposure pathways driving unacceptable risk at the site?
- Which exposure pathways are relatively unimportant and can be excluded from further consideration?

STABILITY OF CONTAMINANTS IN SEDIMENT

A key component of the CSM is its representation of the stability of contaminants in sediment (U.S. EPA 2002; U.S. EPA 2005). Although sediment moves over time in most aquatic environments, the most important consideration is whether movement of the contaminants in sediment is occurring at a scale and rate that poses risks to human health and ecological receptors (U.S. EPA 2005). Thus, it is important to evaluate the stability of contaminants in sediment and how it affects risk rather than just the movement and/or stability of sediment without reference to risk. Table 3 identifies key questions to consider regarding the stability of contaminants in sediment.

TABLE 3. Key stability of contaminants in sediment questions to consider during site evaluation and remedy evaluation and selection (adapted from Evison 2008).

- Have the appropriate lines of evidence been evaluated on the potential stability of the contaminants present in the sediment (as opposed to sediment stability per se)?
- Does contaminant fate and transport through in-place sediment potentially pose an unacceptable risk to human health and ecological receptors? Is movement of contaminated sediment (surface and subsurface) or of contaminants alone occurring or may occur at scales and rates that will significantly change their current contribution to human health and ecological risk?
  -- Are they contributing to risk now?
  -- Are they likely to contribute to risk in the future?
- If yes, can in-situ remedies (e.g., capping, MNR) be designed to adequately reduce risk to human health and ecological receptors?

EVALUATING REMEDIAL ALTERNATIVES AND SELECTING A REMEDY

There are several key concepts that should be applied when evaluating remedial alternatives and selecting a remedy. These concepts are discussed below.

Remedial Action Objectives. To develop and evaluate remedial alternatives, a description should be developed of what risk reduction the cleanup is expected to accomplish (U.S. EPA 2005). These general statements, remedial action objectives (RAOs), are derived from the understanding of exposure pathways, receptors, and risks gained during development of the CSM and from risk assessments. RAOs should reflect objectives that are achievable from remediation of the site. Some goals, such as lifting a fish consumption advisory, may require watershed level actions that are outside the scope of the site cleanup and may not be achievable on a short-term or even a long-term basis regardless of the subject site's remediation success (U.S. EPA 2005). From the RAOs, contaminant-specific risk-based remediation goals and sediment cleanup levels should be developed (U.S. EPA 2002; U.S. EPA 2005).

Comparative Net Risk. U.S. EPA recommends using a risk management process "to select a remedy designed to reduce the key human and ecological risks" (U.S. EPA 2005). Considerations in the risk management process for contaminated sediment sites include (U.S. EPA 2005; Nadeau 2008):

- There is no presumptive remedy for any contaminated sediment site, regardless of the contaminant or level of risk;
- Risks must be characterized over appropriate timeframes;
- Management goals must be framed within a realistic time period;
- Risk management actions must be linked to reduction of significant human and ecological risks;

- Ecological risks are characterized at a level of assessment appropriate for the site;
- All implementation and residual risks of the remedial alternatives must be considered.

An approach recommended by U.S. EPA and the National Academy of Sciences Committee on Remediation of PCB-Contaminated Sediments that incorporates these considerations is comparative net risk evaluation (CNRE) (NRC 2001; U.S. EPA 2005). Use of CNRE ensures that on a site-specific basis decision-makers consider, at the remedy selection stage, not only the benefits of a remedial approach, but also the residual risks associated with the approach and the risks associated with implementing the remedial approach (U.S. EPA 2005; Nadeau 2008). This differs from the traditional approach of either considering implementation risks at the remedy implementation stage or assuming that remedial approaches will be 100% effective on implementation thereby bypassing any consideration of residual risk. CNRE is consistent with the National Oil and Hazardous Substances Pollution Contingency Plan's (NCP) 9 criteria (40 CFR §300.430(e)(9)(iii)), which require evaluation and balancing of short-term and long-term risks and benefits, including residual risk. Failure to account for implementation risks and residual risk during the remedy evaluation stage can skew remedy selection and result in a less effective and less protective remedy than anticipated, a result neither regulators nor the responsible parties should find acceptable.

Specific Remedy Implementation Risks. Each remedy has its own uncertainties and potential implementation risks. For MNR, the risk present at the time of remedy selection should decrease with time (U.S. EPA 2005). The implementation risks associated with MNR are mostly related to continued exposure to contaminants while natural processes work to reduce contaminant bioavailability. Institutional controls may be useful to address risks to human health during MNR implementation (e.g., fish consumption advisories) (U.S. EPA 2005).

For capping, the risk due to direct exposure to contaminated sediment should decrease rapidly as the cap is placed (U.S. EPA 2005). Implementation risks may include contaminant releases during placement of the cap, impacts on the community (e.g., noise, accidents, residential or commercial disruption), construction-related risks to workers during transport and placement of cap materials, and disruption of the benthic community (U.S. EPA 2005). Cap design and placement techniques may be useful in mitigating some construction-related implementation risks (U.S. EPA 2005).

During dredging, risks to human health and ecological receptors may increase due to increased exposure to contaminants resuspended and released to the surface water (U.S. EPA 2005; NRC 2007; Bridges *et al.* 2008). For example, during the 1995 Non-Time Critical Removal Action (NTCRA) in the Grasse River, caged fish deployed along the perimeter of a set of 3 silt curtains for 6 weeks showed several-fold increases in PCB concentrations compared to those observed in the pre-dredging period (NRC 2007). Lessons learned from the 1995 NTCRA and dredging projects at other sites over 10 additional years did not prevent a similar impact to Grasse River fish during the 2005 Remedial Options Pilot Study dredging (NRC 2007). PCB concentrations increased substantially in fish during the 2005 dredging pilot (NRC 2007).

In addition to the effects of releases at the site, resuspended and released contaminants may be transported downstream from the site. For example, at the Fox River Deposit 56/57 dredging project, 2.2% of the mass of contaminants dredged were released downstream (Steuer 2000).

Although there are no standardized best management practices for environmental dredging, lessons learned from other similar sites may yield some useful techniques for reducing resuspension and releases during dredging (U.S. EPA 2005; NRC 2007). Of late, the effectiveness of silt curtains in controlling releases has been questioned (Bridges *et al.* 2008), as evidenced by the Grasse River fish examples. Because some contaminant release and transport during dredging is inevitable, it must be considered during the alternatives evaluation (U.S. EPA 2005).

Other dredging implementation risks may include impacts on the community (e.g., noise, accidents, residential or commercial disruption), construction-related risks to workers during sediment removal and handling, and disruption of the benthic community (U.S. EPA 2005). Implementation risks are site-specific and remedy-specific and must be considered during remedy evaluation and selection (U.S. EPA 2005). Failure to adequately consider implementation risks may skew remedy selection and result in a less protective remedy than anticipated.

Residual Risk. Residual risk is the risk to human health and ecological receptors from contaminated materials or residuals that remain after remedial action has been concluded (U.S. EPA 2005). All remedial approaches leave some contaminants in place after remedial actions are complete (U.S. EPA 2005). The source of residual risk varies for each remedial approach and should be evaluated on a site-specific basis.

For MNR, residual risk is generally related to the possibility that clean sediment overlying buried contaminants may move to such an extent that unacceptable risk is created or that groundwater flow, bioturbation, or other mechanisms may move buried contaminants to the surface in an amount and at a rate that could cause unacceptable risk to human health or ecological receptors (U.S. EPA 2005). Institutional controls and monitoring may be used to address residual risk. Table 4 identifies key questions to consider regarding residual risk following a MNR remedy.

TABLE 4. Key questions to evaluate residual risk from a MNR remedy (adapted from Evison 2008).

- What evidence is there that the system is recovering? Is the pattern of recovery expected to change in the future? If so, how will it change? Will the change result in unacceptable risk?
  -- If the change may result in an unacceptable risk, can institutional controls reduce human health risks?
- Is the rate of recovery sufficient to reduce risk within an acceptable time frame?
  -- If no, can the recovery process be accelerated by engineering means?
  -- If no, can human health risks be addressed by institutional controls?
- Are groundwater flow, bioturbation, or other mechanisms likely to move contaminants to the surface at a rate and concentration that may pose an unacceptable risk?
- Can a monitoring plan be designed to evaluate risk reduction and protectiveness?

For capping, residual risk is generally related to (1) the possibility of cap erosion or disruption exposing contaminants; (2) the potential for contaminants to migrate through the cap; and (3) risks from contaminants remaining in uncapped areas (U.S. EPA 2005). As with MNR, whether erosion or contaminant migration through the cap poses an unacceptable risk depends on the amount and rate of contaminant exposure due to those processes (U.S. EPA 2005). Cap monitoring, maintenance, and design and institutional controls may be used to address residual risk. Table 5 identifies key questions to consider regarding residual risk following capping.

TABLE 5. Key questions to evaluate residual risk from a capping remedy (adapted from Evison 2008).

- Is erosion or disruption of the cap likely to occur in a way that may pose an unacceptable risk?
  -- If likely, can cap design, maintenance, or institutional controls reduce risk to an acceptable level?
- Is contaminant migration through the cap likely to occur at a rate that may pose an unacceptable risk?
  -- If likely, can activated carbon or other material be incorporated into the cap to reduce risk to an acceptable level?
- Is NAPL migration through the cap likely to occur at a rate that may pose an unacceptable risk?
  -- If likely, can an impervious material or reactive material be incorporated into the cap to reduce risk to an acceptable level?
- Is gas migration through the cap likely to occur at a rate that may pose an unacceptable risk?
  -- If likely, can the cap be designed to reduce risk to an acceptable level?
- Can the monitoring plan be designed to detect significant erosion or contaminant movement before unacceptable risk occurs?

For dredging, residual risk is primarily related to residuals, i.e., contaminated sediments remaining in the aquatic environment after the completion of dredging. (U.S. EPA 2005; NRC 2007; Bridges *et al*. 2008). Because residuals will occur to some degree with every dredging project (NRC 2007), they should be considered during remedy evaluation and selection (U.S. EPA 2005). There are two types of residuals, undisturbed and generated, both of which are important. Undisturbed residuals are contaminated sediments found at the post-dredge sediment surface that have been uncovered, but not fully removed as a result of the dredging operation (Patmont and Palermo 2007; Bridges *et al*. 2008). Generated residuals are contaminated sediments that are dislodged or suspended by the dredging operation and are subsequently redeposited on the bottom either within or adjacent to the dredging footprint (Patmont and Palermo 2007; Bridges *et al*. 2008). A series of dredging project results has shown that generated residuals ranged from 2 to 9% of the contaminant mass from the last production pass (Patmont and Palermo 2007). Lessons learned from previous dredging projects indicate that residuals are likely to be higher in areas where there are debris, rocks, bedrock, and/or hardpan as well as in areas with low dry density sediment (e.g., “fluff”) (U.S. EPA 2005; NRC 2007).

Residuals are not inconsequential. For example, during the 2005 Remedial Options Pilot Study at the Grasse River, the average surficial concentration of PCBs increased substantially immediately following dredging (NRC 2007). The increase occurred despite removing approximately 80% of the PCB mass in the dredging footprint (NRC 2007). Thus, mass removal did not equate to risk reduction in this more modern-day pilot (NRC 2007). Table 6 identifies key questions to consider regarding residual risk from dredging.

TABLE 6. Key questions to evaluate residual risk from a dredging remedy (adapted from Evison 2008).

- Is it likely that resuspension will pose an unacceptable risk?
- Is it likely that releases will pose an unacceptable risk?
- Is it likely that residuals will pose an unacceptable risk?
- If residuals are estimated to exceed cleanup levels, should an engineered cap be considered as an alternative to dredging?
- If residuals are estimated to exceed cleanup levels, can cleanup levels be achieved with backfill? If so,

how is the backfill intended to function? -- If it is intended as a dilution layer - Is the added material going to change the amount of contaminant mass that is bioavailable? - Would thin layer placement without dredging be more appropriate? -- If it is intended as a cap - Has it been evaluated for erosion potential? - Has it been evaluated for the effects of groundwater advection? - Would engineered capping be more appropriate? • Can the monitoring plan be designed to ensure the backfill is functioning as designed?

Selecting A Remedy. Once the remedial alternatives have been evaluated, a risk-based decision-making process should be applied to select a remedy or combination of remedies that will effectively reduce risks to human health and ecological receptors (U.S. EPA 2005). This risk-based decision-making process includes the 9 criteria from the NCP and complies with the NCP (U.S. EPA 2005; Evison 2008). Table 7 identifies key remedy selection considerations.

TABLE 7. Key remedy selection principles (adapted from U.S. EPA 2005 and Evison 2008).

• There is no presumptive remedy for any contaminated sediment site, regardless of the contaminant or level of risk. • Risk management goals should be developed that can be evaluated within a realistic time period, acknowledging that it may not be practical to achieve all goals in the short term. • Evaluate uncertainties concerning the predicted effectiveness of various remedial alternatives and the time frames for achieving cleanup levels, remedial goals, and remedial action objectives. • Use realistic time frames for remedy design, implementation and completion, and incorporate risks associated with remedy implementation when comparing on-going risks • The effectiveness of in-situ (capping and MNR) and ex-situ (dredging) alternatives should be evaluated under the conditions present at the site. There should not be a presumption that removal of contaminated sediments from a water body will be more effective or permanent than capping or MNR. • Contaminants that are deeply buried, have no significant migration pathway to the surface, and are unlikely to be exposed in the future may not need removal because they do not necessarily contribute to site risks. • No remedy is perfect. A combination of sediment management options may be the most effective way to manage risk. • Developing accurate cost estimates is an essential part of evaluating alternatives. An important risk management function is to compare and contrast the cost and benefits of various remedies.

CONCLUSION

Contaminated sediment sites pose difficult challenges due to complex technical issues. Addressing these sites requires applying risk-management principles within a risk-management framework to remedy evaluation and selection. To be effective, this risk management framework must include consideration of implementation risks and residual risk at the remedy evaluation and selection phase. U.S. EPA's "Contaminated Sediment Remediation Guidance for Hazardous Waste Sites" provides such a framework.

REFERENCES

Bridges, T., S. Ells, D. Hayes, D. Mount, S. Nadeau, M. Palermo, C. Patmont, and P. Schroeder. 2008. *The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk*. ERDC/EL TR-08-4. U.S. Army Corps of Engineers, Engineer Research and Development Center. February 2008.

Evison, L. 2008. "Decision Tool for Remedy Evaluation". Presented at *Optimizing Decision-Making and Remediation at Complex Contaminated Sediment Sites Conference*, January 8-10, 2008, New Orleans, Louisiana. Conference jointly sponsored by U.S. Environmental Protection Agency, U.S. Navy Space and Naval

Warfare Systems Center, U.S. Army Corps of Engineers – Engineer Research and Development Center, and Sediment Management Work Group.

Great Lakes Regional Collaboration. 2005. *Strategy To Restore And Protect The Great Lakes*. December 2005.

Nadeau, S. and M. Skaggs. 2007. "Analysis of Recontamination of Completed Sediment Remedial Projects." Paper D-050 in *Proceedings, 4th International Conference on Remediation of Contaminated Sediments*, January 22-25, 2007, Savannah, GA. Battelle Press, Columbus, OH:

Nadeau, S. 2008. "Applying the Principles of Comparative Net Risk and Risk Management to Sediment Sites." Presented at *Optimizing Decision-Making and Remediation at Complex Contaminated Sediment Sites Conference*, January 8-10, 2008, New Orleans, LA. Conference jointly sponsored by U.S. Environmental Protection Agency, U.S. Navy Space and Naval Warfare Systems Center, U.S. Army Corps of Engineers – Engineer Research and Development Center, and Sediment Management Work Group.

NRC. 2001. *A Risk-Management Strategy for PCB-Contaminated Sediments*. National Research Council. National Academies Press, Washington, DC.

NRC. 2007. *Sediment Dredging at Superfund Megasites: Assessing the Effectiveness*. National Research Council. National Academies Press, Washington, DC.

Patmont, C., and M. Palermo. 2007. "Case Studies of Environmental Dredging Residuals and Management Implications." Paper D-066 in *Proceedings, 4th International Conference on Remediation of Contaminated Sediments*, January 22-25, 2007, Savannah, GA. Battelle Press, Columbus, OH.

Steuer, J. 2000. *A Mass-Balance Approach for Assessing PCB Movement During Remediation of a PCB-Contaminated Deposit on the Fox River, Wisconsin*. USGS Water Resources Investigation Report 00-4245.

U.S. EPA. 2002. *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites*. OSWER Directive 9285.6-08. February 2002.

U.S. EPA. 2004. *The Incidence and Severity of Sediment Contamination in Surface Waters of the U.S., National Sediment Quality Survey: Second Edition*. EPA-823-R-04-007. November 2004.

U.S. EPA. 2005. *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*. OSWER Directive 9355.0-85.

U.S. EPA and WDNR. 2007. *Record of Decision Amendment, Lower Fox River and Green Bay Superfund Site*. U.S. Environmental Protection Agency and Wisconsin Department of Natural Resources. June 2007.

U.S. EPA. 2008. "Contaminated Sediments in Superfund." http://www.epa.gov/superfund/health/conmedia/sediment/index.htm. Website last visited January 14, 2009.