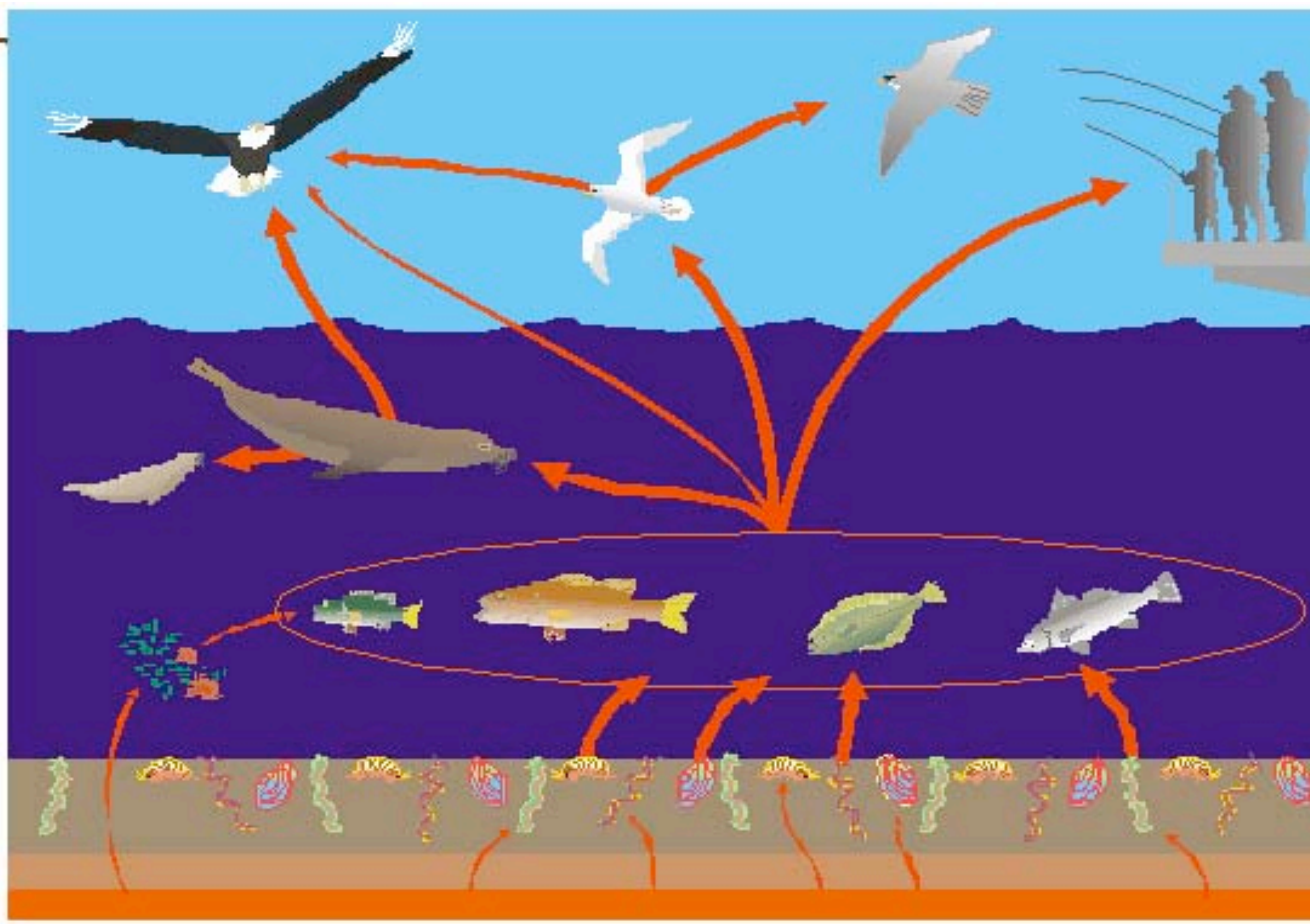
PALOS VERDES SHELF

OPERABLE UNIT 5 of the
MONTROSE CHEMICAL CORP.
SUPERFUND SITE

FEASIBILITY STUDY
MAY 2009

REGION IX
U.S. ENVIRONMENTAL PROTECTION AGENCY



Palos Verdes Shelf Superfund Site
Operable Unit 5 of the Montrose Chemical Corp. Superfund Site

Final Feasibility Study

May 2009

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Acronyms and Abbreviations

°C	Celsius
µg/cm^2/yr	micrograms per square centimeter per year
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µm	micrometer(s)
ARAR	applicable or relevant and appropriate requirement
ASTM	American Society for Testing and Materials
AWQC	ambient water quality criteria
Bight ′94	1994 Southern California Bight Pilot Project
BMP	best management practice
CAD	contained aquatic disposal
CCR	California Code of Regulations
CDF	confined disposal facility
CDFG	California Department of Fish and Game
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
CGS	California Geological Survey
cm	centimeter(s)
cm/sec	centimeters per second
cm/year	centimeters per year
cm^2	square centimeter(s)
CO_2	carbon dioxide
CSMW	California Coastal Sediment Management Workgroup
CST	Los Angeles Contaminated Sediment Long-Term Management Strategy
CTE	central tendency exposure
CZMA	Coastal Zone Management Act
DBW	California Department of Boating and Waterways

DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethene
DDMU	1-chloro-2,2-bis (p-chlorophenyl) ethylene
DDNU	unsym-bis (p-chlorophenyl) ethylene
DDT	dichlorodiphenyltrichloroethane
DDTs	dichlorodiphenyltrichloroethane and its metabolites
DNAPL	dense nonaqueous phase liquid
EE/CA	Engineering Evaluation/Cost Analysis
Eh	redox potential
EPA	United States Environmental Protection Agency
ERA	ecological risk assessment
ERDC	Engineering Research and Development Center
FCEC	Fish Contamination Education Collaborative
FDA	Food and Drug Administration
Fe	iron
FR	Federal Register
FS	Feasibility Study
g	gram(s)
g/day	grams per day
g/L	grams per liter
gpm	gallons per minute
GPS	global positioning system
GRA	general response action
HARS	Historical Area Remediation Site
H_2O_2	hydrogen sulfide
HHRE	human health risk evaluation
HI	hazard index
HQ	hazard quotient
IRIS	Integrated Risk Information System
JWPCP	Joint Water Pollution Control Plant
kg	kilogram(s)

km	kilometer(s)
km^2	square kilometer(s)
L	liter(s)
LACDHS	Los Angeles County Department of Health Services
LACSD	Los Angeles County Sanitation Districts
lbs	pound(s)
LC	Landward Center
LD	Landward Downstream
LOEC	lowest observed effects concentration
LU	Landward Upstream
m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
MDS	Mud Dump Site
mg	milligram(s)
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mgd	million gallons per day
mi^2	square mile(s)
ml	milliliter(s)
mm	millimeter(s)
MMS	United States Minerals Management Service
MNR	monitored natural recovery
Montrose	Montrose Chemical Corporation of California
MPRSA	Marine Protection, Research, and Sanctuaries Act of 1972
MSRP	Montrose Settlements Restoration Program
NAS	National Academy of Sciences
NCP	National Contingency Plan
NEL	Naval Electronic Laboratory
ng/L	nanograms per liter
NOAA	National Oceanic and Atmospheric Administration

NOEC	no observed effects concentration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NPV	net present value
NRDA	Natural Resource Damage Assessment
OCHCA-EHD	Orange County Health Care Agency – Environmental Health Division
O&M	operations and maintenance
OEHHA	Office of Environmental Health Hazard Assessment
OSWER	Office of Solid Waste and Emergency Response
Pa	pascal(s)
PCBs	polychlorinated biphenyls
ppm	parts per million
ppt	parts per trillion
PRA	Priority Remediation Area
PV Shelf	Palos Verdes Shelf
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act of 1976
redox	reduction-oxidation
RI	Remedial Investigation
RME	reasonable maximum exposure
ROD	Record of Decision
SAB	species diversity, abundance, biomass
SAIC	Science Applications International Corporation
SCB	Southern California Bight
SD	Seaward Downstream
SEC	sediment effect concentration
SMP	Sediment Master Plan
SPI	sediment-profile image/imagery
SPMD	semipermeable membrane device
SU	Seaward Upstream
SWRCB	State Water Resources Control Board

TAB3	tetrapropylene-based alkylbenzene isomer
TBC	to be considered
TCLP	toxicity characteristic leaching procedure
TOC	total organic carbon
TSS	total suspended solids
TTLC	total threshold limit concentration
U.S.	United States
U.S.C.	United States Code
UCL	upper confidence level
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WES	Waterways Experiment Station
yd^3	cubic yard(s)

Executive Summary

The Palos Verdes Shelf Superfund site (PV Shelf) is a large area of contaminated sediment on the continental shelf and slope off the coast of Los Angeles, California. PV Shelf is Operable Unit 5 of the Montrose Chemical Superfund site. At one time, the Montrose Chemical Corporation of California, Inc. (Montrose) operated the nation's largest manufacturing plant of the pesticide, dichlorodiphenyltrichloroethane (DDT). Montrose dismantled its Los Angeles County plant in 1983. However, waste-related contamination at the former plant site led to its placement on the National Priorities List of hazardous sites (i.e., Superfund) in 1989. The former plant property is now the core of the Montrose Chemical Superfund site in Torrance, California. Wastes from the manufacturing plant contaminated soil and groundwater in the vicinity of the former plant property as well as the waters and sediment within the Port of Los Angeles and in the ocean, on the PV Shelf. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) response activities on the PV Shelf are part of the response activities being conducted by EPA in connection with the Montrose Chemical Superfund Site.

Waste from Montrose reached PV Shelf via the Los Angeles County sanitation system. Since 1937, the main wastewater treatment plant of the Sanitation Districts of Los Angeles County (LACSD) has sent treated industrial and municipal wastewater (effluent) to ocean outfalls at White Point on the Palos Verdes Peninsula. From the 1950s to 1971, Montrose released tons of DDT and associated waste into the sewer system to be discharged ultimately from the outfalls at White Point. Other industries, notably Westinghouse, Simpson Paper Company, and Potlatch Corporation, discharged chemical compounds used as coolants and lubricants, called polychlorinated biphenyls (PCBs), into the Los Angeles sewer system as well. Peak mass emissions of effluent solids from the outfalls occurred in 1971. Since 1971, the heavily contaminated sediment has been gradually buried by less contaminated effluent and natural sediment. This has created a layer of cleaner sediment on top of the DDT- and PCB-contaminated sediment.

Purpose and Scope

This Feasibility Study (FS) describes the development, evaluation, and comparison of remedial action alternatives to manage the contaminated sediment at the PV Shelf site. Remedial action alternatives that ensure the protection of human health and the environment may involve reductions in concentrations of contaminants to health-based levels, prevention of exposure to contamination through engineering or institutional controls, or some combination of these activities depending on the site-specific conditions (EPA, 1988a). The purpose of the FS is to develop and evaluate a range of remedial alternatives that are appropriate to site-specific conditions, protective of human health and the environment, and comply with CERCLA. This FS has been prepared in accordance with the EPA documents *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988a) and *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (EPA, 2005).

In keeping with the recommendations of the *Contaminated Sediment Remediation Guidance,* EPA has decided to recommend an interim remedial action. While carrying out the interim action, EPA will conduct additional investigations and pilot studies that will contribute to the design of a Superfund remedy for PV Shelf that reduces risk and provides a permanent solution to the maximum extent possible.

Site Description

The California coast from Pt. Conception to the Mexican border curves inward, forming a large bay called the "Southern California Bight." The Palos Verdes Peninsula is a small but prominent land mass extending into the Southern California Bight. It is bordered by Santa Monica Bay to the north and the San Pedro Shelf to the south. The Channel Islands lie to the west and northwest. The narrow underwater shelf off the Palos Verdes Peninsula is called the Palos Verdes Shelf. The shelf is about 1.5 to 4 kilometers (km) wide, up to 25 km long, and has a slope of 1 to 3 degrees. Kelp beds and rocky patches are found in shallower waters near shore; however, most of the shelf is covered by thick sediment. A shelf break (i.e., a zone of transition from the relatively flat shelf to the steeper continental slope) occurs at water depths of 70 to 100 meters (m). The continental slope drops seaward from the shelf, with a width of approximately 3 km and an average slope of 13 degrees, to a depth of approximately 800 m (Lee, 1994).

The FS defines the PV Shelf Study Area as the area of the shelf and slope off the Palos Verdes Peninsula between Point Fermin and Redondo Canyon, from the shore to the 200-m isobath (depth contour). This is the study area used in the ecological risk assessment and represents a recognizable geographic area. It includes the deposit of highly contaminated sediment and the area around it. An estimated 5.7 million tons of sediment have been affected by the effluent discharged from the White Point outfalls. Mixed within this effluent-affected sediment are an estimated 110 tons of DDT and 10 tons of PCBs.

The effluent-affected sediment forms an identifiable deposit over a mile offshore at a depth of 50 m to the shelf break. The deposit ranges in thickness from 5 centimeters (cm) to over 60 cm. A moderately contaminated surface layer of sediment covers a buried layer of highly contaminated material deposited before 1980. DDT concentrations in the buried deposit exceed 200 mg/kg, while PCBs in the buried deposit reach 20 mg/kg. For most of the deposit, these maximum concentrations are found under about 30 cm of cleaner sediment. The exception is the area near the outfalls, where surface concentrations of DDT can be as high as 200 mg/kg. The deposit is thickest and has the highest concentrations of DDTs and PCBs along the 60-m isobath. The slope has the second highest contaminant concentrations in surface sediment; however, the deposit is thin.

The area of PV Shelf with surface concentrations exceeding 1 mg/kg DDT is approximately 15 square miles. The area with surface concentrations exceeding 1 mg/kg PCBs is about 2.4 square miles. Although contaminant concentrations have dropped from historical highs, concentrations of DDT and PCBs in fish continue to pose a threat to human health and the natural environment.

Risk Summary

The PV Shelf sediment is too deep for direct human contact; however, fish residing on PV Shelf accumulate concentrations of DDTs and PCBs that are potentially harmful to humans and wildlife. EPA's updated human health risk evaluation, contained in Appendix C, assessed two seafood consumptions scenarios: a reasonable maximum exposure (RME) for people who consume fish several times a week, and a central tendency exposure (CTE) that represents a meal a week. Under the RME scenario, all six species of fish analyzed contained levels of DDTs and PCBs that posed a potential health risk. The health also extends to wildlife. Concentrations of DDTs and PCBs in fish are above protectiveness levels recommended for piscivorous wildlife.

DDTs and PCBs are the contaminants of concern (COCs) at the site. COCs in sediment are the source of contamination to surface water and biota. Once remedial actions to remove, treat, or contain the COCs in the sediment deposit are taken, reduction of in surface water and fish will occur naturally.

Applicable or Relevant and Appropriate Requirements

As discussed above, EPA will recommend an interim remedy to begin remediation of the PV Shelf site. Any action taken by EPA must comply with existing laws and regulations. During the development of remedial alternatives, applicable or relevant and appropriate requirements (ARARs) are identified. ARARs generally are classified into the following three categories: chemical-specific, location-specific, and action-specific requirements.

Remedial Action Objectives

Many fishes found on PV Shelf are unsuitable for human consumption because of their levels of DDTs and PCBs. Wildlife that consume fish or fish-eating animals are potentially at risk as well. The Food and Drug Administration (FDA) has set action limits or tolerance levels for contaminants in fish fillets: 5 mg/kg DDT and 2 mg/kg PCBs. However, these are not risk-based levels. The PV Shelf Remedial Investigation Report included risk assessments that used PV Shelf-specific data to calculate exposures that would fall within EPA's acceptable risk range.

Based on CERCLA and the National Contingency Plan (NCP), the remedial action objectives (RAOs) established for the PV Shelf Study Area and their associated quantifiable remediation goals are as follows:

- Reduce to acceptable levels the risks to human health from ingestion of fish exposed to DDTs and PCBs.
    - Achieve interim goals of 400 µg/kg DDT and 70 µg/kg PCBs in white croaker. These concentrations provide levels of protection of 1×10^{-4} excess lifetime cancer risk for anglers under the reasonable maximum exposure scenario (i.e., 116 g/day) and of 1×10^{-5} excess lifetime cancer risk for the central tendency exposure (21.4 g/day), representative of recreational anglers.

  - Achieve median sediment concentration of 230 µg/kg DDTs at 1 percent Total Organic Carbon (TOC) and 70 µg/kg PCBs at 1 percent TOC.
  - Maintain institutional controls program that aims to prevent contaminated fish from reaching markets and educates anglers on safe fishing practices.
- Reduce concentrations of DDTs and PCBs in the surface waters over the PV Shelf to meet ambient water quality criteria (AWQC) for protection of human health and ecological receptors.
  - Achieve AWQC for protection of human health (i.e., 0.22 ng/L DDT and 0.064 ng/L PCBs). These criteria are more stringent than those for ecological receptors; therefore, achieving these goals will protect wildlife as well.
- Minimize potential adverse impacts to sensitive habitats and biological communities on the PV Shelf during remedial implementation.
  - Before implementation of any remedy, prepare a monitoring program to assure the kelp beds on PV Shelf are protected.
  - Use low-impact techniques and best management practices, e.g., plan field work for season when tides and currents are less energetic, set not-to-exceed surge speeds for dredging or capping, monitor sediment resuspension, contaminants in water column, and stop action if monitoring plan standards are exceeded.

The goal of the FS is to develop and evaluate remedial alternatives that achieve these RAOs.

Remedial Action Alternatives

Section 4.0 of the Feasibility Study identifies general response actions (GRAs) used to develop remedial action alternatives. Response actions typically applied to sediment sites are containment, removal, or monitored natural recovery. These three response actions along with their applicable technology types and process options were assessed in detail. Technical assessments of natural recovery, containment (capping) and removal (dredging) are contained in Appendices B, E and F. The remedial technologies are used to construct alternatives, and these alternatives are then screened for effectiveness, implementability, and relative cost. During analysis of response actions, it became clear that additional studies would be necessary to design the most effective remedy and that an iterative or phased approach to remediating PV Shelf was appropriate.

EPA will issue an interim ROD. The interim ROD will call for studies that will help formulate the final ROD. The FS developed five alternatives; however, the removal alternative was screened out as technically impracticable. The following four remedial action alternatives are selected for detailed analysis.

Alternative 1—No Action. The no action alternative serves as a baseline against which other options are compared. The National Contingency Plan (NCP) requires consideration of the no action alternative in order to determine the risks to public health and the environment if no actions were taken.

Alternative 2—Institutional Controls and Monitored Natural Recovery. This alternative monitors reductions in contaminants in the PV Shelf Study Area while reducing risks to human health associated with the consumption of fish that contain DDTs and PCBs through nonengineered controls. Alternative 2 is designed to limit consumption of contaminated fish through an extensive institutional controls (ICs) program while monitoring the naturally occurring reductions of COCs in sediment, water and fish.

Data collected from the PV Shelf Study Area indicate natural processes such as chemical transformation of DDE, contaminant loss through transport, and sediment burial are reducing contaminant levels in sediment, water, and fish. This alternative would monitor the migration and degradation of contaminants and the impact of contaminants on ecological receptors at the PV Shelf. Until contaminant concentrations drop to RAO levels, this alternative would keep in place the institutional controls (ICs) program. The ICs program limits human consumption of potentially contaminated fish by educating the public on safe fishing practices, supporting state commercial fishing ban and fish advisories, and monitoring fish contamination levels from ocean to market.

The cost of Alternative 2 is estimated to be $15.5 million dollars over 10 years. Table ES-1 details the elements of this alternative.

Alternative 3—Institutional Controls, Monitored Natural Recovery and Small Cap. This alternative includes the ICs and MNR program elements of Alternative 2; however, it would enhance natural recovery by placing clean silty sand over an area of PV Shelf that appears to be eroding and where the highest surficial contaminant concentrations are found. The small cap would accelerate natural recovery through:

- Physical armoring of the bottom boundary layer (mudline) from erosion caused by waves and currents
- Chemical isolation of contaminants from the water column to reduce molecular diffusion of dissolved contaminants into the water column
- Reduction of exposure and uptake of contaminants by benthic organisms by replacing effluent-affected sediment with a clean layer for recolonization by sediment-dwelling invertebrates.

Enhanced monitored natural recovery would use low-impact techniques to place a 45-cm layer over approximately 1.3 km^2 (320 acres). Treatability studies to verify effectiveness of low-impact engineering techniques, and to characterize thoroughly the target area would precede construction. The ICs program would continue until contaminant concentrations in fish reach remediation goals.

The cost of Alternative 3 is estimated to be $49 million dollars over 10 years. Table ES-1 details the elements of this alternative.

Alternative 4—Containment with Monitored Natural Recovery and Institutional Controls. This alternative consists of placing a sand cap over contaminated effluent-affected sediment at the PV Shelf Study Area, implementing institutional controls, and monitoring natural recovery processes. This alternative is designed to limit the uptake of contaminants of concern by marine organisms and ultimately reduce the contaminant concentration in fish within the PV Shelf Study Area. The objectives of placing a cap at the PV Shelf Study Area are:

- Physical isolation of the effluent-affected sediment from the benthic environment to reduce exposure and uptake of contaminants by organisms
- Physical armoring of the bottom boundary layer (mudline) from erosion caused by waves and currents
- Chemical isolation of contaminants from the water column to reduce molecular diffusion of dissolved contaminants into the water column.

Alternative 4 would place a 45-cm cap over 2.74 k m^2 (approximately 680 acres) where the effluent-affected deposit is thickest and has the highest contaminant concentrations at depth.

The cost of Alternative 4 is estimated to be $76.7 million dollars over 10 years. Table ES-1 details the elements of this alternative.

Remedial Alternative Evaluation

The alternatives are evaluated in detail on the basis of the two threshold and five primary balancing criteria specified in the *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988a); these criteria are:

- Overall protectiveness of human health and the environment
- Compliance with ARARs
- Long-term effectiveness
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

In Section 6.0, alternatives are evaluated individually and comparatively against each criterion. Table 6-8 shows how each alternative fares against the selection criteria. A Proposed Plan describing EPA's preferred alternative will be developed and distributed for public comment. The final two criteria—state acceptance and community acceptance—will be evaluated following analysis of public comment on the proposed plan. After assessing public comment, EPA will prepare an interim Record of Decision (ROD) detailing the selected remedy.

Table ES-1: Description of Alternatives, Estimated Cost by Element
(Totals do not equal sums because of rounding, contingencies, project management costs)

Alternative 1: No Action Alternative				
Program	Cost	Element	Details	Timeframe
NA	NA	NA	NA	NA
No cost associated with this alternative				

Alternative 2: Institutional Controls and Monitored Natural Recovery Summary				
Program	Cost	Element	Details	Timeframe
Institutional Controls Program				
Community Outreach and Education	$880,000	General population	Work with CBOs, media, and community relations specialists to inform people about behaviors that reduce risk of eating contaminated fish. Partner with health fairs, community fairs and local health depts. to provide educational materials and training; includes feedback to gauge behavior change; materials in multiple languages	Ongoing
		High-risk population	Specific outreach materials and messages focused on fish preparation to reduce COCs, for ethnic groups who include fish, particularly white croaker, as important part of their diet, and women of child-bearing age	Ongoing
		Fish markets	Outreach to commercial fish market owners to inform them about dangers of buying fish from unlicensed dealers; coordinated with market enforcement element.	Ongoing
Angler outreach	$120,000	fishing piers and bait shops	Visit 8 fishing locations, 4-hr sessions at 4 times a week. Educate anglers about fish contamination, fish advisories, ID of contaminated fish species, and safer fish consumption practices. Keep bait shops supplied with educational materials.	Ongoing
	$58,000	pier-caught white croaker	Every year collect 10 white croaker from four fishing locations to analyze for DDTs and PCBs	Annual
Enforcement and Monitoring	$180,000	Commercial fish markets; white croaker analysis	Long Beach, LA and Orange counties Env. Health Dept. market inspections. Estimate 250 market visits per year to 55 different markets; Check documentation of white croaker found in markets, purchase fish and analyze for DDTs and PCBs	250 market visits per year to approx. 55 markets

Alternative 2: Institutional Controls and Monitored Natural Recovery Summary				
Program	Cost	Element	Details	Timeframe
		Wholesalers/ distributors	Local Env. Health Depts.—check wholesaler/ distributor documentation; Work with CDFG/local depts. to develop inspection plan for random sampling of white croaker for analysis	Ongoing, look for opportunities to expand program
	$128,000	Collect fish from catch ban area	Catch ban area monitoring: 5 areas, 10 white croaker and 10 kelp bass	Every 5 years
	$33,000	Commercial catch ban, sport bag limit	CDFG patrols and enforcement; patrol catch ban area	Monthly patrols
Monitored Natural Recovery Program				
Natural Recovery Monitoring	$100,600 + 30,000 for recovery plan	Fish in ocean monitoring	Sample fish from southeast and northwest of White Pt. outfalls Collect 30 fish each of two species: 1 benthic feeding & 1 pelagic, for example: • white croaker, barred sand bass or CA scorpionfish; and • Pacific sardine or California chub mackerel Analyze fish for DDTs & PCBs; analyze fillet and whole body	Year 1 and at Year 5 and 10 for the Five-Year Review
	$1,100,000	Sediment sampling	Use LACSD sampling grid stations 1 through 10, B thru D. take duplicates at C & B stations for total of 50 cores; analyze 4-cm intervals for grain size, TOC, DDT (6 isomers, DDMU, DDNU or DBP) and PCB congeners	Year 1 baseline, fewer stations for Year 5 and 10 Five-Year Reviews
	$274,000	Pore water and water column sampling	Use passive samplers at same 30 stations at 3 m above seabed, mid-column and 5 m below water surface. Deploy 3 samplers at each location. Analyze for DDT (6 isomers) and PCBs (congeners)	Year 1 baseline, fewer stations for Year 5 and 10 Five-Year Reviews

	Capital cost	Net Present value (7% discount rate, 10 year horizon)	Total	Grand Total
Total ICs	$ 1,900,000	$10,600,000	$12,500,000	
Total MNR	$ 1,750,000	$ 1,250,000	$ 3,000,000	
Alternative 2	$ 3,650,000	$11,850,000		$15,500,000

Alternative 3: Institutional Controls and Enhanced Monitored Natural Recovery Summary				
Program	Cost	Element	Details	Timeframe
Institutional Controls Program				
Community Outreach and Education	$880,000	General population	Work with CBOs, media, and community relations specialists to inform people about behaviors that reduce risk of eating contaminated fish. Partner with health fairs, community fairs and local health depts. to provide educational materials and training; includes feedback to gauge behavior change; materials in multiple languages	Ongoing
		High-risk population	Specific outreach materials and messages focused on fish preparation to reduce COCs, for ethnic groups who include fish, particularly white croaker, as important part of their diet, and women of child-bearing age	Ongoing
		Fish markets	Outreach to commercial fish market owners to inform them about dangers of buying fish from unlicensed dealers; coordinated with market enforcement element.	Ongoing
Angler outreach	$120,000	fishing piers and bait shops	Visit 8 fishing locations, 4-hr sessions at 4 times a week. Educate anglers about fish contamination, fish advisories, ID of contaminated fish species, and safer fish consumption practices. Keep bait shops supplied with educational materials.	Ongoing
	$58,000	pier-caught white croaker	Every year collect 10 white croaker from four fishing location to analyze for DDTs and PCBs	Annual
Enforcement and Monitoring	$180,000	Commercial fish markets; white croaker analysis	Long Beach, LA and Orange counties Env. Health Dept. market inspections. Estimate 250 market visits per year to 55 different markets; Check documentation of white croaker found in markets, purchase fish and analyze for DDTs and PCBs	250 market visits per year to approx. 55 markets
		Wholesalers/ distributors	Local Env. Health Depts.—check wholesaler/ distributor documentation; Work with CDFG/local depts. to develop inspection plan for random sampling of white croaker for analysis	Ongoing, look for opportunities to expand program
	$128,000	Collect fish from catch ban area	Catch ban area monitoring: 5 areas, 10 white croaker and 10 kelp bass	Every 5 years
	$33,000	Commercial catch ban, sport bag limit	CDFG patrols and enforcement; patrol catch ban area	Monthly patrols

Alternative 3: Institutional Controls and Enhanced Monitored Natural Recovery Summary				
Program	Cost	Element	Details	Timeframe
Natural Recovery Monitoring Program				
Natural Recovery Monitoring	$100,600 + 30,000 for recovery plan	Fish in ocean monitoring	Sample fish from southeast and northwest of White Pt. outfalls Collect 30 fish each of two species: 1 benthic feeding & 1 pelagic, for example: • white croaker, barred sand bass or CA scorpionfish; and • Pacific sardine or California chub mackerel Analyze fish for DDTs & PCBs analyze fillet and whole body	Year 1 & Year 5 and 10 for Five-Year Review
	$1,100,000	Sediment sampling	Use LACSD sampling grid stations 1 through 10, B thru D. take duplicates at C & B stations; analyze 4 cm intervals analyze for grain size, TOC, DDT (6 isomers, DDMU, DDNU or DBP) and PCB congeners	Year 1 baseline, fewer stations for Year 5 and 10 Five-Year Reviews
	$274,000	Pore water and water column sampling	Use passive samplers at same 30 stations at 3 m above seabed, mid-column and 5 m below water surface. Deploy 3 samplers at each location. Analyze for DDT (6 isomers) and PCBs (congeners)	Year 1 baseline, fewer stations for Five-Year Review
Enhancement (sand/silt cover) Program				
Sand/silt Amendment	$6,000,000	Treatability Studies	define area to cover; characterize sediment, pilot low-impact techniques	Year 1 & 2
	$25,050,000	Construction	placement of 45-cm cover over approx. 320 acres; requires 864,000 CY of coarse silt /fine to medium sand material	Year 4
	$1,900,000	Construction Monitoring	monitoring arrays to track resuspension plume and turbidity, sediment and water column sampling	
	$1,800,000	O&M Monitoring	sediment and water column sampling to assess cover thickness and movement and contaminant flux	At 1st Five-Year Review
	Capital cost	Net Present value (7% discount rate, 10 year horizon)	Total	Grand Total
Total ICs	$ 1,900,000	$10,600,000	$12,500,000	
Total MNR	$ 1,750,000	$ 1,250,000	$ 3,000,000	
Total cover	$32,950,000	$ 555,000 (Cap 5-Yr Review)	$33,500,000	
Alternative 3	$36,600,000	$12,405,000		$49,000,000

Alternative 4: Containment, Institutional Controls and Monitored Natural Recovery Summary				
Program	Cost	Element	Details	Timeframe
Institutional Controls Program				
Community Outreach and Education	$880,000	General population	Work with CBOs, media, and community relations specialists to inform people about behaviors that reduce risk of eating contaminated fish. Partner with health fairs, community fairs and local health depts. to provide educational materials and training; includes feedback to gauge behavior change; materials in multiple languages	Ongoing
		High-risk population	Specific outreach materials and messages focused on fish preparation to reduce COCs, for ethnic groups who include fish, particularly white croaker, as important part of their diet, and women of child-bearing age	Ongoing
		Fish markets	Outreach to commercial fish market owners to inform them about dangers of buying fish from unlicensed dealers; coordinated with market enforcement element.	Ongoing
Angler outreach	$120,000	fishing piers and bait shops	Visit 8 fishing locations, 4-hr sessions at 4 times a week. Educate anglers about fish contamination, fish advisories, ID of contaminated fish species, and safer fish consumption practices. Keep bait shops supplied with educational materials.	Ongoing
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Enforcement and Monitoring	$180,000	Commercial fish markets; white croaker analysis	Long Beach, LA and Orange counties Env. Health Dept. market inspections. Estimate 250 market visits per year to 55 different markets; Check documentation of white croaker found in markets, purchase fish and analyze for DDTs and PCBs	250 market visits per year to approx. 55 markets
		Wholesalers/ distributors	Local Env. Health Depts.—check wholesaler/ distributor documentation; Work with CDFG/local depts. to develop inspection plan for random sampling of white croaker for analysis	Ongoing, look for opportunities to expand program
	$128,000	Collect fish from catch ban area	Catch ban area monitoring: 5 areas, 10 white croaker and 10 kelp bass	Every 5 years
	$33,000	Commercial catch ban, sport	CDFG patrols and enforcement; patrol catch ban area	Monthly patrols

Alternative 4: Containment, Institutional Controls and Monitored Natural Recovery Summary				
Program	Cost	Element	Details	Timeframe
		bag limit		
Monitored Natural Recovery Program				
Natural Recovery Monitoring	$100,600 + 30,000 for recovery plan	Fish in ocean monitoring	Sample fish from southeast and northwest of White Pt. outfalls Collect 30 fish each of two species: 1 benthic feeding & 1 pelagic, for example: • white croaker, barred sand bass or CA scorpionfish; and • Pacific sardine or California chub mackerel Analyze fish for DDTs & PCBs; analyze fillet and whole body	Year 1 & Year 5 and 10 for Five-Year Review
	$1,100,000	Sediment sampling	Use LACSD sampling grid stations 1 through 10, B thru D. take duplicates at C & B stations; analyze 4 cm intervals analyze for grain size, TOC, DDT (6 isomers, DDMU, DDNU or DBP) and PCB congeners	Year 1 baseline, fewer stations for Year 5 and 10 Five-Year Reviews
	$274,000	Pore water and water column sampling	Use passive samplers at same 30 stations at 3 m above seabed, mid-column and 5 m below water surface. Deploy 3 samplers at each location. Analyze for DDT (6 isomers) and PCBs (congeners)	Year 1 baseline, fewer stations for Year 5 and 10 Five-Year Reviews
Capping Program				
Sand/Sediment capping	$6,000,000	Treatability Studies	define area to cover; characterize sediment, pilot low-impact techniques	Year 1 & 2
	$51,100,000	Construction	placement of 45-cm cover over approx. 680 acres; requires 1,776,000 CY of sand/sediment material; assume 1/3 of placement using low-impact technique, 2/3 use spreading technique	Year 4 - 5
	$3,300,000	Construction Monitoring	monitoring arrays to track resuspension plume and turbidity, sediment and water column sampling	during construction
	$2,500,000	O&M Monitoring	sediment and water column sampling to assess cover thickness, movement and contaminant flux	At 1st Five-Year Review

	Capital cost	Net Present value (7% discount rate, 10 year horizon)	Total	Grand Total
Total ICs	$ 1,900,000	$10,600,000	$12,500,000	
Total MNR	$ 1,750,000	$ 1,250,000	$ 3,000,000	
Total capping	$60,450,000	$ 750,000 (Cap 5-Yr Review)	$61,200,000	
Alternative 4	$64,100,000	$12,600,000		$76,700,000

1.0 Introduction

The first draft of the Palos Verdes Shelf (PV Shelf) Feasibility Study (FS) was prepared by CH2M HILL for the United States Environmental Protection Agency (EPA) under Work Assignment No. 282-RICO-09CA (EPA Contract No. 68-W-98-225). Subsequent drafts were prepared by EPA.

The PV Shelf is located off the coast of the Palos Verdes Peninsula near Los Angeles, California. Marine sediment on the PV Shelf have been contaminated with the pesticide dichlorodiphenyltrichloroethane (DDT) and its metabolites (hereafter referred to collectively as DDTs), lubricants, called polychlorinated biphenyls (PCBs), metals, and other contaminants. These contaminants entered the Los Angeles County sewer system as industrial waste and, after treatment at Los Angeles County Sanitation Districts (LACSD) Joint Water Pollution Control Plant (JWPCP), were discharged in the effluent onto PV Shelf through submarine outfalls at White Point (see Figure 1-1).

1.1 Purpose and Organization of the Report

This FS describes the development, evaluation, and comparison of remedial action alternatives to manage the contaminated sediments at the PV Shelf. It has been prepared in accordance with the EPA documents *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988a) and *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA, 2005). The appendices include the detailed analyses of the technologies considered in development of the alternatives (i.e., dredging, capping, and natural recovery), as well as the institutional controls program currently in place to control risk and the food web models used in assessing risk.

This FS is organized as follows:

- **Section 1.0 – Introduction:** Describes the purpose and report organization and summarizes the remedial investigation report.
- **Section 2.0 – Risk Assessments and Predictive Modeling of Future Conditions:** Summarizes human health and ecological risk assessments prepared for the site and predictive models of future condition of the site, and their use in quantifying future risk.
- **Section 3.0 – Remedial Action Objectives and Development of Remediation Goals:** Presents the development of remedial action objectives (RAOs), and lists the applicable or relevant and appropriate requirements (ARARs) and remediation goals (RGs) for the alternatives under consideration in the FS.
- **Section 4.0 – Identification of General Response Actions and Screening of Remedial Technologies:** Identifies general response actions and remedial technologies and screens them as they pertain to site conditions and contaminated media.
- **Section 5.0 – Development and Screening of Alternatives:** Develops and describes the remedial action alternatives and conducts preliminary screening.

- **Section 6.0 – Detailed Analysis of Remedial Alternatives:** Provides a detailed analysis of the remedial alternatives using EPA criteria.
- **Section 7.0 – References:** Lists the references used in preparing the FS.

1.2 Background Information

This section summarizes the site description, site history, nature and extent of contamination, fate and transport, and baseline risk assessments associated with the PV Shelf.

1.2.1 Site Description

The PV Shelf is a narrow part of the continental shelf off the Palos Verdes Peninsula along the coast of Southern California. North of PV Shelf is Santa Monica Bay and south, San Pedro Basin. About 42 kilometers from PV Shelf is Catalina Island, the Channel Island nearest to PV Shelf. The PV Shelf is about 1.5 to 4 kilometers (km) wide, up to 25 km long, and has a slope of 1 to 4 degrees. A shelf break (i.e., a zone of transition from the relatively flat shelf to the steeper continental slope) occurs at water depths of 70 to 100 meters (m). The continental slope extends seaward from the shelf, with a width of approximately 3 km and an average slope of 13 degrees, to a depth of approximately 800 m (Lee, 1994). For the purposes of the remedial investigation (RI) and FS, the PV Shelf Study Area is defined as the area of the shelf and slope between Point Fermin and Redondo Canyon from the shore to the 200-m isobath, as shown in Figure 1-1. The net ocean patterns surrounding PV Shelf are shown in Figure 1-2.

In general, the PV Shelf region is characterized by (1) hard-bottom (rocky) habitat, including some kelp bed areas and associated invertebrate, fish, and algae communities, from shore to at least 20 m of water depth; (2) soft-bottom habitat, including invertebrate and fish communities, over most of the rest of the shelf and slope to a water depth of at least 600 m; and (3) pelagic or water column zones, representing important habitat for fish, invertebrates, birds, and mammals from near the sea floor to the water surface. The exception to this pattern is the hard-substrate, artificial reef habitat represented by the White Point outfall pipes that extend primarily over soft-bottom areas to a water depth of approximately 63 m, some hard-bottom areas scattered along the shelf, and more extensive hard-bottom areas paralleling the shelf break.

The thickness of naturally occurring shelf sediment varies, ranging from 32 m on the southeastern part of the shelf to less than 10 m near Point Vicente. A patchy, thin sediment layer with areas of bare rock occurs at the shelf break. Similar bedrock outcrops also occur over the seafloor to the east of the outfall and over the Redondo Shelf to the west (Lee, 1994). Less than one meter of sediment covers the Redondo Shelf (Drake et al., 1994).

The Palos Verdes Peninsula lies within the Palos Verdes Fault Zone. This fault zone is one of many fault zones in the Los Angeles Basin and adjoining offshore areas in the California continental boundary. The Palos Verdes Fault is a major fault that crosses the peninsula, approximately parallel to the coastline. U.S. Geological Survey research estimates total fault-slip rate near the Palos Verdes Peninsula to be around 3 mm/year (USGS, 2004). No large earthquakes have occurred in the recent past along the Palos Verdes Fault Zone, which strikes generally southeast across the San Pedro Shelf and nearshore areas. However, it is estimated that this fault could produce an earthquake as large as M 7 (USGS, 2004).

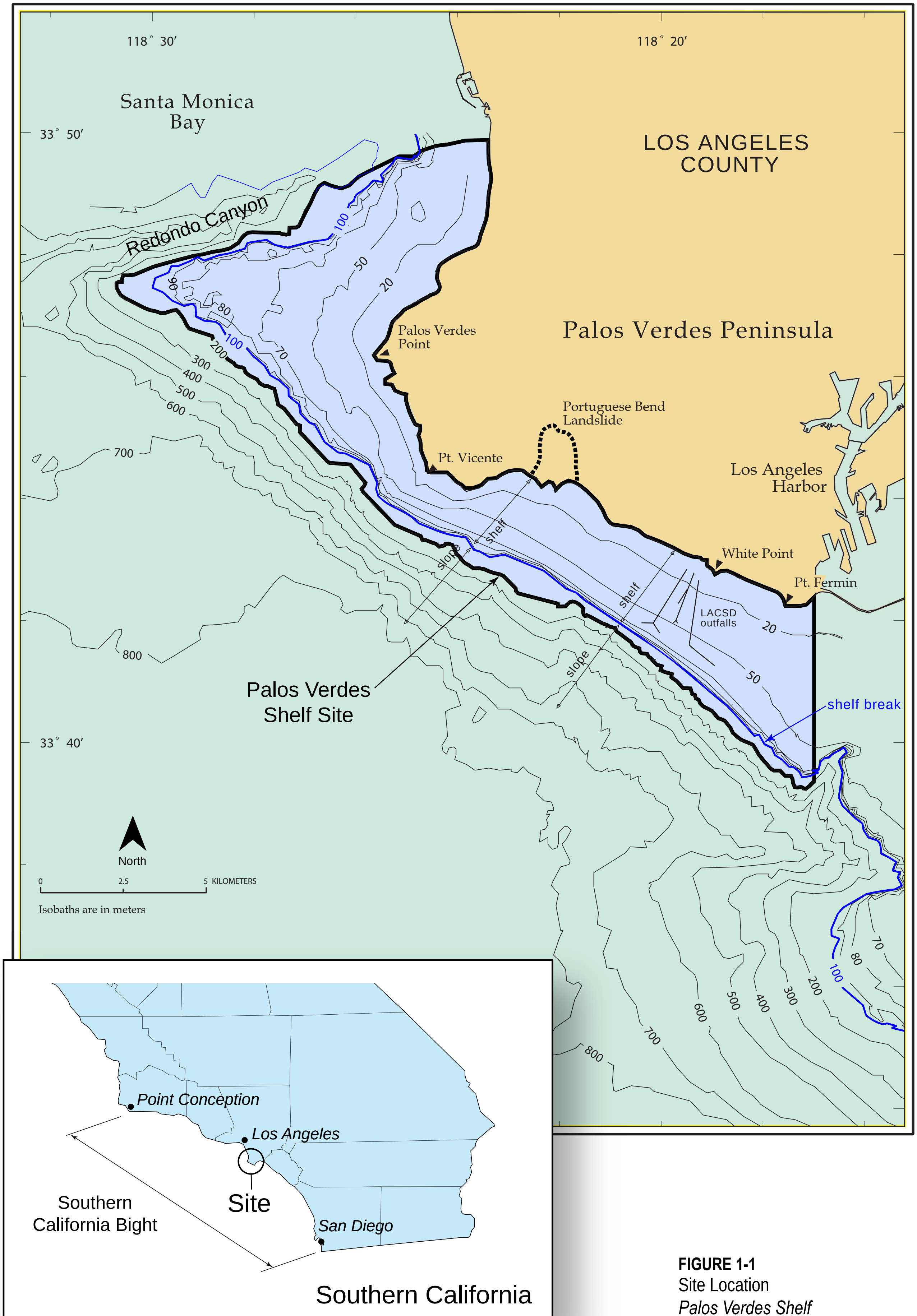

FIGURE 1-1
Site Location
Palos Verdes Shelf
Remedial Investigation Report

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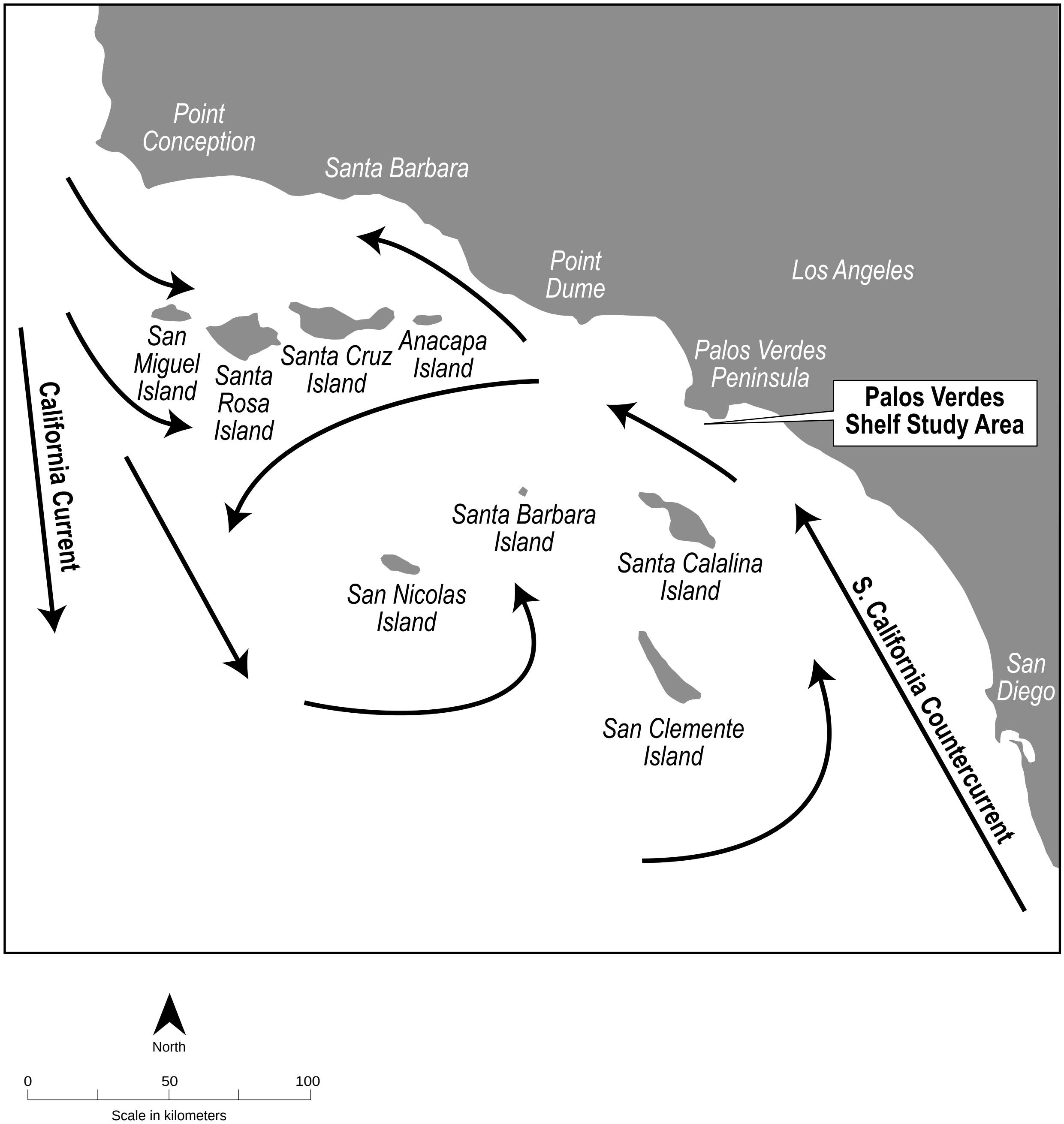

FIGURE 1-2
Net Water Movement
in the Southern California Bight
Palos Verdes Shelf Study Area
Feasibility Study

Source: After Hickey, B.M., 1992, Progress in Oceanography, V30: 37-115.

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1.2.2 Site History

1.2.2.1 Montrose Chemical Superfund Site

From 1947 until 1982, Montrose Chemical Corp. (Montrose) operated a DDT-manufacturing plant on 13 acres at 20201 Normandie Avenue in Los Angeles County, California. Stauffer Chemical Company was the landowner. The Montrose plant operated 24 hours a day, 7 days a week, 365 days a year, except for occasional plant shutdowns. During its 35 years of operation, Montrose produced approximately 800,000 tons of DDT.

When the plant first opened, it discharged DDT-contaminated wastewater from its production operations to a city sewer line via a private pressure sewer line owned by Stauffer Chemical. This connecting line periodically clogged, resulting in the discharge of Montrose DDT-contaminated wastewater to the natural stormwater drainage. When EPA investigated the natural stormwater drain in the 1990s, residual levels of DDT in the drainage immediately downstream of the Montrose plant property were in excess of 8,000 parts per million (ppm). The Normandie Avenue plant property itself was contaminated by Montrose operations. Investigations directed by EPA beginning in 1985 found significant contamination (primarily DDT and chlorobenzene) in the shallow and deep soil at the Montrose plant property, groundwater beneath and downgradient from the Montrose plant property, soil adjacent to and in the vicinity of the property, the sewer line adjacent to and downstream of the Montrose plant property, and, as mentioned above, portions of the stormwater pathway leading from the Montrose plant to the Consolidated Slip in Los Angeles Harbor. Groundwater at the Montrose site is contaminated with monochlorobenzene and other contaminants across six hydrostratigraphic units and to distances up to 1.3 miles from the former Montrose plant site. Dense nonaqueous phase liquid (DNAPL) is present under the former plant property to great depth and is serving as a continuous source of groundwater contamination.

The Montrose Chemical Superfund Site was included on the National Priorities List (NPL) of federal sites (i.e., Superfund) on October 4, 1989. There are six operable units at the Montrose Chemical Superfund Site: operable unit (OU) 1 soils, OU-2 stormwater pathway, OU-3 ground water, OU-4 residential area, OU-5 Palos Verdes Shelf, and OU-6, historical stormwater pathway. These OUs cover contamination found in soil, groundwater, the residential area near the former Montrose plant, marine sediment, and stormwater pathways.

1.2.2.2 Sewer Lines to Palos Verdes Shelf

The Joint Water Pollution Control Plant (JWPCP) operated by the Sanitation Districts of Los Angeles County (LACSD) has discharged treated waste onto PV Shelf since 1937. The first submarine outfall discharged offshore of White Point at a depth of 34 m. As Los Angeles grew, so did demand on the JWPCP. New outfalls were added every ten years. Treated effluent was discharged at White Point:

- From 1937 to 1958 – through a 60-inch-diameter, three-outlet diffuser at a depth of 34 m
- From 1947 to 1966 – through a 72-inch-diameter diffuser at a depth of 49 m
- Since 1957 – through a 90-inch-diameter, Y-shaped diffuser at a depth of 64 m
- Since 1967 – through a 120-inch-diameter, L-shaped diffuser at a depth of 58 m

Currently, the 120-inch- and 90-inch-diameter outfalls are the primary outfalls, discharging treated effluent through diffusers approximately 1.5 miles offshore. The older, 60-inch-diameter and 72-inch-diameter outfalls are not in use, but could be used for backup or emergency operations. The four outfalls are shown in Figure 1-3.

From 1953 until 1971, Montrose discharged DDT-contaminated wastewater from its operations at the Montrose plant to two sewers operated by LACSD. These sewers conveyed the wastewater to the JWPCP, where it received primary treatment and was discharged through the White Point outfalls located on the PV Shelf.

In the early 1970s, LACSD initiated an investigation to identify and eliminate discharge of DDTs and PCBs into their sewer system. LACSD identified the Montrose plant as the only significant source of DDT in sewer flows to the JWPCP. PCBs entered the LACSD sewer system from several industrial sources in the Los Angeles area, most notably from the Westinghouse Electric Corporation, which manufactured and repaired electrical equipment at its Los Angles County plant; from a paper-manufacturing plant in Pomona owned by Potlatch Corporation; and from Simpson Paper Company. Like DDT from the Montrose plant, PCBs from these plants were sent to the JWPCP and, after treatment, were discharged from the White Point outfalls onto the PV Shelf.

LACSD estimated that the discharge from the Montrose plant was contributing 654 pounds (lbs) of DDT per day to the LACSD system. In 1971, Montrose ceased discharging waste into the county sewer system. LACSD conducted cleaning operations in the two sewer lines adjacent to and downstream of the Montrose property. Sediments in the two sewer lines contained in excess of 7,700 lbs of DDT, according to LACSD estimates.

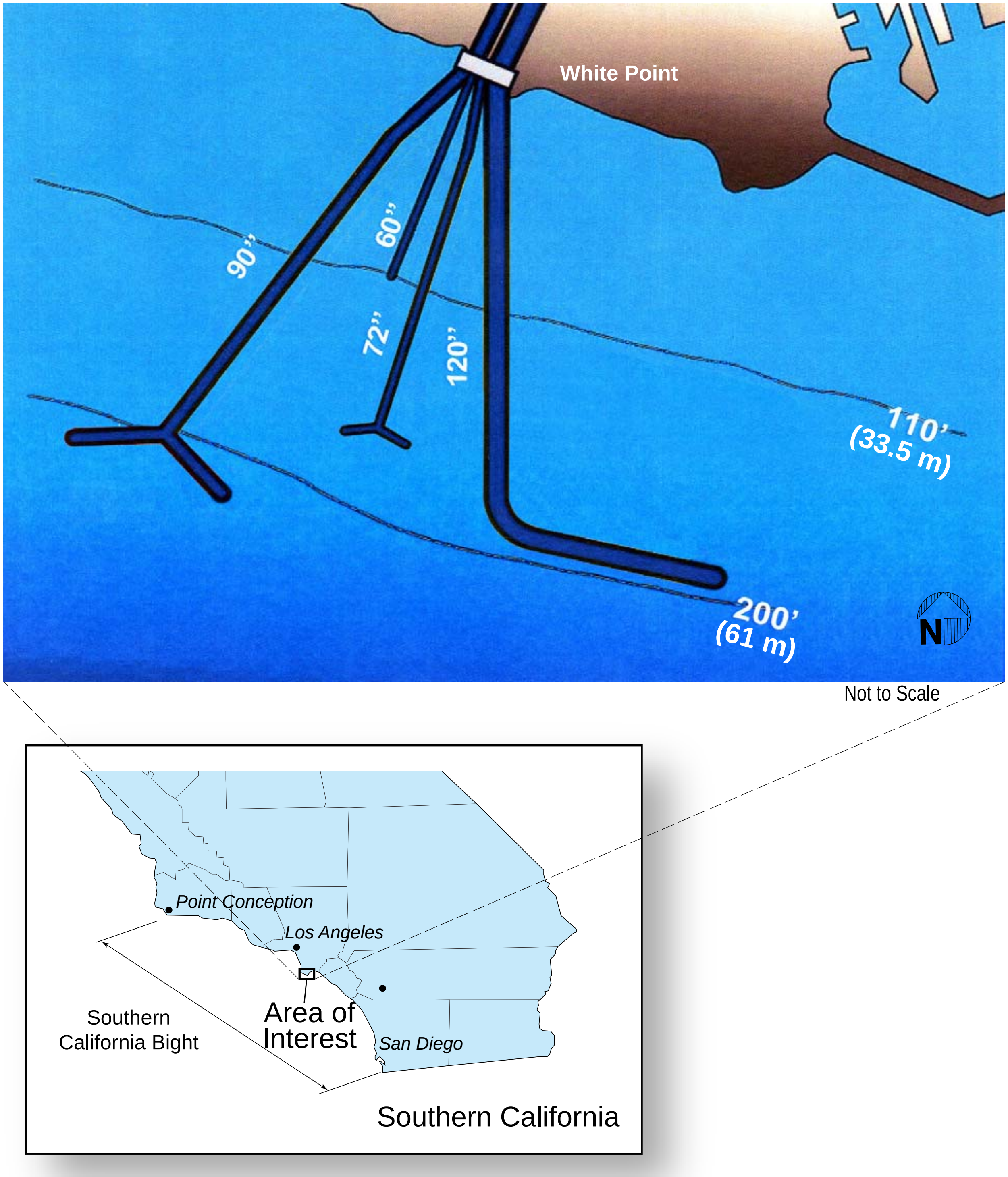
Despite these efforts by LACSD, significant quantities of DDT-contaminated sediment remained in the sewer line. After the plant closure in 1983, under EPA order, Montrose removed approximately 162,000 lbs of sediment from the sewer line downstream from the plant. Sewer sediment samples from this removal operation showed levels of DDT in the sediment at 490,000 milligram per kilogram (mg/kg) and chlorobenzene at 2,200 mg/kg.

1.2.3 Summary of Remedial Investigation Report

1.2.3.1 Discharges of DDTs and PCBs

The primary historical source of chemical contaminants on the PV Shelf is effluent discharged through the White Point outfalls. Contaminants in the effluent included chlorinated hydrocarbons (e.g., DDTs and PCBs) as well as trace metals (e.g., cadmium, copper, lead, zinc, and other metals), and organic matter. The primary source of DDTs was wastewater from Montrose, which was the nation's largest DDT manufacturer. Sources of PCBs included various industries in the greater Los Angeles area. The peak annual mass emissions of effluent solids (167,000 metric tons), DDT (21.1 metric tons), and PCBs (5.2 metric tons) occurred in 1971 (USEPA, 2000a). The total discharge of suspended solids from 1937 to 1995 has been estimated at about 4.1 million metric tons (Lee et al., 2002). An estimated 800 to 1,200 metric tons of DDT were discharged from the outfalls from the 1950s through 1971 (USDOJ, 2000).

Contaminant emissions decreased after 1971 due to the disconnection of Montrose from the sewer system and improved treatment of the effluent prior to discharge. Since then, continuous improvements in treatment have reduced the load of suspended solids and contaminants, culminating in November 2002, when all of the wastewater discharged from the JWPCP started receiving full secondary treatment. Discharge of suspended solids is now less than 8,000 metric tons a year (mt/yr). The effluent concentrations of DDT have been near or below the detection limit since 1989 and have not been detected since 2002. PCBs have not been detected above the



Note: The 120-inch- and 90-inch-diameter outfall are the primary outfalls.
Please refer to Section 1.2.3.1 for more information on the outfalls.

Source: Annual Report 2004 - Palos Verdes Ocean Monitoring, LACSD, 2005.

FIGURE 1-3
LACSD Outfalls Schematic
Palos Verdes Shelf Study Area
Feasibility Study

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detection limit since 1985 (LACSD, 2006). The reporting limits are currently 0.01 microgram per liter (µg/L) for the various isomers of DDT, and between 0.05 µg/L and 0.5 µg/L for the PCB Arochlors (LACSD, 2007).

1.2.3.2 Nature and Extent of Contamination

Sediment from the outfalls combined with material from other sources (most notably, erosion from the Portuguese Bend Landslide) formed an effluent-affected (EA) deposit on the PV Shelf and slope. Studies in 1992 for the Natural Resource Damage Assessment (NRDA)(Lee et al., 1994) indicated that a 5-centimeter (cm) to 60-cm-thick elliptical-shaped, EA deposit extended over most of the shelf and slope from Point Fermin to Point Vicente. The EA deposit had an estimated total volume of over 9 million cubic meters (m^3) and covered more than 40 square kilometers (km^2). Of that total, 70 percent occurred on the shelf and 30 percent on the slope (Lee, 1994). The 1992 studies and biennial sediment monitoring conducted by LACSD showed that almost the entire deposit was contaminated with DDTs and PCBs. The accumulated mass of DDTs and PCBs remaining in sediment at the PV Shelf have been estimated at 100 metric tons and 10 metric tons, respectively (EPA, 2001).

The shore side of the EA deposit ends relatively sharply at the 30-m depth contour, while the ocean side extends over the PV Shelf break to the Mid- to Lower Slope (LACSD, 2005). Cross-shore, the thickest part of the EA deposit extends along the 60-m isobath. Along-shore, the deposit is thickest (60+ cm) near the 90-inch outfall. It thins rapidly toward the southeast, just exceeding 15 cm a kilometer (km) from the outfall. It tapers much more gradually toward the northwest. About 12 km northwest from the outfalls, the EAdeposit is still 25 cm thick. This elliptical shape of the deposit is consistent with bi-directional dispersion from the outfall that has been skewed upcoast in the direction of the long-term average current. On the northwest end, the increased thickness of the EA deposit and lower contaminant concentrations also suggest admixture of Portuguese Bend Landslide sediment.

Contaminant concentrations are lowest in the surface sediment (top 5-20 cm of the deposit) and much higher in the older and more deeply buried layers of the deposit. Despite reductions in the discharge of suspended solids, a large mass of effluent-affected sediment remains on the PV Shelf and slope (LACSD, 2005). The sediments can be categorized into three layers:

- **Native Sediments** –Native sediment pre-dates the outfall construction. The native sediment is coarser, has less organic material, and is less cohesive. It was supplied by local rivers and by erosion of the coastline, including the Portuguese Bend Landslide. Generally, the EA deposit lies on top of the native sediment; however, in waters less than 40 m deep, where bottom wave activity is higher, sediments are generally sandy, and there is no obvious layer of EA sediment on top of pre-effluent sediment. Some EA material may be worked into surface sediment at these inshore regions; however, wave activity kept EA sediment from accumulating. Native sediment is characterized by higher bulk densities and lower organic carbon content (Eganhouse and Pontolillo, 2000).
- **Heavily Contaminated Sediment** – Above the native sediment exists a heavily contaminated layer approximately 20 to 25 cm thick. These sediments have the highest levels of contamination and slightly higher water content, consistent with more rapid deposition when large amounts of highly contaminated sediment were discharged from the outfalls. They are characterized by clay and silts, significantly elevated organic carbon content, and low bulk densities. These sediments were deposited when discharges from the

outfalls contained high levels of suspended solids, DDTs, and PCBs (Eganhouse and Pontolillo, 2000).

- **Surficial Sediments** – These sediments in the upper 15 to 20 cm are characterized by lower concentrations of DDTs and PCBs, they are more uniform, and have higher bulk densities, and slightly elevated organic carbon concentrations. The properties of the surface layer are consistent with lower deposition rates of less contaminated material and physical reworking by waves, currents and benthic invertebrates. This is the most biologically active layer of sediment (Eganhouse and Pontolillo, 2000).

1.2.3.3 Historical Distribution of Mass of DDTs and PCBs: 1992 Data

Areal Extent of Contaminants

Under its National Pollutant Discharge Elimination System (NPDES) permit, LACSD is required to monitor the health of the PV Shelf. As part of its monitoring program, LACSD collects surficial sediment samples from 44 sampling stations and analyzes them for a number of parameters, including DDTs and PCBs (Figure 1-4). LACSD's sampling grid consists of 11 transects from Redondo Canyon to Point Fermin, with sampling locations at 4 depths:

- 30 m (D Stations)
- 61 m (C stations)
- 152 m (B stations)
- 305 m (A stations)

LACSD samples collected in 1992 had surface concentrations of DDTs ranging from 0.2 milligram per kilogram (mg/kg) at Station 0D to 27.7 mg/kg at Station 8B, with the highest concentrations of DDTs found near the Y-outfall (Stations 8B and 8C). Concentrations of DDTs exceeding 10 mg/kg covered approximately 8 km^2, extending north from the 9 transect to the 4 transect, encompassing the 60-m isobath and extending to the 200-m isobath (Figure 1-5). Concentrations of DDTs exceeding 1 mg/kg covered approximately 44.5 km^2, extending from the 10 transect to north of the 1 transect, encompassing the 60-m isobath and extending to the 200-m isobath.

Please note that in addition to the 1992 LACSD data, Figure 1-5 uses four samples collected during the 1994 Southern California Bight Pilot Project (Bight '94), one 1993 LACSD sample, and two 1992 National Oceanic and Atmospheric Administration (NOAA) samples to provide actual concentrations of DDTs between the 0 and 1 transects and north of the 0 transect. Shoreline concentrations have been set at 0.05 mg/kg for contouring.

For PCBs, the highest concentrations were found at Stations 6B and 5B, northwest of the outfall, followed by Stations 8B and 8C near the Y-outfall. Concentrations of PCBs exceeding 1 mg/kg covered approximately 8.4 km^2, extending from midway between the 8 and 9 transects east to the 4 transect, and from approximately the 40-m isobath to the 200-m isobath (Figure 1-6). Concentrations of PCBs exceeding 0.3 mg/kg covered approximately 22.5 km^2, extending from the 10 transect to north of the 1 transect, and from approximately the 40-m isobath to the 200-m isobath. Please note that in addition to the 1992 LACSD data, Figure 1-6 uses two simulated transects inserted between the 0 and 1 transects to approximate sediment concentrations where no data exist. The simulated transects were set as an average of the 0 and 1 transect concentrations. Shoreline concentrations have been set at 0.05 mg/kg for contouring.

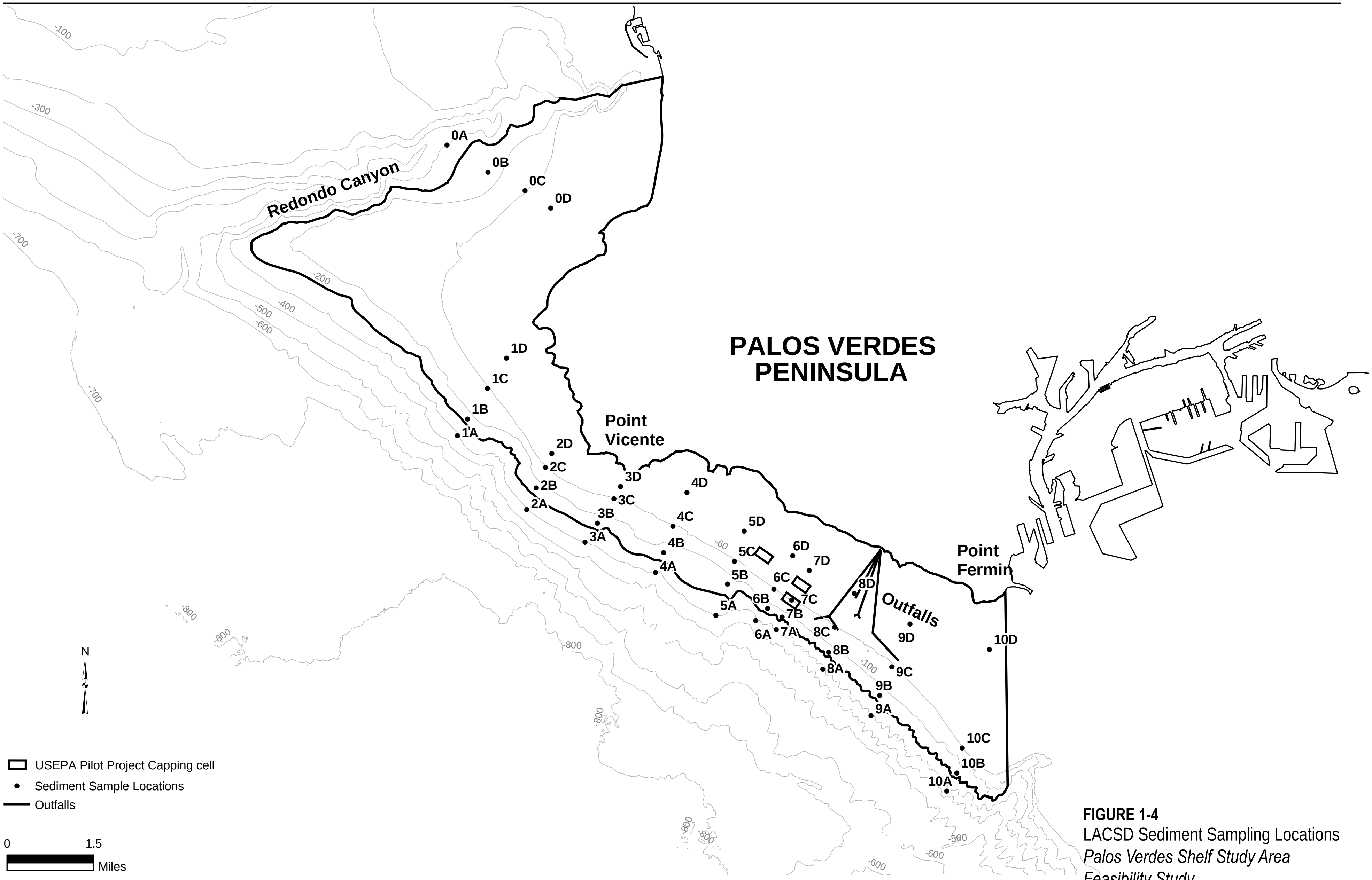

FIGURE 1-4
LACSD Sediment Sampling Locations
Palos Verdes Shelf Study Area
Feasibility Study

Source: Los Angeles County Sanitation District, 2006. *Annual Report, 2005 Palos Verdes Ocean Monitoring, July.*

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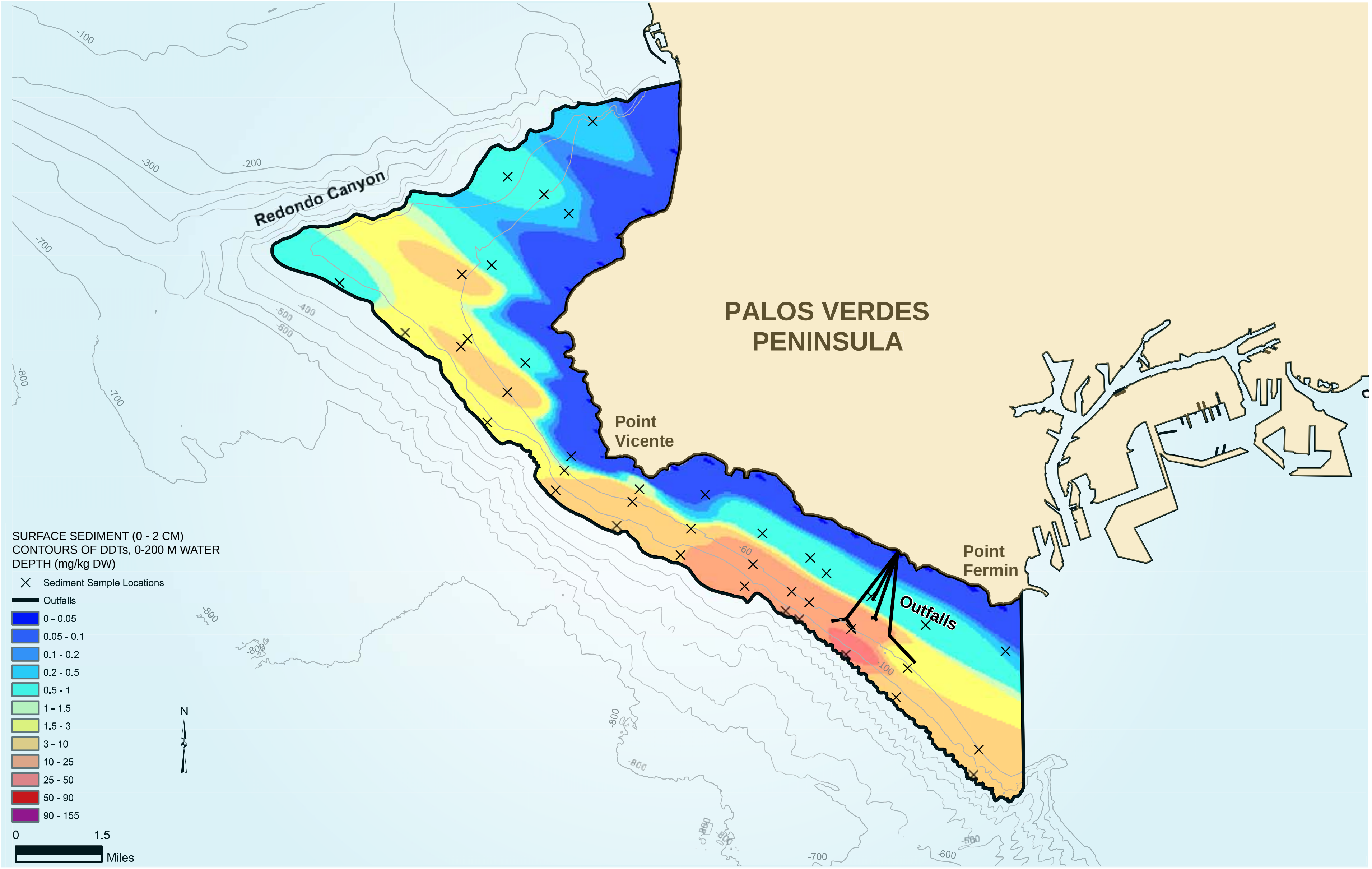

FIGURE 1-5
Surface Sediment Contours of DDTs - 1992
Palos Verdes Shelf Study Area
Feasibility Study

Note: In addition to the 1992 LACSD data, this figure uses four Bight '94 samples, one 1993 LACSD sample, and two 1992 NOAA samples to provide actual concentrations of DDTs between the 0 and 1 transects and north of the 0 transect. Shoreline concentrations have been set at 0.05 mg/kg for contouring.

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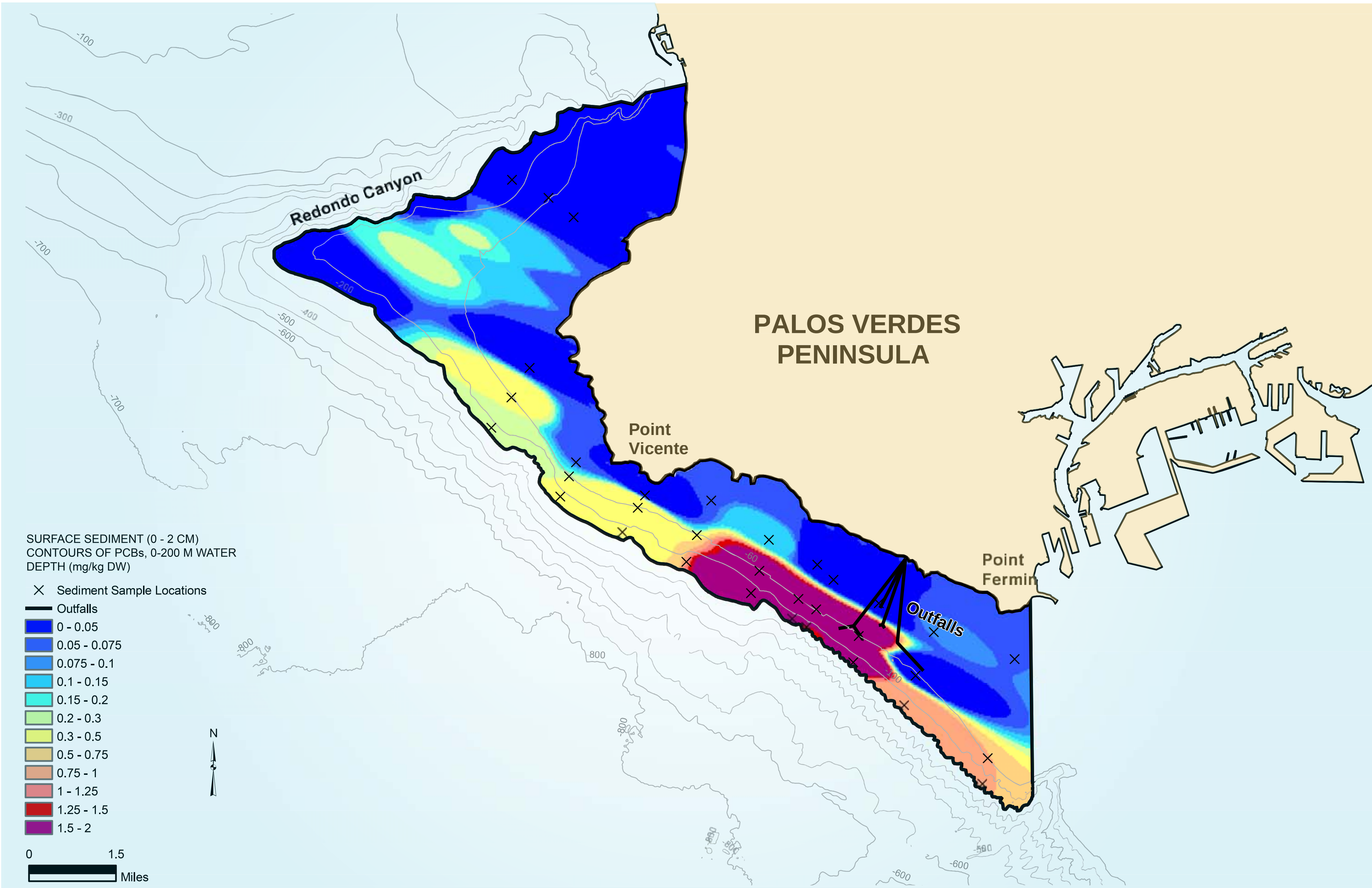

FIGURE 1-6
Surface Sediment Contours of PCBs - 1992
Palos Verdes Shelf Study Area
Feasibility Study

Note: In addition to the 1992 LACSD data, two simulated transects were inserted between the 0 and 1 transects to approximate sediment concentrations where no data exist. The simulated transects were set as an average of the 0 and 1 transect concentrations. Shoreline concentrations have been set at 0.05 mg/kg for contouring.

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As stated above, The Natural Resource Trustees performed a comprehensive evaluation of the mass and distribution of contaminants within the PV Shelf Study Area in 1992 (Lee et al. 1994). As part of these studies, the United States Geological Survey (USGS) collected sediment cores at 23 stations and analyzed them for DDTs (Figure 1-7). The average and maximum concentrations of DDTs southeast of the outfalls were highest in the shallow or surface sediment interval (0 to 15 cm). Northwest of the outfalls, the highest concentrations of DDTs occurred in the 16- to 30-cm or 31- to 45-cm intervals. The highest concentrations of DDTs were located in water depths of 50 to 60 m; the maximum concentration of DDTs (305 mg/kg) was detected at Station 564 at a water depth of 56 m in the 16- to 30-m sediment depth interval.

1.2.4 Present Distribution of Mass of DDTs and PCBs: 2001 through 2005 Data

As mentioned above, LACSD takes surface sediment samples at 44 stations across the Shelf and slope as part of its NPDES monitoring program. The current distribution of DDTs and PCBs in the top 2 cm of sediment was developed using LACSD surface samples collected in 2002 and 2004. In addition, sediment cores collected by LACSD at sample stations located along the 61-m isobath in 2001, 2003, and 2005 provide a view of the current sediment-contamination profile at depth in the PV Shelf Study Area. The comparison of these new data sets to older data (primarily the 1992 USGS cores and LACSD data) is presented as evidence of long-term changes in the distribution and magnitude of sediment concentrations of DDTs and PCBs.

1.2.4.1 Areal Extent of Contaminants

Averaging the LACSD samples collected in 2002 and 2004, surface (0 to 2 cm) concentrations of DDTs range from 0.159 mg/kg at Station 2D to 140.5 mg/kg at Station 8C, with the highest concentrations of DDTs found near the Y-outfall (Stations 8B and 8C). Concentrations of DDTs exceeding 10 mg/kg covered approximately 3.6 km^2, primarily along the 61-m isobath and the slope, from the outfalls to the 4 transect (Figure 1-8). Concentrations of DDTs exceeding 1 mg/kg covered approximately 39.1 km^2, extending from the 9 transect to north of the 1 transect, encompassing the 61-m isobath and extending down the slope. In addition to the 2002/2004 LACSD data, Figure 1-8 uses four Bight' 94 samples, one 1993 LACSD sample, and two 1992 NOAA samples to provide actual concentrations of DDTs between the 0 and 1 transects and north of the 0 transect. Shoreline concentrations have been set at 0.05 mg/kg for contouring.

Concentrations of PCBs range from not detected at several stations to 3.19 mg/kg at station 7B, on the slope. The highest concentrations of PCBs were located at station 7B, 8B, and 8C near the Y-outfall. Concentrations of PCBs exceeding 1 mg/kg covered approximately 6.2 km^2, extending from the 8 transect to the 4 transect, primarily on the slope (Figure 1-9).

Concentrations of PCBs exceeding 0.3 mg/kg covered approximately 13.7 km^2, extending from the 9 transect to the 3 transect, encompassing the 61-m isobath and extending to the 200-m isobath. Please note that in addition to the 2002/2004 LACSD data, Figure 1-9 uses two simulated transects inserted between the 0 and 1 transects to approximate sediment concentrations where no data exist. The simulated transects were set as an average of the 0 and 1 transect concentrations. Shoreline concentrations have been set at 0.05 mg/kg for contouring.

Table 1-1 provides a comparison of the area of surface contamination for DDTs and PCBs in 1992 and 2002/2004.

TABLE 1-1: SURFACE CONTAMINATION AREA OF DDTS AND PCBS

	DDTs		PCBs	
	Area > 1 mg/kg	Area > 10 mg/kg	Area > 0.3 mg/kg	Area > 1 mg/kg
1992 Surface Sediment Data	44.5 km^2	8.2 km^2	22.5 km^2	8.4 km^2
2002/2004 Surface Sediment Data	39.1 km^2	3.6 km^2	13.7 km^2	6.2 km^2
Percent Reduction 1992 to 2002/2004	12%	56%	49%	26%

1.2.4.2 Depth of Contaminants

Sediment core data collected by LACSD in 2001 are summarized in Figure 1-10. Average and maximum concentrations of the dominant DDT isomer, p,p'-DDE (or DDE) are shown for 15-cm depth intervals (0 to 15 cm, 16 to 30 cm, 31 to 45 cm and deeper until concentrations of DDE remain below 1 ppm, assumed to indicate pre-effluent sediment) at selected LACSD sampling stations, most of which are located along the 61-m isobath (C stations). In general, as shown in Figure 1-10, the average and maximum DDE concentrations southeast of the outfalls were highest in the shallow or surface sediment interval (0 to 15 cm). Northwest of the outfalls, the highest concentrations occurred in the 16- to 30-cm or 31- to 45-cm intervals. The maximum DDE concentration detected was 238 mg/kg, found at Station 8C in the 16- to 30-cm depth interval.

No recent survey for PCBs at depth has been performed. However, Figure 1-11 shows sediment core data collected by USGS in 1992 at 17 sampling stations located in water depths from 26 to 167 m. Average and maximum concentrations of PCBs are shown for 15-cm depth intervals. In general, the average and maximum concentrations of PCBs southeast of the outfalls were highest in the shallow or surface sediment interval (0 to 15 cm). Northwest of the outfalls, the highest concentrations of PCBs occurred in the 16- to 30-cm or the 31- to 45-cm intervals. The highest average concentrations of PCBs were at stations located between or immediately northwest of the outfalls, with the average interval concentrations ranging from 1.3 to 18 mg/kg. The highest concentrations of PCBs were located in water depths between 50 and 60 m; the maximum concentration of PCBs (20.6 mg/kg) was found along the 56-m isobath at Station 564 in the 31- to 45-cm sediment depth interval.

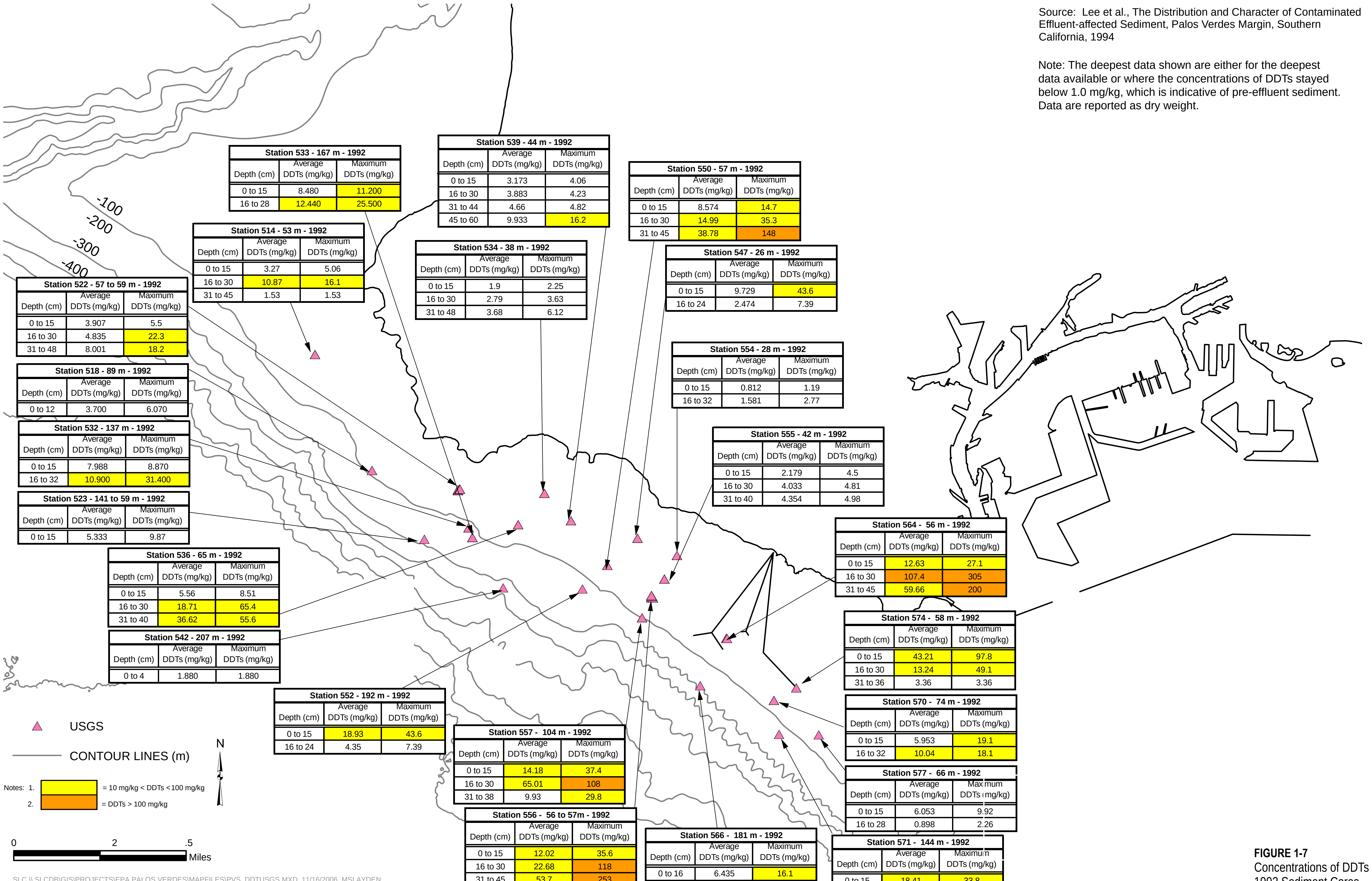
1.2.5 Sediment Transport and Fate

1.2.5.1 Oceanographic Processes

Sediment transport on the PV Shelf is believed to follow the predominant direction of the near-bottom flow, extending northwestward along the shelf (Drake et al. 1994). The Portuguese Bend landslide and the White Point outfalls effluent have dominated the recent supply of solids to the PV Shelf. Since 1988, the rate of erosion from the Portuguese Bend landslide has decreased as a result of stabilization projects, which reduced movement to about 10 percent of former rates. Redondo Canyon and San Pedro Canyon bound the PV Shelf Study Area to the northwest and southeast, respectively, and limit sediment transported from adjacent shelf areas. Los Angeles-Long Beach Harbor and its breakwater limit nearshore sediment transport (Drake et al. 1994).

Source: Lee et al., The Distribution and Character of Contaminated Effluent-affected Sediment, Palos Verdes Margin, Southern California, 1994

Note: The deepest data shown are either for the deepest data available or where the concentrations of DDTs stayed below 1.0 mg/kg, which is indicative of pre-effluent sediment. Data are reported as dry weight.



Station 533 - 167 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	8.480	11.200
16 to 28	12.440	25.500

Station 539 - 44 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	3.173	4.06
16 to 30	3.883	4.23
31 to 44	4.66	4.82
45 to 60	9.933	16.2

Station 550 - 57 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	8.574	14.7
16 to 30	14.99	35.3
31 to 45	38.78	148

Station 514 - 53 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	3.27	5.06
16 to 30	10.87	16.1
31 to 45	1.53	1.53

Station 534 - 38 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	1.9	2.25
16 to 30	2.79	3.63
31 to 48	3.68	6.12

Station 547 - 26 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	9.729	43.6
16 to 24	2.474	7.39

Station 522 - 57 to 59 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	3.907	5.5
16 to 30	4.835	22.3
31 to 48	8.001	18.2

Station 554 - 28 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	0.812	1.19
16 to 32	1.581	2.77

Station 518 - 89 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 12	3.700	6.070

Station 532 - 137 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	7.988	8.870
16 to 32	10.900	31.400

Station 555 - 42 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	2.179	4.5
16 to 30	4.033	4.81
31 to 40	4.354	4.98

Station 523 - 141 to 59 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	5.333	9.87

Station 564 - 56 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	12.63	27.1
16 to 30	107.4	305
31 to 45	59.66	200

Station 536 - 65 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	5.56	8.51
16 to 30	18.71	65.4
31 to 40	36.62	55.6

Station 574 - 58 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	43.21	97.8
16 to 30	13.24	49.1
31 to 36	3.36	3.36

Station 542 - 207 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 4	1.880	1.880

Station 552 - 192 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	18.93	43.6
16 to 24	4.35	7.39

Station 570 - 74 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	5.953	19.1
16 to 32	10.04	18.1

Station 557 - 104 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	14.18	37.4
16 to 30	65.01	108
31 to 38	9.93	29.8

Station 577 - 66 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	6.053	9.92
16 to 28	0.898	2.26

Station 556 - 56 to 57m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	12.02	35.6
16 to 30	22.68	118
31 to 45	53.7	253

Station 566 - 181 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 16	6.435	16.1

Station 571 - 144 m - 1992

Depth (cm)	Average DDTs (mg/kg)	Maximum DDTs (mg/kg)
0 to 15	18.41	33.8
16 to 20	1.13	1.13

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FIGURE 1-7
Concentrations of DDTs - USGS
1992 Sediment Cores
Palos Verdes Shelf Study Area
Feasibility Study

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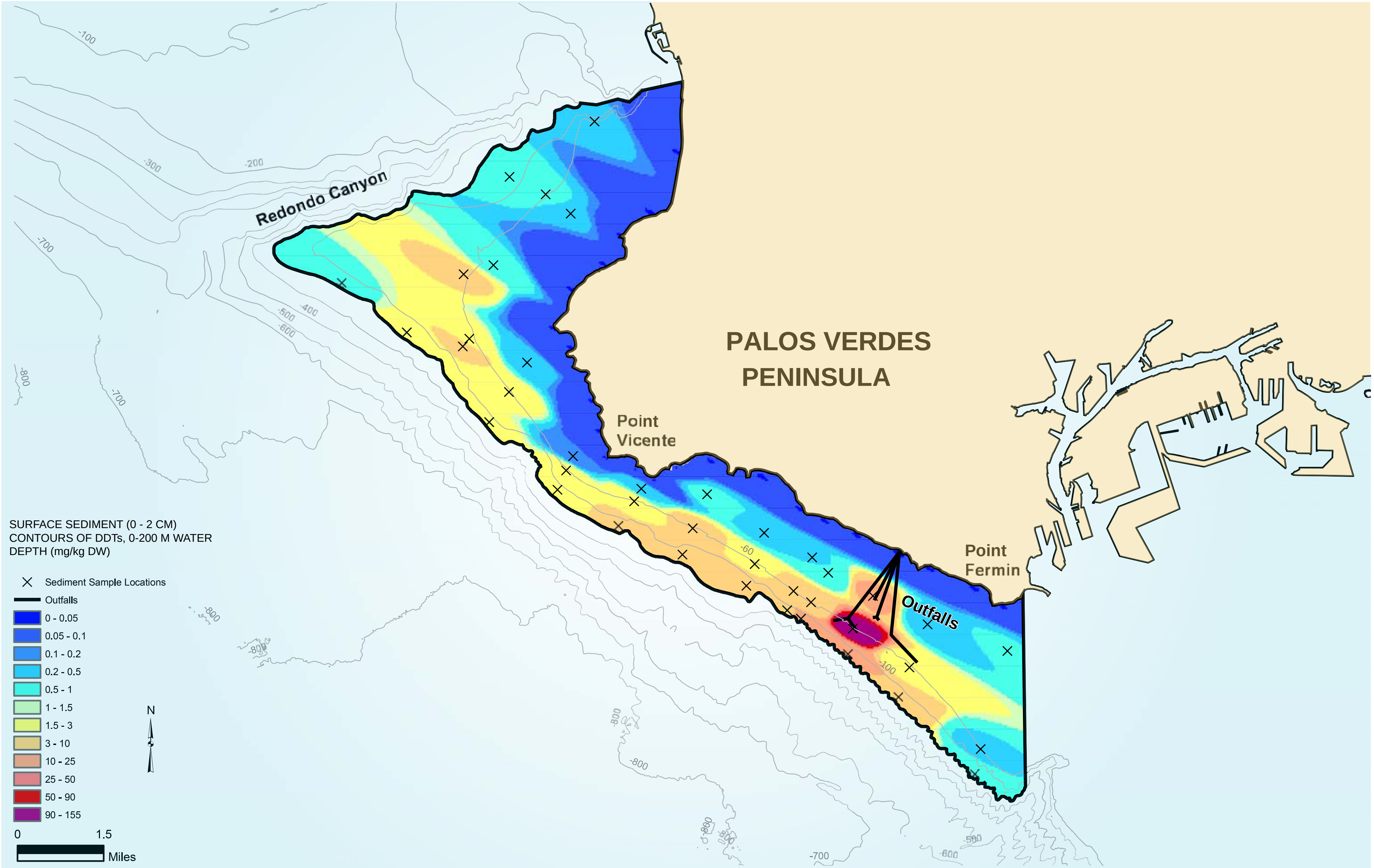

FIGURE 1-8
Surface Sediment Contours of DDTs - 2002/2004 Average
Palos Verdes Shelf Study Area Feasibility Study

Note: In addition to the 2002/2004 LACSD data, this figure uses four Bight '94 samples, one 1993 LACSD sample, and two 1992 NOAA samples to provide actual concentrations of DDTs between the 0 and 1 transects and north of the 0 transect. Shoreline concentrations have been set at 0.05 mg/kg for contouring.

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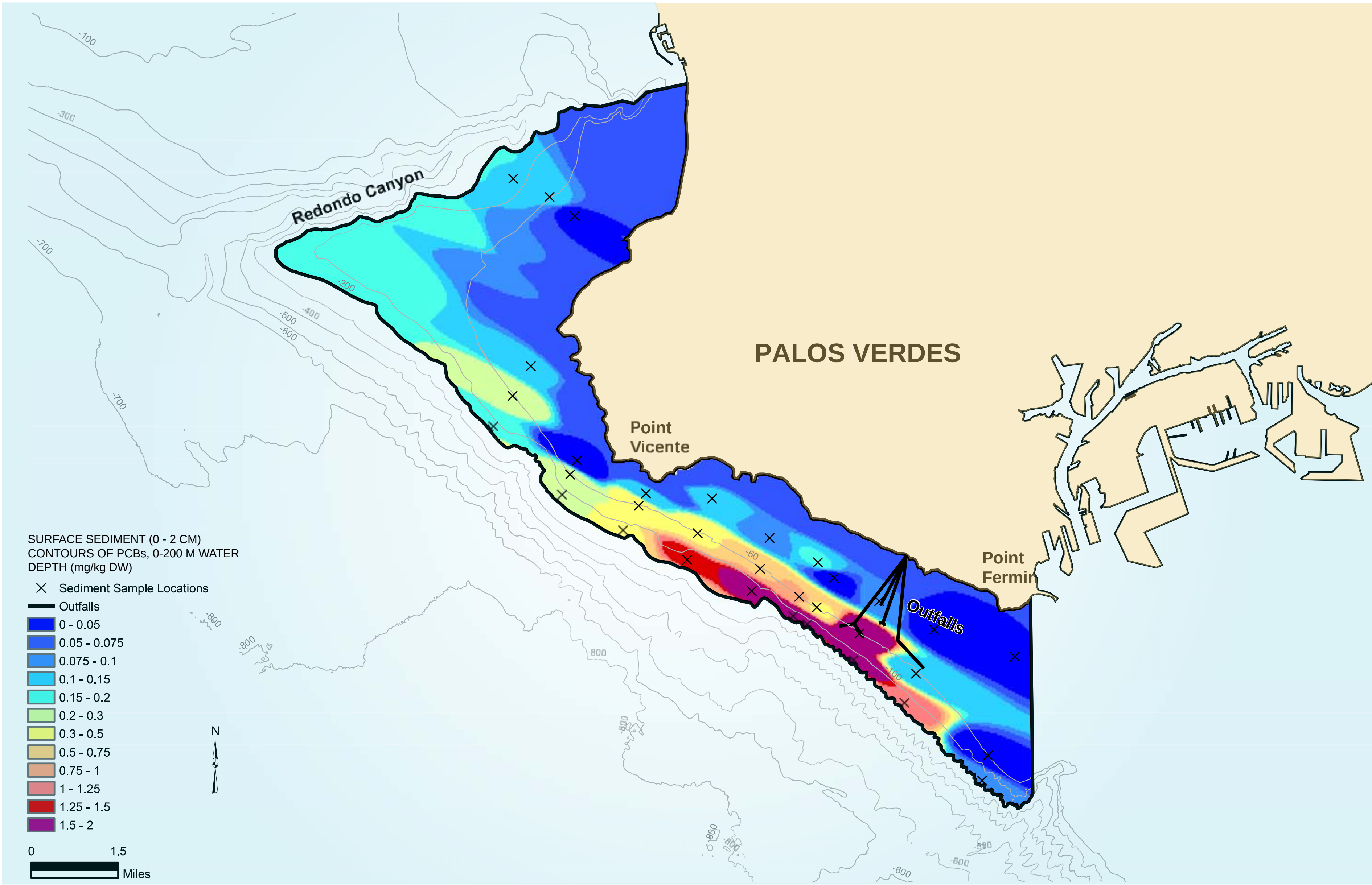

FIGURE 1-9
Surface Sediment Contours of PCBs - 2002/2004 Average
Palos Verdes Shelf Study Area
Feasibility Study
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Note: In addition to the 2002/2004 LACSD data, two simulated transects were inserted between the 0 and 1 transects to approximate sediment concentrations where no data exist. The simulated transects were set as an average of the 0 and 1 transect concentrations. Shoreline concentrations have been set at 0.05 mg/kg for contouring.

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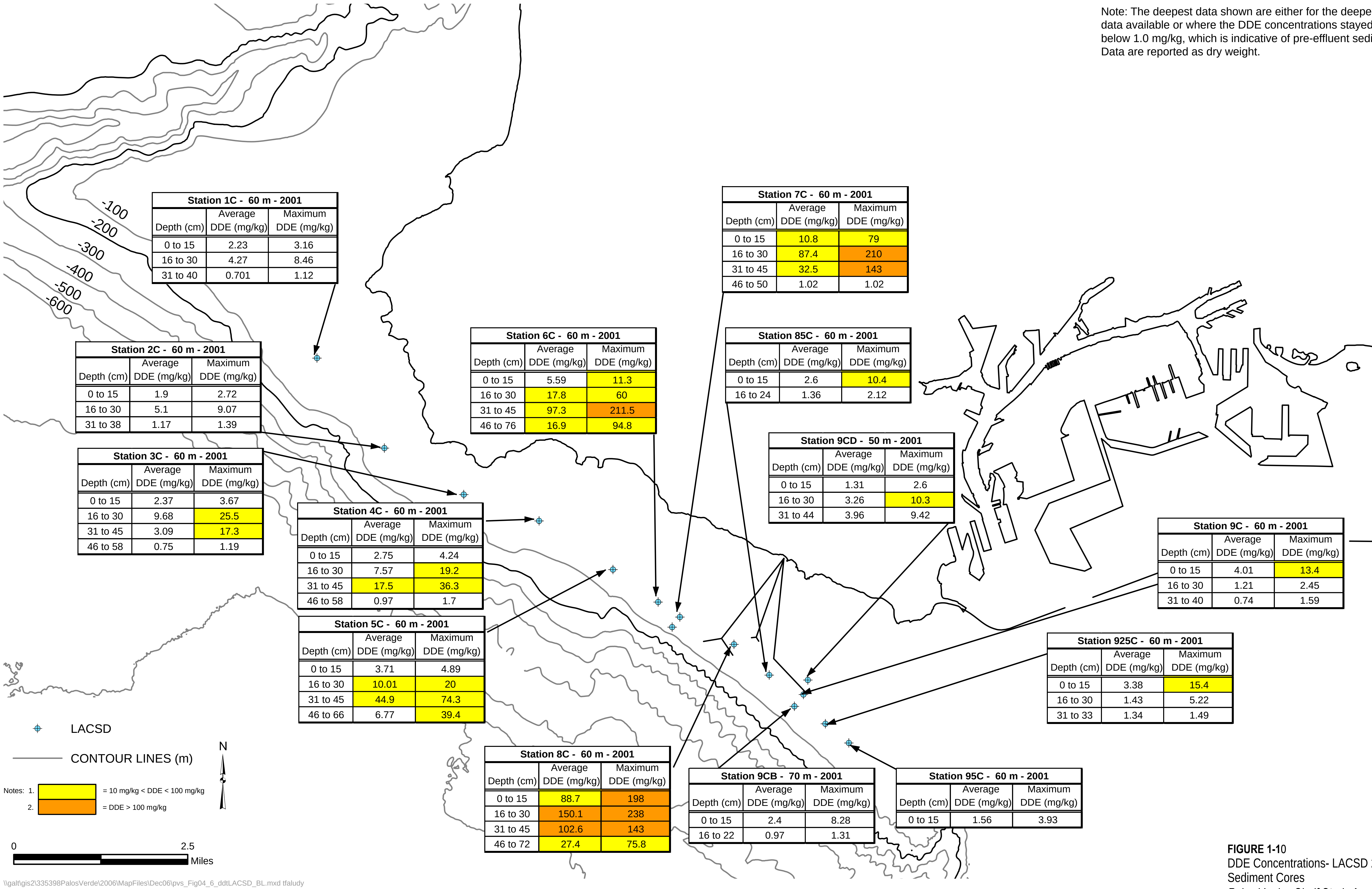
Note: The deepest data shown are either for the deepest data available or where the DDE concentrations stayed below 1.0 mg/kg, which is indicative of pre-effluent sediment. Data are reported as dry weight.



Notes: 1. (yellow) = 10 mg/kg < DDE < 100 mg/kg
2. (orange) = DDE > 100 mg/kg

Station 1C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	2.23	3.16
16 to 30	4.27	8.46
31 to 40	0.701	1.12

Station 2C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	1.9	2.72
16 to 30	5.1	9.07
31 to 38	1.17	1.39

Station 3C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	2.37	3.67
16 to 30	9.68	25.5
31 to 45	3.09	17.3
46 to 58	0.75	1.19

Station 4C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	2.75	4.24
16 to 30	7.57	19.2
31 to 45	17.5	36.3
46 to 58	0.97	1.7

Station 5C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	3.71	4.89
16 to 30	10.01	20
31 to 45	44.9	74.3
46 to 66	6.77	39.4

Station 6C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	5.59	11.3
16 to 30	17.8	60
31 to 45	97.3	211.5
46 to 76	16.9	94.8

Station 7C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	10.8	79
16 to 30	87.4	210
31 to 45	32.5	143
46 to 50	1.02	1.02

Station 85C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	2.6	10.4
16 to 24	1.36	2.12

Station 9CD - 50 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	1.31	2.6
16 to 30	3.26	10.3
31 to 44	3.96	9.42

Station 9C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	4.01	13.4
16 to 30	1.21	2.45
31 to 40	0.74	1.59

Station 925C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	3.38	15.4
16 to 30	1.43	5.22
31 to 33	1.34	1.49

Station 8C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	88.7	198
16 to 30	150.1	238
31 to 45	102.6	143
46 to 72	27.4	75.8

Station 9CB - 70 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	2.4	8.28
16 to 22	0.97	1.31

Station 95C - 60 m - 2001

Depth (cm)	Average DDE (mg/kg)	Maximum DDE (mg/kg)
0 to 15	1.56	3.93

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FIGURE 1-10
DDE Concentrations- LACSD 2001
Sediment Cores
Palos Verdes Shelf Study Area
Feasibility Study

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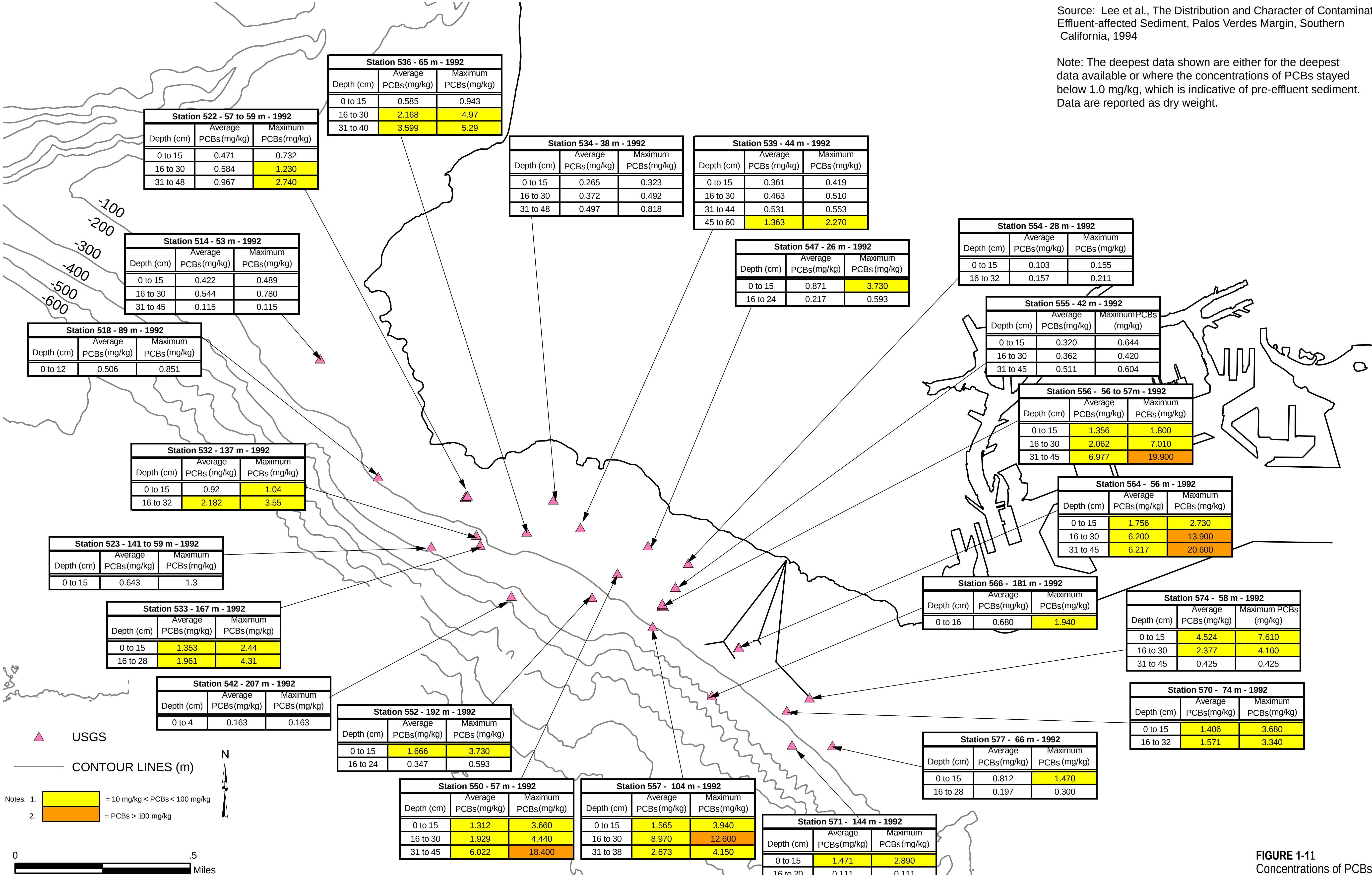
Source: Lee et al., The Distribution and Character of Contaminated Effluent-affected Sediment, Palos Verdes Margin, Southern California, 1994

Note: The deepest data shown are either for the deepest data available or where the concentrations of PCBs stayed below 1.0 mg/kg, which is indicative of pre-effluent sediment. Data are reported as dry weight.



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Station 536 - 65 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.585	0.943
16 to 30	2.168	4.97
31 to 40	3.599	5.29

Station 522 - 57 to 59 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.471	0.732
16 to 30	0.584	1.230
31 to 48	0.967	2.740

Station 534 - 38 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.265	0.323
16 to 30	0.372	0.492
31 to 48	0.497	0.818

Station 539 - 44 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.361	0.419
16 to 30	0.463	0.510
31 to 44	0.531	0.553
45 to 60	1.363	2.270

Station 554 - 28 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.103	0.155
16 to 32	0.157	0.211

Station 547 - 26 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.871	3.730
16 to 24	0.217	0.593

Station 514 - 53 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.422	0.489
16 to 30	0.544	0.780
31 to 45	0.115	0.115

Station 555 - 42 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.320	0.644
16 to 30	0.362	0.420
31 to 45	0.511	0.604

Station 518 - 89 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 12	0.506	0.851

Station 556 - 56 to 57m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	1.356	1.800
16 to 30	2.062	7.010
31 to 45	6.977	19.900

Station 532 - 137 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.92	1.04
16 to 32	2.182	3.55

Station 564 - 56 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	1.756	2.730
16 to 30	6.200	13.900
31 to 45	6.217	20.600

Station 523 - 141 to 59 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.643	1.3

Station 566 - 181 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 16	0.680	1.940

Station 574 - 58 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	4.524	7.610
16 to 30	2.377	4.160
31 to 45	0.425	0.425

Station 533 - 167 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	1.353	2.44
16 to 28	1.961	4.31

Station 542 - 207 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 4	0.163	0.163

Station 570 - 74 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	1.406	3.680
16 to 32	1.571	3.340

Station 552 - 192 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	1.666	3.730
16 to 24	0.347	0.593

Station 577 - 66 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	0.812	1.470
16 to 28	0.197	0.300

Station 550 - 57 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	1.312	3.660
16 to 30	1.929	4.440
31 to 45	6.022	18.400

Station 557 - 104 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	1.565	3.940
16 to 30	8.970	12.600
31 to 38	2.673	4.150

Station 571 - 144 m - 1992

Depth (cm)	Average PCBs (mg/kg)	Maximum PCBs (mg/kg)
0 to 15	1.471	2.890
16 to 20	0.111	0.111

FIGURE 1-11
Concentrations of PCBs - USGS
1992 Sediment Cores
Palos Verdes Shelf Study Area
Feasibility Study

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Knowledge of the oceanographic processes that govern resuspension and transport of bottom sediment on the PV Shelf is primarily based on the following historical studies:

1. Pre-1990 oceanographic studies of tidal and low-frequency current regimes in the PV Shelf region, as derived from time-series current measurements at a limited number of locations and for relatively short time periods (e.g., well less than one year).
2. Extensive oceanographic and geotechnical field studies that were conducted on the PV Shelf in 1992-1993 by USGS and reported in a special volume of *Continental Shelf Research* dedicated to PV research topics (CSR, 2002). Current data acquired during these studies were sufficient to assess forcing mechanisms having seasonal, synoptic, and tidal periods. However, the measurements were limited in their vertical resolution, near-bottom measurements were lacking, and the sampling rates were insufficient for analysis of high-frequency processes.
3. In 2004, USGS and SAIC undertook an oceanographic measurement program from mid-February to July that was focused on making multiple-parameter, high-frequency measurements in the bottom boundary layer to capture sediment resuspension events and the physical processes responsible for those events. This program furthered our understanding of oceanographic processes and geotechnical properties of the sediment.

Key elements of the oceanographic conditions on the PV Shelf, as based upon these studies, are given below:

- The magnitude and frequency of tidal currents on the PV Shelf and upper slope are well documented by field observations. The most dominant tidal constituent is the MS semi-diurnal tide with a magnitude of approximately 5 centimeters per second (cm/s) and period of approximately 12.4 hours (hrs). Tidal currents alone are not sufficient to resuspend sediments.
- Sub-tidal (low frequency) currents on the PV Shelf are predominantly northwestward and relatively weak, with mean velocities of 4 to 5 cm/s at mid-depth and 3 to 4 cm/s near the bottom. Data collected by Wiberg (2002) on two sites (figure 1-12) measured mean alongshelf velocity of 1.9 to 3.2 cm/sec to the northwest at Site B, and 0 to 1.4 cm/sec across-shelf in the seaward direction. Mean current speed (regardless of direction) at Site B was 7.9 to 9.8 cm/sec. At Site D, mean along-shelf velocity was 4.1 to 4.2 cm/sec along shelf to the northwest and 0.2 to 0.4 cm/sec across-shelf in the landward direction. Mean current speed regardless of direction at Site D was 9.6 to 10.7 cm/sec.
- Current fluctuations typically reach speeds of 20 to 30 cm/s. Fluctuations in these low-frequency, along-shelf currents often occur at periods of 5 to 20 days and are independent of season. Sub-tidal cross-isobath currents are much weaker. The low-frequency currents on the PV Shelf are driven by the along-shelf pressure gradient more so than by local winds.
- Data from LACSD moorings show that current speeds are less than 20 cm/sec more than 98 percent of the time and are smaller than 25 cm/sec more than 99 percent of the time.
- LACSD current monitoring stations extended further south than those of the USGS 1992-1993 study. Data from the southern stations indicated increased near-bottom velocities compared with sites at and northwest of the outfalls. Near-bottom currents in excess of 15 cm/sec were recorded only 5.9 percent and 8.8 percent of the time northwest of the outfalls at Stations A3 and A4, respectively. Near the diffuser at Station 5A, 9.2 percent of the near-

bottom observations were above 15 c/sec. Near-bottom currents at Stations A6 and A7, southeast of the outfall, were above 15 cm/sec 15 percent and 36 percent of the time.

- Subtidal currents were aligned roughly with the isobaths with a tendency for currents to flow offshore (northwestward) near Point Vicente as the isobaths bend northeastward (Noble et al., 2002). Noble also reported that because the shelf narrows toward the northwest, near Point Vicente, the subtidal along-shelf currents were stronger near Site D than near the Site B. Wiberg et al. (2002) reported similar findings indicating that mean along-shelf currents were greater at Site D than Site B, and mean across-shelf current was weakly onshore at Site D and offshore at Site B.
- Wave data from offshore buoys combined with numerical model predictions suggest that ambient bottom sediments on the PV Shelf will be resuspended at sites having water depths of 60 m or less when impacted by large-amplitude waves (swell) having periods in excess of 9 sec and wave orbital velocities exceeding 14 cm/s.
- Waves having the potential to resuspend bottom sediment at the 60-m depth occur, on average, 10 times per year, with a mean duration of 1.6 days. The average time between these events during winter is 8 days. Wave-driven resuspension normally does not occur during summer. Wave-driven sediment resuspension is very rare for water depths greater than 100 m on the outer PV Shelf.
- Currents are generally not of sufficient strength to mobilize (scour or erode) sediment in the area. LACSD current meter data indicate occasional periods of stronger currents that could result in some sediment mobilization. However, the frequency and duration of these events limit their significance.
- Increased river discharge during meteorological storms does not significantly effect PV Shelf currents.

1.2.5.2 Sediment Physical Characteristics

PV Shelf sediment samples have been collected for analysis of physical characteristics on a semiannual basis from the summer of 1992 through the winter of 2005. Sediment particle size distribution was calculated according to the Wentworth grain size scale to determine the mean percent dry mass of gravel (sediment with grain size greater than 2,000 micrometers [μm]), sand (2,000 μm > grain size > 63 μm), silt (63 μm > grain size > 4 μm), and clay (grain size less than 4 μm) in samples collected over the 14-year history of the semiannual sampling events (27 total). Samples were not collected from all locations during every event; however, each location was sampled 21 to 23 times. The sediment particle size distribution for samples collected at LACSD sampling stations is shown in Table 1-2.

In general, sediment along the 30-m isobath (D stations) contain a higher percentage of coarse-grained material (gravels and sands with grain size greater than 63 μm). Previous studies of the PV Shelf Study Area have concluded that strong wave-generated currents are common on the inner shelf and, as a result, resuspension of sediment is common (Kolpack, 1987). This causes a greater turnover in fine-grain sediment and, as a result, the percentage of coarse-grain sediment is greater. Sediment samples collected along the 61- and 152-m isobaths (B and C stations, respectively) tend to consist of primarily fine-grained sediment (silts and clays with grain size less than 63 μm). The exceptions to these trends are Stations 2C, 9C, 10C, and 10B, which each consist of greater than 50 percent coarse material.

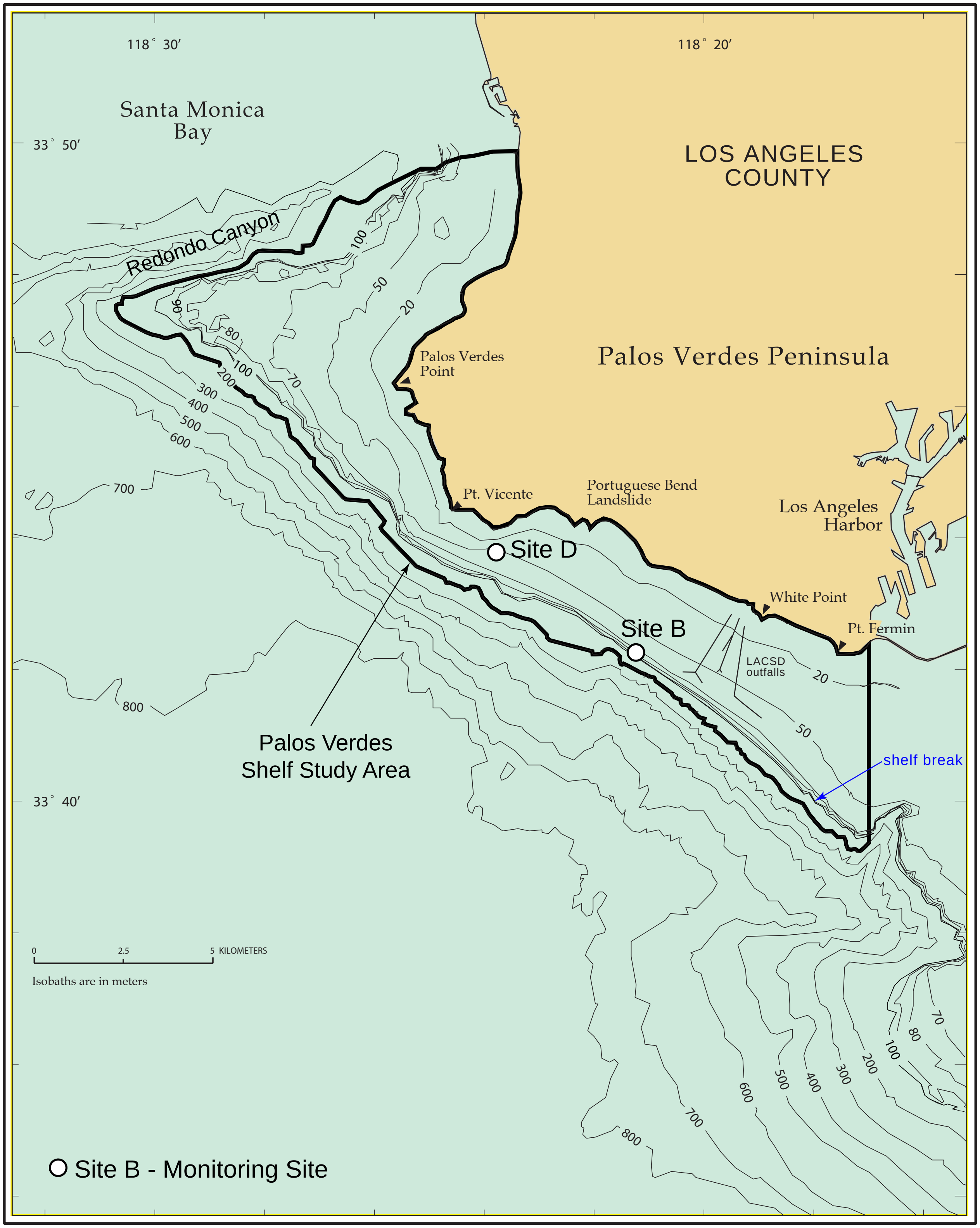

FIGURE 1-12
Monitoring Sites Used by Wiberg et al. (2002)
Palos Verdes Shelf Study Area
Feasibility Study

Source: Wiberg et al., 2002.

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TABLE 1-2
Sediment Physical Characteristics

Cell	Particle Size Distribution (%) [1, 2]								Particle Distribution Summary [4]	
	Gravel[3]		Sand[3]		Silt[3]		Clay[3]			
	(mean %)	(StDev)	(mean %)	(StDev)	(mean %)	(StDev)	(mean %)	(StDev)	% Course	% Fines
0B	0.04	0.11	15.77	5.22	63.63	3.12	20.54	3.00	15.81	84.17
0C	0.34	1.35	28.26	4.05	59.77	3.55	11.61	1.37	28.61	71.38
0D	0.00	0.00	74.84	5.57	20.64	4.67	4.49	1.13	74.85	25.14
1B	0.19	0.30	45.53	4.71	39.12	4.01	15.14	2.13	45.72	54.26
1C	0.03	0.13	40.88	4.51	45.28	4.20	13.79	1.60	40.91	59.07
1D	1.20	2.33	88.59	5.63	6.04	3.49	4.14	1.30	89.79	10.19
2B	0.18	0.20	45.58	7.63	38.14	4.91	16.08	3.69	45.76	54.22
2C	0.17	0.21	56.12	5.10	29.69	3.39	14.00	2.16	56.29	43.69
2D	8.43	5.65	87.42	5.81	1.65	1.31	2.49	1.57	95.84	4.14
3B	0.07	0.09	29.48	6.39	51.40	6.03	19.03	3.05	29.55	70.43
3C	0.08	0.15	39.06	5.20	42.60	3.80	18.23	2.17	39.14	60.84
3D	0.05	0.08	79.07	3.62	12.16	2.07	8.71	1.78	79.11	20.87
4B	0.39	0.51	13.12	4.77	61.68	5.17	24.79	3.46	13.52	86.46
4C	0.08	0.18	21.60	5.40	59.28	4.76	19.02	2.38	21.68	78.30
4D	0.02	0.05	62.91	6.38	24.31	4.61	12.75	2.37	62.93	37.06
5B	0.52	1.38	14.74	6.80	60.10	6.63	24.62	2.94	15.26	84.72
5C	0.01	0.03	17.84	3.81	62.70	3.80	19.43	2.15	17.85	82.13
5D	0.11	0.15	62.25	8.83	24.99	5.88	12.63	3.19	62.36	37.62
6B	0.36	0.54	16.81	6.63	58.53	5.87	24.28	3.58	17.17	82.81
6C	0.16	0.63	21.16	4.37	59.59	4.34	19.07	1.72	21.32	78.66
6D	0.03	0.06	69.95	6.26	21.35	4.63	8.65	2.14	69.98	30.01
7B	0.33	0.53	19.01	6.44	55.41	5.14	25.22	2.93	19.34	80.64
7C	0.08	0.18	37.01	22.55	46.53	16.53	16.37	6.47	37.09	62.89
7D	0.12	0.15	75.87	10.25	16.87	7.27	7.13	3.17	75.99	24.00
8B	0.26	0.35	19.64	6.43	55.97	5.25	24.11	2.99	19.90	80.08
8C	1.40	1.57	36.40	7.96	45.18	6.22	17.00	2.89	37.80	62.19
8D	0.03	0.03	83.56	5.43	11.15	4.26	5.24	1.42	83.60	16.38
9B	0.19	0.38	24.48	6.35	53.64	5.54	21.67	3.15	24.67	75.31
9C	0.06	0.23	53.92	4.41	36.77	3.83	9.24	2.08	53.98	46.01
9D	0.00	0.01	76.39	3.28	17.61	2.69	5.98	0.95	76.39	23.60
10B	0.04	0.09	54.37	5.61	32.85	4.52	12.72	1.86	54.41	45.57
10C	0.32	0.63	76.90	6.90	16.32	5.52	6.44	1.35	77.22	22.76
10D	0.02	0.04	73.88	4.36	18.44	3.37	7.65	1.33	73.90	26.08

[1] Data collected by the LACSD semiannually between summer 1992 and winter 2005.

[2] Mean particle size and standard deviation determined using a minimum of 21 samples.

[3] Grain size defined as follows: gravel < 500 µm < sand < 63 µm < silt < 4 µm < clay

[4] Summary shows a comparison between percentage course-grained material (gravel and sand) and percentage fine-grained material (silt and clay).

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1.2.5.3 Chemical Transformation of Contaminants

DDTs and PCBs are considered to be highly persistent in the environment. However, under appropriate conditions, they may be transformed through a variety of processes to other related chemicals called "daughter products." The following conclusions can be made about the degradation of DDTs and PCBs at the PV Shelf:

- The primary DDT compound observed in EA sediments is DDE. Data indicate that the DDT-contaminated effluent discharged onto PV Shelf was transformed relatively rapidly from DDT to DDE in the deposited sediments (Eganhouse et al., 2000).
- Laboratory studies using sediment collected from PV Shelf have shown that biochemical transformation (reductive dechlorination) of DDE to DDMU (*1-chloro-2,2-bis [p-chlorophenyl] ethylene*) can occur in PV Shelf EA sediments. The calculated first-order half-lives for DDE transformation to DDMU in these laboratory experiments ranged from 3 to 10 years and are considered to be upper limits on the transformation rate that might be observed (CH2M HILL, 2007).
- USGS studies of PV Shelf sediment in 1992 observed the presence of DDMU throughout the EA deposit. Sediment core data from two areas investigated in 2003 have shown that the inventory of DDE has decreased since 1992 while that of DDMU has increased. Sediment cores taken in 1992 and 2003 by USGS near LACSD Station 3C show that, while recalcitrant compounds such as PCBs and certain branched long-chain alkylbenzenes (e.g., TAB3) have very similar inventories (within 5 percent) in the two cores, the inventory of p,p'-DDE has decreased (43 percent) while the inventories of the degradation products, DDMU and DDNU (*unsym-bis [p-chlorophenyl] ethylene*), have increased by 34 and 33 percent, respectively. Although this was a limited study, it supports the hypothesis that DDE is breaking down in the PV Shelf sediment and warrants further investigation (Eganhouse and Pontolillo, 2007).
- DDMU, DDNU and other daughter products are not classified as toxic substances; however, research on these substances is scant. Thus, the relative importance of these transformations to any associated changes in human or ecological risk is unknown and warrants additional study.
- The congener-specific compositions of PCBs in shelf sediments are highly uniform and no temporal changes have been observed in the congener distribution profiles for PV Shelf sediment cores at depth. Therefore, there is no evidence that PV Shelf PCBs are degrading. However, PCB concentrations in surface sediments have dropped over time due to other loss processes, i.e., mixing, dispersal.

Additional assessment of the longterm fate of the contaminated sediment deposit and its risk to human health and the environment is found in Section 2.0.

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2.0 Risk Assessments and Predictive Modeling of Future Conditions

This section describes the risk assessments and models used to provide an evaluation of the potential threat to human health and the environment posed by the PV Shelf superfund site in the absence of any remedial action. Risk assessments address toxicity and levels of hazardous substances present in relevant media, (e.g., water, sediment, and biota), potential human and environmental receptors and exposure routes, and extent of expected impact or threat. Along with a quantification of current risk, this section presents predictive modeling of future conditions of the site to assist in the selection of remedial actions to eliminate, reduce or control these risks.

2.1 Summary of Risk Assessments

This section summarizes the 1999 Human Health Risk Evaluation plus its 2006 update, and the 2003 Ecological Risk Assessment. The section also discusses the *2002-2004 Southern California Coastal Marine Fish Contaminants Survey* (EPA, 2007), LACSD contaminant trends in fish, recent fish-in-market analyses, and application of a bioaccumulation model (HydroQual, 1997) to establish a relationship between contaminant concentrations in fish tissue and sediment (Anchor QEA, 2009).

The risk assessments concluded that fish consumption is the exposure pathway that poses the greatest level of risk to receptors. The contaminants of concern (COC) are DDT and its metabolites, herein referred to as DDTs, and PCBs. Both PCBs and DDTs are classified as probable human carcinogens (USEPA, 1991, USEPA, 1997d).

2.1.1 1999 Human Health Risk Evaluation

A streamlined Human Health Risk Evaluation (HHRE) was conducted for the PV Shelf site in 1999, in accordance with the *Guidance on Conducting Non-Time-Critical Removal Actions under CERCLA* (EPA, 1993a). The purpose of the 1999 HHRE was to summarize, using existing data, the human health risks posed by contaminated effluent-affected (EA) sediment on the PV Shelf. The HHRE was based on historical data from a variety of sources, including the following:

- LACSD NPDES bioaccumulation monitoring reports (LACSD, various years) and other data collected by LACSD, which include fish tissue concentration data for white croaker, kelp bass, black surfperch, and California halibut.
- California OEHHA *Study of Chemical Contamination of Marine Fish from Southern California* (Pollock et al., 1991), which reports tissue concentration data in 16 fish species from 24 sites in Southern California, including locations on the PV Shelf.
- *Santa Monica Bay Seafood Consumption Study* (Santa Monica Bay Restoration Project [SMBRP], 1994), which describes fish consumption patterns and rates in areas including the PV Shelf.

The HHRE focused on the consumption of contaminated fish as the primary exposure pathway. Potential risks to human health are due to the consumption of fish that have bioaccumulated contaminants from sediment and sediment-dwelling prey. The evaluation included a quantitative assessment of the following:

- **Human health risks from the chemicals of greatest concern:** Although other contaminants are present in PV Shelf sediment and fish tissue, potential risks due to DDT and its metabolites (referred to collectively as DDTs) and PCBs are significantly higher and, therefore, the HHRE focused on these compounds.
- **Human health risks due to the most significant exposure route:** Although other routes of exposure to DDTs and PCBs in sediment or fish may be possible, consumption of contaminated fish by recreational anglers is believed to be the most significant exposure pathway and, therefore, was evaluated quantitatively in this HHRE. Although subsistence fishing may occur in the PV Shelf area, site-specific (e.g., Santa Monica Bay area) fish consumption data were available for recreational anglers only. A qualitative assessment of the potential risk to nursing infants was also conducted.
- **Reasonable Maximum Exposure (RME) and Central Tendency (CT) scenarios:** In accordance with EPA guidance (EPA, 1995b and 1995c), a high-end exposure scenario was evaluated to ensure the assessment was protective of human health. The RME scenario is an exposure scenario based on single-species consumption rates (i.e., consumption rates averaged over anglers who consume a particular species). In addition, a CT exposure scenario was evaluated, using average and/or median values for exposure parameters. The CT, or average, scenario assumed a mixed-species diet and used median consumption rates averaged over all boat anglers (EPA, 1995b).

2.1.1.1 Exposure Assessment

The 1999 HHRE considered consumption of the 12 species of fish most commonly consumed by Santa Monica Bay boat anglers, based on information collected for the *Santa Monica Bay Seafood Consumption Study* (SMBRP, 1994). Fish tissue concentrations of DDTs and PCBs for these 12 species were based on data collected by the LACSD (white croaker, kelp bass, California halibut, surfperch) and for the OEHHA Comprehensive Study (barred sandbass, California scorpionfish, California sheephead, chub mackerel, halfmoon, Pacific barracuda, Pacific bonito, and rockfishes [Pollock et al., 1991]).

Fish consumption rates were based on 338 boat anglers who reported consuming fish in the previous 4 weeks (28 days) in the *Santa Monica Bay Seafood Consumption Study* (SMBRP, 1994). An RME scenario was evaluated for each of the 12 fish species included in the HHRE; consumption rates were based on consumers of a particular fish species. For example, 13 people reported eating white croaker during the previous 28 days. The average consumption rate (estimated using the 95 percent upper confidence limit [UCL] on the mean) of white croaker by these 13 white croaker consumers (27.9 grams per day [g/day]) was used to quantify the RME scenario for consumers of this species. This represents about six 150-gram meals per month. The CTE scenario assumed that an angler would eat all 12 fish species, with consumption rates for each species calculated by multiplying the species diet fraction by the median fish consumption rate for all 338 boaters. For example, white croaker represents 2.2 percent, or 0.48 g/day, of the overall median fish consumption rate (21.4 g/day) for boat anglers, based on the results of the SMBRP (1994) study. This represents about one 175-gram meal (about 6 ounces) of white croaker every year.

Exposure durations used to quantify human health risks were based on the reported fishing durations of boat anglers in the *Santa Monica Bay Seafood Consumption Study* (SMBRP, 1994). Reported fishing duration reflected only the length of time the surveyed individuals had been fishing up to the time of the survey. Because no information was available on how long these individuals will continue to fish in the future, the reported fishing duration is not equivalent to total exposure duration. The 90th percentile reported fishing duration of 30 years was used to quantify the RME scenario; the mean reported fishing duration of 13.8 years was used to quantify the CTE scenario. Exposure point concentrations were assumed to remain constant for the selected exposure duration.

2.1.1.2 Risk Characterization

Because of fundamental differences in the mechanisms through which carcinogenic and noncarcinogenic processes occur, risks are characterized separately for these two types of health effects. Cancer risks and noncancer hazard quotients (HQs) were calculated for the RME and CTE scenarios.

Potential health risks associated with carcinogens were estimated by calculating the increased probability of an individual developing cancer during his or her lifetime as a result of exposure to a carcinogenic compound. For example, a cancer risk of 2×10^{-6} means that for every 1 million people exposed to the carcinogen during the agreed upon exposure period (e.g., 30 years for RME scenario), the average incidence of cancer might increase by two cases. EPA uses an excess lifetime cancer risk (ELCR) of 10^{-6} (one in 1,000,000) as the point of departure for cancer risk estimates that are of concern. EPA uses an acceptable risk range of 10^{-4} to 10^{-6} to determine whether a site poses a risk to human health (40 CFR §300.430) (EPA, 1999).

For noncancer health effects, the likelihood that a receptor will develop an adverse effect was estimated by comparing the predicted level of exposure for a particular chemical with the highest level of exposure that is considered protective, i.e., the reference dose (RfD) appropriate to that exposure period. When the estimated exposure exceeds the RfD, the HQ of a chemical exceeds 1 (i.e., HQ > 1).

RME Scenario

The RME scenario represents the potential risks to boat anglers who consume a particular species of fish collected from the PV Shelf, assuming mean tissue concentrations and consumption rates (as represented by the 95 percent UCL on the mean). Cancer risks exceeded 1×10^{-4} for consumers of the following fish species: white croaker (2×10^{-3}) and surfperches (2×10^{-4}). Several species of fish posed a potential noncancer hazard under the RME scenario: white croaker (HQ for PCBs = 32, HQ for DDTs = 17), surfperch (HQ for PCBs = 5), barred sandbass (HQ for PCBs = 3), California halibut (HQ for PCBs = 3), California sheephead (HQ for PCBs = 2), and kelp bass (HQ for PCBs = 2). This scenario reflects consumption of a single species of fish using a conservative estimate of the mean consumption rate (i.e., the 95 percent UCL) for that species. It should be noted, however, that boat anglers generally do not consume only a single species of fish. For example, since the 95 percent UCL on the mean total fish consumption rate (i.e., all species) is 53.0 g/day, a consumer of white croaker (at the RME consumption rate of 27.9 g/day) also may be consuming a variety of other fish species. The contribution of DDTs and PCBs in these other fish species to human health risk is not reflected in the RME results.

CTE Scenario

The CTE scenario represents the potential risk to boat anglers who consume a mixed-species diet of fish collected from the PV Shelf, assuming arithmetic mean tissue concentrations and median consumption rates for all boat anglers (rather than for consumers of a particular species). The total cancer risk (DDTs and PCBs combined) for anglers who fish from boats (mixed-species diet) was 2×10^{-5}. The noncancer HQs were 0.3 and 0.9 for DDTs and PCBs, respectively. These HQs indicate that noncancer health hazards were not of concern.

Monte Carlo Simulation

In addition to the point estimate risk calculations described above, a Monte Carlo simulation was performed to evaluate uncertainty and variability in the consumption of white croaker by boat anglers. Results of the Monte Carlo simulation indicated that the mean cancer risk is 3×10^{-4}, and the 95th percentile cancer risk is 1×10^{-3}. About 45 percent of simulation results were above 1×10^{-4}; in other words, a cancer risk of 1×10^{-4} corresponds to a 55th percentile of the output distribution. The mean and median noncancer HQs (7 and 3, respectively) are greater than 1, the level above which there may be a concern for potential noncancer health effects. The 95th percentile HQ is 26. About 75 percent of simulation results exceeded an HQ of 1 (i.e., an HQ of 1 corresponds to a 25th percentile of the output distribution).

Sensitivity studies were performed to identify those input parameters that represent the greatest contributors to variance in the cancer risk and noncancer hazard for recreational boat anglers consuming white croaker. Exposure duration was the largest contributor to variance in the cancer risk results, followed by DDTs and PCBs concentrations in white croaker tissue. Tissue concentrations of DDTs and PCBs were the largest contributors to variance in the noncancer hazard, followed by the white croaker consumption rate. These exposure factors reflect both uncertainty and natural variability in a population.

Risk to Nursing Infants

The potential risks to breast-fed infants due to consumption of DDTs and PCBs in breast milk were also evaluated. Results indicated that DDTs and PCBs breast milk concentrations, based on maternal consumption of one 150-gram meal of white croaker per month, could be as high as 0.8 mg/kg and 0.05 mg/kg, respectively. This corresponds to noncancer HQs of 220 and 370 for DDTs and PCBs, respectively. Based on maternal consumption of kelp bass, noncancer HQs to an infant were 3 and 16 for DDTs and PCBs, respectively.

Uncertainty Analysis

An uncertainty analysis provides a qualitative and, where possible, semi-quantitative evaluation of the assumptions and limitations inherent in each step of the risk assessment process and their effects on the overall risks calculated for the site, particularly those uncertainties not addressed as part of the Monte Carlo analysis. Uncertainties are associated with each step of the risk assessment process, including data evaluation, exposure assessment, toxicity assessment, and risk characterization. Uncertainties associated with the human health risk assessments are discussed in section 2.1.2.3.

2.1.2 2006 Technical Memorandum (Supplemental HHRE)

The 1999 HHRE used available fish data. The purpose of the supplemental HHRE was to update the analysis of human health risk using 2002 fish data from the *2002/2004 Southern*

California Coastal Marine Fish Contaminants Study (EPA/MSRP 2007) and from LACSD 2002 fish monitoring data. The supplemental HHRE Technical Memorandum (TM) used ocean fish data collected from the PV Shelf Study Area (from Point Fermin to Redondo Canyon).

2.1.2.1 Summary of Data Used

As mentioned above, data from two ocean fish sampling studies were used in the Supplemental HHRE: the EPA/MSRP 2002/2004 ocean fish sampling effort, and the 2002 LACSDS ocean fish sampling study.

Since 1971, LACSD has monitored the marine environment on the PV Shelf to assess the long-term environmental impacts form the effluent discharged from JWPCP outfalls. Regional marine conditions in the area of the outfalls are monitored according to the requirements of the LACSD NPDES permit. The permit includes monitoring requirements for accumulation of DDTs and PCBs within tissues of various fish and invertebrate species. The purpose of the monitoring is to evaluate temporal and spatial trends associated with bioaccumulation of DDTs and PCBs in biota collected within three zones across the PV Shelf: Zone 1, from White Point to Bunker Point; Zone 2, from Long Point to Point Vicente; and Zone 3, from Palos Verdes Point to Bluff Cove. The Supplemental HHRE includes white croaker and kelp bass data collected in 2002 from these three zones. In 2002, LACSD analyzed fish tissue for DDTs and PCBs as the sum of Aroclors (Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260).

The *2002/2004 Southern California Coastal Marine Fish Contaminants Survey* (EPA/NOAA 2007) caught 23 species of fish from Ventura to Orange counties. The Supplemental HHRE used fish caught from Point Fermin to Redondo Canyon (*Fish Survey* segments 9, 12, 13/14, 15 and EPA B) (Figure 2-1). Six fish species were included in the updated HHRE because they represented a sufficient number of samples to make the assessment statistically valid. The fish species evaluated represent a mix of water-column and bottom feeders, and pelagic and local dwelling species: white croaker, kelp bass, surfperch, barred sandbass, and California scorpionfish. Unlike the LACSD data, which analyzed PCBs as Aroclors, the *Fish Survey* analyzed and reported PCBs as congeners. Combining the data increases overall variation and effect point estimates in the risk and hazard results; however, the Supplemental HHRE attempted to minimize this effect by estimating risk using minimum, 95 percent UCL, and maximum concentrations of PCBs for each fish species evaluated.

2.1.2.2 Exposure Assessment

The evaluation of potential human cancer and noncancer risks is based on skin-off-fish-fillet results. The fish fillet scenario simulates fish consumption rates of all anglers as described in the *Santa Monica Bay Seafood Consumption Study* (SMBRP, 1994). To address the potential for high fish ingestion rates found in some Asian communities and other ethnic groups, high-end fish consumer scenarios were included in the evaluations. The risk scenario included RME and CTE scenarios based on all-angler and Asian-angler consumption rates. RME consumption rates used in the analysis were 107.1 g/day and 115.7 g/day. CTE consumption rates for all-angler and Asian-anglers were both 21.4 g/day.

2.1.2.3 Risk Characterization

As discussed below, under the RME and CTE conditions (using 95 percent UCLs), DDTs contributed the most to the total cancer risk for five species, while PCBs contributed the most to cancer risk for one species (rockfish). Under the RME and CTE conditions, PCBs contributed most to HI values for all six species.

RME Scenario

For both all-angler and Asian-angler consumers under RME consumption of fish fillets, excess lifetime cancer risks from DDTs and PCBs for three species (white croaker, California scorpionfish, and barred sandbass) ranged from 3×10^{-4} to 7×10^{-3}, based on 95 percent UCL concentrations. Of the six species tested, the highest risk was from white croaker fillets with a risk of 6×10^{-3}. White croaker fish typically contain higher levels of DDTs and PCBs than other fish from the PV Shelf. This is primarily because white croaker is a nonmigratory fish that feeds off the ocean floor. Risks from the other three species (kelp bass, rockfish, and surfperch) ranged from 7×10^{-5} to 1×10^{-4}.

As with the HQ (which is for a single chemical), when the HI (Hazard Index) for exposures to multiple chemicals exceeds 1, the calculated intake exceeds the daily reference dose. The HI values for all six species were 2 to 198. White croaker fillets also had the highest HI values.

CT Scenario

For both all-angler and Asian-angler consumers under CTE conditions (using 95 percent UCLs), for consumption of fish fillets, cancer risks from DDTs and PCBs for one species (white croaker) was 6×10^{-4} based on 95 percent UCL concentrations. Risks from the other five species ranged from 6×10^{-6} to 3×10^{-5}. The HI values from three of the six species (white croaker, California scorpionfish, and barred sandbass) were 2 to 37. Kelpfish, rockfish, and surfperch have HI values below 1.

Uncertainties and Limitations

These risk calculations are quantitative estimates of current and future potential cancer risks and noncancer adverse health hazards. However, these numbers do not predict actual health outcomes. Using approaches and methodologies based on EPA guidance documents, the potential cancer risks and health hazards are estimated in a conservative, public health-protective manner.

The estimation of exposure in the supplemental HHRE requires numerous assumptions regarding the likelihood of exposure, frequency of ingestion of contaminated fish, the concentration of contaminants in fish and the period of exposure. Another main assumption of the exposure assessment is that the period of constituent intake is assumed to be constant and representative of the exposed population. Assumptions used in the supplemental HHRE tend to simplify and conservatively approximate actual conditions, thereby serving to maximize confidence in decision-making.

The following uncertainties should be considered when interpreting the results for the supplemental HHRE:

- *Fish Sampling and Laboratory Analysis*. Uncertainty associated with fish sampling and laboratory tissue analysis includes representativeness of the fish samples collected, sampling errors, the variable nature of fish exposures to DDTs and PCBs from the PV Shelf, and the inherent variability (standard error) in the laboratory analyses.
- *DDTs and PCBs in Fish Fillet (Muscle).* Human health risks were evaluated using DDTs and PCBs. Although other contaminants are present in PV Shelf sediments and fish tissue, potential risks from exposure to or consumption of DDTs and PCBs are of

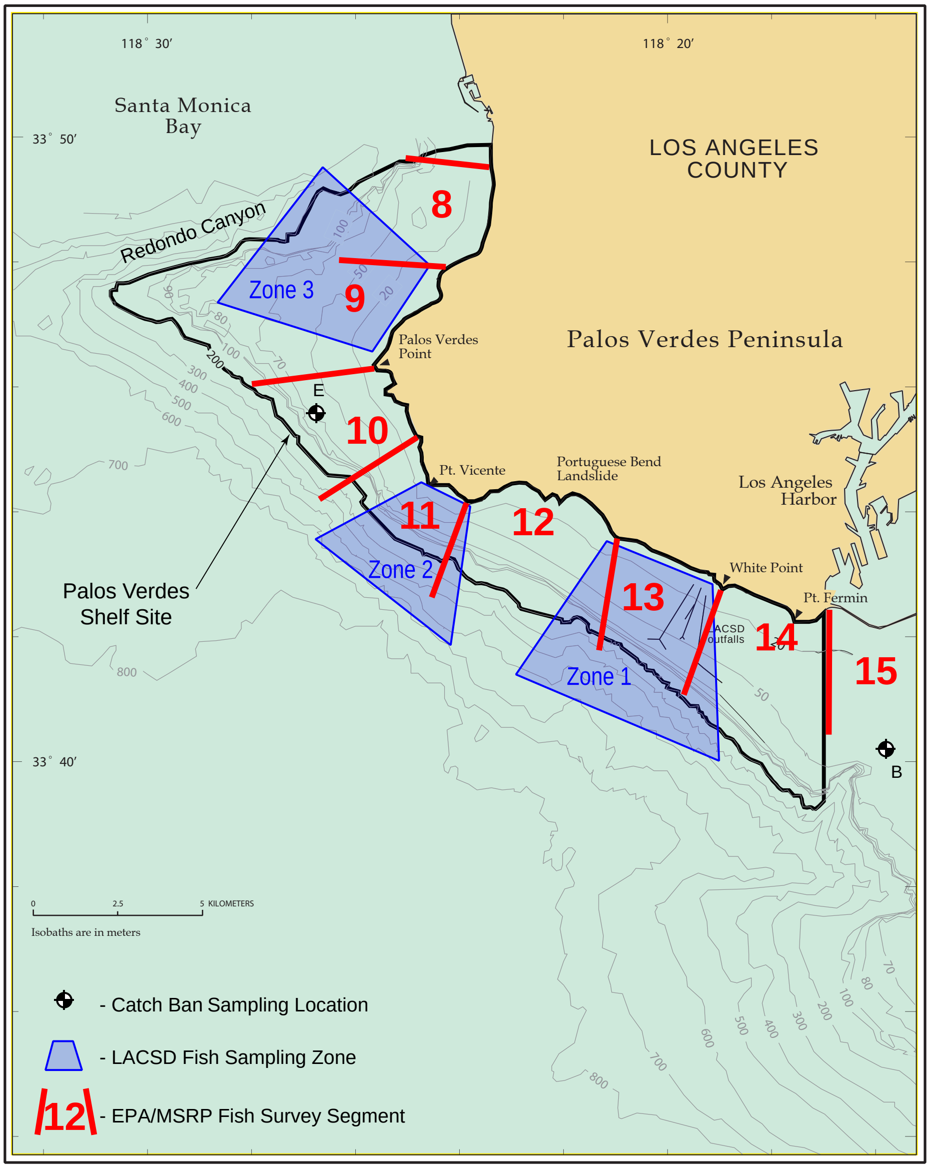

FIGURE 2-1
EPA, MSRP and LACSD 2002
Fish Sampling Locations

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- greatest concern. Therefore, the evaluation focused on these compounds. Exclusion of other chemicals detected in PV Shelf fish tissue could result in a significant underestimation of cumulative risk, but only in the event that the other chemicals bioaccumulated, were of high toxicity, were present in high enough concentrations in the fish fillet of fish typically caught by recreational and commercial fishers, and were typically eaten by fish consumers.
- *Method of Fish Preparation.* No attempt was made in the study to quantitatively evaluate the effects of fish preparation methods on human health risks, which could result in an under- or overestimation of risk. Contaminant burdens in fish could decrease by 10 to 70 percent depending on how the fish is prepared and cooked (EPA, 1993b). Conversely, the risk analysis used only contaminant concentrations found in fish tissue (i.e., skin off fish fillets). DDT and PCBs concentrations in whole fish are 8 to 10 times higher. Therefore, the risk assessment underestimates risk to populations that consume whole fish.
- *Fish Consumption Rates.* The *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* (EPA, 2000) provides a mean total fish consumption rate for the general population of 17.5 g/day for the general population recreational anglers in the United States. This rate includes fish that are caught both recreationally and commercially, and meals that are eaten at home and away from home. The median consumption rate used in the supplemental HHRE, 21.4 g/day, is based on 338 boat anglers who reported consuming fish in the previous 4 weeks (28 days) in the *Santa Monica Bay Seafood Consumption Study* (SMBRP, 1994). The RME rates of 107.1 and 115.7 g/day represent the upper 90 percent consumption rates, respectively, for all anglers and Asian anglers, from the same study.

2.2 2002/2004 Coastal Marine Fish Contaminants Survey

The levels of DDTs and PCBs vary among fish species and locations along the Southern California Bight and even in the PV Shelf Study Area. The most contaminated fish found in the region is the white croaker, a fish found in soft-bottom habitats (Allen et al. 1996). This fish feeds on worms, crustaceans, and other organisms living in the contaminated bottom sediments. White croaker is a mainstay of anglers fishing from piers, jetties, and small boats along the Southern California coast (Allen et al. 1996). Fishing statistics show that it is the third most commonly caught fish in Los Angeles County, with a high consumption rate relative to catch rate.

Fish that forage in reef habitats, such as kelp bass and some surfperch, reside in the contaminated area but do not feed on prey living in bottom sediments. In previous studies they were generally found to be less contaminated than white croaker; however, in certain locations sampled in the 1987 OEHHA survey, these species had high enough levels of DDTs and PCBs that the State included them in the fish consumption advisories (Pollock et al., 1991).

Pelagic fish, such as Pacific chub mackerel and Pacific bonito, do not reside full time in the contaminated area and do not feed on mud-dwelling organisms. Previous studies found that concentrations of DDTs and PCBs in pelagic species generally were low, and no such species were included in the State consumption advisories for southern California coastal waters. However, these previous analyses were generally limited to DDTs and PCBs; little data existing on the levels of mercury and other potential contaminants of concern across all the species targeted by subsistence and sport fishers.

2.2.1 Survey Design

The EPA and the Natural Resource Trustees jointly sponsored a multi-purpose survey of contaminants in marine fish along the Southern California Coast between Ventura and Dana Point. The objectives of the study were:

- Generate reliable information on contaminants of concern in fish caught by subsistence and sport fishers in the study area;
- Provide data to support the State's assessment of the existing commercial catch ban zone for white croaker in the vicinity of the Palos Verdes Shelf;
- Identify suitable locations for artificial reef project to restore lost fishing services to the public; and
- Support EPA's PV Shelf Superfund site remediation program.

With the assistance of a scientific review board (SRB), in 2002 the Trustees and EPA designed and implemented an extensive fish sampling and analysis program to address these objectives. The SRB included nearly two dozen public- and private-sector individuals with expertise specific to the Southern California coastal areas and experience in key technical areas necessary for the development of the plan. Overall, the Trustees and EPA implemented a plan that collected 2,676 fish, including individuals from 30 locations between Ventura and Dana Point (Figure 2-2), representing 23 different species.

Locations and species were targeted for collection based on several factors relevant to project objectives, including current fish advisories in Southern California, available data on recreational and subsistence fishing, historical fish contamination data, and considerations regarding artificial reef implementation. Most fish were collected between August and November 2002. White croaker were collected in the vicinity of the commercial catch ban in 2002, 2003, and 2004. Not all collected fish were analyzed; in some cases initial rounds of testing eliminated the need for further testing of certain species-location combination.

The laboratory analysis included five contaminants of potential concern: DDTs, PCBs, mercury, chlordane, and dieldrin. The rationale for analyzing for non-Palos Verdes Shelf related contaminants was to address the possibility that fish might have high levels of other contaminants that could affect restoration decision-making and/or management of the fishery. Factors in the contaminant selection process included bioaccumulation, persistence, and regional detection history.

For most organochlorine contaminant analysis, i.e., PCBs, DDTs, chlordane, and dieldrin, contaminant levels were measured for each individual fish, with a sample size of ten fish per species-location combination. Transient pelagic species, e.g., Pacific chub mackerel, Pacific sardine, Pacific barracuda, expected to have lower, more uniform contaminant levels relative to resident species, as well as a few other species, were analyzed as composites, generally of ten fish. For mercury analysis, all species were initially analyzed as 10-fish composites due to expected lower variability within a species. Where composite results indicated that spatial differences in mercury concentrations might be significant within a species, individual fish were subsequently analyzed for mercury.

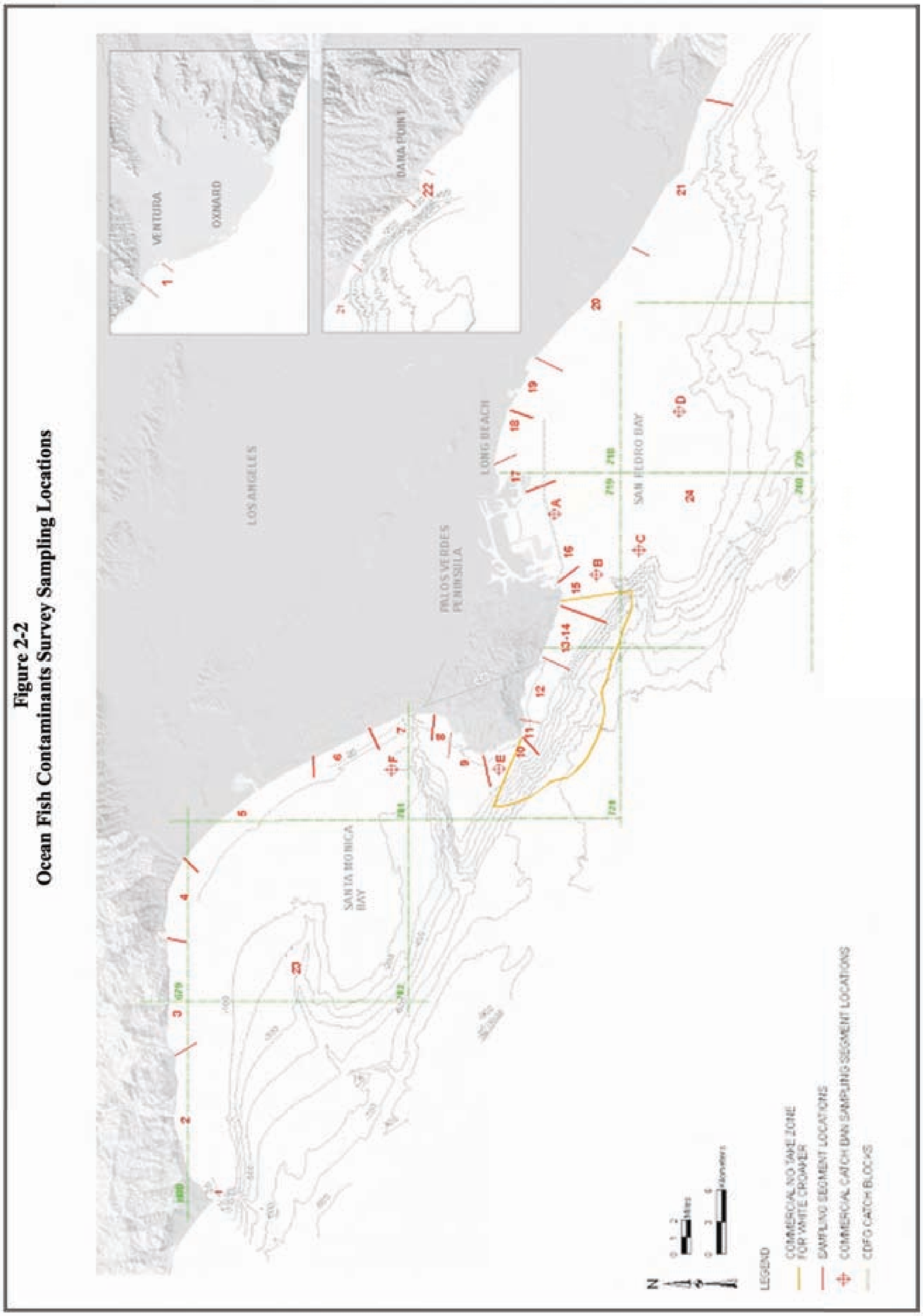

Figure 2-2
Ocean Fish Contaminants Survey Sampling Locations

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2.2.2 Summary of Data

Overall, concentrations of PCBs, DDTs, and chlordane varied broadly throughout the species and segments. In contrast, very few fish had detectable concentrations of dieldrin. Concentration data discussed below are expressed as mean concentrations for a given species and segment, which includes up to ten fish. For each contaminant, the range and distribution of mean concentrations are based on a log-normal distribution of mean concentrations, divided into quartile ranges (the "lower range", up to the 25th percentile; the "interquartile range" from the 25th to the 75th percentile; and the "higher range" above the 75th percentile). The designation of "higher" and "lower" indicate the relative contaminant levels in groups of fish.

DDTs

For DDTs, the lowest mean concentration was found in opaleye from King Harbor (segment 7, 0.9 ppb) and the highest mean concentration in white croaker from the ocean side of the Los Angeles breakwater near Cabrillo Pier (segment 15, 3180 ppb). The interquartile range of the species/segments was roughly between 60 and 200 ppb. Species most commonly found in the higher quartile range for DDTs included white croaker, kelp bass, California scorpionfish, and barred sandbass. Species that were consistently below the 75th percentile included black croaker, California corbina, California halibut, jacksmelt, Pacific barracuda, Pacific chub mackerel, queenfish, shovelnose guitarfish, surfperch, white seabass, and yellowfin croaker.

PCBs

Mean concentration of total PCBs varied broadly among species and locations, but less so that DDTs. The lowest mean PCB concentration was found in opaleye from the Seal Beach area (segment 19, 3.06 ppb), while the highest mean PCB concentration was found in white croaker from the ocean side of Cabrillo Pier (segment 15, 347 ppb). The inter-quartile range for mean PCB concentrations was roughly between 20 and 70 ppb. No species had mean PCB concentrations consistently above the inter-quartile range throughout the area. Species that were consistently below the 75th percentile were black croaker, California corbina, California halibut, California sheephead, jacksmelt, Pacific barracuda, Pacific chub mackerel, queenfish, rockfish, shovelnose guitarfish, water-column-feeding surfperch, white seabass, and yellowfin croaker.

Chlordane

The mean concentration of chlordane also varied broadly among species and locations. Jacksmelt from inside the Los Angeles breakwater at Cabrillo Pier (segment 16, 0.18 ppb) had the lowest mean concentration, while the highest mean concentrations were found in white croaker from Santa Monica Bay (segment 5, 71 ppb). The inter-quartile range for mean chlordane concentrations was 4.27 to 11.2 ppb. This range represented most species and segments.

Summary for Organochlorines

With few exceptions, the spatial and interspecies variability in organochlorine concentrations found in this survey were largely consistent with those from previous surveys. White croaker was generally found to be the most highly contaminated species. Fish caught in locations closest to the Palos Verdes Shelf, i.e., southern Santa Monica Bay, Palos Verdes Shelf, San Pedro Bay, tended to have higher contaminant levels than those caught further north or south, i.e., Ventura County or Orange County. Variation in organochlorine concentrations did not follow a clear pattern of higher concentrations in fish that occupy higher trophic levels or larger sizes.

In most cases, DDT concentrations were higher than PCB concentrations, particularly close to the Palos Verdes Shelf. This DDT/PCB ratio is consistent with the reported sediment concentrations of DDTs and PCBs, which have approximately a 10 to 1 ratio in the sediments (LACSD, 2006). Opaleye were an exception to this general trend, and were consistently found to have higher PCB concentrations than DDTs. The PCB concentrations in opaleye were similar to those of other reef/surf zone fish species, but opaleye DDT concentrations were much lower. While opaleye is the only herbivore among the species analyzed, it is not clear if this explains the lower DDT concentrations.

Mercury

Mean concentrations of mercury were lowest in Pacific sardine from inside the Los Angeles Breakwater at Cabrillo Pier (segment 16, 18.6 ppb) and highest in black croaker from inside the Los Angeles breakwater (commercial catch ban segment A, 582 ppb). Interestingly, while black croaker mean organochlorine concentrations were at or below averages found in other species, black croaker had the three highest mean mercury concentrations. The inter-quartile range (based on log-normal distribution) for average mercury concentrations was roughly 75 to 180 ppb. Overall, mean concentrations of mercury above the interquartile range were found in 11 species (barred sandbass, kelp bass, black croaker, California scorpionfish, Pacific barracuda, sargo, California halibut, rockfish, shovelnose guitarfish, white croaker, and white seabass). Ten of the species with mean mercury concentrations in the higher range did not have any samples that were in the lower range, suggesting a more species-dependent pattern for mercury than was found for the organochlorines. Species that were consistently either “intermediate” or “lower” in mean mercury concentrations were benthic-feeding surfperch, California corbina, California sheephead, jacksmelt, opaleye, Pacific chub mackerel, queenfish, topsmelt, water-column feeding surfperch, and yellowfin croaker. Variation in mercury concentrations among the fish collected in this survey appears to be driven by differences between species and fish size, as has been generally found in other surveys. No consistent hot spots for mercury were identified. Larger, higher trophic level species (kelp bass, barred sandbass) were generally higher in mercury concentrations than smaller, lower trophic level species. Pacific chub mackerel had some of the lowest mercury concentrations of all the species analyzed.

Whole Fish Analysis

In addition to the skin-off fillet data described above, multiple body components were analyzed for a subset of kelp bass and white croaker. These results enabled the estimation of quantitative relationships between contaminant concentrations in the different body components, as well as the total contaminant levels in whole, ungutted fish. These relationships may be specific to particular species and locations, as well as to specific contaminant types and levels, e.g., organic contaminants, which may be higher in lipid-rich tissues, and mercury, which may be higher in muscle-rich tissues. An analysis of covariance was used to quantify relationships between contaminant levels (PCBs, DDTs) in three body components (skin-on fillets, viscera, and “remainder”) and skin-off fillets. The effect of species (kelp bass, white croaker) on these relationships also was investigated.

All of the body component concentrations were significantly correlated with the fillet concentrations, with higher fillet concentrations associated with higher component concentrations. In most cases, the relationship between fillet concentration and the concentration in other body parts was not significantly affected by species. Skin-on fillets had the lowest increase in PCB and DDT concentrations compared to skin-off fillets, averaging approximately 6 to 7 times the DDTs and PCBs found in associated skin-off fillets. Viscera and "remainder" samples had similar, but greater, increases in PCB and DDT concentrations compared to skin-off fillets, averaging approximately 11 to 17 times the DDTs and PCBs found in associated skin-off fillets, depending on contaminant and component.

Component concentration data also were used to develop equations that estimate the PCB or DDT concentration in a whole, ungutted fish based on the concentration in a skin-off fillet. First, equations were developed to estimate the PCB or DDT concentration in the three additional body components (skin-on fillets, viscera, and "remainder") of a fish based on its fillet concentration. These concentrations, in combination with estimated component proportions (based on the laboratory weight of each of the four components) were then summed to estimate concentrations in a whole, ungutted fish. The results suggest that whole fish have concentrations of PCBs and DDTs that are generally 8 to 10 times higher than the fillet concentrations.

2.2.3 LACSD vs. Fish Survey Comparison

The Ocean Fish Survey and the 2002 LACSD annual monitoring program collected kelp bass and white croaker from comparable locations on Palos Verdes Shelf (Figure 2-1). Fish survey segment 13-14 is similar to LACSD's Zone 1, segment 12 is similar to LACSD's Zone 2, and segment 9 is similar to LACSD's Zone 3. Combined, these collections allowed for a comparison of two collections of kelp bass from segment 13-14 to collections from LACSD's Zones 2 and 3. This analysis revealed no significant effects of body size or location among the four collections (segments 13-14, Zones 1, 2, 3) for either DDTs or PCBs. Kelp bass from the region encompassing southern Santa Monica Bay to San Pedro Bay outside the Los Angeles breakwater had similar concentrations of PCBs and lower, but comparable, concentrations of DDTs.

For white croaker, concentrations of DDTs and PCBs were an order of magnitude lower than those from comparable locations in the 2002 LACSD survey conducted on the PV shelf. The difference in contaminant results between LACSD's Zone 1 collection in 2002 and the fish surveys segment 13-14 is particularly striking, given the proximity of the two stations (Figure 2-3). Various potential drivers for this pattern were explored: (1) interlaboratory variability in contaminant results; (2) seasonal differences in contaminant concentrations; (3) general size differences in collected fish; and (4) small-scale differences in habitat and/or location.

The first three explanations were eliminated based on the study of interlaboratory variability and the timing and size of the fish collected in the two studies. Differences between the two laboratories, while potentially responsible for a two-fold difference in concentration results, could not explain the orders-of-magnitude difference between LACSD Zone 1 and segment 13-14. Both collections were made within a month of each other in fall 2002, so it is unlikely that timing drove the differences in contaminant results between the two collections. White croaker collected from LACSD Zone 1 were significantly smaller than those collected from segment 13-14. However, in order for this size difference to drive contaminant values, an inverse relationship between size and contamination level in the fish is necessary. No statistically significant inverse relationship between organochlorine concentrations and size was found for white croaker, so it is unlikely that size differences are the source of the differences in PCB and DDT concentrations.

The LACSD Zone 1 and segment 13-14 collections have two key differences in microhabitat: separation by depth differential and by a hard substrate. The LACSD Zone 1 collection was made from deeper water than the segment 13-14 collection (47 m versus 25 m). Sediment in the deeper areas in the PV Shelf have higher organochlorine concentration than the shallow areas (LACSD 2006). Thus, if particular white croaker spent the majority of its time in either deep or shallow water, the shallow-water associated individuals would tend to have lower concentrations of organochlorines than the deep-water-associated individuals. Second, the two collections were made in different areas relative to the JWPCP White Point outfalls. The LACSD Zone 1 collection was located near the pilot capping cells, west of the outfall pipes, where higher sediment concentrations of PCBs and DDTs exist. The segment 13-14 collection was made inshore and on the east side of the outfalls, away from the effluent-affected sediment deposit, where sediment concentrations are much lower (LACSD, 2006). White croaker will actively avoid hard substrates under some conditions (Allen, 2001), so the outfall pipes may act as a barrier to along-shore movement of white croaker.

To test for differences between fish collected at different depths and sides of the outflow pipes, LACSD conducted a revised sampling survey in 2005. This survey collected ten white croaker from the traditional Zone 1 location, ten white croaker from the west side of the outfalls in 25 meters of water, and ten white croaker on the east side of the outfalls in 25 meters of water, close to where the original segment 13-14 white croaker were collected (Figure 2-4). LACSD captured and filleted these fish using the same protocol used in the fish survey. These 30 white croaker were analyzed for DDTs and PCBs at the LACSD laboratory.

The concentrations of PCBs and DDTs in the white croaker collected off of White Point in 2005 by LACSD were consistent with the hypothesis that the more highly contaminated fish reside on the west side of the outfalls. Although concentrations of PCBs and DDTs were greater in the deeper location, the difference between deep and shallow locations west of the outfalls was not significant. However, the concentrations of DDTs and PCBs on the east side of the outfalls were significantly lower than either location west side of the outfalls, and matched the concentrations found in white croaker in segment 13/14 in 2002. The results from LACSD's 2005 sampling suggest differences between the east and west sides of the outfalls, and raises questions regarding home ranges and feeding patterns of white croaker.

LACSD Fish Contaminant Trend Data

The difference in contaminant concentrations between white croaker caught on PV Shelf for the EPA/MSRP survey and by LACSD in 2002 was striking. The 2005 comparison found concentrations in white croaker east of the outfalls were similar to the concentrations measured in 2002. While the contaminant concentrations were higher west of the outfalls, the LACSD white croaker Zone 1 catch in 2005 had contaminant concentrations an order of magnitude lower than in 2002: average DDT concentration 33,740 ppb in 2002 vs. 3,850 ppb in 2005. Table 2-1 shows LACSD fish trend data since 1999. DDT concentrations in Zone 1 white croaker are the lowest recorded by LACSD. However, as the table shows, vacillations in concentrations are not uncommon.

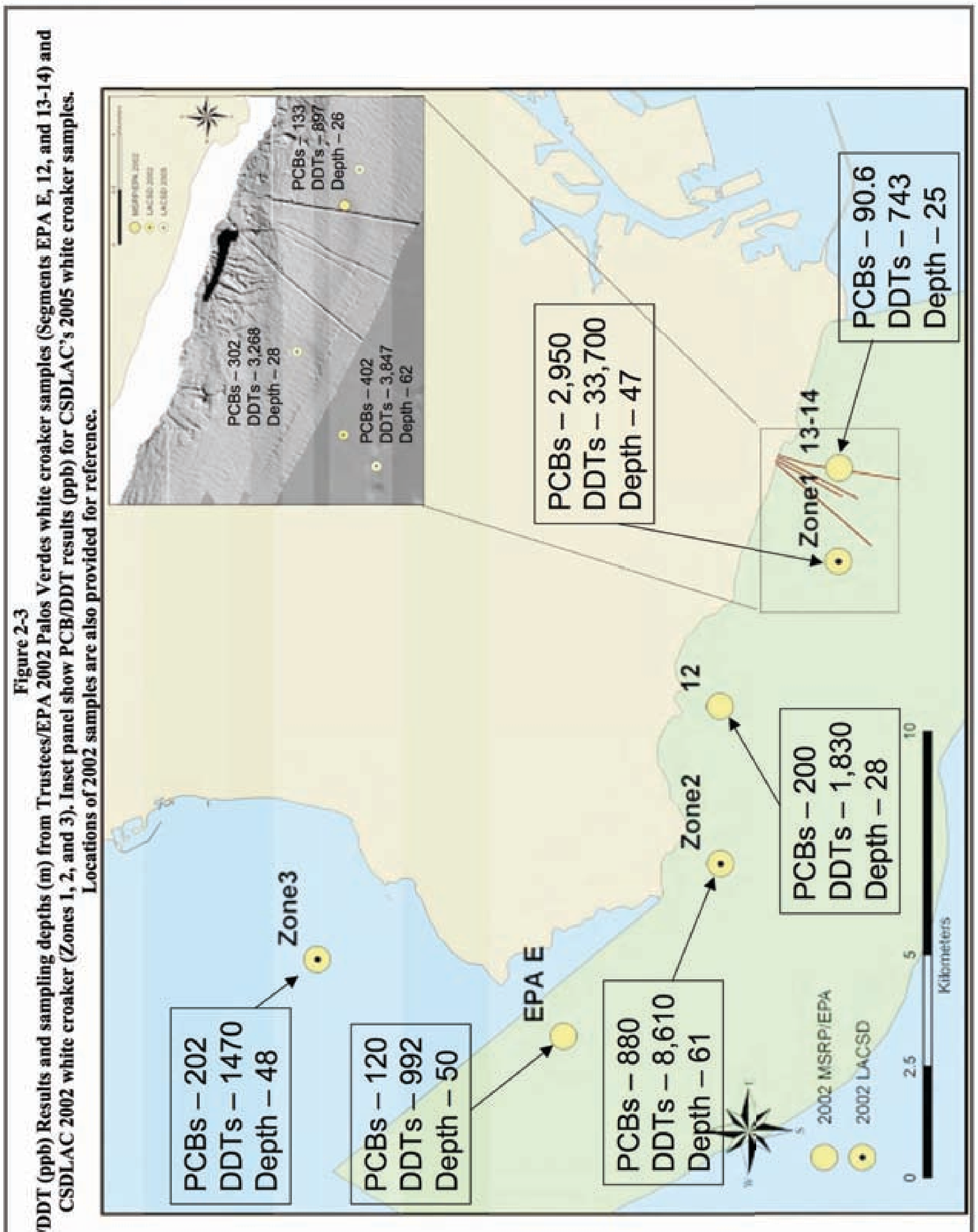

Figure 2-3 from *EPA/MSRP Contaminant Fish Survey* (June 2007)

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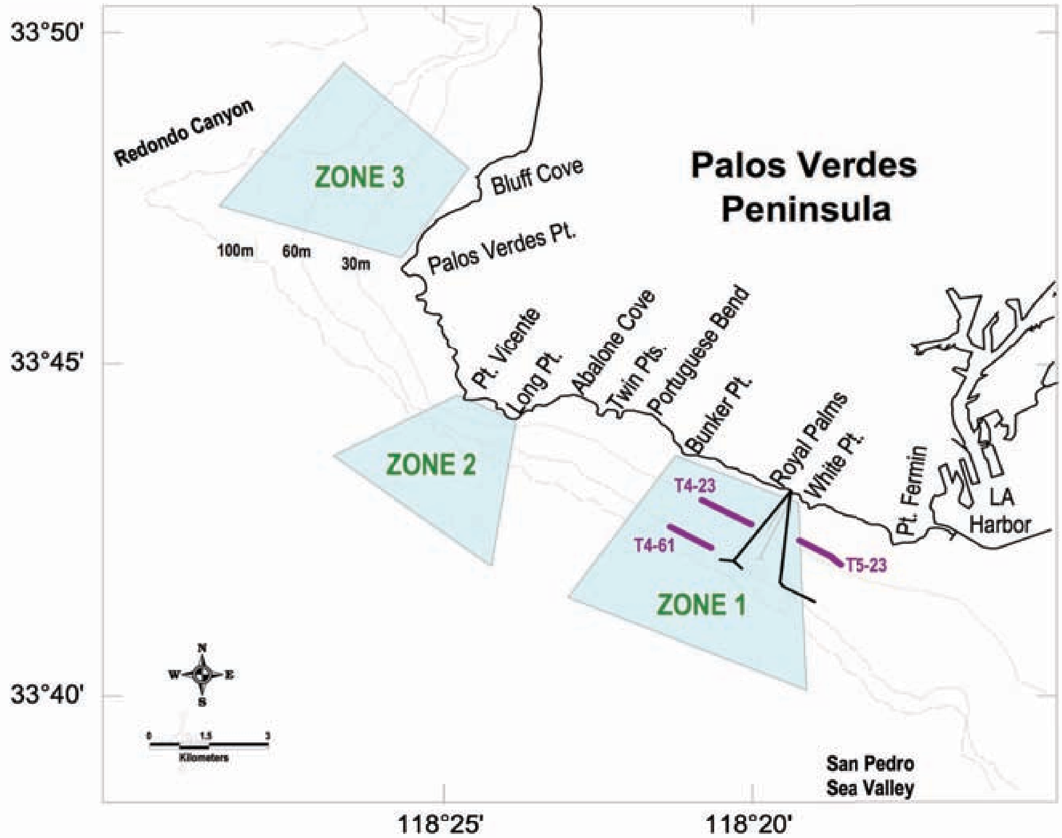
Figure 2-4 Palos Verdes white croaker contaminant bioaccumulation sampling locations for 2005



Zone 1 - Royal Palms (White Point) to Bunker Point.

Zone 2 - Long Point to Point Vicente.

Zone 3 - Palos Verdes Point to Bluff Cove.

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Table. 2.1 Trend in White Croaker Contaminant Concentrations (g/kg), LACSD Data

Year	Zone 1		Zone 2		Zone 3	
	DDTs	PCBs	DDTs	PCBs	DDTs	PCBs
1999	26,410	1,600	6,010	680	4,250	20
2001	25,390	1,880	5,450	540	2,510	140
2002	33,740	2,950	8,610	880	1,470	30
2004	10,820	1,190	7,050	920	1,610	80
2005	3,850	400	NA	NA	NA	NA
2006[a]	3,880	440	2,740	350	1,550	190

[a] In 2006, LACSD's analysis changed from Aroclors to PCB congeners and from single fish to composites from each zone.

2.3 Ecological Risk Assessment

An Ecological Risk Assessment (EcoRA) was conducted for the PV Shelf site in 2003 (CH2M Hill, 2003). The EcoRA corresponds to the baseline EcoRA as described in EPA guidance, *Ecological Risk Assessment Guidance for Superfund Sites: Process for Designing and Conducting Ecological Risk Assessments* (EPA, 1997), and a Validation Assessment as described by DTSC guidance, *Guidance for Ecological Risk Assessment at Hazardous Waste Sites and Permitted Facilities* (DTSC, 1996).

2.3.1 Purpose and Scope of the Ecological Risk Assessment

The EcoRA was prepared in 2003 to evaluate ecological risk through identification and characterization of existing concentrations of contaminants at the site, and potentially complete exposure pathways to ecological receptors. The EcoRA summarized data collected throughout the Southern California Bight (SCB) with an emphasis on the PV Shelf site, from as many different sources as was practical, for the period of 1990 to 2002 (birds were summarized for 1985 to 2000). The EcoRA relied on work completed for the Natural Resource Damage Assessment, including a Food Web/Pathways Study (HydroQual, Inc., 1994). The EcoRA described the risk from DDTs and PCBs to marine biota that inhabit or may use the PV Shelf site and the SCB. These biota include benthic invertebrates, benthic and water-column fish, brown pelicans, double-crested cormorants, bald eagles, peregrine falcons, and sea lions and their pups. This assemblage of receptors represents the marine food web from contaminated sediments up through invertebrate and vertebrate prey to wide-ranging, higher order consumers.

2.3.1.1 Exposure Assessment

Exposure to contaminants of potential ecological concern (COPECs) was evaluated in multiple ways, depending on the receptor and available data. Internal exposure, in the form of measured and estimated concentrations of COPECs in tissues, was considered for invertebrates, fish, birds, and mammals. External exposure, defined as contact with COPECs in environmental media (sediment and water), was considered for biota directly exposed to the media in which they live, such as benthic invertebrates and fish. In addition to measured and estimated internal and external exposures, a food exposure model for birds and marine mammals was used to estimate the daily dosages of COPECs from diet. The model required knowledge of dietary composition, ingestion rates, and foraging ranges as compared to the modeled geographic distribution of fish contamination. The bird and sea lion exposure model was based on the establishment of regression relationships between COPEC concentrations in sediment and fish tissues at locations throughout the SCB. The sediment-to-fish regressions were then used to estimate potential concentrations of COPECs in fish tissue for any SCB location. Overlapping concentrations in a mixed dietary fish assemblage within their foraging range yielded an estimated daily dosage of COPECs for the bird and sea lion receptors. Peregrine falcon exposure estimates required the additional step of estimating tissue concentrations in their seabird diet (as derived from estimated fish concentrations in the seabird diet). Bald eagle exposure required a combination of exposure through dietary fish as well as sea lion carcasses and seabirds (with tissue concentrations, in turn, as estimated from their fish diets). Sea lion pup exposures were estimated from maternal milk, as estimated from maternal dietary exposure and the use of literature-derived equations for transfer of contaminants to milk.

The food web model concluded that the SCB did not exceed DDT screening values for marine mammals but did exceed screening values for birds and fish. PCBs exceeded screening values for sea lion pups and double-crested cormorants, and to a lesser extent brown pelicans and peregrine falcons, but not fish.

2.3.1.2 Food Web Exposure Model Update

The food web model discussed in the 2003 EcoRA incorporated data for the period of 1990 to 2001. In 2006, the food web model was updated with more recent sediment and fish data from 2001 to 2005, i.e, LACSD sediment core data (2001 and 2003) and fish tissue data (2004 and 2005), and MSRP/EPA fish tissue data (2002). The updated food web model lacked data to credibly model COC uptake beyond the local, bottom-feeding fish of PV Shelf. Collaboration with the Natural Resource Trustees on data collection and analysis is necessary to update existing food web models of the Southern California Bight.

Recently, the SCCWRP completed a study of COCs in pelagic fish that form the principle diet of piscivorous birds and sea lions (Jarvis et al., 2007). Although concentrations of DDTs and PCBs have dropped dramatically since the 1980s (see Table 2-2), DDT concentrations continue to exceed risk screening values for northern anchovy, Pacific sardine, and Pacific chub mackerel throughout the SCB. Virtually none of the fish sampled exceeded wildlife risk screening values for PCBs. Another recent study of pinnipeds (Blasius and Goodmanlowe, 2008) found concentrations of DDTs and PCBs in California sea lions to have dropped over the 12-year period of the study (1994 to 2006). However, concentrations of DDTs and PCBs in California sea lions and Pacific harbor seals continue to be among the highest values reported worldwide for marine mammals.

2.3.2 Bioaccumulation Modeling

The FS uses a food web model developed by HydroQual (rev1997) for the Natural Resources Damage Assessment (NRDA) to develop relationships between concentrations of DDTs and PCBs in sediment and in white croaker. HydroQual's bioaccumulation model was developed to determine whether the sediment of the PV Shelf constituted the dominant source of the DDE and PCBs found in local fish. The model consisted of mechanistic equations for bioenergetics and toxicokinetics that were parameterized using a combination of literature-derived and site-specific data. The similarity of the field-measured and model-calculated fish tissue concentrations supported the contention that the sediment of the shelf constituted the dominant source of DDE and PCBs to white

Table 2-2: Comparison of total DDT and total PCBs measured in pelagic forage fishes and squid of the Southern California Bight in the early 1980s and 2003-2004 (Southern California Costal Water Research Project 2007 Annual Report – Chlorinated hydrocarbons in pelagic forage fishes and squid of Southern California Bight, Jarvis et al.)

Species/ Location	Year	Composite Type	*n*	Total DDT (µg/mg wet wt)		Total PCBs (µg/mg wet wt)	
California market squid				Mean	SD	Mean	SD
Coastal	1980-81[a]	Mantle	3	10.0	10.0	10.0	9.0
SCB	2003-04[b]	Whole	28	0.8	1.2	0.0	0.1
Northern anchovy							
Coastal	1980-81[a]	Muscle	5	47.0	33.0	8.0	9.0
LA/LB Harbor	1980[c]	Muscle	5	121.0	31.0	98.0	21.0
SCB	2003-04[b]	Whole	24	60.6	38.3	3.1	5.1
Pacific chub mackerel							
Coastal	1980-81[a]	Muscle	6	130.0	145.0	26.0	22.0
Santa Monica Bay	1981[d]	Muscle	5	57.0	37.0	15.0	7.0
Palos Verdes	1981 [d]	Muscle	5	44.0	__	12.0	12.0
Laguna Beach	1981 [d]	Muscle	1	129.0	86.0	34.0	22.0
SCB	2003-04[b]	Whole	13	41.4	40.2	2.3	3.1
Pacific Sardine							
Coastal	1980-81[a]	Muscle	5	484.0	112.0	105.0	40.0
SCB	2003-04[b]	Whole	34	34.1	28.7	1.6	2.5

a Schaefer et al. 1982
b Jarvis et al. 2007
c Mearns and Young 1980
d Gosset et al. 1983

croaker. The same model framework was extended to include birds and mammals as part of the NRDA and, as stated above, formed the basis for the exposure assessment for birds and mammals in the Ecological Risk Assessment for PV Shelf (CH2M Hill, 2003). The model is included in Appendix C along with a memorandum showing the calculations used to apply the model to current PV Shelf conditions. The bioaccumulation model provides estimates of white croaker/sediment relationships for COCs with fish tissue concentrations expressed on a lipid basis (mg/kg lipid) and sediment concentrations on an organic carbon basis (mg/kg organic carbon). The relationships were converted from lipid-normalized fish tissue concentrations to wet weight-based contaminant concentrations in skin-off fillets (mg/kg wet weight) by multiplying the model relationships by an estimate of the average lipid content of skin-off fillets of white croaker.

Fish tissue concentrations of 490 ppb DDT and 80 ppb PCBs represent a 1 x 10^{-5} risk for the recreational angler consumption rate of 21.4 g/day (i.e., central tendency exposure). The carbon-normalized sediment concentration that achieves these values in white croaker is 28 mg/kg organic carbon (OC) DDT and 8 mg/kg OC PCBs in sediment. A comparable 1 x 10^{-5} risk using RME consumption rates (i.e., 116 g/day) would be 2.3 mg/kg OC DDT and 0.7 mg/kg OC PCBs in sediment. It is unclear whether these sediment concentrations are achievable since they are near or below background. In the interim, a less stringent 1 x 10^{-4} risk is proposed for the RME value, which translates to fish tissue concentrations of 400 ppb DDTs and 70 ppb PCBs. Sediment goals associated with the 1 x 10^{-4} risk using RME consumptions rates would be 23 mg/kg OC DDT and 7 mg/kg OC PCBs.

The model correlates lipid content in fish to carbon-normalized sediment data. The model used lipid values from the 2002/2004 Coastal Marine Fish Contaminants Survey discussed in section 2.2. The survey measured a range of lipid concentrations in white croaker; the fish analyzed from PV Shelf (segment 13/14) did not have the highest lipid content. The bioaccumulation model provides a correlation between contaminant concentrations in sediment and white croaker that would need further refinement to accurately predict contaminant levels in fish. EPA and NOAA are planning a white croaker tracking study to learn more about white croaker feeding patterns on PV Shelf that will allow EPA to refine the biota to sediment relationship. Data from the white croaker tracking study will contribute to the development of the final remediation plan.

2.4 Predictive Model of Natural Recovery

As part of the Natural Resource Damage Assessment of the Palos Verdes margin, the U.S. Geological Survey (USGS) and its co-investigators were asked to provide a quantitative prediction of the fate of the effluent-affected (EA) sediment deposit and associated contaminants, DDTs and PCBs, that had accumulated on the Palos Verdes Shelf and slope. The research specifically addressed the question of the fate of the contaminated sediment under natural recovery conditions. The expert report (Drake et al., 1994), produced in 1994, used data collected in 1992 and earlier. A supplement to the report was issued in 1996 (Sherwood et al., 1996) using additional sediment data from 1991 and 1993. In 2000, the USGS revisited natural recovery predictions using new data to further refine the predictive model developed in 1994 (Sherwood et al., 2002). These reports are included as appendix B.

The reports concluded that the majority of the buried EA deposit north of the outfalls would most likely stay buried. Episodic events, primarily winter storms, would winnow out surface contamination associated with fine, effluent-affected sediment and bring in uncontaminated sediment, causing contaminant concentrations to drop in the short-term, i.e., the next ten years. The model indicated surface concentrations most likely would increase temporarily near the outfalls as sediment sources lapsed. However, surface contaminant concentrations would drop again below 1 mg/kg as new, uncontaminated material is added to the system.

Data collected from 1995 through 2005 have confirmed the predictive value of the model and have provided additional material to further refine the model. The following sections discuss the natural recovery model and more recent studies.

2.4.1 Summary of the 1994 Predictive Modeling of Natural Recovery

Data collected in the early 1990s for the Natural Resource Damage Assessment as well as available background information were used to develop and calibrate a one-dimensional numerical model of resuspension and transport of sediment in the near-bottom waters of the shelf, and a one-dimensional model of contaminant profiles in the bed. These models provided a mechanism to predict rates of natural recovery. The models used two LACSD monitoring sites, 3C and 6C, as representative of the EA sediment deposit far field and near field to the source, i.e., White Point outfalls (see Figure 2-5). Both of these sites are on the 60-m isobath and have long records of measurements of p,p'-DDE (hereinafter referred to as DDE) concentrations and other properties in the EA sediment deposit. Sediment cores from these two sites provided an important time-series that yielded reliable information on changes in sedimentation rates and contaminant profiles for the period 1970 to 1991.

2.4.1.1 Model of Processes Affecting Inventory and Distribution of DDE

The model identified the following factors as those that influence the ultimate fate of the reservoir of DDT and PCBs in the effluent-affected sediment:

1. burial or erosion caused by either wave/current or gravity-induced sediment transport and/or variation in sediment supply;
2. biological activities that cause solid-phase mixing of the bed sediment and associated contaminants, and changes in particle characteristics;
3. resuspension of contaminated sediment and subsequent loss of contaminant to overlying water via desorption;
4. in situ desorption of contaminant to porewater in the bed, followed by molecular diffusion to the overlying sea water, and/or loss through bed irrigation processes;
5. contaminant losses or gains due to biological or chemical degradation or transformation; and
6. biological uptake of contaminants and removal (via migration or predation).

At the time of the 1994 report, DDT and PCBs were considered resistant to degradation by natural biological and chemical processes (Moore and Ramamoorthy, 1984), therefore, contaminant losses via those mechanisms were not considered. Neither was loss via biological uptake considered in the report. The processes that were factored into the model are discussed below.

Sediment Erosion and Deposition

The rate of sediment accumulation or erosion at a given location on the shelf was an important input parameter for the model. Rapid burial of the historical DDT- and PCB-contaminated sediment beneath a thick layer of clean sediment would isolate the contaminant, whereas sediment erosion would lead to increased surface concentrations, either through direct physical exposure or via increased biodiffusive flux, at least until the contaminated layer eroded completely. Sedimentation rate is determined by the balance between sediment supply and the capacity of currents to transport and disperse the sediment that is delivered. Whereas it is generally believed that the capacity of waves and currents to transport sediment varies little over decades on the PV Shelf, the supply of sediment particles to the shelf from the two major sources, the JWPCP outfalls and the Portuguese Bend landslide (PBL), has varied markedly over time.

In the mid-1950s, the supply of sediment to the PV Shelf increased approximately an order of magnitude above natural background rates owing to erosion from the PBL at the northwest end of the shelf and the discharge of particulates by JWPCP diffusers at the southeast end of the shelf. Sedimentation rates reflected these large new local sources, reaching values as high as 2 cm/yr at 6C and about 1 cm/yr at 3C in the 1970s (Drake, 1994). However, the high sedimentation rates observed in the 1970s and 1960s on the outer shelf were not sustained in the 1980s, despite a substantial increase in the rate of sliding of the PBL. Sedimentation rates on the outer shelf, i.e., at 3C and 6C, declined to less than 50 percent of previous values. This decrease is correlated with the reduced discharges of particulates from the JWPCP diffusers in the late 1970s and 1980s. Strong control of sedimentation rate by the diffuser system was especially apparent at the nearfield site 6C.

USGS studies (Kayen, 1994) indicate that a portion of that the PBL sediment resides on the inner and middle parts of the shelf (<60 m depths) and is being gradually reworked by waves and currents and transferred to deeper water and downstream areas to the northwest. This sediment will continue to supply particles to outer shelf and slope sites at relatively high rates, compared with estimated pre-effluent and pre-PBL rates, for some years. Figure 2-6 contrasts the sediment bed of the northwest area of the Shelf to the southeast area.

Bioturbation

Typically, a large number of animals live on or within the seabed on continental shelves, and their normal activities cause bed mixing, which strongly affects the preservation of strata and the distribution of particles and associated chemical compounds within the seabed. The impacts of these activities fall into two broad categories, bed mixing through bioturbation and alterations of the sediment properties, e.g., bulk density and particle size distribution changes. Normal activities of the benthic organisms include locomotion over and within the seabed, burrow excavation, tube building and deposit feeding, i.e., ingestion of particles and assimilation of organic compounds. Figure 2-7 shows small organisms typical of those that inhabit the shelf floor—brittle stars and sea urchins.

Many of the organisms displace particles in all directions within the bed, resulting in a diffusive bioturbation that is usually most intense in a near-surface layer but that can extend, at much reduced rates, tens of centimeters into the bed. If concentration gradients of particle-associated materials exist in the bed within the zone of biodiffusion, the mixing will cause a flux of that material, i.e., a net transport, upward or downward depending on the direction of the gradient. The effluent-affected sediment deposit on the PV margin contains a buried horizon of DDT- and PCB-rich sediment, and therefore biodiffusive mixing tends to transport more contaminant upward, resulting in a net gain of contaminant in the surficial sediment.

Rates of solid-phase biodiffusion in the surface layer (5-10 cm depth) were measured at shelf sites from the JWPCP diffusers to the Redondo shelf using Thorium 234 (^{234}Th) profiles in sediment cores collected in 1992 and 1993 by Wheatcroft and Martin (1996). Their data demonstrate considerable variation in bioturbation rate along the 60-m isobath. Biodiffusivity values ranged from 1 to 89 cm^2/yr, with most values in the 5 to 25 cm^2/yr range (Wheatcroft and Martin, 1996). Low to moderate mixing rates occurred near the diffusers, and substantially larger mixing rates occurred to the northwest, where the benthic communities are known to be more balanced and less influenced by the current JWPCP discharges. These data were used to determine the biodiffusion coefficients in the numerical model.

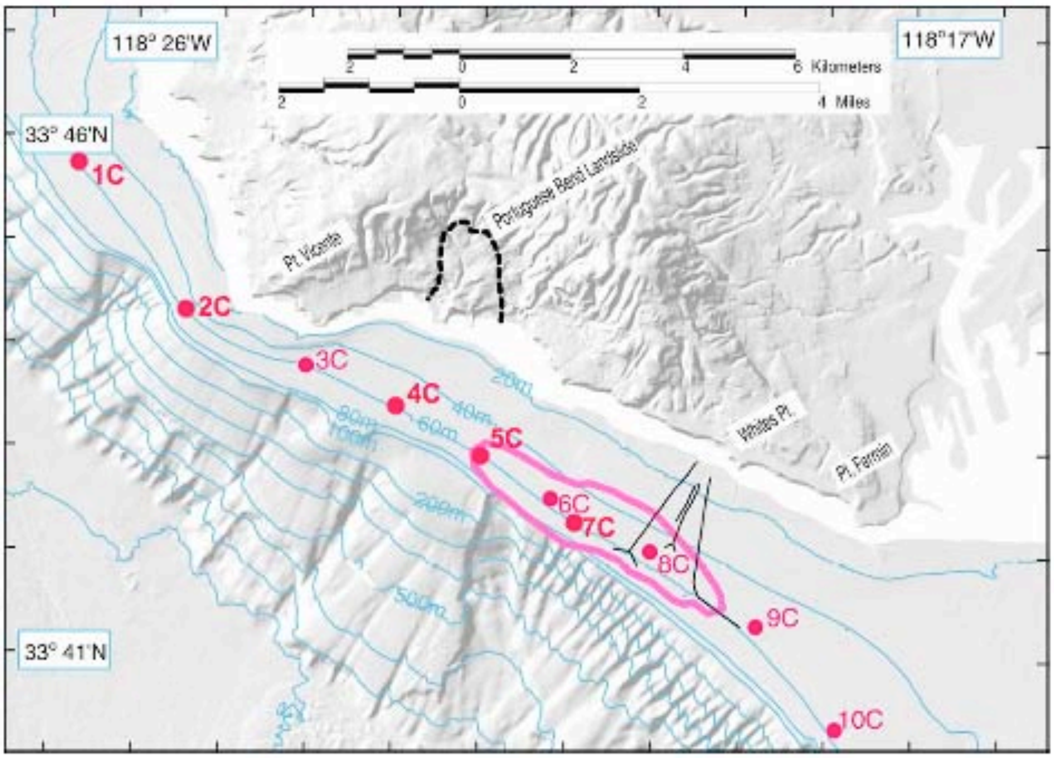

Figure 2-5: Palos Verdes Shelf, LACSD stations along 60 m isobath (USGS, 2002)

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NW-16
A

SE-41
B

Figure 2-6. Examples of bedforms (A) and shell hash (B) in plan-view images observed over the PV Shelf, resulting in physical changes in surface topography (SAIC, 2005)

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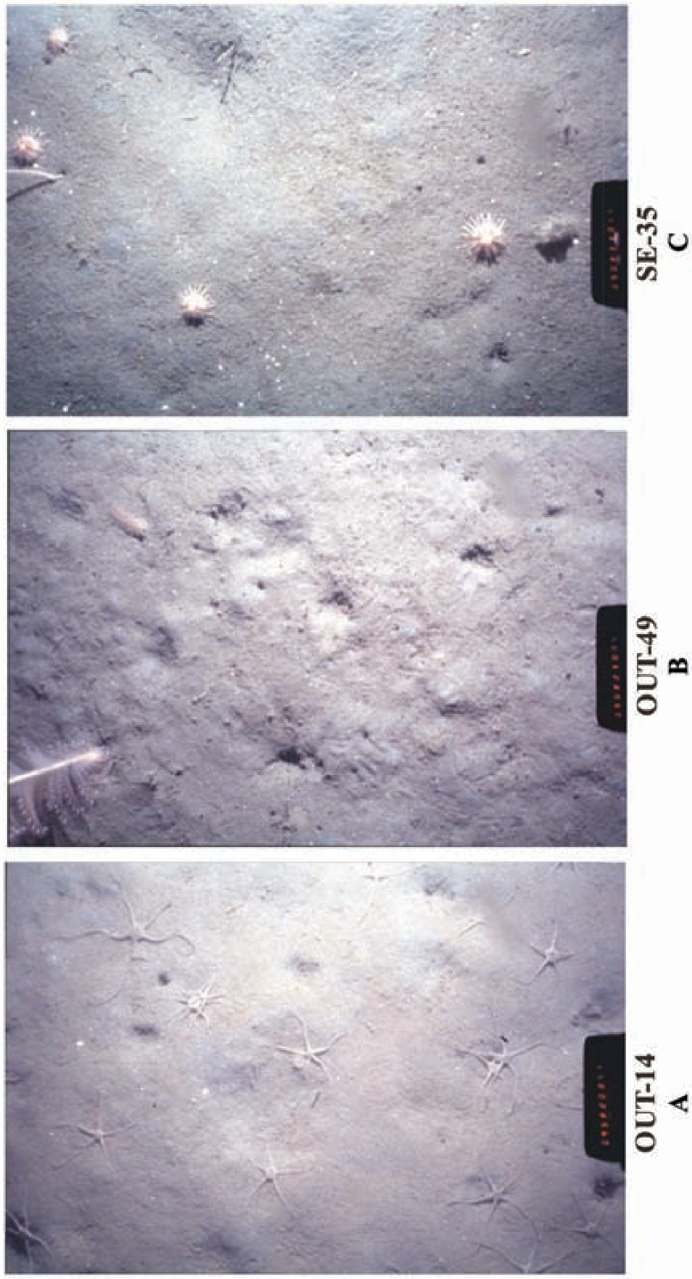

Figure 2-7. Examples of biological organisms observed in plan-view images over the Palos Verdes shelf. Brittle stars (A), sea pens and sand dabs (B), as well as urchins were present within the survey area (SAIC, 2005)

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Molecular Diffusion

The measured concentrations of DDE in the bed sediment and calculated concentrations in porewater on the PV Shelf greatly exceed concentrations in the water above the bed, and this gradient will drive DDE from the bed by molecular diffusion. Loss due to molecular diffusion depends on the nature of the thin water layer immediately above the sediment-water interface, the aqueous solution diffusivity of the dissolved compound, and the porosity of the bed (Chen, 1993). The molecular diffusion coefficient is similar in magnitude to bioturbation coefficients and constitutes an important mechanism for release of organic chemicals from the bed. Molecular loss for the effluent-affected sediment at 6C is estimated using the model of Chen (1993) developed for analysis of the release of hydrophobic species from the sediment of Boston Harbor. The calculated magnitude of the loss term is approximately the same as that for loss due to resuspension and desorption during storm events, and is included in the predictive model.

2.4.1.2 Numerical Model of Processes

Numerical values or equations were developed to represent the key processes: sediment deposition or erosion, bed mixing through biodiffusion, and loss of contaminants from the sediment through resuspension and sorption during storm events or through molecular diffusion to the ocean water above the sea bed. Terms in the equation equate temporal changes in the contaminant profile at a specific depth with changes caused by biodiffusion and molecular diffusion in porewater, sedimentation, and loss due to degradation, resuspension and desorption or decay.

The model was initialized using profiles of DDE measured in 1989 cores from sites 3C and 6C and was tested in various ways to confirm that it was correctly implemented and that it provided correct results when used to model evolution of the EA sediment deposit during the years for which good data coverage was provided. The model results compared favorably with historical data.

2.4.2 1996 Supplement to the Expert Report

The numerical model was updated in 1996 using new data from 1991 and 1993. These data were used to revise the estimate of historical burial velocities, revise and supplement the time series of DDE inventories, initialize model runs, and for a comparison with previous model results.

Revised burial velocities were estimated from DDE profile data between 1981 and 1991 at Site 3C and between 1983 and 1993 at Site 6C, and were assumed to continue through 2003, when full secondary treatment of wastewater at the JWPCP was expected to be implemented. These burial velocities were 0.44 cm/yr at Site 3C and 0.47 cm/yr at Site 6C and included contributions from redistribution of existing bottom sediments, natural background sedimentation, PBL material and JWPCP emissions. Expected future background rate, (i.e., the natural background supply, estimated as 0.1 cm/yr) to provide estimates of the future burial velocity associated with all sources of sediment supply.

The report acknowledged that timing of the burial velocity scenarios was uncertain. However, the most likely scenarios assumed that no changes would occur until 2003, when full secondary treatment would be implemented at the JWPCP. The scenarios assumed that the burial velocity would quickly (by 2010) reach the future burial velocity of 0.32 cm/yr for Site 3C and -0.61 cm/yr for Site 6C. After 2010, redistribution of sediment would steadily reduce the contribution of flux divergence until, in 2025, the only contributions would be from the PBL, JWPCP emissions, and natural sources.

Long-term equilibrium sedimentation rate for Site 3C was calculated to be 0.13 cm/yr, slightly less than half of the historical rate. Bounds on this rate, estimated by propagating uncertainties through the calculations, ranged from 0.02 to 0.22 cm/yr. At site 6C, the burial velocity associated with future sediment supplies was calculated to be 0.21 cm/yr, 45 percent of the historical rate, with a range of 0.06 to 0.33 cm/yr. These rates would continue indefinitely under model runs that extended to 2100. These calculations indicated that sediment supply at both sites would decrease significantly; however, sedimentation rates would remain depositional.

At Site 6C, this rate included erosion that would be caused by divergence in the alongshelf sediment-transport rate associated with alongshore changes in sediment size. Near the southeast end of the EA deposit, fine sediment would be transported away (alongshelf toward the northwest) more quickly than they could be replaced by the coarser, pre-effluent sediment. If not offset by accumulation of sediment from the outfalls, PBL, or natural background supply, this would result in erosion. Removal of the finer material and armoring of the deposit would eventually reduce the alongshore gradients in grain size, and long-term equilibrium would be established. In the absence of any sediment supply, final equilibrium would require that fine sediment be removed until armoring produces a 10-cm thick surface layer with grain-size characteristics that match pre-effluent sediment. This would amount to about 50 percent by volume of the existing fine sediment, and would require erosion of 10 cm of material, which would take until about 2035, depending on the burial-velocity scenarios (Sherwood 1994). The burial velocity scenarios presented in the report assumed that the input of background sediment supply and cross-shelf transport would reduce the time to final equilibrium, so the most likely scenarios assumed final equilibrium would occur in 2025.

Model results for the most likely scenario at Site 3C indicated that concentration of DDE in surface sediment will fall steadily, reaching 1 mg/kg in 2009 and decreasing to less than 0.02 mg/kg at the end of the model simulation in 2100. Model results for the maximum deposition scenario predicted that surface concentrations would fall below 1 mg/kg even earlier (2006); maximum erosion scenario predicted surface concentrations would fall more slowly, reaching 1 mg/kg in 2025, and a final value of 0.1 mg/kg in 2100.

Model results for the most likely scenario at Site 6C predicted that concentrations of DDE at the surface would decrease from the 1991 maximum of 11.4 mg/kg to slightly more than 1 mg/kg in 2008, then rise to about 2 mg/kg in 2019 as erosion brings the subsurface maximum into the zone of biodiffusivity. After that, surface concentrations would fall gradually, reaching 1 mg/kg in 2044 and 0.1 mg/kg in 2100. Results for the maximum deposition scenario predicted a steady decrease in surface concentrations, reaching 1 mg/kg in 2012 and <0.05 mg/kg in 2100. Results for the maximum erosion scenario showed an initial drop in surface concentration until 2003, after which it would increase to a peak value of 39.4 mg/kg in 2018. Surface concentration would then fall, reaching 1 mg/kg in 2064 and a final value of 0.2 mg/kg in 2100.

The predictive model was developed before JWPCP implemented full secondary treatment of wastewater. The most recent measurement of sediment cores at 3C and 6C occurred in 2005. The median surface concentration of DDE at 3C was 1.26 mg/kg and at 6C 1.36 mg/kg, both in agreement with the USGS model's most likely scenario. Figures 2-8 and 2-9 show longterm trends in sediment cores collected and analyzed by LACSD for DDE.

Additional data collected through 2005 have been used to refine predictions of the fate of DDE in the EA sediment on PV Shelf.

2.4.3 Ongoing Refinements of the Predictive Model

Sherwood et al. (2002) continued to refine the model using field measurements, laboratory analyses, and calculations to set parameters for the model. Analyses of available data, including measurements made every two years from 1981 to 1997 by the LACSD, suggest that the two sites northwest of the White Point outfalls, 3C and 6C, will remain depositional, even as particulate supply from the sewage-treatment plant and nearby PBL decreases. At these sites, model predictions for 1991-2050 indicate that most of the existing inventory of DDE will remain buried and that surface concentrations will gradually decrease. Analyses of data southeast of the outfalls suggest that erosion is likely to occur in the southeast edge of the existing effluent-affected deposit. Model predictions for this area show that erosion and biodiffusion will re-introduce the DDE to the upper layer of sediment, with subsequent increases in surface concentrations and loss to the overlying water column. Figure 2-10 shows DDE profiles for the sediment deposit across the 60-m isobath. The 2000 model also recognized that some of the EA sediment deposit, i.e., at 3C, had DDE converting into DDMU.

USGS is presently engaged in updating the predictive model using data collected since full secondary treatment was instituted at the JWPCP. The predictive model focused on DDE as the dominant contaminant on the shelf. Historical investigations found that PCBs were collocated with DDE, but at approximately one-tenth the concentration. Therefore, it was assumed that loss rates could be applied equally to both contaminants. Data from 2005 confirmed that DDE is undergoing reductive dechlorination but PCBs are not. New model parameters added transformation rates for DDE along with loss estimates; however, PCB-specific model runs were not performed.

Another potentially significant factor that had been identified but not measured is compaction of the sediment deposit. The initial model did not consider compaction in calculating burial velocity. Recent data show bulk density has been increasing over time, i.e., sediment has been compacting, and the changes are on the order of 15 to 20 percent in the top 15 cm of sediment. Bulk density increases with distance from the outfalls to the northwest. Areas that were considered potentially erosive, because the area of peak contaminant concentration appeared to be shifting upward toward the surface, are depositional when corrected for compaction. Similarly, sedimentation rates can be underestimated if not corrected for compaction.

Based on the DDE loss calculations, sediment concentrations will fall below 1 mg/kg except for the outfall area in approximately 10 years (2018). The exception is the outfall area. Median PCB concentration in sediment across the PV Shelf Study Area was 0.2 mg/kg in 2004. Inshore and southeast of the outfalls PCB concentrations were below detection limits.

Nearer to the outfalls and on the shelf slope PCB concentrations approach or exceed 1 mg/kg.

2.4.4 Ambient Water Quality Forecasting

In order to compare alternatives in the feasibility study, estimates of future contaminant concentrations in water as well as biota and sediment are necessary. The length of time required for PV Shelf to reach EPA's ambient water quality criteria (AWQC) for human health and ecological receptors depends on sediment mixing rates, DDE loss rates within the EA deposit as well as through mass flux to the overlying water. USGS performed preliminary calculations using simple transfer models to estimate PV Shelf water quality changes over time. These calculations are included in Appendix B.

The first model estimated DDE concentrations in surface sediment on the PV shelf and mass fluxes of DDE from sediment to overlying water. It assumes no erosion or deposition. The second model used the estimate of mass flux of DDE as a loading term, and calculated dilution of DDE in PV Shelf water, exchange with SCB water, and ultimate loss to the North Pacific Ocean.

The models assume PV Shelf water is rapidly exchanged with surrounding SCB water. The resident time for PV Shelf water is about one day. The SCB water is exchanged more slowly, but its residence time is also short, about 78 days. Water quality in the SCB responds very quickly to changes in loading from contaminated sediment. Rough calculations of flushing time for the water column over the PV Shelf suggest a half-life of a few days or less. The flushing time for water closer to the sediment is slower. Transfer rates from sediment to overlying water were inferred from the apparent loss rates in surface sediment.

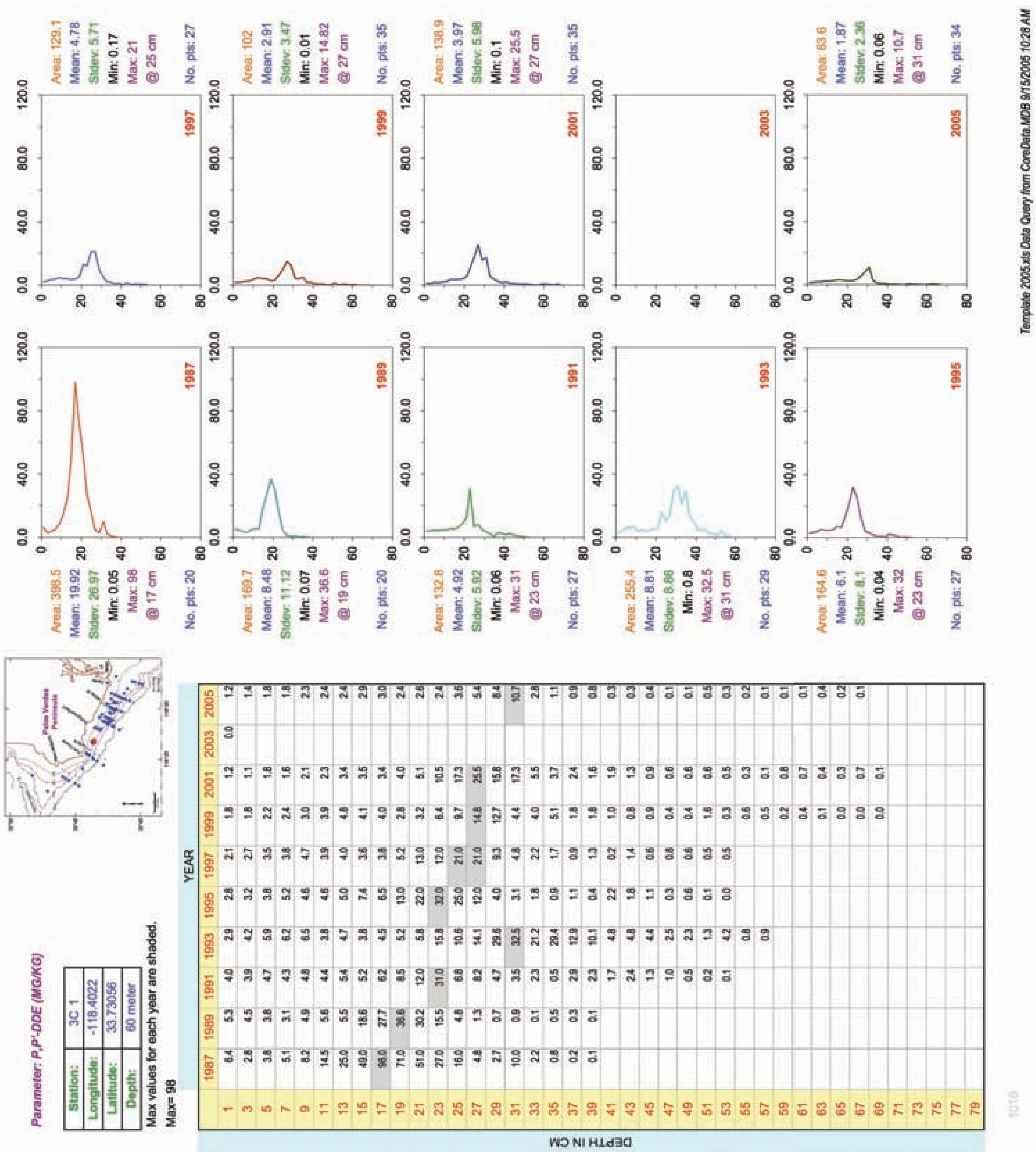
The sediment box model requires estimates of biodiffusive mixing, in-situ transformation rate from DDE to DDMU, and transfer rate from sediment to the overlying water column. Estimates of future water quality are sensitive to these variables. Depending on mass flux rate from sediment to overlying water, PV Shelf water reaches EPA's AWQC for DDT for protection of human health in water in 30 to 60 years.

Table 2.3 Summary of box model parameters and results, 150-year model simulation.

Case	β_1 (yr^{-1})	β_2 and β_3 (yr^{-1})	K_{23}	Final Inventory (metric tons)	Final Surf. Conc. mg/kg	Mean Surf. Conc. mg/kg	Mean Flux to Water kg/yr	Year Surf. <1 mg/kg	Year Surf. <200 µg/kg	Year PV Shelf Water <0.22 ng/L	Year PV Bottom Water <0.22 ng/L
1	0.07	0.03	5	0.2	0.003	0.6	85	2024	2053	2037	2065
3	0.03	0.01	5	5	0.2	1.6	96	2070	>2150	2067	2136
4	0.07	0.01	0.5	13	0.03	0.7	97	2027	2052	2039	2065

Model assumes initial DDE inventory is 84 metric tons. Depending on loss rates and sediment to water transfer rate, ambient water quality criteria of 0.22 ng/L is reached in 2037 to 2067.

Figure 2-8: DDE Trend at Station 3C (LACSD, 2005)



DEPTH IN CM	YEAR 1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
1	6.4	5.3	4.0	2.9	2.8	2.1	1.8	1.2	0.0	1.2
3	2.8	4.5	3.9	4.2	3.2	2.7	1.8	1.1		1.4
5	3.8	3.8	4.7	5.9	3.8	3.5	2.2	1.8		1.8
7	5.1	3.1	4.3	6.2	5.2	3.8	2.4	1.6		1.8
9	8.2	4.9	4.8	6.5	4.6	4.7	3.0	2.1		2.3
11	14.5	5.6	4.4	3.8	4.6	3.9	3.9	2.3		2.4
13	25.0	5.5	5.4	4.7	5.0	4.0	4.8	3.4		2.4
15	49.0	18.6	5.2	3.8	7.4	3.6	4.1	3.5		2.9
17	98.0	27.7	6.2	4.5	6.5	3.8	4.0	3.4		3.0
19	71.0	36.6	8.5	5.2	13.0	5.2	2.8	4.0		2.4
21	51.0	30.2	12.0	5.8	22.0	13.0	3.2	5.1		2.6
23	27.0	15.5	31.0	15.8	32.0	12.0	6.4	10.5		2.4
25	16.0	4.8	6.8	10.6	25.0	21.0	9.7	17.3		3.6
27	4.8	1.3	8.2	14.1	12.0	21.0	14.8	25.5		5.4
29	2.7	0.7	4.7	29.6	4.0	9.3	12.7	15.8		8.4
31	10.0	0.9	3.5	32.5	3.1	4.8	4.4	17.3		10.7
33	2.2	0.1	2.3	21.2	1.8	2.2	4.0	5.5		2.8
35	0.8	0.5	0.5	29.4	0.9	1.7	5.1	3.7		1.1
37	0.2	0.3	2.9	12.9	1.1	0.9	1.8	2.4		0.9
39	0.1	0.1	2.3	10.1	0.4	1.3	1.8	1.6		0.8
41			1.7	4.8	2.2	0.2	1.0	1.9		0.3
43			2.4	4.8	1.8	1.4	0.8	1.3		0.3
45			1.3	4.4	1.1	0.6	0.9	0.9		0.4
47			1.0	2.5	0.3	0.8	0.4	0.6		0.1
49			0.5	2.3	0.6	0.6	0.4	0.6		0.1
51			0.2	1.3	0.1	0.5	1.6	0.6		0.5
53			0.1	4.2	0.0	0.5	0.3	0.5		0.3
55				0.8			0.6	0.3		0.2
57				0.9			0.5	0.1		0.1
59							0.2	0.8		0.1
61							0.4	0.7		0.1
63							0.1	0.4		0.4
65							0.0	0.3		0.2
67							0.0	0.7		0.1
69							0.0	0.1		
71										
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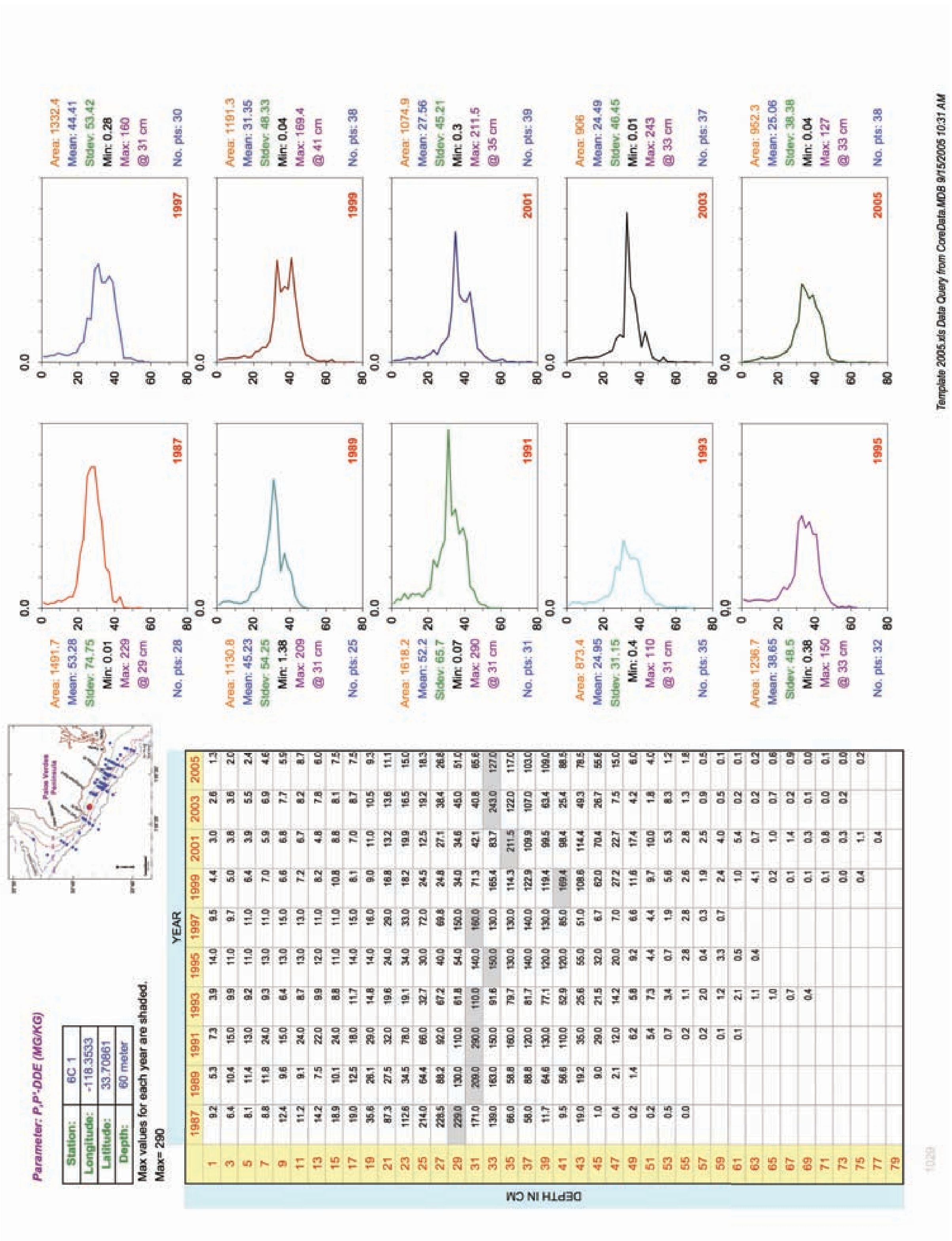

Figure 2-9: DDE trend at Station 6C (LACSD, 2005)

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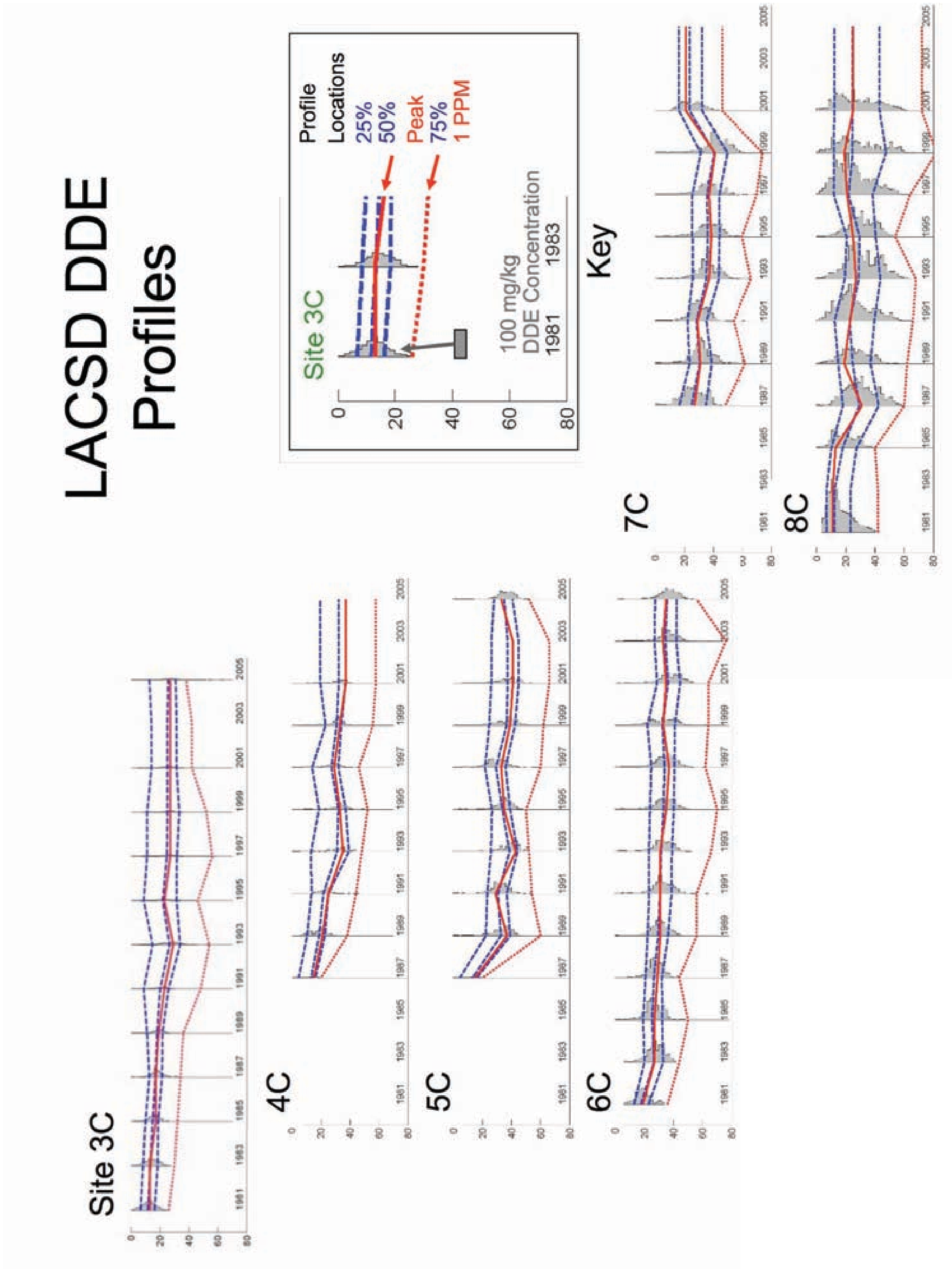
Figure 2-10: Peak DDE in LACSD cores along 60 m isobath (Sherwood, 2006)



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As discussed above, PCB loss rates have not been calculated. Water column data from 1997 (Zeng, 1999) included measurements of PCBs one meter above the sediment bed plus a number of measurements at other depths, up to 35 meters above the bed. While the sample taken at 35 meters met the AWQC of 0.064 ng/L, the samples closer to the bed ranged from 0.2 ng/L to 1 ng/L. In general, PCB concentrations were higher in summer than in winter. In summer of 2003 (Zeng, 2004) sampled water 2 meters above the bed over the EA sediment deposit for 42 PCB congeners. Of these, 7 congeners were detected, totaling 0.556 ng/L PCBs. This is half of the quantity detected at the same location and depth in 1997, i.e., 1.11 ng/L. These two sampling events are insufficient to predict when the PCB AWQC for human health of 0.064 ng/L would be reached; however, it does indicate concentrations are dropping.

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3.0 Remedial Action Objectives and Development of Remediation Goals

This section on remediation goals defines several key cleanup concepts common to all feasibility studies prepared in accordance with CERCLA rules and guidance:

- Remedial action objectives (RAOs);
- Applicable or relevant and appropriate requirements (ARARs) and regulatory guidance that is "to be considered" (TBC) in the development of remedial alternatives.

Collectively, these concepts set the stage for developing effective and protective remedial alternatives for the PV Shelf Feasibility Study.

RAOs are general remedial objectives developed to be protective of human health and the environment. RAOs for PV Shelf are designed to address the threats site contaminants pose to human and ecological receptors, as discussed in Section 2.0.

ARARs and TBCs constitute the body of existing statutes, regulations, ordinances, guidance, and published reports pertaining to all aspects of a potential remedial action for the site. This information typically influences the development of remedial alternatives by establishing numeric remediation goals, operating parameters, monitoring requirements, etc. The alternatives developed in Section 5.0 must, to the extent practicable, attain compliance with all ARARs and address the recommendations of TBCs.

3.1 Development of Remedial Action Objectives

The subsections below summarize the risk assessments and ARAR evaluation used to develop the RAOs for this FS.

3.1.1 Media and Chemicals of Concern

Defining the media and chemicals of concern (COCs) on the PV Shelf is a necessary prerequisite to developing site-specific RAOs. Per Agency guidance, RAOs should specify the relevant COCs, the exposure route(s) to receptors by media (e.g., surface water, soil, or sediments), and an acceptable contaminant level for each exposure route. *See* Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final (1988a), pp. 4-7, 4-15. ARARs and TBC information are generally identified with reference to media and COCs. For example, identifying surface water as a medium of concern triggers consideration of federal clean water regulations.

3.1.1.1 Media of Concern

The RI identified surface water and sediment as the media of concern. Contamination of these media poses risks to human health and ecological receptors. The risk assessments (Section 2.0) determined that addressing sediment contamination will have the greatest impact on improving surface water quality, and thus on reducing risks to humans and wildlife. Remedial actions presented in Section 4.0 describe general cleanup options for COCs contained in sediment only. Cleanup of surface water and reductions in fish tissue COC concentrations will occur naturally once the source of contamination to surface water and biota is removed, treated, or contained.

3.1.1.2 Chemicals of Concern

Investigations of PV Shelf identified various metals and organic compounds associated with industrial and municipal waste. However, the contaminants found to pose the greatest threat to human health and the environment are DDTs and PCBs.

3.1.2 Risk Assessments

Pursuant to CERCLA, the risk assessments conducted in support of the RI (CH2M HILL, 2007) evaluate potential threats to human health and the environment from the chemicals of concern at the PV Shelf Study Area. A summary of the risk assessments can be found in Section 2.0 of this FS.

The general EPA remediation objective for Superfund sites is to reach an acceptable level of risk, rather than to achieve specific concentration levels (USEPA, 1990). In the National Contingency Plan (NCP), EPA defines the acceptable level of excess lifetime cancer risk (ELCR) as ranging from 1×10^{-6} to 1×10^{-4} (USEPA, 1990). For noncarcinogenic effects, EPA uses a Hazard Index (HI) approach, based on reference dose exposures. An HI exceedance (HI > 1), represents an exposure exceeding reference dose levels. The RAOs presented below are based on this guidance from EPA.

3.1.2.1 Protection of Human Health

EPA has developed screening values for common contaminants found in fish (EPA, 2000c). The concentrations are based on a consumption rate of 17.5 g/day, 70 kg body weight and, for carcinogens, a 10^{-5} risk level over a 70-year lifetime.

Table 3-1: Recommended Screening Values for Recreational Fishers, target analyte in µg/kg (ppb)

	Noncarcinogen screening value	Carcinogen screening value (10^{-5} risk level)
Total DDT (sum of 4,4'- and 2,4'- isomers of DDT, DDE, and DDD)	2,000	117
Total PCBs (sum of congeners or Aroclors)	80	20

EPA guidance recommends using these values when site-specific data are not available. As described in Section 2.0, the human health risk assessments used the *Santa Monica Bay Seafood Consumption Study* (SMBRP, 1994) to develop reasonable maximum exposure (RME) and central tendency exposure (CTE) scenarios to calculate potential risk. Based on angler consumption patterns, the updated human health risk evaluation (HHRE) technical memorandum prepared for the remedial investigation report (CH2M Hill, 2007) used a recreational angler consumption rate of 21.4 g/day for the CTE scenario and 115.7 g/day for the high-end consumption rate, or RME. These consumption rates represent the 90^{th} percentile and mean consumption rates for all fish consumed, as reported in the study. In order to provide an additional layer of protectiveness, the HHRE tech memo assigns these consumption rates to one species instead of the multiple species anglers identified consuming in the study. Using these criteria, the following fish tissue concentrations were determined to be protective.

Table 3-2: Protectiveness levels based on local fish consumption rates			
Single species consumption rate	DDTs in fish fillet	PCBs in fish fillet	ELCR*
Based on 21.4 g/day	490 µg/kg (ppb)	80 µg/kg (ppb)	1×10^{-5}
Based on 116 g/day	400 µg/kg (ppb)	70 µg/kg (ppb)	1×10^{-4}

* Excess lifetime cancer risk, i.e., incremental increase in the probability of developing cancer during one's lifetime in addition to the background probability.

3.1.2.2 Protection of Ecological Receptors

As described in Section 2.0, several lines of evidence, including sediment and porewater hazard quotients (HQs), benthic community effects, toxicity tests, effects on fish, and modeling of food chain transfer to birds and mammals, were used to evaluate ecological risk at the PV Shelf. The results show that the highest risks are in the vicinity of the PV Shelf outfalls. Intermediate-risk areas are found generally to the north and northwest of the outfalls. Finally, low-risk areas occur south of the outfalls, in shallower waters (<30 m), at the far northern areas of the PV Shelf, and throughout the remainder of the Southern California Bight (SCB), which is the area of the coastal Pacific Ocean between Point Conception and San Diego, including the Channel Islands (Lee, 1994).

Ecological receptors on PV Shelf include the following: invertebrates that live in the sediment; fish, including fish that consume the invertebrates; piscivorous birds; and mammals. Marine mammals and birds have little to no direct contact with the contaminated sediment on PV Shelf. Part of their body burden of DDT and PCBs can be attributed indirectly to consumption of PV Shelf-dwelling fish, and food web models that estimate trophic transfer of contaminants up the food chain have been developed (Glaser and Connolly, 2002, CH2M Hill, 2003). However, these models contain considerable uncertainty and are not useful in establishing contaminant-specific remediation goals for sediment. Ecological receptors that are affected directly by PV Shelf sediment are benthic invertebrates and local fish species.

Sediment effects concentrations (SEC) protective of benthic invertebrates were developed from a study of sediment quality of the SCB. MacDonald (1994) conducted an exhaustive review of laboratory and field investigations related to the biological effects of DDTs and PCBs to benthic macroinvertebrates exposed to sediment from the SCB. Using a tiered strategy and a weight-of-evidence approach, he established SEC thresholds for DDT, DDE, DDD, Aroclor 1254 and PCBs. Exceedance of the SEC would indicate that effects, e.g., reduced survival and reproduction, on sensitive species are likely to occur. Field data were used only if no information from controlled laboratory studies (i.e., spiked sediment bioassays using arthropods) with dose-response findings were available to determine SECs. The study determined that DDT concentrations of 2.0 mg/kg in sediment with 1 percent total organic carbon (TOC) and 0.577 mg/kg PCBs at 1 percent TOC were protective of benthic infauna. Sediment concentrations for the PV Shelf Study Area are below these SEC values for PCBs and only the immediate area around the outfall exceeds the DDT SEC.

Fish-eating birds and mammals accumulate contaminants through food chain transfer; therefore, their risk relates to the contaminant concentrations in fish rather than in sediment. Literature-derived screening values for COCs in fish as food for piscivorous wildlife vary widely. The most protective benchmark for DDT is from Environment Canada, 14 μg/kg DDT (CCME 1999). Environment Canada does not list a benchmark for total PCBs; however, the British Columbia Ministry of the Environment uses 100 μg/kg as its screening value (BCMOELP 1998). As discussed in Section 2.3.1.2, COC concentrations in pelagic forage fishes in the Southern California Bight exceed the DDT benchmark of 14 μg/kg but not the PCBs benchmark (Table 2.2). The 2007 study found regional differences, with the fish closer to PV Shelf generally containing the most COCs.

3.2 Applicable or Relevant and Appropriate Requirements

Potentially applicable or relevant and appropriate requirements (ARARs) are identified and reviewed during development of remedial actions to ensure that remedial actions comply with applicable laws and regulations. Compliance with ARARs may have a significant effect on the cost and implementability of a particular alternative during the initial action and long-term operation.

3.2.1 ARARs Overview

Section 121(d) of CERCLA states that remedial actions on CERCLA sites must attain (or justify the waiver of) any federal or more stringent state environmental standards, requirements, criteria, or limitations that are determined to be ARARs. Applicable requirements are those cleanup standards, criteria, or limitations promulgated under federal or state law that specifically address the situation at a CERCLA site. A requirement is applicable if the specific terms, or "jurisdictional prerequisites," of the law or regulation directly address circumstances at the site.

If a requirement is not legally applicable, the requirement is evaluated to determine whether it is relevant and appropriate. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not applicable, address problems or situations sufficiently similar to the circumstances of the proposed response action and are well suited to the conditions of the site. The criteria for determining relevance and appropriateness are listed in Title 40, Code of Federal Regulations (CFR), Section 300.400(g)(2).

ARARs are concerned only with substantive, not administrative, requirements of a statute or regulation. The substantive portions of the regulation are those requirements that pertain directly to actions or conditions in the environment. Examples of substantive requirements include quantitative health- or risk-based restrictions upon exposure to types of hazardous substances.

Administrative requirements are the mechanisms that facilitate implementation of the substantive requirements. Administrative requirements include issuance of permits, documentation, reporting, record keeping, and enforcement. Thus, in determining the extent to which onsite CERCLA response actions must comply with environmental laws, a distinction should be made between substantive requirements, which may be ARARs, and administrative requirements, which are not. According to Section 121(e) of CERCLA, a remedial response action that takes place entirely onsite may proceed without obtaining permits. This permit exemption applies to all administrative requirements and permits.

Pursuant to EPA guidance, ARARs generally are classified into three categories: chemical-specific, location-specific, and action-specific requirements. These categories were developed to help identify ARARs, although some do not fall precisely into one group or another. The ARAR categories are defined as follows:

- **Chemical-specific ARARs** include those laws and requirements that regulate the release to the environment of materials possessing certain chemical or physical characteristics or containing specified chemical compounds. These requirements generally set health- or risk-based concentration limits or discharge limitations for specific hazardous substances. If, in a specific situation, a chemical is subject to more than one discharge or exposure limit, the more stringent of the requirements should generally be applied.
- **Location-specific ARARs** are those requirements that relate to the geographical or physical position of the site, rather than the nature of the contaminants or the proposed site remedial actions. These requirements may limit the placement of remedial action and may impose additional constraints on the cleanup action. For example, location-specific ARARs may refer to activities in the vicinity of wetlands, endangered species habitat, or areas of historical or cultural significance.
- **Action-specific ARARs** are requirements that apply to specific actions that may be associated with site remediation. Action-specific ARARs often define acceptable handling, treatment, and disposal procedures for hazardous substances. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy. Examples of action-specific ARARs include requirements applicable to groundwater treatment, effluent discharge, hazardous waste disposal, and emissions of air pollutants.

The response action alternatives will be evaluated in terms of compliance with the ARARs identified above as part of the effectiveness analysis.

3.2.2 Chemical-Specific ARARs

Surface Water

Chemical-specific ARARs for surface water consist of EPA's ambient water quality criteria (AWQC) for DDTs and PCBs. These criteria, which have been developed for the protection of both aquatic life and human health, are summarized in Table 3-4.

Section 304 of the Clean Water Act requires EPA to publish criteria for water quality. 33 United States Code (U.S.C.) Section 1314(a). The EPA AWQC for DDTs and PCBs were originally published in October 1980 (USEPA, 1980a; USEPA, 1980b). The human health values have been updated since the original criteria were published in 1980 to reflect revised consumption rates and carcinogenic potency values from EPA's Integrated Risk Information System (IRIS) database. 40 CFR §131.36 and 57 Federal Register (FR) 60848, December 22, 1992.

Table 3-3: EPA Ambient Water Quality Criteria

Chemical	Saltwater Aquatic Life, 24-Hour Average (ng/L)	Human Health (ng/L)
DDTs	1[a]	0.22[b]
PCBs	30	0.064

[a] The sum of the 4,4'- and 2,4'- isomers of DDT, DDD, and DDE.
[b] For DDE and DDD, the AWQC for protection of human health are 0.59 and 0.83 ng/L, respectively.
ng/L – nanograms per liter

DDTs

Criteria for the protection of saltwater aquatic life are, for most contaminants and pollutants, based on toxic effects data for water-column organisms. However, for DDTs, which bioaccumulate to high levels and may cause toxicity to organisms at higher trophic levels, EPA determined that more restrictive criteria were necessary to protect fish-eating birds and birds feeding at higher trophic levels, including birds that feed on other birds and scavenge on the carcasses of marine mammals. The chronic marine aquatic life criterion for DDT is 1 ng/L, which is equivalent to 10^{-9} grams per liter (g/L) (USEPA, 1980a). This criterion is set to achieve a fish tissue (whole-body) DDT concentration of 150 µg/kg (wet weight) in prey, and is based on a 1975 study of California brown pelicans in the SCB (Anderson et al. 1977).

The EPA AWQC for the protection of human health from DDT exposure through water and consumption of DDT residues that have bioaccumulated in fish is 0.22 ng/L, and is based on a bioconcentration factor (BCF) of 53,600. The BCF relates the concentration of a chemical in aquatic animals to the concentration in the water in which they live. The steady-state BCFs for a lipid-soluble compound, such as DDT, in the tissues of various aquatic animals seem to be proportional to the percent lipid in the tissue. The AWQC is based on a DDT concentration in fish tissue of approximately 12 µg/kg and would result in a lifetime excess cancer risk of up to 1 x 10^{-6}, assuming a consumption rate of approximately one meal per month. *See* 45 FR 79331, updated to reflect current IRIS potency factors. 40 CFR §131.36, 57 FR 60848.

PCBs

The EPA chronic marine aquatic life criterion for PCBs of 30 ng/L is also fish residue-based. It was set at the level that would be protective of sensitive aquatic species and result in achievement of the Food and Drug Administration (FDA) tolerance level (for protection of human health) of 5,000 µg/kg in fish after bioaccumulation (USEPA, 1980b). There is no evidence that acute or chronic toxicity to aquatic life will occur at levels of PCBs less than 30 ng/L; thus, the marine aquatic life criterion has not been revised.

The EPA AWQC for the protection of human health from the bioaccumulation of PCBs in fish is 0.064 ng/L, based on achieving a concentration of 1.4 µg/kg in fish consumed, which would result in a lifetime excess cancer risk of up to 1 x 10^{-6}, assuming a consumption rate of one meal per month (USEPA, 1996).

Section 121(d)(2)(A) of CERCLA requires that remedial actions meet federal AWQC established under Section 304 or 303 of the Clean Water Act, where such AWQC are determined by EPA to be relevant and appropriate to remedial actions at the site. 42 U.S.C. §9621(d)(2)(A) and 40 CFR §300.430(e)(2)(I)(E). In evaluating whether specific AWQC are relevant and appropriate to remedial actions at a Superfund site, CERCLA requires EPA to consider four criteria: (1) the uses of the receiving water body; (2) the media affected; (3) the purposes of the criteria; and (4) current information. 42 U.S.C. § 9621(d)(2)(B)(i); see also USEPA (1990).

EPA guidance to determine if AWQC are relevant and appropriate to remedial action at a Superfund site provides that:

> A water quality criteria component for aquatic life may be relevant and appropriate when there are environmental factors that are being considered at a site, such as protection of aquatic organisms. With respect to the use of water quality criteria for the protection of human health, levels are provided for exposure both from drinking the water and from consuming aquatic organisms (primarily fish) and from fish consumption alone. Whether a water quality criterion is appropriate depends on the likely routes of exposure (EPA, 1988b).

The AWQC for DDTs and PCBs are relevant and appropriate ARARs that would establish response action goals at this site since aquatic organisms, wildlife, and humans may be exposed to these contaminants either directly or through consumption of contaminated organisms. As stated above, the marine chronic AWQC for DDTs was based on the results of studies of reproductive impacts to the California brown pelican in the SCB.

The beneficial uses designated by the State of California for coastal waters, which are discussed below, include fishing, wildlife habitat, preservation of rare and endangered species, fish migration, fish spawning, and shellfish harvesting. EPA's AWQC were specifically developed to protect beneficial uses such as these.

Sediment

There are no chemical-specific ARARs for the remediation of PV Shelf Study Area sediment.

Fish

There are no chemical-specific ARARs for the concentration of DDTs and PCBs in fish.

3.2.3 Location-Specific ARARs

Endangered Species Act

The goal of the Endangered Species Act of 1973, 16 U.S.C. Section 1531 et seq. is the conservation and recovery of species of fish, wildlife, and plants that are threatened with extinction. EPA has consulted with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service to identify threatened and endangered species and ensure that any response action is not likely to jeopardize listed species or adversely modify critical habitat. Because of the presence of endangered/threatened species on the PV Shelf, the substantive requirements at Sections 7 and 9 of the Endangered Species Act may be applicable. 16 U.S.C. §§1536 & 1538,

California Endangered Species Act

The goal of the California Endangered Species Act, Section 2050 of the California Fish and Game Code, is to conserve, protect, restore, and enhance any endangered or threatened species and its habitat. Regarding the birds likely to nest or feed in the area, most of those that are listed as endangered or threatened by the state are also listed federally. Because of the presence of endangered/threatened species on the PV Shelf, the substantive requirements of the California Endangered Species Act, Section 2080 of the California Fish and Game Code, may be applicable.

Coastal Zone Management Act

Section 307(c)(1) of the Coastal Zone Management Act (CZMA) requires that federal agencies conducting or supporting activities affecting land and water resources of the coastal zone do so in a manner that is consistent with approved state coastal zone management programs. The remedial alternatives being considered for the PV Shelf Study Area would affect the resources of the coastal zone. While onsite activities are not subject to CZMA administrative review or permitting processes, the selected remedy must ultimately be consistent with the substantive requirements of the coastal zone management plan that are applicable. 40 CFR §§300.5, 300.430(f)(1)(ii)(B).

The approved coastal zone management program for California coastal waters includes the California Coastal Act, and is administered by the California Coastal Commission. Generally, filling of surface waters is allowable only when public benefits exceed public detriment from the loss of water areas, the filling is for a water-oriented use, and no alternative upland location is available.

Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act

Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act regulate the placement of fill in waters of the United States. 33 U.S.C. §1344, 33 U.S.C. §401. Substantive, as opposed to permitting, requirements would be applicable requirements with regard to the placement of material on the Palos Verdes Shelf for the purpose of constructing a cap. In particular, the criteria for determining the acceptability of placing fill into the waters of the United States as promulgated in 40 CFR Part 300 would be applicable to any capping alternative.

3.2.4 Action-Specific ARARs

A number of ARARs may be triggered by the specific remedial action selected for implementation at the PV Shelf site. This section describes some of these action-specific ARARs.

Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA) and Ocean Dumping Regulations

The MPRSA, commonly called the Ocean Dumping Act 33 U.S.C. Section 1404 et seq., and federal ocean dumping regulations 40 CFR Part 220 et seq. regulate the dumping or disposal of material in the ocean. Ocean disposal of dredged material is administered by EPA and the United States Army Corps of Engineers (USACE) in accordance with the MPRSA. Dredged material must meet substantive federal testing guidelines to be approved for disposal. 40 CFR Part 227. Sediment containing more than trace amounts of organohalogen compounds, such as DDTs and PCBs, typically fail to meet the criteria for ocean disposal. The substantive requirements of the MPRSA and the ocean dumping regulations may be applicable to the capping alternatives.

Clean Water Act

Section 403 of the Clean Water Act, 33 U.S.C. §1343, and associated regulations at 40 CFR Part 125, Subpart M regulate discharges into marine waters that have the potential to degrade the marine environment. These provisions prohibit discharges unless limits can be established to prevent unreasonable degradation or irreparable harm to the marine environment (EPA, 1988b). The substantive requirements of Section 403 may be applicable for remedial alternatives that involve dredging, placement or dewatering of sediment.

Other Action-Specific ARARs

Section 28 of Title 14 of California Code of Regulations (CCR) forbids the taking of certain fish species from California ocean waters. Title 14 Sections 28.05, 28.06 and 28.10 can be considered action-specific ARARs for remedial alternatives that involve fish sampling in that these sections forbid by-catch of protected species.

Section 404 of the Clean Water Act, Section 10 of the Rivers and Harbors Act, and Section 307(c)(1) of the CZMA can be considered action-specific ARARs for remedial alternatives that involve dredging, ocean dumping, and material placement. These requirements are discussed briefly under location-specific ARARs.

3.3 To-Be-Considered (TBC) Criteria and Other Potential Requirements

3.3.1 To-Be-Considered Criteria (TBC)

A requirement may not meet the definition of an ARAR as described above, but still may be useful in determining whether to take action at a site or to what degree action is necessary. This can be particularly true when there are no ARARs for a site, action, or contaminant. Such requirements are called "to-be-considered (TBC) criteria" and are defined at 40 CFR Section 300.400(g)(3). TBC materials are nonpromulgated advisories or guidance issued by federal or state governments that are not legally binding. Although TBC criteria do not have the status of ARARs, they are considered together with ARARs to establish the required level of cleanup for protection of health or the environment. Once a TBC is designated in a ROD, it is enforceable to the same extent as an ARAR.

There are a number of TBC criteria (i.e., guidance and recommendations) that are intended to protect human health and the environment, including fish-eating birds and predators, and may be used to define response objectives or cleanup goals for the PV Shelf.

Surface Waters

Porter-Cologne Water Quality Control Act, *California Ocean Plan*, *and Fish and Game Code*

The State of California adopted water quality objectives for toxic pollutants pursuant to the requirements of Section 303 of the Clean Water Act and the Porter-Cologne Water Quality Control Act, 33 U.S.C. Section 1313 and California Water Code, Article 3. The release of hazardous substances to surface waters is controlled under these statutes and implementing regulations, as well as the state Fish and Game Code Section 5650. The California Ocean Plan, adopted in July 1972 and revised most recently in 2005 (SWRCB, 2005), contains water quality objectives for DDTs and PCBs in surface waters (0.17 ng/L and 0.019 ng/L, respectively), which serve as the basis for determining requirements for waste discharge to the ocean. These chemical-specific objectives apply to all coastal waters of California—including waters off the Palos Verdes Peninsula—out to 3 nautical miles, and are intended to "ensure the reasonable protection of beneficial uses and the prevention of nuisance." The California Ocean Plan lists the following beneficial uses of coastal waters, which include the waters at the site:

- Industrial water supply

- Navigation
- Water contact and noncontact recreation, including aesthetic enjoyment
- Commercial and sport fishing
- Mariculture
- Preservation and enhancement of designated areas of special biological significance
- Rare and endangered species
- Marine habitat
- Fish migration
- Fish spawning
- Shellfish harvesting

Sediment

Unlike contaminants in soil or water, EPA does not have screening values for contaminants in sediment. Local conditions affect the toxicity and bioavailability of certain contaminants, particularly hydrophobic chemicals like DDT and PCBs. The State of California is developing sediment quality guidelines based on multiple lines of evidence; however, these guidelines have not yet been finalized.

Fish

Human Health

The U.S. Food and Drug Administration (FDA) is responsible for protecting the public health by assuring the safety, efficacy and security of the nation's food supply. The FDA has set action levels for DDT and PCBs in seafood: 5,000 µg/kg DDT (FDA, 1978) and 2,000 µg/kg PCBs. 21 CFR §109.30(a)(7). However, these levels are not risk-based and would pose human health risks above EPA's risk range (1×10^{-4} to 1×10^{-6}) when applied to site-specific fish consumption data from the PV Shelf area.

As stated in section 3.1.2.1, this FS uses the updated Human Health Risk Evaluation (HHRE) Technical Memorandum (CH2M Hill, 2007) prepared for the PV Shelf Superfund Site Remedial Investigation to calculate fish tissue contaminant concentrations that would be protective of human health. Currently, contaminant concentrations in white croaker from the PV Shelf Study Area exceed the human health target levels, both for the average (CTE) and high-end (RME) consumers. Table 3-4, below, reflects the sediment concentrations that would achieve CTE and RME targets.

Ecological Receptors

The TBC criteria for the protection of ecological receptors include screening values for fish and fish-eating wildlife, and site-specific sediment effects concentrations for benthic invertebrates. As discussed in section 3.1.2.2., either these benchmarks have been met, e.g., SECs for benthic invertebrates, or additional studies are required in order to translate the benchmark into a sediment goal.

Potential Remedial Goals

Remedial actions cannot reduce contaminant concentrations in fish or water directly. Instead, reductions in fish or water occur after actions are taken to reduce sediment concentrations.

Table 3-4: Relationship of CoCs in White Croaker to Sediment		
	Fish fillet 21.4 g/day consumption rate (achieves 10^{-5} risk)	Fish fillet 116 g/day consumption rate (achieves 10^{-4} risk)
DDTs	490 µg/kg ww	400 µg/kg ww
Sediment Goal	280 µg/kg @ 1% TOC	230 µg/kg @ 1% TOC
PCBs	80 µg/kg ww	70 µg/kg ww
Sediment Goal	80 µg/kg @ 1% TOC	70 µg/kg @ 1% TOC

COC concentrations in surface sediment vary greatly across the PV Shelf and slope. At the 30 m depth (approximately 100 ft.), PCBs are not detected in the sediment and DDTs are well below potential remediation goals. Along the 61-m and 152-m isobaths, DDT concentrations exceed the potential remediation goals while PCBs exceed the goals around the outfalls and most of the slope.

3.3.2 Other Potential Requirements

The legal requirements discussed below are not identified as ARARs because ARARs can only be identified for onsite activities. 42 U.S.C. §9621(d)(2)(A). However, the capping and dredging options evaluated in this FS contemplate potential offsite dredging of clean sediment for ocean disposal (i.e., capping) on the PV Shelf, and potential offsite disposal of contaminated sediment dredged from the PV Shelf. The legal requirements discussed below would independently apply to and regulate such dredging.

Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act

Section 404 of the Clean Water Act, 33 U.S.C. §1344, and Section 10 of the Rivers and Harbor Act, 33 U.S.C. §401, regulate dredging and filling (including in situ capping of sediments) in waters of the United States. USACE typically issues permits to conduct dredge or fill activities, and such permits would be required for activities that are conducted in offsite areas. Elimination of "special aquatic sites" as a result of dredging can trigger requirements for mitigation of the lost resource as a condition for approval.

Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA) and Ocean Dumping Regulations

The MPRSA, commonly called the Ocean Dumping Act, 33 U.S.C. §1404 et seq., and federal ocean dumping regulations in 40 CFR Part 220 et seq., regulate the dumping of material in the ocean. Ocean disposal of dredged material is administered by EPA and USACE in accordance with MPRSA. Dredged material must meet substantive federal testing guidelines to be approved for disposal, set forth at 40 CFR Part 227. Sediment containing more than trace amounts of organohalogen compounds, such as DDTs and PCBs, typically fail to meet the criteria for ocean disposal.

Resource Conservation and Recovery Act

Disposal of dredged sediment containing RCRA hazardous waste would trigger certain independently applicable RCRA requirements. Specifically, the RCRA land disposal restriction set forth at 22 CCR §66268.1(f) prohibits the disposal of hazardous waste to land unless it is treated in accordance with the standards set forth at 22 CCR, Chapter 18, Articles 4 or 11, or in federal RCRA regulations, if applicable.

3.3.3 Summary of Potential Remediation Goals

Table 3-5 summarizes potential remediation goals that were consulted in establishing cleanup levels.

Table 3-5 Summary of Potential Remediation Goals

Criteria	DDTs[a]	PCBs	Sediment
Human Health			
Water	0.22 ng/L	0.064 ng/L	EPA AWQC (EPA, 1980a)
Fish	5000 µg/kg	2000 µg/kg	FDA Action Level (FDA, 1978), FDA Tolerance Level [21 CFR Section 109.30(a)(7)]
	490 µg/kg wet weight in tissue	80 µg/kg wet weight in tissue	10^{-5} cancer risk for CTE ingestion rate of 21.4 g/day based on supplement (CH2M Hill, 2007) to PV Shelf Human Health Risk Evaluation (SAIC,1999)
	40 µg/kg wet weight in tissue	7 µg/kg wet weight in tissue	10^{-5} cancer risk for RME ingestion rate of 116 g/day based on supplement (CH2M Hill, 2007) to PV Shelf Human Health Risk Evaluation (SAIC,1999)
Ecological Health			
Water	1 ng/L	30 ng/L	EPA AWQC (EPA, 1980a)
Sediment	2000 µg/kg @ 1% TOC	577 µg/kg @ 1%TOC	MacDonald (1994) sediment concentrations protective of benthic invertebrates for SCB
Fish as prey for piscivorous wildlife	14 µg/kg wet weight whole body fish tissue	100 µg/kg wet weight whole body fish tissue	Environment Canada, National Standards and Guidelines (CCME 1999) and British Columbia Ministry of Environment, Land and Parks. Water quality guidelines. (BCMOELP, 1998)

[a] The sum of the 4,4’- and 2,4’- isomers of DDT, DDD, and DDE

3.4 Remedial Action Objectives

With consideration of the ARARs and TBCs presented in the previous sections, the following remedial action objects (RAOs) were developed for the PV Shelf site.

3.4.1 Human Health Risks

RAO: Reduce to acceptable levels the risks to human health from ingestion of fish contaminated with DDTs and PCBs.

The human health risk assessments determined that exposure to DDTs and PCBs through consumption of fish is the exposure pathway leading to the greatest potential for adverse human health effects. Reducing COC levels in fish and/or preventing consumption of contaminated fish are two ways to reduce risk.

Protective levels in fish were calculated for two ingestion rates: a reasonable maximum exposure (RME) equivalent to 116 g/day (about six 5-ounce meals a week), and a central tendency exposure (CTE) equivalent to 21.4 g/day (about one 5-ounce meal a week). As discussed in section 3.1.2.1, the general EPA remediation objective is to reach an acceptable level of risk, defined under the NCP as a range of 1 x10^{-6} to 1 x10^{-4} excess lifetime cancer risk, with 1 x 10^{-6} as the most protective. EPA guidance for assessing chemical contaminant data for use in fish advisories (USEPA, 2000c) recommends using the 10^{-5} cancer risk as the target remediation goal.

- Achieve interim goal of median DDT concentrations in surface sediment of 46 mg/kg OC (half the target concentration) and PCB concentrations of 7 mg/kg OC by first Five-Year Review.
- Achieve goal of 400 µg/kg DDT, 70 µg/kg PCBs in white croaker. These concentrations provide levels of protection of 1 x 10^{-4} cancer risk for the RME scenario and 1 x 10^{-5} for the CTE scenario.
- Maintain institutional controls program that aims to prevent contaminated fish from reaching markets and educates anglers on safe fishing practices.

3.4.2 Ecological Risks

RAO: Reduce to acceptable levels the risks from DDTs and PCBs to the ecological community (i.e., benthic invertebrates and fish) at the PV Shelf.

The Natural Resource Trustees through the Montrose Settlements Restoration Program (MSRP) are actively involved in restoring wildlife harmed by DDTs and PCBs. Programs to enhance fish habitat and restore sea birds and bald eagles are well underway. EPA can contribute to these efforts by its remedial actions on PV Shelf. Although PCB concentrations in sediment, water and fish do not appear to pose a threat to ecological receptors, DDT levels continue to pose a threat, particularly to piscivorous birds. Existing food web models that predict changes in bird or marine mammal COC body burdens need to be reassessed with new data and improved understanding of sediment to fish bioaccumulation correlations. Until such work is completed, the ambient water quality criteria for ecological health, discussed in the following section, provides a quantifiable level of protection for fish and wildlife.

- Support the Natural Resource Trustees' strategies to sustain wildlife recovery.

3.4.3 Water Quality

The ambient water quality criterion (AWQC) for protection of human health is 0.22 ng/L DDT in water; this is the equivalent of 12 µg/kg DDT in fish tissue. The 0.064 ng/L PCBs in water is the equivalent of 1.4 µg/kg PCBs in fish. These concentrations represent a 10^{-6} excess lifetime cancer risk. AWQC for ecological health are 1 ng/L DDT and 30 ng/L PCBs.

Water column data collected in 1997 (Zeng, 1999) measured concentrations of DDTs and PCBs at different locations and depths in winter and summer. DDT and PCB concentrations exceeded the AWQC for human health in all samples. All samples except one exceeded the ecological health criterion for DDT. No water sample exceeded the PCB ecological standard of 30 ng/L. Since the human health AWQC are lower than the ecological health AWQC, the human health AWQC are selected as the remediation levels. As discussed in Section 2.4.4, water column samples were analyzed for PCBs and DDTs in 1997 and 2003. Concentrations of PCBs in the water column 2 meters above the bed over station 6C were 1.11 ng/L in 1997 and 0.56 ng/L in 2003. Additional sampling and analysis are necessary in order to calculate when the human health criteria of 0.064 ng/L would be achieved.

RAO: Reduce concentrations of DDTs and PCBs in the surface waters over the PV Shelf to acceptable levels that meet ambient water quality criteria for human health. The AWQC will be calculated as the mean of water column concentrations of COCs over the EA sediment deposit.

- Achieve AWQC for protection of human health (i.e., 0.22 ng/L DDT) within 30 years of remedial action.
- Collect and assess PCB data in order to determine schedule to meet AWQC for PCBs (i.e., 0.064 ng/L) by first Five-Year Review.

RAO: Minimize potential adverse impacts to sensitive habitats and biological communities on the PV Shelf during remedial action.

- Before implementation of any remedy, prepare a monitoring program to assure the kelp beds on PV Shelf are protected.
- Use low-impact techniques and other best management practices, e.g., plan field work for season when tides and currents are less energetic, measure current speeds before dredging or capping, monitor activities, i.e., sediment resuspension, COCs in water column, and stop action if monitoring plan standards are exceeded.

4.0 Identification of General Response Actions and Screening of Remedial Technologies

This purpose of this step of the FS is to develop an appropriate range of waste management options that will be analyzed more fully in the detailed analysis phase, i.e. Section 5.0, of the FS. Appropriate waste management options that ensure the protection of human health and the environment may involve, depending on site-specific circumstances, the removal or destruction of hazardous substances at the site, the reduction of concentrations of hazardous substances to acceptable health-based levels, and prevention of exposure to hazardous substances via engineering or institutional controls, or some combination of all of these options.

This section describes the screening process used to evaluate remediation technologies for the PV Shelf site. The RAOs, developed in conjunction with the remedial investigation and risk assessments, establish the basis for identifying general response actions (GRAs). GRAs are broad categories of actions such as treatment, containment, disposal, or combination of these. Specific categories of GRAs identified for contaminated sediments are as follows:

- No Action;
- Institutional Controls;
- Monitored Natural Recovery;
- Containment;
- Removal;
- In situ Treatment;
- Ex situ Treatment.

4.1 Description of General Response Actions (GRAs)

No Action
Consideration of a "No Action" response is required by the National Contingency Plan (NCP) [see 40 CFR Section 300.430(e)(6)] as a baseline against which the performance of other remedial alternatives can be compared. Under the No Action alternative, no remedial action would be performed. There are no technologies or process options associated with this GRA.

Institutional Controls
Institutional controls (ICs) are restrictions on land use or resource use to limit exposure to hazardous substances. ICs are nonengineered instruments such as administrative or legal controls that reduce exposure to contaminants of concern (COCs) by limiting or controlling activities that could lead to human exposure. Institutional controls typically are used in conjunction with engineering measures.

Monitored Natural Recovery
Natural recovery refers to the processes by which concentrations of COCs in impacted media decline over time by natural processes such as biodegradation, burial, or dilution. Reductions in the concentrations of even persistent pollutants may occur over time as a

result of natural processes. However, not all natural processes result in risk reduction and for those that do, time frames required to achieve significant reductions must be calculated and it must be determined whether the time frame is reasonable and acceptable.

Containment
Containment involves the physical isolation and immobilization of contaminants in sediment. Capping is a common method used in lakes, bays, marine, and riverine environments for containing impacted sediments. No sediment treatment occurs other than by natural processes under the cap surface. Assuming effective cap placement, the bioavailability and mobility of contaminants present in the sediment would be immediately limited.

Removal
Sediment removal by dredging or excavation is another common practice for managing contaminated sediment. Following removal, the material is usually taken to a treatment or disposal facility. Dredging typically includes other unit processes such as:

- In-water controls to minimize contaminant resuspension during removal;
- Dewatering to reduce volume of sediment by reducing moisture content;
- Treatment of dredge water before discharge; and
- Disposal and/or treatment of dredged material.

In Situ Treatment
In situ treatment involves chemical or biological methods for reducing contaminant concentrations or bioavailability without first removing the sediment. Chemical oxidation treatments (for example, persulfate or iron/hydrogen peroxide [Fe/H_2O_2]) are designed to either chemically destroy or reduce the toxicity of the contaminants. In situ chemical treatment may be carried out alone or in conjunction with biological treatment. Biological treatment can be used to destroy (e.g., complete conversion to carbon dioxide [CO_2] or methane) or reduce the toxicity of both DDTs and PCBs. Success is dependent on such factors as sediment redox conditions, pH, microbial communities present, and concentrations of microbial nutrients.

Ex Situ Treatment
Ex situ treatment involves the application of treatment technologies to transform, destroy or immobilize COCs following removal of the contaminated sediments. Ex situ treatment technologies require sediment removal (i.e., dredging), generally followed by dewatering of the sediment and treatment of both the dewatered sediment and water. This approach requires treatment application in a nearby confined facility where technologies use physical, chemical, biological, and thermal processes to remove contaminants from the sediment.

4.2 Summary of Technology Screening Process

As described in EPA's *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988a), GRAs are initially evaluated by screening technologies and process options associated with each GRA for the medium of interest. First, a list of potentially applicable technologies is prepared based on the GRAs and on available information on various technologies and processes that either exist or are under development. Then the list is refined by evaluating each technology for implementability, effectiveness, and relative cost. Technologies are either retained for use in developing remedial alternatives or are dropped from further consideration. The following provides an overview of the review process:

- The initial step involves assembling a comprehensive list of technology types and specific process options applicable to the GRAs discussed in section 4.1.
- Potential technologies are screened against three criteria: implementability, effectiveness, and relative cost.
- The results of the technology screening and a brief description of the primary factors that influenced the retention/elimination screening decisions are followed by a list of retained technologies and process options. These remedial technologies and processes are carried into the development and screening of alternatives (Section 5.0).
- In sum, the FS process starts with a wide range of potential remedial options and, through methodical evaluation, screens out GRAs, technologies, and process options. As the FS process continues, only feasible remedial alternatives remain for detailed analysis.

Evaluation of potential remedial technologies and process options requires consideration of site-specific characteristics, including nature of the COCs, their concentrations, contaminated medium, site constraints, and exposure pathways. Remedial technologies and process options are then screened for effectiveness, implementability, and relative cost.

The COCs, DDTs and PCBs, are persistent, hydrophobic, organic chlorinated compounds that are detectable in effluent-affected (EA) sediment over approximately 34 square kilometers in very deep water. Evidence of the EA sediment deposit is found from water depths of 40 m to over the shelf break (at 70 to 100 m) and down the slope. DDTs and PCBs are found in sediment, water, and fish at the PV Shelf Study Area. The GRAs focus on the EA sediment, as the present source of contamination, and on controlling exposure (i.e., consumption) of fish, as the pathway through which human and ecological health are potentially at risk.

The GRAs describe remedial actions theoretically capable of achieving the RAOs described in Section 3.0. The technologies are grouped according to the GRAs. One or more technologies and technology process options may be considered within each GRA category. Ancillary technologies that are necessary to the overall implementation of a cleanup program, but secondary to the primary functions embodied in the GRAs, are also evaluated. For example, sediment dewatering during removal or suspended solids control during dredging are ancillary technologies.

4.2.1 Screening Criteria

The screening of technologies and process options in this section incorporates information developed as part of the NRDA, *Feasibility Study of Sediment Remediation Alternatives for the Southern California Natural Resource Damage Assessment* (NOAA 1994), *Screening Evaluation of Response Actions for Contaminated Sediment on the Palos Verdes Shelf* (EPA, 1997) and the Engineering Evaluation/Cost Analysis (EE/CA) (EPA, 2000). The EE/CA included response actions involving dredging, capping, and institutional controls. Additional information from these sources was used during development and evaluation of the site-specific remedial alternatives in Section 5.0.

Applicable technology and process options have been identified for each GRA. For the purposes of this FS, the term "remedial technology" refers to a general category of technologies, such as in situ chemical treatment, capping, and monitored natural recovery (MNR). The term "process option" refers to the material, equipment, or methodology used to implement a technology. For example, dredging is a remedial technology under the GRA of sediment removal and hydraulic dredging is a process option that could be used to implement dredging.

The criteria used to evaluate each process option are implementability, effectiveness, and relative cost. These criteria are discussed below.

4.2.1.1 Implementability

Technical implementability refers to the technical feasibility of implementing a particular technology. Technologies that are not applicable to site characteristics or the COCs are eliminated from further consideration. Administrative implementability considers permitting and the availability of necessary services and equipment to implement a particular technology.

4.2.1.2 Effectiveness

Determining the effectiveness of a technology involves consideration of whether the technology can contain, reduce, or eliminate the COCs and achieve the RAOs. Effectiveness is evaluated relative to the other technologies identified in the screening. Consideration must also be given to the many aspects of remediation that contribute to a technology's overall effectiveness including:

- How well the technology will handle the estimated areas or volumes of contaminated sediment to be remediated;
- If the RAOs will be met through implementation of the technology;
- How efficiently does the technology reduce or eliminate the COCs;
- To what degree the technology has been tested and proven;
- How quickly the technology can be implemented; and
- How effective is the process option in protecting human health and the environment during implementation.

4.2.1.3 Cost

Technologies were evaluated with respect to capital and operations and maintenance (O&M) costs. Detailed cost estimates of remedial alternatives are provided in Section 6.0 of the FS Report. Costs used for screening purposes are defined in terms of high, moderate, and low, rather than a specific dollar amount and are determined on the basis of engineering judgement and/or previous experience at the site. The cost of each process option relative to the other process options in the same technology type is compared.

When multiple process options are considered effective, implementable, and cost-effective, a representative process option is chosen for development and analysis. Retained technologies and process options will be combined into site-specific remedial alternatives.

4.3 Evaluation and Screening of Remedial Technologies

General descriptions of the technologies and process options for each of the general response actions (GRAs) are provided below. Based on the evaluation of the technologies and process options, some of the GRAs may be screened out as infeasible.

4.3.1 No Action

The National Contingency Plan (NCP) (see 40 CFR Section 300.430[e][6]) requires consideration of a no action GRA as a baseline to compare against other remedial alternatives. Under the no action alternative, no response action would be performed, and contaminated sediments would be left in place. There are no technologies or process options associated with this GRA.

4.3.1.1 Implementability

There is no implementation associated with no action.

4.3.1.2 Effectiveness

The no action alternative is unlikely to meet RAOs, nor would any action be taken to verify recovery.

4.3.1.3 Cost

No action, by definition, would have no associated costs.

4.3.2 Institutional Controls

Institutional controls (ICs) are restrictions on land use or resource use thT limit exposure to hazardous substances. ICs are nonengineered instruments such as administrative or legal controls that limit land or resource use to prevent activities that could expose humans or wildlife to contamination. Institutional controls typically are used in conjunction with engineering measures.

Institutional controls have been implemented at the PV Shelf site for a number of years. Since 1985, the State of California has issued fish consumption and health advisories for the Southern California coast. These warnings have been included in the California sport fishing regulations since March 1, 1992.

In 1990, the California Department of Fish and Game (CDFG) imposed a commercial fishing ban on white croaker specific to the PV Shelf based on the health risk advisories provided by the CalEPA Office of Environmental Health hazard Assessment (OEHHA). The commercial fishing ban extends 3 miles out from the shoreline from Point Vicente to Point Fermin. In March 1998, in response to concerns about white croaker being sold illegally by sport fishermen to commercial fish markets, CDFG revised the white croaker recreational catch limit from unlimited to 10 fish per day.

In 2001 EPA prepared an Action Memorandum that put in place an institutional controls program for PV Shelf. The 10-year program established a three-pronged approach to limit human exposure to potentially contaminated fish from PV Shelf: public outreach and education, enforcement, and monitoring. For remedial identification and screening purposes, institutional controls constitute a remedial technology. Elements of the institutional controls program for PV Shelf include the following: outreach and education, enforcement, and monitoring. More information about the program can be found in Appendix D, which contains the Palos Verdes Shelf Superfund Site Institutional Controls Program Implementation Plan (draft 2009).

Public Outreach and Education

The current program conducts outreach in four primary areas: piers, commercial fish markets, the media, and general outreach. Pier outreach is designed to educate anglers in the Los Angeles area about the site history, fish advisories, identification of contaminated fish, and safe fish-consumption practices. Outreach to commercial fish markets is conducted to inform markets and restaurants of the dangers of buying fish from unlicensed dealers who may be taking fish from restricted areas. Media outreach is used to inform the general population of the health risks of eating contaminated fish from the PV Shelf through media circulation throughout Los Angeles and Orange Counties. Finally, the general outreach program partners with health and community fairs and local health departments to provide educational materials and training to affected communities. The components of the outreach program have been and would continue to be conducted in several languages commonly spoken in the Los Angeles area.

Enforcement

Enforcement of the commercial catch ban on white croaker off the Palos Verdes Peninsula and the daily recreational catch limit for white croaker reduces the likelihood that contaminated fish will be sold to consumers at public markets. Enforcement of the catch ban is implemented by the California Department of Fish and Game (CDFG) and includes patrolling the catch ban area along with all of the surrounding areas for sport and commercial take of white croaker, as well as monitoring landing data (catch block, landing port, species, gear used, value, and weight of fish) and fish business inspections. All of the enforcement efforts of the CDFG fall within their normal areas of responsibility. However, more emphasis has been directed on white croaker starting in 2009.

Monitoring

The fish monitoring program includes sampling fish from designated ocean locations in the PV Shelf area as well as fish from local markets to keep messages up-to-date on which species have lower COC body burdens and which should be consumed in limited quantities. The *2002/2004 Southern California Coastal Contaminants in Fish Study* (EPA/MSRP 2007) also assessed the effectiveness of the enforcement program by evaluating whether contaminated fish from the PV Shelf are reaching local fish markets, and whether the catch ban boundaries are still adequate.

EPA visited 55 markets in Los Angeles County and 13 markets in Orange County from July 2004 through January 2005. The market list was based on previous studies (Heal the Bay, 1997, and S.R. Hanson & Associates, 2000), and markets that were identified by community based organizations from the Fish Contamination Education Collective (FCEC). After repeated visits, six markets (4 in Orange county and 2 in Los Angeles county) out of 68 markets were found to carry white croaker. Five white croaker were purchased at each of the six markets. Concentrations of contaminants in white croaker fish fillet ranged from 12 mg/kg to 0.058 mg/kg DDTs and from 1 mg/kg to and 0.027 mg/kg PCBs (CH2M HILL 2006). All of the white croaker exceeded the RME targets for DDTs, and three of the six markets sold white croaker with DDT concentrations above the CTE target. All of the markets had white croaker that exceeded both the RME and CTE targets for PCBs. The higher levels of DDTs and PCBs are consistent with the contaminant levels found in white croaker in the commercial catch ban area.

Monitoring, as an ICs process option, would include studies to better identify areas where recreational or subsistence fishing can occur and which species should be consumed in limited quantities.

4.3.2.1. Implementability

The ICs program has been in place since 2001. The processes involved in the ICs program are generally easy to implement as long as there is adequate staff and adequate funding, as discussed in more detail in Appendix D. The multi-agency coordination and large area under the program pose challenges. Public outreach and education for the Los Angeles area is challenging given the plethora of media messages that area residents are exposed to on a daily basis. Enforcement of the commercial catch ban and bag limit are challenging as well. The commercial catch ban area covers small portions of catch blocks 719 and 740 and all of block 720. In 2007, landing data indicate no white croaker were caught in blocks 719 and 720 and 27,585 pounds of white croaker were caught in block 740. In the absence of evidence to the contrary, EPA assumes all of the fish were caught outside the catch ban area. An increase in CDFG patrols in 2009 will lend support to the effectiveness of the catch ban area.

4.3.2.2 Effectiveness

The public outreach and education program has conducted surveys to measure the effectiveness of its activities. It has found that a majority of anglers in the area have heard the messages on safe fish-consumption habits and their role in reducing the risk to human health. More recently, the program has focused on attempting to quantify behavior changes attributable to its initiatives.

Continued enforcement of commercial fishing bans and the sport-fishing bag limit of 10 fish per day for white croaker is a potentially effective measure for reducing the number of contaminated fish reaching the marketplace. However, as the market monitoring discussed above illustrates, fish with contaminant concentrations outside of the EPA risk range are still reaching consumers. Enforcement appears to be controlling the quantity of fish that reach markets but not necessarily the quality. Additional measures to increase the effectiveness of enforcement warrant consideration.

The fish monitoring program is effective when used in combination with the other institutional controls to help assess if enforcement and outreach programs are preventing contaminated fish from reaching the marketplace.

This process option has the potential to effectively curb human health risk; however, institutional controls cannot protect ecological receptors.

4.3.2.3 Cost

Costs for institutional controls are generally less than technology-based cleanup options that involve containment, removal or treatment. The task of enforcement is borne largely by the State, i.e., CDFG with support from local governmental health departments. Administrative and regulatory barriers prevent EPA from directly implementing enforcement activities. However, EPA can provide financial assistance to state and local agencies through cooperative agreements.

4.3.2.4 Screening Decision

Institutional Controls are important features of many sediment cleanup projects and are retained for further consideration in the development of remedial alternatives. The management of some remedial actions and management of residual risk after remediation will likely require implementation of ICs for a period of time until the monitored natural recovery goals and project RAOs are achieved. ICs are retained.

4.3.3 Monitored Natural Recovery

Natural recovery involves one or more processes that effectively reduce or isolate contaminant toxicity, mobility, or volume. These processes include physical, chemical, and biological processes. Monitored natural recovery may be an appropriate remedial alternative when:

- large volumes of contaminated sediment have marginal levels of contamination;
- the area is a low-energy, depositional environment;
- dredging for navigational needs are not required;
- site restrictions and institutional controls can effectively limit exposure;
- review of existing data suggest that the contamination is naturally attenuating and will likely achieve the remediation goals within an acceptable time frame; and
- the cost for an active remedy disproportionately outweighs the risk reduction benefit.

The PV Shelf meets many of these criteria. As discussed in section 1.2.5, the PV Shelf Study Area can be divided into different areas. By depth, the area can be divided into the inshore region, the fairly level shelf, and the steep slope. From east to west, the shelf is divided by the outfalls at White Point into southeast of the outfalls, north-northwest of the outfalls, and the area around the outfalls. The EA deposit does not extend into shallower waters. The area southeast of the outfalls has low levels of contaminants mixed in the sediment, but prevailing currents kept the deposit from forming there like it did north of the outfalls (see Figure 1-8). The area north of the outfalls has highly contaminated sediment covered by approximately 30 cm of cleaner sediment with lower surface contaminant concentrations. Data and modeling suggest the most contaminated sediment in this area may stay buried. Additionally, the buried deposit of DDT appears to be undergoing reductive dechlorination. The outfall area has surface sediment concentrations of contaminants an order of magnitude greater than other areas. In addition, the buried "peak" of contaminated sediment around the outfalls appears to be moving upward, toward the surface. Finally, the slope is too steep for a thick sediment layer to develop; however, the slope has areas of high surface contaminant concentrations.

Monitored natural recovery (MNR) may rely on a wide range of naturally occurring processes to reduce risk to human health and ecological receptors. These processes may include physical, biological, and chemical mechanisms that work together to reduce the risk posed by the contaminants. Under MNR risk reduction is achieved in one or more of the following ways:

- The contaminant is converted to a less toxic form through transformation processes, such as biochemical degradation or abiotic transformation.
- Loss of contaminants through diffusion into overlying water.
- Exposure levels are reduced by a decrease in contaminant concentration levels in the near-surface sediment zone through burial or mixing-in-place with cleaner sediment.
- Exposure levels are reduced by a decrease in contaminant concentration levels in the near-surface sediment zone through dispersion of particle-bound contaminants or diffusive or advective transport of contaminants to the water column.

MNR usually involves acquisition of information over time to confirm that identified risk-reduction processes are occurring as predicted. MNR would measure reductions of contaminants in sediment, water and fish against the remediation goals set forth in Section 3.4. MNR can be combined with engineering approaches, e.g., placement of a thin layer of clean sediment to support existing cover or addition of an amendment to accelerate contaminant breakdown. These combined approaches are referred to as Enhanced Natural Recovery.

As discussed in Section 2.4, there is evidence that PV Shelf is undergoing natural recovery. The following processes have been observed.

Natural Dechlorination.

In 1972, one year after inputs of DDT to the LACSD sewer system had ceased, the DDT composition of sediment on the PV Shelf was found to be dominated by DDE. Existing information suggests that this was the result of dehydrochlorination of DDT that occurred shortly after discharge of DDT-bearing wastes form the JWPCP outfalls. The DDT composition of shelf sediments showed little change between 1972 and 1992 when, for the first time, DDMU was measured in the sediment as part of the Natural Resources Damage Assessment Program. The presence of DDMU in all sediment samples collected in 1992 and its increased relative abundance with depth in many cores suggested that reductive dechlorination of DDE was taking place. However, initial estimates of maximum first-order transformation rates near LACSD station 3C, based on the assumption that DDMU was a dead-end product, were relatively low (0.028 yr^{-1}). Microcosm experiments published in 1998 demonstrated unequivocally that reductive dechlorination could be mediated by microorganisms present in PV Shelf sediment (Quensen et al., 1998). These experiments also showed that dechlorination rates varied spatially with higher rates in sediment collected farther from the outfalls (e.g., station 3C). The microcosm-based dechlorination rates determined for sediment from station 3C were much higher than those estimated from the aforementioned 1992 core analyses (0.99 yr^{-1} vs. 0.028 yr^{-1}).

In 2006, USGS performed a core-to-core comparison of sediment cores that had been collected near station 3C in 1992 and 2003 (Eganhouse, 2007). The 2003 core was analyzed for 8 DDT compounds, 84 PCB congeners, and 38 long-chain alkylbenzenes. This provided a means of estimating DDE transformation rates for the period 1992-2003 through comparison of DDE whole-core inventories and DDE concentrations in coeval sediment layers. The analyses show that the whole-core inventory of DDE decreased by 43.2 percent from 1992 to 2003, whereas inventories of DDMU and DDNU increased by 33.5 percent and

33 percent, respectively, during the same period. The estimated first-order DDE transformation rate based on whole-core inventories was 0.051 yr^{-1}.

Limited data are also available for other locations on the shelf. Based on comparison of whole-core inventories of DDE in sediment collected by the LACSD at station 6C in 1991 and 2005, rates of 0.013-0.028 yr^{-1} were obtained. These are approximately 2 to 3 times lower than those at station 3C.

In contrast to DDE, the cores showed no evidence of reductive dechlorination of PCBs. The reported differences in surficial contaminant concentrations may be a reflection of this.

Vertical Profiling and Biodiffusion

Because the highest concentration of DDT/DDE is buried, sedimentological studies focused on how organisms that live in the sediment transport contaminants upward. As discussed in section 2.5, in the 1990s, investigations for the NRDA (Wheatcroft and Marten, 1996) measured both the physical and biodiffusive rates for contaminant transport. Other investigations focused on how water column processes resuspend and transport contaminants. These results show that contaminants are indeed being mixed to the surface of the sediment bed, primarily through biodiffusion. Once they reach the seabed, surface-wave-induced currents resuspend them and subtidal currents transport them.

In 2004, additional studies of biodiffusion and sediment mixing were undertaken (SAIC, 2005). Radioisotopes were used to calculate sediment mixing/bioturbation rates. Profiles of thorium-234, which decays rapidly (24.1-day half life), were used to evaluate bioturbation and mixing in the sediment surface. Profiles of excess lead-210 (22.3-year half life) were used to determine sediment accumulation rates at four stations across the shelf. Biodiffusivity values based on the thorium-234 profiles, coupled with sedimentation rate data from the lead-210 analyses, indicate low sediment mixing intensities (i.e, average of 19± 21 cm^2/yr vs. 1992/93 values of 31± 20 cm^2/yr). Sediment accumulation rates from the lead-210 data were low (about 0.8 to 1.6 mm/yr). There was some indication that the sediment accumulation rate was relatively lower in the southeast portion of the study area. Thorium-234 results indicated biodiffusive mixing to about 6-cm sediment depths, generally consistent with historical data on the principal vertical distributions of the infaunal community. Overall, data from the 2004 assessment indicate low sediment mixing intensities below surface layers and low biomass and abundance of deep bioturbating infaunal organisms (BIOs).

Evidence of low sediment mixing can be seen by an examination of LACSD sediment cores. LACSD has taken sediment cores from many of their sampling stations throughout the years. Cores taken across the 60-m isobath create an historical record of the sediment deposit. Figures 2-8 and 2-9 provide multiyear sampling data for stations 3C and 6C, indicating changes in contaminant concentration and location of peak contamination. Figure 2-10 shows profiles for all 60-m stations.

Sediment Deposition

Historical (pre-outfall) sedimentation rates have been estimated at approximately 0.1 to 0.2 cm/year (Lee et al., 2002). Discharge of suspended solids from the JWPCP outfalls along with erosion of the Portuguese Bend Landslide added millions of metric tons (mt) of sediment to the shelf. Sedimentation rates have dropped substantially since JWPCP implemented secondary treatment of wastewater in 2002. Present TSS emission rate is 8,000 mt/yr, down from the historical high of 167,000 mt/yr in 1971. Recent calculations indicate the area over the contaminated sediment deposit remains depositional, although rates have dropped (Sherwood 2006). Based on the process model included as Appendix B and described in section 2.5, the shelf may be capable of natural recovery over time.

Sediment Transport and Burial

Analysis of surficial contaminant concentrations over time indicate median DDT concentrations went from 4.0 mg/kg in 1992, to 2.5 mg/kg in 2002, and 2.0 mg/kg in 2004. During the same period, PCBs (as sum of six Aroclors) went from median concentration of 0.5 mg/kg in 1992 to 0.6 mg/kg in 2002 and 0.3 mg/kg in 2004. As shown in table 1-1, the extent of contamination in surface sediment has decreased. From 1992 to 2002/2004, the surface area exceeding 10 mg/kg DDTs has dropped 56 percent, from 8.2 km^2 to 3.6 km^2. For the same time period, the area exceeding 1 mg/kg DDTs decreased 12 percent, from 44.5 km^2 to 39.1 km^2; and the area exceeding 1 mg/kg PCBs decreased 26 percent, from 8.4 km^2 to 6.2 km^2. The reduction in surficial concentrations of DDTs and PCBs are attributed to physical, biological, and, in the case of DDTs, chemical processes. Loss processes that are important at PV Shelf include sediment transport and deposition, physical reworking of sediment by waves and currents, resuspension and desorption, and biological mixing or transport of sediment and liquid-phase contaminants (i.e., in pore water).

4.3.3.1 Implementability

The technical and administrative implementability of MNR is high. Sampling techniques for water, sediment and fish are proven. MNR is not expected to require construction activities, and thus will be less disruptive to the ecological community compared with other remedial technologies. Modeling of sediment fate and transport included in Appendix B, is used to predict recovery rates, loss rates, and reductions in concentrations of COCs. Field monitoring to validate and refine modeling would be required.

4.3.2.2 Effectiveness

Monitored natural recovery may be an appropriate remedial alternative for certain areas of the site. Some areas, such as the northwestern region, appear to be net depositional and the contaminated mass is likely to stay buried. Other areas, such as the slope, cannot be actively remediated.

Although deposition rates along the 60-m isobath have been calculated from the LACSD’s multi-year data set, the rates appear to have dropped since LACSD implemented full secondary treatment of effluent. Studies to calculate current deposition rates and effects of winter storms on the sediment deposit are underway. Depending on rates of sedimentation and erosion, median concentrations of DDTs in surface sediment associated with remediation goals in fish tissue may be reached in 45 to over 100 years, and water quality standards may be met within 30 to 60 years. Additionally, under one scenario (Sherwood, 2002) the area around the outfalls would reach low contaminant surface concentrations through erosion of as much as 80 percent of the deposit, which would be transported off the shelf into deeper waters.

MNR may be effective in the long term, but not in the short term. Comprehensive monitoring and an evaluation of the study area would be essential to assess the rate and effectiveness of MNR for the PV Shelf and to assure that the contaminated sediment is not merely distributed into other areas. Potential risk to human health and the environment will remain during the implementation phase of MNR.

4.3.3.3 Cost

MNR is generally considered a low-cost technology because no active remediation occurs that involves containment, removal, or treatment of sediment. However, monitoring costs may be significant, extending into the millions of dollars, depending on the term and magnitude of the monitoring program. Long-term monitoring costs vary widely depending upon the project expectations, media of concern, and residual risks. Because of the complexity of the site, the cost for MNR will be relatively high compared with MNR for other sites.

4.3.3.4 Screening Decision

MNR is retained for remedial alternative development.

4.3.4 Enhanced Monitored Natural Recovery

For the PV Shelf Study Area there are two potential actions to enhance the natural recovery processes:

- Controlling conditions to encourage natural degradation
- Adding a thin layer of clean sediment over contaminated sediment to reduce surface concentrations of contaminants and stabilize sediment erosion

Both of these approaches are described in more detail below.

Enhanced Natural Degradation

Controlling conditions to accelerate the natural degradation process would consist of determining the primary mechanisms for degradation and enhancing it through the addition of substrate, or otherwise changing the site conditions to encourage degradation. As discussed above, biochemical degradation of DDE is occurring at the site and could be a significant mechanism for natural recovery. However, the mechanism driving reductive dechlorination of DDE is not known. Additionally, once the degradation mechanisms are identified finding a mechanism to accelerate degradation in situ, given the depth of the deposit and the fact that the buried sediment is where the degradation is most pronounced, make enhancement to accelerate degradation challenging. As stated previously, there is no evidence PCBs are degrading; therefore, enhanced natural degradation through reductive dechlorination would not reduce the risk from PCBs.

Clean Sediment Amendment

The placement of a thin-layer cap is another approach to enhance MNR. Thin-layer capping is discussed under section 4.3.5 Containment. Briefly, a 10 to 15 cm thin-layer cap of clean sand would be placed over the deposit with the expectation that it would mix in with the EA sediment, supplementing and diluting the existing surface sediment. As the finer EA sediment erodes, the clean material would remain, reducing COC surface concentrations.

4.3.4.1 Implementability

The implementability of enhanced MNR through clean sediment amendment is moderate to high. The depth of PV Shelf poses a challenge; however, techniques to accurately deliver sediment at depths are available.

4.3.4.2 Effectiveness

The effectiveness of enhancing MNR through controlling degradation of the contaminants is low because the mechanisms for degradation are not fully understood and even if the mechanisms were identified, the depth of the EA sediment deposit would make implementation difficult. In addition, PCBs do not appear to be degrading.

The effectiveness of enhanced MNR through a thin cap is estimated to be moderate to high. The mixing that would occur and the potential for armoring of the surface layer are likely to enhance the natural recovery and are thought to be promising. However, additional information on type of material and best placement locations and techniques would need to be collected as part of a pilot project or other type of treatability study.

4.3.4.3 Cost.

The cost for enhanced MNR would be high because this technology requires more research and understanding prior to implementation. As described below under "Containment," capping material and the placement of a thin-layer cap would be costly to implement. Adding a substrate or controlling site conditions also would be costly.

4.3.4.4 Screening Option

Enhanced MNR is retained for remedial alternative development.

4.3.5 Containment

Containment or in situ capping refers to the placement of a subaqueous covering or cap of clean material over contaminated sediment. Containment does not require removal of sediment; clean sediment is placed over old sediment as a barrier, isolating contaminants within the substrate. Capping has become an accepted engineering option for managing subaqueous contaminated sediment.

In situ capping can quickly reduce exposure to contaminants and, unlike dredging or excavation, requires less infrastructure in terms of material handling, dewatering, treatment and disposal. A well-designed and well-placed cap should reduce the exposure of fish and other biota to contaminated sediment more quickly than dredging, since there should be no or very little contaminant residual on the surface of the cap. Cap placement eliminates the majority of the benthic community, but creates a clean substrate for recolonization. In some cases, it may be desirable to select capping materials that discourage colonization by native deep-burrowing organisms to limit bioturbation and release of underlying contaminants.

The major limitations of in situ capping is that the contaminated sediment remains in the aquatic environment where contaminants could be exposed or be dispersed if the cap is disturbed or if contaminants move through the cap in significant amounts. In some environments it can be difficult to place a cap without significant contaminant losses from compaction and disruption of the underlying sediment. Shear strength, especially undrained shear strength, of contaminated sediment deposits is of particular importance in determining the feasibility of in situ capping. Most contaminated sediment is fine-grained, and is usually high in water content and relatively low in shear strength. Although a cap can be constructed on sediment with low shear strengths, the ability of the sediment to support a cap and the need to construct the cap using appropriate methods to avoid displacement of the contaminated sediment must be considered. Movement of dissolved contaminants by advection (flow of pore water) through the cap is possible, while some movement of contaminants through molecular diffusion is inevitable. Cap thickness and cap material can minimize chemical flux.

Capping operations can disturb and displace loose fine-grained bottom sediment, resulting in resuspension losses and mixing of contaminants into the clean capping layer. Physical characteristics, such as solids content, plasticity, shear strength, consolidation, and grain size distribution affect the displacement of sediment. The sediment characteristics will often form the basis for determining the suitability of capping materials and placement options (Palermo 1991).

The method used to place the cap material must be capable of achieving even placement of material over the target area while limiting the resuspension and loss of contaminated sediment into the water column or the emerging cap layer. Even placement and limited resuspension of contaminated sediment are generally achieved when the capping materials are dispersed and allowed to settle through the water column. The dumping of large, dense masses of capping material (e.g. pushing sands off a barge) or methods that lead to density-driven hydraulic flow should be avoided.

Installation of an in situ, subaqueous cap requires consideration of the following issues:

- The type of capping material with regard to isolation of sediment and protection of cap and sediment against erosion due to environmental factors (wave, current, benthic, etc.)
- The amount (thickness) of capping material required with regard to isolation of sediment against benthic activity or contaminant flux through advection or diffusion
- The amount of capping material required with regard to the required accuracy of placement, gradation of material, and physical/chemical makeup of material (i.e., reactive material or organic substrate)
- The total amount of material required based on the area to be capped and an assumed loss factor through the water column and mixture with the contaminated sediment
- The equipment available and applicable to the area being worked such as shallow water, deep water, open water, lakes, etc.
- The available sources for capping material and proximity to the site
- The techniques that are applicable for the particular situation such as low impact/high accuracy/high volume or high impact/low accuracy/low volume
- The ability to isolate portions of the water body such that turbidity and resuspension do not impact offsite areas
- The affect that placement of material has on the in situ sediment, consolidation, resuspension, mixing, change in redox potential, and bottom failure

Ancillary processes associated with containment technologies include:

- Cap material placement
- Cap placement methods
- Resuspension management
- Residual management
- Cap material conveyance/transport

Cap Material Placement

Caps can be grouped into three general categories: conventional sand, armored and composite. Conventional capping includes sand and clay caps. Armored capping adds heavier material on top of a conventional cap to add physical stability in erosive environments. Other miscellaneous capping techniques include thin-layer capping and enhanced capping.

Conventional caps involve the placement of sand or other suitable cover material (e.g., clay) over the top of contaminated sediment. Material selection and cap thickness are determined based on consideration of contaminant properties and local hydraulic conditions. Sandy soils and sediments are typically preferred as cap materials over fine-grained materials. The latter are more difficult to place evenly, cause a great deal of turbidity during placement and are more erosive (Palermo 1994).

Armored caps are similar to conventional caps with the exception that the primary capping material, e.g., sand, is covered with stone or other suitable riprap (the armor) to add physical stability in erosive environments. Armored caps are commonly used in environments where high water velocities threaten cap integrity.

A composite cap generally involves placement of a geotextile or flexible membrane liner directly over the contaminated sediment. Permeable or impermeable liners may be considered, depending upon the migration potential of the COCs, and the potential for methane buildup under the liner in highly organic sediments. The liner is then armored with stone or riprap to ensure the physical integrity of the cap. Composite caps may also include a sand or activated carbon layer to capture any potential diffusion or advective migration of the underlying contaminants. Composite caps have size and depth limitations.

Additional capping approaches have been tried or are under development, for example, thin-layer capping or use of special capping materials, e.g., Aquablok®. Thin-layer capping involves the placement of a thin (5 to 10 cm thick) layer of clean sediment, that is subsequently mixed with the underlying contaminated sediment to achieve acceptable COC concentrations and/or enhance the natural attenuation processes. Mixing occurs naturally as a result of benthic organism activity (bioturbation). This approach is best suited for situations involving contaminants that naturally attenuate over time.

The effectiveness of capping can be increased by incorporating special materials, such as activated carbon, iron fillings, Aquablok® or other agents into the base capping material (e.g., sand) to enhance adsorption or in situ chemical reaction. This approach targets sediment in which contaminants are mobile and are expected to migrate through the cap as dissolved constituents in the pore water.

Placement Methods

Various equipment types and placement methods have been used for capping projects. Important considerations in selection of placement methods include the need for controlled, accurate placement of capping materials. Slow, uniform application that allows the capping material to accumulate in layers is often necessary to avoid displacement of or mixing with the underlying contaminated sediment. Uncontrolled placement of the capping material can also result in the resuspension of contaminated material into the water column and the creation of a fluid mud wave that moves outside of the intended cap area.

Most available techniques for placement of cap material can be classified as either mechanical or hydraulic. Mechanical placement techniques include clamshells, split-hull barge and split-hull hopper dredge, flat-deck barge using a bulldozer to push material over the edge of the barge, long-handled backhoes, and skip buckets on cranes. Conveyors also have been used to cap areas beneath structures or in shallow draft areas. Fallpipes or tremie tubes used with a clamshell bucket or conveyor can be used in areas of deep water where placement of cap material requires precision. Mechanical methods such as split-hull barges and split-hull hopper dredges can carry 1,000 m^3 of capping material or more and place it very rapidly using point dumping techniques (resting in one place while opening the split hull). A split-hull barge or hopper dredge also can slowly open the hull doors while moving through an area, and release material more slowly and with relatively lower impact. This method is known as a spreading placement technique. Both point placement and the spreading technique are rapid compared to other placement techniques.

Mechanical placement using a clamshell can be conducted by point dumping above the water line or just above the mudline. Material released from the clamshell above the waterline is performed by casting the material while opening the bucket (open on the swing) and will have relatively low impact when the cap material falls onto the mud bottom. The impact of clamshell point placement also can be reduced by lowering the clamshell to several feet above the bottom and opening it. Material released above the mudline is a slower placement technique with higher precision of placement. Material placement also can be achieved by loading a skip bucket (usually loaded with an end-loader or backhoe) and point dumping or casting.

Hydraulic placement techniques include pumping slurry to the site, hydraulically sluicing material off the deck of a flat-deck barge, and spraying or sprinkling a slurry of material. The methods differ primarily in the speed of placement, the accuracy of placement, and the impact or energy of the material placed on the bottom sediment. Tremie tubes can be used with hydraulic placement methods. Similar to using a tremie tube with mechanical placement, projects that require placement of the cap material with high precision can use hydraulic methods. The slurry can be pumped into a tremie tube for placement near the bottom. An energy dissipater, such as a diffuser or spoon, can be used to absorb energy and spread the material before it impacts the bottom. Hydraulic methods offer the potential for more precise placement, although the energy required for slurry transport could require dissipation to prevent resuspension of contaminated sediment. Hydraulic placement methods are typically slower (lower placement rate). Techniques such as pumping from a barge using dredge equipment can move large quantities of material fairly rapidly and fairly accurately as can sluicing from a flat-decked barge using a large water cannon. Methods such as spraying a slurry are more applicable to very slow, accurate placement and have been used in very shallow draft areas such as wetlands.

Resuspension Management

Placement of a sediment cap will involve in-water work, which can cause resuspension of contaminated sediment. The resuspended contaminated sediment might be transported outside the construction zone and settle in other areas. Resuspension of contaminated sediment might cause impacts to aquatic biota adjacent to the construction zone. Therefore, resuspension must be managed to minimize construction impacts.

Water quality impacts resulting from in-water construction would be limited to short-term increases in suspended sediment in the construction area and advection of pore water through the cap material during consolidation of underlying sediment.

Resuspension management would use best management practices (BMPs) during in-water work. Engineering and in-water construction methods would be designed to minimize resuspension. In addition, engineering design would minimize events such as slope failures for removal and craters for cap placement.

Additional BMPs might include placing the cap with a tremie tube, using cap material that has been washed or contains very few fines, installing the initial layer of cap material at a slow rate to minimize resuspension, placing cap material using low-energy spreading methods as opposed to high-energy methods, and using curtain barriers.

Curtain barriers consist of impermeable and permeable silt curtains. A silt curtain is designed to contain sediment within a limited area and provide enough residence time that sediment particles can fall out of suspension and not travel to other areas outside the construction zone. The suspended silt curtain consists of either an impermeable or permeable filter fabric curtain weighted at the bottom and attached to a flotation device at the top. An anchor system attached to the flotation device at the top is typical, and an anchor system at the bottom can be used for additional stability. The silt curtain type must be selected on the basis of flow conditions in the area. Silt curtains are not designed to act as water impoundment dams and cannot be expected to stop the flow of a significant volume of water. They are designed and installed to trap sediment, not to halt the movement of water. Anchoring these curtains would also be a challenge and may not be achievable with even low currents.

Residual Management

Residual management is the process that addresses residual contaminated sediment left behind after a remedial action because further containment is not practical. Contamination that remains exposed after a capping operation is dependent on a number of factors, including the cap placement method, skill of the operators, physical sediment properties, thickness and areal extent of the cap, presence of obstructions such as the LACSD outfalls, and site hydrodynamics such as currents and waves. Residual management is likely to consist of risk evaluation to consider the uncapped areas or additional construction methods to cap difficult areas.

Cap Material Transport/Conveyance

Transport/conveyance considerations would be required for alternatives involving containment. Cap material would be transported from a fill source or vendor to the project site.

Barge/Scow Transport

Typically, a barge, scow, or hopper dredge is used to transport sediment for placement. Maneuvering a barge into position with a tugboat involves a number of logistical considerations. Barges would typically be used to transport from a shoreline source, or in combination with truck transport from an upland source. A hopper dredge would be used to transport materials from an in-water source, such as borrow area or an ongoing maintenance dredging project at a nearby port.

4.3.5.1 Implementability

The USACE prepared *Options for In Situ Capping of PV Shelf* (Palermo et al, 1999), included as Appendix E to assess the feasibility of capping the shelf. USACE determined that the area between 40 m and 70 m was suitable for capping. Capping in water depth less than 40 m would require control measures to prevent erosion. Beyond 70 m, the slope increases to greater than 5 degrees, which would be unsuitable for capping because of susceptibility to flow failure under moderate seismic activity. The report discussed cap material, cap thickness, and erosion, seismic, consolidation and bioturbation evaluations.

In 2000. EPA sponsored a pilot capping project to evaluate three methods of cap placement:

- Conventional placement (point dumping) by a hopper dredge with a split hull
- Spreading placement (slow-dump) by hopper dredge with a split hull moving through the dump zone
- Direct pumpout through the drag arm of a hopper dredge

The direct pumpout method was not successful due to mechanical problems with the equipment and was terminated after less than 300 m^3 (400 yd^3) of material was placed. Approximately 92,625 m^3 of cap material from a total of 92 loads was placed using the conventional dump method. Approximately 10,325 m^3 of cap material from a total 9 loads was placed using the spreading (slow-dump) method. Material generated from the Queen's Gate entrance channel project was used during the conventional placement methods, while the material from a borrow site was used for the spreading method. Information collected during the pilot capping project indicated that the spreading technique resulted in greater uniformity and less disturbance to in-place effluent-affected sediments compared with the point placement method (Fredette et al., 2002). There was not enough information to evaluate the direct pumpout through the drag arm method.

4.3.5.2 Effectiveness

The 2000 pilot capping project evaluated three placement methods for a sand cap over three 45-acre (300 m x 600 m) cells and concluded that capping is a technically feasible option for the site (Fredette et al., 2002). Monitoring during and after cap placement raised questions about the effectiveness of capping in reducing surficial contaminant concentrations (SAIC, 2002). Monitoring equipment measured increases in turbidity as cap material hit the shelf floor and created a surge wave. For the most successful cap, Cell LU at 40 m, the initial drop of cap material created a vertical plume of suspended sediment 13 m thick and, extending from the point of impact, an annulus with a radial dimension of approximately 220 m. However, both plume and annulus quickly decreased with distance and time. Point dump of cap material on the deeper cell SU, produced a vertical plume 5 – 10 m thick and an annulus with a radial dimension of 232 m. Increased turbidity, indicative of suspended sediment, was measured 475 m from the point dump. A vertical plume 13 m thick was measured at Cell LD, which was capped using the spreading technique; however, within 2 minutes plume thickness had decreased 50 percent (SAIC 2002). Turbidity associated with the spreading technique dissipated faster than turbidity from point dump placement.

Post-cap monitoring revealed a depositional layer of fine-grained sediment over all three caps. Two post-cap surveys were conducted. The first survey collected sediment cores using a vibracore; the supplemental survey used a box core after concerns were raised that the vibracore may have contributed to sediment scouring or drag down. Post-cap monitoring found surface DDE concentrations lower than baseline (i.e., pre-capping) for Cell LU, approximately the same for Cell LD, and comparable or higher than baseline concentrations for Cell SU (SAIC 2002). The pilot project illustrated the potential difficulties associated with capping soft sediment at 40 to 60 m depths.

The pilot capping project found the spreading method and the drag-arm method created less of a shock wave and resulted in less disturbance to the effluent-affected sediment compared with the point placement method. The spreading method is a relatively rapid placement technique with a relatively minor modification to conventional methods. The mechanical placement method using a clamshell bucket would be much slower and more costly than the spreading method with a split-hull barge or hopper dredge; however, the impact of the material would be much lower and disturbance of the effluent-affected sediment is expected to be less. Low impact techniques are favored initially to minimize resuspension; however, once the first layer is placed, more rapid methods could be employed. Precision placement would be necessary around the outfalls to prevent clogging of the outfall diffuser ports and around the shelf break to prevent mud flows.

4.3.5.3 Cost

The cost of precision placement techniques is much higher than more rapid techniques. The size and depth of the deposit also increase the cost of this technique.

4.3.5.4 Screening Decision

Containment is retained for remedial alternative development.

4.3.6 Removal

Dredging and excavation are the two most common means of removing contaminated sediment from a water body. Both methods require transporting the sediment to locations for treatment and disposal. They also frequently include treatment of water from dewatered sediment prior to discharge to an appropriate receiving water body. Some of the key components to be evaluated when considering dredging as a cleanup method include sediment removal, transport, staging, treatment and disposal.

The remedial technology associated with removal of the contaminated sediment from the PV Shelf would consist of mechanical or hydraulic dredging. The dredged material would require conveyance to a facility for offloading, treatment, and eventual disposal. Resuspension management, residual management, and conveyance/transport technologies are the associated processes included under the removal GRA.

As part of this FS, EPA tasked its contractor, Innovative Technical Solutions, Inc. to evaluate removal methods for PV Shelf. Their assessment is included as Appendix F.

A complicating factor for this GRA is the need for precision in removing the layer of EA sediment, which is approximately 60 cm thick. It would be easier to remove a greater thickness of material; however, managing a larger volume of sediment and water would significantly increase the cost of removal. The ability of the equipment to keep resuspension of the contaminated sediment to a minimum is also important. The depth of the contaminated material is beyond that normally associated with navigation dredging; however, it is within the range of equipment used for mining. Technologies screened under the removal GRA are as follows:

- Dredging
- Resuspension management
- Residual management
- Conveyance/transport
- Dredged material management

Dredging

Conventional dredging is broadly classified as mechanical or hydraulic. Mechanical dredges use a device such as a clamshell or bucket to excavate the material. Material removed is usually placed in barges for transport to a disposal site. Hydraulic dredges use a centrifugal pump to create a vacuum on the intake side of the pump, where atmospheric pressure then forces a sediment/water slurry into the suction pipe. Material is discharged from the pump into a pipeline to another site, or can be pumped into barges or hoppers contained within the dredge itself. A number of dredges use both principles, e.g., a cutter suction dredge uses the mechanical action of a rotating cutter to dislodge sediment to make it available to be lifted by the centrifugal pump. A third category of specialty dredges includes pneumatic dredges, bottom crawling dredges, and others.

Hydraulic Dredges

Two hydraulic dredges, cutter suction and bucket wheel, do not work in depths greater than 30 m. Also, most of these types of dredges are not well suited for working in the open ocean, i.e., they are limited in their ability to work in sea and swell. Plain suction dredges can operate at depths of 100 m, however the accuracy of the plain suction dredge is poor as it is difficult to leave a smooth bed and troughs are formed. Therefore, dredging a thin layer would be difficult and positioning of the suction head would impose problems, effectively eliminating them from further consideration. Trailing suction hopper dredges are much better suited for work in the open ocean and can perform at the depths found on PV Shelf, i.e., 50 to more than 100 m.

Trailing suction hopper dredges are ships with large bins or hoppers for holding slurry brought to the surface by pumps operating through drag arms which terminate in drag heads that contact the sea bottom. IHC Holland has fabricated hopper dredges capable of dredging down to 100 m (328 feet) with a hopper capacity of approximately 20,000 m^3 (26,160 yd^3). However, due to the long drag arms, it may be difficult to position them precisely. This would likely require additional overlap between passes to insure maximum removal of the contaminated sediment. The additional overlap needed to eliminate the furrowing impact would probably increase the amount of overdepth material dredged. The suction dredge mixes sediment with water to create a slurry for conveyance through a pipeline from the ocean bottom to the hopper. The solids content of the slurry would vary depending on the sediment properties and site conditions, but typically would fall in the range of approximately 8 to 20 percent solids by weight.

Mechanical Dredging

Removal through mechanical dredging equipment would be performed using a mechanical bucket, such as a clamshell. Sediment is removed at nearly in situ water content, and the volume of water to manage is much less compared to hydraulic dredging. Therefore, the volume of sediment is minimized, and there is less water to manage for disposal. The primary advantage of the clamshell is that it can easily dredge down to 100 m with little or no modifications because the bucket is deployed from a cable. Water depth is not a factor in the ability to dredge other than production rate is reduced as depth increases. Special buckets have been developed to reduce resuspension caused by the impact of the bucket on the bottom and during ascent back up through the water column. Disadvantages of mechanical methods include the potential for a loss of sediment in the water column during the dredge cut cycle due to the physical disturbance of the mud bottom. Loss of sediment also can occur during the removal cycle when bringing the bucket up through the water column. Advances in the technology have minimized resuspension of sediment with the advent of the cable arm or similar closed clamshell dredges. The design of the cable arm provides the ability to control the vertical cut in the sediment.

Mechanical dredges require a material barge to contain the dredged material for transport to an offload site. Sediment removed by mechanical dredging requires dewatering. The solids content of material removed will be roughly equivalent to the in situ solids content (for PV Shelf EA sediment, approximately 50 percent).

A trailing suction hopper dredge was determined to be the most appropriate for dredging on the PV Shelf based on the water depth, dredge layer thickness, and sediment type. The trailing suction hopper dredge is able to operate without any form of mooring or spud.

Dredging would require resuspension management, residual management, and conveyance/transport of dredged material. Sediment resuspension during operation of hydraulic dredges occurs when sediment dislodged by the dredgehead escapes the suction pipe. Two important factors in resuspension for hydraulic dredges are the depth of the cut and the speed of advance of the dredgehead. Sediment resuspension by hydraulic dredges is typically more concentrated in the lower portion of the water column, where the dredgehead encounters the sediment (USACE, 2008). Suction dredges are given a high rating in the USACE guidance document, indicating that this dredge type is generally suitable or favorable for sediment resuspension control. This is due to the fact that suction dredges have no mechanical action at the dredgehead to dislodge sediment; therefore, resuspension potential is due solely to the advance of the dredgehead through the sediment (USACE, 2008). When the hoppers on the dredge are full, there are several options for conveyance of the dredged materials. The dredge can go to the disposal area and empty its hopper; the dredged materials can be pumped through pipes directly to the disposal area; or the dredged materials can be pumped into barges for transport to the disposal area. Removal of the contaminated sediment would require the additional process option of disposal. Once the contaminated sediment was removed, it would be necessary to manage it by (1) placing it in a confined disposal facility (CDF) or contained aquatic disposal (CAD), (2) disposing of it in the deep ocean, or (3) disposing of it in a landfill. Each of these options is discussed below.

Confined Disposal Facility

The CDF approach involves placing dredged sediments in a diked structure in order to isolate the contaminants from the environment. The CDF must be designed to effectively contain contaminants. Effluent discharge may require controls such as chemical flocculants and/or filtration to meet water quality standards. A surface cover of clean material may be required for purposes of isolation of the contaminated material and would assist in control of leachate releases. Monitoring to include effluent discharge, wells, and air quality stations would be necessary during and following initial construction of a CDF and placement of material. Water is discharged over a weir structure or allowed to migrate through the dike walls while sediment remains in the CDF (EPA, 2005). Long-term monitoring would be necessary to ensure that contaminants were not discharging from the CDF. Because much of the sediment at the PV Shelf Study Area exceeds the hazardous waste criterion for DDTs, the CDF would have to be located onsite or an offsite location would need to be permitted as a hazardous waste disposal facility. CDFs typically are constructed in shallow water and are not proven in water that is hundreds of feet deep. Onsite construction is not feasible; for example, the diked walls of a CDF at 60-m depth would need to be several hundred feet wide at the base.

Contained Aquatic Disposal

The CAD approach involves placing dredged material in a structure consisting of a constructed or natural depression in the sea floor with a submarine cap. The design objective of the CAD is similar to a CDF: isolation of contaminated sediments from the environment. A CAD cell would be constructed by first constructing stone dikes similar to the lower portion of dikes needed for a CDF. Contaminated sediment would be deposited in the cell and capped. Potential impacts to the dredging site and requirements for long-term monitoring are also similar to those associated with the CDF. Because this technology involves dredging and placement of the dredged material prior to placing a cap, it offers few advantages over containment.

Implementation is difficult because it requires removal of the material through dredging and cap placement. In addition, similar to a CDF, because much of the sediment at the PV Shelf Study Area exceeds the hazardous waste criterion for DDTs, the CAD would have to be located onsite, or an offsite location would need to be permitted as a hazardous waste disposal facility. It is unlikely that such a facility would receive regulatory approval.

Deep Ocean Disposal

Ocean disposal of dredged sediments consists of placing sediments in deep basins offshore from the PV Shelf. The rationale for this option is that circulation at depths below the basin sill is very restricted and dissolved oxygen concentrations, and hence biological activity, are generally low. Therefore, the potential risks associated with waste disposal in the basins also are relatively low. In addition, basins have been used in the past for disposal of DDT wastes (Venkatesan et al., 1996). Regardless, ocean disposal of dredged sediments would require formal designation of an ocean dredged material disposal site according to the Marine Protection Research and Sanctuaries Act (MPRSA). Given the concentrations of DDTs and PCBs in the sediments, material dredged from the PV Shelf Study Area would likely fail toxicity and bioaccumulation suitability tests for ocean disposal required under federal law. Ocean disposal of the effluent-affected sediment from the PV Shelf would not be allowed (personal communication Ross, 2007).

Offsite Landfill

Disposal of dredged sediments at a permitted upland site would be effective at reducing risks to the marine ecosystem. However, pretreatment of sediments prior to disposal would be required to reduce the water content. Under California law, much of the contaminated sediment would require treatment to reduce contaminant concentrations before it would be eligible for disposal in a hazardous waste landfill. The proven technology for destruction of DDTs and PCBs is incineration.

4.3.6.1 Implementability

The implementability of dredging in deep water is difficult. Removal would cause resuspension of the effluent-affected sediment. The dragline of a trailing suction hopper dredge is difficult to control at depth, especially under ocean currents. The required cycle time for the depth of the contaminated sediments would cause low production rates for dredging of significant volumes.
The dredged sediment would undergo initial dewatering by gravity flow and then solidification before it could be treated. Treatment of water generated as a result of dredging and dewatering would be required as well. Pilot studies would be required to ensure that performance standards for water quality and sediment disposal are achievable.

The proposed unloading areas for dewatering would be within the Ports of Los Angeles and Long Beach, approximately five nautical miles from the Shelf. Transportation to the proposed unloading areas could cause issues with ship traffic due to the location within the ports.

4.3.6.2 Effectiveness

The effectiveness of this technology is moderate. Hydraulic and mechanical dredging are proven technologies for removal of ocean sediment but are rarely done at these depths. The volumes of dredged material would slow operations as the hopper dredge or barge would need to be emptied frequently. Resuspension of sediment would occur with each dredge cycle. The volumes of dredged material would be difficult to manage, resulting in frequent interruption of operations. The amount of EA sediment mobilized by dredging would be significant. The volume of water requiring collection and treatment would impact operations and would require construction of a water treatment plant.

4.3.6.3 Cost

The cost of this technology is high due to the amount of sediment and water that would need to be managed and disposed. Dredging would result in the need to treat tens of millions of gallons of water per day. In addition, a feasible disposal option for the dredged material would need to be developed. The EPA Office of Water has indicated that ocean disposal of the effluent-affected sediment from the PV Shelf would not be allowed (Ross, 2007). Therefore, the dredged material would require disposal at a hazardous waste disposal facility or construction of an in-water CDF. Either action would require construction of a waste treatment facility to meet hazardous waste disposal standards. Attaining regulatory approval for an in-water disposal facility is unlikely. Even if a facility were permitted, treatment and disposal would add millions to the cost of remediation.

4.3.6.4 Screening Decision

Removal with treatment and disposal is retained for remedial alternative development.

4.3.7 Ex Situ Treatment

Ex situ treatment options were considered for removal of DDTs and PCBs from PV Shelf sediments. In general, treatment technologies are designed to reduce the toxicity, mobility, and volume of contaminated material.

Ex situ treatment technologies require sediment removal (i.e., dredging), generally followed by dewatering of the sediment and treatment of both the dewatered sediment and water. This approach requires treatment application in a nearby confined facility where technologies use physical, chemical, biological, and thermal processes to remove contaminants from the sediment. Ex situ treatment technologies are evaluated as a category below.

4.3.7.1 Implementability

Implementation of ex situ treatment is not feasible because of the need to dredge, dewater, transport, and treat the sediment, and dispose of treatment residuals. Removal also would cause resuspension of the effluent-affected sediment, which would be difficult to manage.

4.3.7.2 Effectiveness

Ex situ treatment using thermal treatment (incineration) or solidification can be an effective method to destroy or immobilize DDTs and PCBs in sediment after it is dredged. Construction of a thermal treatment plant would encounter the same difficulties discussed under removal. Other ex situ treatment technologies are generally less effective. This treatment would require dredging and its associated process options. Significant resuspension of contaminated sediment will occur when the sediment is dredged prior to treatment. The overall effectiveness is considered low.

4.3.7.3 Cost

The cost of this technology is high due to the need for dredging, transport, dewatering, and treatment of dredged sediments. A treatment facility would need to be constructed solely to treat sediment from the PV Shelf Study Area, which is estimated to be approximately 3,610,000 cubic yards after dewatering.

4.3.7.4 Screening Decision

Ex situ treatment technologies were rejected for alternative development because it would be difficult to implement successfully. Ex situ treatment would require dredging, resuspension management, residual management, transport and dewatering of dredged material, construction of dewatering and/or storage facilities as well as a treatment plant.

4.3.8 In Situ Treatment

In situ treatment technologies are conducted with the sediment in place. The advantage is that dredge removal of the sediment is not required. In situ sediment treatment technologies use physical, chemical, biological, and thermal processes to remove contaminants from the sediment. However, in situ treatments usually require more time than ex situ treatments, and achieving a uniform treatment is more difficult than with ex situ treatment.

In situ chemical treatments (for example, persulfate or iron/hydrogen peroxide [Fe/H_2O_2]) are designed to either chemically destroy or reduce the toxicity of the contaminants. In situ chemical treatment may be carried out alone or in conjunction with biological treatment. Current research has not identified a chemical additive that destroys DDTs. In theory, biological treatment can destroy (e.g., complete conversion to carbon dioxide [CO_2] or methane) or reduce the toxicity of both DDTs and PCBs. Success is dependent on such factors as sediment redox conditions, pH, microbial communities present, and concentrations of microbial nutrients. Reductive dechlorination of DDE to DDMU and other daughter products is occurring at the site. The microbial processes and environmental conditions that are allowing this to occur are currently being investigated.

4.3.8.1 Implementability

The delivery or injection and mixing of substrates into the sediment would be difficult in deep water. In addition, the mechanisms influencing degradation are not well understood. Until the processes driving degradation are identified, there is no way to know if the mechanisms that biologically breakdown the contaminants can be controlled or accelerated.

4.3.8.2 Effectiveness

The effectiveness of chemical oxidation is unproven for the COCs in ocean sediments in the water depths present at the PV Shelf Study Area. Delivering and mixing oxidation chemical into the sediment and achieving uniform treatment success over a large area on the ocean floor at 50 to 100 m is unlikely.

Research indicates that biochemical degradation of DDE is occurring at the site and could be a significant mechanism for natural recovery. However, the mechanism by which this is occurring is not known. Even if the microbial process(es) driving the degradation were identified, delivering or injecting and mixing nutrients or microbes into the sediment and achieving uniform treatment success over a large area on the ocean floor at 50 to 100 m is difficult.

No native biological degradation of PCBs has been observed at the site. Because the process is not naturally occurring, any biological treatment approach for PCBs will require finding microbes that could breakdown the PCBs in the effluent-affected sediment and identifying appropriate nutrients, plus the addition of nutrients and/or microbes to the sediment. Laboratory treatability testing or pilot testing would be necessary to test this approach. However, even if microbial agents could be identified, their success in situ is not guaranteed.

Conversely, biological degradation of DDE at the PV Shelf is thought to be occurring under natural conditions. While there is still much that is unknown about this process, including the relative toxicity of the final degradation product, additional monitoring of sediment characteristics at the site (for example, redox potential [Eh], sulfate, TOC) may provide information on controlling factors needed to allow for laboratory and pilot testing of bioaugmentation strategies for the treatment of DDE and related organochlorine compounds.

4.3.8.3 Cost

The cost for in situ biological treatment would be high because this technology requires more research and understanding before implementation. Even if the mechanisms driving reductive dechlorination were understood, the cost to deliver nutrients or other materials over a large area at depth could be high.

4.3.8.4 Screening Decision

Due to the difficulties in delivering and mixing nutrients or microbes, the limited understanding of the degradation processes, and the limited ability to modify conditions to enhance degradation, in situ treatment is rejected for remedial alternative development.

4.4 Summary of Retained Technologies

Institutional controls, MNR (monitored natural recovery), containment, and removal were retained for alternative development. A summary of each technology is provided below:

- **Institutional controls** are retained for alternative development and consist of public outreach and education, enforcement, and fish monitoring.
- **MNR** is retained and uses ongoing, naturally occurring processes to contain, destroy, or otherwise reduce the bioavailability or toxicity of contaminants in sediment.
- **Containment** with a sand cap is retained and consists of capping all or part of the contaminated sediment to limit the mobility of the contamination and reduce the potential for fish exposure to contaminated materials. Other retained technologies to be used in conjunction with containment are resuspension management, residual management, and material transport/conveyance using barges.
- **Removal** with a hydraulic suction hopper dredge or mechanical clamshell dredge is retained. Dredging of all or part of the contaminated sediment would include dewatering, treatment and disposal.

These remedial technologies may be used alone or in combination to achieve the RAOs for the site. In Section 5.0, these technologies are assembled into site-specific remedial alternatives and initially screened for implementability, effectiveness, and cost.

5.0 Development and Screening of Alternatives

5.1 Introduction

In accordance with EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA, 1988a), remedial action alternatives are developed by assembling the remedial technologies and representative process options that were identified and screened in Section 4.0. This section presents remedial action alternatives that have been developed to manage the waste found on the PV Shelf that poses an unacceptable risk to human health and the environment. These alternatives vary primarily in the extent of active remediation and reliance on long-term management of residuals and untreated wastes.

The objective of alternative development is to provide an appropriate range of alternatives and sufficient information to analyze and compare adequately the alternatives in Section 6.0, Detailed Analysis of Remedial Alternatives. The results of the detailed analysis will be presented to decisionmakers for use during the remedy selection process.

During preparation of the feasibility study it became apparent that additional studies will be necessary during the remedial design phase to quantify risk reduction and assess remedy effectiveness more accurately. Therefore, EPA will select one of the alternatives presented in Section 6.0 as an interim remedial action. After the first Five-Year Review, EPA will prepare a final record of decision, detailing any additional actions it deems necessary to reach the site remedial action objectives.

This section assembles and screens five alternatives. Section 5.2 presents the assembled alternatives and an overview of the alternative components. In the additional subsections the components of the alternatives are described and developed in detail. The names of the remedial alternatives highlight the major components or elements of each alternative. Specific conceptual design or component details were developed for the cost, evaluation, and comparison of alternatives only, and are not meant to serve as a true design or specific recommendation of technologies or process options. In Section 5.2, the alternatives are screened for effectiveness, implementability and cost. The most promising alternatives are selected for detailed analysis in Section 6.0.

5.2 Alternative Development

Five alternatives were assembled by combining GRAs and the process options chosen to represent the various technology types. Alternative 1 is the no action alternative. Alternative 2 consists of institutional controls (ICs) and monitored natural recovery (MNR). Alternative 3 consists of institutional controls (ICs) and a small subaqueous cap to enhance monitored natural recovery (MNR). Alternative 4 consists of containment, i.e., placement of a subaqueous cap over the area of most contaminated sediment, plus ICs and MNR for those areas of PV Shelf that are not capped. Alternative 5 is a removal alternative, hydraulic dredging of the most contaminated sediment, with treatment and disposal onshore. The alternatives are identified as follows:

- Alternative 1—No Action
- Alternative 2—Institutional Controls (ICs) & Monitored Natural Recovery (MNR)
- Alternative 3—Containment (small cap) with ICs and MNR
- Alternative 4—Containment (large cap) with ICs and MNR
- Alternative 5—Removal (dredging) with ICs and MNR

5.2.1 Alternative 1—No Action

Alternative 1, a "no action" alternative is required by the NCP as a baseline for comparison with other remedial action alternatives. No additional attempt is made to satisfy the RAOs, and no remedial measures are implemented. Consequently, the no action alternative does not include active remediation, monitoring, or institutional controls. Under the no action alternative, existing institutional controls are not considered.

5.2.2 Alternative 2—Institutional Controls and Monitored Natural Recovery

Alternative 2 is intended to reduce risks to human health associated with the consumption of contaminated fish from the PV Shelf Study Area through nonengineered controls.

Institutional controls have been in place at the PV Shelf Study Area since fish advisories and health warnings were first issued in 1985. EPA's current institutional controls program consists of three components: public outreach and education, enforcement, and monitoring. As part of Alternative 2, EPA's current institutional controls program would continue, but would be modified as needed to increase effectiveness. Like the current institutional controls program, the future institutional controls program would rely heavily on partnerships with other federal, state, and local agencies. For example, the California-EPA Office of Environmental Health Hazard Assessment (OEHHA) will contribute technical expertise for the updated advisory based on results from the ocean fish monitoring program, and will serve on the Technical Review Board for the public outreach and education component of the institutional controls program. The enforcement component of the institutional controls would be carried out through the CDFG. For more detailed information on the ICs program, the reader is directed to Appendix D: Palos Verdes Shelf Superfund Site Institutional Controls Program Implementation Plan.

5.2.2.1 Public Outreach and Education

EPA created the Fish Contamination Education Collaborative (FCEC) to bring together interested agencies, associations, and community-based organizations to design and implement an outreach program to address the health risks from eating contaminated fish related to the PV Shelf Study Area. The public outreach and education program conducts outreach to anglers and the general community.

The angler outreach program focuses on educating anglers in Los Angeles and Orange Counties about fish contamination, fish advisories, identification of contaminated fish species, and safer fish consumption practices. Currently, this outreach has been conducted at bait shops and eight piers: Belmont, Cabrillo, Pier J, Seal Beach, Santa Monica, Hermosa, Redondo, and Venice. Future outreach for anglers may include different areas if warranted to increase effectiveness.

Current angler outreach consists of a 4-hour session at each pier four times a week (twice during the week and twice on weekends). For this alternative, the same level of outreach is assumed for the next ten years. At the first Five-Year Review, the outreach program would be reassessed based on fish data and angler awareness. Based on fish data, the message on safe eating habits could be revised, or fishing locations could be added or deleted. If it appears the same level of effort is necessary, the four times a week program would continue.

The community outreach program includes outreach to the general population, specific ethnic groups, and commercial fish market owners. Outreach to the general population and specific ethnic groups focuses on educating people about the potential health risks of eating fish from the PV Shelf Study Area and on safer fish consumption practices. This program partners with health fairs, community fairs, and local health departments to provide educational materials and training. Outreach to commercial fish market owners is conducted to educate owners about the dangers of buying fish from unlicensed dealers who may be catching fish from restricted areas.

For Alternative 2, community outreach would involve using a combination of state and local health department services, community-based organizations, or community relations specialists for outreach to the general community and sensitive populations such as certain ethnic groups or women of child-bearing age. The outreach would include working with community-based organizations and media to educate people on behaviors to reduce the risk of eating fish with elevated levels of DDT and PCBs. A feedback component to gauge behavior changes from the information and education program would be included to help determine the program's success.

Based on the Consumption, Attitude, Behavior Study (CABS) survey conducted by the FCEC in 2007 (FCEC Year IV-V Report), women of child-bearing age are much more aware of the fish contamination related to mercury than the local fish contamination issues related to the PV Shelf. The CABS also showed the population at the most risk, (i.e., consumption pattern including frequencies, fish parts eaten, type of fish) are Asian, including Chinese, Vietnamese and Pilipino. The market monitoring data reflect the same community profile in terms of where white croaker are available for purchase. The future FCEC program will include specifically targetting the populations at most risk.

Specific training and outreach materials already have been developed, but would be revised as needed to increase effectiveness. The public outreach and education program includes surveys of the different groups to identify the preferred method of information delivery and to assess changes in behavior resulting in risk reduction. All components of the outreach program have been and would continue to be conducted in several languages that are spoken in Los Angeles and Orange Counties; the outreach efforts have been conducted in numerous languages including English, Spanish, Cambodian, Chinese, Filipino, Korean, Vietnamese, Chamorro, Samoan, Marshallese, and Tongan.

The cost for the community outreach is based on the current level of effort for the existing institutional controls program. It is assumed that the same level of effort would continue for the next ten years. The first five-year review would be used to assess the program's effectiveness and plan for any changes in outreach locations and messages to be included in the final remedy. It is anticipated the level of effort would be reduced over time.

5.2.2.2 Enforcement

The enforcement program focuses on existing commercial and recreational restrictions on fishing for white croaker established by CDFG to help prevent white croaker with elevated levels of DDT and PCBs from being caught and sold. In 1995, the CDFG closed part of the

PV Shelf for commercial catch of white croaker because of the elevated DDTs and PCBs found in the area; Figure 5-1 shows the location of the area closed for white croaker commercial fishing. In March 1998, in response to concerns about white croaker being illegally sold by sport fishermen to commercial fish markets, CDFG revised the white croaker recreational catch limit from unlimited to 10 fish per day.

Current enforcement and monitoring of commercial and recreational fishing at the PV Shelf and adjacent areas is under the jurisdiction of CDFG. The current enforcement program includes periodic inspections by CDFG of the commercial catch ban area during routine patrols and limited shore-based inspections and spot checks at locations where commercial fishermen are expected to return. CDFG also provides EPA with regular documentation describing the results of inspections.

The sport fishing restriction enforcement program has included limited, random inspections of sport fishers' white croaker catch at locations presumed to be within the area where fish are impacted by PV Shelf. Unlike the commercial fishing ban, the sport fishing restriction is not limited to any specific area. Thus, for the future sport fishing restriction enforcement program, the potential areas to be covered could range from Long Beach Harbor to the north side of Santa Monica Bay.

Alternative 2 would increase the enforcement program close to the source. Based on CDFG landing information, 27,358 and 27,538 pounds of white croaker were landed from catch blocks 719 and 740 in 2006 and 2007, respectively (CDFG, 2008). Greater than 90 percent of the white croaker were landed at Terminal Island and Huntington Beach. However, its availability was scarce in local fish markets (2004 EPA market fish sampling). This discrepancy between the reported landed catch vs. actual availability in markets raises questions about other outlets for white croaker. Due to various constraints (legal and others), EPA was unable to obtain the white croaker "landing to markets" pathway information to fill the informational gap. This information is critical for EPA and appropriate agencies to better characterize the potential risks associated with eating contaminated white croakers and design/implement an effective enforcement program that will stop contaminated fish from reaching consumers. EPA and the appropriate State and local agencies are working to identify appropriate water-based and shore-based enforcement tools to address this data gap. Monitoring closer to the source, e.g., of wholesalers and/or commercial fishing fleet, would help clarify the ocean-to-consumer pathway.

Alternative 2 assumes increased enforcement/monitoring in coordination with State and local agencies. A more detailed description of the ongoing ICs program is included as Appendix D.

5.2.2.3 Monitoring for ICs Program

The current monitoring program includes collection of white croaker at designated locations in the PV Shelf Study Area (ocean monitoring) and at local markets (market monitoring).

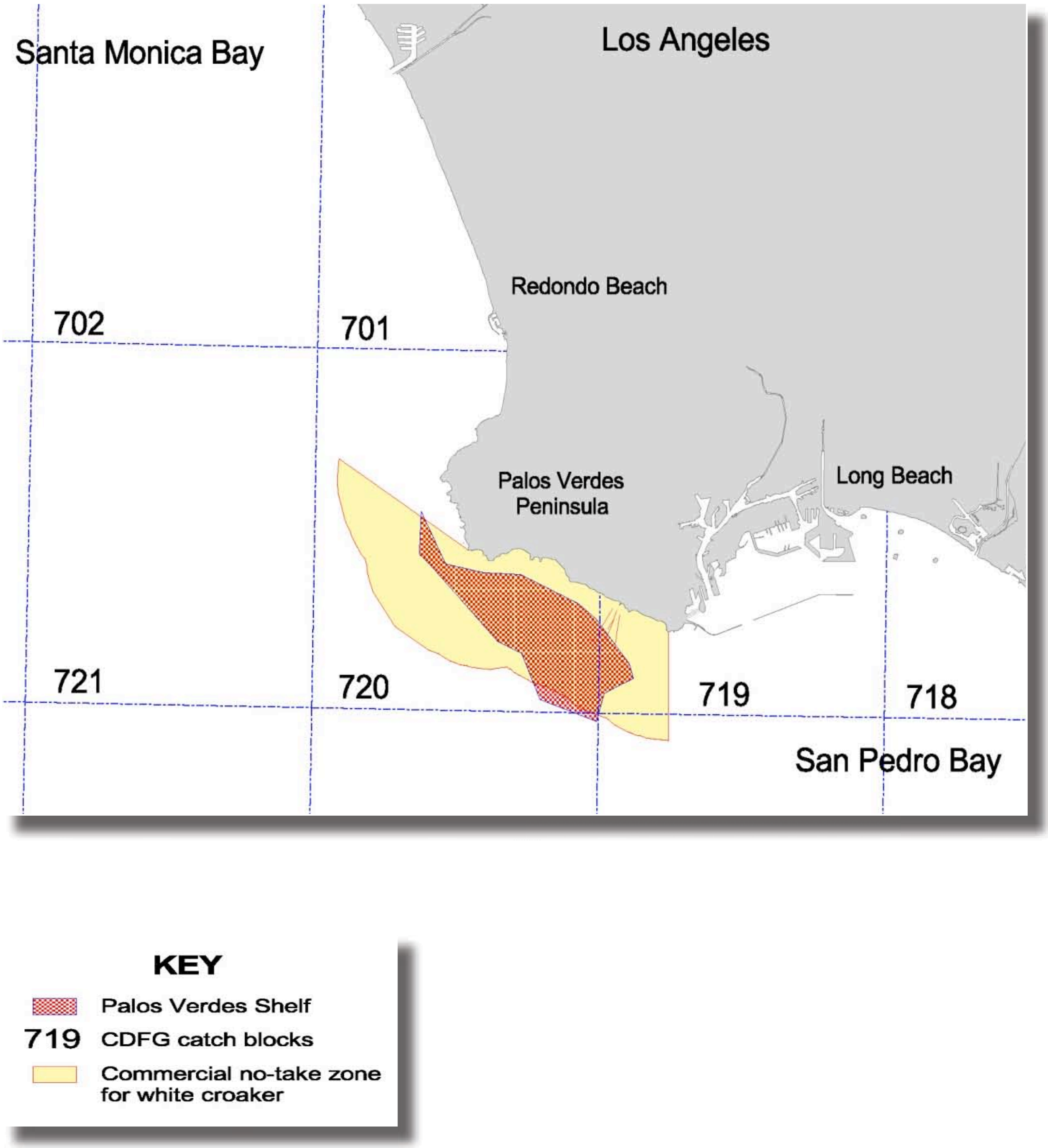

Figure 5-1: Location of CDFG white croaker commercial catch ban area. Note catch blocks included in banned area.

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The purpose of the ocean monitoring is to assess whether the boundaries of the commercial fishing ban are adequate or may need to be expanded and whether recreational anglers are catching fish with elevated levels of DDT and PCBs at popular fishing locations. The purpose of the market monitoring is to evaluate if contaminated white croaker from the PV Shelf StudyArea are reaching local consumers and to determine the source of white croaker with high levels of contaminants found in those establishments.

Market Monitoring

In 2004 and 2005, EPA visited 68 markets a total of 135 times and found only 6 markets that carried white croaker (30 fish total). However, white croaker from these six markets included fish with high concentrations of DDTs and PCBs. It is not known whether the presence of these white croaker in retail establishments is due to violations of the PV Shelf commercial fishing ban, inadequacies of the catch ban area, sport fishers illegally selling croaker to retail establishments, or other factors.

From 2005 to 2006, 45 Los Angeles County Department of Public Health Environmental Health (LADPH-EH) inspectors who were trained by the FCEC program inspected 470 independent fish markets/wholesalers in Los Angeles County. White croaker were found at two markets. In 2005, City of Long Beach Environmental Health (LB-EH) inspectors inspected 46 non-chain markets; only one market carried white croaker and that market could not produce receipts/invoice. More recently, in 2009, CDFG wardens inspected a Los Angeles County market and found 100 lbs. of white croaker that the market could not produce receipts/invoice.

With the available market monitoring results, in September 2006, EPA contacted the Orange County Health Care Agency Environmental Health (OCEH). OCEH and EPA established a draft work plan and budget to conduct monthly inspect of white croaker at targeted markets in Orange County. Orange County joined Los Angeles County and the City of Long Beach environmental health departments in conducting inspections at selected markets throughout the year, starting in 2008.

The future market monitoring program will involve continued monitoring of white croaker in local markets. The City of Long Beach and Los Angeles and Orange counties environmental health inspection agencies will assist by reporting the presence of white croaker in markets for sample collection, and tracking supplier sources for white croaker found in the markets. Approximately 250 total visits will be made annually to 55 different markets in Los Angeles County, Long Beach or Orange County. The market visits will be based on the frequency of health department inspections to markets identified in the previous sampling effort as most likely to carry white croaker. Based on previous results, it is assumed that white croaker will be found at approximately 10 of the 250 markets visits, and that 5 white croaker will be collected from each market. Therefore, up to 50 white croaker may be collected annually and analyzed for DDTs and PCBs.

Ocean Fish Monitoring

The future ocean monitoring program would consist of sampling fish from different areas of the PV Shelf to track contaminant concentrations for public outreach efforts and to ensure the boundaries of the catch ban area are current. The sampling program would build on the EPA-MSRP *2002-2004 Fish in Ocean Survey* (USEPA/MSRP, 2007) and EPA directive *Using Fish Tissue Data to Monitor Remedy Effectiveness* (USEPA, 2008). The ICs component of the ocean monitoring would consist of verifying the catch ban area boundaries by analyzing samples of white croaker from designated sample locations in the PV Shelf Commercial Catch Ban Area for DDTs and PCBs as part of the five-year review.

Sampling also would be conducted biennially from popular fishing piers located in Los Angeles and Orange counties. It is assumed that 10 white croaker would be collected from half of the piers (i.e., 4 piers) every year, for a total of 40 white croaker analyzed for DDTs and PCBs. Additional species also may be included in the pier sampling if warranted based on revised fishing advisories.

5.2.2.4 Monitoring for Natural Recovery

Alternative 2 relies on an aggressive ICs program to control human health risk from consumption of fish with unacceptable levels of COCs. The monitored natural recovery (MNR) component of the alternative tracks reduction of COCs in sediment, water and fish to verify achievement of RAOs. Monitoring will be conducted initially to establish a baseline (Year 1), then five years after remedial action for the five-year review.

MNR would also include studies to learn more about the recovery processes. Specifically, MNR includes toxicity assessments of DDMU and DBP. DDMU is a prevalent daughter product of DDE and could be the most common DDT breakdown product in the sediment besides DDE. DBP has been identified in the sediment as well. As the final breakdown product of DDT, knowledge of DBP's toxicity is important to understand the ultimate fate of the EA sediment. Unlike DDT, there is no evidence that PCBs are breaking down in the EA sediment deposit. Additional analysis of sediment transport and contaminant flux from the EA sediment is underway and will help shape the final remedy. Another study that would be undertaken as part of MNR is a white croaker tracking study that would provide information on white croaker feeding patterns and preferred PV Shelf locations.

EPA's trend monitoring would include:

- Coring of sediment throughout the PV Shelf Study Area to assess vertical distribution and mass of contaminants
- Sampling of contaminant concentrations in pore water and the water column
- Fish sampling

Data collected for the five-year review will be used in the development of the final record of decision. At that time, the monitoring program will be reassessed to determine if there are elements that should be dropped or changed, for example, sediment sampling locations or specific fish species.

Biological Monitoring

Progress toward reaching RAOs will be measured by monitoring fish across the PV Shelf Study Area. The monitoring program will be based on the segments established under the 2002/2004 Contaminant Fish Survey and will follow the Fish Survey sampling plan for fish analysis. EPA will develop the monitoring program in consultation with those agencies that collect and/or use fish data to maximize the utility of the monitoring. Contaminant data on local benthic-feeding fish, e.g., white croaker, as well as pelagic forage fish, e.g., Pacific sardine, will be collected.

Sediment Monitoring

In order to maximize the utility of the sediment sampling program, it will use the LACSD sampling station grid, shown in Figure 1-4 for baseline monitoring. Sediment cores will be collected at 30 LACSD sampling stations (transects 1 through 10) along the 30-, 60-, and 150-m depth contours. Duplicate cores will be taken at selected stations along the 60- and 150-m isobaths, for a total of 50 sediment cores. The contaminant mass and vertical distribution will be evaluated in each core by analyzing 4-cm segments from the surface to the end of the core. Sediment will be analyzed for grain size, TOC, DDTs, and PCB congeners. DDT breakdown products, DDMU, DDNU, and DBP will be included in the analysis. Final data products will include mass estimates of DDTs and PCBs and their metabolites and congeners.

Water Monitoring

Contaminant concentrations in the water column, including suspended particles, have not been routinely monitored over the PV Shelf Study Area. Waterborne contaminants may be assimilated into the food chain by suspended-particle-feeding biota and by chemical exchange and adsorption on respiratory membranes (e.g., gill surfaces). Studies conducted over the PV Shelf in 1997 indicated significantly elevated water column concentrations of DDTs and PCBs in bottom waters where demersal fish populations reside, including white croaker and Dover sole (Zeng et al., 1999). Concentrations of DDTs in water at the site exceed EPA AWQC for saltwater aquatic life (1 ng/L) and for human health (0.22 ng/L). Concentrations of PCBs exceed EPA AWQC for human health (0.064 ng/L), but not for saltwater aquatic life (30 ng/L).

To analyze water samples for COCs at such low concentrations requires special sampling equipment. Examples of sampling systems that are able to analyze COCs at these ultra-low levels include water pump and filtration system and solid phase micro-extraction (SPME) samplers. EPA has used polyethylene samplers to analyze low levels of PCBs in water bodies and is currently testing their utility on PV Shelf. EPA will use passive samplers to monitor water column contaminant concentrations. Samplers will be deployed at the same 30 stations discussed above. Three samplers per location will measure COCs at 3 meters above the seabed, mid-column, and 5 meters below the water surface.

5.2.3 Alternative 3—Small Cap with MNR and ICs

Under this alternative, the ICs program and MNR, as described above, will continue. However, in addition to the sediment-water-fish monitoring described under Alternative 2, this alternative would accelerate natural recovery by adding a small cap of clean sediment over an area near the outfalls where surface concentrations of DDTs are highest. The objectives of small cap/enhanced MNR are to bury the contaminated sediment under clean sand, to block further erosion and to limit contaminant flux or transport from this “hot spot” (Figure 5-2).

Development of Cell Grid

The PV Shelf Study Area was divided into cells based on the LACSD sampling stations (Figure 1-4). An attempt was made to determine the total mass of contaminants present in each grid cell across the full sediment profile. While data are not available on concentrations of DDTs and PCBs at depth across the entire PV Shelf Study Area, surface (0 to 2 cm) sediment data are available from LACSD’s 2002 and 2004 sampling events. These data were used to estimate contaminant mass in surface sediments for each of the 33 cells created by the grid of the PV Shelf Study Area. This method does not accurately reflect the extent of contaminated sediment because it does not include the full depth of the EA deposit. However, surface concentrations tend to correlate to concentrations at depth across the 60-m contour. The grid allows rough quantification of contaminant mass by area, which is necessary to develop capping or dredging alternatives. If an alternative that includes active remediation is selected, additional sediment characterization will be necessary as part of the remedial design. Based on the grid, approximately 1.3 km^2, or 320 acres, would be included in Grid Cell 8C, the locus of the “hot spot.”

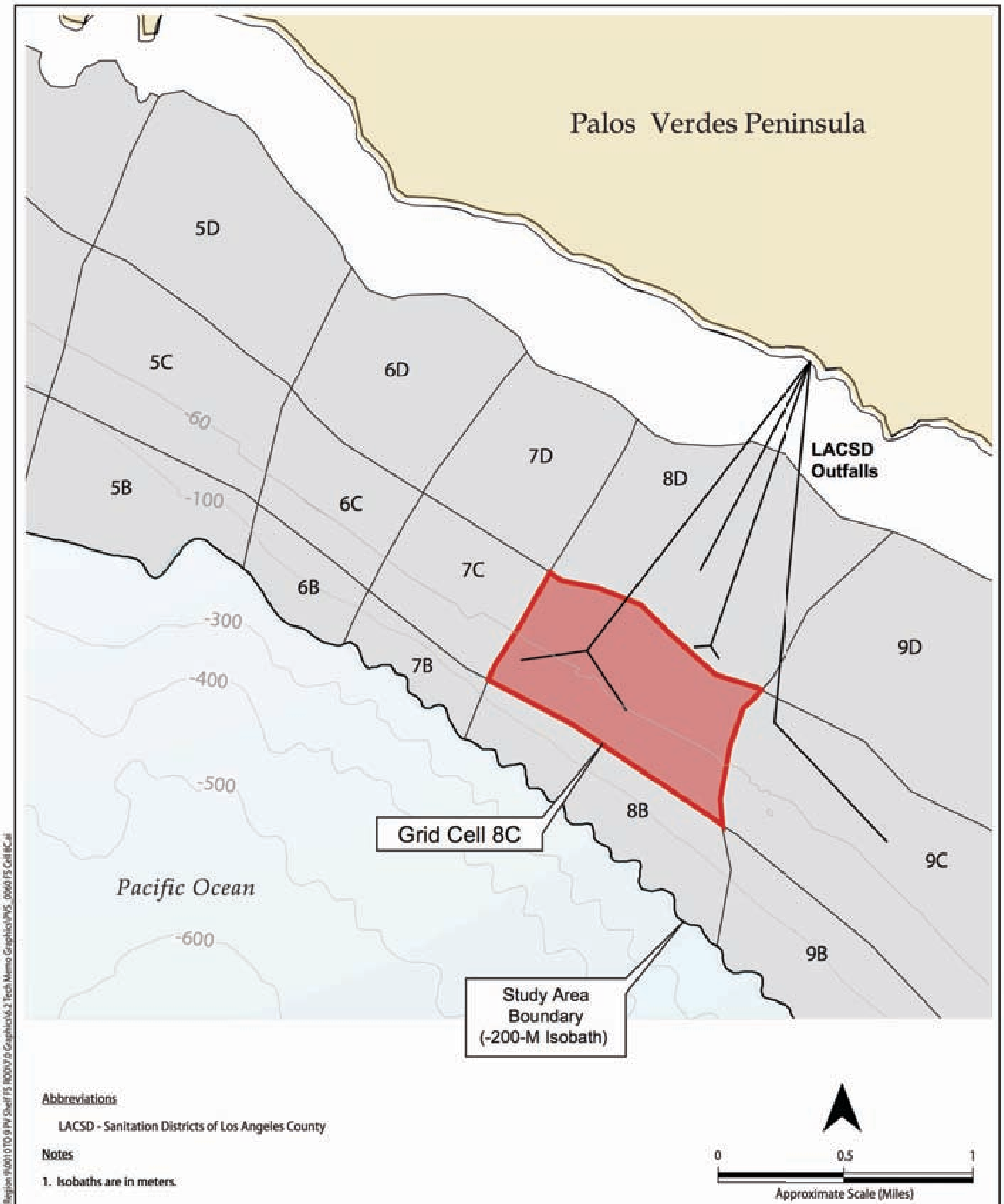
5.2.3.1 Area to be Covered

The 8C “hot spot” has the highest concentrations of DDTs in the surface sediment of the PV Shelf. Figure 5-2 shows the proposed area to be covered: Grid Cell 8C. The total area of Grid Cell 8C is 1.3 km^2, which is equivalent to approximately 1.6 percent of the total area of the PV Shelf. The total mass of DDTs in surface sediment inside the 8C grid boundary is estimated to be 2,250 kg, accounting for approximately 44 percent of the total mass of DDTs in PV Shelf surface sediment. The total mass of PCBs present in surface sediment in Cell 8C is an estimated 85 kg, accounting for 13 percent of the total mass of PCBs in surface sediment. The 8C area is also where the deposit is thickest and contains the highest concentration of contaminants at depth.

5.2.3.2 Enhancement Objectives and Design

While contaminant concentrations have dropped overall, in the vicinity of the Y outfall they have shown little change. Figure 5-3 shows DDE concentrations in sediment cores taken at the outfall over time. The surface concentrations have increased, and the effluent-affected sediment deposit appears to be moving upward. Recent analysis of PV Shelf (Noble, et al., 2008) indicates the ocean velocities are greatest at both ends of the shelf, and smallest around the outfalls. Although the internal waves and currents are weaker in the area between the outfalls, it is estimated to be erosive because of the characteristics of the sediment and lack of a source of new sediment (Ferré and Sherwood, 2008). The apparent erosion between the outfalls is minimal, i.e., 0.1 to 0.3 mm/yr; however, without a source of new material, the analysis indicates the EA sediment deposit in this area will slowly erode (Ferré and Sherwood, 2008). Alternative 3 would add clean sediment to approximately 320 acres. Oceanographic data collected during Winter 2007-08 will be used to assist in selection and design of material placement.

Placement of a sand cap normally accelerates natural recovery by adding a layer of clean material over contaminated sediment. The acceleration can occur through several processes, including increased dilution through bioturbation of clean sediment mixed with underlying contaminants. The target thickness for the cover would be 30 to 45 cm. The sediment source would be selected to meet specific geotechnical properties, such as grain size and density, organic content, and settling velocity. It would be designed to be thick enough to prevent advection of pore water through the material, temporarily eliminate benthic organisms, and allow for some spreading during and after placement until consolidation and compaction solidifies the cap material.



Feasibility Study/Record of Decision Support
Palos Verdes Shelf
Los Angeles County, California

FIGURE 5.2
Grid Cell 8C Layout

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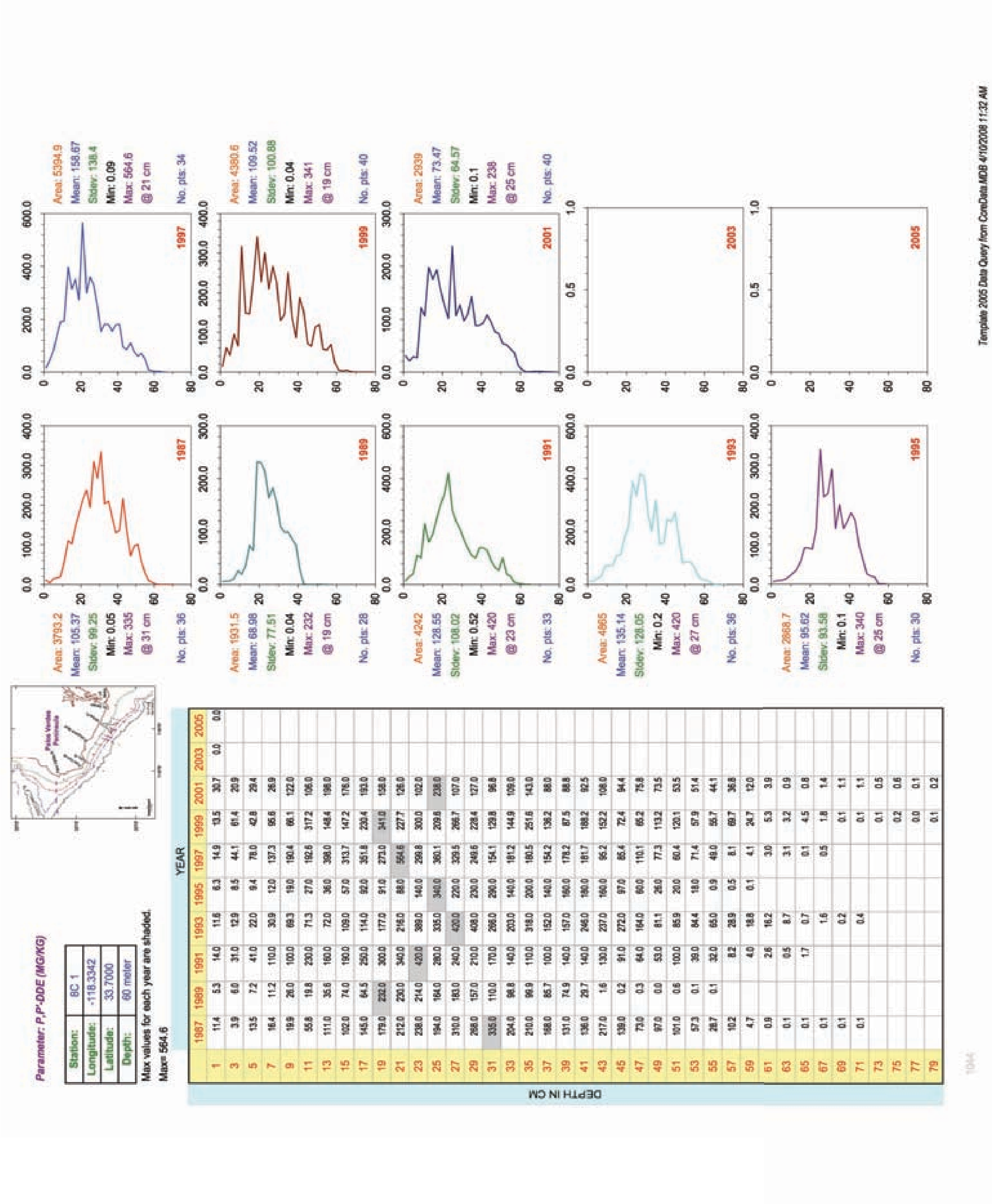

Depth (cm)	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005
1	11.4	5.3	14.0	11.6	6.3	14.9	13.5	30.7	0.0	0.0
3	3.9	6.0	31.0	12.9	8.5	44.1	61.4	20.9		
5	13.5	7.2	41.0	22.0	9.4	78.0	42.8	29.4		
7	16.4	11.2	110.0	30.9	12.0	137.3	95.6	26.9		
9	19.9	26.0	100.0	69.3	19.0	190.4	66.1	122.0		
11	55.8	19.8	230.0	71.3	27.0	192.6	317.2	106.0		
13	111.0	35.6	160.0	72.0	36.0	398.0	148.4	198.0		
15	102.0	74.0	190.0	109.0	57.0	313.7	147.2	176.0		
17	145.0	64.5	250.0	114.0	92.0	351.8	230.4	193.0		
19	179.0	232.0	300.0	177.0	91.0	273.0	341.0	158.0		
21	212.0	230.0	340.0	216.0	88.0	564.6	227.7	126.0		
23	238.0	214.0	420.0	389.0	140.0	299.8	300.0	102.0		
25	194.0	164.0	280.0	335.0	340.0	360.1	209.8	238.0		
27	310.0	183.0	240.0	420.0	220.0	329.5	266.7	107.0		
29	268.0	157.0	210.0	408.0	230.0	249.6	228.4	127.0		
31	335.0	110.0	170.0	266.0	290.0	154.1	129.8	96.8		
33	204.0	98.8	140.0	203.0	140.0	181.2	144.9	109.0		
35	210.0	99.9	110.0	318.0	200.0	180.5	251.6	143.0		
37	168.0	85.7	100.0	152.0	140.0	154.2	136.2	88.0		
39	131.0	74.9	140.0	157.0	160.0	178.2	87.5	88.8		
41	136.0	29.7	140.0	246.0	180.0	181.7	188.2	92.5		
43	217.0	1.6	130.0	237.0	160.0	95.2	152.2	108.0		
45	139.0	0.2	91.0	272.0	97.0	85.4	72.4	94.4		
47	73.0	0.3	64.0	164.0	60.0	110.1	65.2	75.8		
49	97.0	0.0	53.0	81.1	26.0	77.3	113.2	73.5		
51	101.0	0.6	100.0	85.9	20.0	60.4	120.1	53.5		
53	57.3	0.1	39.0	84.4	18.0	71.4	57.9	51.4		
55	28.7	0.1	32.0	65.0	0.9	49.0	55.7	44.1		
57	10.2		8.2	28.9	0.5	8.1	69.7	36.8		
59	4.7		4.0	18.8	0.1	4.1	24.7	12.0		
61	0.9		2.6	16.2		3.0	5.3	3.9		
63	0.1		0.5	8.7		3.1	3.2	0.9		
65	0.1		1.7	0.7		0.1	4.5	0.8		
67	0.1			1.6		0.5	1.8	1.4		
69	0.1			0.2			0.1	1.1		
71	0.1			0.4			0.1	1.1		
73							0.1	0.5		
75							0.2	0.6		
77							0.0	0.1		
79							0.1	0.2		

Figure 5-3: Sediment Cores at LACSD Station 8C

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Material and Placement

Placement of the sand cover would require similar technologies as cap construction, discussed under Alternative 4. Specifically, resuspension management, residual management, material conveyance and transport would be the same as Alternative 4. Because the "hot spot" is between the outfall pipes, low-impact placement techniques would be used. U.S. Army Corps of Engineers (USACE) research on placement techniques and sand/sediment parameters for PV Shelf (Palermo et al., 1999, Guiliani, 2004) as well as lessons learned from the pilot capping project will assist in determining the most effective method to cover the hot spot with minimal resuspension. An advantage to material placement in this area is that it abuts relatively clean sediment, i.e., the area includes the southern edge of the deposit. Thus, placement would begin at the southeast edge, moving to deeper waters to the northwest.

Construction would require studies to determine the most effective techniques; however, low-impact techniques, i.e., submerged diffuser (e.g., tremie tube with a diffuser spoon) would be assessed during remedial design. After placement of the initial layer, faster placement by spreading or casting can be used. The volume of material required to cover 8C is estimated to be 660,000 m^3 or 864,000 cubic yards (yd^3), with a 10 percent loss allowance.

5.2.3.3 Monitoring

Cap construction monitoring would follow EPA guidance on performance monitoring (USEPA, 2005). Monitoring would track the areal extent and thickness of the cover during construction as well as surface sediment resuspension. The intent of the cover is to stabilize sediment and reduce surface concentrations. Longterm monitoring would measure contaminant flux off the cap as well as the remaining thickness of the cover. The assessment of capping (Appendix E) estimates that a 45-cm cap would begin to see recolonization of surface sediment by benthic invertebrates within a year, and that some of the buried EA sediment may be mixed with surficial sediment over time. Sediment monitoring, as described under MNR (i.e., sediment cores across the Shelf to assess vertical distribution and mass of COCs) would indicate whether the clean sediment has reduced surface concentrations of COCs and formed a protective layer, or if there are breaches in the cap.

Analysis of sediment cores would also track reductive dechlorination at depth, as discussed in section 5.2.2.4. Additionally, under this alternative, EPA would investigate the processes that drive the reductive dechlorination of DDE with the goal of assessing rates of transformation, identifying end products, and determining whether this natural process can be enhanced.

5.2.3.4 Institutional Controls

The institutional controls and other monitored natural recovery program elements for Alternative 3 are described under Alternative 2.

5.2.4 Alternative 4—Containment with Institutional Controls and Monitored Natural Recovery

Alternative 4—Containment with Institutional Controls (ICs) and Monitored Natural Recovery (MNR) consists of placing an in situ, subaqueous cap over the areas of the EA sediment deposit that contain the highest contaminant concentrations on the surface and at depth, implementing MNR over those areas not capped, while keeping in place an ICs program. More specifically, Alternative 4 consists of the following technologies:

- Cap placement
- Resuspension management
- Residual management
- Cap material conveyance/transport
- Institutional controls
- Monitored natural recovery

Alternative 4 builds on the work done under *Options for In Situ Capping of Palos Verdes Shelf Contaminated Sediments* (Palermo et al., 1999), included as Appendix E, and the *Engineering Evaluation/Cost Analysis for the Palos Verdes Shelf* (USEPA, 2000) that identified two cap areas that would cover most of the Shelf along the 60-m isobath. More recent data indicate COC concentrations have dropped across the Shelf, allowing a reconsideration of the size and location of potential caps. Tables 5-1 and 5-2 provide fill requirements for various capping scenarios. Grid cells were developed for the entire PV Shelf, although the slope (B cells) can not be capped. The following subsections discuss the various technologies necessary to implement this alternative.

5.2.4.1 Capping Objectives and Design Basis

The objectives of placing a cap on the PV Shelf Study Area are:

- Reduce contaminant flux from the area of highest contaminant concentrations
- Replace effluent-affected sediment with clean material, creating a cleaner environment for benthic recolonization
- Consolidating and stabilizing the bottom boundary layer (mudline)

The EPA *Assessment and Remediation of Contaminated Sediments (ARCS) Program Guidance for In-Situ Subaqueous Capping of Contaminated Sediments* (USEPA, 1998) details design criteria and considerations for an *in situ* cap. Pertinent processes considered in the development of this alternative include effective short- and long-term chemical isolation of contaminants, disturbance and mixing of sediment by benthic organisms, consolidation of compressible material, and erosion. The *Options for In Situ Capping of Palos Verdes Shelf Contaminated Sediments* (Palermo et al., 1999) contains a cap placement and operations plan for a 45-cm cap that would be updated as part of the remedial design/remedial action if this alternative were selected.

5.2.4.2 Capping Areas

Areas considered for capping would be where the COC surface concentrations are highest and/or where erosion is most likely to occur. However, some areas are unsuitable for active remediation. For example, risk of liquefaction from seismic activity was evaluated using USACE's WESHAKE model (Schnable et al., 1972, Sykora et al., 1994). The results indicated that contaminated sediment on slopes of 5 degrees or greater are susceptible to flow failure if subjected to moderate earthquakes (Palermo et al. 1999). Based on this evaluation, areas on the site with bottom slopes less than 5 degrees are suitable for capping from the standpoint of seismic considerations, but areas with bottom slopes exceeding 5 degrees should not be considered for capping. The PV Shelf is relatively flat until the shelf break. In general, areas deeper than the 70-m contour are not suitable for capping.

Alternative 4 caps with clean sand the areas on the shelf with the highest surface concentrations of COCs that are also relatively level. Surface concentrations of COCs are highest around the outfalls and slope; however, as discussed above, the slope is not suitable for remediation. The cells with highest surface concentrations on the more level shelf area are Grid Cells 6C, 7C, and 8C (Figure 5-4). This represents an area of approximately 2.74 km^2, or 680 acres.

Grid Cells 6C, 7C, and 8C.

Grid Cells 6C, 7C, and 8C include the area of highest contaminant concentrations, i.e., the outfall area, as well as the cells to the northwest of the outfall. Cell 8C is on the southeast edge of the deposit and appears to be erosive. North of the outfall pipe, Cells 7C and 6C have been net depositional; however, a recent model of sediment transport suggest that without a source of sediment (e.g., Portuguese Bend or the outfalls), the area may loose 0.3 to 0.1 mm of sediment annually (Ferré and Sherwood, 2008). Earlier models (Sherwood, 1996) suggested the area would experience a temporary increase in surficial concentrations of COCs before reaching equilibrium.

5.2.4.3 Cap Thickness

Considerations that went into cap design include physical and chemical properties of the contaminated and capping sediments, hydrodynamic conditions such as currents and waves, potential for bioturbation of the cap by benthic organisms, potential for consolidation of the cap and underlying sediment, and operational considerations. Total cap thickness is normally composed of components for bioturbation, consolidation, erosion, operational considerations and chemical isolation.

As discussed in the previous section, seismic considerations limit the areas that can be considered for capping. Seismic considerations also limit the thickness of a cap. The weight of the cap reduces the safety factor against flow failure during an earthquake. A cap with thickness up to 60 cm (2 feet) would not render the EA sediment susceptible to flow failure on those areas of the shelf with slopes of less than 5 degrees. A cap on slopes of up to 5 degrees would be susceptible to pore pressure development under cyclic loading, and would likely liquefy if subjected to a moderate earthquake, but would restabilize. With these limitations in mind, to effectively isolate and immobilize the COCs, *Options for In Situ Capping of Palos Verdes Shelf Contaminated Sediments*, (Palermo, et al. 1999) proposed a cap of 45 cm.

Recent assessments conducted for and discussed in the *Palos Verdes Shelf Superfund Site Remedial Investigation Report* (CH2M Hill, 2007) confirm that 45 cm would be adequate for an isolation cap. Recommended cap thickness to physically isolate the EA material from benthic organisms was estimated to be 45 cm, 30 cm to account for the bioturbation zone and the enhanced biodiffusion zone, plus an operational tolerance layer of 15 cm. Recent studies in 2004 (SAIC, 2005) confirmed that bioturbation occurred primarily in a thin (10 to 15 cm) surface layer. Although deep bioturbators like ghost shrimp were found on PV Shelf, their numbers were low and they generally resided in shallower waters than the EA deposit. A 45-cm cap is still considered adequate to isolate the contaminated sediment from benthic organisms.

TABLE 5-1
Fill Volumes Required for Sediment Cap of PV Shelf Study Area Grid Areas

Cell	Cell Area (sq km)	Cell Area (sq mi)	Cell Area (acres)	Volume of Fill [1] (m^3) 45-cm cap	Cap Volume with Assumed 20% Loss Factor (m^3) 45-cm cap
0B	11.06	4.3	2731	4,976,000	5,971,200
0C	7.77	3.0	1918	3,495,000	4,194,000
0D	6.75	2.6	1668	3,040,000	3,648,000
1B	6.88	2.7	1698	3,094,000	3,712,800
1C	4.74	1.8	1170	2,131,000	2,557,200
1D	3.30	1.3	814	1,484,000	1,780,800
2B	1.30	0.5	322	586,000	703,200
2C	1.30	0.5	322	587,000	704,400
2D	1.42	0.5	350	638,000	765,600
3B	1.25	0.5	308	561,000	673,200
3C	1.19	0.5	295	538,000	645,600
3D	0.95	0.4	236	430,000	516,000
4B	1.60	0.6	394	718,000	861,600
4C	1.93	0.7	476	867,000	1,040,400
4D	1.85	0.7	456	830,000	996,000
5B	1.01	0.4	249	454,000	544,800
5C	1.36	0.5	335	610,000	732,000
5D	1.69	0.7	418	762,000	914,400
6B	0.38	0.1	94	171,000	205,200
6C	0.67	0.3	166	302,000	362,400
6D	1.24	0.5	307	559,000	670,800
7B	0.33	0.1	82	150,000	180,000
7C	0.74	0.3	182	332,000	398,400
7D	1.04	0.4	258	469,000	562,800
8B	1.00	0.4	247	450,000	540,000
8C	1.33	0.5	329	600,000	720,000
8D	1.99	0.8	492	897,000	1,076,400
9B	1.45	0.6	357	651,000	781,200
9C	2.48	1.0	611	1,114,000	1,336,800
9D	2.92	1.1	720	1,312,000	1,574,400
10B	1.26	0.5	310	565,000	678,000
10C	4.43	1.7	1094	1,993,000	2,391,600
10D	3.56	1.4	880	1,603,000	1,923,600
Totals	82	32	20290	36,969,000	44,362,800

[1] Estimated volume of fill is equal to the volume of sediment required to fill a 15 cm or 45 cm prism covering the area of each cell. Bulking factor and loss ratio were assumed negligible.

TABLE 5-2

Chemical and Physical Data for Potential Cap Scenarios

Cap Area Scenarios Cap Cells	Area [1]			Mass of DDTs in Surface Sediment [2, 3]		% Mass Study Area DDTs in Surface Sediments	Mass of PCBs in Surface Sediment [2, 3]		% Mass Study Area Total tPCBs in Surface Sediments	Cap Volume (45-cm)		Cap Volume (45-cm) (Assumed 20% Loss)	
	sq km	Acres	% of total	(kg)	(lb)		(kg)	(lb)		(m3)	(CY)	(m3)	(CY)
8C	1.3	329	1.6%	2249	4948	44%	85	188	13%	600,000	790,000	720,000	950,000
7B, 7C, 8B, 8C	3.4	841	4.1%	2589	5697	51%	141	310	21%	1,532,000	2,010,000	1,840,000	2,410,000
5B, 5C, 6B, 6C, 7B, 7C, 8B, 8C	6.8	1685	8.3%	2811	6185	55%	235	518	35%	3,069,000	4,020,000	3,690,000	4,830,000
USACE Cap Area A	4.9	1210	6.0%	2229	4903	44%	145	320	22%	2,205,000	2,890,000	2,650,000	3,470,000
USACE Cap Area AB	7.6	1877	9.3%	2366	5206	46%	199	439	30%	3,420,000	4,480,000	4,110,000	5,380,000
PV Shelf Study Area	82.2	20290	100.0%	5109	11240	100%	666	1464	100%	36,969,000	48,360,000	44,370,000	58,040,000

[1] The area for each polygon was determined by using SURFER based on Figure 1-8.

[2] Surface sediments defined as the upper 0.8 inches (2 cm) of sediment. Data is from LACSD surface sampling (Van Veen sampler) conducted in July 2002 and 2004.

[3] Dry soil density was used to estimate the mass; density varies with station locations and depth based on data from Sherwood et al., 2006 (see table below).

Station	Surface 0-15 cm (g/cm3)	Deeper > 15 cm (g/cm3)
1C	1.00	1.10
2C	0.95	1.10
3C	1.00	1.00
4C	0.90	0.90
5C	0.80	0.75
6C	0.75	0.75
7C	1.10	0.80
8C	0.60	0.50
9C	1.10	1.25

[4] Estimated volume of fill is equal to the volume of sediment required to fill a 45-cm prism covering the area of each cell.
The bulking factor and loss ratio were assumed negligible. The fill volume required to cap individual grid cells is provided in Table 5-1.

Another consideration in selecting cap thickness is consolidation of capping material and effectiveness of cap in containing sediment porewater (i.e., chemical isolation). A consolidation analysis of the underlying EA sediment was necessary to analyze potential contaminant flux. Computation of the volume of pore water expelled is needed to estimate the thickness of cap affected by advection. Compressibility of the EA sediments varies from low to moderate. USACE used their RECOVERY model to estimate diffusive flux and resultant changes over time in sediment and porewater contaminant concentrations and the flux of contaminants into the water column. Results for a 45-cm cap showed essentially complete isolation for over 100 years (Palermo et al., 1999).

5.2.4.4 Cap Material

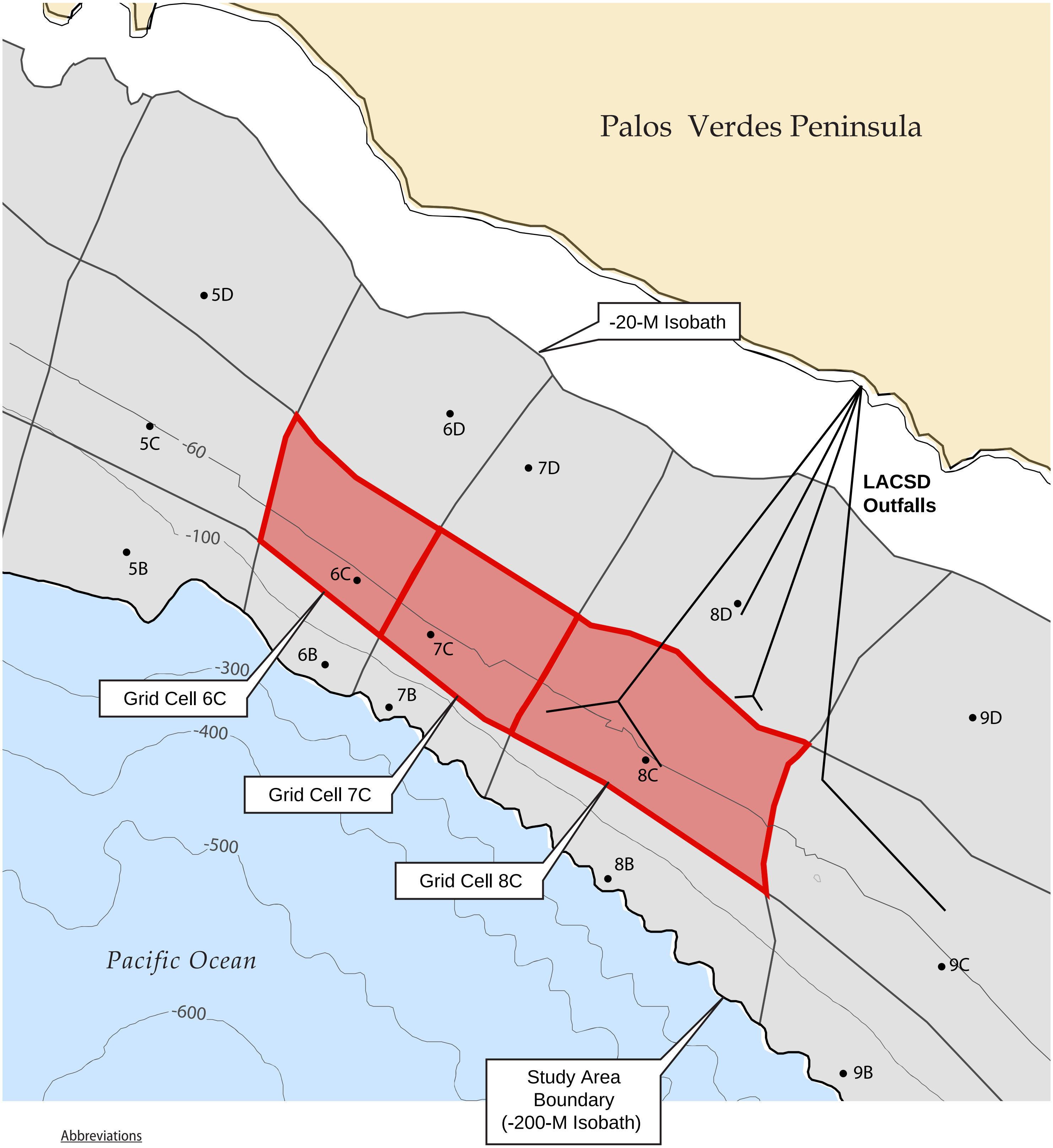
The specification of cap material requires knowledge of the shear stresses created at the bottom boundary layer to assure cap stability. Modeling of potential cap material was performed to determine critical shear stress of the designed cap. A revised and refined version USACE's Long Term FATE (LTFATE) model (Scheffner 1996, Scheffner et al. 1995) was used to screen areas where erosion would be a factor in cap design and/or where capping would not be recommended due to erosion potential. The LTFATE model was used to simulate erosion over defined model grids of 1 x 4 km and 2 x 2 km located in water depths of 30 m to 100 m. Three representative capping materials were modeled: 0.3 mm sand, 0.1 mm sand, and cohesive silt and clay. Wave conditions for the model runs were based on hypothetical events with wave heights of 5.5 and 7.0 m and on historical data of the largest storms from a 20-year period. Results from the LTFATE modeling indicated that significant erosion of sand-sized materials would occur only in water depths shallower than 40 m. Caps of silt and clay material would have greater erosion potential than coarser material. Cap designs consisting primarily of sandy material in water depths exceeding 40 m would be stable with minimum susceptibility to erosion.

Cap Material Sources

The amount of cap material required to provide a 45-cm cap for Grid Cells 6C, 7C, and 8C plus a 10 percent loss allowance is 1,358,000 m^3 (1,776,000 yd^3).

Because beaches in Southern California are eroding, the sand generated from dredging and construction projects is a valuable resource that typically is used beneficially for beach nourishment, or in-water and upland construction. Maintenance or new construction dredging material is often contaminated and not suitable for open water disposal. The availability of cap material will have to be critically evaluated and the project may need to be timed with dredging or major construction projects that will generate enough good quality sand. Cost and timing of procuring cap material will be a critical design consideration.

Potential sand cap sources were identified and evaluated for this FS through review of existing literature regarding sediment in Southern California and discussion with members of the dredging community, the U.S. Army Corps of Engineers, Los Angeles District, and the Ports of Los Angeles and Long Beach. Two major efforts are underway to evaluate sediment and the quality of those sediments in Southern California, as discussed below. An additional, unpublished effort by the California Geological Survey that identified offshore sand resources for borrow pits was completed in 2005.



Abbreviations

LACSD	Sanitation Districts of Los Angeles County
M	Meters

Legend

• 5B LACSD sediment sample station

-600 Isobath contour (meters)

0 0.5

Approximate Scale (Miles)

Feasibility Study Report
Palos Verdes Shelf
Los Angeles County, California

FIGURE 5-4
Layout of
Grid Cells 6C, 7C, and 8C

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The California Coastal Sediment Management Workgroup (CSMW) was formed as a collaborative effort between federal, state, and local agencies and nongovernmental organizations to evaluate California's coastal sediment management needs on a regional, system-wide basis (CMSW, 2007). The CSMW, as part of their Sediment Master Plan (SMP) attempts to address requests of coastal regulators for sediment budget information to assist them in their sediment management decision-making. A complete evaluation of sediment sources and when they will be available is under development by CSMW.

The Los Angeles Region Contaminated Sediment Long-Term Management Strategy (CSTF) is a collaborative effort by staff from federal, state, and local agencies, ports, research organizations, environmental advocacy groups, and private consulting firms. The main goal of the CSTF is to have regional coordination of sediment management efforts with a process for evaluating contaminated sediment dredging projects to minimize potential adverse environmental impacts associated with the dredging and disposal of contaminated sediments. An additional proposed long-term goal is to beneficially reuse sediments.

The CSTF provided projected volumes of sediment from known port capital improvement projects. The CSTF calculated potentially available dredged sediment quantities from anticipated POLA, POLB, and Alamitos Bay capital improvement projects and used historical records to project maintenance volumes from other sites. Data from the 2005 CSTF have not been updated unless noted. These and other projections of potential cap sediment quantities from regional sources are presented in Table 5-3.

Another potential sediment resource for capping material is from offshore borrow pits. The California Geological Survey (CGS) for the U.S. Minerals Management Service (MMS) and the California Department of Boating and Waterways (DBW) has prepared an unpublished assessment of offshore sand resources for potential use as beach nourishment (Higgins et al., 2005.). The assessment mapped the sediment types and volumes offshore of the Southern California Bight. This assessment focused on MMS jurisdiction the three nautical-mile limit that separates the jurisdiction of the federal government (MMS) and the State of California. Maximum water depths for economical operation of hydraulic dredges (cutterhead-suction and trailing-suction hopper, which are standard for offshore sand extraction) are typically limited to 30 m (about 100 feet).

Based on the technological, economic, and legal conditions, there are currently few areas under MMS jurisdiction along the coastal shelf in Southern California that would be accessible for potential extraction of sand. However, sand resources in-shore of the 3-nautical-mile limit, which are in shallower water depths and technically easier to dredge, are under the jurisdiction of the California Division of State Lands and the California Coastal Commission. The CGS report provides maps of mineral type (e.g., sand, mud gravel, rock) and tables of potential supplies. The most desirable deposits are unconsolidated, have large volumes, are similar in physical character to the material of the receiving site, and are free of contaminants and debris.

If this alternative were selected, maintenance dredging projects and construction projects that would coincide with the cap construction would be evaluated as a source during the design phase. A portion of the volume required for a cap may be available from a dredging or construction project, but it is probable that no single dredging or construction project would generate sufficient volumes of acceptable cap material to construct the entire cap. Therefore, it is likely that a borrow area would be required to provide a portion or the entire volume of material needed to construct the cap. While locating a borrow area for source

TABLE 5-3
Potential Cap Source Material and Volumes

Potential Cap Source	Potential Suppliers	Potential Volume (yd^3)	Timeframe	Feasibility Issues	
				Positive	Negative
Dredging Projects	Port of LB Capital Improvement Dredging[1]	2,121,000	Over 5 years	Port of LB has capital Improvement needs	Also needed for Port Construction
	Port of LA Capital Improvement Dredging[1]	1,570,000	Over 6 years	Port of LA has capital Improvement needs	Also needed for Port Construction
	Channel Islands Harbor Maintenance Dredging[2]	1,000,000	Every 2 years	Clean Sand, typically used for beach nourishment	Need approval for alternate disposal location
					Need to evaluate impacts to no beach nourishment alternative
	Marina del Rey entrance channels[1]	43,000 to 87,000[4]	Every 3 to 5 years	Maintenance dredging has historically been necessary	Typically 1/4 to 1/3 of material is unsuitable for open water disposal
	Santa Ana River Maintenance Dredging[3]	1,500,000	About Every 10 years	Distance is manageable	Typically brokered for inland industrial uses
Upland Construction Projects	CalTrans	No Data Available		Clean soil	High Transportation Costs
					Need handling area to transfer from trucks to barge
					Need to evaluate compatibility; could be different than in-water dredged sediments
Borrow Pit					
In-water Mining	Near-shore sand sources in the Los Angeles/Ventura Region[5]	>20,000,000	After an estimated 3 years of permitting	Clean sand supplies in near-shore off of Long Beach, Los Angeles, and Ventura.	No approved sand borrow pits

TABLE 5-3
Potential Cap Source Material and Volumes

Potential Cap Source	Potential Suppliers	Potential Volume (yd^3)	Timeframe	Feasibility Issues	
				Positive	Negative
				Sand similar to existing marine habitat	Need to conduct EIS to evaluate impacts to marine environment, permit process could need 3 years to permit. Sources need to be shallower than 100 feet based on hydraulic dredge technical requirements
Upland Mining		No Data Available			Need to Purchase Material High costs of mining, trucking, handling, and disposal

[1] Estimated dredge volumes at the time of CSTF (2005) publication
[2] Personal communication with Manson Construction and Corps LA District
[3] Moffatt and Nichol, 2006. Final Sand and Opportunistic Use Program Plan. Prepared for SANDAG
[4] Assumes 60,000 to 130,000 cy/year and 1/3 is not suitable for open water disposal
[5] Table A-4 in Higgins, C.T., Downey, C.I., and Clinkenbeard, J.P., 2005*, Assessment of offshore sand resources for potential use in restoration of beaches in California: California Geological Survey*, unpublished report prepared for U.S. Minerals Management Service and the California Department of Boating and Waterways, 153 p.

material, location, type of material, volume of material, and potential regulatory requirements will be considered. Clean areas of the shelf would be assessed as potential borrow areas. For purposes of costing this alternative, it is assumed that a sufficient amount of material will be available from a borrow site.

5.2.4.5 Cap Placement Techniques

This alternative assumes that at least two cap placement techniques would be required: an initial cover would be placed using a submerged release, i.e., a submerged drag arm or a tremie tube with diffuser. The appropriate equipment will be determined during the remedial design phase. Once this initial cover is placed, the cap construction would continue using the spreading method with a split-hull material barge or hopper dredge. The pilot capping project determined that the spreading method resulted in less disturbance to the EA sediment compared to the point-placement method (Fredette et al., 2002). The spreading method is a relatively rapid placement technique with a relatively minor modification to conventional methods. After the initial layer is placed, the spreading method would be used in locations away from the LACSD outfalls. A buffer zone around the outfalls would require use of precise placement methods to avoid any negative impacts to the outfalls from cap construction.

Based on production rates used in *Options for In Situ Capping* (Palermo et al. 1999) cap construction is anticipated to occur over two seasons. Average hopper dredge capacity is 1,800 cubic yards. Therefore, a 45-cm cap would require approximately 1,000 hopper loads. The pilot capping project determined that the sequence of cap material placement had significant effects on disturbance of the EA sediment (SAIC, 2002). Placement sequence would be from up-current to down-current and upslope to downslope, starting at the edge of the deposit.

5.2.4.6 Cap Monitoring

Cap monitoring would consist of two components: (1) construction monitoring, and (2) long-term cap performance monitoring. Monitoring activities for the construction phase are intended to (1) document the preplacement or baseline physical and biological conditions within and adjacent to the capping prisms, (2) guide the placement of dredged material within representative cells of the capping prism, and (3) document changes in water quality and any apparent displacement and transport of contaminated PV Shelf sediments resulting from the construction of a cap. The focus of the construction phase monitoring is to guide the construction work and evaluate whether the cap design specifications were achieved. Part of this monitoring would involve periodic testing of material being used for the cap to ensure that it meets design criteria, particularly for grain size characteristics.

The focus of the long-term performance monitoring is to determine whether physical and chemical isolation objectives are achieved over longer time periods and to provide a basis for determining if further action is needed. Longterm cap performance monitoring would be designed to accomplish the following:

- Determine whether the areal extent and thickness of the cap as constructed achieves the design specifications.
- Determine the effectiveness of the cap in isolating contaminated sediments.

- Determine the extent of biological recolonization and bioturbation.

Construction Monitoring. Cap construction-phase monitoring would require baseline, interim, and post-cap-placement measurements. Construction monitoring would provide real-time feedback on capping progress to allow modification of techniques to improve effectiveness as well as assure environmental impacts are minimized. Construction monitoring would use current and turbidity measurements to track sediment plumes. During the pilot capping project, acoustic doppler current profilers (ADCPs), optical backscatter sensors (OBS), drogues, sediment cores and Niskin water sample bottles were among the equipment used to measure and track current speed and turbidity. Operational procedures and guidelines developed for the pilot capping project (SAIC, 2000) would be modified as needed for cap construction. Interim and post-cap-placement monitoring would be used to determine the thickness and physical properties of the cap layer. Sub-bottom surveys would provide information on the thickness of the cap layer over a relatively large area. The survey would provide information on layering within sediment profiles due to sorting or segregation of distinct sediment size ranges during settling of the cap material.

Sediment cores, collected using box cores, are intended to provide information on cap thickness and layering, as well as the vertical distribution within the core of sediment contaminants. For the purposes of this FS, it is assumed that sediment cores would be collected at 50 locations before, during, and after cap placement. Sediment cores would be analyzed for TOC, bulk density, grain size and DDE. Water column samples would be collected from 12 stations (2 depths) during construction and analyzed for DDTs and PCBs.

Long-Term Performance Monitoring. Long-term cap performance monitoring would consist of evaluating biological recolonization and physical and chemical isolation of the underlying contaminated sediment. The rates and extent of recolonization would be evaluated over a defined grid of 50 sampling locations after capping and before the Five Year Review. Physical isolation of the contaminated sediment layer would be evaluated over the entire cap area after cap construction and for the Five-Year Review. Chemical isolation would be evaluated using passive samplers deployed over the cap to measure contaminant flux from the cap as well as from sediment cores collected at 12 locations at the same sampling frequency as the physical isolation monitoring. For these stations, the contaminant mass and vertical distribution will be evaluated in each core by analyzing 4-cm segments for DDTs and PCBs from the surface to a depth of 100 cm (25 samples/core).

5.2.4.7 Resuspension Management

Resuspension management in Alternative 4 would include using BMPs during in-water work; engineering and in-water construction methods designed to minimize resuspension; and engineering design to minimize events such as slope failures, debris flows, or avalanches. Some examples of specific BMPs that would be implemented at the PV Shelf include the use of low-impact placement techniques, such as dragarm or tremie tube, that minimize the energy with which the cap material impacts the bottom sediments, or staging and tracking of placement locations to prevent mounding that might result in slope failures that could cause debris flows or avalanches. Engineering design to minimize resuspension of sediment during capping would include placing an initial layer of cap material over the sediment of the PV Shelf using low-impact techniques mentioned above, then build the cap using more efficient techniques such as spreading.

5.2.4.8 Residual Management

Alternative 4 will use monitoring to manage residual sediment contamination at the PV Shelf Study Area. Residual contaminated sediment will remain exposed to the environment after cap construction because of limitations to the precision of cap construction (thickness and lateral coverage of cap material), limitations in placement techniques that cause mixing of the cap material and the effluent-affected sediments, and limitations of the constituents that are present in available cap material. This would include material at the margins of the cap where the cap material thickness feathers out or residual contamination that settles on the cap following resuspension during placement of cap material at an adjacent location. Note that the engineering design will consider factors such as prevailing current directions to mitigate these conditions. Ideally, there would be no surface contamination remaining after cap construction; however, that is dependent on a number of factors including the cap material placement technique, thickness of the cap, the number of lifts used to place the cap, sediment physical characteristics of both cap and indigenous sediments, vertical distribution of contaminants in native sediments, and site hydrodynamics such as current and waves.

5.2.4.9 Material Conveyance/Transport

Under Alternative 4, a source for cap material has not been selected. However, some potential sources are identified in Table 5-3. The most likely sources are in-water. A hopper dredge would be used for loading and transport of material from the in-water source to the project site. The hopper dredge can load the material into its hoppers without the use of additional equipment. If the cap material comes from a shore, typically a barge or scow would be used for transport. Material would be loaded onto a barge or scow using a mechanical dredge for near-shore fill sources. Material from upland sources would be transported to the barge using trucks or possibly rail cars and either dumped directly on the barge deck or placed in a stockpile to be transferred to the barge using a crane or excavator.

5.2.4.10 Institutional Controls and Monitored Natural Recovery

The institutional controls and monitored natural recovery programs for Alternative 4 are described under Alternative 2.

5.2.5 Alternative 5--Removal with Institutional Controls and Monitored Natural Recovery

Alternative 5, Removal with Institutional Controls and Monitored Natural Recovery, consists of dredging that portion of the EA sediment deposit that contains sediment with the highest concentrations of contaminants at surface and depth, i.e., Grid Cell 8C. The alternative includes treatment and disposal of dredged sediment at an upland off-site disposal facility. Water collected from the dewatering of dredged sediment would require treatment before disposal. ICs and MNR programs would also be implemented. Appendix F provides details of this alternative.

Dredging technologies were reviewed to determine the most appropriate method to remove sediment from grid Cell 8C at a depth of 50 to 70 m. The main limiting factor is the depth of the deposit. Other dredging issues include resuspension of sediments and dredging accuracy. Performance standards for the site include being able to reach depths up to 70 m, achieve acceptable production rates, dredge in thin lifts while minimizing overdredging, and minimize resuspension of sediments. A trailing suction hopper dredge was selected as the technology most likely to meet these performance standards.

5.2.5.1 Dredging Area

Grid Cell 8C at the PV Shelf covers approximately 320 acres at a depth from 50 m to 70 m, or to the shelf break. The estimated depth of sediment to be dredged is approximately 75 cm, not including overdredging. Grid Cell 8C contains total mass of DDTs in surface sediment of approximately 2,250 kg, accounting for approximately 44 percent of the total mass of DDTs in PV Shelf surface sediment. The total mass of PCBs present in surface sediment in Cell 8C is 85 kg, accounting for 13 percent of total mass of PCBs in PV Shelf surface sediment. Grid Cell 8C includes the JWPCP outfalls. The estimated volume of dredged material is approximately 1,345,000 yd^3, or 1,613,000 yd^3, including overdredging. An estimated 1,487,950,000 gallons of water would be generated during sludge and sediment dewatering (Appendix F: Tech Memo: Development and Analysis of Removal Alternative, ITSI 2008).

5.2.5.2 Dredging Design

Sediment removal would be performed with hydraulic dredging equipment, i.e., a trailing suction hopper dredge and two scow barges. The dredge is connected with drag arms and drag heads that dredge the bottom of the shelf. The sediment is pumped in slurry form through pipes to the scow barge, which is taken to shore upon reaching capacity, where the material is pumped into a decanting basin. Two scow barges would be utilized to allow for continuous dredging operation. One barge would be receiving sediment while the other is unloading the sediment on shore. The trailing suction hopper dredge would be positioned with a tug and dragline. The hopper dredge is more difficult to control the deeper the dredge depth, especially under open ocean currents and with long drag arms. To increase the confidence that the targeted sediment is removed, overlap between dredge passes is recommended.

Production rate for the trailing suction hopper dredge is dependent on many factors, including the size of the dredge pump, the physical composition of the sediments to be dredged, and the physical composition of the materials below the sediment to be dredged. Rough estimates of a U.S. dredging company is 1,000 cubic yards per day, with two 2,000 cubic yard scows working in rotation. Dredging even the limited area defined by Grid Cell 8C would be a multi-year operation, estimated to take 12 years.

The trailing suction hopper dredge would not operate near the outfall pipes or rock outcrops to prevent equipment damage. Additionally, the dredge cannot be controlled accurately enough to dredge steep slopes and could not be used along the PV Shelf slope because of its steepness and depth.

5.2.5.3 Residual and Resuspension Management

Sediment resuspension during operation of hydraulic dredges occurs when sediment dislodged by the dredgehead escapes the suction pipe. Two important factors in resuspension for hydraulic dredges are the depth of the cut and the speed of advance of the dredgehead. Sediment resuspension by hydraulic dredges is typically more concentrated in the lower portion of the water column, where the dredgehead encounters the sediment (USACE, 2008a). Suction dredges are considered favorable for sediment resuspension control because they have no mechanical action at the dredgehead to dislodge sediment; therefore, resuspension potential is due solely to the advance of the dredge head through the sediment (USACE, 2008b).

Contaminated sediment could remain exposed to the environment after dredging operations because of its imprecision. Extra passes is the accepted approach to limit residuals, however, this would increase the volume of material needing disposal. Residual management is addressed by including most of the buried deposit; therefore, the residual sediment would have low COC concentrations. However, a temporary increase in COC availability is typically associated with dredging operations (USACE, 2008a). BMPs to minimize residuals and resuspension would be enforced. Production would be limited to seasons when the ocean is calm, e.g., late spring and summer. Typical mechanisms to manage resuspension and residuals, like containment barriers or silt screens, could not be used during dredging of the PV Shelf because the depth of the site makes them infeasible.

5.2.5.4 Management of Dredged Sediment

Hydraulic dredging operations require the sediment to be mixed with water to allow the material to be pumped through a dredge pipe. The sediment coming out of the dredge pipe for plain suction dredging will have a solids content of approximately 10 percent. The volume of the sediment slurry that would be generated during dredging operations is estimated to be 10,640,000 cubic yards. The Cell 8C sediment is characterized by clay and silts, significantly elevated organic carbon content, and low bulk densities. This sediment generally does not dewater quickly with gravity dewatering and would require a decanting basin. The size of the basin depends on several factors, including dredge production, solids content of dredge sediment, available area, water treatment layout, etc. The decanting basin would be divided into multiple cells where dewatered sediment can easily be transferred to another area within the basin to be prepared for offsite transport by bulking or solidification. Multiple operations would be underway within the decanting basins at each cell. It is estimated that the volume of sediment after decanting would be approximately 3,610,000 yd^3.

After dewatering, the dredged material would undergo solidification through the addition of a reagent. Because the sediment would require further treatment before it could be disposed of, typical binding agents, such as cement or lime, may not be suitable. The reagent would have to be evaluated to provide absorption of moisture without interfering with thermal desorption.

Treatment of water generated as a result of dredging and dewatering is required. The estimated volume of water is 1,487,950,000 gallons. In order for the water to be discharged to the ocean in accordance with Section 403 of the Clean Water Act, Title 40, CFR Part 125, Subpart M, it would have to be treated to meet State of California water quality standards. Filtration would be used to remove suspended solids before water treatment with granulated activated carbon (GAC).

5.2.5.5 Dredged Material Disposal

Removal of the contaminated sediment would require the additional process option of disposal. Once the contaminated sediment was removed, it would be necessary to manage it by (1) placing it in a confined disposal facility (CDF) or contained aquatic disposal (CAD), (2) disposing of it in the deep ocean, or (3) disposing of it in a landfill. As discussed in

Section 4, all of these options are problematic. The most likely option of these four, however, is disposal in an EPA-approved landfill. Because the levels of PCBs in the EA sediment are less than 50 mg/kg, the dredged material would not be considered toxic material under TSCA; however, since the sediment would be considered PCB-remediation waste, per 40 CFR 761.61(c) a site-specific disposal plan would need to be prepared for approval by the EPA Regional Administrator. In addition, the dredged material would be considered RCRA-listed hazardous waste. The material would require pretreatment prior to disposal to reduce the water content and concentrations of DDT and DDE to acceptable concentrations, i.e., less than 0.087 mg/kg.

The technology selected for removal of DDTs and PCBs contained in the dewatered sediment to a level acceptable for land disposal is thermal desorption. Thermal desorption can be high temperature (HTTD) or low temperature (LTTD). Low temperature is typically applied to contaminants with relative low boiling points (i.e., below 600° F) while high temperature is typically applied to contaminants having boiling points above 600° F (Naval Facilities, 1998). DDT would be suitable for LTTD, while PCBs would require HTTD.

5.2.5.6 Institutional Controls and Monitored Natural Recovery

The institutional controls and monitored natural recovery programs for Alternative 5 are described under Alternative 2.

5.3 Screening of Alternatives

The purpose of this section is to screen the five assembled alternatives for implementability, effectiveness, and cost, and to determine if any should be omitted from detailed analysis in Section 6.0. The five alternatives assembled and developed in Section 5.2 are:

- Alternative 1—No Action
- Alternative 2—Institutional Controls with Monitored Natural Recovery
- Alternative 3— Containment (Small Cap) with Institutional Controls and Monitored Natural Recovery
- Alternative 4 – Containment (Large Cap) with Institutional Controls and Monitored Natural Recovery
- Alternative 5 – Removal with Institutional Controls and Monitored Natural Recovery

5.3.1 Alternative 1—No Action

Effectiveness. All current risks would remain unabated under the no action alternative. Untreated contamination in sediment would continue to pose a risk to human health and the environment for many years. Although degradation and other fate-and-transport processes would reduce the concentrations to below levels of concern for much of the shelf, the area around the outfalls would continue to exceed remediation objectives for much longer. Changes in overall risk from the site would be difficult to assess since no monitoring would be performed under this alternative. Based on current understanding of fate and transport processes, under the no action alternative, RAOs would be met in 30 to over 100 years.

Implementability. The no action alternative would be easy to implement because no action is being taken.

Cost. No action, by definition, would have no associated costs.

5.3.2 Alternative 2—Institutional Controls with Monitored Natural Recovery

Effectiveness. The institutional controls (ICs) program has moderate to high effectiveness. Institutional controls can be effective in reducing the number of contaminated fish being eaten by consumers; however, it does not reduce contaminant concentrations in fish. Institutional controls do not reduce the risk to ecological receptors. Monitored natural recovery (MNR) has low effectiveness in the short-term and moderate effectiveness in the long-term. The effectiveness of MNR at the site will be determined through sampling and monitoring. Modeling predicts that contaminant concentrations may reach remedial objectives within 30 to 100 years; however, monitoring would be required to confirm recovery. Although median sediment and water concentrations would drop to levels associated with remediation goals for safe fish consumption, the outfall area would not reach remediation goals for over 100 years. Whether this would prevent fish from reaching remediation goals is not known. Although natural recovery has improved conditions on portions of the shelf, other areas appear to be becoming worse, i.e., the outfall area.

Implementability. Institutional controls are easy to moderate to implement. The materials and services to implement outreach and education, enforcement, and monitoring are readily available. MNR is also easy to implement. Sampling techniques to monitor recovery are proven and readily available.

Cost. The cost of the ICs program and MNR are less than the other alternatives. However, they are elaborate programs that would cost millions over the next ten years.

5.3.3 Alternative 3—Small Cap with Monitored Natural Recovery and Institutional Controls

Effectiveness. The institutional controls (ICs) program has moderate to high effectiveness. Institutional controls can be effective in reducing the number of contaminated fish being eaten by consumers; however, it does not reduce contaminant concentrations in fish. Institutional controls do not reduce the risk to ecological receptors. Alternative 3 is relatively more effective than Alternative 2 because it accelerates natural recovery. The area of the shelf that contains the highest contaminant concentrations and is most susceptible to erosion would be covered with clean sediment to reduce contaminant flux and movement of contaminated sediment. Remediation goals would be achieved fourteen years sooner than under Alternative 2. In the interim, risk to ecological receptors from contaminated sediment and water would continue.

Implementability. The implementability of Alternative 3 is moderate. The ICs program has been in operation for many years. The materials and services to implement outreach and education, enforcement, and monitoring are readily available. Enhancing MNR through placement of a small cap would be more difficult than merely tracking natural recovery. Although placing a sediment layer at 50- to 70-m depth adjacent to discharge outfalls has not been done, the equipment and techniques that would be utilized have been implemented in many other sites.

Cost. The cost of Alternative 3 is seven times higher than Alternative 2.

5.3.4 Alternative 4—Containment with Monitored Natural Recovery and Institutional Controls

Effectiveness. Alternative 4 has the potential to be more effective than the other alternatives. If properly designed and placed, a sand cap can be an effective technology in reducing the overall risk from the site. The 2000 pilot capping project evaluated three placement methods for a sand cap over three 45-acre (300 m x 600 m) cells and concluded that capping is a technically feasible option for the site (Fredette et al., 2002). However, monitoring during and after cap placement found mixed results in effectiveness of reducing surficial contaminant concentrations (SAIC, 2002). Monitoring during cap placement observed increases in turbidity as cap material hit the shelf floor and created a surge wave. For the most successful cap, Cell LU at 40 m, the initial drop of cap material created a vertical plume of suspended sediment 13 m thick and an annulus with the radial dimension of approximately 220 m (SAIC, 2002). However, both plume and annulus quickly decreased with distance and time. Point dump of cap material on the deeper cell, Cell SU, produced a vertical plume 5 – 10 m thick and an annulus with a radial dimension of 232 m. Increased turbidity was measured 475 m from the point dump. A vertical plume 13 m thick was measured at Cell LD, which was capped using the spreading technique; however, within 2 minutes plume thickness had decreased 50 percent (SAIC, 2002). Turbidity associated with the spreading technique dissipated faster than turbidity from point dump placement.

Post-cap monitoring observed a depositional layer of fine-grained sediment over all three caps. Sediment cores were collected across the caps. For the LU cell at 40 m, contaminant concentrations in the 0-8 cm surface layer were generally lower than pre-capping concentrations. However, in three of seven cores, DDE concentrations in the top 0-4 cm layer higher than those in the 4-8 cm layer. For the LD cell, which was capped using the spreading method, only two cores were taken; however, core profiles of sediment DDE concentrations did not show any consistent depth pattern and concentrations generally were comparable to baseline conditions. The SU cell, which was in deeper water than the other two cells and would be included in Grid Cell 7C, had the most unsatisfactory results. None of the four sediments cores collected from the SU cell had a visually distinct cap/sediment interface. Geotechnical measurements and sediment chemistry indicated mixing of EA sediment with cap material. In some cores, surface (0 –4 cm) DDE concentrations were comparable to or higher than baseline values. Core profiles exhibited a pattern of DDE decreasing concentrations with core depth. In two of the cores, DDE concentration peaked in the 0-4 cm interval; in the other two cores the peak was in the 12-16 cm interval (SAIC, 2002). In contrast, pre-capping cores historically had peak concentrations occurring at depths of 25 to 45 cm. The post-cap monitoring suggests erosion/scouring of surface sediment occurred (SAIC, 2002). In assessing these post-pilot capping data, it is important to keep in mind that point placement was used for Cells LU and SU, the pilot cells were much smaller than the proposed cap area(s) and had target cap thicknesses of 15 to 18 cm. Nevertheless, the pilot project illustrated the potential difficulties associated with capping soft sediment at 40 to 60 m depths.

Under this alternative, risk also would be reduced over time through natural attenuation. Monitoring would be required to determine actual long-term effectiveness of a cap and of natural recovery. The institutional controls component can be effective in reducing the number of contaminated fish being eaten by consumers, but it does not reduce the risk to fish or other ecological receptors. Alternative 4 includes monitoring to assess the impact of natural processes on the recovery of the PV Shelf Study Area.

Implementability. The depth of water, the large areal extent of the effluent-affected sediment, and the potential for resuspension of the effluent-affected sediment during cap placement make the implementation of a sand cap in Alternative 4 difficult. The materials and services for Alternative 4 are readily available.

Cost. The cost of Alternative 4 is high due to cap material, conveyance/transport, cap placement, and monitoring costs.

5.3.5 Alternative 5—Removal with Monitored Natural Recovery and Institutional Controls

Effectiveness. The effectiveness of this technology is low. Hydraulic dredging is a proven technology for removal of ocean sediment but is done rarely at these depths. Because of restrictions on use of foreign vessels in U.S. waters, it is unclear whether a trailing suction hopper dredge that operates at the required depth of 60 to 70 m would be available. The volume of material would require an estimated 12 years to dredge, in part because the open ocean location would limit the operational season to six or seven months. The volume of dredged material would be difficult to manage. Although hydraulic dredging has a favorable rating for resuspension, the amount of EA sediment mobilized by dredging would be significant.

Implementability. In theory, Alternative 5 is implementable. However, there are site-specific issues related to technical and administrative implementability that may render this alternative infeasible. This section discusses the technical and administrative feasibility, and the availability of services and materials.

Technical Feasibility. Deep-water dredging is difficult. Dredging would cause some resuspension of the EA sediment, which would be difficult to manage. The volume to be dredged would be approximately 1,233,000 m^3 or 1,613,000 yd^3. The dragline of the trailing suction hopper dredge is more difficult to control at deep-dredge depths, especially under ocean currents and with long drag-arms. Overlapping passes would be required, which could result in increased turbulence and increase volume of dredged material. A comprehensive monitoring and maintenance program would be required. The estimated total quantity of material to be dredged is approximately 10,640,000 yd^3, and the scow capacities are 2,000 yd^3; therefore, dredging would be a multi-year operation.

Technical feasibility of thermal desorption is moderate for the site. There are many factors that can limit the implementability and effectiveness of thermal desorption. High moisture contents require more energy to reach temperatures necessary for destruction of contaminants so a suitable source of electric power is needed. When moisture content is higher than 20 percent, impacts on cost become significant (USEPA, 1997a). In addition, the solids content of the material must be at least 20 percent for effective treatment (USEPA, 1992). Additionally, the pH of the material must be monitored to ensure that corrosion does not occur within the system. The removal efficiency and residence time necessary to achieve treatment standards will be affected by the contaminant concentrations and moisture content of the material (EPA, 1992).

Transportation of the dredged material to the proposed unloading areas could cause issues with ship traffic. Another issue affecting technical implementability is whether adequate space is available for stockpiling treated and untreated materials, dewatering materials, and operating process equipment. The lack of open spaces near PV Shelf may indicate significant limitations to implementability of this alternative.

Dewatering cells are easily constructed; however, available open space near PV Shelf is limited. The shoreline and upland areas are highly developed or public spaces, i.e., beaches and parks. The most likely location is within the Ports of Los Angeles or Long Beach, which are located approximately 5 nautical miles from the dredge site. The Port of Los Angeles has infrastructure for truck traffic already in place along with level topography suitable for dewatering cell construction. However, the availability of port areas is unknown and port operations may preclude their use.

Treatment and disposal of water from dredging and sediment dewatering would require a mobile water treatment facility equipped with pumps, pre-filtration equipment, and GAC units.

Administrative Feasibility. Administrative feasibility for dredging operations would be difficult as these activities would require coordination with the Port of Los Angeles and the U.S. Coast Guard for dredging near the port and for use of the Port for sediment offloading, dewatering, and treatment. In addition, the Jones Act requires that only U.S. vessels be used for dredging and transporting dredged material in U.S. waters.

Administrative feasibility for construction of dewatering cells and a water treatment plant is considered low. These facilities would require approval from multiple state and local agencies. Permits may be required by local authorities for operation and monitoring and limits on hours of operation or noise control measures, may be required.

The volume of material after dewatering is estimated to be approximately 3,610,000 yd^3. A large number of trucks would be required to transport the treated material to an approved off-site disposal facility. Truck traffic is already an issue with the ports, and it is unclear whether port plans to control air emissions from trucks would accommodate the extra capacity that would be needed.

Cost. The cost of this technology is high due to the amount of sediment and water that would need to be managed and disposed. A feasible disposal option for the dredged material would need to be developed. The EPA Office of Water has indicated that ocean disposal of the effluent-affected sediment from the PV Shelf would not be allowed (Ross, 2007). Therefore, the dredged material would require disposal at an upland site after treatment to meet State of California disposal standards for DDT.

Removal, treatment, and disposal would cost over $2 billion. Questions about the effectiveness and implementability of removal, in addition to cost, cause this technology to be rejected from further consideration.

5.4 Summary of Retained Alternatives

Based on an evaluation of the assembled and developed alternatives, alternatives 1 thru 4 are retained for detailed analysis. Alternative 1 is retained because the no action alternative is required as a baseline for comparison with other remedial action alternatives in accordance with the NCP. Alternative 2, Institutional Controls with Monitored Natural

Recovery, is retained because it will protect human health by reducing consumption of contaminated fish and assess the rate of natural recovery processes known to be occurring at the site. Alternative 3 is retained because, in addition to protecting human health through institutional controls, it will accelerate the natural recovery known to be occurring at the site by reducing exposure and contaminant flux from the area of highest COCs. Alternative 4 is retained because it combines the elements of each alternative, reducing risk to human health from consumption of fish, monitoring natural recovery processes, and reducing the risk to the biological community and concentrations in the surface water by isolating sediment with high concentrations of DDTs and PCBs.

6.0 Detailed Analysis of Remedial Alternatives

6.1 Introduction

This section provides a detailed analysis of the alternatives developed in Section 5.0 for remediation of contaminated sediment in the effluent-affected area of the PV Shelf Study Area. As discussed in section 5.0, this feasibility study is for an interim record of decision. The alternatives discussed below are interim remedies that will be supplemented by additional measures after further studies and analysis of the remedy's effectiveness. The four alternatives are evaluated according to the standard criteria specified in the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA, 1988a). Each alternative is evaluated individually against each criterion, followed by a comparison among alternatives to assess specific strengths and weaknesses that must be balanced.

The nine CERCLA evaluation criteria are in the following list:

1. Overall protection of human health and the environment
2. Compliance with ARARs
3. Long-term effectiveness and permanence
4. Reduction of toxicity, mobility, or volume through treatment
5. Short-term effectiveness
6. Implementability
7. Cost
8. State acceptance
9. Community acceptance

The NCP, 40 CFR Section 300.430(e)(9)(iii), categorizes these nine criteria into three types: (1) threshold criteria, (2) primary balancing criteria, and (3) modifying criteria. Each alternative must meet the threshold criteria to be eligible for selection as the preferred alternative. The two threshold criteria are (1) protection of human health and the environment and (2) compliance with ARARs (unless a waiver is obtained).

Primary balancing criteria are used to weigh effectiveness and cost tradeoffs among alternatives. The five primary balancing criteria include (1) long-term effectiveness and permanence; (2) reduction of toxicity, mobility, or volume through treatment; (3) short-term effectiveness; (4) implementability; and (5) cost. The primary balancing criteria represent the main technical criteria upon which alternative evaluation is based.

Modifying criteria are state acceptance and community acceptance, and may be used to modify aspects of the preferred alternative when preparing the Record of Decision (ROD) for the remedial alternative. Modifying criteria are generally evaluated after public comment on the FS and the proposed plan.

These nine evaluation criteria are intended to provide a framework for assessing the risks, costs and benefits for each remedial alternative. The relative performance of each alternative is assessed individually and comparatively with respect to the evaluation criteria in order to identify the key tradeoffs among them. Only the two threshold and the five primary balancing criteria are used to evaluate alternatives in the detailed analysis phase. The following subsections contain descriptions of these seven evaluation criteria, individual evaluations of the alternatives, and a comparative evaluation. Descriptions of the individual alternatives are provided in Section 5.0.

6.2 Threshold Criteria

Threshold criteria serve as essential determinations that should be met by any remedial alternative in order to be eligible for selection. They serve as primary project goals for a remediation program.

6.2.1 Overall Protection of Human Health and the Environment

This evaluation criterion assesses how each alternative provides and maintains adequate protection of human health and the environment. Alternatives are assessed to determine whether they can adequately protect human health and the environment from unacceptable risks posed by contaminants present at the site, in both the short and long term. This criterion is also used to evaluate how risks would be eliminated, reduced, or controlled through treatment, engineering, institutional controls, or other remedial activities.

As discussed in Section 2.0, the primary risk to human health associated with the contaminated sediment is consumption of fish. The primary risk to the environment is direct ingestion of sediment by invertebrates and bioaccumulation of COCs in higher trophic species from the consumption of invertebrates, fish, or piscivorous birds. Protection of human health and the environment is evaluated by estimating the timeframe required 1) to reduce COC sediment loads and improve surface water quality; 2) to reduce COC concentrations in fish to allow safe consumption of fish; and 3) to reach surface sediment concentrations protective of local, benthic-feeding fish.

The key remedial thresholds evaluated during the analysis of each alternative for overall protection of human health and the environment are presented in Table 6-1.

TABLE 6-1: OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Goal	Considerations
Human Health Protection	Likelihood that the alternative meets RAOs to reduce risk to human health from consumption of fish contaminated with DDTs and PCBs, defined as achieving an acceptable risk level: ▪ 400 µg/kg DDT and 70 µg/kg PCBs ▪ Estimated COC concentrations in sediment necessary to achieve above concentrations in white croaker are 230 µg/kg DDT and 70 µg/kg PCBs at 1% total organic carbon and Ambient Water Quality Criteria for protection of human health from contaminants in fish: ▪ 0.22 ng/L DDT and 0.064 ng/L PCBs
Protection of Ecological Receptors	▪ Likelihood that the alternative meets RAOs to reduce risk to ecological receptors, defined as Ambient Water Quality Criteria for protection of ecological receptors: ▪ 1 ng/L DDT

6.2.2 Compliance with Applicable or Relevant and Appropriate Requirements

This evaluation criterion is used to determine if each alternative would comply with federal and state ARARs, or whether invoking waivers to specific ARARs is adequately justified. Other information, such as advisories, criteria, or guidance, is considered where appropriate during the ARARs analysis. Considerations evaluated during the analysis of the ARARs applicable to each alternative are presented in Table 6-2. Potential action-, location-, and chemical-specific ARARs for the alternatives presented in this FS are identified in Section 3.0.

TABLE 6-2: COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Analysis Factors	Considerations
Chemical-specific ARARs	Likelihood that the alternative will achieve compliance with chemical-specific ARARs such as of EPA's ambient water quality criteria for DDTs and PCBs (see Table 6-1) within a reasonable period of time
	Evaluation of whether a waiver is appropriate if the chemical-specific ARARs cannot be achieved
Location-specific ARARs	Determination of whether any location-specific ARARs, such as the Endangered Species Act, apply to the alternative
	Likelihood that the alternative will achieve compliance with any location-specific ARAR
	Evaluation of whether a waiver is appropriate, if the location-specific ARAR cannot be met
Action-specific ARARs	Likelihood that the alternative will achieve compliance with potential action-specific ARARs, such as MPSRA.
	Evaluation of whether a waiver is appropriate, if the action-specific ARAR cannot be met
Other Criteria and Guidance	Likelihood that the alternative will achieve compliance with other criteria (e.g., risk-based criteria)

6.3 Balancing Criteria

Balancing criteria are included in the detailed analysis of alternatives because these five variables (long-term effectiveness, reduction of toxicity, short-term effectiveness, implementability, and cost) are important components that often define the major trade-offs between alternatives. They serve as important elements of project goals that require careful consideration for successful implementation and long-term success of remediation. The five balancing criteria are evaluated for each remedial alternative. The following subsections provide description of the criteria evaluated in this portion of the detailed analysis.

6.3.1 Long-Term Effectiveness and Permanence

This evaluation criterion addresses long-term effectiveness and permanence of the protection of human health and the environment after implementing the remedial action imposed by the alternative. The primary components of this criterion are the magnitude of residual risk remaining at the site after RAOs have been met, and the extent and effectiveness of controls that might be required to manage the risk posed by treatment residuals and/or untreated wastes. For example, important considerations for long-term effectiveness under Alternative 4, which includes capping, would include physical stability of the cap, the depth of bioturbation and potential recontamination. Considerations evaluated during the analysis of each alternative for long-term effectiveness and permanence are presented in Table 6-3.

TABLE 6-3: LONG-TERM EFFECTIVENESS AND PERMANENCE

Analysis Factors	Considerations
Magnitude of Residual Risks	Identification of remaining risks from treatment residuals, as well as from untreated residual contamination
	Magnitude of remaining risks
Adequacy and Reliability of Controls	Likelihood that the technologies will meet required process efficiencies or performance specifications
	Type and degree of long-term management required
	Long-term monitoring requirements
	O&M functions that must be performed
	Difficulties and uncertainties associated with long-term O&M functions
	Potential need for technical components replacement
	Magnitude of threats or risks, should technical components need replacement
	Confidence that controls can adequately handle potential problems
	Uncertainties associated with land disposal of residuals and untreated wastes

6.3.2 Reduction of Toxicity, Mobility, or Volume through Treatment

This evaluation criterion addresses the anticipated performance of the alternative's treatment technologies to permanently and significantly reduce toxicity, mobility, and/or volume of hazardous materials at the site. The NCP states a preference for remedial actions in which treatment is used to reduce the principal threats at a site through destruction of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of total volume of contaminated media. None of the alternatives involve treatment, but it is expected that the toxicity, mobility, and volume will be reduced in each alternative to some extent over time by natural degradation processes. Considerations evaluated during the analysis of each alternative for reduction of toxicity, mobility, or volume of contaminants present at a given site are presented in Table 6-4.

TABLE 6-4: REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT

Analysis Factors	Considerations
Treatment Process and Remedy	Likelihood that the treatment process addresses the principal threat
	Special requirements for the treatment process
Amount of Hazardous Material Destroyed or Treated	Portion (mass) of contaminant that is destroyed
	Portion (mass) of contaminant that is treated
Reduction in Toxicity, Mobility, or	Extent to which the total mass of contaminants is reduced

TABLE 6-4: REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT

Analysis Factors	Considerations
Volume through Treatment	Extent to which the mobility of contaminants is reduced
	Extent to which the volume of contaminants is reduced
Irreversibility of Treatment	Extent to which the effects of the treatment are irreversible
Type and Quantity of Treatment Residual	Types of residuals that will remain
	Quantities and characteristics of residuals
	Risks posed by residuals
Statutory Preference for Treatment as a Principal Element	Extent to which the scope of the action covers the principal threats
	Extent to which the scope of the action reduces the inherent hazards posed by the principal threats

6.3.3 Short-Term Effectiveness

This evaluation criterion considers the effect of each alternative on the protection of human health and the environment during the construction and implementation process. The short-term effectiveness evaluation only addresses protection prior to meeting the RAOs. An important short-term consideration at the PV Shelf Study Area is the resuspension of contaminated sediment during implementation of the capping alternative. Considerations evaluated during the analysis of each alternative for short-term effectiveness are presented in Table 6-5.

TABLE 6-5: SHORT-TERM EFFECTIVENESS

Analysis Factors	Considerations
Protection of the Community During the Remedial Action	Risks to the community that must be addressed
	How risks will be addressed and mitigated
	Remaining risks that cannot be readily controlled
Protection of Workers During Remedial Actions	Risks to workers that must be addressed
	How risks will be addressed and mitigated
	Remaining risks that cannot be readily controlled
Environmental Impacts	Types of environmental impacts expected during construction and implementation of the alternative (e.g., resuspension of contaminated sediments)
	Available mitigation measures and their reliability to minimize potential impacts
	Unavoidable impacts, should the alternative be implemented
Time until RAOs are Achieved	Time needed to achieve protection against the risks being addressed
	Time needed to address any remaining risks

6.3.4 Implementability

This criterion evaluates the technical and administrative feasibility (i.e., the ease or difficulty) of implementing each alternative, and the availability of required services and materials during its implementation. In addition to its sheer size, the PV Shelf Study Area poses unique challenges for implementing remedial actions including the depth of water, physical characteristics of the effluent-affected sediment, and slope. Considerations evaluated during the analysis of each alternative for implementability are presented in Table 6-6.

TABLE 6-6: IMPLEMENTABILITY

Analysis Factors	Considerations
Technical Feasibility	
Ability to Construct and Operate the Technology	Difficulties associated with construction (e.g., water depth)
	Uncertainties associated with construction
Reliability of the Technology	Likelihood that technical problems will lead to schedule delays
Ease of Undertaking Additional Remedial Action	Likely additional remedial actions
	Difficulty implementing additional remedial actions
Monitoring Considerations	Migration or exposure pathways that cannot be monitored adequately
	Risks of exposure, should monitoring be insufficient to detect failure
Administrative Feasibility	
Coordination with Other Agencies	Steps required to coordinate with regulatory agencies
	Steps required to establish long-term or future coordination among agencies
	Ease of obtaining permits for offsite activities, if required
Availability of Services and Materials	
Availability of Treatment, Storage Capacity, and Disposal Services	Availability of adequate treatment, storage capacity, and disposal services
	Additional treatment, storage, and disposal capacity that are necessary
	Whether lack of capacity prevents implementation
	Additional provisions required to ensure additional capacity is available
Availability of Necessary Equipment and Specialists	Availability of adequate equipment and specialists
	Additional equipment or specialists that are required
	Whether there is a lack of equipment or specialists
	Additional provisions required to ensure that equipment and specialists are available
Availability of Prospective Technologies	Whether technologies under consideration are generally available and sufficiently demonstrated
	Further field applications needed to demonstrate that the technologies could be used full-scale to treat the waste at the site
	When technology should be available for full-scale use

	Whether more than one vendor will be available to provide a competitive bid

6.3.5 Cost

This criterion evaluates the cost of implementing each alternative. The cost of an alternative encompasses capital costs (engineering, construction, and supplies) and annual or periodic costs (O&M costs, monitoring, and ongoing administration) incurred over the life of the remedial action. Capital costs are incurred during implementation and startup of the remedy. Annual costs are those costs required to maintain the operation of the remedy over time. According to CERCLA guidance (EPA, 1988a), cost estimates for remedial alternatives were developed with an expected accuracy range of –30 to +50 percent.

The costs of remedial alternatives are compared using the estimated present value of the alternative. The net present value allows costs for remedial alternatives to be compared by discounting all costs to the year that the alternative is implemented. In the *Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (EPA, 2000), EPA suggests that the period of analysis for the present value analysis should be equivalent to the project duration, to provide a complete life cycle cost estimate of the remedial alternative. Most of the remedial alternatives developed for the PV Shelf Study Area require long-term activities, including sediment and fish monitoring; enforcement of fishing restrictions; and maintenance of constructed caps and covers.

The costs of the remedial alternatives are compared using the estimated present value and the total accumulated cost of the alternative. The net present value (NPV) allows costs for remedial alternatives to be compared by discounting all costs to the year that the alternative is implemented. For all alternatives, the NPV was calculated using a discount rate of seven percent as stated in preamble to the NCP, 55 FR 8722, and the Office of Solid Waste and Emergency Response (OSWER) Directive 9355.3-20 entitled "Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis" (EPA, 2000). This specified rate of seven percent represents a "real" discount rate in that it approximates the marginal pretax rate of return on an average investment in the private sector in recent years and has been adjusted to eliminate the effect of expected inflation. Indirect costs including bid and scope contingency, project management, remedial design, and construction management/field activity oversight were added to capital costs as percentages of the total cost. Percentages were determined based on the uncertainty, total cost, and/or complexity of the project. Annual costs were also marked up with bid and scope contingencies. Other indirect costs applicable to annual costs such as project management and technical support were included as separate labor estimates. Detailed cost estimates and cost estimate assumptions are provided in Attachment 1.

The technology or design features assumed in the scope and cost estimate may not necessarily be those implemented in the final design.

6.4 Detailed Analysis of Alternatives

In Section 5.0, the following four alternatives were assembled, developed, and retained for detailed analysis:

- Alternative 1 – No Action
- Alternative 2 – Institutional Controls with Monitored Natural Recovery

- Alternative 3 – Small Cap Containment with Institutional Controls and Monitored Natural Recovery
- Alternative 4 – Large Cap Containment with Institutional Controls and Monitored Natural Recovery

This section presents the evaluation of each remedial alternative against the two threshold criteria (overall protection of human health and the environment and compliance with ARARs) and the balancing criteria (long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost). Table 6-8 at the end of this section summarizes each alternative and Attachment 1 provides cost details for each alternative over a 10-year project duration.

6.4.1 Alternative 1 – No Action

The No Action alternative provides a baseline from which to analyze other alternatives. This alternative does not include any active remediation, monitoring, or institutional controls.

Threshold Criteria

Since no active remediation would be undertaken, the site would remain in its current state, with only natural processes causing change. Based on the sediment transport and food web models, "no action" would not meet protectiveness criteria, including ARARs (i.e., the AWQC), for over 30 years. It is unlikely that fish tissue concentrations for bottom-feeders like white croaker, would reach RME protectiveness levels for 50 years. Routine monitoring would not take place.

6.4.1.1 Overall Protection of Human Health and the Environment

Alternative 1, the No Action alternative, would not control the current risk to human health or to the environment. As discussed in Section 2.0, consumption of fish caught from the PV Shelf Study Area, particularly bottom feeders like white croaker, posed a health risk because of their high levels of DDTs and PCBs. Because the No Action alternative does not include institutional controls or monitoring to limit human exposure to contaminated fish, it would not protect human health until natural processes reduce contaminant concentrations in fish to acceptable levels.

6.4.1.2 Compliance with Applicable or Relevant and Appropriate Requirements

Existing site conditions do not comply with the ambient water quality criteria (AWQC) for protection of human health. Waters overlying the shelf contain concentrations of DDTs and PCBs that exceed the EPA AWQC of 0.22 ng/L DDT and 0.064 ng/L PCBs (Zeng et al., 1999) for protection of human health and the AWQC for ecological health of 1 ng/L DDT. It is estimated that the waters of PV Shelf will meet human health AWQC for DDT in 30 to 60 years (Appendix B). Insufficient data are available to predict when the human health AWQC for PCBs would be attained.

Balancing Criteria

6.4.1.3 Long-Term Effectiveness and Permanence

Under the No Action Alternative, untreated contamination in sediment would continue to pose a potential risk to human health and the environment through bioaccumulation. Although DDT and PCB concentrations in sediment have dropped, concentrations in fish continue to exceed safe consumption guidelines. Remediation goals for COC concentrations in fish (400 µg/kg DDTs and 70 µg/kg PCBs in white croaker) would not be met for 50 years.

DDT concentrations in sediment do not meet SEC values for protection of invertebrates at the outfall area and portions of the slope, although median concentrations for PV Shelf sediment meet SEC values. PCB concentrations in sediment already meet the SEC goal.

Risk to both human health and ecological receptors would remain until fate-and-transport processes reduce the concentrations below levels of concern. Because no monitoring would be conducted under this alternative, the rates of the natural recovery processes would not be tracked.

6.4.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

There would be no reduction of toxicity, mobility, or volume through treatment with this alternative, because no remedial action would be implemented. Some permanent reduction in toxicity, mobility, or volume would occur through natural recovery processes over a period of time at the site. However, the significance and rate of natural recovery processes would not be assessed because no monitoring would be conducted under this alternative.

6.4.1.5 Short-Term Effectiveness

Because no remedial action, including institutional controls, is included under Alternative 1, short-term effectiveness would be lower than under the existing institutional controls program. No additional short-term risks to the community or to workers would occur as a result of implementing the alternative. Similarly, no environmental impact from implementation activities would occur.

6.4.1.6 Implementability

Implementability of Alternative 1 would not be applicable as, by definition, no action would take place. No monitoring would be performed, no institutional controls would be implemented, and no construction would occur under this alternative.

6.4.1.7 Cost

Because Alternative 1 assumes no further action, there would be no cost associated with its implementation.

6.4.2 Alternative 2 – Institutional Controls with Monitored Natural Recovery

Alternative 2, Institutional Controls, is intended to reduce risks to human health associated with consumption of contaminated fish from the PV Shelf Study Area through non-engineered controls while monitoring natural processes that contribute to the recovery of the site. Under this alternative, ICs remain in place until RAOs are met. A long-term monitoring plan will verify natural recovery rates.

Institutional controls have been in place at the PV Shelf since the State of California first issued fish advisories and health warnings in 1985. EPA’s Action Memorandum (2001) created the current institutional controls program, which consists of three components: public outreach and education, enforcement, and fish monitoring. The institutional controls program relies heavily on partnerships with other federal, state, and local agencies, and community-based organizations. Under Alternative 2, EPA’s current institutional controls program would be strengthened by increasing ocean-to-market monitoring. Existing State of California fish advisories and catch ban would remain in place.

Although there have been numerous studies of PV Shelf, the only regular monitoring that occurs is that of LACSD under its NPDES permit. Under this alternative, EPA would institute a monitoring program to track reductions in concentrations of COCs in fish, water and sediment. Subsection 5.2.2.4 discusses monitoring for natural recovery. Appendix D presents the current draft institutional controls implementation plan.

Threshold Criteria

According to EPA guidance (EPA, 2005), natural recovery is an appropriate remedy at sites where the levels of contamination are relatively low, the area of contamination is large, and natural recovery is proceeding at a high rate. As discussed in Section 2.0, these criteria are met for some—but by no means all—of PV Shelf. Median PCB concentrations in surface sediment are 200 μg/kg (CH2M Hill, 2007). Sediment transport modeling predicts DDT concentrations in sediment will fall below 1000 μg/kg in approximately 15 years, except for the outfall area, where concentrations are likely to increase (Sherwood, 2002). Median DDT concentrations are predicted to fall below 200 μg/kg by 2053.

6.4.2.1 Overall Protection of Human Health and the Environment

Institutional controls reduce the risks to human health associated with the consumption of contaminated fish through public outreach, education and enforcement programs. However, institutional controls do not directly reduce contaminant levels in fish.

The education component of the existing institutional controls program has increased awareness and understanding of the fish consumption advisories and commercial fishing restrictions. However, monitoring and analysis of fish for sale in Los Angeles County and Orange County markets indicate that contaminated fish are still available to consumers.

Since Alternative 2 relies on natural recovery processes to reduce risk, ecological receptors would continue to be exposed to contamination in sediment and water. Although natural recovery has reduced the risk to ecological receptors from PCBs, birds and sea lions would continue to be at risk from DDT through consumption of contaminated fish for many years.

Institutional controls would not affect whether or not fish accumulate DDTs and PCBs to levels that exceed federal or state criteria for human consumption, although effective enforcement of the commercial fishing ban and the daily bag limit would tend to reduce the likelihood that such fish could turn up in retail fish markets.

DDT concentration in sediment is expected to fall below 200 μg/kg in approximately 45 years. As described in Appendix C, depending on organic carbon in sediment and lipid content in fish, 230 μg/kg is correlated with the goal of 400 μg/kg DDT in fish tissue.

6.4.2.2 Compliance with Applicable or Relevant and Appropriate Requirements

Existing site conditions do not comply with human health ARARs (Zeng et al., 1999). Waters overlying the shelf contain concentrations of DDTs and PCBs that exceed the EPA ambient water quality criteria (AWQC) for human health: 0.22 ng/L DDT and 0.064 ng/L PCBs and the AWQC for protection of ecological receptors, 1 ng/L DDT.

Human Health ARAR for DDT is forecasted to be met in 30 to 60 years. As discussed under the No Action alternative, the rate of recovery depends on a number of variables that affect water quality.

Balancing Criteria

6.4.2.3 Long-Term Effectiveness and Permanence

As discussed in the No Action alternative, PV Shelf is undergoing natural recovery, which over time will reduce contaminant concentrations to levels protective of human health and ecological receptors. In the interim, institutional controls can reduce but not completely prevent human exposure to DDTs and PCBs via fish consumption. A study conducted in the early 1990s, before implementation of EPA's current institutional controls (ICs) program, found that 77 percent of anglers (boat and shore-based anglers) were aware of the health warnings, but only 50 percent of them altered their consumption habits (SMBRP, 1994). The ICs program has been successful in altering behavior, but relies on angler cooperation—which is not entirely reliable-- to control risk.

Similarly, the enforcement component of institutional controls has been largely, but not completely, successful. Visits to fish markets in Los Angeles and Orange counties, discussed below, found few markets selling white croaker. However, among the few white croaker found, most exceeded the remediation goals for PCBs and DDT in fish fillet. While enforcement appears to have limited the number of white croaker reaching fish markets, it clearly has not succeeded in eliminating the risk of contaminated fish reaching commercial outlets. Alternative 2 would increase market monitoring and pursue additional ocean-to-market enforcement to increase the long-term effectiveness.

Since contaminant concentrations are dropping in sediment and water, concentrations in fish are dropping as well. Remediation goals for white croaker should be met in 50 years and sooner for other fish that aren't local bottom-feeders.

Results of Current Education/Outreach Programs

The education component of the existing institutional controls program was initiated in 2002 and has been effective in informing thousands of community members about contaminated fish from the PV Shelf Study Area. The EPA created the Fish Contamination Education Collaborative (FCEC) to bring together interested agencies, groups, and community-based organizations to design and implement an outreach program to address the health risks from eating contaminated fish related to the PV Shelf Study Area. The FCEC has developed outreach program components targeting anglers, market owners, and families who consume locally caught fish. The outreach efforts have been conducted in numerous languages including English, Spanish, Cambodian, Chinese, Filipino, Korean, Vietnamese, Chamorro, Samoan, Marshallese, and Tongan.

From 2003 to 2005, the institutional controls angler outreach program reached 33,753 anglers at eight popular fishing piers in Los Angeles and Orange counties: Belmont, Cabrillo, Pier J, Seal Beach, Santa Monica, Hermosa, Redondo, and Venice. The outreach effort included training community members to go to the piers to inform anglers about the fish contamination history, fish advisories, identification of contaminated fish, fish they could safely eat and how much, and how the anglers could prepare the fish to reduce their risk of exposure. Of the anglers that had previously been outreached, 97 percent indicated some type of behavior modifications based on the outreach message (e.g., change fishing spots, throw fish back and/or stop or reduce amount of white croaker consumption).

From 2003 to 2005, community members or county environmental health inspectors contacted 328 fish markets, restaurants, or wholesalers for the commercial fish program. The outreach effort relies on community members trained to go to markets and restaurants to inform the owners and/or managers about the PV Shelf Study Area fish contamination and to recommend purchasing fish only from licensed wholesalers, brokers, or commercial fishermen; to know where the fish are caught; and to keep invoice records when fish are purchased.

From 2003 to 2005, the FCEC program reached more than 100,000 people through 4,668 community fairs, health fairs, and other forms of outreach sessions. Community-based educators from the most affected communities were trained to create and conduct in-language health education around the PV Shelf Study Area fish contamination issues in their communities. Local health departments also serve as partners in disseminating information. Of those who attended training workshops, 91 percent expressed intent to modify fish consumption behavior due to the information received during outreach sessions.

Enforcement of Institutional Controls

The institutional controls program includes enforcement of existing state fishing regulations by the appropriate state agencies (white croaker bag limit for sports fishing and white croaker catch ban for commercial fishing). State agencies have increased enforcement when warranted. In 1997, CDFG documented a problem with the commercial sale of sport-caught white croaker in Los Angeles and Orange counties, including fish caught in areas where the health advisories recommend no consumption of white croaker. In response, CDFG instituted a daily bag limit on white croaker in 1998.

Keeping the commercial catch ban boundaries current presents a challenge. The 2002/2004 fish contaminants survey (EPA/MSRP 2007) found some white croaker caught outside the catch ban area had concentrations of DDTs and PCBs equal to and even higher than those caught inside the catch ban. Commercial fishermen could inadvertently catch and sell contaminated white croaker outside the current catch ban area. The State OEHHA is evaluating recent fish survey data to assess whether the boundaries of the white croaker catch ban zone are sufficient or need to be expanded, and to update the fish consumption advisories. Enforcement and monitoring of commercial and recreational fishing at the PV Shelf and adjacent areas is performed by CDFG.

EPA undertook a market fish survey in part to evaluate the effectiveness of the catch ban and bag limit and to assess whether contaminated white croaker are being sold in retail fish markets. In 2004 and 2005, EPA visited 68 markets a total of 135 times and found only six markets that carried white croaker (30 fish total). However, white croaker from all of the markets contained detectable levels of COCs, and some white croaker in all of the six markets exceeded remediation goals as well. Concentrations of DDTs and PCBs in fish tissue were as high as 11,800 μg/kg and 970 μg/kg, respectively. The market fish survey demonstrated that few markets carry white croaker, but that white croaker with unacceptably high concentrations of contaminants can still be found in the markets that do carry the fish. The suppliers of white croaker to the markets have not been determined, nor has it been determined if the contaminated white croaker were caught within the commercial catch ban area or in other locations.

As a result of EPA's fish market survey, EPA CDFG and the Los Angeles and Orange counties' environmental health inspection agencies have developed a white croaker market inspection component for the enforcement program. The goal is to stop contaminated white croaker from reaching consumers through enforcement and outreach by CDFG wardens and county inspectors. Data collected by the inspectors provide baseline information on white croaker availability and their suppliers. Alternative 2 would strengthen the market monitoring program and strengthen outreach to, and monitoring of, wholesale markets and distributors.

Monitored Natural Recovery

The natural recovery monitoring component of Alternative 2 would track reductions in contaminant concentrations in fish, sediment, and water. Natural recovery will likely consist of reduction in risk through a combination of the following:

- Burial of effluent-affected sediment below the biologically active zone
- Mixing of cleaner sediment with effluent-affected sediment
- Transport of contaminants offsite through natural processes
- Conversion of DDE to a less harmful form
- Reduction of contaminant bioavailability to receptors through changes in the resident biological communities (including microbial)

An estimated 7 percent of the DDE (the principal DDT isomer remaining in the sediment) in the sediment is lost annually through natural processes (Sherwood et al. 2006). Sediment cores collected at Stations 3C and 6C for over 20 years show a significant reduction in the DDE inventory from the early 1980s to the early 2000s (Sherwood et al., 2006). Sediment core data collected for investigation from two sites has shown that the inventory of DDE has decreased while that of DDMU has increased (Eganhouse and Pontolillo, 2007). Surface sediment concentrations have also decreased significantly over the last 15 years (Table 1-1). However, further studies are necessary to determine whether the DDE daughter products are less toxic than DDE, and whether or not surface reductions in contaminant concentrations are permanent and not subject to future erosion. The USGS is investigating the reductive dechlorination of DDE to identify the causes and estimate degradation rates throughout the EA sediment deposit. Analysis of oceanographic data collected during Winter 2007-08 will allow USGS to complete their model of sediment transport that will answer the question regarding rates and locations of potential erosion.

6.4.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

There would be no reduction of toxicity, mobility, or volume through treatment with this alternative, because no treatment would be implemented. Some permanent reduction in toxicity, mobility, or volume would occur through natural recovery processes at the site over a period of time.

6.4.2.5 Short-Term Effectiveness

To the degree that Alternative 2 implements additional ICs programs targeting ocean-to-market fish monitoring, further reductions in short-term risks for fish consumers is possible.

No risks of exposure to site-related contaminants will occur for the workers. Implementation of the institutional controls program, including sampling fish, would present a slight risk to workers due to the usual physical hazards from working on a boat and visiting markets. No environmental impacts are expected from the implementation of Alternative 2.

The timeframe for the remedial action objectives to be achieved is projected to be 30 to 60 years for this alternative. Monitoring of sediment, fish and ocean water would verify the predictive ability of the natural recovery model and time period necessary to achieve RAOs.

6.4.2.6 Implementability

Alternative 2 is implementable. This section briefly describes the technical feasibility, administrative feasibility, and the availability of services and materials.

Technical Feasibility

The institutional controls in this alternative do not involve technology, other than monitoring and sampling equipment, which are proven and reliable. Thus, technical feasibility is high for this institutional controls/monitored natural recovery alternative.

Administrative Feasibility

This alternative requires a high degree of coordination among numerous agencies to conduct education, enforcement, and monitoring activities. For example, OEHHA will contribute technical expertise for the updated advisory based on results from the ocean fish monitoring program, as well as serve on the Technical Review Board for the public outreach and education component of the institutional controls program. The enforcement component of the institutional controls would be carried out through the CDFG. State and local health agencies, such as the California Department of Health Services (DHS), Environmental Health Investigations Branch, DHS--Food and Drug Branch, Los Angeles County Department of Health Services (LACDHS), and Orange County Health Care Agency--Environmental Health Division (OCHCA-EHD) would assist with outreach and provide inspection resources to support the market monitoring program. Additionally, OCHCA-EHD may assist with delivery of public outreach and education materials to target populations. While the MNR program would be run by EPA, coordination with other agencies and organizations that monitor PV Shelf, e.g., Natural Resource Trustees, LACSD, would occur.

Availability of Services and Materials

Services and materials to implement the ICs program and the MNR program are readily available. To the extent that the ICs program relies on state and local agencies and nonprofit organizations, cooperative agreements and other mechanisms are necessary to assure personnel and materials are available. Fish monitoring would require trained personnel and materials for sample collection and data analyses, as well as laboratory testing and reporting results of fish tissue contaminant analyses. The personnel and materials for these activities are readily available. Conducting public outreach and education would also require personnel and materials that are readily available.

6.4.2.7 Cost

The estimated cost for Alternative 2 is just $15,500,000 over 10 years. This estimate includes IC costs for market monitoring, pier monitoring, ocean monitoring, community outreach, angler outreach and enforcement, and MNR costs for sediment, water and fish sampling. The estimated costs are based, in part, on the current institutional controls program. The costs for the ICs program are approximately $1,900,000 a year. The MNR cost for Year 1 baseline monitoring is $1,750,000. Sampling and analysis of COCs in sediment, fish and water would occur at Years 5 and 10. Preparation of the Five-Year Reviews would include collection of field data for the ICs and MNR programs.

A discount rate of seven percent is applied as stated in the preamble to the NCP, 55 FR 8722, and the Office of Solid Waste and Emergency Response (OSWER) Directive 9355.3-20 entitled "Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis" (EPA, 2000). Attachment 1 provides details of the cost estimate for Alternative 2. Appendix D provides details of the ICs program.

6.4.3 Alternative 3 – Small Cap with Monitored Natural Recovery and Institutional Controls

Alternative 3 consists of the institutional controls and monitored natural recovery programs described in Alternative 2 combined with placement of clean sediment to accelerate natural recovery. Median PCB concentrations in surface sediment are 200 μg/kg. Median DDT concentrations in surface sediment are 2000 μg/kg (CH2M Hill, 2007). Sediment transport modeling predicts DDT concentrations in sediment will fall below 1 mg/kg in approximately 20 years, except for the outfall area, where concentrations may increase (Sherwood, 2002). Median DDT concentrations are estimated to reach 200 μg/kg by 2053 (Appendix B).

Alternative 3 would cover the area near the outfall that has the highest surface concentrations of COCs, approximately 320 acres, with clean material. This would reduce median DDT surface concentrations across the Shelf to approximately 47 mg/kg OC and 5 mg/kg OC PCBs. The clean cover would reduce contaminant flux from EA sediment and armor the outfall area from potentially erosive storms. Subsection 5.2.3 provides a detailed description of Alternative 3.

Threshold Criteria

6.4.3.1 Overall Protection of Human Health and the Environment

Fish caught in the PV Shelf area contain concentrations of DDT and PCBs that exceed EPA acceptable risk levels for human health. By addressing the source of contaminants, i.e., the sediment, this alternative would accelerate natural recovery of the site.

Alternative 3 would apply a clean cover over the contaminated sediment in the outfall area to physically isolate and immobilize COCs where they are highest. This would reduce the median concentration of DDT in the surface sediment to approximately 47 mg/kg OC and the median concentration of PCBs in the surface sediment to approximately 5 mg/kg OC. The lower PCB sediment concentration would allow white croaker to reach the interim goal of 70 μg/kg PCBs in white croaker fish tissue within 10 years, as white croaker loose their existing body burden of PCBs. Under this alternative, median DDE concentrations in sediment across the shelf are projected to drop to 230 μg/kg in thirty years. This sediment level is correlated with the 400 μg/kg DDT in fish.

Until fish tissue concentrations meet remediation goals, the institutional controls would continue to protect consumers and reduce the likelihood that white croaker turn up in retail fish markets. Outreach programs to keep consumers informed of which fish are safer to eat and which cooking methods reduce contaminant content would continue. Bioaccumulation in ecological receptors would continue until contaminant concentrations in fish drop to target concentrations. The monitoring program would track reductions in contaminant concentrations.

6.4.3.2 Compliance with Applicable or Relevant and Appropriate Requirements

Waters overlying the shelf contain concentrations of DDTs and PCBs that exceed the EPA ambient water quality criteria (AWQC) for human health, 0.22 ng/L DDT and 0.064 ng/L PCBs (Zeng et al., 1999). DDT concentrations in water exceed the AWQC for ecological health of 1 ng/L.

The water quality goal for DDT would be met 14 years sooner under Alternative 3 than under natural recovery. An estimate of when PCB water criteria will be achieved will be calculated once more recent data on PCBs in water are analyzed. PCB samplers were deployed along the shelf during Winter 2007-2008 and recovered in April 2008; the data analysis has not been completed.

Because Alternative 3 involves placement of a sand/sediment layer, action-specific ARARs that would apply to this alternative include:

- The Marine Protection, Research, and Sanctuaries Act of 1972, commonly called the Ocean Dumping Act, 33 U.S.C. Section 1404 et seq.
- Federal ocean dumping regulations, 40 CFR Part 220 et seq.
- Section 403 of the Clean Water Act
- Section 404 of the Clean Water Act
- Section 307(c)(1) of the Coastal Zone Management Act

Theses ARARs are discussed in more detail in Section 3.0.

Balancing Criteria

6.4.3.3 Long-Term Effectiveness and Permanence

As discussed in Section 1.0, most of the time near-bottom currents are too weak to move fine sand. A cover of mixed sand, as is found in the potential borrow areas, would provide a long-term protective layer. Periodic storms would mobilize the finer grained material; however, studies of oceanographic conditions on the Shelf indicate the remaining coarser sand would compact and form a stable layer (Sherwood et al., 2006, Ferré and Sherwood, 2008). The proposed thickness of the cover (45 cm) will contain the EA sediment even if some of the cover material is lost. Monitoring of cap integrity from erosion or bioturbation from large burrowing infauna organisms, such as ghost shrimp, would be required. Data collected over the last twenty years indicate the buried EA sediment has undergone little disturbance north of the outfalls. Data collected during Winter 2007-2008 will provide additional information on near-bed current velocities to assist in designing a cover that will contribute clean sediment to the surrounding area but retain enough coarse material to prevent erosion of the cover.

6.4.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

There would be no reduction of toxicity, mobility, or volume through treatment with this alternative, because no treatment would be implemented. Some reduction in toxicity, mobility, and volume would occur through physical isolation of the most contaminated sediment and natural recovery processes that are ongoing at the site.

6.4.3.5 Short-Term Effectiveness

Minimal short-term risks would occur as a result of implementing Alternative 3. Some resuspension of sediment is inevitable during material placement. Depending on the degree of resuspension, a short-term increase in bioavailability of COCs may be experienced. However, the temporary increase in COCs would be offset by the reduction in contaminant concentrations in surface sediment. Natural recovery processes would be expected to accelerate after completion of the cover and the current risk from consuming contaminated fish would be expected to decline.

Sediment placement by low-impact techniques would present a risk to workers due to the usual physical hazards from working on a hopper dredge and operating heavy equipment. The ICs and other MNR components of the alternative pose minimal risk to workers. CDFG wardens would face the usual risks inherent in performing such tasks as boat patrols of fishing areas and enforcement of fishing restrictions.

6.4.3.6 Implementability

Alternative 3 is implementable. This section briefly describes the technical feasibility, administrative feasibility, and the availability of services and materials.

Technical Feasibility

Treatability studies to determine the most effective and lowest impact placement techniques would be carried out as part of the remedial design. EPA would use low-impact techniques and overlapping placement to minimize disturbance of the EA sediment.

Cap placement using a submerged discharge technique, such as a fallpipe/tremie tube with a diffuser, will be much slower and more costly than the spreading method with a split hull barge or hopper dredge. The placement technique is expected to have less impact on the effluent-affected sediment. Scouring and resuspension are expected to be less when compared with the bottom dump barge or hopper placement technique. Difficulties associated with submerged discharge include the need for a high degree of control and proper positioning. For example, because a tremie tube is a large-diameter straight vertical pipe, there is little reduction in momentum or impact energy. The fallpipe/tremie tube would need a diffuser to disperse the impact energy. Alternative 4 also discusses issues associated with placement implementability and effectiveness.

The rest of this alternative does not involve technology, other than monitoring and sampling equipment, which are proven and reliable.

Administrative Feasibility

Coordination with other state and federal agencies, including the California Coastal Commission, Regional Water Quality Control Board, U.S. Fish and Wildlife Service, and California Department of Fish and Game, would be required.

Sand placement would require preparation of plans and specifications, environmental documentation and, for off-site activities, permit applications. Specific requirements would vary depending on the source of the materials and potential magnitude of environmental impacts associated with dredging at a borrow site. This documentation is a normal requirement of most dredging projects; thus, administrative requirements should not interfere with implementation of this alternative.

Availability of Services and Materials

The availability of services and materials are potential limitations for Alternative 3. However, sand/sediment sources are available, as listed in Table 5-1. Dredging and placement equipment are proven, although not at this depth, and are available.

6.4.3.7 Cost

Alternative 3 would place a sand/sediment layer over Grid Cell 8C, an area of 1.3 km^2. The volume of material needed is 864,000 yd^3, which includes a 10 percent margin to account for material that may be lost during placement. The cost for covering Grid Cell 8C would be approximately $25 million plus another $6 million for treatability studies to assess low-impact techniques and placement sequence. Construction monitoring and O&M would bring the cost to $33.5 million. With institutional controls and monitored natural recovery, the alternative would cost about $49 million over 10 years. The estimated cost includes the institutional controls and monitoring programs described in Subsection 5.3.2.7. Attachment 1 provides details of the cost estimate for Alternative 3.

6.4.4 Alternative 4 – Containment with Monitored Natural Recovery and Institutional Controls

Alternative 4 combines the institutional controls and the monitoring of natural recovery processes of Alternative 2 with containment, which consists of placing 45 cm of cap material over the effluent-affected sediment deposit with the highest contaminant concentrations. The cap area was selected because it represents the area of highest contaminant concentrations in surface sediment and within the deposit. Non-capped areas would under go natural recovery. The effectiveness of the remedy would be evaluated at the first five-year review. Post remedy implementation data plus data from the additional studies would be used to develop a final remedy for the site. Natural recovery processes would be evaluated for the five-year review to verify that remediation goals are on track. Institutional controls would continue as well. A more detailed description of Alternative 4 is provided in Subsection 5.2.4.

Threshold Criteria

6.4.4.1 Overall Protection of Human Health and the Environment

Alternative 4 would apply a clean cover over EA sediment to physically isolate and immobilize COCs where they are highest. This would reduce the median surface concentration of DDT on the shelf to 36 mg/kg OC and of PCBs to 3 mg/kg OC. The timeframe required to meet RAOs for human health would be 18 years sooner than under natural recovery. Median DDE concentrations in sediment associated with 400 μg/kg DDT in fish are estimated to be reach 22 years sooner than under no action. Median PCB concentrations in sediment would be below the target sediment concentration of 7 mg/kg OC.

Until fish tissue concentrations meet remediation goals, the institutional controls would continue to protect consumers and reduce the likelihood that white croaker turn up in retail fish markets. Outreach programs to keep consumers informed of which fish are safer to eat and which cooking methods reduce contaminant content would continue. Bioaccumulation in ecological receptors would continue until contaminant concentrations in fish drop to target concentrations. The monitoring program would track reductions in contaminant concentrations.

6.4.4.2 Compliance with Applicable or Relevant and Appropriate Requirements

Waters overlying the shelf contain concentrations of DDTs and PCBs that exceed the EPA ambient water quality criteria (AWQC) for human health, 0.22 ng/L DDT and 0.064 ng/L PCBs

(Zeng et al., 1999). DDT concentrations in water exceed the AWQC for ecological health of 1 ng/L.

Under Alternative 4, which caps the area around the outfalls and to the north over grid cells 8C, 7C and 6C, PV Shelf waters are expected to meet AWQC 18 years sooner than if no action is taken. However, as discussed in Section 4.0, the placement of a cap would cause some sediment resuspension, which could result in short-term increase in COCs in water. An estimate of when PCB water criteria will be achieved will be calculated once more recent data on PCBs in water are analyzed.

Because Alternative 4 involves placement of cap material, action-specific ARARs that would apply to this alternative would include:

- The Marine Protection, Research, and Sanctuaries Act of 1972, commonly called the Ocean Dumping Act, 33 U.S.C. Section 1404 et seq.
- Federal ocean dumping regulations, 40 CFR Part 220 et seq.
- Section 403 of the Clean Water Act
- Section 404 of the Clean Water Act
- Section 307(c)(1) of the Coastal Zone Management Act

Theses ARARs are discussed in more detail in Section 3.0.

Balancing Criteria

6.4.4.3 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence of Alternative 4 would be determined by the physical stability of a cap, as measured by its resistance to erosion and seismic events; the depth of significant bioturbation; and the potential for construction with minimal resuspension of EA sediment. These factors are each discussed in more detail below. Long-term effectiveness and permanence of Alternative 4 will also be determined by the monitored natural recovery and institutional controls elements of this alternative, as described in Alternative 2.

Physical Stability of the Cap

Erosion resistant cap material must be able to withstand the shear stresses created by waves and currents at the site. As discussed in Section 1.0, waves and currents over the deposit are less energetic than inshore. The cap would be designed to withstand typical shear stresses that are produced by currents and normal wave action, but should also be thick enough to weather storm-induced stresses without compromising cap impermeability. Bottom boundary shear stresses are the subject of ongoing research by the USGS, but initial estimates are that the shear stress is less than 0.5 Pa (Cacchione, 2007). These initial estimates do not include the possible bed stresses caused by internal tides/bores and solitons (Cacchione, 2007).

USACE estimated the critical shear stress for design purposes to be 5 dynes/cm^2 or 0.5 Pa (Palermo et al., 1999). Erosion was modeled using the computer program Long-Term Fate (LTFATE), which is a site-analysis program that uses coupled hydrodynamic sediment transport and bathymetry change sub-models to compute site stability over time as a function of local waves, currents, bathymetry, and sediment characteristics. Palermo et al. (1999) concluded a minimum grain size of 0.1 mm or 0.3 mm (described as a fine sand) is sufficient to withstand bottom boundary shear stresses at the PV Shelf Study Area at depths greater than 40 m. Using 0.5 Pa for a noncohesive sediment, calculations indicate an approximate 0.1 cm median grain size is sufficient for erosion protection. Modeling and laboratory tests would be performed on cap source material to determine critical shear stress of the designed cap. Resistance to erosion will be a critical design factor

Sedflume analysis was performed at eight locations at the PV Shelf Study Area during the March 2002 pilot cap survey (Gailani et al., 2004). Test results indicated that cap material only eroded at shear stresses from 0.25 to 1.0 Pa. Cap material at the surface that was mixed with effluent-affected sediment eroded at shear stresses from 0.25 to 4.0 Pa. Material below the surface that consisted of cap material mixed with effluent-affected sediment as well as effluent-affected sediment below the cap was most resistant to erosion. This material generally required shear stress of 1.0 to 6.0 Pa to induce measurable erosion rates (Gailani et al., 2004).

Seismic stability of the cap also would be considered in the design and construction of an in situ cap. The seismic stability of the PV Shelf was evaluated during the pilot capping study. Palermo et al. (1999) demonstrated that liquefaction of cap materials and underlying sediments may occur during seismic events of magnitude 5.5 or greater, but lateral deformation in areas of slope less than 5 degrees would be not be expected to exceed three feet. Based on this evaluation, areas of the PV Shelf with bottom slopes less than 5 degrees would be suitable for capping from the standpoint of seismic stability, whereas a cap placed on the adjacent slope would be susceptible to failure. Consequently, only areas of the shelf shallower than about 70 m (i.e., slopes less than 5 degrees) would be considered suitable for capping.

Bioturbation Depth

Biological mixing (bioturbation) processes are important both to the physical integrity of a cap and the net movement of contaminants present in buried sediment. Protection from biodiffusion can be accomplished through the construction of a cap with sufficient thickness to limit recolonization into the effluent-affected sediment beneath the cap. The thickness of the sediment layer affected by bioturbation can vary depending on the types and abundances of organisms present and the characteristics of the substrate. The mean depth of the mixed layer from worldwide estimates in marine sediments utilizing radionuclide techniques is about 10 cm (Boudreau, 1994). Estimates of mixed layer depth for PV Shelf sediment vary, but appear to be on the order of 5 to 8 cm (see Wheatcroft and Martin 1994; Santschi et al., 2001; SAIC, 2005b).

Biological activity below the surface mixed layer declines rapidly. In this transition layer, organisms are much less abundant due to reduced availability of labile organic matter for food and from demands placed on organisms (tube building, irrigation) resulting from the hypoxic or anoxic state of surrounding interstitial water, requiring animals to maintain connection with the surface. In 2004, SAIC (2005b) sampled the infauna from 64 cores (0.06 m^2 surface area) and recorded the presence of organisms within three vertical core segments: 0 to 15 cm, 15 to 30 cm, and > 30 cm below the sediment water interface. Most of the cores (83 percent) penetrated beyond 30-cm depth, while 29 (45 percent) penetrated deeper than 40 cm. Retained animals were sieved through a 2-mm screen, identified to species, counted, and weighed. A total surface area of 3.42 m^2 was sampled from 19 stations, which included replicates. The upper segment had the highest abundance, but the 15- to 30-cm abundance was relatively high at 62 percent of the surface density. Below 30 cm, densities dropped to 5 percent of surface levels. Mid-core biomass was nearly as high as the surface (92 percent), declining to 30 percent below 30 cm. Average weight of individual organisms was greatest in the deep core section, where individual organisms were 4 to 7 times as large as organisms from mid- and upper strata.

Based on these considerations, a cap thickness of 30 cm, equal to the combined depths of the completely mixed zone and the enhanced biodiffusion zone, was considered adequate for providing complete physical, as well as biological, isolation of the contaminated sediments. A

15-cm layer was added to accommodate operational variation in constructing a cap of uniform thickness.

The actual long-term effectiveness of Alternative 4 will be determined by changes in fish tissue contaminant concentrations measured during the MNR monitoring events. Although capping will reduce surface sediment concentrations to levels associated with fish remediation goals, average fish tissue concentration will not change immediately. Fish tissue reductions in contaminants will occur as fish mature and grow (dilution of concentrations, internally) and from the steady replacement of older, contaminated fish (pre-capping adults) with new fish raised on the capped environment.

6.4.4.4 Reduction of Toxicity, Mobility, or Volume through Treatment

There would be no reduction of toxicity, mobility, or volume through treatment with this alternative, because no treatment would be implemented. Physical isolation of COCs in sediment would reduce their exposure and mobility. Some permanent reduction in toxicity, mobility, or volume would occur through natural recovery processes at the site over time.

6.4.4.5 Short-Term Effectiveness

The primary considerations for the short-term effectiveness of Alternative 4 are resuspension of effluent-affected sediments and the burial of benthic organisms due to cap placement. Short-term effectiveness for the institutional controls and MNR component are discussed under Alternative 2.

Sediment Resuspension

Cap construction will cause resuspension of contaminated surface sediment due to turbulence associated with placement of the cap material. Resuspension of contaminated sediment would temporarily promote desorption of DDTs and PCBs to waters overlying the PV Shelf Study Area. Short-term adverse effects of this nature can be reduced by using low-energy construction methods; however, resuspension can not be avoided. Resuspension and scouring of contaminated sediment were observed during the pilot capping project (Fredette et al., 2002, SAIC 2002).

The degree to which capping will cause resuspension of bottom sediment will depend on the force with which the capping material impacts the bottom as well as the depth of previously placed cap material. Use of a submerged diffuser technique to place the cap material closer to the sediment bed is designed to reduce the force of impact. Fredette et al. (2002) determined that using a spreading method allowed for controlled placement and less resuspension compared with point placement. However, as observed during capping, the spreading technique generated vertical plumes up to 30 feet high, comparable to those from point placement, although they dissipated more quickly. Resuspension can be controlled through use of accurate positioning information for the scows, barges, or hoppers distributing the material, by facilitating overlapping placement techniques, and by controlling the rate of release from the disposal equipment.

Minimizing short-term effects of resuspension appear to be possible using best management construction practices and lessons learned from the pilot capping project.

Burial of Benthic Organisms

Covering existing shelf sediment with a cap of sand-sized materials would result in burial of a large portion of the present benthic infaunal community. The subsequent recolonization of the cap will typically occur in stages. The proposed sediment cap is expected to be populated within days to weeks by adults and juvenile macrobenthic invertebrates that swim or migrate onto the cap from the adjacent bottom, recruit from the plankton, or burrow upward to the new sediment surface (burial of larger burrowers). Most of the existing benthos is likely to perish from burial, as it is represented by a large component of nonmotile species. Emergent recolonization will be most successful at cap thicknesses less than or equal to 10 cm, and thus will be most likely in the thin flank deposits. Nonreproductive colonization (e.g., by organisms transported to the site or burrowing through the deposit) can occur within a period of hours to days. Later successional stage organisms are likely to appear within months and almost certainly within 2 to 5 years following cap placement. Macrofaunal organisms comprising later successional stages typically are larger and capable of burrowing to greater depths than earlier stage organisms. High rates and densities of pioneering benthos may attract demersal predators to the site during the productive stages of recolonization.

6.4.4.6 Implementability

Implementability of the institutional controls and monitored natural recovery elements of this alternative are described in the evaluation of Alternative 2.

Containment requires identification of sand sources, verification of a placement method, and monitoring to determine long-term effectiveness of the cap. This section briefly describes the technical feasibility, administrative feasibility, and the availability of services and materials for the capping component of the alternative.

Technical Feasibility

The technologies and services for this alternative, such as dredges and cap placement equipment, are proven and reliable, although there are few precedents for capping at the depth of the deposit. Challenges include finding suitable cap material, controlling resuspension and residuals, developing low-impact placement techniques, and constructing a level, thick cap.

Cap Placement Technique

It is assumed that at least two cap placement techniques would be used: the spreading method using a split hull material barge or hopper dredge, and low-impact methods, represented by submerged diffuser placement method. The spreading method was considered to cause less disturbance to the effluent-affected sediment compared with the point placement method (Fredette et al., 2002). The spreading method is a relatively rapid placement technique with a relatively minor modification to conventional point placement methods. The spreading method would be used for placement of cap material in locations away from the LACSD outfalls after an initial layer is placed using a drag arm or tremie tube with diffuser. A “buffer” zone around the outfalls would be designated to protect the outfalls from burial.

The results of the sediment displacement study (SAIC, 2005a) indicated that the thickness of the effluent-affected sediment layer displaced during capping can vary from a few cm, at sites where cap placements overlapped, up to 15 to 40 cm, at sites where cap material was placed directly on top of effluent-affected sediment. This conclusion was based on the relatively uniform depths for the peak DDE concentrations prior to capping compared with peak concentrations after capping.

Scour depths of the effluent-affected sediment must be considered during the design phase. Results from the pilot capping project indicated scour was greatest during the initial placement events using point placement technique. Data also indicated scour was greatest directly below the point placement location (SAIC, 2005a). Scours appears to be less in the areas radiating out from the point placement location and also less using the overlapping point placement technique. Limited data indicate the spreading placement technique caused less scour than the point placement technique (SAIC, 2002). Low-impact techniques and overlapping placement to place cap material on top of cap material would be used to minimize scour where possible. Additionally, the extra thickness of the cap will make up for any loss of surface EA sediment from scouring.

Administrative Feasibility

Coordination of capping activities with other state and federal agencies, including the California Coastal Commission, Regional Water Quality Control Board, U.S. Fish and Wildlife Service, and California Department of Fish and Game, would be required.

Cap construction would require preparation of plans and specifications, environmental documentation, and for off-site activities, permit applications. Specific requirements would vary depending on the source of the capping materials and potential magnitude of environmental impacts associated with dredging at a borrow site. This documentation is a normal requirement of most dredging projects; thus, administrative feasibility is not expected to be difficult.

6.4.4.7 Cost

Alternative 4 includes costs for maintaining an institutional control program and monitored natural recovery activities.

Cost estimates were developed for both low-impact placement and spreading placement methods. Low-impact placement techniques, i.e., submerged drag-arm, tremie tube with diffuser, are expected to be within the cost range of clamshell placement. During design and procurement, other construction methods may be evaluated.

The estimate for containment includes cost of cap material, dredging, cap placement using a low-impact technique or a bottom dump barge (spreading placement), and cap monitoring. A unit cost was developed based on 1,000,000 yd^3 of cap material, including dredging, and placement of the material using either a clamshell barge or a bottom dump barge. The unit cost for low-impact placement is approximately $44/$yd^3$ and the unit cost for spreading placement is approximately $21/$yd^3$. The cap would be constructed using multiple techniques. About a third of the cap material, for the initial cover and the area around the outfall, would be placed using the more expensive low-impact method; the rest would be placed through spreading. Alternative 4 would cap Grid Cells 6C, 7C, and 8C, an area of 2.74 km^2. The cap volume, plus 10 percent, is 1,776,000 yd^3.

The cost for capping Grid Cells 6C, 7C, and 8C would be approximately $57.1 million, which includes $6 million for treatability studies. Construction monitoring would bring the cost to $60.4 million. The estimated cost for a Five-Year Review would total $756,000. With institutional controls and monitored natural recovery this alternative would cost about $76.7 million. Attachment 1 provides details of the cost estimates for Alternative 4.

6.5 Comparative Analysis of Alternatives

This section presents a comparative analysis of alternatives, in which the relative performance of each alternative is evaluated for each of the seven evaluation criteria. The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to one another to identify key tradeoffs that need to be balanced. Table 6-8 summarizes the comparison of each alternative to CERCLA criteria.

Threshold Criteria

6.5.1 Overall Protection of Human Health and the Environment

Alternative 1, the no action alternative, takes no measures to protect human health and the ecosystem of the PV Shelf Study Area. The overall protection of human health and the environment of Alternative 2 is better than the no action alternative because the institutional controls would effectively reduce risk to human health by educating consumers about contaminated fish and by enforcing fishing restrictions. However, institutional controls do not reduce risk to ecological receptors. Alternative 2 relies on natural processes to reduce risk over time to ecological receptors. Evidence of contaminant loss and transformation has been documented (Sherwood et al., 2006, Eganhouse and Pontolillo, 2007) as well as reductions in fish contaminant concentrations (CH2M Hill, 2007). Predictive modeling (Appendix B) estimates median concentrations in sediment will drop to levels correlated to the interim goal for DDT in fish (400 µg/kg) in 45 years. However, sediment in the outfall area would continue to have DDT concentrations over 500 mg/kg OC for the foreseeable future or until the deposit is eroded (Sherwood, 2002).

Alternative 3 places a sand cover in the outfall area on the southeast edge of the deposit that is susceptible to erosion and is the area of highest surface and subsurface contamination. Under Alternative 3, mean sediment concentrations on the Shelf would drop to 1,200 µg/kg DDT and 150 µg/kg PCBs; median carbon normalized values would be 47 mg/kg OC DDT and 5 mg/kg OC PCBs. The DDT concentration is twice the remediation goal of 23 mg/kg OC; the PCB value is less than the PCB remediation goal of 7 mg/kg OC. Sediment concentration (230 µg/kg dw) associated with fish tissue goal (400 µg/kg) would be reached about 14 years sooner than under natural recovery. Under Alternative 4, a cap covers twice the area of Alternative 3. Alternative 4 would reduce average sediment concentrations on the Shelf to 885 µg/kg DDT and 110 µg/kg PCBs; median carbon normalized values would be 36 mg/kg OC DDT and 3 mg/kg OC PCBs. Sediment DDT concentration would reach 230 µg/kg eight years sooner under Alternative 4 than under Alternative 3. The PV Shelf slope has areas of high COC concentrations in sediment that cannot be actively remediated because of the slope. How much this sediment contributes to fish contamination will be the focus of a white croaker fish tracking study under alternatives 2, 3 and 4. Alternatives 3 and 4 would retain the institutional controls program and monitoring program of Alternative 2.

6.5.2 Compliance with Applicable or Relevant and Appropriate Requirements

Waters overlying the shelf contain concentrations of DDTs and PCBs that exceed the EPA ambient water quality criteria (AWQC) for human health, 0.22 ng/L DDT and 0.064 ng/L PCBs (Zeng et al., 1999). Contaminant concentrations in water meet the PCB AWQC for ecological health, i.e., of 30 ng/L, but not the DDT AWQC for ecological health of 1 ng/L.

Appendix B presents the assumptions and calculations used to project AWQC achievement. Because of the lack of data on COCs in water, these estimates are highly speculative. The data are useful in quantifying relative ranking of each alternative more than in predicting an exact timeframe to reach AWQC goals. Data collected during Winter 2007-2008 will be used to verify or amend the timeframe. Under Alternative 2, human health AWQC are projected to be met in 30 to 60 years. Under Alternative 3, AWQC are projected to be met 14 years sooner than under Alternative 2. Alternative 4, which caps the area around the outfalls and to the north over grid cells 6C and 7C, PV Shelf waters are expected to meet AWQC 18 years sooner than if no action is taken. An estimate of when PCB water criteria will be achieved will be calculated once more recent data on PCBs in water are analyzed.

Placement of capping material under either Alternative 3 or 4 would require compliance with the substantive requirements in Section 404 of the Clean Water Act, the Ocean Dumping Act, 33 U.S.C. Section 1404 et seq., federal ocean dumping regulations at 40 CFR Part 220 et seq. Dredged material must meet substantive federal testing guidelines before it can be approved for disposal; *see* 40 CFR Part 227.

6.5.3 Long-Term Effectiveness and Permanence

The PV Shelf is undergoing natural recovery and over time the surface layer of EA sediment would be diluted or dispersed. However, in the interim, contaminants would continue to bioaccumulate in fish and other organisms. The long-term effectiveness and permanence of Alternative 1 is low because DDTs and PCBs in sediment would continue to pose a risk to human health and the environment without any measures being taken to reduce human exposure. All of the other alternatives use the institutional controls program to reduce risk through education, enforcement, and monitoring. Alternative 3 would accelerate natural recovery by applying a nonengineered cap to the southeast edge of the deposit where the contaminant concentrations are greatest. Alternative 4 would construct a cap over the thickest part of the deposit. All of the alternatives achieve comparable long-term protectiveness, they vary according to the time involved. Alternative 2 would require 30 to 45 years to reach remediation goals in water and sediment. A factor that could influence recovery time under Alternative 2 is the contaminant contribution from the outfall area. Although this is a small area, about 1.6 percent of the site, it's estimated to contain 44 percent of the shelf's DDT and 13 percent of the PCBs. Field studies to quantify contaminant flux and sediment transport from this area are necessary to more accurately predict recovery rates under any alternative.

Alternative 3 places a 30- to 45-cm cover over the area of greatest contamination. Although the area has weaker currents than those measured at either end of the Shelf (Noble, et al. 2008), the characteristics of the sediment make it more susceptible to erosion (Ferré and Sherwood, 2008). These data indicate a 45-cm thick cover would provide long-term protection. Alternative 4 caps the high concentrations of DDTs and PCBs in the outfall area and to the north where analysis of currents and sediment properties indicate erosion may occur (Ferré and Sherwood, 2008), although existing measurements show the area is still net depositional (Figure 2-11). Erosion, seismic events, bioturbation, and recontamination are the primary processes that have a potential to impact the long-term effectiveness and permanence of a cap (Palermo et al., 1999). As stated in Subsection 5.2.4.3, the cap thickness is considered adequate to provide complete physical as well as biological isolation of the contaminated sediments. Long-term monitoring (O&M) would be necessary to check cap integrity and perform any repairs to the cap if breaches are found. The alternative would provide long-term effectiveness.

6.5.4 Reduction of Toxicity, Mobility, or Volume through Treatment

None of the alternatives reduces the toxicity, mobility, or volume of contamination at the PV Shelf Study Area through treatment. Some permanent reduction in toxicity, mobility, or volume (without treatment) would occur through natural recovery processes over a period of time at the site. Capping would reduce mobility; however, this is not considered treatment.

6.5.5 Short-Term Effectiveness

Alternative 1 would not increase short-term risks to the community or to workers since no action would occur under this alternative. Similarly, no environmental impact from construction activities would occur.

Alternative 2 would pose little short-term risk to the community. Implementation of the institutional controls and monitoring programs, including sampling fish, would present a slight risk to workers due to the usual physical hazards from working on a boat and visiting markets. No short-term environmental impacts are expected from the implementation of Alternative 2.

Compared to the other alternatives, Alternatives 3 and 4 pose a greater short-term risk to the environment at the PV Shelf Study Area because they would resuspend effluent-affected sediment and bury the benthic community. In-water work, including placement of cap materials and dredging will cause resuspension of sediment. The suspended sediment is likely to be transported outside the construction zone and settle in other areas. Resuspension of contaminated sediment may adversely impact aquatic biota in and adjacent to the construction zone. Water quality impacts resulting from in-water construction would be limited to short-term increases in suspended sediment. Resuspension management would include using best management practices (BMPs) during in-water work and engineering and in-water construction methods designed to minimize resuspension (use of spreading and low-impact placement techniques). Monitoring of turbidity, current speeds, surge impacts, etc. would be performed during remedial action to determine effectiveness of resuspension management and modify capping activities if warranted.

Another short-term impact from Alternatives 3 and 4 is that a cover or cap will bury a large number of benthic organisms, although some larger-sized species would be capable of burrowing up through deposited material. Most of the existing benthos is likely to perish from burial, as they are represented by a large component of nonmotile species. Emergent recolonization will be most successful at cap thicknesses less than or equal to 10 cm, and thus will be most likely in the edges of the cap. In the thinner areas, it is likely that the cap would be populated within weeks by adults and juvenile macrobenthic invertebrates that swim or migrate onto the cap from the adjacent bottom, recruit from the plankton, or burrow upward to the new sediment surface (burial of larger burrowers). Recolonization would take 2 to 5 years.

Alternatives 3 and 4 are not expected to pose a short-term risk to the community. There would be an increase in ship or truck traffic, depending on cap material source. Alternative 4 would require more material. The alternatives would pose some risk to workers from the usual physical hazards of working on the water (e.g., dredging, cap placement).

6.5.6 Implementability

Technical Feasibility. The no action alternative, Alternative 1, requires no additional effort and would be readily implementable. Implementation of any of the others alternatives evaluated present technical challenges, especially the placement of sand material in Alternatives 3 and 4. However, all alternatives evaluated are considered technically implementable. Alternative 4 would be the most difficult alternative to implement.

The technical feasibility of the institutional controls program and monitored natural recovery are high. The ICs program has been in place for many years and has a proven track record of successful implementation. Monitoring activities on PV Shelf have been conducted by local and federal agencies. The water depth poses challenges to collection of sediment cores; however, suitable equipment is available and has been used successfully. Collection of fish, sediment, and water are all technically feasible.

Technical feasibility for containment requires evaluation of source materials for the cap and the placement method. The availability of sand for capping at PV Shelf Study Area is difficult to predict because of the need of sand for beach replenishment or in-water and upland construction. However, the volumes required, 864,000 yd^3 for Alternative 3, and 1,776,000 yd^3 for Alternative 4, is less than sediment volumes projected to be generated by maintenance dredging (Table 5-3). It is likely that the most cost-effective source of cap material would be from an on-site borrow area or from maintenance dredging of Southern California ports and harbors. Material source(s) would be identified during the design phase.

Placement of subaqueous material under either Alternative 3 or 4 would be technically difficult because of the fine grain and high moisture content of the effluent-affected sediment. Cap material would need to be applied slowly and uniformly to reduce resuspension of contaminated sediments. Placement techniques considered in this FS include the spreading method using a split hull material barge or hopper dredge and low-impact placement methods such as submerged drag-arm or tremie tube with diffuser. Low-impact techniques would be used to place an initial cap layer of 10 to 15 cm, then the rest of the cap could be applied using the spreading technique. The spreading method could be used to place most of the cap material while more precise placement methods could be designated for areas nearer to the outfalls. A buffer zone would be established around the outfall so that cap material would not interfere with operation or maintenance activities.

Administrative Feasibility. The administrative feasibility of Alternative 1 is high because no action is taken. Alternatives 2, 3 and 4 require a high degree of coordination among numerous agencies to conduct education, enforcement, and monitoring activities for the institutional controls program. However, the existing ICs program has been operating for several years, and many of the administrative issues have been worked out. The plan for monitoring natural recovery is administratively feasible as well. The site has been monitored and sampled for many years, the administrative feasibility is high.

Cap construction would require preparation of plans and specifications and coordination with other agencies. Placement of capping material under either Alternative 3 or 4 would require compliance with the substantive requirements in Section 404 of the Clean Water Act, the Ocean Dumping Act, 33 U.S.C. Section 1404 et seq., federal ocean dumping regulations at 40 CFR Part 220 et seq. Dredged material must meet substantive federal testing guidelines to be approvable for disposal, 40 CFR Part 227. Specific requirements would vary depending on the source of the capping materials.

6.5.7 Cost

A comparison of the costs for each alternative is provided in Table 6-7. As stated at the beginning of this section, this feasibility study is for an interim action. A final remedy selection will occur after the first five-year review. Alternative costs are projected out over a 10-year period. The no action alternative would require no capital or operating costs and would be less expensive than current cost due to existing ICs program. Besides the no action alternative, Alternative 2 is the least expensive with total costs estimated at $15.5 million over 10 years. Alternative 3 is considerably more expensive, with total costs over 10 years of $49 million. Alternative 4 would be the most expensive remedial alternative, at $76.7 million over 10 years. Both alternatives budget $6 million for treatability studies as part of remedial design and post-cap construction monitoring.

Table 6-7: Comparison of Remedial Alternative Costs (10-Year Implementation Horizon)

Alternatives	Capital Costs	Periodic Costs	Total Costs
	Non-Discounted Cost	Net Present Value Cost	
Alternative 1 – No Action	$0	$0	$0
Alternative 2 – Institutional Controls (ICs) and Monitored Natural Recovery (MNR)	$3,650,000	$11,850,000	$15,500,000
Alternative 3 –Enhanced Monitored Natural Recovery and Institutional Controls	$36,600,000	$12,400,000	$49,000,000
Alternative 4 – Containment with MNR and Institutional Controls	$64,100,000	$12,600,000	$76,700,000

Table 6-8: Evaluation of Alternatives against CERCLA Criteria

CERCLA Criteria	Alt.1 No Action	Alt. 2 Institutional Controls & Monitored Natural Recovery	Alt. 3 ICs, MNR & Small Subaqueous in situ Cap	Alt 4: ICs, MNR & Subaqueous in situ Cap
Threshold Criteria				
Overall Effectiveness				
Human Health Protection RAO 1: reduce to acceptable levels the risks to human health from ingestion of fish contaminated with DDTs and PCBs Achieve interim goal of 400 µg/kg DDT and 70 µg/kg PCBs in white croaker and other benthic-feeding fish	No reduction in risk. DDT concentrations will remain high around outfalls but drop in other areas. Impact of high conc. in outfall area unclear.	Controls, but does not eliminate, risk from ingesting contaminated fish. CoC in fish exceed $1x10^4$ risk. CoCs on the Shelf would drop over time. Median DDT conc. in surface sediment is estimated to fall <1 ppm by 2024 and reach target if 230 µg/kg by 2053.	See Alt. 3 would apply a sand cover to the area of highest contaminant conc. (approx. 1.3 km^2), to prevent erosion and reduce COCs in sediment. DDT conc. in white croaker would reach 400 µg/kg in 30 yrs. PCB conc. of 70 µg/kg would be reached in 10 years.	See Alt. 2. Cap would cover approx. 2.74 km^2 of the Shelf, including the flat areas (not slope) that exceed the PCB cleanup goal. Median concentrations of DDT associated with 400 µg/kg in white croaker would be reached in 22 yrs. CoCs in fish would drop thru depuration; it could take 10 yrs (one lifetime) for PCB conc. in white croaker to drop to 70 µg/kg.
Environmental Protection RAO 2: reduce to acceptable levels risks to PV Shelf fish and benthic invertebrates Support Natural Resource Trustees' strategies to sustain wildlife recovery Achievement of human health ARARs would also provide protection for wildlife.	No reduction in risk	Does not provide additional protection. Median DDT conc. forecasted to fall <1000 µg/kg by 2024, and <200 µg/kg by 2053.	Isolates 1.3 km^2 area w/ highest CoC concentration. Immediately reduces mean conc. of DDT to 1200 µg/kg & PCBs to 150 µg/kg. DDT projected to fall below 200 µg/kg 14 yrs sooner than under no action.	Isolates 2.74 km^2 of sediment with highest CoC concentrations, reducing mean conc. to 890 µg/kg DDT & 110 µg/kg PCBs. DDT forecast to fall below 200 µg/kg 22 yrs sooner than under no action.
Compliance with ARARs				

Table 6-8: Evaluation of Alternatives against CERCLA Criteria

CERCLA Criteria	Alt.1 No Action	Alt. 2 Institutional Controls & Monitored Natural Recovery	Alt. 3 ICs, MNR & Small Subaqueous in situ Cap	Alt 4: ICs, MNR & Subaqueous in situ Cap
Chemical-Specific ARARs Environmental AWQC: DDT 1 ng/L; Human Health AWQC: DDT 0.22 ng/L; PCBs 0.064 ng/L	DDT levels in water projected to meet HH AWQC by 2037. Date for PCBs to reach HH AWQC being determined. This alt. has no monitoring to confirm AWQC met.	DDT levels in water projected to meet HH AWQC by 2037. Alt. includes monitoring. Date for PCBs to reach HH AWQC being determined.	DDT levels in water projected to meet HH AWQC by 2023. Alt. includes monitoring. Date for PCBs to reach HH AWQC being determined.	DDT levels in water projected to meet HH AWQC by 2019. Alt. includes monitoring. Date for PCBs to reach HH AWQC being determined.
Location-Specific ARARs	none	none	capping must comply with CZMA	capping must comply with CZMA
Action-Specific ARARs	none	monitoring must comply with CDFG Title 14 fish protection regulations	See Alt. 1. capping must comply with MRPSA & CWA	See Alt. 1. capping must comply with MRPSA & CWA
Balancing Criteria				
Long-Term Effectiveness				
Magnitude of Residual Risk	Existing risk will drop over time, but this alt. does not track changes.	Loss processes are predicted to reduce risk over 30-60 years.	Action predicted to reduce risk over 15-40 years. Because waste is only contained, hazard remains until natural processes degrade DDE. Cover would prevent exposure, but also prevent CoC loss.	Action predicted to reduce risk over 10-30 years. Because waste is only contained, inherent hazard remains until natural processes degrade DDE. Cap would prevent exposure and CoC loss.
Adequacy & Reliability of Controls	No controls over remaining contamination.	ICs have limited effectiveness. Contaminated fish limited, but not absent, from markets.	ICs have limited effectiveness. Reliability of a cap can be high. Would need monitoring & maintenance.	ICs have limited effectiveness. Reliability of a cap can be high. Would need monitoring & maintenance.

Table 6-8: Evaluation of Alternatives against CERCLA Criteria

CERCLA Criteria	Alt.1 No Action	Alt. 2 Institutional Controls & Monitored Natural Recovery	Alt. 3 ICs, MNR & Small Subaqueous in situ Cap	Alt 4: ICs, MNR & Subaqueous in situ Cap
Need for 5-Yr Reviews	Yes.	Yes. Review would be required to ensure adequate protection of human health and the environment.	Yes. DDTs & PCBs left in sediment. DDTs degrading, but not PCBs.	Yes. DDTs & PCBs left in sediment. DDTa degrading, but not PCBs.
Reduction of Toxicity, Mobility, or Volume thru Treatment				
Treatment Process	None.	None	None	None.
Reduction of Toxicity, Mobility or Volume	Reduction in volume thru loss processes & DDE transformation. Toxicity of daughter products unknown.	See Alt. 1	See Alt. 1. Cap would reduce mobility but is not considered treatment.	See Alt. 1. Capping would reduce mobility but is not considered treatment.
Statutory Preference for Treatment	Does not satisfy.	Does not satisfy.	Does not satisfy.	Does not satisfy.
Short-Term Effectiveness				
Community Protection	Risk to community increased since existing ICs would stop under this alt.	Risk to community managed through ICs.	Risk to community managed thru ICs. May cause short-term increase in CoC bioavailability from resuspended sediment.	Risk to community managed thru ICs. May cause short-term increase in CoC bioavailability from capping resuspended sediment.
Worker Protection	N/A	N/A	No significant risk from monitoring activities.	No significant risk from monitoring & capping.
Environmental Impacts	N/A	N/A	Resuspension of EA sediment; burial of benthic organisms	Resuspension of EA sediment; burial of benthic organisms
Time Until Action is Complete	N/A	RAOs predicted to be met in 30-45 years under	RAOs predicted to be met 14 years sooner thru	RAOs predicted to be met 18 to 22 years

Table 6-8: Evaluation of Alternatives against CERCLA Criteria

CERCLA Criteria	Alt.1 No Action	Alt. 2 Institutional Controls & Monitored Natural Recovery	Alt. 3 ICs, MNR & Small Subaqueous in situ Cap	Alt 4: ICs, MNR & Subaqueous in situ Cap
		natural loss processes.	hot spot cover than thru natural loss processes.	sooner thru capping than thru natural loss processes.
Implementability				
Ability to Construct & Operate	No construction or operation.	No construction. ICs program in operation since 2001. MNR program easy to implement.	Placement difficult because of location, depth, & characteristics of sediment. ICs & MNR easy to implement.	Capping difficult because of location, depth, & characteristics of sediment. ICs, MNR easy to implement.
Ease of Doing More Action if Needed	By pursuing an interim ROD, additional action would be easy.	Interim ROD leaves door open for further action at time of final ROD.	Interim ROD leaves door open for further action at time of final ROD.	Interim ROD leaves door open for further action at time of final ROD.
Ability to Monitor Effectiveness	No monitoring.	ICs & MNR programs monitor CoCs in sediment, water, fish & behavior changes from outreach.	MNR would track CoCs in water, sediment & fish. Cover easy to monitor.	Easy to monitor. MNR would track COCs in water, sediment & fish.
Ability to Obtain Approvals & Coordinate with Other Agencies	N/A	Successful ongoing coordination with State, federal & local agencies.	See Alt. 2., anticipate no difficulties coordinating with other agencies for monitoring. Need CA Coastal Commission approval & possibly USACE permit if marine sediment is dredged for cover material.	See Alt. 3. Need CA Coastal Commission approval & possibly USACE permit if marine sediment is dredged for cap material. Coordination with other agencies for ICs and MNR.
Availability of Equipment and Materials	N/A	No special equipment.	Cover material sources available.	Cap material sources available.

Table 6-8: Evaluation of Alternatives against CERCLA Criteria

CERCLA Criteria	Alt.1 No Action	Alt. 2 Institutional Controls & Monitored Natural Recovery	Alt. 3 ICs, MNR & Small Subaqueous in situ Cap	Alt 4: ICs, MNR & Subaqueous in situ Cap
Availability of Technologies	N/A	Monitoring equipment and procedures well established.	Technologies available; additional studies needed to determine best methods.	Capping technologies available; RD studies needed to determine best methods.

Table 1: Institutional Controls Details					
Description	**Quantity**	**Unit Cost**	**Unit**	**Total**	**Comment**
Year 1 Costs					Based on hours in 2001 EPA work plan
Institutional Controls Plan	1	$ 30,000	EA	$ 30,000	
Monitoring					
Monitoring - Market					
Plans	1	$ 14,000	LS	$ 14,000	FSP, QAPP, HSP
Sample Collection	1	6,600	LS	6,600	Assumes 10 markets; based on hours in 2007 EPA work plan
Sample Materials	1	1,000	LS	1,000	
Shipping/Transport	1	1,000	LS	1,000	Samples and equipment
Data Assessment	1	22,000	LS	22,000	Includes data management, and QA/QC oversight and data validation; based on hours in 2007 EPA work plan
Analysis	50	720	EA	$ 36,000	10 markets, 5 white croaker at each; sample preparation, lipid content, DDT (6 isomers) and PCB congener analysis
Monitoring- Catch Ban Area					
Plans	1	$ 10,000	LS	$ 10,000	FSP, HSP – same QAPP for market monitoring
Mobilization/Demobilization	1	3,400	LS	3,400	Includes travel and per diem
Boat Rental	4	4,500	LS	18,000	Includes boat and labor for 4 days
Sampling Materials	1	1,000	LS	1,000	
Shipping/Transport	1	1,000	LS	1,000	Samples and equipment
Data Assessment	1	22.000	LS	22,000	Includes data management and QA/QC oversight and data validation; based on hours in 2007 EPA work plan
Analysis	100	720	EA	72,000	5 catch ban area locations, 10 white croaker and 10 kelp bass each; sample preparation, lipid content, DDT (6 isomers) and PCB congener analysis
Monitoring – Pier					
Plans	0	$ -	LS	$ -	same as market monitoring plan
Sample Collection	1	5,300	LS	5,300	Assumes 4 piers
Sampling Materials	1	1,000	LS	1,000	
Shipping/Transport	1	1,000	LS	1,000	Samples and equipment
Data Assessment	1	22,000	LS	22,000	Includes data management, QA/QC oversight and data validation; based on hours in 2007 EPA work plan
Analysis	40	720	EA	28,800	4 piers, 10 white croaker at each; sample preparation, lipid content, DDT (6 isomers) and PCB congener analysis
Outreach					

Table 1: Institutional Controls Details

Description	**Quantity**	**Unit Cost**	**Unit**	**Total**	**Comment**
Community Outreach	1	$ 880,000	LS	$ 880,000	Based on 2007 EPA work plan
Angler Outreach	1	120,000	LS	120,000	Based on 2006 costs and 2007 EPA work plan
Enforcement					
City & County Health Agencies	3	$ 60,000	EA	$ 180,000	Training, tracking, and reporting for LA and OC market inspections; based on 2007 estimate
CA Dept. of Fish and Game					
Catch Ban Patrol	192	$ 75	HR	$ 14,400	Monthly patrol with 2 wardens; 8 hrs/patrol
Pier Patrols	192	75	HR	14,400	Monthly patrol with 2 wardens' 8 hrs/patrol
Reporting	48	75	HR	3,600	Monthly reporting; 4 hrs/month
Subtotal A				1,508,500	
Contingency (20% of Subtotal A)				301,700	10% scope and 10% bid
Subtotal B				1,810,200	
Project Mgmt (6% of Subtotal B)				108,612	From USACE and EPA estimating Guide July 2000
Total Capital Costs for ICs				1,900,000	
O&M Costs					
Annual Costs for Years 2 – 5 Monitoring – Market	1	$ 30,000	LS	$30,000	Includes sample collection, data management, an QA/QC oversight and data validation; based on hours in 2007 EPA work plan
Analysis Monitoring – Market	50	720	EA	36,000	10 markets, 5 white croaker at each; sample preparation, lipid content, DDT (6 isomers) and PCB congener analysis.
Monitoring – Pier	1	$ 29,300	LS	$29,300	Includes sample collection, materials, shipping/transportation, data management and QA/QC oversight and data validation; based on hours in 2007 EPA work plan
Analysis Monitoring – Pier	1	$ 720	EA	$ 28,800	4 piers, 10 white croaker at each;; sample preparation, lipid content, DDT (6 isomers) and PCB congener analysis
Community Outreach	1	$1,000,000	LS	$1,000,000	same as initial LOE
Enforcement	1	212,400	LS	212,400	same as initial LOE
Subtotal A				$1,336,500	
Contingency (20% of Subtotal A)				267,300	10% scope and 10% bid
Subtotal B				1,603,800	
Project Mgmt (6% of Subtotal B)				96,228	From USACE and EPA Estimating Guide July 2000
Annual O&M Subtotal for Years 2-5				$1,700,000	annual cost
Total O&M NPV for Years 2 -5				$5,400,000	7% discount rate

Table 1: Institutional Controls Details					
Description	**Quantity**	**Unit Cost**	**Unit**	**Total**	**Comment**
Year 5 Only					
Monitoring – Catch Ban Area	1	$ 31,900	LS	$ 31,900	Year 5 only; includes mob/demob, boat rental, labor, materials, shipping/transport, data management, and QA/QC oversight and data validation; based on hours in 2007 EPA work plan
Analysis Monitoring – Catch Ban Area	100	$ 720	EA	72,000	Year 5 only; 5 catch ban locations, 10 white croaker and 10 kelp bass each; sample preparation, lipid content, DDT (6 isomers) and PCB congener analysis
5-Yr Review Report	1	$ 36,000	EA	36,000	Year 5 only
Subtotal A				139,900	
Contingency (20% of Subtotal A)				27,890	10% scope and 10% bid
Subtotal B				167,880	
Project Mgmt (6% of Subtotal B)				10,073	From USACE and EPA Estimating Guide (July 2000)
Additional O&M for Year 5 Only				177,953	annual cost
Total O&M NPV for Year 5 Only				$127,000	7% discount rate
Annual Costs for Years 6 - 10					
Monitoring – Market	1	$ 230,000	LS	$30,000	Includes sample collection, data management, an QA/QC oversight and data validation; based on hours in 2007 EPA work plan
Analysis Monitoring – Market	50	720	EA	36,000	10 markets, 5 white croaker at each; sample preparation, lipid content, DDT (6 isomers) and PCB congener analysis.
Monitoring – Pier	1	$ 29,300	LS	$29,300	Includes sample collection, materials, shipping/transportation, data management and QA/QC oversight and data validation; based on hours in 2007 EPA work plan
Analysis Monitoring – Pier	40	$ 720	EA	$ 28,800	4 piers, 10 white croaker at each; sample preparation, lipid content, DDT (6 isomers) and PCB congener analysis
Community Outreach	1	1,000,000	LS	1,000,000	same as initial LOE
Enforcement	1	212,400	LS	212,400	same as initial LOE
Subtotal A				$1,336,500	
Contingency (20% of Subtotal A)				267,300	10% scope and 10% bid
Subtotal B				1,603,800	
Project Mgmt (6% of Subtotal B)				96,228	From USACE and EPA Estimating Guide (July 2000)
Annual O&M Subtotal for Years 6-10				1,700,028	annual cost
Total O&M NPV for Years 6-10				4,970,000	7% discount rate

Table 1: Institutional Controls Details					
Description	**Quantity**	**Unit Cost**	**Unit**	**Total**	**Comment**
Year 10 Only					
Monitoring – Catch Ban Area	1	$ 31,900	LS	$ 31,900	Year 10 only; includes mob/demob, boat rental, labor, materials, shipping/transport, data management, and QA/QC oversight and data validation; based on hours in 2007 EPA work plan
Analysis Monitoring – Catch Ban Area	100	$ 720	EA	72,000	Year 5 only; 5 catch ban locations, 10 white croaker and 10 kelp bass each; sample preparation, lipid content, DDT (6 isomers) and PCB congener analysis
5-Yr Review Report	1	$ 36,000	EA	36,000	Year 10 only
Subtotal A				139,900	
Contingency (20% of Subtotal A)				27,890	10% scope and 10% bid
Subtotal B				167,880	
Project Mgmt (6% of Subtotal B)				10,073	From USACE and EPA estimating Guide July 2000
Additional O&M for Year 10 Only				177,953	annual cost
Total O&M NPV for Year 10 Only				90,400	7% discount rate
Total O&M NPV Cost				$10,600,000	7% discount rate
Total Cost				$12,500,000	

Table 2: Monitored Natural Recovery Details					
Description	**Quantity**	**Unit Cost**	**Unit**	**Total**	**Comment**
Year 1 Costs					Based on hours in 2001 EPA work plan
Natural Recovery Plan	1	$ 30,000	EA	$ 30,000	
Sediment and Water Sampling and Analysis					
Plans (SAP, QAP, HSP)	1	$ 50,000	LS	$ 50,000	
Mobilization/Demobilization	1	14,000	LS	14,000	
Equipment Rental	18	6,300	DAY	100,800	Includes boat and labor for 16 days
Materials	1	7,000	LS	7,000	
Shipping/Transport	1	4,000	LS	4,000	
Data Assessment Report	1	200,000	LS	200,000	
Sediment Analysis					
Sample Preparation	750	244	EA	183,000	50 cores total; 30 stations, LACSD transects 1- thru 10-B, C, D; duplicate cores at 60-m and 150-m stations; 4-cm increments; box core
Water Content	750	5	EA	3,750	
Total organic content (TOC)	750	35	EA	26,250	
Grain Size	750	75	EA	56,250	
DDTs	750	226	EA	169,500	includes 6 DDT isomers, DDMU, DDNU, DBP
PCBs	750	245	EA	183,750	specific congener list will be used
Pore Water Analysis	50	$ 225	EA	$ 11,250	50 samples total, taken with sediment samples
Sample Preparation					
Hydrogen Sulfide	50	100	EA	5,000	
DDTs	50	400	EA	20,000	includes 6 DDT isomers, DDMU, DDNU, DBP
PCBs	50	400	EA	20,000	specific congener list will be used
Water Column Analysis					30 stations; , LACSD transects 1- thru 10-B, C, D; 9 passive samplers per station: 3 m from bed, mid-column and 5 m below surface
Polyethylene Device (PED)	270	$5	EA	1,350	
DDTs					
PCBs	270	400	EA	$ 108,000	includes 6 DDT isomers, DDMU, DDNU, DBP
	270	400	EA	108,000	specific congener list will be used
Sediment and Water Sampling Subtotal				$1,271,900	
Fish Sampling					
Plans (SAP, QAP, HSP)	1	14,000	LS	$ 14,000	
Mobilization/Demobilization	1	3,400	LS	3,400	
Equipment Rental	4	4,500	DAY	45,000	Includes boat and labor for 10 days
Materials	1	1,200	LS	1,200	
Shipping/Transport	1	1,000	LS	1,000	
Data Assessment Report	1	36,000	LS	36,000	

Table 2: Monitored Natural Recovery Details					
Description	**Quantity**	**Unit Cost**	**Unit**	**Total**	**Comment**
Demersal and Pelagic Fish	60				Cost included with fish sampling: trawl paths, species identified, counted, weighed; 30 fish each of two species (1 benthic-feeding, 1 pelagic) from 2 locations on PV Shelf, southeast and northwest from outfalls
Sample preparation	60	244	EA	14,640	Whole body lipid normalized muscle fillet tissue
Lipid content	60	25	EA	1,500	
DDTs	60	226	EA	13,560	Includes 6 DDT isomers and DDMU, DDNU, DBP
PCBs	60	245	EA	14,700	Specific congener list will be used
Fish Sampling Subtotal				$100,600	
Baseline Monitoring				$1,372,500	
Subtotal A				274,500	10% scope and 10% bid
Contingency (20% of Subtotal A)					
Subtotal B				$1,647,000	from USACE and EPA Estimating Guide July 2000
Project Mgmt (6% of Subtotal B)				98,800	
				1,745,800	
Total Baseline Monitoring				$1,745,800	
O&M Costs					
Year 5 Monitoring					
Plans (SAP, QAP, HSP)	1	$ 0	LS	0	Use Baseline Plans
Mobilization/Demobilization	1	14,000	LS	14,000	
Equipment Rental	18	6,300	DAY	63,000	Includes boat and labor for 10 days
Materials	1	5,000	LS	5,000	
Shipping/Transport	1	4,000	LS	4,000	
Sediment Analysis					
Sample Preparation	480	244	EA	117,120	
Water Content	480	5	EA	2,400	32 cores total; 16 stations, LACSD transects 2- thru 9 stations B & C;
Total organic content (TOC)	480	35	EA	16,800	duplicate cores; 4-cm increments; box core
Grain Size	480	75	EA	36,000	
DDTs	480	226	EA	108,480	
PCBs	480	245	EA	117,600	includes 6 DDT isomers, DDMU, DDNU, DBP specific congener list will be used
Pore Water Analysis	32	$ 225	EA	$ 7,200	32 cores total, taken with sediment samples
Sample Preparation					
Hydrogen Sulfide	32	100	EA	3,200	
DDTs	32	400	EA	12,800	includes 6 DDT isomers, DDMU, DDNU, DBP
PCBs	32	400	EA	12,800	specific congener list will be used
Water Column Analysis					16 stations, LACSD transects 2- thru 9-B, C; 9 passive samplers per
Polyethylene Device (PED)	144	$5	EA	720	station: 3 m from bed, mid-column and 5 m below surface

Table 2: Monitored Natural Recovery Details					
Description	**Quantity**	**Unit Cost**	**Unit**	**Total**	**Comment**
DDTs	144	400	EA	$ 57,600	includes 6 DDT isomers, DDMU, DDNU, DBP
PCBs	144	400	EA	57,600	specific congener lisst will be used
Fish Sampling and Analysis	60	100,600		100,600	Cost included with fish sampling: trawl paths, species identified, counted, weighed; 30 fish each of two species (1 benthic-feeding,1 water column) from 2 locations on PV Shelf southeast and northwest of the outfalls Whole body lipid normalized muscle fillet tissue Includes 6 DDT isomers and DDMU, DDNU, DBP Specific congener list will be used
Five-Year Report	1	50,000		50,000	Five-Year Report
Year 5 Monitoring				$786,900	
Subtotal A				157,380	10% scope and 10% bid
Contingency (20% of Subtotal A)					
Subtotal B				$944,280	from USACE and EPA Estimating Guide July 2000
Project Mgmt (6% of Subtotal B)				56,700	
				1,000,980	
Total O&M NPV for Year 5				$713,700	7% discount rate
Year 10 Monitoring				$786,900	
Subtotal A				157,380	10% scope and 10% bid
Contingency (20% of Subtotal A)					
Subtotal B				$944,280	from USACE and EPA Estimating Guide July 2000
Project Mgmt (6% of Subtotal B)				56,700	
				1,000,980	
Total O&M NPV for Year 10				$508,800	7% discount rate
Total O&M NPV Cost				$1,222,500	7% discount rate
Total Cost				$3,000,000	

Table 3: Containment Details

Description	Quantity	Unit Cost	Unit	Total	Comment
Treatability Studies				$6,000,000	Studies to define area to be capped, characterize the sediment, and test techniques. $6 million is a rough estimate based on 2000 pilot capping project
Construction Capital Costs					
Submerged Diffuser Placement – 1,000,000 CY scenario					
Onshore Staging Area	1	$104,125.00	LS	$ 104,125	
Crewboat (transport from shore to bargers)	704	3,748.50	DAY	2,638,904	
Material	1,000,000	5.41	CY	5,412,500	assumes 24 hr/day
Dredging of Material	1,000,000	0.66	CY	660,000	$5.00 per cy and 8.25% tax
Crew for dredging barge	9,000	62.00	HR	558,000	assumes 15-CY clamshell barge
Tugboat for Dredging Barge	384	3,795.00	DAY	1,457,280	assumes 2 crew for 24 hrs/day
Crew for Tugboat for Dredging	18,432	62.00	HR	1,142,784	assumes 24 hrs/day
Transport Materials to Site	1,000,000	2.59	CY	2,590,000	assumes 3 3000-CY hopper barges
Crew for Transport Barge	19,000	62.00	HR	1,178,000	assumes 2 crew per barge for 24 hrs/day
Placement Barge	1,000,000	1.25	CY	1,250,000	assumes placement barges for 24 hrs/day
Crew or Placement Barge	17,000	62.00	HR	1,054,000	assumes 2 crew per barge for 24 hrs/day
Tugboat for Placement Barge	704	3,795.00	DAY	2,671,715	assumes 2 tugboats for 24 hrs/day
Crew for Tugboat for Placement	33,792	62.00	HR	2,095,104	assumes 2 crew per tugboat for 24
Anchoring and Positioning	1	312,375.00	LS	325,250	hrs/day
Survey Boat and Crew for Placement Confirmation	353	6,247.50	DAY	2,205,368	
Subtotal A				$25,343,080	
Field Detail Allowance (5% of Subtotal A)				1,267,154	
Subtotal B				26,610,234	
Overhead (12% of subtotal B)				3,193,228	
Subtotal C				29,803,462	
Profit (6% of subtotal C)				1,178,208	
Subtotal D				31,591,670	
Contingency (20% of Subtotal D)				6,318,334	10% scope and 10% bid
Total Direct Capital Cost				$37,910,004	
Non-Construction capital Costs					
Project Management (5% of Total Direct Capital Cost)				1,895,500	USACE & EPA Estimating Guide (2000)
Remedial Design (6% of Total Direct Capital Cost)				2,274,600	USACE & EPA Estimating Guide (2000)
Construction Mgmt (6% of Total Direct Capital Cost)				2,274,600	USACE & EPA Estimating Guide (2000)
Total Non-construction Capital Cost				6,444,700	

Table 3: Containment Details					
Description	**Quantity**	**Unit Cost**	**Unit**	**Total**	**Comment**
Total Capital Costs for Submerged Placement				$44,355,000	
SUBMERGED DIFFUSER UNIT COST			CY	44	
Construction Capital Costs					
Spreading Placement – 1,000,000 CY scenario					
Onshore Staging Area	1	$104,125.00	LS	$ 104,125	
Crewboat (transport from shore to barges)	384	3,748.50	DAY	1,439,424	Assumes 24 hrs/day
Material	1,000,000	5.41	CY	5,412,500	$5.00 per CY and 8.5% tax
Dredging of Material	1,000,000	0.66	CY	660,000	assumes 2 15-CY clamshell barge
Crew for dredging barge	9,000	62.00	HR	558,000	assumes 2 crew per barge for 24 hrs/day
Tugboat for Dredging Barge	384	3,795.00	DAY	1,457,280	assumes 2 tugboats for 24 hrs/day
Crew for Tugboat for Dredging	18,432	62.00	HR	1,142,784	assumes 2 crew per tugboat for 24 hr/day
Transport and Placement of Materials	1,000,000	0.87	CY	870,000	assumes 5 1000-CY bottom dump barges, split hull
Crew for Transport/Placement Barge	14,000	62.00	HR	868,000	assumes 2 crew per barge for 24 hrs/day
Anchoring and Positioning	1	208,250.00	LS	208,250	
Survey Boat and Crew for Placement Confirmation	88	6,247.50	DAY	549,780	
Subtotal A				13,270,143	
Field Detail Allowance (5% of Subtotal A)				663,507	
Subtotal B				13,933,650	
Overhead (12% of subtotal B)				1,672,038	
Subtotal C				15,605,203	
Profit (6% of subtotal C)				936,341	
Subtotal D				16,542,029	
Contingency (20% of Subtotal D)				1,654,203	10% scope and 10% bid
Total Direct Capital Cost				18,196,232	
Non-Construction Capital Costs					
Project Management (5% of Total Direct Capital Cost)				909,812	USACE & EPA Estimating Guide (2000)
Remedial Design (6% of Total Direct Capital Cost)				1,091,774	USACE & EPA Estimating Guide (2000)
Construction Mgmt (6% of Total Direct Capital Cost)				1,091,774	USACE & EPA Estimating Guide (2000)
Total Non-Construction Capital Cost				3,093,400	
Total Capital Costs for Spreading Placement				$21,290,000	
SPREADING UNIT COST			CY	21	

Table 3: Containment Details					
Description	**Quantity**	**Unit Cost**	**Unit**	**Total**	**Comment**
Monitoring During Alt. 3 Construction					
Resuspension and plume monitoring arrays (automated resuspension surveillance system)	6	$110,000	EA	$ 660,000	Assumes placement at 6 locations during construction
Sediment Profile Imagery (SPI)	3	$45,000	LS	$ 135,000	Assumes 50 locations for pre-, during, and post-construction monitoring
Sediment and Water Column Sampling					
Plans (SAP, QAP, HSP)	1	$ 45,000	LS	$ 45,000	
Equipment Rental	16	6,300	DAY	100,800	Includes boat and labor for 16 days
Materials	1	4,000	LS	4,000	
Shipping/Transport	1	3,000	LS	3,000	
Report	1	200,000	LS	200,000	
Sediment Analysis					
Sample Preparation	360	245	EA	88,200	Assumes 12 core locations for a depth of 60 cm with 4-cm sample increments for 180 samples for during and post-construction monitoring
Water Content	360	$5	EA	1,800	
Total organic content (TOC)	360	35	EA	12,600	
Grain Size	360	75	EA	27,000	
DDTs	360	205	EA	73,800	
PCBs	360	245	EA	88,200	
Water Column Analysis					
DDTs, total	24	206	EA	4,944	
PCBs, total	24	245	EA	5,880	
DDTs, dissolved	24	206	EA	4,944	
PCBs, dissolved	24	245	EA	5,880	
Subtotal A				1,461,048	
Contingency (20% of Subtotal A)				292,210	
Subtotal B				1,753,258	
Project Mgmt (5% of Subtotal B)				105,195	
Total Construction Cap Monitoring				$1,900,000	

Table 3: Containment Details					
Description	**Quantity**	**Unit Cost**	**Unit**	**Total**	**Comment**
O & M Costs					
Sediment Monitoring – Five-Year Review					
Sediment Profile Imagery (SPI)	1	$45,000	LS	$45,000	Assumes 50 locations for each event
Sediment and Water Column Sampling					
Plans (SAP, QAP, HSP)	0	$45,000	LS		Use same plans as for baseline monitoring
Equipment Rental	16	$6,300	DAY	$100,800	Includes boat and labor for 16 days for each sampling event
Materials	1	$4,000	LS	$ 4,000	
Shipping/Transport	1	3,000	LS	3,000	
Report	1	200,000	LS	200,000	
Sediment Analysis					
Sample Preparation	300	245	EA	73,500	Assumes 12 core locations to a depth of 100 cm with 4-cm sample increments for 300 total samples for each sampling event
Water Content	300	$5	EA	1,500	
Total organic content (TOC)	300	35	EA	10,500	
Grain Size	300	75	EA	22,500	
DDTs	300	205	EA	61,500	DDT 6 isomers &DDMU/DDNU/DBP
PCBs	300	245	EA	73,500	specific congener list wll be used
Water Column Analysis					Assumes 12 locations at depths/location (mid-winter near bottom)
DDTs, total	24	205	EA	4,944	DDT 6 isomers &DDMU/DDNU/DBP
PCBs, total	24	245	EA	5,880	specific congener list wll be used
DDTs, dissolved	24	205	EA	4,944	DDT 6 isomers &DDMU/DDNU/DBP
PCBs, dissolved	24	245	EA	5,880	specific congener list wll be used
Subtotal A				617,448	
Contingency (20% of Subtotal A)				123,490	10% scope and 10% bid
Subtotal B				740,938	
Project Mgmt (5% of Subtotal B)				37,047	From USACE and EPA Estimating Guide (July 2000)
O&M Sediment Monitoring for Year 5				$778,000	annual rate
Total O&M NPV for Year 5				554,700	7% discount rate

Monitoring During Alt. 4 Cap Construction					
Description	**Quantity**	**Unit Cost**	**Unit**	**Total**	**Comment**
Resuspension and plume monitoring arrays (automated resuspension surveillance system)	12	$110,000	EA	$ 1,320,000	Assumes placement at 6 locations during 2 construction seasons for a total of 12 locations
Sediment Profile Imagery (SPI)	6	$45,000	LS	$ 270,000	Assumes 100 locations for pre-, during, and post-construction monitoring
Sediment and Water Column Sampling					
Plans (SAP, QAP, HSP)	1	$ 45,000	LS	$ 45,000	
Equipment Rental	25	6,300	DAY	157,500	Includes boat and labor for 25 days
Materials	1	4,000	LS	4,000	
Shipping/Transport	1	3,000	LS	3,000	
Report	1	200,000	LS	200,000	
Sediment Analysis					
Sample Preparation	720	245	EA	176,400	Assumes 24 core locations for a depth of 60 cm with 4-cm sample increments for 360 samples for during and post-construction monitoring
Water Content	720	$5	EA	3,600	
Total organic content (TOC)	720	35	EA	25,200	
Grain Size	720	75	EA	54,000	
DDTs	720	205	EA	147,600	
PCBs	720	245	EA	176,400	
Water Column Analysis					
DDTs, total	48	206	EA	9,888	
PCBs, total	48	245	EA	11,760	
DDTs, dissolved	48	206	EA	9,888	
PCBs, dissolved	48	245	EA	11,760	
Subtotal A				2,626,000	
Contingency (20% of Subtotal A)				525,000	
Subtotal B				3,151,000	
Project Mgmt (5% of Subtotal B)				158,000	
Total Construction Cap Monitoring				$3,309,000	

Monitoring During Alt. 4 Cap Construction					
Description	**Quantity**	**Unit Cost**	**Unit**	**Total**	**Comment**
O & M Costs					
Sediment Monitoring – Five-Year Review					
Sediment Profile Imagery (SPI)	1	$45,000	LS	$45,000	Assumes 50 locations for each event
Sediment and Water Column Sampling					
Plans (SAP, QAP, HSP)	0	$45,000	LS		Use same plans as for baseline monitoring
Equipment Rental	25	$6,300	DAY	$157,500	Includes boat and labor for 25 days for each sampling event
Materials	1	$4,000	LS	$ 4,000	
Shipping/Transport	1	3,000	LS	3,000	
Report	1	200,000	LS	200,000	
Sediment Analysis					
Sample Preparation	480	245	EA	117,600	Assumes 24 core locations to a depth of 80 cm with 4-cm sample increments for 480 total samples for each sampling event
Water Content	480	$5	EA	2,400	
Total organic content (TOC)	480	35	EA	16,800	
Grain Size	480	75	EA	36,000	
DDTs	480	205	EA	98,400	DDT 6 isomers &DDMU/DDNU/DBP
PCBs	480	245	EA	117,600	specific congener list wll be used
Water Column Analysis					Assumes 24 locations at depths/location (mid-winter near bottom)
DDTs, total	48	205	EA	9,888	DDT 6 isomers &DDMU/DDNU/DBP
PCBs, total	48	245	EA	11,760	specific congener list wll be used
DDTs, dissolved	48	205	EA	9,888	DDT 6 isomers &DDMU/DDNU/DBP
PCBs, dissolved	48	245	EA	11,760	specific congener list wll be used
Subtotal A				841,600	
Contingency (20% of Subtotal A)				168,300	10% scope and 10% bid
Subtotal B				1,009,900	
Project Mgmt (5% of Subtotal B)				50,500	From USACE and EPA Estimating Guide (July 2000)
O&M Sediment Monitoring for Year 5				$1,060,400	annual rate
Total O&M NPV for Year 5				756,000	7% discount rate

Summary of Containment Costs	Unit Cost	Capital	Alt. 3: Enhanced MNR		Alt. 4: Containment	
Treatability Studies	NA	$6,000,000		$6,000,000		$6,000,000
Low Impact, (e.g., clamshell) Placement	$44 CY		300,000 CY		600,000 CY	
Spreading Placement	$21 CY		564,000 CY		1,176,000 CY	
Total cover*			864,000 CY		1,776,000 CY	
Total material placement cost				$25,050,000		$51,100,000
Construction Monitoring				$1,900,000		$3,309,000
NPV 5-Yr Monitoring				$554,700		$756,000
TOTAL				**$33,500,000**		**$61,200,000**
Based on 45-cm cover, includes 10% increase for material loss						

7.0 References

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